SEPTEMBER 2008
ISSUE 3 ■ VOLUME 4

water asset management INTERNATIONAL

PAPERS

IWA Publishing

water21 magazine of the International Water Association

Regulator warns water companies must do more maintenance

The Environment Agency (EA), which regulates the water companies in England and Wales, has responded to AMP 5 draft business plans by warning the companies that they must invest more in maintenance to improve the environment and cut the risk of pollution incidents.

Last year, water companies caused 20% of all serious pollution incidents, most of which were related to poorly maintained, overloaded or ageing sewerage infrastructure.

The EA called on the industry to 'be clear' about its capital maintenance priorities, taking into account potential environmental impacts. Its response welcomed many of the water companies' proposals, but urged them to do more to manage their resources and work with customers to reduce demand, which could include introducing compulsory water metering in areas of high water usage.

The environmental regulator will also ensure that water companies plan for secure supplies for people and industry, and adapt to population growth and climate change, it added.

The water companies will also be pressed to review their draft plans to take account of the increased risk of flooding to key assets due to climate change. Such infrastructure is often located by rivers and is particularly susceptible to flooding.

The Environment Agency voiced concern that few companies are proposing action on the issue of flooding from surface water drains – an issue highlighted by the Pitt Review of last summer's flooding as a key cause of the floods.

Although it recognises that companies have made a start on tackling the issue, the Environment Agency wants to see more commitment from companies to help with production and delivery of plans to help reduce surface water flooding. It is also calling on water companies to include firm proposals to reduce the number of properties at risk from sewage flooding.

David King, the Environment Agency's director of water management, said: 'There is a lot to commend in the proposals from the water companies, however we are keen to see more detail on their plans for capital maintenance. We need to be reassured that such investment is in the right areas to protect the environment and will deliver value for money.'

Industry reports highlight experts' concerns

Two new research initiatives have produced a profile of water industry experts' concerns that suggest leakage and source water supply protection are at the forefront of the industry's collective consciousness at the moment.

Research commissioned by newly-launched water loss management company Miya reveals that a majority of the industry experts polled believe that water loss 'is a disaster waiting to happen'.

Conservative estimates suggest that around the world average losses are in the order of 33% of potable water put into supply – equivalent to 32 billion cubic metres, and worth around $18 billion.

The survey found around a third of respondents were unaware of the scale of the problem and nearly all (93%) found it unacceptable. A further 67% agreed with the statement that 'if water loss is not resolved in the next 15 years, we are likely to face crisis'.

The industry believes it has 'an environmental obligation' to address water loss, the report found. Two thirds of respondents felt that the water industry will be held accountable for water loss and will be expected to compensate for it within the next ten years.

The Miya report contrasts in some respects with the new AWWA 'State of the industry' report, which places source water supply and protection as the top area of concern among North American water professionals.

Other top issues identified in the AWWA report include the continent's ageing infrastructure, which was described as 'crumbling' and 'failing' by respondents. This concern, which equates directly to leakage, was the subject of disquiet that other pressing expenditure meant utilities were deferring infrastructure maintenance and therefore risking higher future bills.

EPA releases water system awareness video

The US EPA is encouraging the US public to learn about the dire need to overhaul the country's ageing water system in a programme called 'Liquid assets' which was aired on television stations around the country. The video looked at the state of the nation's potable, wastewater and stormwater infrastructure and illustrated solutions.

water asset management INTERNATIONAL

EDITORIAL

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Water Asset Management International is an international newsletter on asset management in water and wastewater utilities. The focus of the newsletter is on the strategic aspects of this developing field, providing utilities with international perspectives on infrastructure planning and maintenance as they seek to deliver cost-effective services to their customers.

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Water Asset Management International is published four times a year (March, June, April, December) by IWA Publishing. Statements made do not represent the views of the International Water Association or its Governing Board.

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Web: www.iwapublishing.com

SUBSCRIPTIONS

Water Asset Management International is available as either a print or an online subscription.

2008 price (4 issues):
£187 / €282 / $373
(IWA members: £162 / €243 / $312)

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Portland Customer Services
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Or visit: www.iwaponline.com/wami/subscriptions.htm

Design & print
Original design: John Berbuto
Printed by Hobbs The Printers, UK

ISSN (print): 1814-5434
ISSN (online): 1814-5442

South African national strategy for water asset management

The Department of Water Affairs and Forestry (DWAF) of South Africa has been making steady progress with formulating a national water services infrastructure asset management (IAM) strategy. A 'scan' of the state of water services infrastructure is long complete. This was followed by a process to identify elements needed for an enabling environment to ensure sound IAM. Since then, DWAF has been identifying priority strategic actions and formulating an implementation plan.

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Introduction

The South African government has made substantial progress on its election promises to improve the lives of previously disadvantaged citizens, and on its commitment to achieving Millennium Development Goal targets. The expenditure on infrastructure has been considerable and since 1994 there has been:

- An increase of 90% in the number of people with access to a basic level of water supply; and
- An increase of 60% in the number of people with access to a basic level of sanitation service.

Further infrastructure targets have been set

However there is cause for concern that this huge national effort to provide better services is in many instances being eroded by neglect of maintenance and refurbishment. Insufficient attention is being paid by the majority of municipalities to their responsibility to manage their infrastructure. In addition, many have, due to years of neglect, built up a backlog of need in respect of maintenance and also refurbishment, renewal and replacement.

The national Department of Water Affairs and Forestry (DWAF) acknowledges that, as sector leader, it needs to provide guidance. Accordingly, with the assistance of consultants, it has formulated a national water services infrastructure asset management (IAM) strategy.

The strategy formulation work has been undertaken in four phases:

- a desktop strategic study, a 'scan', of the state of South Africa's water

services infrastructure and the state of its asset management.
- a process of identifying the key factors that drive these states, and identifying elements needed for an enabling environment to ensure sound IAM.
- the identification of a set of priority actions required.
- formulation of the strategy itself.

National IAM initiatives

The South African government is promoting IAM by means of initiatives in respect of the following:
- Legislation
- Guidance: strategy, policy and tools to manage IAM
- Training: educational material
- Implementation: hands-on technical assistance
- Continued improvement: sharing of information and research.

A number of national IAM initiatives are planned to complement each other. Principal among these are the 'National Infrastructure Maintenance Strategy' (NIMS) (Department of Public Works (DPW) et al 2006 – approved by Cabinet in 2006), the Government-wide Immovable Asset Management Act (GIAMA) (sponsored by DPW – Act 19 of 2007), and National Treasury's several measures over recent years to increase provincial and local government accountability for assets. (For example, National Treasury has published regulations requiring municipalities to do impairment testing at both the asset and network level.)

The national water services infrastructure asset management strategy (hereinafter abbreviated as the 'Water IAM Strategy' or, simply 'the Strategy') will, in respect of water services, further the aims of all of the above, and will assist water services infrastructure owners and other stakeholders with interpretation and alignment of these initiatives in respect of the water services environment.

The Water IAM Strategy is not an isolated initiative. It will need to synergise with, and will in turn to varying degrees be supported by, many current initiatives, some within the water sector, and some not. Figure 1 shows the context of the Strategy in relation to the most relevant of the national frameworks, water-only national enabling strategies, and local implementation strategies and plans.

At a local level, water services IAM must take cognisance of municipal implementation strategies and plans, and indeed must be implemented as part of the municipal infrastructure master plan and its infrastructure asset management plan for all infrastructure.

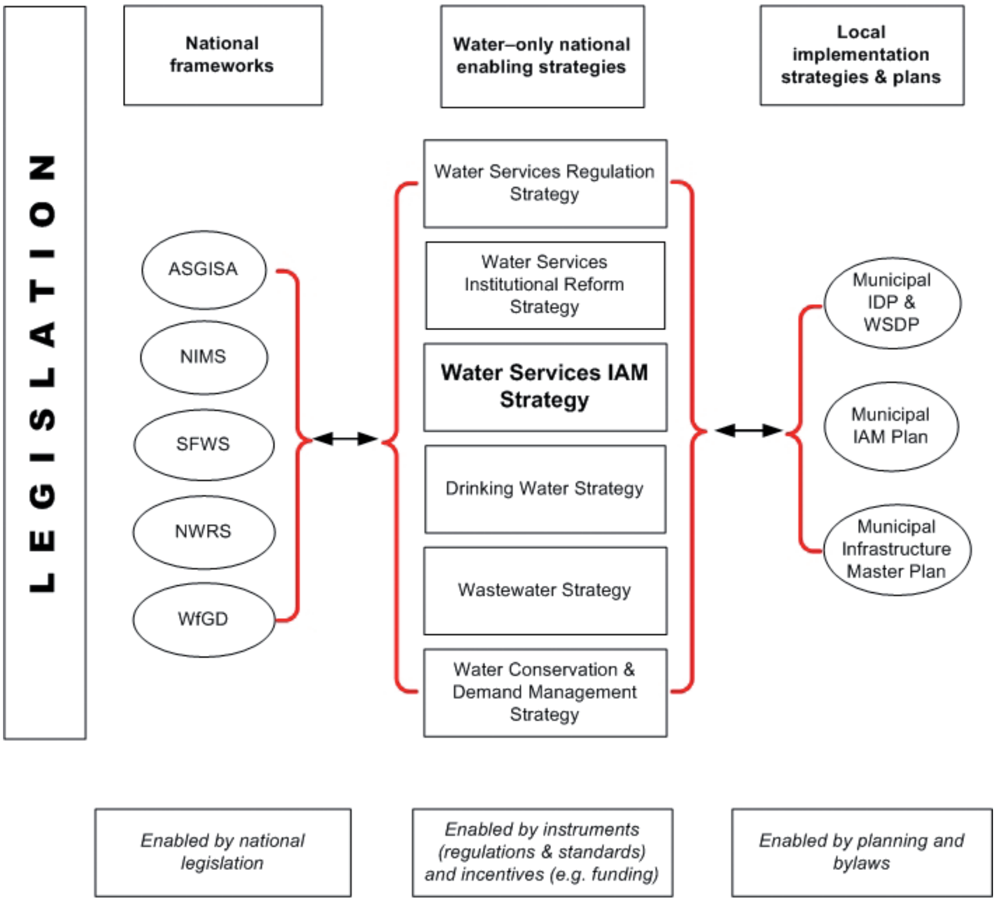

Figure 1
The national water services IAM strategy in context with other strategies and plans

Municipal plans and priorities, and budget and capacity limitations, determine the extent to which water services IAM needs would be met in the context of a municipality having a range of demands and priorities.

Fact-finding to solution-identifying

The findings of a desktop 'scan' of the state of South Africa's water services infrastructure and the state of its asset management, and analysis of those findings, has been the foundation upon which the IAM Strategy has been built.

Analysis of the scan's findings ('proceeding from fact-finding to solution-identifying') commenced with a process of identifying the key factors that drive the existing state of water services infrastructure and the state of its management. This phase involved not just problem identification, but also analysis and classification of problems. It led to identification of elements needed for an enabling environment to ensure improved infrastructure asset management, and also started to broadly identify which institution should be responsible for leading each element of the improvement process.

More than 400 generic challenges were identified. They were then rigorously analysed and classified into 'challenge areas'. This analytical approach facilitated better understanding of individual challenges, as well as of the bigger picture in terms of priority needs.

The analysis then proceeded from challenges to the identification of a solution for each of the 400-plus generic challenges. Evaluation and finding commonality of solutions enabled classification of solutions into one or other of nine 'solution types', viz:
- Awareness
- Finance
- Guidelines
- HR (including skills and appointments)
- Legal and procurement
- Monitoring and evaluation
- Management and leadership
- Operation and maintenance
- Technical

Figure 2 shows the count of solutions per solution type (DWAF 2006, page 22). This Figure indicates that much needs to be done on the human resources, skills development and capacity building aspects. While the focus of capacity building is on municipal and other water services institutions' capacity, capacitation must also include DWAF and other national and provincial roleplayers that have to manage the process and regulate effective service delivery.

