TRIPARTITE GROUP

BEST PRACTICE PRINCIPLES IN THE ECONOMIC LEVEL OF LEAKAGE CALCULATION

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SUMMARY

1. CONTEXT

This report presents a best practice approach to leakage target setting for water companies in England and Wales. This report builds on the earlier report “Report A: Key principles in the Economic Level of Leakage Calculation, WRc Ref: UC3893, January 2001”. A parallel report, WRc Ref: UC3894 considers the development of Leakage Key Performance Indicators.

The project has been jointly commissioned by a Tripartite Group comprising Ofwat, the Environment Agency and the Department for Environment, Food & Rural Affairs (DEFRA).

It is also recognised that leakage targets are set within the political arena; guidance from the Environment Minister has indicated that leakage should continue to decline.

2. OBJECTIVES OF THE BEST PRACTICE REPORT

This aspect of the study is primarily concerned with reviewing methods for determining the economic level of leakage (ELL) which balances the costs and benefits of leakage management. The stated objectives of the work described in this report are

- to establish a set of key principles to be followed when calculating the ELL arising either from best practice aspects of companies’ methodology or other improvements proposed by the consultant.

- to develop a forward looking approach taking into account possible changes in technology or practices to reduce the cost of leakage detection and repair and changes in future demand patterns and climate change.

The report then looks to estimate the future trends in technological change and the likely impact on the economic level of leakage. The report also considers whether the economic level of leakage is the appropriate target setting methodology, and if alternative approaches could provide a better basis.

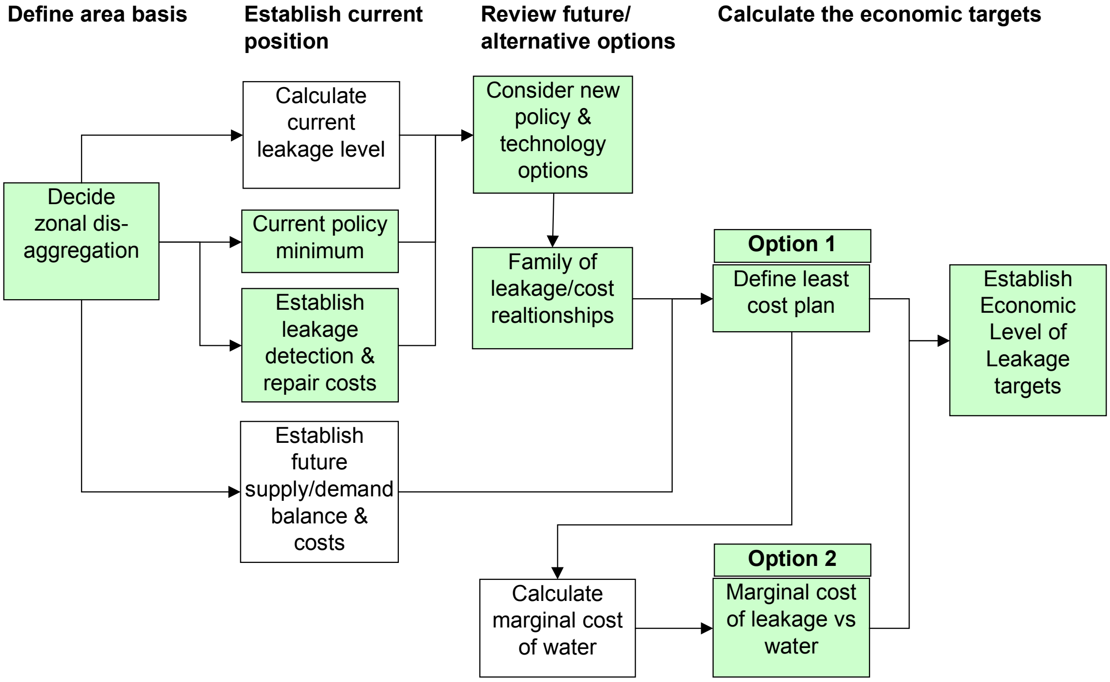
3. BENEFITS

The identification of key principles will allow existing water company methodologies to be improved to an acceptable standard where necessary without requiring companies to implement prescribed detail at each stage.

4. APPROACH

Figure S.1 shows a simplified process map for developing leakage targets for the ELL. All of the processes which are shaded in the diagram have been considered within the project.

Figure S.1 ELL target setting process map



5. SUMMARY OF KEY PRINCIPLES

I. Current leakage levels

1. The annual average level of leakage for each study area should be calculated using the July Return methodology.

2. The leakage trend during the year should be assessed in order to calculate future transitional costs.

II. Current policy minimum leakage levels

1. Policy minimum leakage estimates (i.e. the lowest level of leakage that can be achieved) should be based on company specific District Meter Area (DMA) data.

2. Policy minimum leakage estimates should accurately reflect the lowest level of leakage that can be achieved in each DMA through intensive active leakage control using conventional active leakage control methods and ‘reasonable’ effort.

3. The policy minimum will depend on the leakage control policy and system conditions.

4. Each company should ensure that the approaches used for calculating current leakage and policy minimum leakage from measured night flows are consistent with each other.

III. Leakage control activities and leakage cost relationships

Two distinct approaches are currently used by water companies to evaluate and model leakage control activities and costs. The first considers total costs which are split into steady state costs (the cost of maintaining leakage at a given level) and transitional costs. The second considers unit costs and estimates the cost of reducing leakage assuming a natural rate of rise. The first of these methods is considered more reliable.

The following conclusions and recommendations can be made:

1. Actual company costs should be used which are consistent with leakage budgets.

2. The model should give the current expenditure at the current level of leakage.

3. The form of leakage/cost relationship (curve/equation) is less important than the use of reliable input data.

4. Input parameters should be clearly defined and understood. The more parameters required by the method, the greater the ability to influence results and the greater the need for reliable data.

5. The cost per repair should be assumed to be independent of the level of leakage unless evidence can be provided to the contrary.

6. Actual costs versus levels of leakage should be compared to modelled values over a number of years.

7. The relationship between costs and the level of leakage should be based on reliable and up to date data. This should be based on a minimum of a 12-month period.

IV New policy and technology options

1. The ELL should be determined for the current leakage policy to give a baseline. Other leakage policies may then be evaluated against this baseline.

2. New policy options that should be considered include improvements in district metering, pressure management, leak survey technology, efficiency of leakage surveys, repair times and costs, additional household metering and system rehabilitation/replacement.

3. For each option the operating and capital expenditure should be balanced against the impact on leak location costs, level of leakage, policy minimum leakage and leak breakout rate.

4. The interactions of different policies and the target level of leakage must be taken into account to avoid double counting.

5. A five to ten year analysis period is recommended.

6. The economic level of leakage should be assessed using the least cost leakage control policy.

V Calculating the economic level of leakage

1. A least cost planning approach, which minimises the net present value of costs of managing the supply-demand balance over a long term (25 - 30 years) planning horizon should be used. The least cost plan should be updated at least every five years or following significant changes to the supply-demand balance.

2. An approach using the long run marginal cost of water will provide consistent values to the least cost planning approach if appropriate values for the marginal cost of water are used. This approach only considers the trade-off between leakage and resource/treatment options. This should be used at least annually to assess the impact of changing leakage management costs on the economic level, although formal reporting to Ofwat should remain on the current 2-year cycle.

3. The economic level of leakage should initially be developed using company costs (capital and operating), but should then be reviewed including environmental and social costs.

4. A best practice framework for including environmental and social costs and benefits is provided. It is recommended that a desk-based study, making use of benefits transfer is undertaken to determine the likely impact on the ELL. Only if this indicates a significant impact should a full social and environmental costing be undertaken. A worked example of a desk-based study is included to illustrate the process.

5. Over time the increase in the number of properties will make maintenance of constant volumetric (e.g. Ml/d) targets increasingly difficult. Targets should be set on the basis of per-property or per-km. New properties will therefore tend to result in increasing volumetric leakage, however efficiency savings and the need for supply-demand investment will tend to cause leakage to trend downwards.

6. Company leakage targets should be based on the average over a number of years. This is more difficult to monitor when companies are driving leakage down, but when in steady state the level of leakage may fluctuate about the target. Over or under achievement of the target, due to external factors, should not cause the following target to change. For example, a company that ‘beats’ it leakage target by 1 Ml/d should not be required to maintain this new lower level in future years.

7. New technology will result in efficiency savings. Until supply-demand investment is required the water company will look to maintain the current level of leakage – new technology will therefore result in lower costs. When supply-demand investment is required the new technology will result in a lower economic level.

VI Target Setting Methodologies

A range of alternatives to the current method for setting economic leakage targets are discussed. These range from methods that can be used to validate companies ELL calculations, to setting leakage targets based on a theoretical relationship through to a system of trading in leakage permits/credits. A discussion is also included of the different ways to regulate leakage.

The remainder of this report is structured as follows:

- Section 1 presents the strategic objectives of a leakage target and the procedure for evaluating best practice.
- Section 2 considers general issues in connection with leakage target setting, including zonal disaggregation and the time path for achieving leakage targets.
- Section 3 considers the costs and benefits of leakage reduction.
- Section 4 sets out the methodology for calculating the economic level of leakage.
- Section 5 reviews sets out alternative methods for leakage target setting.

1. INTRODUCTION AND OVERVIEW

1.1 INTRODUCTION

A number of potential approaches exist to establish an appropriate leakage target. This report is primarily concerned with setting out a best practice approach for determining the economic level of leakage (ELL) which balances the costs and benefits associated with leakage management.

The UK Water Industry set out the framework for the approach to calculate the economic level of leakage in reports published in 1994[(1)] and 1996[(2)]. Since that time most water companies have prepared ELL assessments based around the framework methodology provided by these reports but with some considerable differences in technical approach. These assessments have been submitted to Ofwat in the lead up to the Periodic Review in 1999 and in subsequent updates.

The economic level of leakage is the point at which the cost of reducing leakage is equal to the benefit gained from further leakage reductions. It would appear to be a relatively straightforward exercise to determine the two key relationships:

1. **The leakage cost relationship**: the least cost (or most efficient way) of sustaining leakage at different levels and the one-off cost (or saving if leakage is increased) of moving from one leakage level to another.

2. **The cost of water relationship**: the impact that different leakage levels have on water delivery operating costs and programmed water capacity capital (and related operating) expenditure or plant downsizing[1].

In reality the stages in the process of preparing the leakage cost relationship and identifying the economic level of leakage target are highly complex and interrelated.

Due to the range of technical approaches which are currently used we consider that there is not sufficient consistency in the quality and accuracy of the leakage targets derived by water companies. A first step in understanding the extent of the variability is to develop an understanding of what constitutes best practice with respect to the method of target setting, the leakage cost relationship and the cost of water relationship.

An important success factor for this work is the need for a transparent approach for defining best practice and identifying the key principles. This is achieved by using standard business development techniques such as process mapping and benchmarking.

In the context of an ELL, best practice is defined as ‘the identification of business processes, data collection requirements, analytical procedures and presentation techniques that most fully comply with the strategic objectives and goals of the resulting leakage target'.

[1] This could include social and environmental costs too.

In preparing this analysis we initially intended to draw heavily on the submissions made by companies to Ofwat, in order to develop a detailed understanding of the procedures and techniques used. However, when evaluating the submissions it became evident that many were strong on description but short on detail. We have therefore augmented the information gained from the submissions with discussion with leakage practitioners at selected companies and specialist leakage management contractors.

It is possible that, even when applying a best practice approach to economic target setting, the methodology will not provide a result which is more robust than some simplified method (Ofwat pragmatic approach, metric benchmarking, econometric modelling). This is likely to be due to the initial assumptions used in the development of the simplified model. It is, however, only possible to develop robust ELL targets through a full economic analysis. This report also considers if an alternative target setting methodology would be more appropriate. It is also important that any target setting methodology should provide incentives both to strive for economic leakage levels and to implement leakage management with greater efficiency.

This report presents the consultants' current views on best practice based on the information we were able to draw upon. Due to continual developments it is likely that further refinements to processes or data may allow future improvements to best practice.

1.2 OBJECTIVES AND APPROACH

1.2.1 Objectives

The overall objectives of the work described in this report are:

- To establish a set of key principles to be followed when calculating the ELL arising from either best practice aspects of companies' methodology or other improvements proposed by the consultant.

- To develop a forward looking approach taking into account possible changes in technology or practices to reduce the cost of leakage detection and repair and changes in future demand patterns and climatic conditions.

The first objective was met by identifying best practice in terms of the preparation of a robust ELL calculation. The identification of key principles allows existing methodologies to be improved to an acceptable level without requiring companies to implement a prescribed approach at each stage. In some cases a number of alternative procedures are considered to be best practice.

It was not the objective of this work to identify best practice technology and working procedures for leakage management.

1.2.2 Approach

Best practice is a subjective measure. Therefore it is necessary to set out the procedures and criteria by which any assessment of best practice is to be made. In general the selected approach must be transparent, objective and appropriate. It should not necessarily be solution driven or favour one particular technical solution or software system. To comply with these requirements an approach was developed using the following stages:

- Define the strategic objectives of a leakage target
- Develop a series of process maps and define boundaries for data analysis
- Establish 'best practice' criteria for evaluation
- Review company submissions to identify and develop best practice for each process
- Consider linkages, consistency and practicalities.

1.3 STRATEGIC OBJECTIVES OF A LEAKAGE TARGET

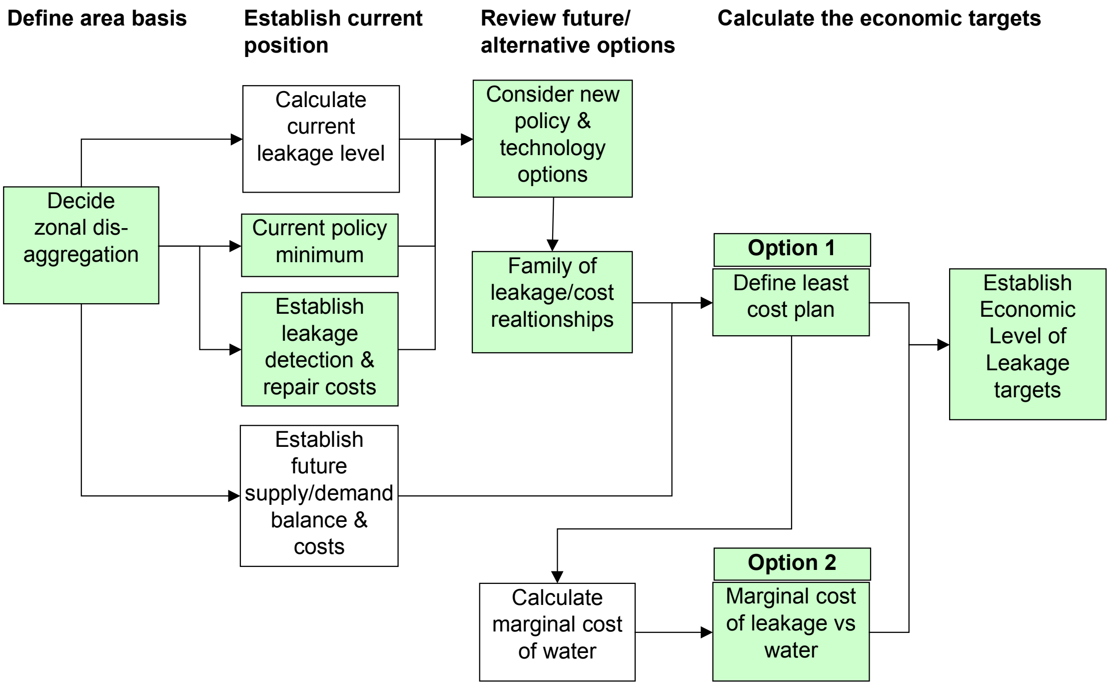
The following strategic objectives were defined in consultation with the project steering group:

- The Government seeks to minimise leakage for environmental and social reasons.
- Companies want to deliver customer security of supply at minimum cost.
- Additional requirements:
  - Need for a coherent and consistent national policy on leakage.
  - Leakage assessments to be consistently applied in the evaluation of environmental (water resource) sustainability.
  - Continued incentives for new leakage management technology and efficient working practices.
  - Understanding the role of leakage in water infrastructure sustainability and management.

1.4 PROCESS MAP

The high level process map for conducting an ELL assessment is shown in Figure 1.1. Key steps in the process which have been considered within the project are shaded in the diagram. Non-shaded processes are important in their own right and have been (or need to be) evaluated elsewhere.

Figure 1.1 ELL target setting process map



The key stages in this process are:

Define area basis	Decide zonal disaggregation (consistent water supply and leakage management areas)
Establish the current position	Calculate current leakage level (trunk mains & supply system, distribution mains and customer service pipes) Determine current policy minimum (existing policy) Establish leakage detection and repair costs (existing policy) Establish current and future supply demand balance and alternative investment costs (resources & demand management)
Review future/ alternative options	Consider new policy and technology options (for leakage management, pressure management, mains replacement, etc) Develop family of leakage/cost relationships
Calculate the economic target	Option 1 = leakage level output of least cost planning analysis (programme with lowest NPV) Option 2 = relationship between active leakage control cost curve and cost of water

Table 1.1 Key stages in ELL target setting process

1.5 BEST PRACTICE CRITERIA

A series of best practice criteria were established at the outset of the project. These criteria have been used to review the appropriateness of the processes and sub-processes developed in company submissions. The criteria are:

- The general approach is understandable to all stakeholders, both within the industry and external regulators.
- There is consistency between the outputs of the ELL evaluation and company management information systems and regulatory reports. (A key item is the budget for active leakage control and leak repairs).
- The approach reflects the company's operating environment, its current working practices and efficiency.
- It delivers the appropriate incentives, including use of improved working processes, new technology, alternative leakage management methods and IT systems.
- It is sufficiently accurate (e.g. Ofwat grades) and there is an understanding of the accuracy of numbers throughout the various stages of the analysis.
- The interaction with other sub-processes is correct; whilst the individual sub-process may all be best practice it is essential that they are linked in a best practice manner.
- Where possible, all input data and results are directly derived from or validated against actual data.

1.6 REVIEW OF COMPANY SUBMISSIONS

The company submissions used for this work are from those water companies whose ELL appraisals have been accepted by Ofwat. These are listed in Table 3 of Ofwat report 'Leakage and the Efficient Use of Water', 1999/2000.

The documents used were:

- Submission E (Supply Demand Balance) June 1998.
- Supporting documents to Submission E.
- Section K (Supply Demand Balance) April 1999.
- Water resource plan (leakage section) Environment Agency April 1999.

Where information was incomplete or further clarification was required, the consultants have discussed the issues with industry practitioners and specialist leakage management contractors.

A total of eighteen water company submissions were reviewed for the purpose of this study to determine the range of processes used. The documentation was generally of sufficient detail to understand the overall process, but was not sufficient to enable understanding of the detailed processes used nor the robustness of the input data. It was considered however, that the documents met their purpose; they provided the regulators with basic details of the methodology used. Given the limited details it was not always possible to determine if the calculated economic level of leakage had been determined robustly.

Although a wide variety of different approaches were used they could be categorised under a small number of generic approaches.

The main differences in approaches relate to:

- **Development of the leakage vs cost relationship**: nine of the companies had used models based on the BABE principles, six companies had used a relationship based on an understanding of steady state costs, two approaches were based on curve fitting through data from previous years and one was based on the natural rate of rise in leakage.
- **Taking account of the supply-demand benefits of leakage control**: nine companies used a least cost planning approach (these tended to be the larger companies in the sample), seven used a marginal cost of water based approach while two companies used both approaches.
- **Inclusion of other (i.e. non-leakage) supply-demand options**: nine of the companies included non-leakage supply-demand options.
- **Inclusion of Environmental & Social costs and benefits**: eight of the companies made an explicit inclusion of these costs.

Various combinations of approaches had been used across the companies, which appeared to reflect both the development of models historically and the use of different consultants to assist in the ELL analysis. Following discussion with leakage practitioners from a number of the companies it was also clear that there were significant differences in details, even when companies were using the same generic approach. These differences reflected alternative assumptions and/or data input to the models.

The process mapping in the following sections is used to determine the different sub-processes that were used by the various companies.

1.7 LINKAGES, CONSISTENCY AND PRACTICALITY

In preparing this analysis of key principles and best practice, consideration has been given to the linkage between methods and processes. Examples include consistency of leakage definitions from year to year, consistency between the definition of policy minimum and total leakage and practicalities of linking methods to establish total leakage spend with a separation of steady state and transitional costs.

2. LEAKAGE TARGET SETTING – INITIAL CONSIDERATIONS

This sections draws out some key principles that have been identified during the evaluation of company submissions. These items need to be considered before an ELL calculation is prepared.

2.1 DEFINITION OF TARGET

A number of options exist for defining a leakage target:

- Period of analysis:
  - Annual average leakage level (1 April to 31 March)
  - Leakage level at 1 April (starting level)
- Unit of measurement
  - As a volume (e.g. megalitres per day)
  - As a volume per property (e.g. litres per property per day)
  - As a volume per length of main (e.g cubic metres per Km per year)

When leakage assessments were originally carried out following the 1995 drought, many companies were in the process of bringing about substantial reductions in leakage. In such circumstances there are arguments in favour of using the 31 March/1 April level of leakage as a baseline. Use of an annual average level would result in an overshoot of the leakage level at end of year in order to achieve the annual average.

In general, the annual average level of leakage should be used in the ELL calculation since it is set within the context of the supply demand balance.

A further issue is whether companies should aim to operate below their target to mitigate the risk of a bad winter. A better approach, which is currently operated by Ofwat, is to operate at the target for normal winter conditions. In bad weather conditions companies should develop a recovery plan to ‘get back on course’ and quantify the extent to which the winter conditions affected leakage levels. In years with a bad winter the ELL will be higher due to higher burst rates and associated costs of location and repair.

2.2 ZONAL DISAGGREGATION

It is recommended that leakage is built up on a zonal basis. The two key drivers for zonal disaggregation are:

- Water resource zones
- Operational areas for leakage control (e.g. county, local authority area, etc).

The recommendation is that ELL calculations should be built up on whichever is the smaller unit of geographical area. In addition there is a need to evaluate whether the scope for using bulk supply arrangements is adequately taken into account.

It is not appropriate to calculate the ELL at DMA level.

2.3 TIME PATH OF ACHIEVING LEAKAGE TARGETS

This is often referred to as the leakage glide path. The ELL target initially set by Ofwat whereby the medium/long term target should be achieved by 2002/03 is not economically efficient for many companies. Where companies have prepared a robust supply/demand balance projection, leakage reductions (below the lower of the current level or short-term target based on operating costs) should only be introduced when the defined headroom between supply and demand is about to be breached. Subject to practical issues the annual leakage reduction should be equivalent to the sum of the increase in the demand forecast and decrease in deployable output due to sustainability reductions until the target is reached. Leakage targets will therefore tend to move downwards as supply/demand investment is required. The company may decide to start leakage reductions earlier to smooth out the profile and make the annual reductions smaller. Alternatively, it may be cost effective to make a large reduction in response to say, a reduction in water available for use at the end of a time-limited licence.

2.4 IMPACT OF PAST INVESTMENT

The ELL methodology is initially based on the current policy using the existing technology for leakage management. Therefore any company which has not invested in technology (such as DMAs, telemetry, permanent loggers) will identify a higher ELL. These companies are, however more likely to see a greater benefit from new technology and so may “leap-frog” over companies currently at the forefront of technology.

Future options will be considered within the ELL evaluation process but this may show that the major investment (which has been undertaken by the majority of companies and which would result in a lower ELL) is not cost effective.

All analysis should be based on changes from current costs, and so the cost of past investment (or “sunk costs”) should not be considered – they will already have resulted in lower operating costs against which any future investment will need to be compared.

3. COSTS AND BENEFITS OF LEAKAGE REDUCTION

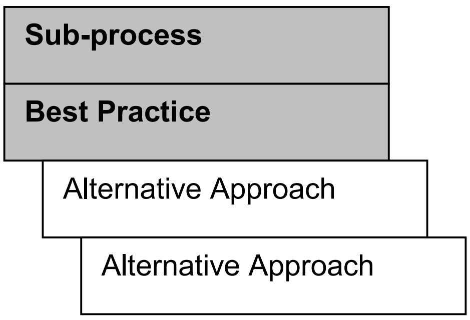
3.1 INTRODUCTION

The key stages in evaluating the costs and benefits of leakage reduction for a study area are:

1. Calculate the current annual level of leakage and the leakage trend.
2. Determine the minimum achievable level of leakage for the current leakage policy, i.e. the 'policy minimum' leakage level.
3. Analyse current leakage control activities and costs.
4. Develop a leakage cost relationship for the current leakage policy.
5. Evaluate alternative leakage policies against the current policy, taking account of the interaction of different approaches and leakage targets, in order to determine the least cost leakage control policy.
6. Determine the least cost way of achieving a given level of leakage using the least cost leakage control policy.