Financial solutions were also shown

to be important. Necessary measures include, amongst others, improved budgeting and allocations for IAM, financial incentives for effective IAM performance, cost recovery, and various other planning, regulation and administration issues.

Management and leadership is another significant area. Specific actions need to be taken by DWAF as sector leader, and by water sector managers and their political leadership in general. To make a strategic intervention of this kind, it is essential that politicians and senior managers fully understand, appreciate and support IAM.

The water services IAM strategy

DWAF's vision is that it, together with its strategic partners, will empower and guide water services institutions to practice sound infrastructure asset management (IAM), aimed at ensuring optimal utility from public investments in water services infrastructure, and the reliable and sustainable meeting of service delivery obligations.

The objective of the National Water Services Infrastructure Asset Management Strategy is to achieve the following outcomes:

- Service delivery failures in targeted water services institutions in the short term, and effect improvements that can be publicised in order to demonstrate the benefits of IAM.
- Develop in the water sector in the longer term of a culture of sustained improvement in IAM.

The Strategy therefore sets out at a high level how this objective will be achieved by DWAF and its strategic partners. It identifies the 'what and who' that needs to be done (but not the 'when') in respect of each important action. The Strategy outlines a suite of instruments designed to achieve the 'outcomes' quoted above – including both a facilitative approach (through empowerment and guidance) and an approach that relies on monitoring and regulation.

While the Strategy is firmly focussed on water services, linkages between the Strategy and water resource IAM initiatives must, in the broader interest of the water sector and consumers, be forged, and good IAM practices pursued across the whole of the water sector, water resources included.

The principles underpinning the Water IAM Strategy are:

- **Systems approach**. IAM planning must look at the entire water services delivery chain, identify the constraints within the system as a whole, and then methodically address these, prioritising the most serious constraints.
- **IAM is an integral part of ongoing service delivery**. IAM is a continuous process, not a once-off project or an event.
- **Water services focus**. This Strategy addresses improvements in the practice of water services IAM, as opposed to the management of other municipal infrastructure or water resource infrastructure.
- **IAM focus.** This Strategy recognises the broad array of challenges with which infrastructure managers are presented, but concerns itself with the formulation of priority actions to address IAM-specific issues.
- **Recognition that water services delivery is both a human right and commodity-based**.
- **Outcomes-based.** Each priority must be outcomes-based and measurable.
- **An appropriate mix of short term successes and long term sustainability.** Whereas this Strategy recognises that the full establishment of IAM practices has a medium to long term horizon, it also recognises that short term successes are not only possible but are required to establish credibility, harness support and to improve failing service standards.
- **Promotion of an integrated, inter-disciplinary and inter-sectoral approach.** This Strategy promotes appropriate inter-disciplinary and inter-sectoral alignment, and thus an integrated approach to IAM.
- **Focus on the key challenges, and prioritise.** The Strategy recognises that only a select group of challenges can be addressed at any one time, and that the key challenges that impede the adoption and practice of sound IAM must receive priority attention.
- **Adoption of the Pareto (80/20) Principle**. Extending this thinking, a 'scan' effort, to determine as quickly as possible where the most critical problems lie, followed by the first steps of what would be a longer improvement process, would often be worthwhile.
- **No one size solution fits all.** While the general principles of IAM remain valid for all institutions, the priorities differ from institution to institution, and also change with time – as do the techniques, the technological and non-infrastructure options and other factors.
- **Start with the basics, and get them right.** The approach must be incremental. Do not attempt to progress further until the basics are right.
- **Political, management and operational focus.** All levels must commit to IAM in order for it to be successful.

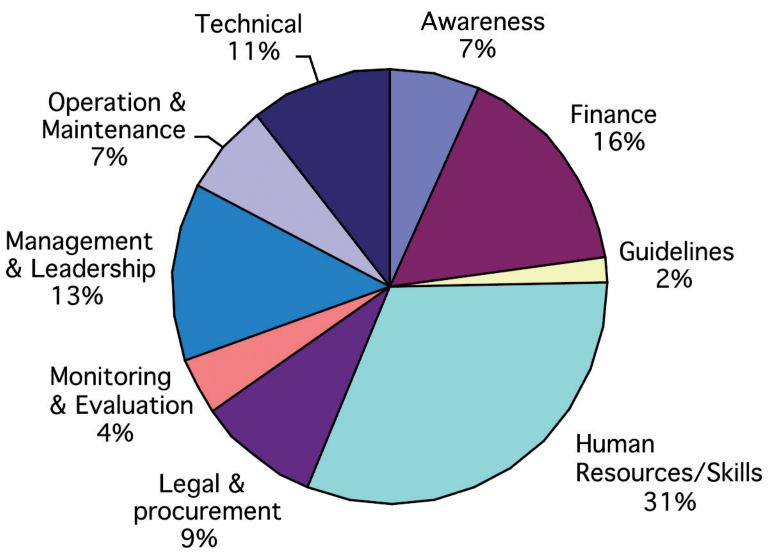

Figure 2
Solutions, by type

The Strategy comprises the components listed below. These are defined in detail in the implementation plan.

The Strategy components are:

- Create awareness. Start with issuing a water services IAM policy statement and with priming the sector.
- Scan and analyse IAM initiatives other than those of DWAF, and also other initiatives for support to water services institutions, and achieve synergy with these where appropriate.
- Review existing water services monitoring and evaluation. Extend monitoring and evaluation coverage before increasing depth. Outline how regular milestones for assessment of water services reliability and sustainability, and in particular IAM performance, will be determined, and how progress

towards these in particular will be monitored.

- As quickly as possible:
  - Set out in sufficient detail the criteria for selection of water services institutions for priority attention from DWAF and its strategic partners, and for identification of the specific actions in respect of each – and prioritise.
  - Also set out the information requirements of the selection process, and create appropriate links to the existing and evolving databases identified for this purpose.
  - Initiate the selection process, select, and programme the work for the first year or other period decided upon – also resource it.
  - Then commence implementation.
- In this:
  - prioritise quick wins (not 'prioritise the worst cases' – not necessarily the same thing, although it could be in some instances)
  - prioritise actions, focused on the specific problems, in respect of a small number of the very worst crisis cases.
- Make it clear to institutions what they are expected to do for themselves, and what they can get assistance with.
- In all these, address the basics first, and get them right. And, in addressing the basics, prioritise attention to the weakest links among the basics.
- Define and structure incentives for water services IAM. Tighten the regulatory process, and build on existing corporate and individual incentives (such as levying penalties for non-compliance, enforcing skills level requirements, and offering assistance to those institutions willing to improve).
- Identify, adapt if necessary, and prioritise utilisation of existing tools, such as guidelines and systems, that are required for each level of need. Identify the further tools needed, and start the process of developing these, together with means for their use.
- Discover, select, organise, and disseminate good practice in water services IAM, so that the good practice lessons are put to good use. (In almost all circumstances, 'good' practice is needed, not 'best'!)
- Assess the most frequently encountered obstacles to bringing the needed resources to bear on improvement, and, where advisable, resolve these. Also assess the advantages and disadvantages of, and opportunities for, outsourcing.
- Review the content of and the relationship between municipal planning and budgeting and IAM, prioritise, and rationalise – in respect of what government expects in the general case, but also, in the course of time, in respect of each municipality.
- Where unsustainability and/or unviability of institutions is shown to be a significant factor retarding IAM, start the process of addressing this.
- Analyse skills resources in the sector, decide on required actions, and start the process of resolving this.
- Discover, through pilot implementation, the resources that are required for institutions to be able to undertake sound water services IAM.
- Draw up a pro forma recovery plan.

To emphasise: the foundation of the Strategy is the rigorous process of fact-finding and analysis that preceded its formulation.

These components of the Strategy constitute a set, the carefully considered final output of an extensive water services infrastructure asset management investigation. All must be proceeded with if water services infrastructure asset management is to improve significantly. None must be omitted or put on hold for an indefinite period. Putting some on hold would jeopardise progress with others.

DWAF does not have the mandate or resources to address all of these. Some of them, entirely or partially, are the responsibility of other parties to resolve – DWAF should only seek to influence what must be addressed, and its outcome. The issue of procurement, for example, sits squarely with other national government departments (National Treasury and Department of Provincial and Local Government (DPLG), in particular). For another example, whereas DWAF needs to assist with the devising of appropriate norms for budgeting for water services IAM, the financial situation of water services authorities, and regulation of their budgets, is the responsibility of National Treasury – not of DWAF.

The Strategy, at the time of writing (July 2008) in final draft, spells all of the above in some detail (DWAF 2008).

It will no doubt assist progress towards improved water services IAM that there currently is –

- growing recognition on the part of national and provincial government of the serious problems facing many water services institutions, and of the necessity for water services IAM improvement – if necessary, through intervention from outside the institutions; and
- increasing public pressure for improvement in service delivery – including for improvement in delivery by existing infrastructure.

Finally, and very important:

- whereas the emphasis of the Strategy, and of the 'most important actions' listed, is generally on practices establishment and improvement, with the assumption that the state of water services infrastructure and the state of its management will as a direct result improve;
- it is acknowledged that in many cases the infrastructure asset decay is so serious that direct intervention by national government, for example of a capital works nature (e.g. complete refurbishment of the asset, or even its replacement), would first be necessary.

Implementation plan

At the time of writing, the implementation plan and programme is being formulated. This is in broad terms identifying not just the 'what and who', but also the 'when', and will indicate prioritisation in terms of both urgency and importance. It also indicates the 'how', including tactics, culture and incentives, and identifies key performance areas and sets key performance indicators.

These details of selected aspects of the plan and programme are being formulated with the assistance of an external team and with the involvement of key sector partners such as DPLG, National Treasury, DPW, the South African Local Government Association and the Water Research Commission, and taking into account the roles of the various water services institutions. Cognisance is being taken of the main other national IAM initiatives, and how they are complementing achievement of the objectives of DWAF. The result will be an integrated and co-owned implementation framework. ●

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Integrated approach for water network rehabilitation

The importance of lowering leakage to improve the efficiency of a water network is well understood. What is less appreciated is the impact that a high leakage level has on the environment and the quality of service to the customer. The key is to achieve significant improvements without incurring high rehabilitation costs. This, in essence, is what was recently achieved in an innovative project undertaken in Tuscany, Italy.

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Introduction

Lucca is a wonderfully preserved wall town around 30 km east of Pisa in central Italy. It's water network is supplied by eight boreholes, many located in the heart of the city centre with minimal integration from a spring source just outside the city. As a result of the overexploitation of the aquifer, Lucca started experiencing water quality problems and in extreme cases, signs of subsidence in some historic buildings. Furthermore, the extensive pumping was proving to be financially very costly. The need for urgent action was clear; the question was, how.

Eliminating some of the boreholes would immediately ease the environmental and qualitative problems as well as yielding enormous financial savings. An attractive solution to replace the lost capacity of the boreholes was to exploit further the Le Vene spring source located around 10 km from the city centre which at certain times of the year exceeds 200 l/s.

For this solution to be feasible though, three potential problems had to be overcome: firstly, that the existing connection pipe was old and undersized and so unsuitable for carrying the quantity of water needed to supply Lucca; secondly that the available quantity, though at times considerable, would not alone be enough to always compensate for the production of the boreholes; thirdly, that it was not certain that the whole city could be served just with the head of the service reservoir.

The solution to the first problem was comparatively easy, as it was possible to construct a new supply pipe. The solution to the second and third problems involved the reduction of the leakage level which was equivalent to almost half the water produced. Not only would this significantly reduce the overall consumption of the network, but in doing so, reduce the headloss, thus increase the operating pressures to allow the furthermost parts of the network to be supplied by the service reservoir. However achieving a lower leakage level was far from straight forward, particularly considering the age, complexity and lack of accurate mains records of the network of Lucca.

The objective appeared simple. The question was how it could be achieved, particularly bearing in mind the age and interconnectivity of the network. GEAL SpA, which is part of the ACEA group and which manages the water network of Lucca, commissioned DEWI Srl, an international expert in the analysis and optimisation of water networks, to identify and implement a plan of action.

Technical approach

Experience has shown that the best way to lower and subsequently maintain a low leakage level in a water network is to divide it into a number of permanent sectors which ideally are supplied by a single pipe on which is installed a flow meter. In this way it is possible to identify immediately the presence of a new leak and know in which part of the network it is located. Consequently, the leakage teams are always able to work in the highest priority sectors to maintain the leakage at its minimum level. This approach has proved very successful in many parts of the world. The difficulty arises when dividing an old and hydraulically complex networks such as that of Lucca, where the knowledge of the system is incomplete and where there are numerous inter-connections between the supply and distribution networks, without affecting the quality of the service to the customers.

The solution is found in the application of a mathematical model which simulates the operation of the real network in all of its key hydraulic features; in particular the connectivity of the network, the diameter and material of the pipes, the characteristics of the pumps, capacity of the reservoirs and the consumption of all the consumers. Only in this way is it possible to identify those pipes having little hydraulic importance and which can therefore be closed without causing service problems to the customers.

To successfully simulate the operation of the real network with a mathematical model, it is necessary to reproduce the structure of the network as accurately as possible, to allocate the consumption with care and to verify the results of the model by comparing them with the pressures and flows measured in the network during a field test.

Great effort was taken in Lucca to verify the accuracy of the mains records by checking the connectivity between the key pipes in the field. However, it is important to remember that at best this can only be considered a partial check as not all elements of the network are directly accessible. For this reason, a mathematical simulation model is invaluable to determine the real hydraulic configuration of a water network.

The historical consumption of the customers was extracted from the billing database by street and type of customer. These were then allocated to

Figure 1
The Le Vene spring source

the nodes of the model in proportion to the number of nodes in each street. A demand profile was assigned to each customer type, derived from an extensive monitoring programme undertaken by DEWI Srl in other cities in Italy and internationally which have similar characteristics to Lucca. The leakage level was calculated by measuring all the inflows into the network (Figure 2) and subtracting from it the customer consumption. The resulting quantity was then allocated to the model in terms of the length of mains. Where possible, sub-areas were monitored separately so as to simulate more accurately the real distribution of leakage in the network. In fact, the extensive experience of DEWI Srl in building and calibrating mathematical models all over the world has highlighted the fundamental importance of the correct distribution of consumption for the accuracy of the final model.

Calibration is the term used for the process of verifying the accuracy of the model. Without this activity, the model cannot be considered a true representation of the reality and therefore suitable for designing leakage sectors. Specifically, calibration involves comparing the calculated pressures and flows with those measured in the network. In this way, differences between the historical knowledge of the network and the real operation can be highlighted and resolved. For instance in Lucca, many unknown closed valves or inexistent connections were identified.

The Lucca model is illustrated in Figure 3. This was built using the EPANET simulation programme and has a verified accuracy of better than +/- 1.5 m. This is more than sufficient to allow the design of the sectors to be undertaken with confidence.

Permanent control system

Mathematical simulation models, when properly constructed and calibrated, are immensely powerful tools. As they contain all the key elements of the water network, they allow the actual and future operation of the system to be thoroughly understood. This was particularly important in the case of Lucca where the objective was to divide an old, highly interconnected and hydraulically complex network into permanent sectors. An error in the design would not only compromise the efficiency of the system, but would severely reduce the quality of service to the customers, with particular reference to pressure and water quality. In fact, the latter point was a major concern in Lucca, where manganese deposits brought into suspension can significantly alter the quality of the water to the customer.

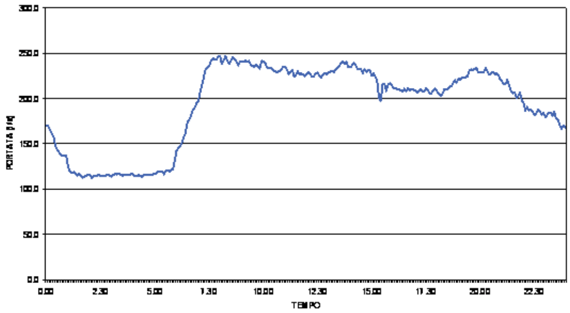


Figure 2
Inflow into the network of Lucca measured during the field test

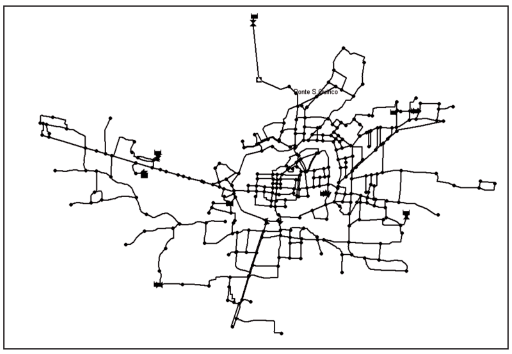
The objectives defined for the design of the sectors of Lucca were the following:

- Separate the distribution network from the supply network so as to maintain the operational flexibility of the latter system;
- Supply each sector by a single pipe;
- Close line valves to create a permanent sector boundary;
- Minimise the change in the hydraulic conditions.

The mathematical model was used to identify the exiting pipes having very low flows, which could be closed without modifying the hydraulic operation of the network. Twelve permanent sectors were designed, each supplied by a single pipe.

The significance of pressure on leakage has been appreciated for a long time. In fact, all recent documentation relating to leakage control, including IWA's Guidance Notes, highlight the importance of pressure reduction. Much less appreciated is the importance of controlling pressure. This means maintaining the optimum pressure in the network irrespective of the operating conditions, often by reducing pressure just at night. So successful has this innovative approach been, that DEWI Srl has even created pressure control systems in networks such as Jakarta, Indonesia where the existing operating pressures are as low as 10 m. The aim in Lucca was to install a pressure reducing valve (PRV) on all the inlets. This was possible only because a well calibrated mathematical simulation was applied during the design process. It is interesting to note that despite the long experience of managing the Lucca network, GEAL personnel were initially sceptical of the chances of success of such an ambitious and innovative approach. It is to their credit that once the first application was operational, they became converts.

Figure 3
The model of Lucca



Permanent leakage control system of Lucca

To test the validity of the approach developed for Lucca, it was decided to create the first two sectors in an area of the city called Sant'Anna. These sectors were chosen as they accurately reflect the characteristic of the whole network. In particular the distribution network is supplied by two boreholes through a number of direct connections from the DN 200 supply main. The design of the sectors required the closure of most of these connections to create two distinct sectors. It was known before the start of the project that one part of the distribution network of Sant'Anna suffered from low pressure problems. The model however indicated that there was no hydraulic explanation for this situation, other than an unknown closed valve, an effective diameter different to the one shown on the mains records or a big leak. Further investigation confirmed the last hypothesis and the situation returned to normal immediately upon its repair.

The analysis with the calibrated model showed that a there was also scope for reducing the night time pressures using a PRV. Both districts were created successfully and without affecting the quality of service to the customers. An electronic controller was connected to the PRV to vary the downstream setting during the night hours.

Step testing was undertaken to identify the pipes with most leakage. The test involves the progressive closure at night of the network. By measuring the flow during the test, it is possible to identify the leakiest parts of the network. The leaks were then located using acoustic instruments and repaired by GEAL SpA.

A GSM logger was connected to each meter which transmits daily to the control centre the flow into each sector. In this way it is possible to continuously check the leakage level and immediately identify the presence of new leaks. It is interesting to note, in the two years since the Sant'Anna sectors were created and the original leaks located and repaired, that the leakage level has remained constant confirming the validity of the approach.

The results achieved are summarised as follows:

- Original minimum night flow into both sectors – 13 l/s

- Final night flow into both sectors – 4 l/s
- Leakage recovered – 9 l/s or more than 280,000 m^3/year.

A more detailed analysis of the work involved to achieve these results yields the following parameters:

- Replacement of 0.1 line valves/km
- of network;
- Rehabilitation of 0.1% of the network;
- Repair of 0.6 leaks/km of network;
- Leakage recovery equivalent to 0.6 l/km/s.

The importance of optimising the control of pressure was further illustrated when the permanent sectors of the historic city centre were created. Here the operating diurnal pressures were less than 30 metres, in part due to the deteriorated internal condition of the pipes. However by careful design, it was still possible to create a permanent sector supplied by a single pipe on which were installed a flow meter and pressure reducing valve. The results are shown below in Figure 5.

It emerges that by simply reducing the pressure from 38 m to 18 m, the night flow reduced by 5.5 l/s which, when extrapolated over 24 hours, represents a saving of over 50,000 m^3/year. Repairing the leaks will yield further reductions.

Analysis of the results

When the results are applied across the whole network, it yields a possible leakage recovery of 72 l/s or over 2.2 million m^3/year. It is estimated that to do so will involve installing 12 new line valves, replacing around 1200 m of pipe and repairing 75 leaks. In this way it will be possible to eliminate at least five boreholes and supply the network mainly from the spring source of Le Vene through the service reservoir of San Quirico.

The mathematical model was also extended to cover the existing Le Vene supply area to assess the requirements for transporting the water to the San Quirico reservoir. This analysis demonstrated the need to construct a new 7.5 km long DN 350 trunk main not just to provide the necessary carrying capacity, but also ensure sufficient head to supply the exiting customers connected to the Le Vene system. The model also showed that with a reduced leakage level and the increased capacity of the supply pipe, it would be possible to supply the entire city from the San Quirico service reservoir without the need for the bore holes.

Around half the permanent sectors have so far been created, including a number in the city centre. It is anticipated that the project will be completed in 2009.

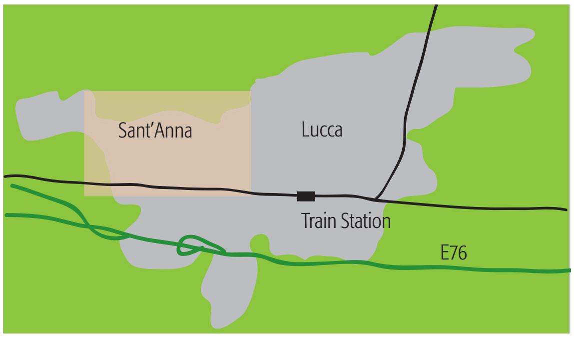


Figure 4
Sant'Anna part of Lucca

Conclusions

The importance of lowering leakage to improve the efficiency of a water network is well understood. What is less appreciated is the impact a high leakage level has on the environment and how with an integrated approach it is possible to optimise rehabilitation interventions. This is evident from the Lucca project undertaken in Tuscany, Italy.

Lucca is supplied primarily by eight boreholes, many located in the heart of the city centre with minimal integration from a spring source just outside the city. As a result of the overexploitation of the aquifer, Lucca started to experience a water quality problem which requires costly treatment and in some cases, has even caused the slight subsidence of a few historic buildings. Furthermore, the extensive pumping was proving to be financially very costly. The need for urgent action was clear; the question was, how?

Eliminating some of the boreholes would immediately ease the environmental and qualitative problems as well as yielding enormous financial savings. However there was need to compensate for the significant loss in production capacity. This was possible by a combination of leakage reduction and exploiting the unused capacity of the Le Vene spring source located around 10 km from the city centre.

The traditional approach to leakage reduction is to undertake wholesale rehabilitation of the network which usually involves pipe replacement. Not only is this extremely costly, but without first a change in the operational configuration of the network, is not necessarily guaranteed to succeed. In fact, there are numerous examples of large scale pipe replacement programmes yielding little or no direct benefit.