The leakage cost relationships will be most reliable for the current policy, particularly as many are now approaching their ELL and will be maintaining leakage levels. Predictions will be less reliable for leakage targets a long way from the current level of leakage, and for leakage policies which are very different from the current policy. It is therefore important that leakage models are updated annually using the latest available information and that model predictions are compared to actual company data.

The best practice methodology is presented in this section (and Appendices A, B and C) using process maps. These take the following form, with best practice in the shaded box and alternative approaches listing in decreasing order of robustness:



3.2 CURRENT LEAKAGE LEVELS

3.2.1 Introduction

This is discussed in detail in Appendix A. A summary of the best practice approach for estimating the current level of leakage is provided in Figure 3.1.

3.2.2 Key messages

1. The annual average level of leakage for the company during the report year should be calculated based on night flows in continuously monitored areas.

    - Night use allowances should be consistent with the assessed minimum flow.

    - Leakage from trunk mains and service reservoirs should be assessed independently.

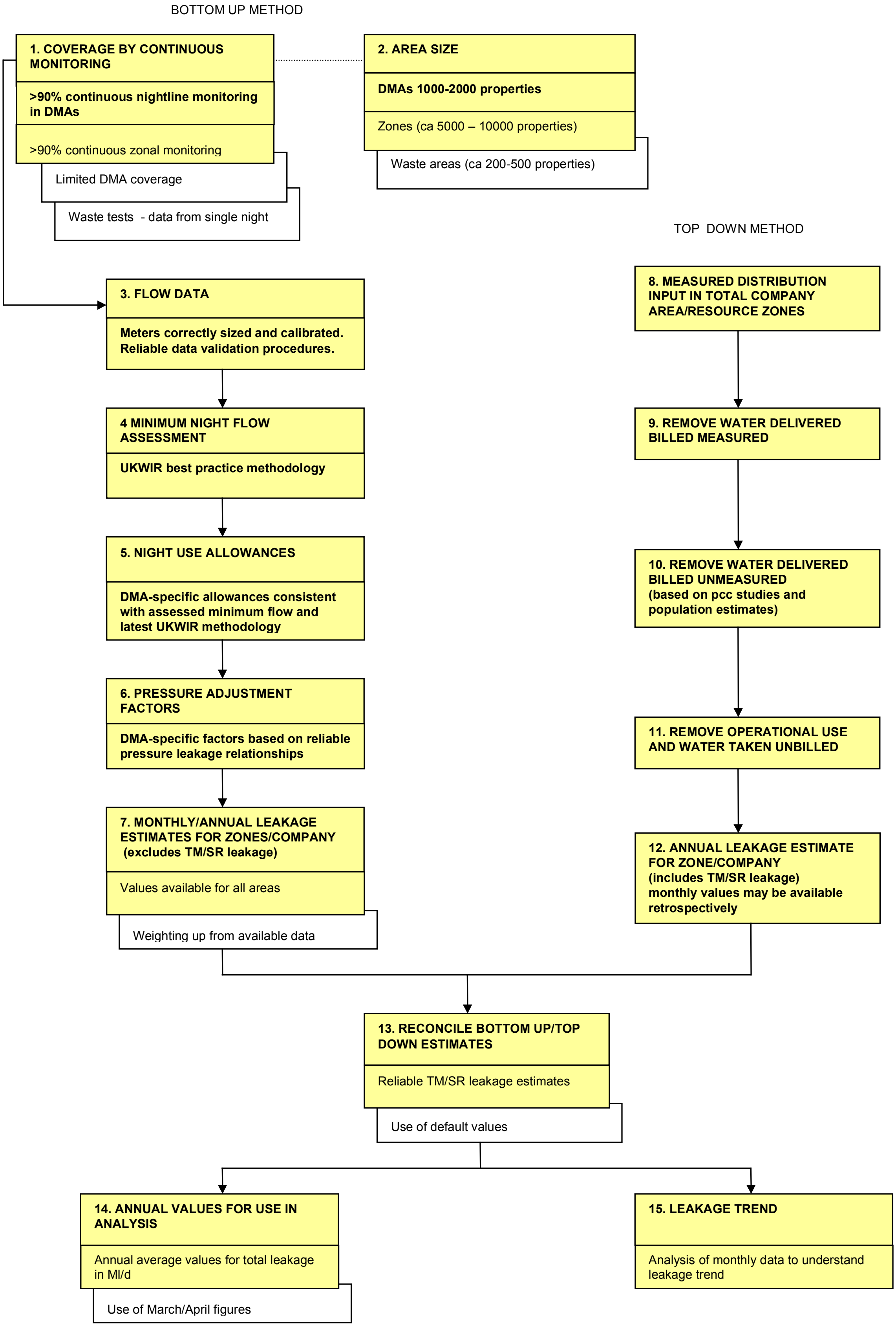
2. The night flow leakage estimate should be reconciled against the leakage estimate derived from the annual water balance. Discrepancies should be distributed across the components. Current Ofwat guidance is that only discrepancies of less that 5% should be distributed across the components.

    - The resulting annual average level of leakage should be used to develop the leakage cost curve.

    - The method for calculating the level of leakage in the model should be consistent with the July Return methodology.

3. The leakage trend during the year should be assessed in order to calculate future transitional costs.

Figure 3.1 Process map for best practice estimation of current leakage level



3.3 CURRENT POLICY MINIMUM LEAKAGE LEVELS

3.3.1 Definition of Policy Minimum

From experience, it is evident that within each DMA there is a minimum level of leakage which can be achieved by intensive and repeated leak detection and repair work. The minimum level can vary substantially from DMA to DMA even if the same leakage control methods are used. The residual leakage is thought to consist predominately of small leaks and seepages, which cannot be detected by the current leak detection methods. Even on new systems some leakage may occur due to weeping joints.

The minimum achievable level of leakage has generally been referred to as '*base*' or '*background*' leakage. However, as it is dependent upon the leakage policy (leak detection methods and technology, pressure management, etc.) as well as company policies (such as mains replacement or customer metering) it is suggested that a more useful concept is 'policy minimum' leakage. However component based calculations of a base level such as expressed in UKWIR report 97/WM/08/10 can sensibly be used as a check to actual recorded policy minimum levels.

The 'current policy minimum' is defined as the lowest level of leakage which can be achieved through intensive active leakage control using conventional active leakage control methods, 'current' technology and 'reasonable' effort. If, for example, additional pressure management is introduced or there is a move to increased leakage detection at night there will be a reduction in policy minimum level of leakage. These changes should be considered as part of 'New Policy and Technology options', see Section 3.5, and will result in a 'New Policy Minimum' which should be used in the economic analysis.

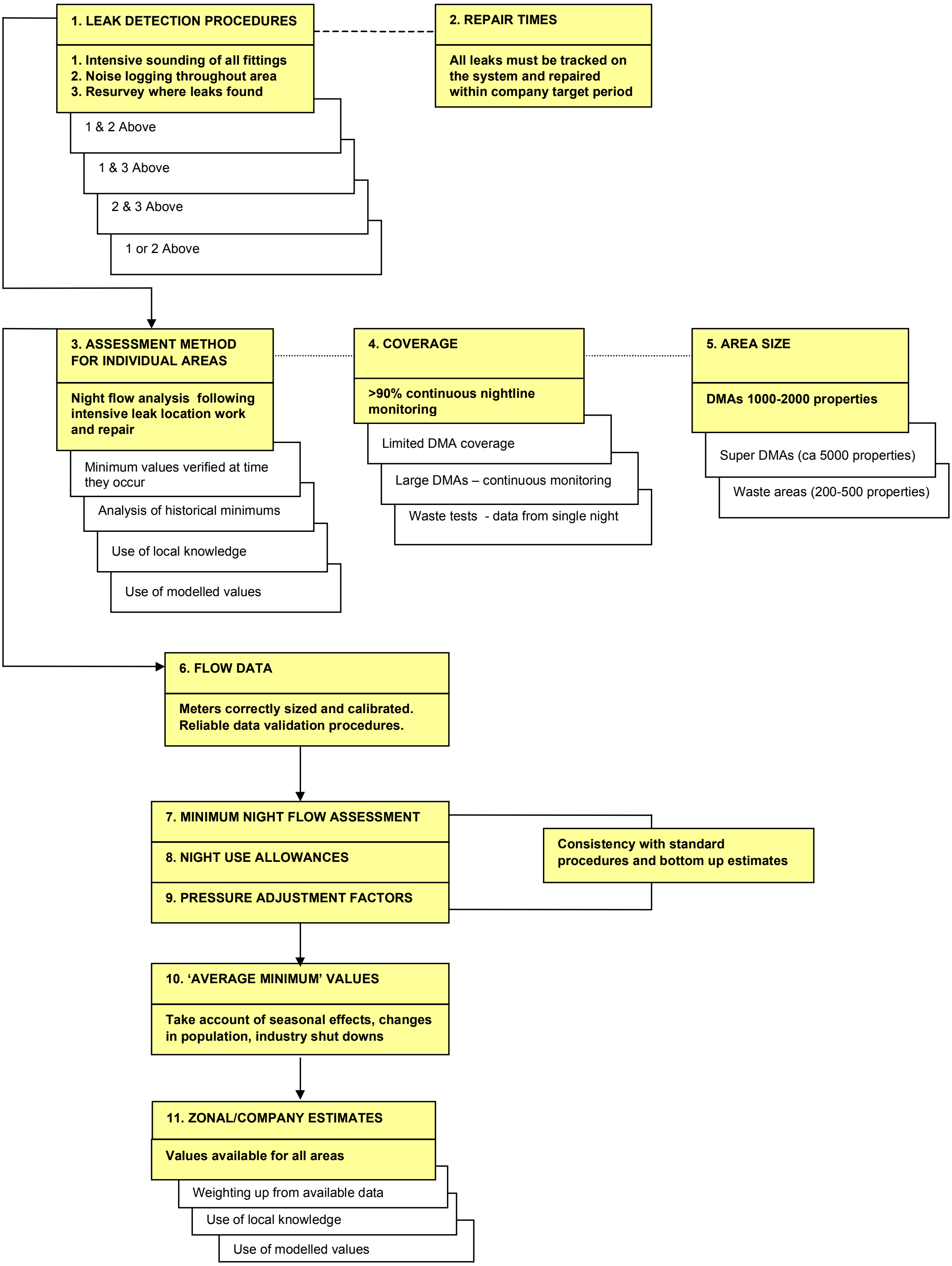
'Reasonable' effort also needs to be considered on economic grounds. To derive the current policy minimum 'special' intensive leakage control exercises are required to drive down leakage. From examining minimum night flow data during these exercises it is evident that in many DMAs each repeated intensive active leakage control sweep results in a reduction in leakage, but these reductions are progressively smaller with each sweep, and very quickly stop being cost effective. 'Reasonable' effort therefore needs to be determined on economic grounds. Reliable estimates of policy minimum levels are also key to cost effective prioritisation of leak location work in DMAs.

It is not possible to operate at the policy minimum level of leakage as this would require all DMAs to be reduced to the minimum achievable level and then held steady, i.e. the run time of all detectable leaks would be zero.

At the policy minimum level of leakage it is assumed that additional expenditure on leakage control will fail to achieve further reductions in leakage unless there is a change in policy. The policy minimum level is a key input in the development of the leakage cost curve and will have a substantial impact on the resulting economic level of leakage. All approaches used in the UK for developing leakage cost curves rely on the concept of policy minimum.

A summary of the best practice approach for estimating the current policy minimum level of leakage is provided in Figure 3.2 and discussed in detail in Appendix B. The definitions for Policy Minimum are being further refined as part of an ongoing UKWIR project.

Figure 3.2 Process map for best practice estimation of current policy minimum



3.3.2 Key messages

1. Policy minimum leakage estimates should be based on company specific DMA data.
2. The policy minimum level of leakage should accurately reflect the lowest level of leakage which can be achieved in each DMA through intensive active leakage control using conventional active leakage control methods, current technology and 'reasonable' effort.
3. Meters should be reliably sized and calibrated in order to record minimum flows.
4. The data should be verified at the time at which it is recorded.
5. The method of calculating policy minimum leakage should be consistent with standard procedures for calculating leakage from night flows.
6. When determining the current policy minimum, care should be taken to account for seasonal variations in night use.
7. Minimum levels should be updated if verified lower leakage levels are achieved in a particular DMA or if there is a change in policy that would affect the policy minimum.

3.4 LEAKAGE CONTROL ACTIVITIES AND LEAKAGE COST RELATIONSHIPS

3.4.1 Introduction

The analysis of leakage control activities and development of leakage cost relationships is required in order to predict how the on-going costs of leakage control will change if a different level of leakage is maintained. It also allows the transitional costs incurred in achieving the new target level of leakage to be assessed. The relationship is developed for the current leakage control policy (current leakage detection methods and technology). Costs of operating at different levels of leakage are calculated assuming the method of leakage control is unchanged and leakage is reduced through applying more of the same effort (e.g. increasing the numbers of leakage inspectors). The analysis of introducing changes to the leakage control policy and technology used (e.g. the introduction of leakage performance contracts for leakage detection contractors) are considered under ‘New Policy and Technology options’ (see Section 3.5).

The cost analysis should include the operating costs (including capital maintenance) of monitoring leakage, detecting and locating leaks and repairing leaks.

Two alternative approaches for evaluating and modelling leakage control activities and costs are currently used. These are quite distinct and have therefore been presented separately as Method A and Method B in Figures 3.3 and 3.4 respectively. The various approaches used within Method A are shown in Figure 3.3 and are discussed in detail in Appendix C with worked examples.

3.4.2 Analysis of leakage control activities and costs

There are two possible methods for analysing costs (assuming that the backlog of leaks has been removed):

A. Split current costs into steady state costs (the cost of *maintaining* leakage at a given level) and transitional costs (the cost of moving from one level of leakage to another)

   - the split should be based on the number of leakage repairs and leakage levels over a number of years
   - weather conditions, changes in infrastructure condition and pressure management should be considered
   - total costs are used

B. Estimate the cost of *reducing* leakage and determine a natural rate of rise (NRR)

   - the NRR must be determined accurately for individual areas
   - unit costs are used

Examples of Method A are APLE, BABE and 'Managing Leakage Approach A'. An example of Method B is that encapsulated in the MELT software. However, not all sub-processes in these applications meet best practice. There are also differences in the application of these approaches in individual companies, for example, the sub-processes that make up the BABE approach in one company were found to be different from those in another, and therefore reflect different degrees of meeting best practice.

For each study area for which a leakage target is to be produced:

1. Actual company costs should be used which are derived from the company finance and management information systems.

   - These should be consistent with leakage budgets

   - These should include all costs associated with leakage control including manpower/labour, vehicles, capital maintenance, etc.

   - They should exclude 'special' one off capital projects.

2. The model should give the current expenditure at the current level of leakage.

3.4.3 <u>Leakage cost relationships</u>

Three methods are currently used for determining a relationship between costs and leakage:

i. a theoretical model based on changes in the leak run time and fixed and variable cost components. This does not require estimates of current leak run times, since it only considers changes. Variable costs are costs that increase proportional to the number of leakage control surveys. Fixed costs are costs that are independent of survey frequency.

ii. regression analysis through historical data year on year for the same area using total costs (this implies the same efficiency savings year on year)

iii. regression analysis through data points for different areas for the same year using marginal costs.

3.4.4 <u>Key messages</u>

1. The form of the relationship (i.e. curve/equation) used by the different methods is considered to be less crucial than the use of reliable input data. This data should be specific for each area.

2. The more parameters required by the method, the greater the ability to influence results and the greater the need for reliable data.

3. Input parameters must be clearly defined and understood.

   - The measure of leakage/leakage reduction should be clearly defined.
   - Use of marginal costs increases the complexity and the potential for errors.

4. All of the approaches rely on the concept of the policy minimum level of leakage and are asymptotic to this point.

    - the policy minimum for the current policy and for alternative policies should be derived robustly.

5. The cost per repair should be assumed to be independent of the level of leakage (unless evidence can be provided to the contrary).

6. Where the leakage/cost relationships are for steady state costs, transitional costs (for moving from one level of leakage to another) must be calculated.

7. Actual costs (corrected for steady state) versus levels of leakage should be compared with modelled values over a number of years.

    - efficiency savings and changes in policy must be taken into account
    - uncertainty over efficiency savings and changes in policy makes curve fitting through historical data points potentially unreliable.

8. Fitting through data points for a number of areas to generate the relationship is only recommended if the characteristics of the areas are identical.

9. The relationship should be based on reliable and up to date data (minimum 12 month period) and should therefore reflect the current policy and efficiency. The relationship should be updated at least every year (Ofwat currently require a review every 2 years).

10. Where companies use performance contracts for leak detection, the leakage/cost relationship is defined by the cost matrix within the contract.

Figure 3.3 Process map for best practice development of leakage costs relationships – Method A

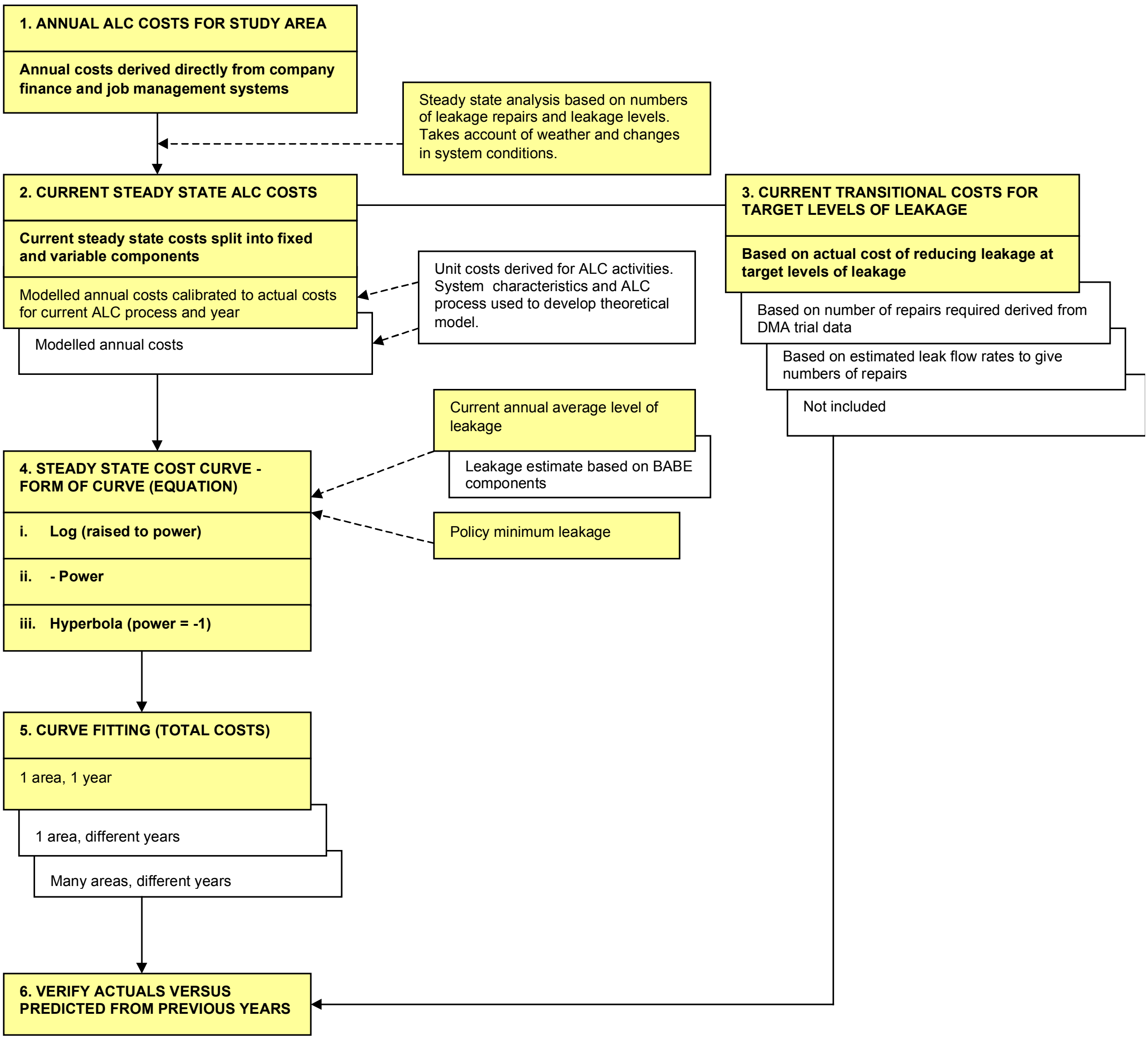
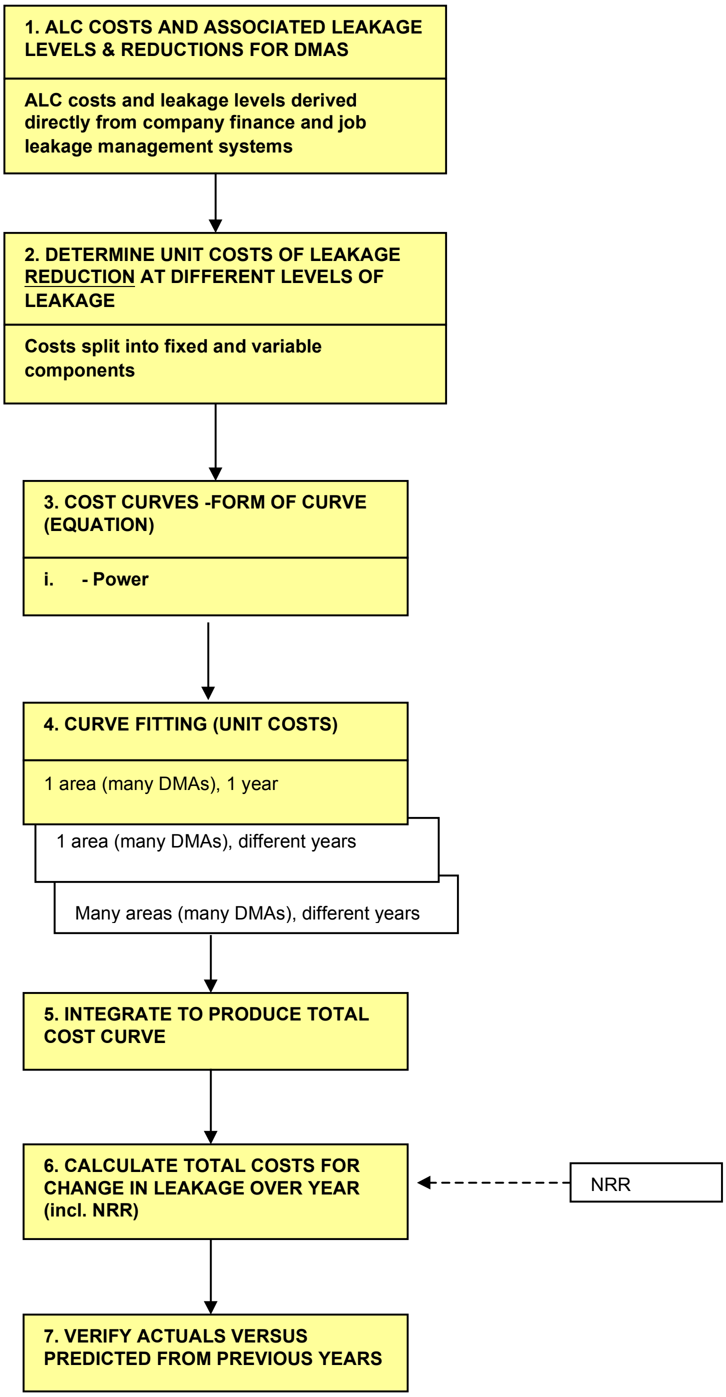


Figure 3.4 Process map for best practice development of leakage costs relationships – Method B

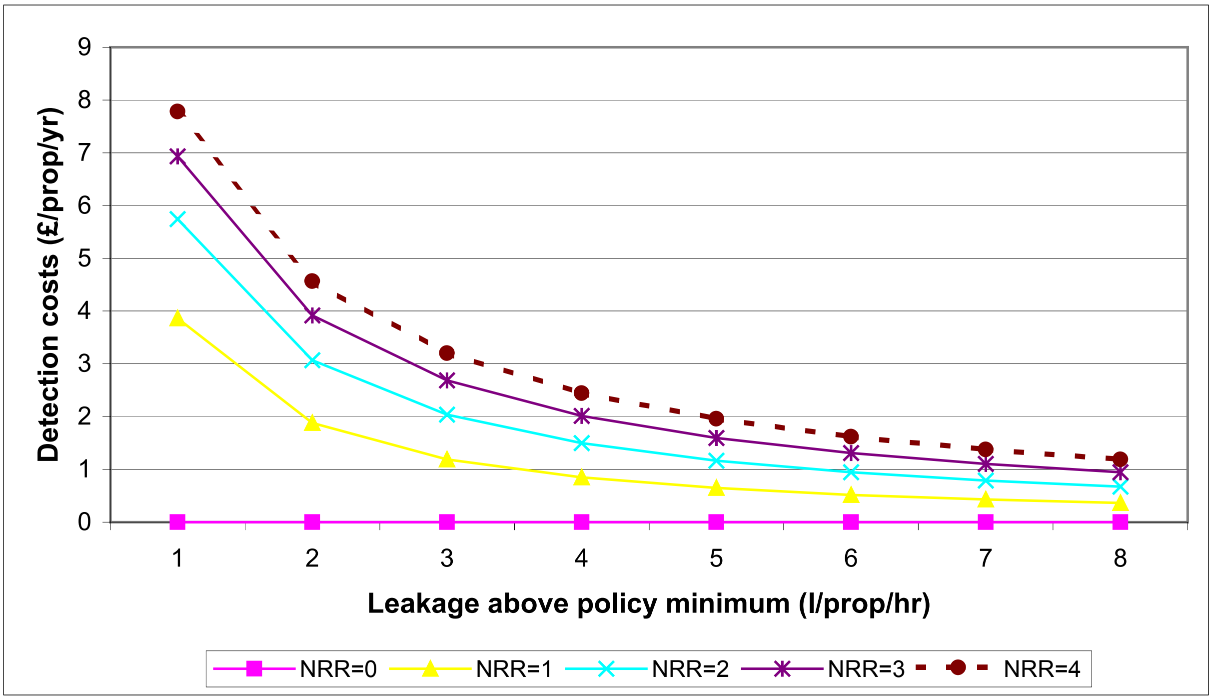


3.4.5 Discussion

The best practice approach under Method A is currently more reliable than Method B because:

- The natural rate of rise which is used in the analysis has a substantial impact on results (see Figure 3.5). The graph shows the NRR for supply areas in the range of 1 to 4 l/prop/hr/yr. Typical industry estimates are of the order of 2 l/prop/hr/yr in resource zones, although values can range from –5 to 20 l/prop/hr/yr are observed for smaller areas. Specific estimates are required for each study area and, at present, it appears to be very difficult to determine the NRR accurately for individual areas.