Figure 5
Effects of pressure control on leakage

Experience in many parts of the world has show that the best way to lower and subsequently maintain a low leakage level is to divide the water network into a number of sectors supplied by a single pipe on which is installed a flow meter. In this way, the leakage level can be permanently controlled and the presence of a new leak immediately identified. The division of an old and inter-connected network like that of Lucca's, by closing line valves to create a permanent boundary, is a very delicate operation. If not undertaken with care, it can lower significantly the standard of service to the customers, in particular pressure and water quality. The solution was to construct and calibrate a mathematical simulation model which allowed the existing hydraulic balance points to be identified and where the closure of a line valve would not significantly modify the existing operation of the network. In this way the optimum configuration was achieved.

Around a third of the sectors have now been successfully constructed which has yielded a leakage reduction of over 750,000 m^3/year. When all of the sectors have been created and the leaks have been located and repaired, it is estimated the saving will amount to 2 million m^3/year which alone represents an annual economic saving of around €250,000 ($340,000). This result, coupled to the construction of a new DN 350 supply pipe to connect the Le Vene spring source with the city, will allow at least five of the eight existing boreholes to be regularly eliminated. Not only will this further improve the operational efficiency of the network, but will also yield important environmental benefits. All this has been achieved without the need to resort to wide-scale pipe replacement thanks to in-depth analysis, careful design and optimised interventions.

The Lucca project demonstrates that by applying an integrated approach, with leakage reduction and control at its heart, it is possible to resolve many conflicting requirements, most notably, eliminating environmental problems whilst at the same time drastically improving the efficiency of the water network. Best of all, the Lucca project shows that this is all possible with a surprisingly limited capital investment. ●

Strategy for the development of optimized flushing plans

One aspect to be considered in asset management are the costs for measures to safeguard the drinking water quality in the network. The main reason for visible quality changes is the mobilisation of loose sediments which leads to customer complaints. To avoid brown water the deposits have to be flushed out of the network before a critical level is reached. The distance of time between the flushing procedures depends on the deposit formation process in the pipes. As the velocity of the deposit accumulation is different, in dependence on the material and hydraulic situation, a strategy was developed at DVGW Water Technology Center Karlsruhe (TZW) to determine the sediment-forming processes as a basis for establishing network-specific flushing plans.

A. Korth, Sebastian Richardt and Burkhard Wricke in this paper discuss an optimized flushing plan, which offers a minimization of expenditures for the water supplier and an optimization of the cleaning effect. Through this, the water supplier has a clear basis for the calculation of costs for the regular cleaning of the distribution network.

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Introduction

A good management practice for the distribution network is essential for safeguarding the drinking water quality in the network. Therefore, pipe flushing plays an important role in the removal of deposits, as sediments can be the reason for brown water events (Powell and Brandt, 2003, Böhler et al, 2004), microbiological irregularities (Besner et al, 2002), and the growth of invertebrates (Schreiber, 1996).

In many cases, flushing is carried out only after brown water events have occurred as a result of the mobilization of deposits. Often, only an exchange of water with a low flow rate is carried out to remove the resuspended particles. Whirling up of deposits in the surrounding pipes is to be avoided. A far-reaching removal of existing deposits often is not possible due to low flushing velocities.

Aside from the flushing after brown water events, end pipe flushing is carried out. Hereby, the cleaning effect remains restricted only to these pipes, however, sufficient flow velocities must be reached there as well.

Through the regular and systematic flushing of the complete network, the accumulation of critical amounts of deposits can be avoided. However, in Germany this is carried out rather seldom as it is connected to high personnel expenditure and a large consumption of water. In the flushing of the entire network, there are also pipes flushed, which, on the basis of the deposit situation, are not necessarily categorized as in need of flushing. The portion of such pipes in a network may be rather considerable so that the flushing is connected to a higher expenditure than the deposit situation in the network would require.

The growing pressure on costs leads to a more frequent examination of the expenditures for the network management, so the question about the necessity of network measures also comes up. On the other hand, brown water events can lead to a supplier's image loss. Therefore, optimized flushing of the pipe network is to be aimed at. This means that flushing is carried out by taking into consideration the actual formation and the risk of the mobilization of deposits. In recent research projects (Techneau, BMBF/DVGW project 02WT0618) a strategy for the implementation of optimized network flushing plans is being developed, which will be introduced as follows.

Formation of deposits in the distribution system

The formation of deposits in the network is determined by the input from the treatment plant, the corrosion in the network, as well as the mobilization of deposits. The following processes play a major role:

- **Input of particles due to insufficient treatment**. Because of insufficient treatment, iron or aluminium flocs as well as algae or sand can be carried into the network (Slaats et al, 2002). Hereby, freight plays a major role. Already very small rest amounts of iron or particles can lead to a significant accumulation of sediments.
- **Input of dissolved particles via treatment plant**. Aside from the input of particles, dissolved substances such as iron, manganese, calcium or organic compounds can also be carried into the network by the treatment plant (Sly et al, 1990). In such a case, the freight can also be quite considerable. Aside from the sedimentation, the formation of flocs in the water also influences the formation of deposits.
- **Corrosion in unprotected cast**

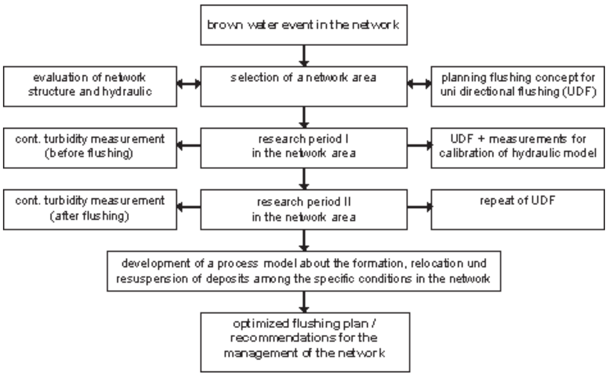


Figure 1
Procedure for the development of an optimized flushing plan

iron and steel pipes. In the networks with a high portion of unprotected cast iron and steel pipes, corrosion, which is influenced mainly by the water quality and the hydraulic conditions, is to be understood as the primary input path (Boxall et al, 2003). Iron(II) released due to corrosion is, among others, changed into iron(III) hydroxides. The formation of iron(III) hydroxides can take place immediately on the surface of the corrosion layer, creating a deposit. Beyond that, the formation of iron(III) oxides can also take place in the water (Kuch, 1984), which causes the iron to be displaced into other pipes.

- **Relocation of sediments**. Under stable conditions the deposition of particles takes place depending upon their characteristics, as well as the hydraulic situation. If a resuspension of sediments takes place due to a sudden disturbance in hydraulic conditions, considerable amounts of deposits can be moved to pipes downstream.

Methods

The preparation of an optimal flushing plan proceeds step by step on the basis of the concept depicted in Figure 1.

If the flushing plan is to be determined only for a small supply area, the complete network is included in the investigations. However, if it concerns a larger supply network, a representative partial area with a network length of approximately 5 km is selected as area of investigation.

In the first step, an analysis of the network structure as well as the hydraulic conditions is carried out, as far as a hydraulic model is available. The first conclusions may be drawn about the accumulation of deposits. Additionally, the measuring points for the continuous turbidity measurements are identified and the flushing concept is established for the first basic flushing (uni-directional flushing (UDF)) of the investigation area.

In the next step, continuous turbidity measurements at the predetermined points are carried out for recording the behaviour of particles in the network. After that, the network area is cleaned by UDF and the amount of removed deposits is determined. If necessary, the first flushing can be used for a calibration of the hydraulic model.

For the determination of the velocity of the formation of deposits, flushing is repeated after a defined time-frame. Afterwards, continuous turbidity measurements are carried out again. From the comparison of the turbidity measurements before and after flushing, the influence of the deposits onto the particle situation in the water body can be determined.

As a result of the measurements, a model of the formation and the behaviour of the deposits is established under the specific local parameters. Based on this, the optimized flushing plan is made. In addition, recommendations can be made for targeted network measures (e.g. changing the hydraulic situation or rehabilitation).

The methods used for the investigations as well as the important work steps will be described in detail in the next parts.

Results and discussion

Network analysis

Figure 2 shows an example of the network structure as well as the flow conditions in an investigation area at maximum daily consumption. The chosen measuring points for the turbidity measurements are also included. The local input pipe for this network area is a gray cast iron pipe DN 150 GG (measuring point 1), with a flow velocity of approximately 0.2 m/s. Due to the material, corrosion takes place in the pipe. Because of the comparably high flow velocity it can be assumed that the deposit level in the pipe will be low and the formed corrosion products will be moved into the pipes downstream. There, a portion of the input particles deposits are due to the low flow velocity. Additionally, there is further formation of deposits in the cast iron pipes because of corrosion. Due to a low flow velocity, a higher deposit level builds up in these pipes than in the main pipe of the area.

The points for the turbidity measurement were selected as follows: The behaviour of the turbidity in the main pipe was detected at the points 1 (input), 2 (centre), and 3 (end). Point 4 served for a relatively well flowed pipe. At points 5 and 7, sedimentation of the in-carried turbidity can be observed. The influence of the corrosion at low flow velocity was determined at point 6.

Continuous turbidity measurement

Through continuous turbidity measurement, the behaviour of the particles in the network can be detected. For this, turbidity meters were modified in such a way that they do not require any external power supply and can therefore be installed at any one hydrant in the network. The measurements are carried out simultaneously with six to eight turbidity meters for about one week. Figure 3 shows the results at four consecutive measuring points in an area with unprotected cast iron pipes. At input point 1 only a low turbidity was measured. Thus, the input of turbidity from the main pipe is low. At the following measuring points 2 and 3 in the area with

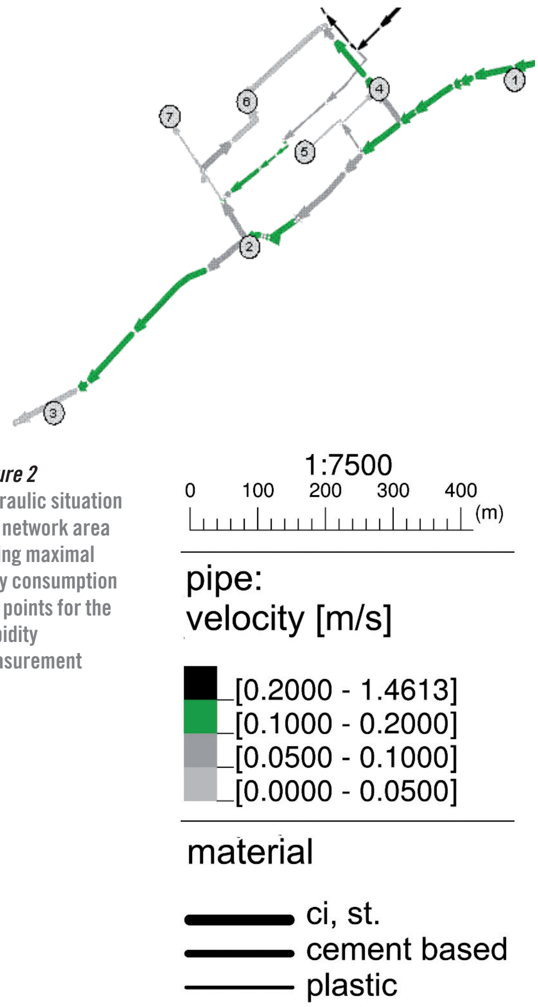
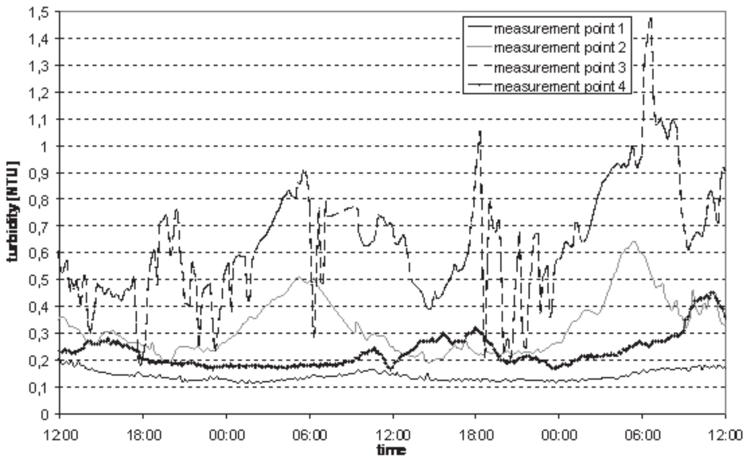


Figure 2
Hydraulic situation in a network area during maximal daily consumption and points for the turbidity measurement

unprotected cast iron pipes, there is an increase of the turbidity. The highest values occurred during the night-time hours. This is due to the iron release from the pipe material into the water body due to the corrosion processes and the following formation of flocs. The increase during the night-time hours is caused by the effect of an emerging concentration of corrosion products due to the decrease of the flow velocities. At measuring point 4, which is located behind measuring point 2 in the area of an end pipe of corrosion protected material, only a relatively low turbidity was measured. This means that the iron flocs that had formed are, for the most part, sedimentated on the flow path between measurement point 2 and 4.