Figure 3.5 Impact of NRR on modelled detection costs



- The theory used in Method B assumes smaller leaks at lower levels of leakage and therefore the NRR increases with the level of leakage. However, due to the difficulties associated with determining the NRR this assumption has not been verified from the data analysis carried out.

- Fitting through data points for a number of areas to generate the relationship will be inaccurate if the area characteristics are different.

- The best practice approach under Method A is straightforward and requires fewer input data.

3.5 NEW POLICY AND TECHNOLOGY OPTIONS

3.5.1 Introduction

A summary of the best practice approach for evaluating new policy and technology options is provided in Figure 3.6.

At present, those companies which carry out a detailed analysis of alternative policy and technology options follow this general approach. The exact details of how these are included within the analysis will depend on how the leakage cost relationships are generated.

3.5.2 Key messages

1. The ELL should be determined for the current policy to give a baseline. Other policies may then be evaluated against this baseline. The current position (leakage level and policy) will impact on the cost effectiveness of alternative policies - what is appropriate for one company at one level of leakage may not be appropriate for another.

2. The following options should be assessed:

   - additional district metering
   - reducing DMA size/sub-metering
   - pressure management, including fixed outlet and flow modulated PRVs
   - alternative leak survey technology
   - efficiency of leakage surveys
   - impact of additional household metering
   - repair times and costs, including supply pipe repair policy
   - mains and communication pipe rehabilitation/replacement

3. For each option the following parameters should be considered:

   - operating and capital expenditure
   - impact on leak location costs
   - impact on level of leakage and policy minimum leakage
   - impact on breakout rate of leaks/NRR

4. The options should be ranked by their cost effectiveness.

5. The interactions of different policies and the target level of leakage must be taken into account to avoid double counting (savings may be reduced at lower levels of leakage).

6. It is suggested that a period of 10 years is used to assess the cost effectiveness of alternative leakage control polices due to rapid technological developments. This also ties in with the periodic review period, after which time Ofwat builds any efficiency savings into price limits. Alternatively it would be possible to base the analysis on the expected life of the technology, after which time it is written off, this would typically be around five to ten years. This is not inconsistent with the standard 25-30 year analysis period used for least cost planning, it is recognising the different level of confidence between setting a short-term leakage policy and developing a long-term supply-demand plan.

7. The final ELL should be assessed using the least cost leakage control policy, i.e. the most efficient mix of the policy options at the target level of leakage.

3.5.3 Discussion

It is important to consider the possible long-term consequences of the current policy, e.g. mains replacement with plastic mains will result in short term benefits but it may make leaks more difficult to locate in the future.

Efficiency and motivation of staff is likely to have a substantial influence on the cost effectiveness of any approach. Under performance contracts for leak location, the contractor has a strong incentive to improve performance. However, companies should consider major long-term investments in new technology in partnership with the contractor since, a contractor is unlikely to make investments with a pay-back period longer than the duration of the current contract.

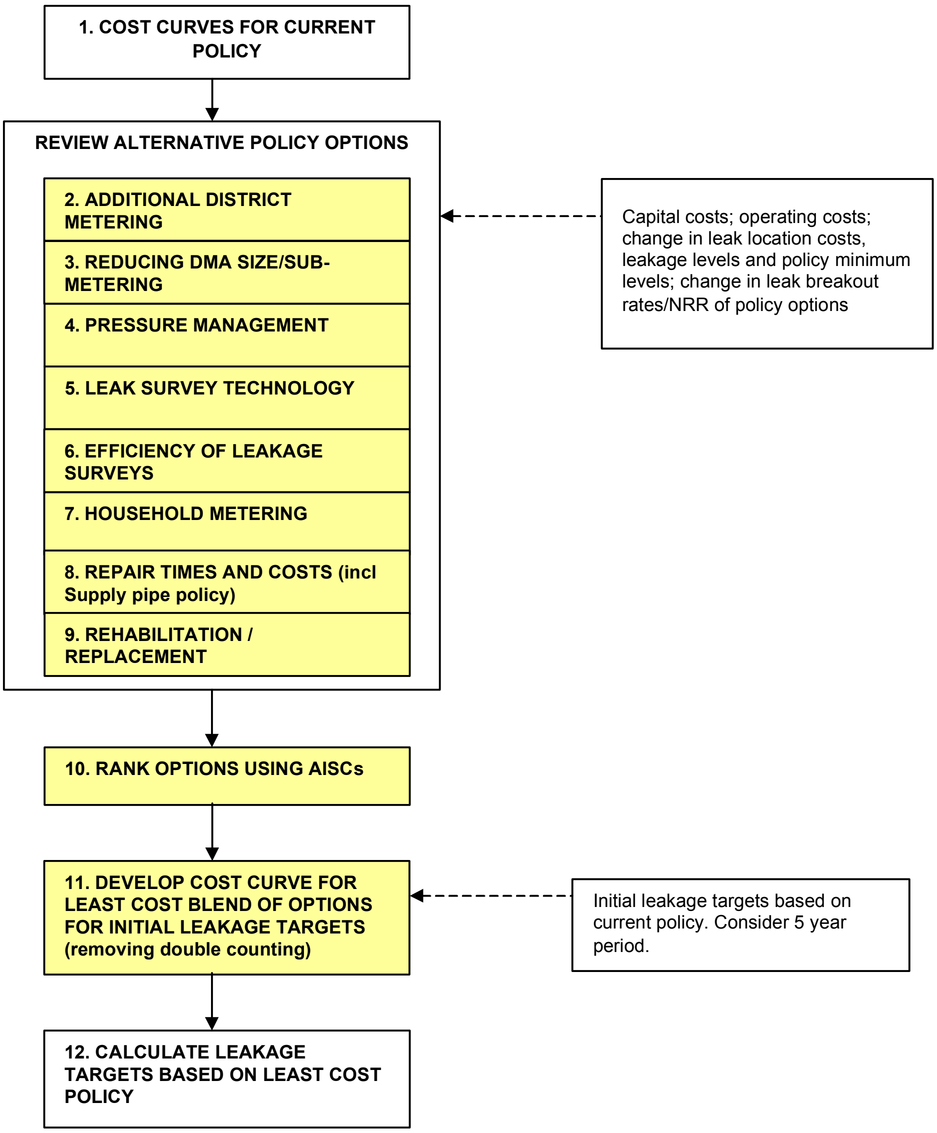
The leakage cost relationship used to derive leakage targets should be based on the current efficiency of the leakage control process. In the short term this will result in higher ELLs for companies with less efficient processes. There is, however, incentive for the water company to achieve the leakage target for lower cost (i.e. to increase efficiency). As the ELL is revised annually the following year's revised ELLs will then be based on the more efficient processes.

Some leakage reduction options, establishing DMAs for example, will have wider benefits than an increase in leakage control efficiency. These benefits are potentially less tangible, but just as real – a telemetered network of DMAs will not only provide the water company with an efficient leakage control process, but will also provide valuable data on "where the water goes". Were feasible these benefits should be built into the least cost planning exercise, alternatively where this is not possible a range of other techniques are available, including multi-criteria decision analysis. These approaches may be able to justify options that cannot be justified on supply-demand economics alone.

Some leakage options may also have a wider impact on the supply-demand balance which should, where possible, be quantified and built into the least cost plan. For example, the introduction of pressure management will not only reduce leakage but may also reduce demand. Pressure management has the potential to reduce peak demand by reducing the water available for garden watering. Conversely, mains replacement may actually increase demand, in that it is likely to increase the capacity of the network.

Section 3.6 below discusses the potential for further, longer-term technological change.

Figure 3.6 Process map for best practice evaluation of new policy and technology options



3.6 TECHNOLOGICAL CHANGE

3.6.1 Approach

The general approach has been to extend previous reviews of technological development, primarily Managing Leakage Report J, *Leakage Management Techniques, Technology and Training*[13]. The purpose of this section is to illustrate the progress that has been made, and to identify any possible future advances.

The intention is not to provide specific reviews of manufacturer's equipment but to provide broad indications of development trends in equipment and applications. Any reference to a specific manufacturer should not be taken as a recommendation of a particular technique or piece of equipment.

3.6.2 Leak detection and Repair process

As part of a water company "active" leakage control policy, the leak detection process can be categorised into the following six steps:

1. Night flow measurement at District Meter Area meters }
2. Communication to leakage management staff } "Awareness"
3. Targeting of leak detection activity }
4. Leak location surveys (Localisation)
5. Leak pin-pointing
6. Leak repair, checking and return to service.

Processes that impact on both the current and policy minimum level of leakage will result in additional benefits to those that only impact on the current level.

The six steps can be further categorised into awareness, localisation, pinpointing and repair. The challenge faced by water companies is to improve the cost-effectiveness of these activities through:

- reductions in the time to undertake the task,
- increases in effectiveness (quality) and
- reductions in the cost of undertaking the task.

Efficiency improvements will be brought about by varying combinations of:

- reduced manpower numbers (de-manning)
- reduced manpower costs (de-skilling)

- improved accuracy and processing capability (including increased staff motivation),
- improved speed of communications
- reduced equipment price

It is clear that there will be strong interactions between these possible improvements. For example, new technology could result in reduced manpower numbers, but require a higher skill level, resulting in improved speed but at a higher cost. Improvements in efficiency will only be realised if the full combination of impacts results in net reductions of time/increase in quality and/or reduction in cost.

Improvements in efficiency do not therefore rely on development of new technologies, but may also be achieved through the continuing development of established technologies and changes in leakage management practices. These other approaches would be expected to follow similar efficiency gains to other similar industrial sectors and be included with the assumed efficiency savings for other business areas with the water company.

3.6.3 Equipment Categorisation

Available technology

Awareness	Localisation	Pinpointing
Metering	Step-testing	“listening stick”
Data Logging	Acoustic logging	Ground microphones
Communications		Correlators

Awareness

i) Metering

The most widely used leakage function for metering is to measure night flow into DMAs. Metering can also be used to provide awareness of flows at other important interfaces such as source, zone or individual customer. The principal types of meter comprise hydraulic, ultrasonic, mechanical and electromagnetic.

Hydraulic meters include venturi and orifice types, but are generally considered obsolete. Ultrasonic meters are used in limited numbers. The most common type of meter in use for monitoring DMA flows is the mechanical meter.

Electromagnetic meters offer various benefits over mechanical meters, including improved accuracy, an unobstructed bore and the option of burying without a chamber. However, these meters require a power supply and a housing for the readout and so tend to be more expensive.

Options for temporary metering include electromagnetic insertion probes, which require a tapping on a straight length of main and an access chamber. These have the disadvantage of reduced accuracy, particularly if installed for a significant period.

The most accurate meters currently available are electromagnetic, with a reported accuracy of 0.2%. This usually places metering as one of the lowest sources of error in the leakage calculations.

Data output from meters is generally available as both cumulative and instant readings.

The capital cost of meters is relatively high, but with low operating costs.

The development of metering technology appears to be fairly static, with current production models providing sufficient accuracy for DMA night flow measurements. In addition the establishment of DMAs appears to be well advanced with a good coverage in most companies. Upstream of the DMAs, in trunk mains and service reservoirs, the accurate measurement of leakage appears to be less well advanced and requires improvements in metering equipment or techniques.

ii) Data logging

Data logging is widely employed to record changes in flow or pressure. This data is used in calculations of the total water input and minimum night flow calculations to determine leakage levels.

Available methods include manual recording, chart recorders and digital loggers. Manual recording is widely used for single readings at multiple sites, such as periodic customer meter readings. Chart recorders are generally obsolescent because of the low accuracy of the data and expense of transcription to a useful electronic format.

Digital logging is generally used for recording data trends at single sites. Digital logging has changed little in recent years, apart from advancements in miniaturisation, the volume of data stored and reduced costs. Current trends are for data logging functions to be integrated with other functions through improved communications.

iii) Communications

A variety of methods are used to communicate data to a central point for analysis. These include physical transport of the data record, PSTN, radio, GSM and Satellite.

A common practice for the collection of DMA meter data is for the logger on each meter to be downloaded by a technician at predetermined intervals. The data is then carried to the office. Although labour-intensive, this is often the cheapest method of collecting data and is suitable for monitoring stable DMAs. However this method has the disadvantage of providing data at infrequent intervals. This has a potential economic cost in water lost to leakage between downloads.

Data can be retrieved by a telephone landline (PSTN – Public Switched Telephone Network). This has the advantage of providing data on demand. A typical application would be an outstation that is automated to download minimum flow data every night. A disadvantage of this method is the cost of installing a telephone line and the onsite installation. The level of sophistication onsite can vary from a simple logger incorporating a modem, to a complex telemetry installation collecting data from a number of sources.

Radio communication is available for sites where a telephone landline is impractical, such as rural areas. A disadvantage is the cost of installation and operation.

A development of the recent advances in mobile phone technology has been the use of GSM for data retrieval (GSM – Global System for Mobile Communications). This has resulted in a self-contained data logger that passes data to the office every night. These appear to operate satisfactorily wherever there is mobile phone coverage. The most significant disadvantage at present is cost, although this is usually lower than an equivalent landline.

Satellite communication technology is also available for retrieving data. The principal disadvantage at present is cost, although it may be appropriate for the more remote parts of the world.

Current developments in communications are significant in reducing the time that it takes to become aware of increased leakage. In particular, improvements in software are achieving faster reaction times by automating the translation of DMA metered flows into leakage levels and comparing these with preset alarm levels at daily intervals. Internet technology is also allowing the rapid dissemination of this information to those responsible for analysing and monitoring leakage levels and co-ordinating repairs.

Localisation

i) Step testing

Step testing has been widely used to localise suspected leaks. This requires valves to be closed to isolate parts of the DMA and the drop in flow at the meter to be noted. An unexpectedly large drop indicates the location of a suspected leak. This work is usually undertaken at night when demand is low and there is less disruption to customers.

There have been few changes in this method of leak localisation. The most significant advance was remote meter reading, which enabled the technician to see the drop in flow as he shut each valve (MAST – Mobile Advanced Step Tester). This reduces the length of time each valve needs to be shut and can enable a single large step to be identified, so removing the need for subsequent steps.

Step testing is falling out of favour due to the loss of supply to customers, risk of discolouration and the cost of night working which is leading to a drop in efficiency.

ii) Acoustic logging

Acoustic logging is a popular method of leak localisation. The logger is normally placed in contact with a fitting on the main and records sounds, including those from leaks. The sounds are either detected by an accelerometer in contact with the pipe or by a hydrophone in contact with the water at a hydrant. The hydrophone tends to work better on plastic pipes where leak sounds tend to travel further through the water than the pipe wall.

The logger is programmed to record sounds at a preset time, which is usually at night. This is when the background noise is generally quietest and the higher pressure makes the leak louder. Pressure management, which is now widespread, results in lower pressures and so can make leak location more problematic. The programming and downloading of the logger is normally carried out during the day and so avoids expensive night working. In addition, deployment of the loggers does not require any specialist skills.

Acoustic logging has been developed with the miniaturisation of equipment, development of software to discern leak noise and the facility to download via a radio link. This enables loggers to be left insitu and periodically checked via a short-range radio link. By patrolling the area on a regular basis, leak alarms can be rapidly detected and followed up.

Acoustic logging appears to be an area of technology that is continuing to develop, with advancements in the equipment and integration with other functions and systems including GIS for example.

Pinpointing

i) Sounding

Listening for the sound of a leak through pipe fittings, using the human ear, is a well established practice. The only equipment required is a metal rod with a wooden plug on one end for holding against the ear. With practice this method is useful in localising and pin pointing leaks. The only significant advancement has been the provision of simple electronic amplification.

The disadvantages of this method include the need for some skill in the practice and a low level of background noise. This can require expensive night working in noisy urban environments.

ii) Ground microphones

Ground microphones are simple microphones with mechanical contact to the ground. They assist the pinpointing of leaks and are particularly useful where there are few fittings, but the line of the main is known. Electronics amplify the sound and can also provide enhanced sensitivity to important low frequency sounds. As with sounding, a low level of background noise is required, which can necessitate night-time working.

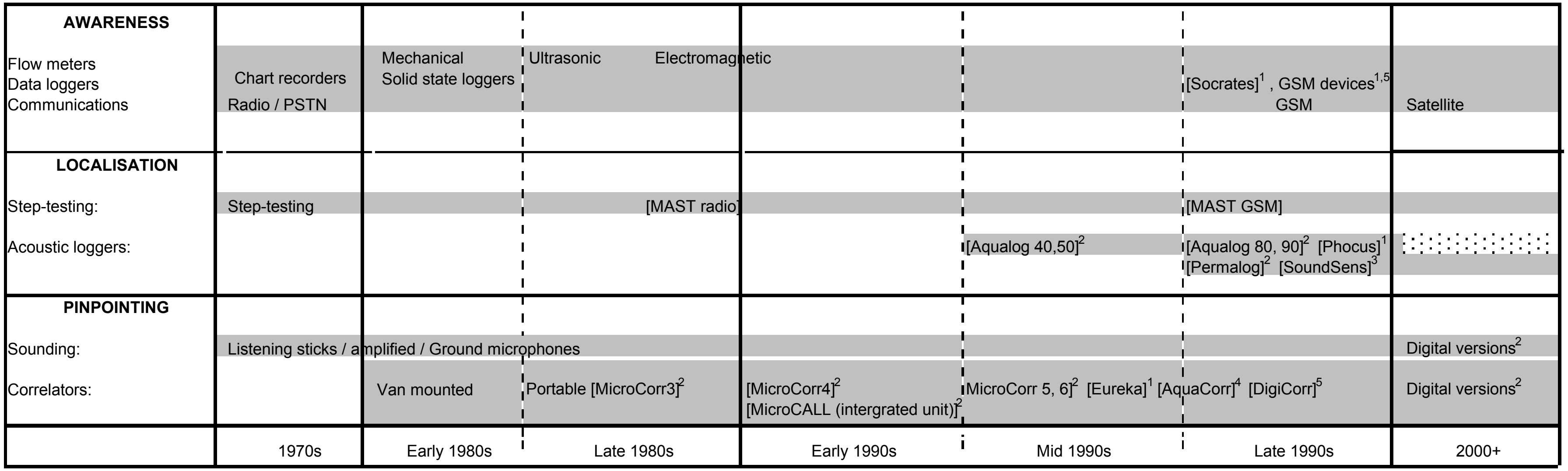
iii) Correlators

Correlators compare the sound from two fittings on a main, to pinpoint a leak between them. The sensors are connected to the Correlator by either hard wiring, a radio link or can be separately downloaded. Various improvements have been made including the change from analogue to digital, miniaturisation, improved sensitivity, software advancements and cost.

The advantages of Correlators are their ability to accurately locate leaks that cannot be pin pointed by other methods. This can save considerable expense in unnecessary excavation. A disadvantage is the need for skill in operating the equipment and interpreting the results. Expensive night working can also be required in urban areas.

Acoustic loggers have been successfully adapted for use in leak correlation. This enables a larger area to be covered by multiple loggers left insitu overnight. This avoids expensive night working whilst enabling the pin pointing of leaks. Some skill is still required to analyse and interpret the results.

A problem with all of the pinpointing techniques is locating leaks in plastic pipes. This is because plastic does not transmit the leak sound as well as other materials. The use of hydrophones in contact with the water and improved software, are improving the effectiveness of locating leaks in plastic pipes.



1 Primayer
2 Reten / Palmer
3 Radcom
4 Biwater Spectrascan
5 Technolog

NB List not intended to be exhaustive

Figure 3.7 Milestones in technological development

Key to product names:

Socrates	Data logger with software to identify, record and analyse the minimum night flow. Manufactured by Primayer.
Aqualog	Acoustic loggers produced by Reten / Palmer.
Phocus	Acoustic loggers manufactured by Primayer.
Permalog	Acoustic loggers including software to discern leak noise and facility to download via a radio link. Manufactured by Palmer.
SoundSens	Leak pinpointing device. Manufactured by Radcom Technologies Ltd.
MicroCorr	Leak noise correlator. Manufactured by Palmer.
MicroCall	PC based leak noise correlator. Manufactured by Palmer.
Eureka	Leak noise correlator manufactured by Primayer.
Aquacorr	Leak noise correlator manufactured by Spectrascan.
DigiCorr	Digital leak noise correlator manufactured by Flow Metrix.

Figure 3.7 provides a “Time Line” of technological development in each of the above categories and gives an indication of the significant “step changes” which have brought about shifts in efficiency. **Some examples of widely available equipment are also provided. The list is not intended to be exhaustive and mention of a particular device does not necessarily imply endorsement**. However, the table serves to illustrate the significant increase of technological development particularly through the mid 1990s to the present day.

Emerging technology

Awareness	Localisation	Pinpointing
Neural networks	Infra-red Imaging	Gas sensing
Real-time network models	Ground Penetrating Radar	Pressure transient analysis
Leak sensitive pipe walls	Ground motion sensors	Pig-mounted acoustic sensing

Research is being carried out on a variety of technology to assist in locating leaks. These include methods already employed in other industries.

Awareness

Network models are widely used in the water industry to test modifications to the distribution system. However they are normally only compared to real data at the calibration stage. By constantly updating the data, using telemetry, any abnormal flows attributable to leakage can be rapidly identified. Neural networks are a developing method for identifying these abnormal patterns.

The data available for real time network models is improving as the coverage of metering of individual domestic and commercial customers increases. Trials have been held where flow data from all of the properties in an area have been downloaded on a daily basis and deducted from the DMA inflow to calculate the leakage. Improvements in techniques for reading customers meters are making this data collection more viable. These include ‘drive by’ meter reading and connections to the customers telephone line.

Various methods are used in other industries to monitor the integrity of pipe walls. One of these techniques employs an electrically conductive layer within the pipe wall. If a leak occurs, contact is established with the surrounding soil or water and an automatic warning device is activated. This would appear to be a promising technique for plastic pipes.

Localisation

Research has been carried out into airborne spectrometer, airborne thermal and high resolution satellite imagery. Using these techniques it is possible to verify the pipeline location and identify ground surface anomalies that could relate to leaks. These techniques are most effective in rural areas and are sensitive to the ground conditions.