In addition to the turbidity measurements, a regular determination of the iron concentration for the characterization of the particles is carried out at the measurement points.

Figure 3
Results of turbidity measurements in a network area with cast iron pipes



Flushing procedure

The network analysis and the results of the turbidity measurements allow for indirect conclusions about the deposit situation. However, estimating the actual amount of the deposits is only possible by the removal of the sediments by flushing. In the first step, a UDF of the entire area is carried out. For this, a flushing concept is worked out which determines the sequence of the flushing elements as well as the necessary valve positions for a defined flushing direction. For every flushing segment the turbidity in the flushing water is continuously recorded. From the turbidity, in connection with the determination of the iron and manganese concentrations in flushing water samples, the amount of the deposits as well as their location in the pipe can be determined. Figure 4 shows the result of a turbidity measurement during the flushing of a cast iron pipe (DN 100) which branches from a main pipe (DN 180 PE) with a higher flow velocity. The high basis level of the turbidity in the flushing water of the gray cast iron pipe is mainly caused by the formation of deposits due to corrosion. However, the turbidity peak, which is localized at the end of the gray cast iron pipe, is connected with to the input of sediments from the main pipe, which were deposited in the first pipe segment due to the relatively low flow velocity.

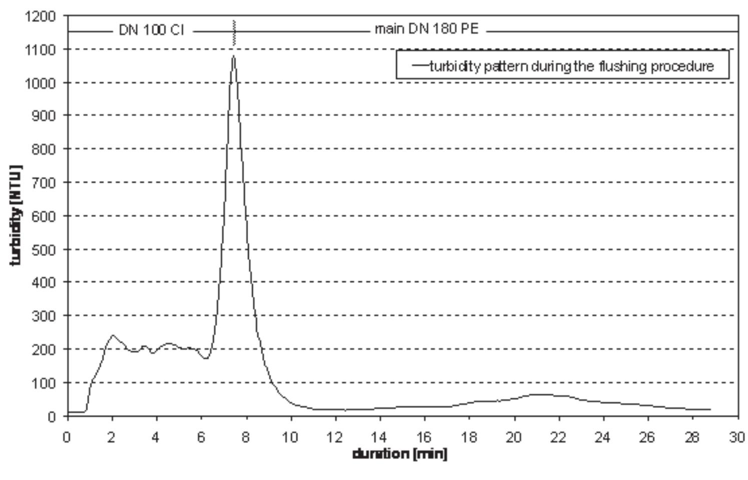
For the determination of the mobilization behaviour of the deposits, the flushings are carried out on selected pipes with a step-by-step increase in flushing velocity. As can be seen in the example in Figure 5, there were considerable deposits in the pipe, which, to a large part, had been flushed out with a velocity of 0.35 m/s. In the second flushing step (0.7 m/s) there was still an increase in turbidity to be noticed. In contrast, during the further flushing steps there was a low turbidity. Therefore, in the present pipe type, flushing velocities of about of 0.7 m/s are sufficient for reaching an extensive output of the loose deposits. From the investigation it can also be deduced that there are sufficient amounts of deposits in the pipe to cause considerable brown water events in a flow velocity increase of approximately 0.3 m/s.

In most cases it is not possible to deduce the velocity of deposit formation from the results of the first systematic flushing of the network area because there is no defined operation interval of the pipes. For this reason, a second systematic flushing is carried out after a defined interval (six to 12 months). Figure 6 shows the amounts of iron deposited between two systematic flushings (g iron/m^2 pipe interior surface) as an example of the investigation area depicted in Figure 2. There are distinct differences between the pipes, which are determined by the different processes of deposit formation and relocation. It is to be noticed that there was only a small amount of deposits found in the input of the unprotected cast iron pipe at point A. This results from the relatively high flow velocity during the day maximum consumption which leads to the limitation of the deposit situation in this pipe. The particles which are transported through the main pipe (point A), sedimentate in the connecting pipe (point B). Only a small amount of meterial is transported to point C due to the continuously low water flow. The largest amount of deposits was found at point D. On account of high flow velocities only little sedimentation is possible in the pipe ahead (from point E to point F). Turbidity value in the water reach the connected pipe segment D which has only a low flow velocity. Because of the decrease of the flow velocity particle sedimentate at the connection of the two pipes, the deposit formation at this point is relatively fast.

Preparation of flushing plans

In the outcome of the measurements, a process model is being established of the processes which lead to the formation of deposits (input of turbidity material, sedimentation, influence of corrosion, etc). From this the optimal flushing plan is worked out. In dependence on the velocity of

Figure 4
Pattern of the turbidity during flushing of a cast iron pipe



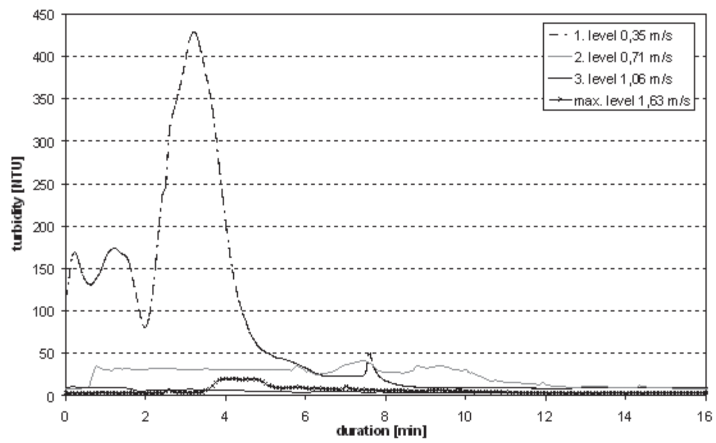


Figure 5
Results of a stepwise flushing of a pipe

the accumulation of the deposits as well as under taking into consideration the risk of the remobilization events, the pipes are divided into flushing groups for which flushing rhythms, flushing velocities as well as valve positions have been determined. A risk evaluation of the mobilization of deposits is carried out in consideration of their mobilizability and possible irregularly occurring flow velocity or flow direction changes.

The development of a process model allows for the deduction of flushing recommendations also for other network areas with similar conditions. Beyond that, the effects of hydraulic changes as well as rehabilitation measures can be estimated and precise recommendations can be made for the rehabilitation strategy.

Summary and conclusions

Pipe network flushing is an essential measure for safeguarding the water quality in the supply network system. In practice, this is carried out in different ways. The aim of flushing should be to remove loose deposits to the greatest extent possible to avoid water deterioration. The question is, which pipes are to be flushed at which velocities and at which intervals? From investigations in different networks a procedure was developed to record the processes of the formation of deposits and, based on this, to establish an optimized flushing plan. The flushing plan contains the following information:

- Classification of the pipes depending on the velocity of deposit formation
- Timetable for flushing the different categories of the pipes
- Required valve changes during flushing to avoid sediment resuspension in other pipes
- Required flushing velocity for a complete removal of the deposits
- Identification of pipes (cast iron) of a high priority for rehabilitation due to dirtying other pipes

Using a reasonable flushing plan, the water supplier has a clear basis for the calculation of the costs for the measures which are essential for avoiding a deterioration of the drinking water quality in the network. Furthermore, the investigations give information about a useful and cost-efficient rehabilitation strategy for the network, because of identifying which pipes are dirtying other pipes.

In the EU research project 'Techneau' and the BMBF/DVGW research project 02WT0618 further investigations about the behaviour of deposits are carried out in networks of various water suppliers as well as in test rigs. In the outcome, a mathematical approach shall be developed which allows for the description of the formation of deposits in a network. The mathematical approach is to be coupled with a hydraulic modelling programme to develop a tool for establishing optimized network flushing plans.

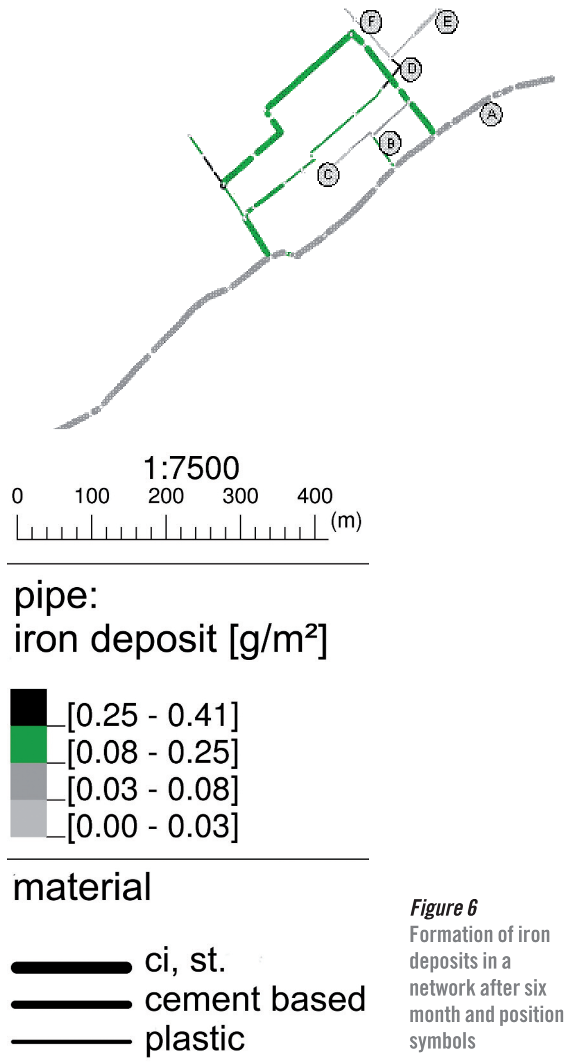


Figure 6
Formation of iron deposits in a network after six month and position symbols

Acknowledgement

The authors would like to thank the Bundesministerium für Forschung und Bildung as well as the Deutscher Verband des Gas- und Wasserfachs e.V. and the EU (Techneau) for the support of the project. They also thank the Stadtwerke Chemnitz, the Dahme Nuthe Wasser und Abwasser Betriebsgesellschaft, the Hallesche Wasser und Abwasser GmbH, the OEWA Wasser und Abwasser GmbH and other water supply companies for the possibility to carry out investigations. ●

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Paper presented at LESAM 2007 – 2nd Leading Edge Conference on Strategic Asset Management

Strategic selection of materials for wastewater networks

The city of Oslo is rethinking its strategies for the selection of materials for its wastewater networks, in particular pipes and manholes. The new strategy is meant to provide a best possible performance and low costs for maintenance and repairs over a 100 year perspective. It includes selection of materials for new constructions and renovation works and evaluation of existing pipe materials used. Their approach is broad, including all aspects that are important to meet the performance goals, i.e. reliable sanitary service, enough capacity to avoid flooding, and no pollution to local receiving waters.