Ground based infra-red imaging measures the changes in ground surface temperature. It is a possible localisation tool as it can detect small increases or decreases in ground temperature caused by the leak. It needs to be employed under suitable conditions, such as on a warm day or cool night to achieve maximum contrast.

Ground penetrating radar detects voids formed by escaping water or an increase in apparent depth due to saturated soil. This method is very dependant on the soil conditions, being more effective in normally well drained soils and less effective with depth.

Geophone sensing has been trialled. This uses ground motion sensors in an array to pinpoint a leak. This equipment was found to be cumbersome but worthy of further development.

These techniques are continuing to be developed for other applications and offer some promise in the water industry, particularly in rural areas where the ground is less disturbed.

Pinpointing

Tracer gases, such as helium and hydrogen, have been used in the telecom industry to locate leaks in pressurised telecom cables. This technique has been found to be most effective on small diameter customer water supply pipes. Gas is introduced into the pipe under pressure and its presence tested at ground level. It has been found to be effective, but time consuming, as it can take over an hour for the gas to reach detectable concentrations at the surface.

CCTV is an established technique for inspecting sewers and could be applied to the internal inspection of trunk mains. However, although this method would reveal pipe condition, it would be unlikely to be effective in locating leaks.

Inverse transient analysis is a method of locating leaks based on changes in pressure detected at pressure transducers. This method has been successfully employed in a laboratory situation, but has not yet been scaled up to a field trial. The method is based on the way that any pressure change is reflected through the network. The pressure wave could be due to a valve operation or could be deliberately generated for the test. Any outlet from the network such as a leak or point of consumption will reflect these pressure waves. The technique is dependent on an extremely accurate network model and consequently may not be suitable for large-scale application.

Pig mounted acoustic sensor have been used in the oil industry and can be very successful on new pipelines. For water mains the sensor is propelled through the main by the water and detects the sound of water escaping from the main. This technique has been successfully utilised in *Saraha*™ for use on trunk mains, and is currently being trialled on distribution mains.

3.6.4 Repair Technology

Replacement

This is the most common form of repair, particularly for small diameter mains and service connections. The main is first drained and then a short length of pipe is cut out either side of the leak and replaced. This is usually connected to the existing pipe using compression fittings and so requires a relatively low level of skill.

Methods of stopping the flow in the main during repair vary, depending on the size of the main and available fittings. Alternatives include:

1. Closing a valve.
2. For plastic pipe, squeezing it flat with a suitable tool.
3. Forming a plug by freezing the water.
4. For large diameter mains, inserting an inflatable water stop through a tapping.

Repair clamps

These allow a repair to be carried out rapidly with only a short interruption to supply and so are particularly useful for large diameter mains. They require a relatively low level of skill to install. Each repair clamp is manufactured to only fit a small range of outside pipe diameters and so a large stock holding may be required to cover all likely pipes.

Rehabilitation

Where a main shows signs of reaching the end of its economic life or where water quality problems are occurring, rehabilitation of significant lengths of main may be necessary. Available techniques include replacement, lining and bursting.

Pipe lining and bursting techniques have the advantage over replacement, of reduced disruption from excavation. These techniques only require a limited number of excavations to gain access to the existing main. However, this advantage can be reduced in distribution mains, where an excavation is required to reconnect each customer service pipe. These techniques also require specialist skills.

Other repair methods

A variety of other techniques are used to repair leaks in sewers and other pipelines. These include injecting the ground around the leak and patching the leak from inside the main. However, water quality concerns generally preclude their application to water supply mains.

3.6.5 Where next?

Awareness

DMA meter coverage is generally well established and data logging is a common practice. However there are wide variations in logger download intervals and hence in awareness times between leaks forming and coming to the attention of the water company. The widespread application of existing communications technology could have a significant effect in reducing the awareness period.

Current trends in available data collection technology are reducing the length of the awareness period. This trend is likely to continue as the various items of equipment become more integrated and the analysis software becomes more proficient at identifying leakage.

With the current focus on DMAs, possible losses in trunk mains and service reservoirs receive less attention. This appears to be an area in which improved monitoring could be beneficial.

The most significant area of potential improvement in awareness could be in customer metering (if installed externally). About a third of current leakage occurs in customers supply pipes. If the current trend of increasing numbers of customer meters continues, this will assist in identifying and quantifying this leakage. Recently, however, some water companies have tended to install meters internally and so this benefit is not realised.

Leak Localisation

Step-testing appears to be declining because of high manpower costs and potential water quality problems.

The use of acoustic loggers for leak localisation appears to be increasing; In particular the use of Permalog type loggers that incorporate software to discern leak noise. These enable the leak localisation process to be de-skilled and will also improve awareness in those areas where DMAs are not established. However, a large amount of investment has been made in establishing DMAs and unless there are significant reductions in cost, it is unlikely that widespread “permanent” installations of Permalogs will become common practice.

Leak Pinpointing

Portable leak noise correlators are now widely used throughout the industry and a range of devices are available which are able to provide reliable positional accuracy over a range of pipe materials and sizes. Manufacturers have indicated that the particular “low frequency” problems associated with plastic pipes and trunk mains are also being overcome. It would appear that the limits of “analogue” technology have been reached and the new “digital” equipment will overcome issues such as local noise, providing greater reliability, and will give the user more functionality.

3.6.6 Summary

The cost-effectiveness of technology has significantly improved over the last 20 years and has enabled significant gains to be made in reducing awareness times, improving the accuracy and reliability of leak localisation and pinpointing. The net effect of these improvements is:

1. a reduction in the average size of undetectable leakage

2. a reduction in the average unit-cost of detection

3. a reduction in the volumes of water lost through leakage

The expectation is therefore that these improvements will continue to generate reductions in economic levels of leakage through further technological advancement.

However, although a variety of alternative techniques are being researched, no big technological step-changes are currently apparent. Instead, the wider application and cost-effectiveness of existing technologies such as digital technology and GSM communications are likely to incrementally improve awareness times, accuracy and reliability of data. This will probably result in reduced manpower and de-skilling.

The development of integrated systems that address all aspects of the leak detection and repair process is likely to increase, but the cost benefits of such technological developments will only be made possible by changes in leakage management practices involving a greater degree of co-ordination of activity.

4. CALCULATING THE ECONOMIC LEVEL OF LEAKAGE

4.1 INTRODUCTION

This section examines the key principles that should be applied when calculating the economic level of leakage. As indicated earlier there are alternative approaches that can be applied to leakage target setting; these are discussed in Section 5. The economic level of leakage is when the additional cost of reducing leakage is equal to the additional benefit gained from further leakage reductions. Section 3, above, examined the key principles that should be applied when calculating the cost of further leakage reductions. This section examines the key principles that should be applied when calculating the benefit of further leakage reductions.

The economic level of leakage is set within the context of the balance between supply and demand (the so-called supply/demand balance) for a company. Within the supply/demand balance leakage is a “volume of water lost”. A reduction in leakage will reduce the total volume of water that is treated and pumped into supply, resulting in a reduction in the operating costs (or system costs). This will be seen as an immediate saving in power and chemical costs. Additionally, there may also be a reduction in the future capital investment requirements (and associated operating costs) if supply/demand balance investment is required within the planning period. This benefit is less certain than the operating cost saving, since it requires estimates of the future supply-demand balance to be made.

There may also be environmental and/or social benefits of leakage reductions. These will generally depend on regional factors including abstraction from sensitive rivers and construction within, or abstraction from, environmentally sensitive areas. The potential for environmental and social benefits is considered in Section 4.5.

Sections 4.2 and 4.3 consider the options for calculating the future cost savings associated with leakage reductions. There are two related approaches that are considered best practice:

i) Least cost plan

The least cost planning approach looks to minimise the total cost of managing the supply/demand balance over the planning period (typically 25 to 30 years).

There is an issue as to whether in addition to direct costs such as those associated with system savings, power, chemicals and capital expenditure a company should include environmental and social costs. Leakage reduction is compared with all other options for managing the supply-demand balance, including demand management and resource development.

This approach allows the trade-off between leakage control, resource development and other supply-demand options to be considered in a consistent and transparent manner. It does, however, require a detailed understanding and modelling of the interactions of the supply-demand balance.

Due to the complex nature of developing the least cost plan the marginal cost of water approach, see below, may provide an initial solution. Full details of least cost planning are presented in Section 4.2.

ii) Marginal cost of water

The marginal cost approach can be seen as complementary to least cost planning. Estimating the marginal cost(s) required can require much or all (depending on the approach chosen) of the information required to carry out a least cost planning exercise.

The approach requires a comparison of the marginal cost of active leakage control with the marginal cost alternative options for balancing supply and demand. In its simplest form this could consist of comparing the marginal cost of leakage with the marginal cost of the next representative resource scheme. If a number of supply/demand options are to be considered then a full least cost plan should be developed. We will discuss the use of this methodology in its simplest form. This approach should therefore be considered appropriate for intermediate years between full least cost plans.

This approach requires a calculation of the marginal cost of the next representative resource/treatment option; the economic level of leakage is the point where the additional cost of leakage control equals the marginal cost of the next option. It is less robust than the least cost planning approach, since it requires a number of assumptions to be made. It is, however, considered to be suitable for the development of economic level of leakage targets, particularly when the current level of leakage is close to the economic level.

The main feature of this approach is that it requires the calculation of an appropriate and robust marginal cost of the next representative resource/treatment option. This will not be the same as the long run marginal cost of water, but should be calculated using the same source data.

If there is no supply-demand balance investment planned then the economic level of leakage is set based on system costs. When supply-demand balance investment is required then leakage is reduce until the marginal cost of leakage control equals the marginal cost of the next representative resource.

Full details of this approach are presented in Section 4.3.

4.2 LEAST COST PLAN

The least cost planning approach requires the development of a long-term plan (typically 25 to 30 years) for managing the supply/demand balance. The purpose of the analysis is to minimise the net present value of the cost of all supply-demand related investment (capital, system, operating and possibly social and environmental costs). Leakage is considered as one of the options to manage the supply-demand balance. The leakage profile that results in the lowest net present value of costs is thus the economic level of leakage profile. The ongoing UKWIR/EA/Ofwat study "Economics of Balancing Supply and Demand" is re-examining the issue of least cost planning.

Least cost planning is the favoured approach, in that the economic level of leakage is set on the basis of the impact of the supply-demand costs and benefits. It is the most flexible and transparent of the alternative approaches since it allows all supply-demand policy options to be considered on a like-for-like basis.

The remainder of this section considers the key features that are required for best practice:

- **Minimise net present cost:** The basis of the analysis should be to develop the programme that results in the lowest net present cost. If an optimisation algorithm is used these can potentially select local minima and not locate the true least cost position. It is therefore important that a wide range of policy options and leakage levels are considered. An appropriate discount rate (generally within the range of 6% to 8%, consistent with the company's cost of capital) should be used.

- **Time period**: The least cost plan should be developed over a period of 25 to 30 years.

- **Include all costs**: The least cost plan should look to minimise all variable supply-demand balance costs. Due to the nature of the least cost planning approach only costs that vary as a result of changes to the supply-demand policy options will have an impact on the results. Any costs that are fixed across all options will be constant in all polices. It is therefore not possible to include too many costs, and all possible costs should be considered. The following costs should all be included:

  – Variable system/operating costs (power and chemicals). This should initially relate to the current most expensive source in the zone, and may be varied through time (if the current most expensive source is replaced with a more or less expensive source).

  – Capital costs should be included for all supply-demand options at current (or base year) levels. In addition to the initial capital cost it is also necessary to include capital maintenance (or replacement) costs. This will include, for example, meter replacement costs.

  – Fixed operating costs should also be included for any of the supply-demand balance options being considered. Current fixed costs are not required if they will not vary throughout the planning period.

  – Cumulo rates are local authority charges that are linked to the throughput of the works, as such they may be considered variable. However, since the local authority will look to recover the same costs following a reduction in throughput it is likely that the unit cost will be increase. It is therefore considered that cumulo rates will only be reduced for a short time following a leakage reduction and should be considered fixed. They can therefore be excluded from the analysis.

– Abstraction charges are fixed for current abstractions, and so would not vary with the level of leakage. Fixed abstraction charges can therefore be excluded from the analysis.

- **Environmental and Social costs:** It is suggested that these be considered separately to the private company (financial) costs listed above. Section 4.5 considers these costs in more detail.

- **Supply-Demand forecasts**: The least cost plan should be based on those supply-demand forecasts that are driving the investment. For example in a zone with projected peak week deficits it is important that the peak week supply-demand balance is considered. Some zones may have more that one factor driving investment (i.e. peak year and peak week). When considering leakage reductions the impact on the forecast driving the investment should be considered. For example, a reduction in leakage of 1 Ml/d will not always result in a 1 Ml/d reduction in peak day demand (due to the impact of reduced pressure at peak times).

  The supply forecast should allow for the latest estimated impact of climate change and for all agreed or proposed changes to licences agreed with the Environment Agency.

  Industry standard approaches should be applied to the development of the supply demand balance. These should include target headroom, outage analysis and demand forecasting.

- **Costs and impacts of other supply-demand measures**: The full least cost plan will consider all options to manage supply and demand. In addition to leakage all other demand management options should be optimised to produce the lowest 30-year cost.

  These alternative options, including water efficiency for example, should be treated on a like-for-like basis with leakage. Each option will have a impact on the supply-demand balance and an associated capital/operating cost. Where the benefit to the supply-demand balance is greater than the long-term cost then it should be included within the least cost programme.

The least cost planning approach will generate a curve of a similar form to that shown in Figure 4.1.

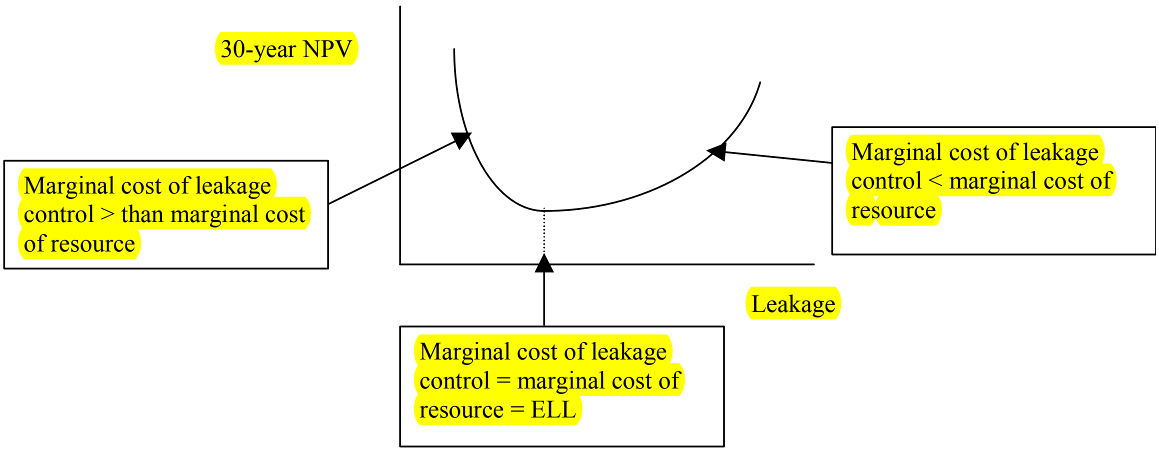


Figure 4.1 Least cost planning – 30 year graph

Figure 4.1 illustrates the three regions of the cost:benefit of leakage reductions:

- At low levels of leakage (towards the left-hand side) the additional cost of leakage control is greater than the benefit of deferring resource/treatment schemes. The curve increases rapidly as the policy minimum level of leakage is approached. It is not economic to operate in this area since the cost of active leakage control is greater than the cost of developing new resources.

- At high levels of leakage (towards the right-hand side) the reduction in active leakage control costs is less than the increase in resource/treatment costs. It is not cost economic to operate in this area since cost savings could be achieved by reducing leakage.

- The central portion of the curve is typically relatively flat – in this region the additional costs of active leakage control are balanced by the benefits of reduced resource/treatment costs. The minimum point of the curve represents the economic level of leakage. In practice, however, it would be sensible to develop an economic range of leakage. Levels of leakage that had a total cost within 1% of the minimum would be considered to be within the economic range. Water companies should maintain leakage within this economic range.

There are a number of other issues that, whilst not considered essential for the development of the least cost plan they do represent additional benefits of developing a detailed supply-demand plan:

- **Impact of climate change:** The supply (or capacity) forecasts should include the latest view of the impact of climate change. Due to the uncertainty surrounding the likely impact of climate change the impact on the economic level of leakage of a range of scenarios could be considered.

- **Level of service:** the supply-demand balance should reflect the company's current planned level of service to their customers. Increases (or reductions) would need to be supported by customers and applied through risk modelling (see below).

- **Risk modelling**: One of the key variables in the development of the least cost plan is the target headroom between supply and demand to be used. A large target headroom will ensure a low risk of interruption to supply to customers (e.g. through hosepipe bans and rota-cuts), but will result in a high resource investment cost. Lower target headroom will reduce the cost of balancing supply and demand, but will increase the risk of the need to implement emergency (or short-term) measures.

  The supply/demand balance could be based on either a pragmatic approach to achieving a given level of headroom using the methodology set out in the UKWIR/Environment Agency Report[8] or more sophisticated approaches that would seek to quantify the value of a continuous supply of water to customers. There is current a UKWIR project underway (UKWIR WR-27) that is seeking to set out an approach to estimating such values. Alternative approaches have also been suggested which could develop a relationship between headroom and an 'insecurity cost'.

- **Other supply-demand balance options:** If circumstances change, either due to external (e.g. regulation) or internal (e.g. company policy) reasons this may result in changes to the supply-demand balance. For example, the level of domestic metering will have an impact on the supply-demand balance and may therefore result in a change to the economic level of leakage.

  A change in leakage control policy or efficiency is likely to reduce the marginal cost of active leakage control. As the economic level of leakage is set within the context of the supply-demand balance this reduction will not necessarily result in an immediately lower leakage target. A reduction in leakage will only be cost effective if there is an associated benefit. If the zone currently has sufficient headroom then the benefits of leakage reductions are likely to be minimal. The reduced marginal cost of active leakage control is however, likely to result in a lower economic level of leakage when the next resource/treatment scheme is required.

4.3 MARGINAL COST OF WATER

In this approach the marginal cost of obtaining additional water from leakage control is compared with the marginal cost of obtaining water from developing the next representative resource scheme. If the marginal cost of obtaining additional water from leakage control is less than that for the next resource then it will be cost effective to reduce leakage. The economic level of leakage is when the marginal cost of leakage control equals the marginal cost of water (from the next resource). At levels below the economic level of leakage further reductions in leakage will be more expensive than developing the resource, and so at this stage the resource should be developed.

Figure 4.2 presents the traditional leakage vs. marginal cost curve. Three alternative marginal cost of water values are plotted on the graph (on the y-axis), which each have a corresponding economic level of leakage (on the x-axis). Cost of water (A) represents the marginal operating (system) cost, and results in a relatively high ELL. As the cost of water is increased this results in lower ELLs.

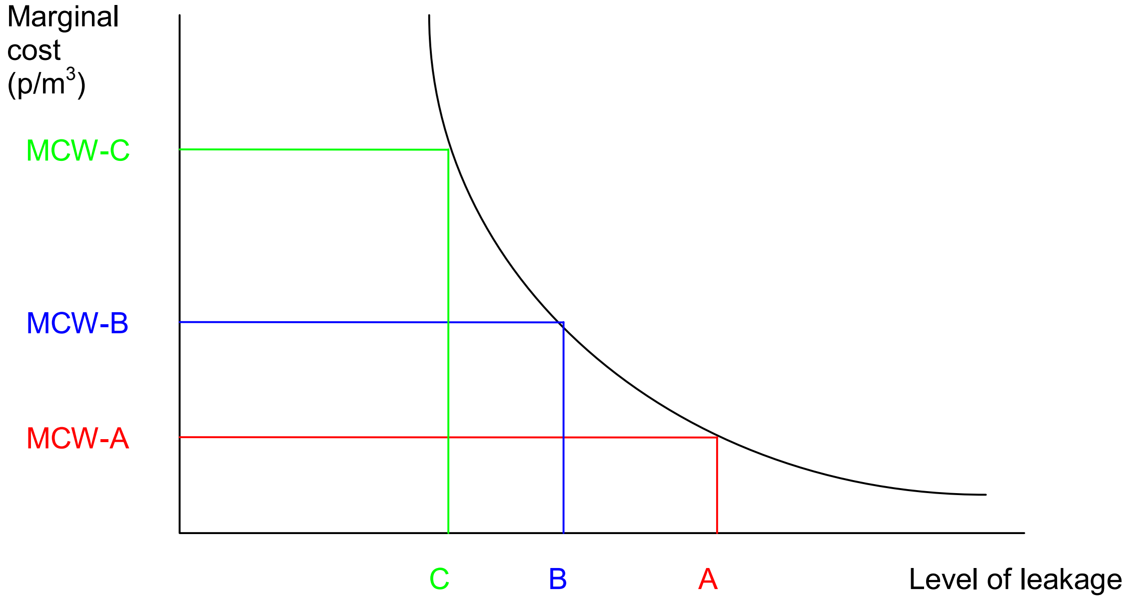


Figure 4.2 Marginal Cost of Water vs. ELL target

The analysis presented in Figure 4.2 allows the ELL to be determined for any value of marginal cost of water. The timing for any economic reductions must then be set in the context of the supply/demand balance. Figure 4.3 presents an indicative 30-year supply-demand balance, with a corresponding leakage profile (or 'glide-path'). In this example the current level of leakage is lower than the short-run level (A) and so it is maintained at this level until the first resource investment is required (at B). At this point the marginal cost of leakage control is less than the marginal cost of the next resource. It is therefore more cost effective to reduce leakage, at the same rate as demand is increasing, until the point that the marginal cost of leakage control equals the marginal cost of water.

At the point where the marginal cost of water equals the marginal cost of leakage control then further leakage reduction is not cost effective, and so the resource should be built. The reduction in leakage has resulted in the resource investment being deferred. Construction of the new resource results in spare capacity, and so leakage should then be maintained until the next resource investment is required (at C). The cycle is then repeated.

An economic appraisal might suggest that leakage should be allowed to rise after the construction of a new resource. The balance between supply and demand will have been enhanced and the need to keep leakage at its previous level will have reduced (as the marginal cost of doing so is not met by the accruing marginal benefits in terms of the level of security). However, given the uncertainty in estimating transitional costs of allowing leakage to rise and then drive it back down again it is considered prudent to maintain a flat leakage profile. A profile that presented an increase in leakage would require a careful and robust analysis of the transitional costs of leakage control. Guidance from the Environment Minister has indicated that leakage should continue to fall. The analysis in this report assumes that once leakage has been reduced targets will not be set which allow it to rise.

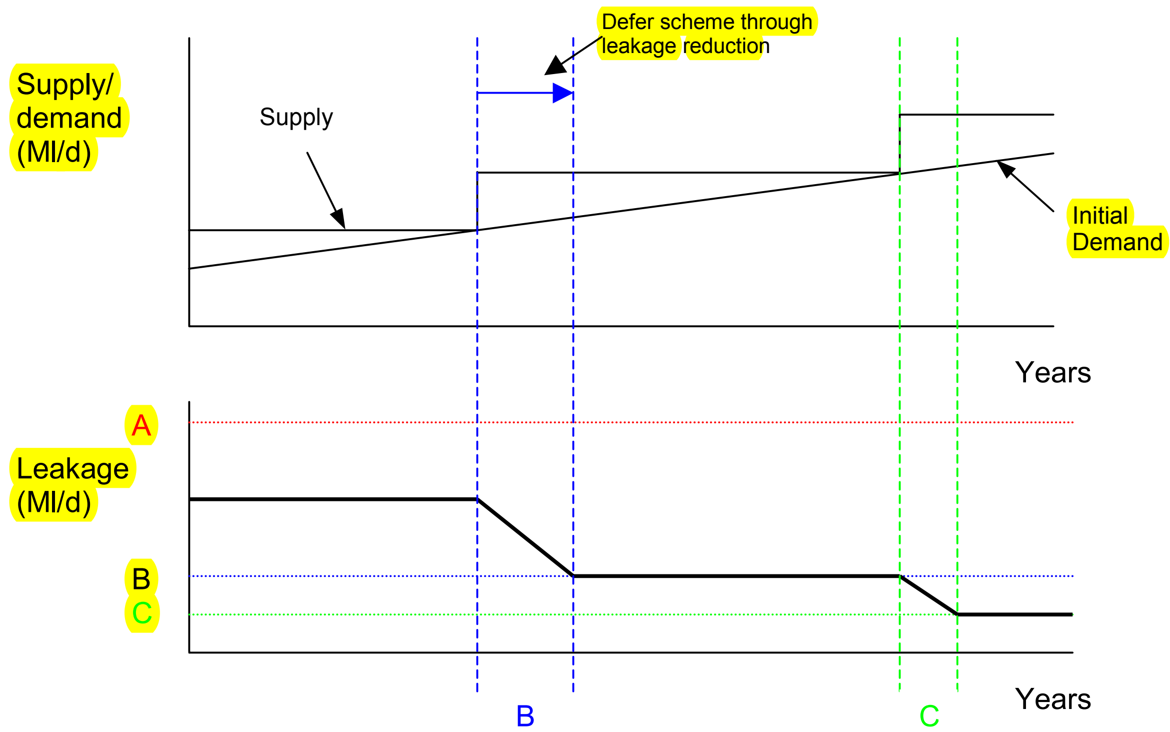


Figure 4.3 Supply-demand balance and leakage profile

This approach is less flexible in developing a leakage profile, but still requires a full understanding of the timings, yields and costs of the supply-demand options.