The strategy comprises the combination of materials and construction practise as well as the relationship between materials and construction practises used and needs for operation and maintenance.

Sveinung Sægrov, Leif S. Hafskjold, Per Kristiansen and Terje Skaug in this paper outline criteria for the future management of wastewater network in Oslo, and conclude that attention on systems for documentation of all steps in the life cycle is a crucial instrument to maintain sustainable development.

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The city of Oslo is rethinking its strategies for the selection of materials for the wastewater networks, in particular pipes and manholes. This also includes pipe materials for new constructions as renovation methods. The strategy shall give basic recommendations for rules and guidelines, valid for all players in the wastewater network business in Oslo, and also act as a basis for future staff training. Further, it shall contribute to an environmentally-friendly method of wastewater network management. The overall aim of the strategy is thus to safeguard a system that over its entire life period maintains its flood capacity without limitations due to constructional failures, or failures influencing the flow capacity. As Oslo wants to appear as an environmentally-friendly city, the vulnerability of local flooding as well as pollution of local water courses due to network failures are considered, and also resources spent to produce, transport and construct the pipes,and maintain the pipelines. The selection further obviously depends on the availability of pipe materials as well as their mechanical and degradation properties.

Material candidates for wastewater are mainly ceramic, concrete and plastic pipes, for renovation also special solutions like 'Cured-In-Place-Pipes' (CIPP) or 'Formed-In-Place-Pipes' (FIPP). They are analysed by the criteria above to find their ability to obtain the demands of performance over their life time. As such, this is a contribution to a 'bottom-up' based life cycle assessment of wastewater systems. The approach also includes an evaluation of experiences of an existing system. Oslo has complete digitized data of network failures since 1980 and also complete digitized records of network properties. Advanced tools are being used to analyse governing factors of failures, for example; What decides where and when a blockage occur? What is the reason for observed biological growth on wastewater plastic pipe walls?

The wastewater network lifecycle

The life cycle of wastewater networks comprises the construction, operation and maintenance, repair works, renovation and final replacement of the pipelines, as can be seen from Table 1. This is due to different types of failures that may occur, namely wrong design, construction failures, failures due to operational circumstances and failures due to degradation of old pipes.

The operational aims are to avoid floods on terrain and in buildings, and avoid pollution discharge to the local receiving waters. To reduce the vulnerability with this regard, some investments are considered necessary during the life cycle of each pipe. It is a major objective to minimize the life cycle costs needed to maintain the environmental standard. This can be obtained by keeping the single pipes as long as possible before renovation/ replacement and by minimizing the need for maintenance and repair. A robust procedure for the takeover of new pipelines from contractors is a crucial element to secure a minimal burden to the water company at later stages of the pipeline life cycle.

In general, the material itself is not the main factor for life cycle costs, but the material in an interaction with construction and control works. Thus, materials are decisive for the pipe construction strength and deterioration, they may influence the biological growth, and they may, together with the quality of installation work, play a role related to sags, leakages and roots. The other factors that determine service life are independent of material type.

Materials

Table 2 includes a summary of the most common pipe materials that are available in Norway. In general, pipe properties make them appropriate in most situations. However, there are some situations when certain material

Failure type	Correction by finalising new construction	Maintenance/ repair	Renovation	Replacement (end of life)
Wrong design				
Hydraulic capacity			X	X
Wrong localization				X
Construction failures				
Cracks	X		X	X
Sags	X			X
Leakage	X		X	
Roots	X			
Inserted pipe	X			
Operational problems				
Blocking		X		
Biological growth		X		
Old pipes				
Crack			X	X
Deformation				X
Collapse				X

Table 1
Elements of life cycle cost for wastewater networks

Material	Advantages	Disadvantages
Concrete pipes	Normally good corrosion protection Wide application Strong	Surface damaged if rough handled Heavy Corrosion under septic condition Corrodes if low pH
Ceramic pipes	Resistant to chemical attacks, no corrosion Strong	Brittle – careful handling required Short pipe length, many joints Heavy
Plastic pipes	Light Resistant to chemical attacks (normally) Resistant to wear and tear Hydraulic low-friction surface Flexible	Exposed to certain types for chemical attacks Require good quality installation work
Corrugate pipes	Light Large product specter from simple and low-price to advanced and costly	Require good installation work Buoyancy effect may occur due to water pressure or frost
Constructed pipes	Light Resistant to corrosion	Brittle Require good installation work
Ductile iron pipes	Strong Stable when corrosion protected	Need corrosion protection Heavy

Table 2
Overview of pipe materials advantages and disadvantages

properties represent an advantage or disadvantage.

In Europe, manufacturing of pipe materials is regulated by standards that are fairly well developed and build on long-term practical experience. In future world trade, the markets may include material and equipments that are not under that strict control, and they may be dumped into the European market. This should be met with a requirement that all products used shall be produced with respect to our standards.

Service life limitations

Various physical and chemical processes may cause harm to pipe materials. Table 3 includes a summary of potential limiting factors for material-related service life. Cracks formed under production, transport or construction may grow if the material is brittle and external load is causing pipe wall stress. Crack growth may thus occur for cast iron, ceramic and PVC pipes depending on their toughness. Plastic pipes may also suffer from deformation, depending on the stiffness ratio (wall thickness/pipe diameter), while the main degradation factor of concrete pipes is chemical dissolution of concrete elements. These limiting factors have been well known by the industry for many years, and product improvements have been launched to compensate the potential weaknesses. Thus, under normal circumstances, modern pipes will probably last for far more than 100 years.

The occurrence of hydrogen sulphide in wastewater will destroy even modern well-made concrete pipes in a few years. This is a well-known example of a specific situation where even modern pipes will have a limited performance. Another example is polyethylene pipes in the ground containing traces of petrol-based compounds, where the compounds will penetrate the pipe wall. These are examples where a problem may be solved by choosing an alternative pipe material, or eliminate the source of gas or ground condition.

Construction practises

Even if several standards on construction exist, it should be expected that mistakes will occur and construction is not by 100% good quality. Examples where particular concern is needed are:

- Very shallow pipelines under traffic area (< 1m)
- Week soil, no reinforcement
- Border between soft soil and rock
- Backfill materials not suitable
- Impropriate compaction (too heavy equipment, too thick layers, too few passages)

Failures may lead to structural overload and deficiencies with regard to hydraulic performance. Even if clear codes of practise exist on these matters, under tough work pressure and limited benefit, there will always exist temptations to cut some rules and hope the results are not affected. The control issue is under discussion, and it is questioned if current system accepting self control is adequate to achieve a long time working solution.

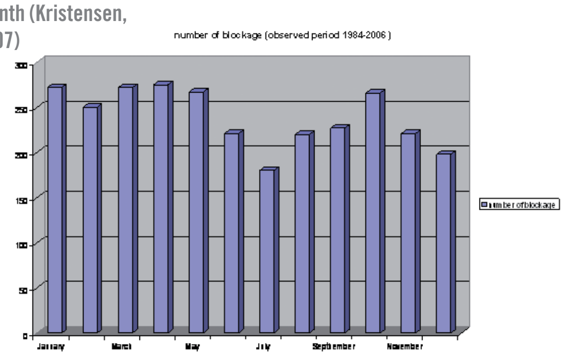
In addition to the issues discussed above, pipelines with many joints are vulnerable to joint failures and pipes with a low weight are more exposed to failures related to slope.

Maintenance needs

Construction failures will increase the need for maintenance. Root cutting and pipe cleaning are examples of actions necessary to avoid blocking of the pipes. During the period 1984–2006, a total number of 2869 blockages and additional 113 collapses were recorded in Oslo. This is in total an average of 130 blockages per year for the city or 25 per 100,000 inhabitants per year (Kristensen, 2007). Figure 1 presents the number of blockages by month observed in Oslo during the period 1984-2006.

Unexpected blockages that are not observed immediately are expected to be the main reason for pollution of local rivers in Oslo, since the sewage will find its way though ordinary or eroded overflows. The blockages are therefore considered to be a main problem on wastewater network

Figure 1
Blockages in wastewater per month (Kristensen, 2007)



Material	Degradation mechanism	Critical material property	Comment
Concrete not reinforced	Chemical degradation	Porosity	Porosity is connected to production practise
Concrete reinforced	Corrosion reinforcement	Porosity Concrete cover over reinforcement	Old pipes sometimes produced with too small concrete cover
Ceramic	Crack growth	Fracture toughness	
Glass fibre reinforced polyester (GRP)	Crack growth		Damage may occur internal when load is exposed external
PP non-pressurised	Deformation	E-module, wall thickness	
PVC non-pressurised	Deformation	E-module, wall thickness	
PVC pressure pipes	Crack growth	Fracture toughness	First generation pipe has lower fracture toughness compared to later productions
PE pipes for renovation	Crack growth	Surface fractures	
PE pipes for pumping	Crack growth	Surface fractures	Not known as a problem
CIPP (Polyestersleeve)	Not known		

Table 3
Deterioration of pipe materials

management in Oslo. There is surprisingly no clear correlation between pipeline properties like slope and the probability of blockage.

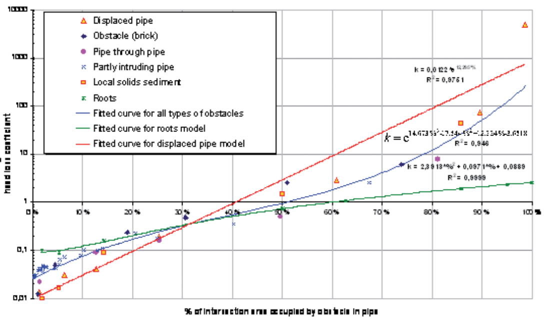
Since the reasons for blockages are multiple, three different analyses were conducted to understand the situation, i.e. a plain data analysis, analysis by CARE-S blockage tool (Hafskjold 2005) and a multi-criteria regression analysis by Evolutionary Polynomial Regression (EPR). The later is a new hybrid model combining genetic programming and regression technique (Giustolisi and Savic, 2005).

It was concluded from this exercise that the EPR model did not work satisfactorily at pipe level, however useful results were discovered through the analysis of a groups of pipes. The CARE-S blockage tool was on the other hand very easy to use. This tool required some preliminary work, but the results were obtained quickly (Kristensen, 2007).

The three different analysing methods gave pretty much the same results. Age, dimension and slope influence the blockage rate to some degree, type of sewer and material are also influencing, but many of the differences for those variables can be attributed to age and dimension.

Several other variables should have been included in the analysis to obtain a more complete picture. Results from CCTV (Closed Circuit Television), inspections could have given more information about the structural state of the pipes. The water flow and filling ratio would have been useful for calculation of shear stress, and thereby to judge if the self-cleansing is obtained for each pipe.

Figure 2
Failure and hydraulic performance. Friction coefficients by selected failure types (from CARE-S, Ugarelli, 2005)



Hydraulic performance

Several internal investigations have been conducted to determine wall roughness for various pipe materials.

Table 4
Design values for pipe wall roughness (PH consult 2001)

	v< 1 m/s	v > 1 m/s	
		Sewer	Storm water
Concrete	3.0	15	0.6
Plastic	1.5	0.6	0.6

The roughness is not temporarily constant and will depend on the composition of wastewater.

A UK investigation (Perkins and Gardiner 1982) concluded that roughness depends on the existence of a 'sewer skin' and that there are large spatial and temporal variation in roughness due to development and degradation of this skin. In general, less 'skin' is found on PVC pipes, filled pipes have smaller roughness than partly filled pipes and max roughness decreases when slope is increased from 4% to 10%. The Danish company PH-consult made a large literature survey on adequate design values for pipe wall roughness and concluded according to Table 4.