Given the complexity of the development of a least cost plan the marginal cost of water approach can be used to provide an initial leakage profile. Given the relative simplicity and transparency of the marginal cost of water approach it may also be appropriate for Regulators and/or Reporters to use this approach when validating or understanding company least cost plans.

If it is to be used the following guidelines should be applied:

i) A variable operating cost (system) economic level of leakage should be calculated using the variable operating cost of water (power and chemicals). Leakage should not be allowed to rise above this level.

ii) A long run economic level of leakage should be calculated using the marginal cost of the next representative resource (see below for details of the calculation). A leakage profile should then be developed moving from the current (or short-run economic level if this is lower) level of leakage to the long run level. The level of leakage should be reduced at the same rate as the supply-demand gap closes (practical issues may result in a company starting leakage reductions earlier, so as to smooth out the leakage profile).

Whilst this approach is less flexible than the least cost plan approach, it can still be used to develop a robust economic level of leakage.

The following features are required for the approach to be considered robust:

- **Variable operating/system economic level of leakage**: The concept of the variable operating cost economic level of leakage is required since this acts as the level of leakage that should be achieved as soon as is practical.

- **Long term economic level of leakage**: This is the level of leakage that should be achieved before the next resource/treatment scheme is commissioned. The profile of leakage between the short term and the long-term level will depend on the rate of closure of the supply-demand balance.

- **Calculation of the marginal cost of water**: A key feature of this approach is the calculation of appropriate values of the variable operating and long run marginal costs of water. This calculation must be focussed on the development of a marginal cost that allows like-for-like comparison with the marginal cost of leakage control.

  – **Variable operating:** This calculation should consider the variable elements of the power and chemical costs, and is generally in the range of 5-10 p/m^3.

  – **Long run:** The long run cost should include costs (capital, fixed operating, variable operating and capital maintenance) over a period of 25 to 30 years and the yield over an identical period. The net present value of cost divided by the net present value of capacity results in the marginal cost of water that is appropriate for use in the economic level of leakage calculation. The ongoing UKWIR/EA/Ofwat study “Economics of the Supply/Demand Balance” is re-examining the appropriate calculation of the long run marginal cost of individual supply/demand options. The output of this study should be consulted when it becomes available.

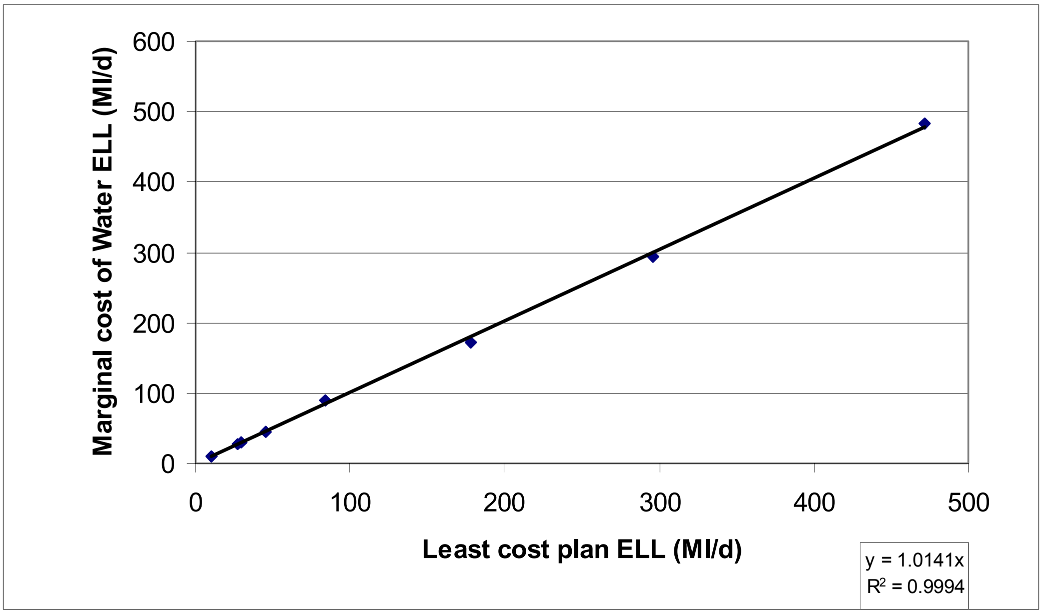
    The long run marginal cost of water developed for this purpose should be consistent with (i.e. include the same base costs and capacities) the long run marginal cost calculated for other purposes, but will not necessarily have the same numerical value. In particular the calculation for the ELL is based on the next resource whereas, in general, LRMCs for Ofwat returns are calculated in a variety of different ways.

- **Leakage profile**: The economic level of leakage analysis will derive a value for the short run and long run economic targets. Between these two values a leakage profile should be developed that balances supply and demand.

When calculating a LRMC based on the capital programme Ofwat recommend using the NPC of the impact on the supply-demand gap (i.e. capacity utilised + demand management savings) as the denominator. When calculating the marginal cost of the next representative resource for ELL calculations it is necessary to use the capacity of the scheme as the denominator.

Using a marginal cost calculation based on the output from the scheme would suggest that leakage is driven down to a low level just before the scheme and then allowed to rise after it has been commissioned. Given the constraint, that leakage shall not be allowed to rise, it is found that the capacity of the scheme should be used as the denominator – this results in a marginal cost of water that is the average of the time-path of the MCW. This calculation gives ELLs consistent with least cost planning, whereas the alternative approach can result in values that are significantly lower. Figure 4.4 demonstrates the agreement between ELLs calculated using a least cost plan and those based on the MCW (using capacity as the denominator) for a sample of resource zones.

Figure 4.4 Comparison of the MCW and Least cost planning approaches to setting leakage targets



The marginal cost of water approach only considers the trade-off between leakage and resource/treatment costs. It could be extended to consider other supply-demand options, but this could get complex, it would therefore be more appropriate to develop a least cost plan. The marginal cost of water approach is therefore considered as an interim update to an economic level of leakage that has been developed through least cost planning (or at least a full modelling of the supply-demand balance).

4.4 LEAKAGE GLIDE-PATH

The long-term leakage glide-path can be developed through either the least cost planning or the marginal cost of water approach. There are a number of important features of this glide-path:

Zone in current deficit

If the zone is in current deficit, then the current economic level of leakage should be based on the marginal cost of the current resource/treatment schemes. In these circumstances the economic level of leakage is a less useful concept – the aim of the company should be to balance supply and demand by the most practical and timely measures.

Zone has a large surplus

If the zone currently has a large surplus headroom the variable operating cost economic level of leakage should be used. The company should look to utilise this excess capacity through transfers to neighbouring zones. If links to other zones exist (or are made) then the long run marginal cost should then refer to the receiving zone.

Alternatively the analysis should consider the economics of reducing the current capacity by closing existing sources, either permanently or for possible use in the future.

If links to other zones are not economic then any changes to leakage control efficiency, or the adoption of new technology, will not change the short-term ELL. The company should look to maintain the current level of leakage, and will see active leakage control cost savings. If (when) the next supply-demand investment is required then the new leakage control process should be used in the ELL analysis – this will result in a lower ELL than the original process.

In the short-term, therefore, the water company will make efficiency savings which will only be translated into lower ELLs when supply-demand investment is required.

Transfer of leakage control activities between zones

Within a water company some zones may be operating below their ELL where others may be above their ELL. Where practical it is recommended that leakage effort in the zones below their ELL could be transferred to those zones above their ELL. The aim of this re-allocation should be to ensure all zones operate at (or below) their ELL, but ensuring that the company level of leakage does not rise.

Company level target

The target level of leakage should be seen as a long-term target. Over a number of years it is likely that, on occasions, the target will be beaten (“good” years) and missed (“bad” years). The water company should, however, always plan to attain the target. If a company misses the target (due to factors outside their control) then they should aim to meet the target the following year. In the same way, if a company achieves a lower level of leakage it should not be required to maintain this lower level in future years.

Impact of new properties

When developing long-term leakage profiles one of the most significant factors is the impact of the increase in the number of properties. The leakage/cost modelling is normally undertaken using leakage units of litres/property/day. To set leakage targets within the context of the supply-demand balance it is necessary to present leakage in units of Ml/day.

Table 4.1 below, illustrates the impact of a 15% increase in properties on leakage levels in England & Wales to 2025-26. To maintain leakage at the current (1999-2000) level of 3,306 Ml/d will require the leakage per property to be decreased from 142.6 to 124.0 l/prop/day. If leakage is maintained at 142.6 l/prop/day then total leakage will increase by 495 Ml/d to 3801 Ml/d.

Table 4.1 Impact of increasing property counts on leakage targets

	1999-2000	2025-26	
Total connected properties	23,180,000	26,657,000	Assuming 15% increase over the 25 years.
Total leakage	3,306 Ml/d	3,801 Ml/d	At constant l/prop/day
	142.6 l/prop/d	124.0 l/prop/d	At constant Ml/d

The impact is particularly severe for companies that have a high projected increase in properties and/or are already working at low levels of leakage. To maintain leakage at constant volume the company must decrease leakage per property at the same rate as properties increase. For example, a company currently at 100 l/prop/day facing an increase in properties of 20% over the next 25 years will need to reduce leakage to 83 l/prop/day over the same period.

There is currently uncertainty over the impact of the increase in properties on future leakage levels. It is necessary to consider the impact on the distribution system of both capital maintenance and new properties – will leakage levels (both current and base) remain at their current levels, increase or decrease in terms of l/prop/day ?

4.5 ENVIRONMENTAL AND SOCIAL COSTS

In their decision making about leakage control activity, water companies can be expected to take account of the financial costs and benefits that are respectively borne by and accrue to them. Leakage control can, however, be associated with a set of external (to the water company) costs and benefits. Where those external costs and benefits are material, then the worth placed by Society on a given level of leakage control activity will differ from the worth placed by the water company. The economic level of leakage will correspondingly differ as a result of the inclusion of these costs and benefits. In this section we discuss approaches for incorporating environmental and social costs and benefits to the economic analysis. The available methodologies for estimating environmental and social costs are in the early stages of development. For this reason it is less easy to identify best practice as the evaluation of alternative approaches remains the subject of considerable debate and continuing academic research. Our focus, therefore, is on setting out a practical approach using available methodologies that will enable water companies to evaluate environmental and social costs and benefits when determining their ELL.

4.5.1 The External Costs and Benefits of Leakage Control

For ease of reference it is worth setting out the types of external costs and benefits typically attributed to leakage control activity. Table 4.2 provides an indicative classification by the type of impact and / or consequence of leakage control activity.

Leakage control activity itself comprises a range of options (e.g. find and fix, mains replacement, pressure management) and the extent of external costs and benefits will in practice vary for different options.

There is, moreover, an important difference between these external costs and benefits. The external costs associated with leakage control can be said to be directly attributable to the *activity* of leakage control. Thus, for example, external costs such as increased traffic congestion and travel times associated with mains replacement and find & fix can be expected to be a function of the frequency and duration of such activities.

By contrast, the external benefits of leakage control can be attributed to the *effect* of the activity rather than the activity itself. Thus the extent to which further leakage reduction allows a water company to reduce its level of water abstractions, then the economic value placed on the environmental and / or social benefits of lower abstraction provides a measure of an external benefit of leakage control. Since it is recommended that companies assess their ELLs at resource zone level, the implied level of network integration means that companies should assume that leakage reduction in a resource zone impacts directly on abstractions within the same zone.

Table 4.2 External Costs and Benefits of Leakage Control

Impact / Consequence of Leakage Control Activity	External Cost	External Benefit
Increased travel times through higher road congestion and road diversions	Cost of delays	Reduction in frequency of mains bursts leading to disruptions (for example, associated with programmes of mains replacement)
Pedestrian Disruption through footpath restriction/closure	Cost of pedestrian delay and nuisance value	
Domestic Disruption through planned or unplanned interruptions	Costs of Disruption net of any compensation payments (e.g. under Guaranteed Standards Scheme)	
Reduced River Abstractions		Use (e.g. recreation, angling) and Non-use (e.g. conservation value) benefits of improved river flows
Reduced Groundwater abstractions		Use and non-use benefits of improved wetlands and river flows
Deferred reservoir construction	Avoided benefits of water based recreation (e.g. angling, water sports)	Avoided costs of landscape disamenity and construction

4.5.2 Available methodologies for estimating the costs and benefits of environmental and social impacts

The current approach to estimating the external costs and benefits of water management options (including leakage control activity) is to be found in the synthesis of a number of recent publications, namely:

- *Framework to assess environmental costs and benefits for a range of total water management options*[9] (EFTEC, CES & CSERGE).
- *Assessing the Benefits of Surface Water Quality Improvements*[10](FWR, 1996)
- *The Environmental and Social Value of Leakage Reduction (in context with other resource and demand management alternatives)*[11](NERA 1998) and
- *The Environmental Costs and Benefits of Water Resources: A Preliminary Methodology*.[12](RPA 1998).

These studies in combination provide comprehensive coverage of relevant information sources and manual style guidance on the estimation of a range of external costs and benefits that can be identified for water management options.

The estimation approach proposed is primarily one that is desk-top in nature and relies almost entirely on "benefits transfer". That is, estimates of environmental and social costs and benefits are derived from valuation studies conducted in one site or context and are "transferred" to the site or context that is the subject of interest. We discuss the advantages and disadvantages of "benefits transfer" in more detail in Appendix D.

The primary advantages of benefits transfer are those of pragmatism and cost effectiveness. The approach avoids the more expensive option of undertaking original valuation studies and it is perhaps this, above all else, that has motivated its adoption in the current approach to valuing the external costs and benefits of water resource options.

4.5.3 Evidence from Company Submissions

We have examined the water companies' regulatory submissions to discern whether, and if so how, they have incorporated environmental and social costs into their water resource planning.

Three summary points stand out from this review:

- First, the commentary on environmental and social costs varies greatly in terms of detail and it is not possible to determine whether that variability is attributable to genuine differences in the treatment of external costs and benefits or simply variations in the depth of reporting;

- Secondly, where reference is made to environmental and social costs it is in practice difficult to verify or cross-check the conclusions reached by companies on the basis of their reported analysis; and

- Finally, where reasonable supporting material is provided companies appear to be reaching the conclusion that the inclusion of external costs and benefits does not materially change their calculations of ELL. As suggested above, this outcome may be more reflective of the informational advantages possessed by companies and the absence of any real incentive to internalise a true picture of such costs and benefits than it is of an underlying position. Equally, such outcomes may be the consequence of errors of exclusions that it is only possible to glean from detailed examinations of company models and analysis.

These points notwithstanding two generic approaches characterise those company submissions incorporating analysis of environmental and social costs:

- In the first approach, environmental costs and / or benefits are identified and included alongside the financial costs for each water management option following the RPA (1998) / NERA (1998) "manuals". Least cost planning methods – or more straightforwardly the ranking of option AISCs - are then used to determine a least cost mix of options. This least cost set of options should thus minimise the costs to society as by implication the external costs and benefits of the options are internalised within the least cost plan.

- With the second approach, external costs and benefits are not included in the determination of a company's least cost solution for balancing supply and demand. This private solution provides a ranking or sequence of water management options that the company would choose to implement free of any constraints that force it to take account of external costs and benefits. From this ranking of options, it can be discerned what the cost impact of changing the sequencing of schemes would be. For example the change may be to bring forward leakage reduction activity to replace resource development associated with lower financial costs. If the additional financial costs can be shown to be more than offset by the economic value of an associated environmental benefit, then this sequencing of options attracts greater worth for Society.

4.5.4 A framework for the incorporation of environmental and social costs and benefits

There is an evident lack of consistency in the approach companies have taken to the incorporation of environmental and social costs and benefits to their analyses of ELL. This lack of consistency reflects in part the absence of an unified methodological framework that integrates the work noted in 4.5.2 above.

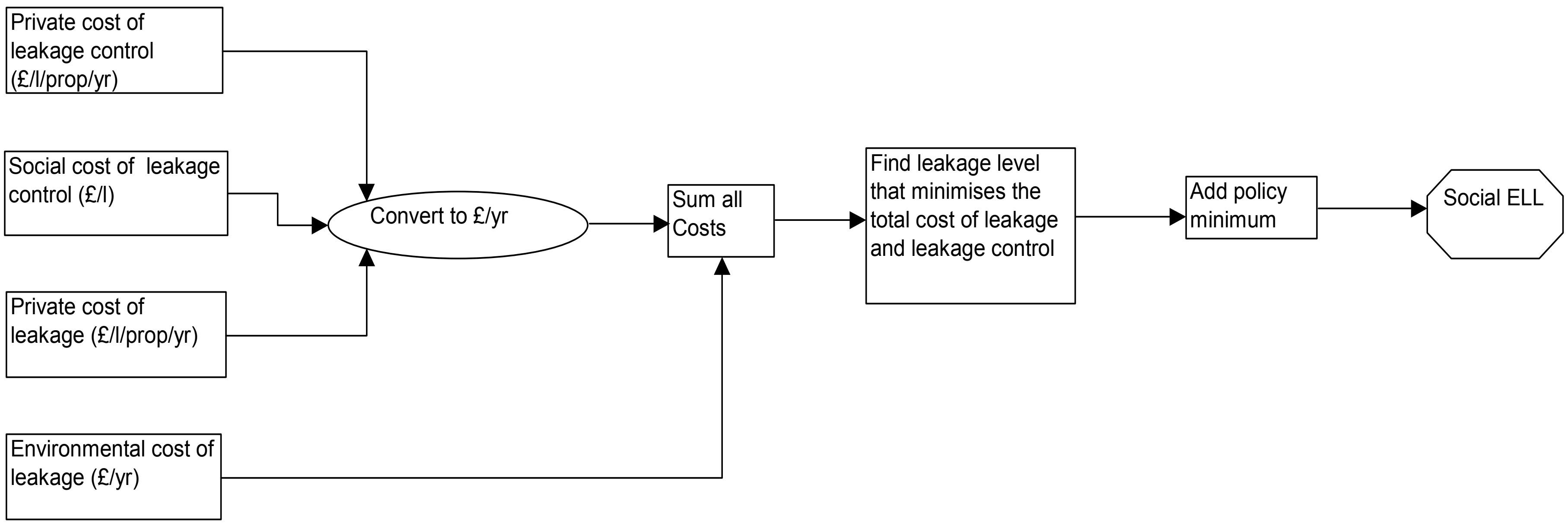
In this section, therefore, we propose a framework that is intended to promote a more consistent approach to the estimation of environmental and social costs and benefits. Figure 4.8 summarises the recommended approach. To illustrate application of the framework we provide details of a "case-study" in Appendix D. Our proposed framework has two components:

- Identification / estimation of the environmental and social costs and benefits of leakage; and

- Identification / estimation of the environmental and social costs and benefits of leakage reduction activity.

Figure 4.5 summarises the method for calculating the ELL that is efficient from an environmental and social perspective.

Figure 4.5 Process for calculating environmental and social ELL



The environmental and social costs and benefits of leakage

Estimation of the Economic Level of Leakage without taking into account the social and environmental impacts of leakage will provide an ELL that does not reflect the wider societal impact of leakage. Where leakage imposes a net environmental and social cost and therefore an estimate of the ELL which excludes these factors, this will generate a target leakage level that is too high from the point of view of society. The explicit inclusion of environmental and social costs of leakage moves the leakage target away from the leakage level that a water company would aim for based purely on its costs of water and costs of leakage control.

Identification of the costs of leakage

Table 4.3 summarises the range of costs that should in principle be identified for this stage of the analysis.

Table 4.3 Examples of the private, environmental and social costs of leakage

Cost type	Stage of supply process	Example
Private cost	Abstraction	Reservoir enhancement/development Pumping to treatment works
	Treatment	Expansion to works Need for treatment chemicals
	Distribution*	Energy costs of pumping water
Environmental cost	Abstraction	Reduced flows in rivers
	Treatment	Risk of chemicals entering environment
	Distribution	Energy use causing impact of power generation on environment
Social Cost	Continuity of supply	Lost customer value associated with unplanned interruptions to supply / compensation payments to customers

Note: * The amount of water that finally reaches the consumer will be the same as previously, though the amount that needs to be pumped out of the treatment works is less. Hence there might be some additional savings at the top end of the distribution system if less pipe re-enforcement has to take place.

The private costs of leakage should be estimated from the approaches set out in earlier sections of the report. Appendix D sets out in more detail the estimation of environmental and social costs.

When looking at a reduction in leakage close attention needs to be paid to the part of the environment that benefits from the reduced flow into the supply system. It may be that there is reduced abstraction from a river or from a groundwater source, or it may be that a water company maintains its level of abstraction but allows the water level in a reservoir to rise, or some combination of all three. A water company would need to be aware of the proportions in which these options could be used, as the environmental impacts of each are different.

Eliminating double-counting

It may be the case that certain environmental costs, e.g. the cost of energy consumption in pumping, have already been internalised into companies' private costs of pumping through environmental policies (energy tax) that cause companies to pay the full costs of their environmental impact. The cost of energy therefore includes the environmental cost so the private cost to the company alone should be incorporated, otherwise double counting will occur.

Similarly, a consequence of leakage may be a certain probability of unplanned interruptions to supply (e.g. due to mains bursts). This leads to an associated cost to customers represented by the loss of value or economic welfare attributable to a lower security of supply.[2] Since unplanned interruptions to supply are covered by, for example, the Guaranteed Standards Scheme, this lower security is internalised through the required compensation payments. Hence, to include both the lost value to customers and any compensation payments payable by companies would be an example of double-counting. Where evidence suggests that the lost value does not equate to the level of compensation payments, then it would be appropriate to count within the analysis any net difference between the external social cost and the internal compensation payment. i.e. If the compensation payment is lower than the cost to the consumer of the interruption then the cost that is not compensated could be included as a cost of leakage alongside other social and environmental costs.[3]

Desk-based quantification using benefits transfer

A desk-based quantification of the environmental benefits of reducing leakage using benefits transfer can be undertaken with little primary research. This offers the considerable advantage of estimating the main elements of environmental and social costs in a cost-effective manner. Estimation of the environmental value of the abstraction site and affected area can be carried out using site specific information and standardised environmental values. This provides an

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2 In the electricity sector this is known as "Value of Lost Load".

3 At present there is limited knowledge concerning the cost to the consumer of supply interruptions. However, in the context of looking at the impacts of changes to abstraction licencing arrangements, it has been proposed that water companies undertake “contingent valuation” studies to quantify such costs to the consumer. The output from such studies would quantify the value to the consumer of an improvement in reliability from, for example, a 3 week hosepipe ban to a 1 week hosepipe ban. If a reduction in leakage was used to increase headroom, rather than decrease abstraction, then the benefit from the increased headroom that different levels of leakage control would generate, could be calculated.

estimate of the value of the site with the current level of flow (hence the current level of leakage). The change in the value of the site due to increased flow, which would be expected if leakage was reduced, is estimated using the Environment Agency's PHABSIM model. PHABSIM relates the flow rate, as a proportion of natural flow. It is important to recognise in analyses of this nature, however, the limitations of benefits transfer. This is discussed further in Appendix E. We also highlight in Appendix E possible approaches that help to minimise these limitations.

Costings based on benefits transfer can be used to provide a broad indication of the impact of environmental costs and benefits on the ELL. For small environmental impacts we suggest the estimated figures produced by this approach will suffice in the calculation of the ELL. Where the impacts are more significant, benefits transfer can be used to highlight the larger environmental impacts for which more sophisticated and site-specific investigation should then be undertaken. While it is difficult to be categorical about the incorporate vs. investigate threshold, our recommendation would be that any element of environmental cost that in isolation changes the ELL by more than 5% should require more detailed investigation.

Figure 4.6 demonstrates our recommended approach for identifying and including environmental costs.

Figure 4.7 presents the process for the calculation of the environmental costs of leakage. We illustrate application of this process in Appendix D. It assumes that a company would identify the most environmentally sensitive site from which water is currently abstracted that would experience reduced abstraction (or the reservoir that would contain a higher volume of water) if leakage were reduced. It would then quantify the environmental value of the site arising from the characteristics of the site that generate benefits to users and non users at the current level of abstraction (which reflects the current level of leakage). It would then adjust this value to estimate the value of the site at the level of abstraction that would be undertaken if leakage were reduced in stepped increments down to the policy minimum. This allows for identification of a schedule of environmental costs associated with each level of leakage above the policy minimum. The cost of leakage is then calculated against the policy minimum position, which is consistent with the calculation of the private costs of leakage. The costs of leakage are the same regardless of the method of control used because these are based on having to abstract, treat and supply water which will leak from the system. Therefore the impact is no different for the combination of find-and-fix, mains replacement and pressure reduction selected.

The above approach, and Figure 4.7, make use of the PHABSIM methodology to quantify the physical habitat of a river over a range of flow regimes. This gives a quantitative measure of the ecological value of river flows. On the basis of limited field observations this may then be used as a predictive tool.[15,16]

In Appendix D we provide details on the standard values and site specific values required for implementation of the desk-top exercise.

Figure 4.6 Process map for identification and estimation of environmental and social costs and benefits of leakage

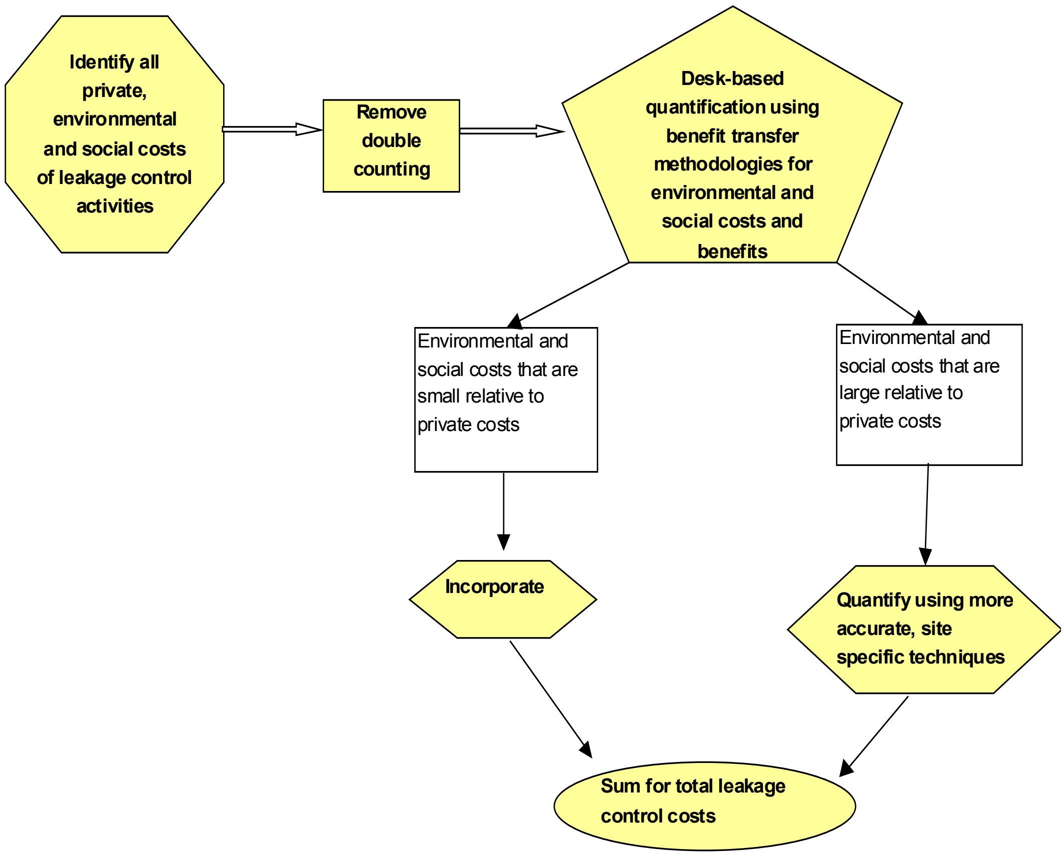
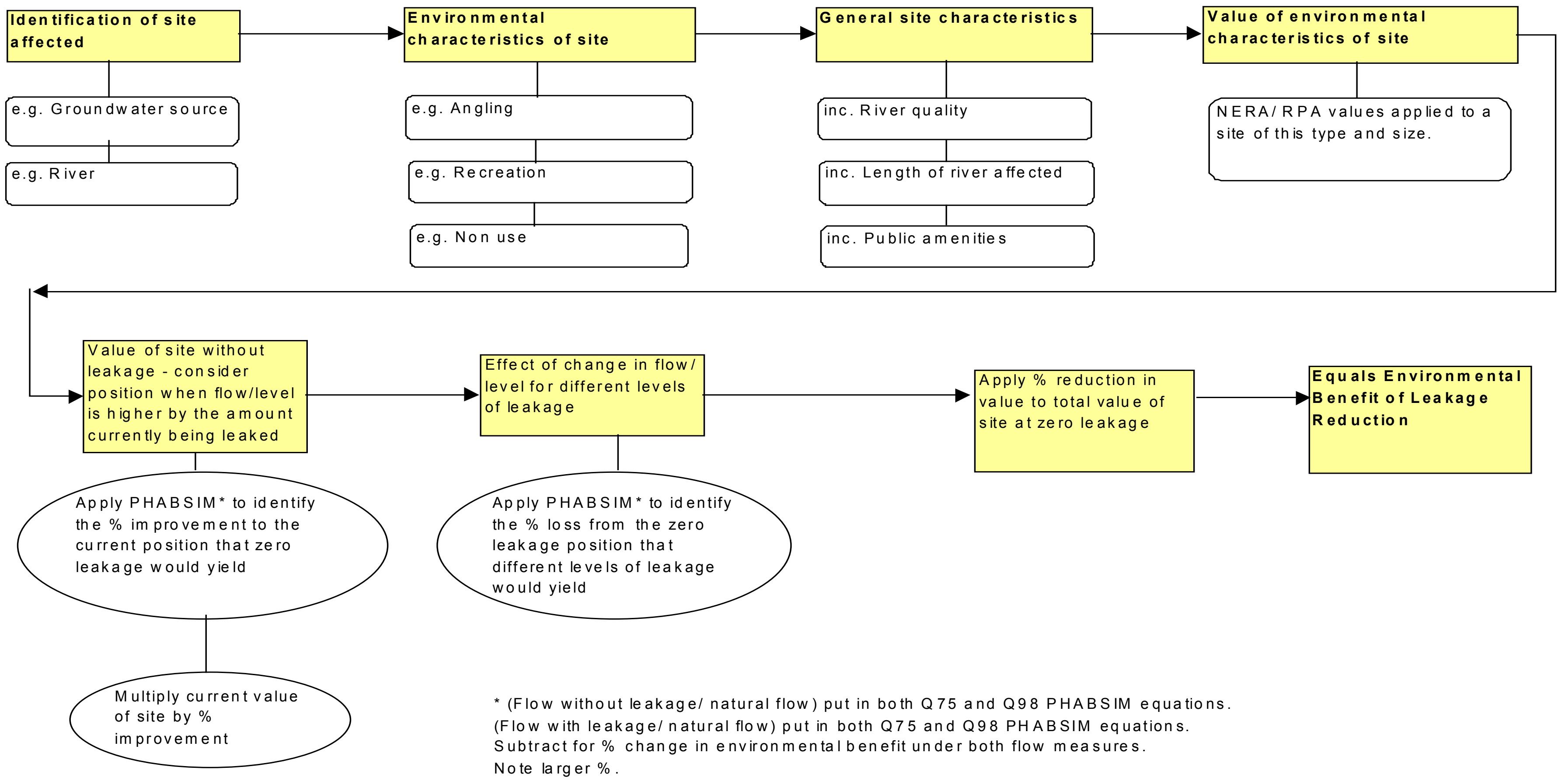


Figure 4.7 Process Map for calculation of environmental costs of leakage



Site-specific costing

Where the desk-top exercise identifies a particular environmental or social impact which significantly influences the ELL, we recommend further detailed investigation given the broad nature of benefits transfer. Depending on the level of detail required and existing studies available, there are two approaches available for achieving a more detailed costing.

1. Undertake an original valuation study; or

2. Using models of value generated by existing studies and recalculating the total value of the benefits using site specific data on the environmental characteristics of the waterway, the visitors to the waterway and the population in the area of the waterway (this is a more sophisticated form of benefits transfer).

Method 1 will give accurate, site specific results but may be expensive and time consuming. However, if site developments have occurred in recent years that required EA approval then studies of this type may have already been carried out.

There are a number of different approaches to environmental valuation which are now well established. These fall into three main categories:

- Hedonic pricing – The environmental characteristics of a location affect the property or land prices in that location so a valuation can be inferred by comparing these prices with the prices in areas of similar housing/land use which do not have the same environmental characteristics.

- Travel cost methods – For environmental sites that people visit, the value of the site can be estimated from the value to the visitor of the visit. This value is revealed by the amount the visitor pays in terms of time and transportation in order to reach the site.

- Survey Methods – These are typically used to estimate non-use values. Where there is no market through which the person valuing the site demonstrates their valuation, a more direct survey approach needs to be taken. Contingent valuation surveys are used to elicit the values that, for example, individuals are willing to pay (or some similar question) to improve the environmental characteristics of a site. Appendix F provides further details on the survey method approach.

The use of existing studies, as described in method 2 will involve the gathering of data from various sources but will not include primary data collection. This approach is a not as precise as method 1 but will provide more accuracy than the simple desktop study and will be cheaper than method 1. Method 2 should be designed to overcome some of the limitations of benefits transfer as shown in Appendix E.

The social and environmental costs of leakage reduction

The private, social and environmental costs of leakage reduction will vary depending on the particular method of leakage reduction selected. The private costs of maintaining a particular level of leakage increase towards infinite as leakage tends to zero. This section considers the social and environmental costs of leakage reduction that arise at different levels of leakage and should therefore be added to private costs when the water company is seeking to determine socially efficient levels of leakage.

The social and environmental costs associated with leakage reduction arise in three main areas:

1. The social cost of the disruption to traffic caused by leakage repair activity. However, where active rather than reactive leakage control reduces the risk of a mains burst, then potentially more severe social consequences due to unplanned disruptions may be avoided. In such circumstances leakage control would be a social benefit.

2. The social cost or loss of the social benefit of a reservoir development. Whilst reservoir developments may generate recreation activities they create environmental impacts and hence costs, e.g. during construction, lost landscape/amenity, therefore when leakage reduction impacts on decisions concerning reservoir development, both these factors need to be considered.

3. The social cost of a pressure reduction to customers which might affect the functioning of appliances and increase the time to undertake domestic tasks. (Though it may be the case that the risk of a domestic leak is reduced).

These costs and benefits can be evaluated following a similar process to that highlighted in Figure 4.7.

Identification of costs

Table 4.4 below details some of the social and environmental factors that might warrant consideration.

Table 4.4 Examples of social costs and benefits of leakage reduction activity

Impact	Social Cost or Benefit
Traffic disruption due to active / reactive leakage control	Social Cost
Avoided / deferred traffic disruption due to active leakage control	Social Benefit
Non / deferred construction of a reservoir resulting in loss of recreation value	Social Cost
Reduced pressure in system affecting domestic / industrial appliances	Social Cost

Elimination of double counting

There are not many instances where this is likely. However, there are a number of areas where social and environmental costs may already be adequately internalised through taxation and other instruments. In these circumstances water companies should be careful to avoid double-counting.

As an illustration, the Street Works (Charges for Unreasonably Prolonged Occupation of the Highway) (England) Regulations 2001 provide powers for highway authorities to charge water companies a daily fee where they fail to complete works by an agreed deadline. While at present there is no indication that such charges will be set to reflect the social cost of traffic disruption, they are designed to provide incentives to minimise the disruption associated with roadworks. Hence, inclusion of the fee and the estimated social cost can be considered double counting. Only if good data is available to suggest social costs differ significantly from the fees or where the fees do not apply, should an estimate of social costs be required. In the case of the former only the net difference should be incorporated (as an element of the cost is already internalised).

Desk based quantification

At present, to our knowledge, no research has been carried out on the cost to consumers of reductions in water pressure, or their valuation of maintaining pressure at its current level. Without values from other sources it is not possible to estimate this social cost by desk based methods.

Environmental and social costs of reduced reservoir construction will only arise where leakage reduction could alter the decision regarding the construction of a reservoir. If a reservoir development is being considered then the full environmental and social costs and benefits are likely to have been quantified as part of an economic Impact assessment of the scheme. A company with such circumstances can apply these values in a desk based study.

It is possible to carry out a desk based study on the likely cost arising from traffic disruption, though as total costs are built up of many different traffic interruption events, the estimate of annual costs will only be rather approximate.

The costs of traffic disruption will depend on the type of road (which relates to the number of cars and the speed with which they usually travel), the length of road that will be disrupted and the time period over which the disruption will occur.

Trying to identify these costs exactly for a number of different leak repair levels would be a complex exercise. A more practical approach makes use of averaging and medians. For example:

- apply the calculation to the median road type in the area;
- consider the volume of water, per property per day that could be saved on average by repairing a leak;
- estimate the hours of traffic disruption associated with the leak repair; and

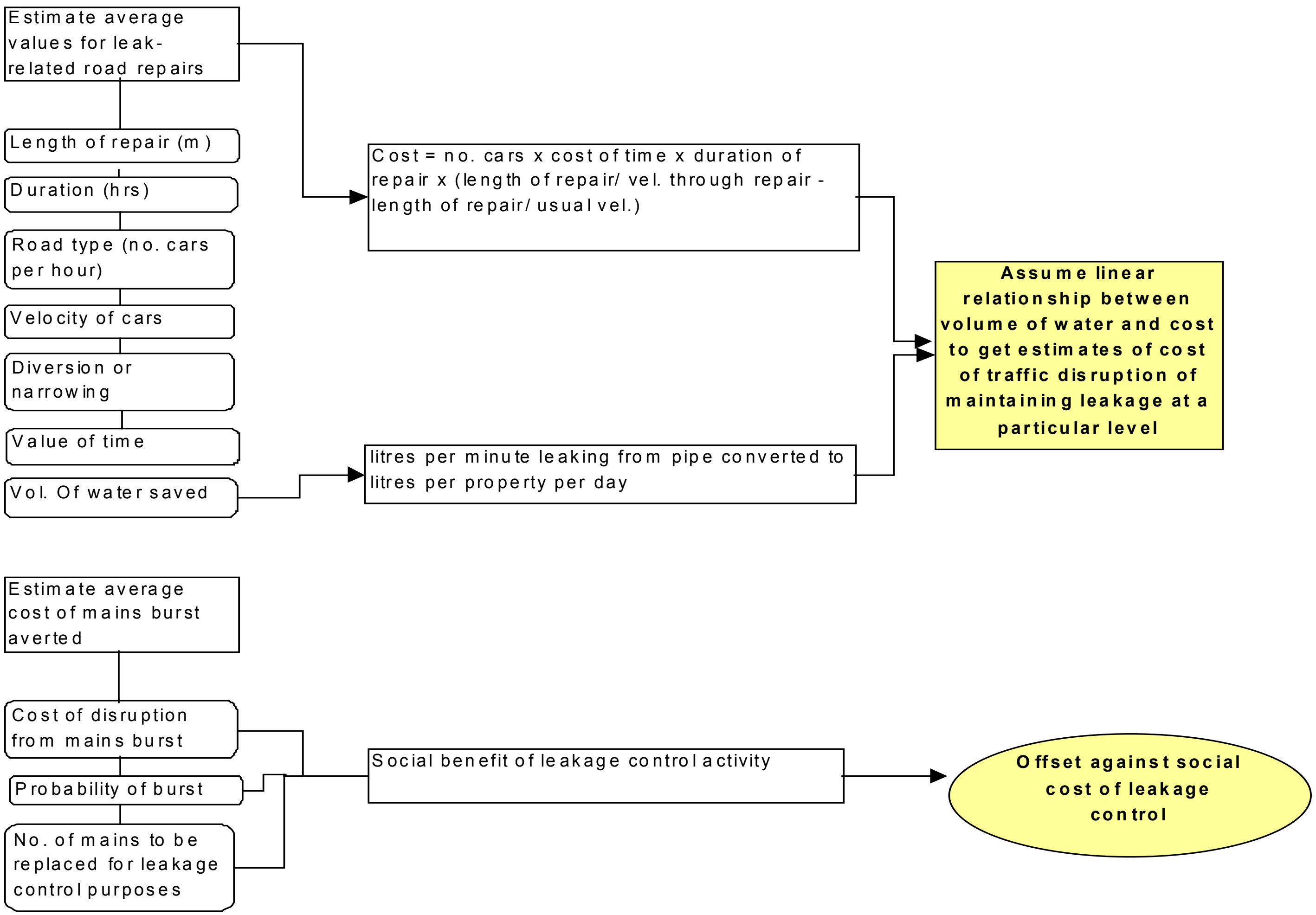
- hence, calculate this particular social cost of leak repair.

Without leakage control activity there may be a higher risk of a mains burst that will impose a high social cost on road users, in part because of the unexpected nature of the event. Ideally we would want to net off the social benefit of a reduction in such bursts against the social cost of leakage repair. Quantification of this benefit is difficult but under a mains replacement leakage control policy the expected cost of a burst could be factored in by multiplying the probability of the mains burst with the social cost of that failure. Figure 4.8 presents a process map to illustrate this approach.

More sophisticated approaches might involve basing the calculation on previous years leakage repair volumes and traffic interruptions, or using planned actual leakage repair over one month and estimating annual cost from this (after adjusting for seasonal variations).

Appendix D illustrates the desk-top methodology in more detail.

Figure 4.8 Process map for calculating social costs of road disruption



Primary research

The leakage control option that involves a reduction in water pressure has a social cost which as yet, has not been researched. Primary research to quantify the social cost could be carried out in several different ways. For businesses this cost could be established through:

- Quantifying expenditure by business on technology that alleviates the impact of low pressure, eg. Pumps.

- Conducting surveys of commercial customers to estimate the impact on their business of low water pressure. This might include the cost of a reduced pace of production or relocation or the increased premium to insure against fire risk for commercial customers.

For domestic consumers survey methods are the most likely to illicit the cost to households of a reduction in pressure. Further details of available methodologies are provided in Appendix G.

4.5.5 Sensitivity of ELL to environmental and social costs

The inclusion of the environmental and social costs of leakage will reduce the ELL. The inclusion of the social costs of leakage reduction activity may raise the ELL. The extent of the impact on the ELL will vary enormously depending on the characteristics of a particular supply zone / water company.

The figures used in this section are purely illustrative. Their purpose is to demonstrate the technique for examining sensitivity. No conclusions should be drawn about the actual costs presented.

A suggested approach to examining the sensitivities

The approach to examining the sensitivity of the ELL calculation to the inclusion of environmental and social costs should allow for, first and foremost, the identification of the most material elements of external cost. This allows the water company to determine those aspects of the calculations that merit closer examination.

We illustrate the suggested process using the "case-study" developed in Appendix D.

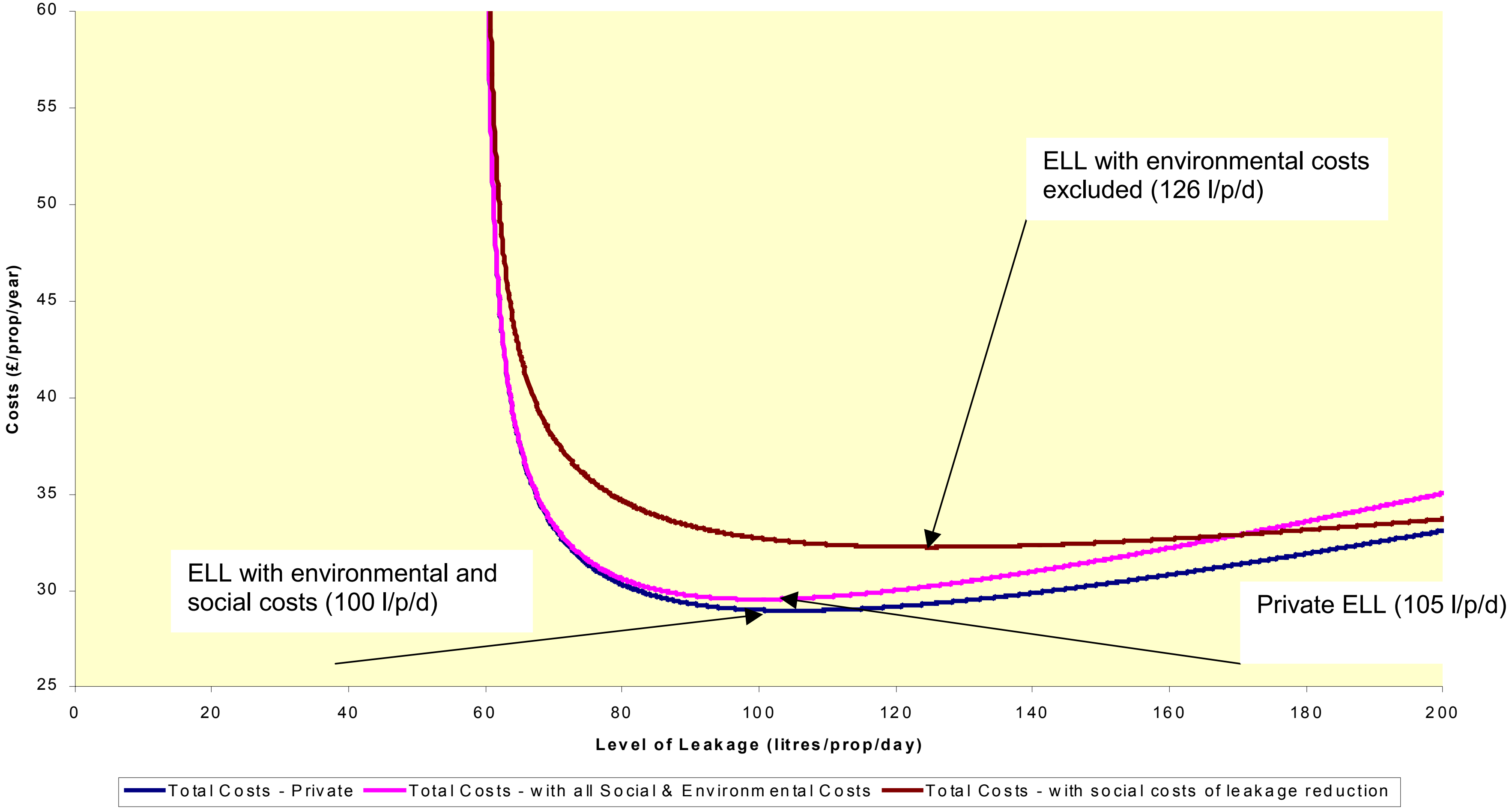
Figure 4.9 illustrates three possible "ELLs" that show the impact of incorporating the environmental and social costs of leakage and leakage reduction:

- For a baseline comparison, the private ELL calculated only from the private costs and benefits faced by the water company (in our example 105 litres/prop/day);

- A social ELL that incorporates the environmental and social costs of leakage and the social costs of leakage reduction (in our example 100 litres/prop/day); and

- An ELL that compares the full social cost of leakage with the private costs to the water company of leakage reduction (in our example 126 litres/prop/day), i.e. that excludes environmental costs.

Figure 4.9 Illustration of Private vs. Social Economic Levels of Leakage



From these comparisons, we see in this example that:

- Including the full social and environmental costs of leakage and leakage reduction would decrease the ELL by 5 litres/prop/day relative to the private water company baseline;

- Including the full social cost of leakage reduction increases the ELL by 20 litres/prop/day relative to the private baseline, while including the full environmental costs of leakage is worth a reduction in ELL of about 25 litres/prop/day.

In this particular example, the social and environmental costs are significant (albeit in opposing directions). In line with our suggested framework this finding would signal the need for more detailed primary research to verify the magnitude these costs quantified initially via the desk-top exercise.