Network failures like displaced joints, roots, inserted pipes will influence the flood capacity, i.e the head loss will increase for pressurized pipes. The CARE-S project developed a system that quantify this impact (Ugarelli, 2005). Depending on the severity of a failure the disturbance can be modelled by increased single loss or a friction parameter for the particular pipeline affected by a failure (Figure 2).

Environmental safety

To secure an environmentally-friendly management practice, emissions from activities connected to the wastewater services should be minimized. One criteria for the selection of materials will therefore be the demand at production, transport and construction with regard to energy, CO_2, SO_2 and NO_x. A summary of a number of LCA analysis on the most important pipe materials was presented by Chalmers (Andersson, 1998). The main findings are included in Table 6. These results should be understood as an example, since they rely on specific conditions, i.e. transport length.

The most important conclusion from this exercise is probably that the transport is found to be the most resource-consuming stage of pipe building. Energy use due to transportation is found to be relatively equal for all pipe types, but favour pipe manufacturers situated nearby. Normally concrete pipes are produced locally, are less resource demanding and therefore totally more environmental friendly compared to plastic pipes.

Recycling systems for the most important pipes are emerging. For example, PVC pipes are recycled to produce new pipes. Recirculation of used concrete has already been a practise in many years, i.e. road foundations.

Documentation

It is obviously necessary to know where we have pipes, and the hydraulic capacity of those. Since the flow capacity depends on diameter and slope, this information is also obvious and is normally collected. However, to understand the long term service life and maintenance need, the need of documentation goes beyond this. It is necessary to record the entire life cycle from manufacturing (labelling), via transport and construction, operation and maintenance.

In spite of this, the latter documentation is very often neglected in cities and little data is stored in databases. Thus, a complete control of the logistic process from production via transport and construction is missing, and damaged pipes and equipments may not be abandoned (Figure 3).

Documentation of network constructions should therefore include a protocol from reception control, and labelling of pipes and equipment (production series, data, pressure class, standard approved etc). This information should be stored in a network record system, if possible connected to the general GIS records applied for the network mapping in the city. It should be noticed that some categories of pipes include a several

Material	Energy Energy demand MJ/m pipe	CO_2 emission kg/m pipe	NO_X emission g/m pipe	SO_2, SO_X emission g/m pipe
Concrete (pipes and manholes)	596[1)]			
Concrete	413 (195-947)	38 (21-72)	359 (63-735)	50 (22-93)
PVC	760 (337-1044)	33 (16-62)	360 (140-651)	85 (34-223)
PE	992 (367-1699)	37 (11-79)	388 (117-750)	83 (32-110)
PP	777 (351-1083)	32 (13-62)	362 (117-673)	92 (38-120)
Ceramic	443[1)]			

[1)] This is a result from an analysis, while the remaining is average from 3-6 analysis

Table 5
Environmental impact from pipe materials, entire life cycle included (Andersson 1998), brace values are smallest and largest value form different exercises

different qualities, and a careful registration should reflect this.

A future registration could also include advanced 'tracing', an information chip to include the manufacturing data and also provide signals for localization.

Future materials

Since built pipelines are expected to live more than 100 years, it is a good exercise to ask what kind of mistakes we may do today that we will regret in decades from now. Since pipes are cheap compared to the entire construction cost, cost saving at pipe material appears to be a poor idea.

It is expected that future materials based on nanotechnology will resist corrosion and wear, be lightweight, robust and easy to install. The nanotechnology may also comprise integrated sensors water flow, pressure and water quality. It is further expected that renovation and directed drilling will dominate future building of pipelines.

Conclusion

Strategic selection of pipe materials influences the entire value chain from pipe production via transport and laying, operation and maintenance, renovation, replacement and destruction. Thus, the technical properties and the properties to support the hydraulic functionality are important. The objective for the wastewater network management is to keep it cost-minimal for the customers, at the same time as the energy use and effluent discharge of hazardous components like CO_2 and NO_x from the value chain are minimal and the environmental objectives are met, and such that minimum problems are created for the customers.

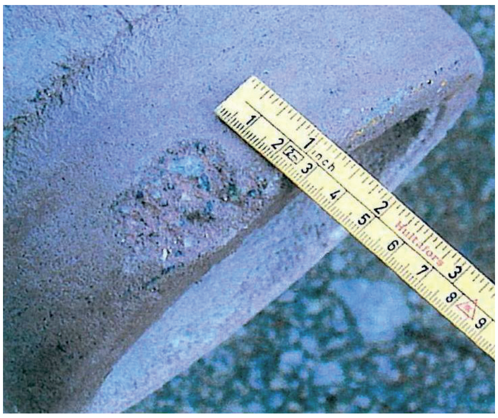
Modern materials produced and delivered according to European standards and used according to their properties will normally not deteriorate within a practical timeframe (100 years). However, material selection should be fitted to local conditions, being it particular aggressive wastewater qualities or extreme external mechanical load. In Norway, normally PVC and concrete are used for wastewater pipes, and the experiences are mainly very good. Ceramic is a potential pipe material alternative, and German cities report good experiences. Long transportation routes with corresponding costs and emissions may be a limiting factor for the application of these pipes in Norway.

Inadequate performance may increase costs for operation and maintenance (sags, low slope) and shortening of service life (crack formation). Existing standards provide requirements for bedding materials and compaction practises. During periods with a tight labour market or with a large competition, quality of work may be threatened. During such situations construction control should be enhanced and extra robust materials selected.

Flow capacity is determined based on slope and wall roughness. Missing self cleansing introduces sediments in pipes which increase roughness and decrease flow capacity. Inadequate construction where design requirements for slope are not fulfilled and even sags occuring lead to further reduction of self-cleansing capacity, the build up of sediments and reduction of flow capacity. In general, construction therefore is more important to hydraulic performance than the materials.

Organic growth in wastewater networks are correlated to fat content in wastewater. The evaluation did not find any correlation between such growth and pipe materials.

Figure 3
Damage due to transport



The analysis concluded into three major tasks for Oslo to maintain a robust system for materials used for wastewater networks:

- It is important to safeguard that records from building of wastewater pipelines are collected and stored in a consistent way that is easily available for the city's engineers. In principle this documentation should not need external explanation and not rely on local knowledge. This is a challenge for Oslo, as for many other cities in Europe, and will be a comprehensive task for the city in coming years.
- A future-minded network management should comprise an analysis of energy demand and emissions from the entire value chain. It is recommended that an integrated study on this issue is performed, including availability of pipe materials, transportation needs and destruction.
- To minimize life cycle costs, it is important that renovation and replacement is not carried out until it is absolutely necessary to prevent an unacceptable vulnerability with regard to probability and consequence of lacking structural and hydraulic performance. Therefore it is recommended to carry out an integrated analysis of rehabilitation needs, counting all relevant factors for rehabilitation. This may rely on available technology for renovation and replacement, principles for identifying and ranking of projects and evaluation on when they should be carried out. This may be supported by the rehabilitation planning system CARE-S. ●

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Paper presented at LESAM 2007 – 2nd Leading Edge Conference on Strategic Asset Management

Infrastructure strategic management in contingency situations

Since the year 2000, the Algarve Multimunicipal System has supplied water to approximately one million people in high season. Surface water sources include various dams, namely Odeleite – Beliche, Funcho and Bravura. However, a main dam – Odelouca – is still under construction and water scarcity can occur in the region. In fact, at the end of 2004 a situation of hydric stress occurred leading to the preparation of a partial contingency plan, which covered part of the Algarve region. At the beginning of 2005 the whole region of Algarve was affected by hydric stress due to the drought registered in the hydrological year 2004/2005 in Portugal and as a result, a Contingency Plan was developed for the whole region. This Contingency Plan foresees the possible re-activation of old municipal boreholes for groundwater extraction, which have been inactive since 2000. This Plan was activated in 2005, according to the restrictions imposed by the Drought Commission in order to fulfil the region's water supply.

This Action Plan established measures and investments for the reinforcement of the supply system, until the new dam is built. The Plan ensured greater flexibility and reliability of the system to meet contingency scenarios such as drought and other emergency situations. Alternatives to water supply included the transfer of treated water between the two sub-regions of Algarve as well as the establishment of new water sources in the region.

The Plan also included a regional campaign for the efficient use of water by consumers, which was effective in reducing water consumption, in addition to a study on the evolution of water consumption highlighting the measures. In this paper, A. Ribeiro, H. Lucas, J. Sousa, R. Coelho, M. Viriato and S. Dias discuss drought management in the Algarve.

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Introduction

During the hydrological year 2004/2005 a serious situation of drought occurred in Portugal which led to the preparation of a contingency plan for the Algarve Multimunicipal System (MAS), (Figure 1) in addition to the creation of an action plan establishing measures and investments aimed at the reinforcement of Algarve's water supply.

At the time, the MAS was fed from the following water sources:

- Odelouca-Funcho water development scheme (surface water);
- Odeleite-Beliche water development scheme (surface water);
- Vale da Vila extraction, at the Querença-Silves aquifer (groundwater);
- Bravura reservoir dam (surface water).

Figure 1
Map of the Algarve multimunicipal water supply system

The situation of drought which occurred in the region severely damaged the regularisation of the flow rate in the region's reservoirs and increased the risk of marine intrusion in the main aquiferous system (Figure 2), due to the deepening observed and total absence of natural recharging.

The extraction of raw water from these sources was limited, the seriousness of the consequences of this situation forced the immediate reactivation of municipal groundwater extraction and the taking of urgent water saving measures.

Following the meetings of the Drought Commission, the Águas do Algarve (AdA) and Águas de Portugal, SGPS, prepared an action plan which summarised the proposals of measures and actions for immediate and short term implementation to combat the serious effects of the drought.

The following measures were instituted in the aforementioned plan:

Immediate measures

- Rationing of water for washing the streets, irrigation of gardens and other uses which are possible to reduce, involving the control or closure of fountains, springs and improved management of swimming pools;
- Creation of actions involving interaction with consumers for the communication of ruptures in the network and obvious wastage of water;
- Reactivation of existing municipal boreholes;
- Implementation of strong inspection in order to check compliance with the water saving measures;
- Awareness-creating campaign for the efficient use of water.

Short term measures

- Reuse of treated wastewater;
- Reinforcement of the Sotavento-Barlavento connection;
- Use of water stored in the reservoir created by the Odelouca cofferdam;
- Reinforcement of extraction from the Querença-Silves aquifer;
- Inclusion of municipal boreholes in the MAS;
- Studies on alternative extraction from the Guadiana river;
- Studies on possibilities for desalinisation;
- Alternative study on reinforcement from the Foupana stream;
- Analysis of the viability of supply fed from the Rogil canal;
- Study on the protection of the Estombar Water Sources;
- Use of the dead storage of the Odeleite and Beliche reservoirs;
- Study on the maximisation of use of the volume stored at the Bravura reservoir;
- Use of the water stored at the Santa Clara dam reservoir;
- Implementation of measures conducive to reducing distribution network losses.

Objective and method

The objective of the present document is to present the planned investment costs and actions after a scenario of extreme drought, carry out an analysis of the benefits introduced into the system to increase its reliability, with the implementation of the main measures.

The preparation of the Action Plan was the result of the involvement of various actors (Águas do Algarve, SA, Águas de Portugal – Holding –, Regional Coordination and Development Commission of the Algarve, Municipalities, Water Institute and other users such as the region's farmer associations).

The AdA carried out the main studies to ensure the viability of the actions, planned these future actions and developed the necessary works.

Results and discussion

Table 1 presents the Action Plan programme and its measures, planned investment and the volume of reinforcement forecast to be obtained.

The measure which can enable obtaining greatest availability of water from surface sources is through the use of the dead storage of the Odeleite and Beliche reservoirs (30 Mm^3), but the viability of this measure is only possible if the minimum level of the reservoir is reached. For this **remedial** measure, the conditions will have to be created permitting its viability when it becomes necessary.

Another measure enabling great availability of water from its source is the connection to the Santa Clara reservoir (20Mm^3), but this will require carrying out an environmental impact study (EIS) and an assessment of the environmental impact (AEI), for it to be viable in the **long term**.

The measure involving the extraction of water from the Rio Guadiana is the third largest in terms of water availability, in similarity to Barlavento and Sotavento desalinisation, and integration of municipal extraction in the system.

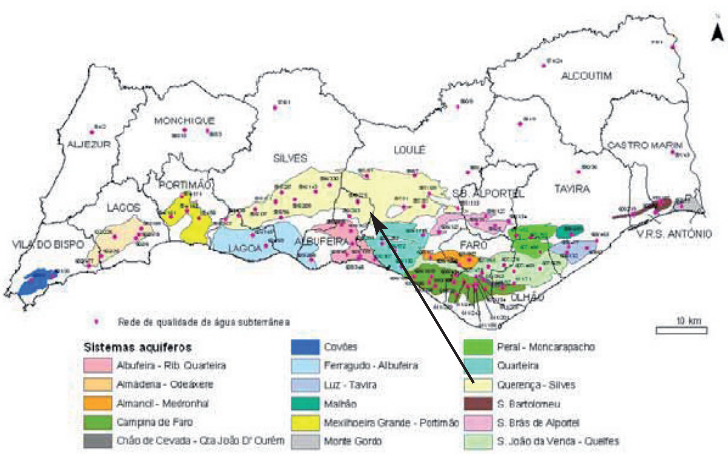

Figure 2
Aquiferous systems of the Algarve

Legend:
Rede de qualidade de água subterrânea – * Groundwater quality network
Sistemas aquíferos – Aquiferous systems

These last four measures require high levels of investment and greater environmental impacts with the exception of the integration of municipal extraction.

Figure 3 presents the relationship between planned investment and the reinforcement volume which will be obtained through the implementation of the various measures defined in the action plan.

Figure 3 demonstrates that the measures with lowest availability (4 to 15 Mm³) are those in which less investment is planned, but they are also the most viable and minimally reinforce the system until the conclusion of the Odelouca dam, increasing its reliability.

Figure 4 presents the relationship between investments carried out and the expected volume of reinforcement due to the measures implemented to date in the system.

The analysis of the ratios indicates that the most efficient actions, in terms of cost to reinforcement volume obtained, is the use of the water from Odelouca cofferdam, followed by the integration of municipal groundwater extraction and the extraction of groundwater from the Querença-Silves aquifer. The action related to the reinforcement of the Sotavento-Barlavento connection presents the lowest efficiency, however this action enables greater flexibility in the system.

The results of the estimated ratios indicate that all the actions present an acceptable cost-benefit ratio, lower than one, with the most unfavourable situation having a ratio of 0.67.

Conclusion

AdA has developed and is currently implementing average availability actions in terms of reinforcement volume for the systems and those involving relatively less investment. The AdA has carried out an assessment study on the salinity of the Guadiana and an environmental impact study on the connection to the Santa Clara dam in addition to preliminary studies on the implantation of Barlavento and Sotavento desalinators.

All the short-medium term measures developed and currently being implemented by the AdA are those presenting lowest cost (including environmental), but are also those providing lower availability in terms of reinforcement volume.

The measure permitting greater reinforcement volume (use of Odeleite-Beliche dead storage) can immediately become viable, if necessary, as a remedial measure.

The measure presenting the lowest benefit (cost/availability) – Sotavento-Barlavento connection – enables greater flexibility in the system and increases its reliability in the long term. The measure presenting greatest benefit (cost/availability) – the Odelouca cofferdam – is the one which will have the shortest period of useful life.

In conclusion, the AdA chose measures with the lowest cost-benefit for the short-medium term. ●

Table 1
Activities planned in the action plan

Measure	Planned investment (*10³ €)	Volume of reinforcement (Mm³)
Use of the volume stored at the Bravura reservoir	1000	3 – 6
Odelouca cofferdam	750	6 – 10
Supply fed by the Rogil canal	-	0.4
Use of the water stored at the Santa Clara dam reservoir	27000	20
Extraction from the Querença-Silves aquifer	4500	13
Integration of municipal boreholes in the MAS	8000	15 – 20
Desalinisation	43500	15
Use of the dead storage of the Odeleite and Beliche reservoirs	1300	30
Reuse of treated wastewater	-	-
Extraction from the river Guadiana	23000	15
Reinforcement of the Sotavento – Barlavento connection	2800	10
Alternative study of the Foupana Stream	500	5 – 9
Reduction losses in distribution network	-	-

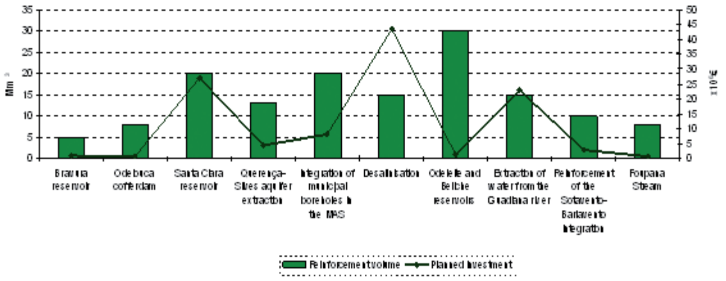

Figure 3
Relationship between planned investment and the reinforcement volume obtained

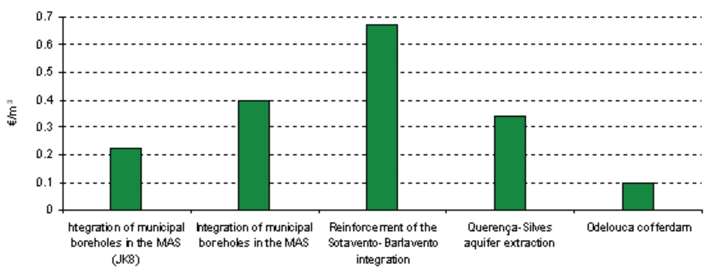

Figure 4
Relationship between the investment cost and reinforcement flow rate

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Paper presented at LESAM 2007 – 2nd Leading Edge Conference on Strategic Asset Management

Water Budgets and Rate Structures: Innovative Management Tools

AwwaRF Report 91205
Authors: P Mayer, W DeOreo, T Chesnutt, D Pekelney and L Summers

Water budgets – volumetric allotments of water to customers based on customer-specific characteristics and conservative resource standards – are an innovative means of improving water use efficiency. Once thought to be impractical because of technological constraints, water budgets linked with an increasing block rate structure have been implemented successfully in more than 20 utilities. As utilities develop advanced customer information systems and geographical information systems, these rate structures are expected to be applied more broadly. Water budget rate structures are attractive to water agencies searching for stable revenue generation, improved customer acceptance, increased water use efficiency, augmented affordability of nondiscretionary customer water consumption, and improved drought response.

The objectives of this study were to examine water budgets and their potential value to North American water utilities and the varying applications of the water budget concept that have been adapted to different conditions. Key research issues included different practical approaches to water budget rate structures, the benefits and challenges of these approaches, the potential uses of water budgets during drought, and important steps in the water budget implementation process.

An extensive literature review was conducted using bibliographic and web-based searches. The researchers conducted numerous structured interviews with water agencies that have already implemented water budgets and water agencies interested in the concept, but not yet using water budgets. This research focused on the technical ability and readiness of the agency as well as the potential barriers to implementation. Agencies also provided annual reports, consumption data, information on customer classes, and information on customer billing systems. Case studies on implemented water budget programmes were developed by the research team and reviewed by agency personnel to ensure accuracy.

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Autogenous Healing of Concrete in the Drinking Water Industry

AwwaRF Report 91210
Authors: J Parks, M Edwards, P Vikesland, M Fiss, and A Dudi

Little research expenditure has gone towards the investigation of processes responsible for the corrosion of concrete drinking water infrastructure. One important mode of attack on concrete involves access of corrosive water to underlying reinforcing steel through cracks. Under some circumstances it is known that cracks in the concrete surface can repair themselves through reactions with constituents in the water. This phenomenon has been termed ‘autogenous healing.’

The objective of this project was to examine the effects of bulk water chemistry on concrete corrosion and autogenous repair of concrete.

This project identified that autogenous healing can be controlled by water chemistry, and it can be an effective method of sealing small cracks that initiate in concrete before they develop into larger cracks that can cause failure. When high levels of magnesium and silicon are present this seal can develop high strength. Carbonation of internal surfaces was not detected when cracks were sealed via autogenous healing. In some cases, water permeability and chloride diffusion are impeded by autogenous healing regardless of strength attained.

IWA Publishing, August 2008
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Impact of Hydrocarbons on PE/PVC Pipes and Pipe Gaskets

AwwaRF Report 91204
Authors: S K Ong, J Gaunt, F Mao, C-L Cheng, L Esteve-Agelet, and C Hurburgh

Some of the factors for the increased use of plastic pipes in water distribution systems are their ease of installation and handling, durability, and good resistance to the chemicals used in water treatment, such as chlorine. In many urban areas, plastic pipes may come into contact with contaminated soils as a result of leaks from underground storage tanks,chemical spills, and improper disposal of used chemicals. These pollutants from leaking storage tanks and contaminated soils can and have posed serious threats to the longevity and structural integrity of plastic pipes and elastomeric gaskets which, in turn, can affect the water quality in the distribution system.

Although there are research studies and case studies documenting the permeation of organic compounds through plastic pipes and elastomeric gaskets, there is still a lack of understanding of the performance of polyethylene (PE) and polyvinyl chloride (PVC) pipe materials and elastomeric gaskets in hydrocarbon-contaminated soils commonly encountered under field conditions.

The objective of this project was to study the impact of hydrocarbons on PE and PVC pipes and elastomeric gaskets. Specific tasks were to (1) survey water utilities to learn about their experiences with plastic pipes and permeation of mains and services, (2) study permeation through PE and PVC pipes exposed to hydrocarbon contamination, (3) develop laboratory tests to predict permeation of pipes and gaskets, and (4) study permeation through pipe gaskets.

IWA Publishing, July 2008
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AM DIARY

A listing of upcoming asset management-related events and conferences. Send event details to WAMI for inclusion.

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29-30 January 2009, Wuerzburg, Germany
Contact: Gabriele Struthoff-Mueller
Email: gabriele.struthoff-mueller@otti.de
Web: www.otti.de/pdf/wea3091.pdf

3rd Specialised Conference on Decentralised Water & Wastewater International Network
9-11 February 2009, Kathmandu, Nepal

Water Loss 2009
26-29 April 2009, Cape Town, South Africa
Email: waterloss2009@randwater.co.za
Web: www.waterloss2009.com

Water Malaysia 2009
19-21 May 2009, Putra Word Trade Centre, Kuala Lumpur
Contact: Ms Kelly Liau
Tel: 603 6140 6666
Email: kelly@protempgroup.com
Web: www.watermalaysia.com

Singapore International Water Week
22-25 June 2009, Singapore

Asset Management of Medium and Small Wastewater Utilities
3-4 July 2009, Alexandroupolis, Greece
Contact: Konstantinos P. Tsagarakis
Tel: +30 28310 77433
Email: iwa@econ.soc.uoc.gr
Web: http://iwasam.env.duth.gr

2nd International Conference on Water Economics, Statistics & Finance
3-5 July 2009, Alexandroupolis, Greece
Contact: Konstantinos P. Tsagarakis
Tel: +30 28310 77433
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19-21 October 2009, Sydney, Australia