Examining more closely those elements of environmental costs and benefits that appear to be of greatest importance can extend the analysis of sensitivity further. Applying RPA (1998) and NERA (1998) as part of a desk-top methodology allows environmental costs and benefits to be split into, for example, the loss of angling, recreation and non use value and the recreation cost of a reduction in reservoir levels. Table 4.5 illustrates the approach by highlighting the relative impacts of different types of environmental costs and benefits.

Table 4.5 Impact of different environmental costs of leakage on calculation of ELL

	ELL* (litres/prop/day)	**% Difference from "no environmental cost" position**
No environmental costs included	125.6	
Inclusion of all environmental costs	100.2	-20%
Including all environmental costs except angling	115.2	-8%
Including all environmental costs except recreation	114.8	-9%
Including all environmental costs except non-use	115.4	-8%
Including all environmental costs except reservoir impacts	123.4	-2%

* All calculations are based on the full social cost of active leakage control

In this case the reservoir impacts stand out as having a very significant impact on the ELL, since when the impacts are excluded there is only a small (2%) impact on the ELL. In all other options, which all include the reservoir impacts, the impact on the ELL is significantly larger. This finding provides a focus for further analysis to better understand this particular environmental impact.

4.5.6 Recommendation for appropriate inclusion of costs

Environmental and social costs may make a difference to the ELL but the size of this difference is not known for any particular company until a quantification exercise has been undertaken. The exclusion of environmental and social costs could result in abstraction levels remaining higher than is efficient in a sensitive area. However, a requirement for exact costing of the environmental costs and benefits of reducing leakage could place a significant information burden on companies.

We therefore recommend that companies undertake a desk-based study of the type demonstrated in order to identify the major social and environmental impacts of their leakage reduction activities. Companies can then carry out more detailed studies of such major factors to achieve more accurate quantification. The ELL for a company would then be calculated using the private cost data, the approximate estimates from the desk based studies for small impacts and the detailed figures for any major impacts.

In the demonstration above it is apparent that leakage has a very damaging effect on reservoir use and that reducing leakage would generate a large benefit to reservoir users. This impact would warrant more detailed investigation. The company in question could carry out a study to quantify numbers of visitors more accurately, try to use historic data about visits during a period when reservoir level was higher or lower and carry out a site specific survey about the time and petrol cost of the typical visit.

The magnitude of cost or change in the ELL from a particular impact that requires detailed investigation could be established as part of regulatory guidance to companies. We suggest impacts equating to a 5% difference in the private ELL merit more detailed investigation. Alternatively, companies could be required to use the upper limit (in keeping with the precautionary principle) of any approximate estimation of environmental cost. This would give companies the incentive to calculate large impacts accurately as it could allow some increase in the ELL.

4.5.7 Incentives for the internalisation of social and environmental costs and benefits

The ELL as quantified by the method used above provides a guide to the socially efficient level of leakage. This section discusses the effects on water companies of including social and environmental impacts and then identifies alternative methods of achieving the desired level of leakage.

Effects on companies of including social and environmental impacts

A company assessing its optimal level of leakage control would seek to minimise the private costs of leakage and leakage control (or maximise the net private benefits from reducing leakage). The efficient private level of leakage is likely to be higher than the ELL that takes into account social and environmental costs. Reducing leakage to the lower level will therefore impose an additional cost on water companies. At present there is no allowance for the additional costs of this leakage control activity in price limits, therefore the water companies are not able to pass on costs to the consumer.

An ELL target that reflects the social and environmental cost of leakage is therefore effectively an environmental tax on water companies. There is a strong case for allowing at least some of the incidence of this tax to be borne by consumers in order that the consumer meets some of the cost of his or her consumption decision. This would give consumers the incentive to reduce their water consumption where their water was abstracted from a sensitive source.

Alternative methods for achieving efficient levels of leakage

The setting of a leakage target for each water company individually means that the cost of leakage and leakage control is minimised for each firm. However, it is likely that different companies will have different costs of achieving leakage reduction depending on the state of their assets, the difficulty in accessing parts of the system and the urban density of supply area. Within a catchment area the environmental costs of abstraction are likely to be similar, hence within a catchment area water companies will create the same environmental costs of leakage but will pay different costs of leakage reduction and need to meet different leakage targets. Efficiency gains could be made by minimising the cost of leakage and leakage control activity across the catchment area.

There are two ways of using economic instruments to achieve this objective:

1. Set a price for abstraction that reflects the environmental costs resulting from this activity, or

2. Setting the leakage level for the catchment area by authorising leakage permits up to this level, then allowing companies to trade these permits to reflect their cost of leakage control.

These alternatives are discussed in turn;

Abstraction Charging

At present water companies do not pay a price for the abstraction of water that reflects the environmental cost of this abstraction. If companies paid for water abstraction then they would have a greater incentive to ensure that it was not lost through leakage. If the price they paid reflected the full environmental cost of abstraction (and the full social cost of traffic interruption) then the cost minimisation decision proposed in this report to set the ELL would lead to the socially efficient outcome.

There is a risk with charging that lack of knowledge or inertia may prevent companies from operating at the private efficient level of leakage as they are unaware of the benefits that could be achieved by doing so. Under such circumstances revenue would accrue to the Environment Agency but the desired reduction in abstraction would not occur.

However, the recent DEFRA paper, “Tuning Water Taking” indicates that there is no intention to allow the Environment Agency to charge at a rate higher than that which recovers the Agencies costs of Licence administration and supervision.

Tradeable Permits / Credit for Leakage Control

Under a permit or credits system the level of leakage for a particular catchment area would be set at a fixed level reflecting the environmental damage caused by additional abstraction. The exact level of leakage arising for each company would be driven by their activities in the leakage permit market. It is to be expected that companies with particularly low costs of leakage control would opt to sell their permits and maintain very low levels of leakage whilst companies with higher leakage costs would buy them. If the market operated efficiently the resulting allocation of leakage permits would ensure that the catchment level leakage target was met but at a lower cost than could be achieved by setting targets at the company level.

4.6 IMPACT ON THE ECONOMIC LEVEL OF LEAKAGE OF MOVING TO BEST PRACTICE

4.6.1 Overview

The impact on the Economic Level of Leakage (ELL) of moving to Best Practice can be discussed by consideration of the individual processes, as presented in Figure 4.10. It is not possible to draw firm conclusion on the likely overall impact of moving all companies to best practice since:

i) It is difficult to determine in advance the magnitude of the change in ELL as a result of a water company moving to best practice.

ii) Adoption of best practice process may result in the ELL moving higher or lower, depending on the individual process.

The remainder of this section discusses, for each individual process, the likely impact of moving to best practice. This section only considers processes that were considered within the best practice study. Other processes, including for example development of a robust supply/demand projection, will also have a significant impact on the ELL.

Figure 4.10 ELL targets setting process map

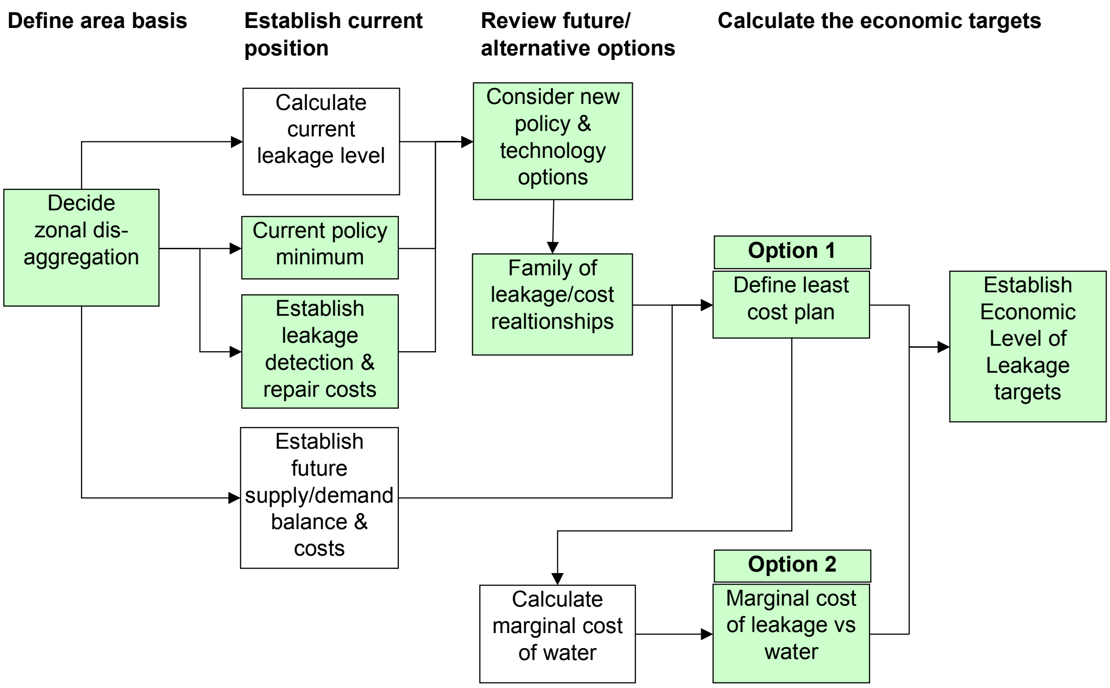


Table 4.6, below, summarises the likely impact on the ELL on moving to best practice for each of the processes. The following sections then provide more details of the reasons for these impacts.

Table 4.6 Impact of moving to Best Practice

Process & change when adopting best practice	Likely impact on ELL
Decide zonal disaggregation	
Move to smaller zone	↑↓
Move to larger zone	↔
Calculate current policy minimum	
Increase policy minimum	↑
Decrease policy minimum	↓
Current Active leakage control	
Adopt best practice modelling approach	↑↓
Inclusion of on-costs	↑
Inclusion/Exclusion of fixed costs	↔
New policy options	
Range and robustness of policies increased	↑↓
Efficiency increased (of current or new policy)	↓(1)
Least cost planning	
Adopt glide path	↑(2) ↓(3)
Allowance for the impact of new properties	↑(3)

1: When supply-demand investment is required
2: Short term
3: Long term

↑= ELL will increase ↓= ELL will decrease ↑↓= ELL may increase or decrease ↔= no impact on ELL

4.6.2 <u>Decide zonal disaggregation</u>

The selection of an appropriate size of zone will have an impact on the ELL. The best practice approach recommends using the geographically smaller of a water resource zone and a leakage control operational area.

- Use of a zone that is too large (undertaking the analysis at company level for example) will not allow full consideration of local issues:
    - Local supply-demand issues, that could result in a lower ELL. At a company level there may be sufficient headroom for the whole planning period, whereas at a local level supply/demand investment may be required (and hence leakage reductions may be economic).
    - Local leakage cost issues that could result in a higher or lower ELL (i.e. leakage control may be more/less expensive in areas where supply/demand investment is required).

- Use of a zone that is too small is unlikely to impact on the higher levels ELLs, but may themselves be misleading if based on a breakdown of leakage costs that is not robust.

- If leakage is not allowed to increase at the resource zone level (as opposed to the company level) then this would result in lower ELLs.

4.6.3 Calculate current policy minimum

From experience it is considered that the estimate of the policy minimum (or base level of leakage) has a significant impact on the ELL in zones where leakage is reduced due to the need for supply/demand investment.

- Under-estimation of the policy minimum will result in an ELL that is too low.
- Over-estimation of the policy minimum will result in an ELL that is too high.

As a *rule of thumb* a change in the policy minimum of, say, 10 Ml/d typically results in a change to the ELL of approximately 8 Ml/d.

4.6.4 Active Leakage Control and Repair Costs

Current policy

The current active leakage control costs will impact on the relationship between level of leakage and the cost of achieving leakage targets. When considering the economics of reducing leakage it is the rate of change (or gradient) of the relationship that is important.

The inclusion of on-costs is one area where there are significant differences between companies. Again, only costs that vary with the level of leakage will have an impact on the ELL. On-costs will typically be added onto direct costs as a fixed percentage, and so will have the impact of increasing the gradient of the leakage vs cost relationship. An increase in on-costs will tend to increase the ELL.

Where companies have included or excluded fixed costs which do not change with the level of leakage then this will have no impact on the ELL. When operating at steady state the cost of repairs will be a fixed cost, and so repair costs will have no impact on the steady state ELL. However, when driving down leakage (or allowing leakage to rise) the number of repairs will be higher (or lower) than the steady state number, and so in these circumstances repair costs will have a (relatively minor) impact on the ELL.

It is also important to be consistent over which costs to include when considering new policy and technology options. In these circumstances, costs that are fixed for the current policy may change when looking at the new policy. Again, it is important that any costs that change are built into the analysis.

The impact of moving to best practice may result in higher or lower costs of active leakage control, but as indicated earlier it is gradient of the leakage vs cost relationship that will impact on the ELL. It is not possible to predict how this relationship will change on moving to best practice, and so it is not possible to predict the impact on the ELL.

New policy and technology options

A key component of the best practice ELL analysis is that a full range of alternative policy options should be considered. It is only by considering a wide range of potential options that the true least cost policy can be determined. The analysis should consider a range of options from minor changes to the current policy to significantly different policies. Some policies are likely to clearly be uneconomic, through comparison of their AISCs. As a first step it is therefore only necessary to calculate AISCs and not to consider all options within the least cost planning exercise.

The company should consider a range of policy options that are technically feasible for their circumstances. There is clearly a role for the companies' Reporters to confirm that an appropriate range of options has been considered. In subsequent updates to ELL it would be expected that companies would develop more robust estimates of the leakage vs cost relationships for these new policies. It is therefore likely that the current (2001) submissions contain more robust relationships than the Strategic Business Plan (1999) submissions. These changes may make the alternative policies more or less favourable, and so it is not possible to predict the likely impact on the ELL.

Efficiency

It would also be expected that, over time, companies that do not make significant changes to their leakage management process will become more efficient. This increased efficiency will be built into the 'current' leakage vs cost relationship. As indicated in the report this increase in efficiency will initially result in lower costs, until the next supply/demand investment, when it will result in a lower ELL.

4.6.5 Least cost plan

The leakage glide path which is recommended in the report will tend to result in an ELL profile that declines over time. In the short term this will tend to result in higher ELLs, particularly for companies that had originally developed a plan to reach the long run ELL by 2002-03. However, in longer term the best practice approach is likely to result in lower ELLs, as leakage is reduced in response to increasingly more expensive resource options.

The period of analysis (a period of 25 – 30 years is recommended) may also impact on the ELL profile. Leakage reduction options are generally a high operating cost/low capital cost solution. Resource development options are generally a low operating cost/high capital cost solution. Longer time periods will tend to favour capital based solutions and so may result in higher ELLs.

Inclusion of the impact of leakage from additional properties during the planning period will tend to result in a higher ELL.

The best practice approach requires that a full range of supply/demand options are considered as part of the least cost planning exercise. Inclusion of an additional supply/demand option will tend to delay the need for future supply/demand investment and hence future leakage reductions. The ultimate ELL is unlikely to change, since this will be largely dictated by the cost of the resource schemes.

A discussion of the likely impact of including social and environmental costs was presented in Section 4.5.5.

5. ALTERNATIVE METHODS OF TARGET SETTING

Ofwat have pursued the route of setting leakage targets to achieve an economic level of leakage, i.e. balancing the cost of leakage reduction against the benefit of leakage reduction, set within the context of managing the supply-demand balance. This has required a detailed analysis of water companies' costs (and to a lesser extent benefits). This section examines the potential alternatives that could be used to set leakage targets.

One of the main issues that Ofwat as well as DEFRA and the Environment Agency should address is "Should water companies determine economic targets or meet targets economically ?" Currently targets are set on an economic basis within the context of the supply-demand balance. In this approach the costs of any reductions in leakage are balanced with benefits (reduced system, operating or capital costs).

The second approach is where the regulator(s) sets leakage targets based on a range of factors, that could include political, sustainability, environmental and technological reasons. It may not be possible to base these targets on a full economic analysis (although it would be expected that some consideration of economics would be taken into account). In these circumstances the companies would need to achieve these targets at lowest cost, but would need to be allowed expenditure in price limits to achieve them. There is a strong parallel with the achievement of quality targets which are set by the regulators.

There are three alternative routes that can be applied by Ofwat (in conjunction with the Environment Agency and DEFRA) within the context of setting/validating leakage targets for the water companies:

1. Ofwat could continue to set pragmatic targets for those companies who have not produced a robust assessment of the ELL and for those companies that have set targets on the basis of ELL. The pragmatic approach takes account, at a basic level, the availability of water resources within the company's area. Ofwat undertake a comparison of leakage targets and determine the required trends in leakage for companies that have not undertaken a robust economic level of leakage analysis. The pragmatic approach is based on very little data and will thus potentially produce uneconomic leakage targets.

   It is considered that the approach used to assess the availability of water resources ("tight", "marginal" or "adequate") does not adequately account for the range of factors that impact on water availability. For example, due to supply characteristics a six percent headroom may be "adequate" for one company but "tight" for another.

2. Validation of detailed company analysis – build on the Ofwat pragmatic target approach but include more of the key data from the detailed ELL analysis. Based on experience of developing detailed ELL analysis under a range of circumstances. For example best practice is least cost planning, but a simplified marginal cost of water (MCW) approach could be used by Ofwat.

3. Alternatively set targets without direct reference to the economics of supply and demand; an extreme example is that all companies could be set an identical target. In these circumstances the water companies would then look to achieve these targets economically.

The remainder of this section provides an overview of a number of alternative approaches to leakage target setting.

5.1 POLICY SET BY MARGINAL COST OF WATER

In this approach the marginal (or unit) cost of water for the next resource/treatment option defines both the leakage policy and the target level of leakage that the water company should be using. The approach is illustrated in Figure 5.1, below.

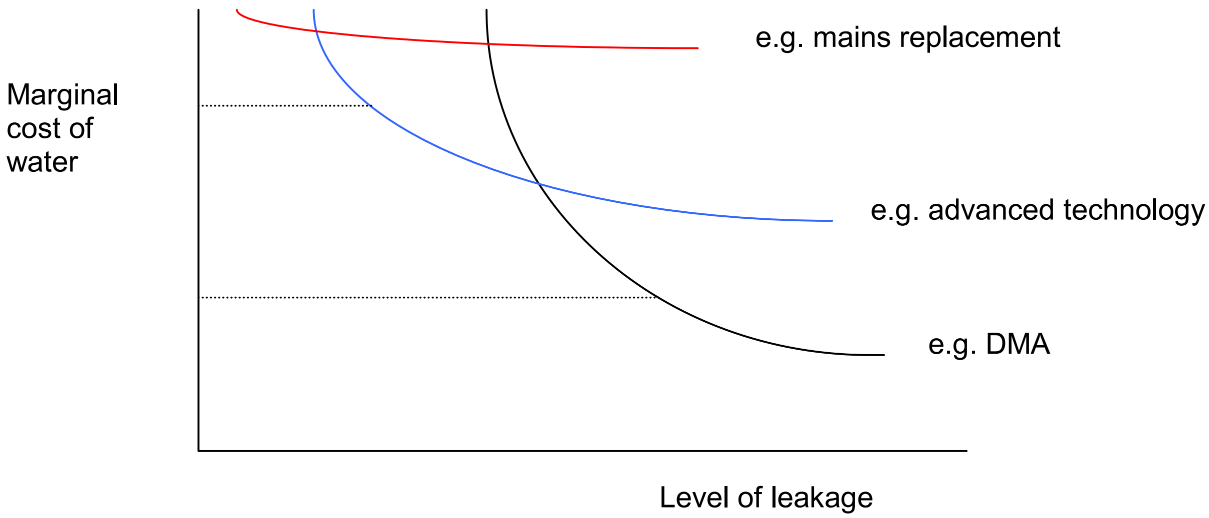


Figure 5.1 Policy set by marginal cost of water

As can be seen in Figure 5.1 a high marginal cost of water suggests “advanced technology” whereas a lower marginal cost of water suggests “traditional” DMAs. The water company would be set both a policy and a leakage target.

This approach requires the following (which will both need to be validated):

i) Detailed leakage/cost curves from the water company.

ii) Detailed MCW (or AISC) calculations from the water company.

Advantages

This approach draws heavily on water company data, and so would set a leakage target and leakage policy consistent with the company’s least cost plan. It is therefore also a possible approach that Ofwat could use to validate a company’s targets.

This approach which is the most consistent of the alternatives with the least cost planning best practice approach. It draws on the same range of data that a water company will have used in preparation of its least cost plan.

Use of an appropriate cost of water will result in an ELL set within the context of the supply-demand balance.

Disadvantages

The approach requires a large amount of information to be provided to the regulator by the water company. Whilst the majority of the information will have been developed by the company in developing their own ELL analysis it will increase amount of data that the regulator will need to review.

Since the approach relies heavily on water company data the regulators cannot apply the approach independently. The cost curves are specific to individual areas - it is unlikely that standard curves could be developed that could apply across the UK.

A robust calculation of the marginal cost of the next resource/treatment option is required. The definition of this calculation is fundamental to the approach.

5.2 THEORETICAL TARGET SET ON SYSTEM CHARACTERISTICS

This approach estimates a technically achievable level of leakage based on the physical characteristics of the system. The leakage target may be set based on either without reference to the availability of water or be adjusted to take account of water scarcity.

It will be necessary to develop a relationship between an acceptable leakage target and a range of system characteristics including:

- Mains length
- Number of connections
- Pressure
- Leak occurrence rate
- Others ?

The first four factors are essential for inclusion in any equation, but it may be necessary to include a range of other explanatory factors. Development of this relationship could draw on the range of explanatory factors listed in the Leakage Performance Indicators report (UC 3894) and on the work by Lambert et al on international leakage comparisons(14). A critique of this approach is presented in Appendix A of the Leakage Performance Indicators Report.

The current method of active leakage control used by the water company should not be included as a factor within the relationship. It should remain a company policy decision on how to achieve the leakage target.

Advantages

The data requirements are more straightforward than for the detailed analysis required for least cost planning or policy set my marginal cost of water. It is therefore more suitable for forming part of a regulatory return and could be audited.

The same relationship would be applied to all water companies.

Disadvantages

The derivation of equation is key to this approach. It would require detailed analysis, and an appropriate range of explanatory factors. There is a trade-off between the number of factors and the accuracy of the approach – if too few factors were used water companies could argue they were being unfairly discriminated against.

The approach does not set leakage targets within the context of the supply-demand balance unless a “water availability” factor is built into the relationship. Therefore the targets are not necessarily economic – merely the least cost way of achieving a certain outcome.

5.3 TARGET SET ON POLICY MINIMUM

From experience of examining a range of economic level of leakage analyses it is clear that the policy minimum (or base/background) level of leakage is one of the most significant factors. Experience suggests that the ELL for water resource zones with proposed supply-demand investment in the short term will tend to be 20-30% above the base level of leakage.

In this approach a “moving target” is developed based on the policy minimum. This policy minimum should be the lowest of:

i) Theoretical minimum achieved – this should draw on the relationships from the Managing Leakage(6) reports or any industry research.

ii) Actual minimum achieved

These should be calculated on a sub-zonal (i.e. DMA) level. The target level of leakage is then set at a fixed percentage above this minimum achieved. This percentage should be based on an assessment of the supply-demand position within the company and is likely to be within the range of 20% (very tight resources, with imminent major investment requirements) to in excess of 50% (where no resource investment is required within the planning period). These percentages should be derived initially by reference to robust ELL analyses.

As companies drive down leakage to achieve their target then the minimum achieved in individual DMAs will also decrease, driving down the target. It is suggested the minimum achieved level of leakage (and hence the leakage targets) should be re-assessed on a 5-yearly basis.

Impact of new technology – companies should be able to retain the benefits of their investment – re-assess minimum achieved on a 5-yearly basis ?

This approach effectively re-aligns targets every 5-years (at the periodic reviews ?)

Advantages

This is a straightforward and transparent approach that is based on data (minimum night flows) that are readily available for the majority of water companies.

Any technology changes are implemented by the water company based on their economic analysis.

In this approach the water companies are looking to achieve a target economically (rather than achieve an economic target) – the regulators only need to audit achievement of the target and not the water companies’ economic analysis

Disadvantages

To be effective and reliable the approach requires an accurate assessment of leakage.

The approach does not set leakage targets within the context of the supply-demand balance.

5.4 TRADING IN LEAKAGE PERMITS/CREDITS

A further option for target setting borrows heavily from the lengthy literature on the use of tradeable pollution permits to minimise the costs of meeting pollution control standards. Trading in carbon rights provides, perhaps, an even closer analogy. Appendix F discusses this option in more detail.

This approach could be designed to achieve two principal objectives. First, to introduce more tangible financial incentives for water companies to reduce their levels of leakage through the introduction of more efficient options and practices. This would help to counter current suspicions that companies have little incentive to innovate and thereby lower their ELL.

Secondly, a more efficient allocation of leakage control activity across companies would help to minimise the cost of meeting current levels of leakage in the aggregate. Equally, more efficient allocations of activity would allow for lower levels of leakage to be achieved at current levels of cost.

The key to achieving these twin objectives lies in creating tangible financial value to water companies of further leakage reductions and providing a mechanism that allows the differences in marginal leakage control costs between companies to be exploited.

The principal elements of that mechanism could be as follows:

- The current levels of leakage are defined as an appropriate starting point and this could be assumed synonymous with companies meeting the present targets set by Ofwat;
- Regulators specify targets for further leakage reduction, possibly informed by views about the scope for savings through technological innovation and / or environmental objectives;
- These targets are expressed in the form of a stock of leakage reduction permits that may initially be distributed across companies through either an auction or grandfathered process. One advantage of an auction process would be the revelation of the initial price of permits / credits. Prices, thereafter, would be determined in the market through bilateral trade rather than regulatory intervention being required;
- The permits can then be traded at some price, possibly determined initially with reference to a value that includes an estimate of the environmental cost of water.

The expected incentive properties of the mechanisms are intended to be:

- Companies with marginal leakage control costs below the permit price can reap a return by investing in further leakage reduction and offering their reduction permits for sale at the higher market price. This provides an incentive to seek out lower cost methods of leakage control;
- Companies who consider their current level of leakage to be above an economic level should be expected to be buyers in the market, choosing to purchase leakage reduction permits that can be used to “buy” an increase in permitted leakage. Such companies should also reap a marginal return, but only if it is true that their marginal cost of leakage control exceeds the market price of a permit.

- Companies who do not seek out lower cost leakage options and wish to buy a rise in their permitted leakage level because of a poor understanding of their leakage costs (both actual and potential) will in effect face the self-imposed “fine” of buying leakage permits.

Clearly, analysis is required to understand in more detail the feasibility and practicality of this possible approach to target setting. Critical issues to be resolved would include:

- Whether the marginal costs of leakage control vary sufficiently across companies to allow sufficiently material gains from trading to be realised;

- The most appropriate level for the setting of aggregate reductions. Possible options would be by region or by river catchment;

- Regional or possibly catchment variations in the environmental costs of leakage might also have to be taken into account. This would be the equivalent of ambient permits systems/offset systems observed in permit mechanisms for pollution emissions control;

- The scope for introducing mechanisms of this type within the current legal frameworks; and

The allocation of regulatory responsibilities for the setting of targets and for the monitoring of the permit market.

Advantages

The approach can draw on consultation and discussions for the introduction of tradeable pollution permits. This will allow further analysis of the costs/benefits of this option to be progressed with limited legislative input.

For England and Wales as a whole the leakage reductions will be achieved at the locations with the lowest cost of leakage control.

Targets are set at the national level – all water companies are working to the same target.

Disadvantages

Targets are not set within the context of the supply-demand balance. Water companies will need to consider their supply-demand position when determining the mix of actual leakage reductions and leakage permits to achieve their target.

Potentially requires tight regulation, particularly to ensure that the larger water companies do not distort the market in leakage permits.

5.5 NATIONAL RE-ALLOCATION OF WATER RESOURCES

Setting economic leakage targets based on the current supply-demand position within the resource zone results in some companies having relatively high economic levels due to historic (or inherited) surplus resources.

A re-allocation of water resources (based on an allowance per customer for example) would ensure all companies would have similar economic levels of leakage. In effect all water companies would have the same supply-demand position.

In developing this approach it would need to be considered whether the re-allocation should this done on a notional or actual basis:

- A notional reallocation requires estimating an economic level for England & Wales
- An actual reallocation would provide little incentive for those companies who were below the average (and would be unlikely to be feasible)

What is the benefit to a company of reducing leakage if its actual resources are greater than its notional allocation.

Advantages

This approach would be seem to compensate those companies that for, historical reasons had been allocated less water resources than others.

All water companies would have the same incentives to increase the efficiency of leakage control.

Disadvantages

An actual re-allocation of water resources would be difficult, if not impossible, since the current allocation is geographically based.

A notional allocation would still leave resource deficient water companies needing to consider the economics of leakage reductions within their supply-demand balance.

5.6 TARGETS SET ON ABSTRACTION LEVELS

A recent CIWEM paper[7] outlines the potential use of abstraction targets as an alternative to leakage targets. The paper recognises that leakage reductions will not necessarily result in Environmental and Social benefits. In some circumstances a reduction in leakage may result in an increased Environmental and Social cost (no environmental benefit and higher social cost).

The approach is based on the development of abstraction targets to achieve an acceptable socio-environmental quality. All abstractors within the catchment must then work within this level (this is a similar process to that currently being undertaken by the Environment Agency in the development of Catchment Abstraction Management Strategies (CAMS)). Where the level of abstraction must be reduced this could be through the least cost mix of leakage reductions and demand management.

There are a number of areas that would need to be clarified within this framework, particularly:

- How to get the co-operation of the range of abstractors.
- Impact of year-on-year demand for water. In wetter years the demand may be lower, which may allow water companies to allow leakage to rise. In hot-dry summers demand will be high, suggesting lower levels of leakage, but active leakage control is difficult during periods of high demand.
- The approach moves the focus away from leakage targets, to water abstraction and hence the real environmental benefits, but leakage is likely to remain a political issue.

Advantages

This approach recognises that leakage in itself is not the main factor causing an impact on the environment – it is the total quantity of water abstracted. The approach seeks to derive an economic level of abstraction.

Moves the emphasis away form leakage, which is only one of the factors that impact on the environment, to the wider impact of total volume abstracted.

Could be implemented as part of the ongoing CAMS process.

Disadvantages

The emphasis moves away from the highly regulated public water supply companies to the wider context of water abstractors who are not subject to the same degree of regulation.

Requires collaboration between all abstractors within a catchment.

May result in water companies “taking their eye of the ball” of leakage. Leakage is still likely to remain a political issue.

5.7 DEREGULATORY APPROACH TO LEAKAGE TARGETS

5.7.1 Objective of leakage control

Underlying the desire to control the losses of water due to leakage is concern over the waste of resources that leakage represents. If water that is abstracted does not reach the consumer then private costs arise to the water company and environmental costs may arise at the source from which the water was abstracted. Private costs to the water company will depend on the costs of abstraction, treatment, storage and pumping and these will vary between companies. Environmental costs will depend on the source from which water is being taken, according to the recreational and agricultural use of the source and the non-use benefits of conservation at the site. Such costs will depend on the site and so will be equal for all those undertaking abstraction. The objective of leakage control is therefore to minimise these costs.

5.7.2 Approaches to leakage control regulation

There are a number of different ways to regulate leakage. These are described briefly below.

- Command and control – the Regulator sets the level of leakage permitted by each company, as is currently done.

- Tradeable permits for leakage control – the Regulator sets the level of leakage permitted for those abstracting from the catchment area by issuing leakage permits up to that level of leakage. Abstractors are able to buy and trade permits according to their private costs of leakage control activity.

- Deregulatory approach – the Regulator sets the level of leakage permitted for the catchment area and leaves abstractors to determine how leakage/abatement is allocated between them.

The first of these approaches demands that the Regulator has access to large amounts of reliable information on company costs of leakage and leakage control. It then needs to monitor and penalise at the company level.

The second of these approaches requires much less company information (depending on how the catchment level target is set). An effective market for permits would need to be established which might be problematic for some catchment areas that have few abstractors. Monitoring of the permit market would be necessary, though such tasks would not necessarily fall to the Regulator.

The third approach leaves much more to the discretion of the companies. This approach is assessed in more detail below.

5.7.3 How a non-prescriptive approach could work

Setting the target

The Environment Agency would be responsible for setting the target level of leakage for the catchment area. This would be based on the environmental costs of abstraction for that specific catchment. In order to set an economically and environmentally efficient leakage target the average company private and social costs of leakage control activity would need to be compared against the benefits of leakage control.

More simplistically the EA might set a target to achieve a specific environmental goal. Provided this was not unduely onerous companies might accept this goal rather than undertaking a costing exercise.

Options to abstractors

Faced with a target level of leakage in Ml/day or l/prop/day the Licenced abstractors would need to allocate responsibility for meeting the target amongst themselves. Possible options would include,

- Allocation according to some agreed rule,
- Catchment level auction of permits organised by the companies, and
- Joint effort involving the sharing of find and fix teams, mutually agreed levels of water pressure and intercompany arrangements over the timing and purchase of mains replacement.

The EA would not need to involve itself with the details of such schemes as these would be the responsibility of the companies that held the abstraction licences.

Monitoring and penalties

The EA involvement would be limited to monitoring at the catchment area level. This might take the form of a random check of night water flows or an ongoing measurement of abstraction and recorded flow/ consumption at points further down the system.

If the target for the catchment area was breached the EA would penalise all licenced abstractors for the area thus placing the responsibility for the functioning of the leakage allocation system firmly on the shoulders of the participants. This would have the effect of encouraging self monitoring to avoid being penalised. Further analysis would need to be undertaken as to whether the penalty should be imposed equally across companies, according to turnover or by some other method.

The level of the penalty would need to be such that self monitoring leading to compliance was the most cost effective approach that a water company could take. This can be demonstrated by this Prisoners' Dilemma game.

The companies agree to divide the leakage target for the catchment between themselves. To meet their agreement it will cost each company 5. If a company decides not to meet the agreement on leakage the cost to that company will be 0.

Game before penalty:

Company A strategy ▼	Company B strategy ►	Comply	Cheat
Comply		-5, -5	-5, 0
Cheat		0, -5	0, 0

With no penalties Company A will always choose to cheat because there is a cost to compliance. Company B will also choose to cheat. Hence the outcome will be cheat-cheat as shown in the bottom right square. i.e. neither company will undertake the amount of leakage control that they agreed with each other they would undertake, therefore the catchment area leakage target will not be met.

Game with penalty:

Company A strategy ▼	Company B strategy ►	Comply	Cheat
Comply		-5, -5	-25, -20
Cheat		-20, -25	-20, -20

If the Agency imposes a penalty of 20 on all companies in a catchment area that does not meet the catchment target then it is in the interests of participants to comply and to monitor the compliance of others. If Company A cheats it will always be fined 20. Company A's best result is if it complies and Company B complies as it only incurs a cost of 5. However, if Company A complies but company B doesn't, Company A pays 25. Therefore Company A will comply and will want to ensure that Company B does likewise. Company B faces the same incentives so it will want to monitor Company A as well as complying. Thus a credible fine and an amount of catchment level monitoring by the EA will give companies the incentive to comply and monitor one another.

5.7.4 Advantages of deregulatory approach

The main advantage of this approach is the improved economic efficiency it achieves over other approaches, whilst still attaining the environmental goal. Companies can choose the allocation rule for leakage that is cheapest and most effective for their circumstances. This should be an allocation rule that encourages greater amounts of leakage control activity to be undertaken by those for whom the cost is lowest. Companies with high costs of leakage control will do less, though may have to compensate the other participants for this.

This approach is characterised by the “light touch” approach to regulation. This should minimise the Regulator’s costs of administration and supervision. Costs to companies of administering their own allocation will be determined by the demands of that allocation, hence if they decide to have a highly complex scheme then they will bear the costs of this and the responsibility for it.

An approach of this sort would be industry-led so companies would feel that they “owned” their scheme. Success of the scheme could be publicised to improve companies’ environmental profiles whilst failure would be perceived as failure on the part of companies themselves.

Where differences exist in companies’ cost of leak abatement a greater reduction in leakage could be achieved for the same cost.

Figure 5.2 Deregulatory approach - comparison of companies

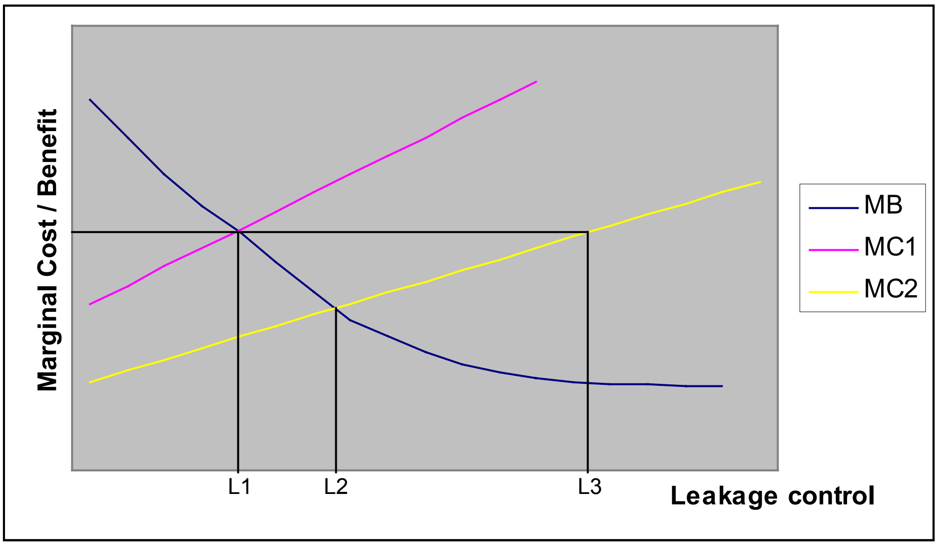


Figure 5.2 shows the case where company 2 experiences significantly lower costs of leakage control. If companies’ leakage targets are set individually, company 2 carries out L2 of leakage control and company 1 carries out L1. However company 2 could carry out much more leakage control at lower cost than company 1 thus a different allocation rule could result in lower control costs overall. Similarly, a different allocation rule could allow a greater quantity of leakage control to be undertaken for the same cost.

Savings in the setting of targets could be achieved as the marginal benefit curve of leakage control would only need to be quantified once for the catchment area, rather than by each company individually.

Finally, if companies decided to pool their leakage control efforts they might be able to achieve lower costs of control, e.g. Find and fix teams could be shared thus overcoming the "lumpy" nature of expenditure on these. More sophisticated leak identification technology could be purchased with pooled resources. Knowledge about effective leakage control could be shared. Leak control activities that generate traffic disruption could be co-ordinated to minimise social impacts.

5.7.5 Disadvantages of deregulatory approach

The major drawback of an approach of this type is that it does not allow the Regulator control of the entire process. This would make it inappropriate if the damage caused by non compliance was particularly high. However, it is not thought that this level of concern applies to leakage where potential risks are important but not critical.

An efficient allocation rule would result in companies with lower costs of leakage reduction activity carrying out more leakage control. Unless the social costs of leakage control activities, such as traffic disruption, are internalised by the companies there may be a divergence between companies which have low private costs of leakage reduction and low social costs of leakage reduction. Under these circumstances the allocation of leak control activity would be inefficient. Therefore in considering this approach there would need to be consideration of whether social costs of leakage reduction were systematically higher for companies with low private costs.

All companies end up undertaking different amounts of leakage control which may defeat a wider objective of getting companies to consider their full costs of abstraction.

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APPENDIX A CURRENT LEAKAGE LEVELS

A.1 INTRODUCTION

Methods of leakage estimation

Company leakage cannot be measured directly. Instead it may be estimated by two methods:

i. The integrated flow approach (top down)

Leakage = distribution input - consumption

In this case leakage is the residual or balancing item in the annual water balance calculation. Top down leakage estimates are for total leakage, i.e. including trunk mains and service reservoir leakage.

A consistent methodology is used by companies for top down leakage assessment. This allows the impact of variation in the component data on the leakage estimate to be assessed directly. Top down leakage estimates may be robust if consumption by unmeasured households is reliably monitored. However, work carried out on behalf of UKWIR [(3)] showed that top down leakage assessments may be subject to large errors (in excess of 20%). As leakage becomes a smaller component in the water balance, percentage errors will increase.

ii. Minimum night flow approach (bottom up)

Leakage = (minimum night flow – legitimate night use) * pressure adjustment factor

Bottom up leakage estimates are usually based on continuous night flow monitoring in small district meter areas (DMAs) of around 1500 properties. A leakage estimate is provided for each DMA each night; these together give an estimate of ‘distribution’ or ‘operational’ leakage. In most cases leakage from trunk mains and service reservoirs must be estimated separately.

The night use allowance should be consistent with the assessed minimum flow. Pressure adjustment (hour day) factors take account of diurnal variations in the system pressure to provide an average leakage estimate from leakage measured at night.

Considerable differences exist in the approaches used by companies for bottom up leakage estimation. Detailed investigations are required to show the impact of these differences on the resulting leakage estimate. Another UKWIR project [(4)] showed that differences in the approaches used by companies for bottom up leakage estimation and inconsistencies between the minimum night flow and the night use allowances can affect the leakage estimate by up to 50 l/prop/d.

It is recommended that both top down and bottom up leakage estimates should be used for company analyses for setting leakage targets and monitoring performance against targets. The bottom up values should be consistent with operational leakage data used for prioritisation and should be reconciled against top down data to give values consistent with reported leakage. Leakage data must also be consistent with policy minimum estimates.

While allowing companies discretion in their approach to leakage estimation it is important that methods are used appropriately. For example, whatever method is used for night flow analysis, the night use allowances must be consistent with the assessed minimum flow.

Note: use of models to provide estimates of current leakage levels is not reliable, and should not be used within the target setting process.

Annual assessments and leakage trends

Some companies used March/April leakage levels in their initial economic studies to take account of the large reductions in leakage which had been made during the year. However, weather conditions may distort the analysis if the leakage data are derived from a single month, and there may be difficulties in providing consistent leakage and cost data. Once steady state is reached, use of the annual average level of leakage is preferred. This also ensures that the leakage target is consistent with reported leakage.

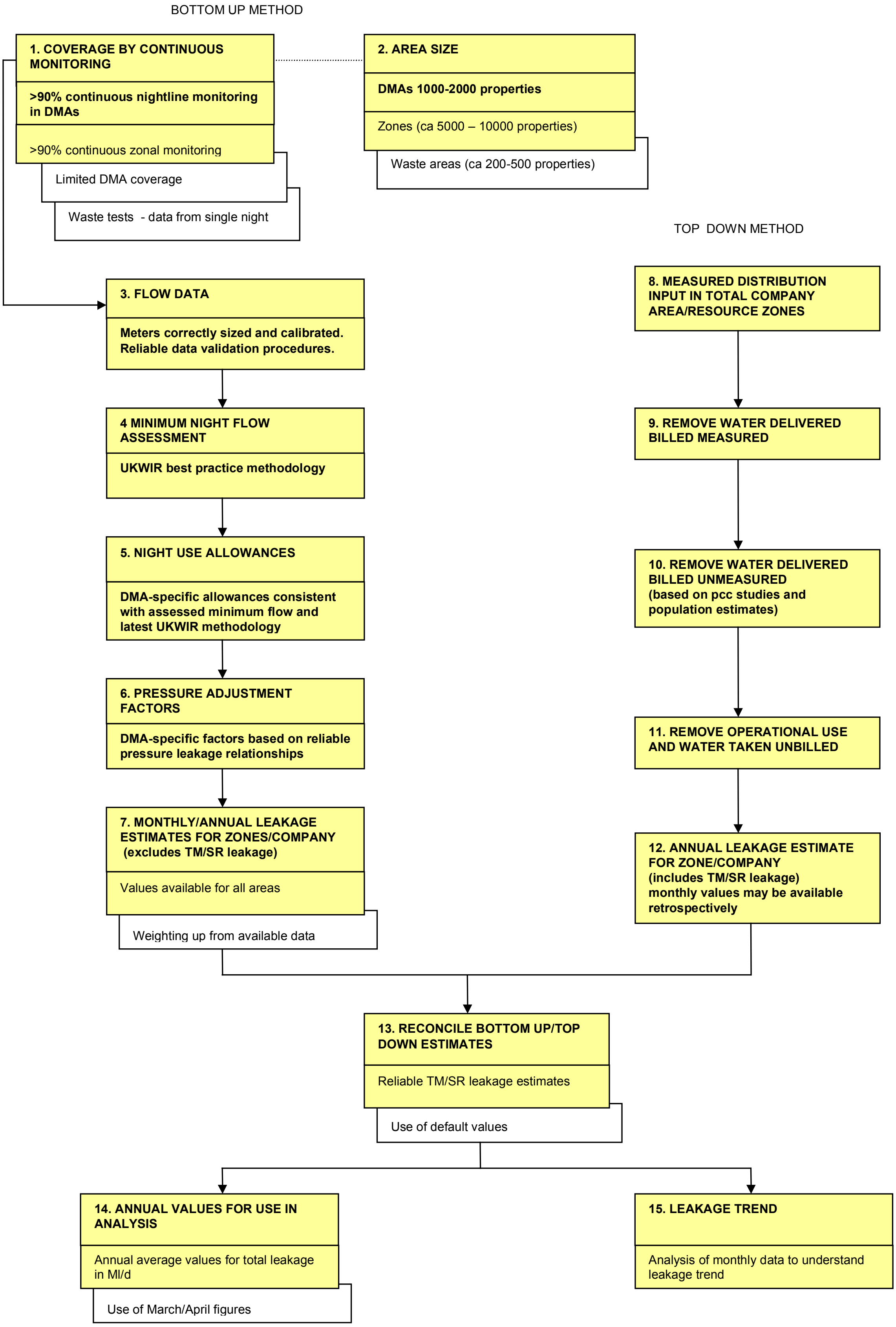
The analysis of leakage trends during the year is important as leakage data sometimes show a pronounced dip at end of the previous year in order to hit the target. This means that although the average leakage level for the current year is below that of the previous year, leakage has gradually been drifting up throughout the year. Companies must be aware of this and take action at an early stage to ensure that the number of leaks running does not increase.

Top down estimates are based on metered demand and per capita consumption, and it is therefore difficult to produce reliable leakage figures each month. The monthly values may be corrected retrospectively in order to give more accurate trend information. Bottom up leakage estimates should take account of seasonal changes in night use.

A.2 BEST PRACTICE METHODOLOGY FOR ESTIMATING THE CURRENT LEVEL OF LEAKAGE AND SUMMARY OF METHODS USED BY COMPANIES

Figure A.1 is a process map for best practice estimation of the current leakage level. The top down method is not discussed in detail as it is well understood by companies.

Figure A.1 Process map for best practice estimation of current leakage level



Input 1	Coverage
Best practice	> 90% continuous nightline monitoring in DMAs
More robust	> 90% continuous zonal monitoring
↓	Limited DMA coverage
Less robust	Waste tests – data from single night

Best practice

Night flows should be obtained from continuously monitored DMAs. The area covered by continuous monitoring should be in excess of 90%.

Discussion

Although small DMAs are important for operational purposes and for determining policy minimum leakage, there are a number of potential advantages of using larger monitoring areas for leakage reporting, for example if this increases the coverage by continuous monitoring or overcomes the problems of open boundary valves and cascading systems where demand within DMAs may be a small residual of total inflow and outflow. Waste tests are not robust for leakage estimation as they provide only a very limited amount of data, usually from a single night, and corresponding night use estimates will be difficult to produce.

Input 2	Area size
Best practice	DMAs 800 to 2000 properties
	Flow Monitoring Zones (ca 5000 – 10,000 properties)
	Waste areas (200 – 500 properties)

Best practice

Either DMAs with an average size within the range 800 properties to 2000 properties or Flow Monitoring Zones (e.g. 'super DMAs' or water quality zones) of around 10,000 properties will provide reliable leakage estimates. (Note: night use allowances will be correspondingly larger for large monitoring areas.)

Discussion

Waste meter areas typically containing 200-500 properties. Although some waste areas are continuously monitored leakage estimates will be less reliable due to uncertainty over night use estimates and a greater proportion of mains outside the monitored areas.

Input 3	Flow data
Best practice	Meters correctly sized and calibrated, reliable data validation procedures

Best practice

District meters must be correctly sized and calibrated. Ideally there should be a single boundary meter for each DMA. Procedures should be in place to ensure that a minimal amount of data is lost, and that any possible data anomalies are quickly identified and investigated.

Discussion

About half of the companies have an average of 1.5 meters per DMA or less. Some companies typically have around 3 or more meters at DMA boundaries. Clearly the more meters which are present, the greater the chances of lost or invalid data. Flow data is unlikely to be reliable if consumption within the DMA is a small residual of measured inflows and outflows.

Input 4	**Minimum night flow assessment**
Best practice	UKWIR best practice methodology

Best practice

The UKWIR recommended methodology defines the minimum night flow as the rolling 7 day 50 percentile value based on the minimum rolling hour each night [(4)].

Discussion

The UKWIR procedure is gradually being implemented, but the majority of companies still use individual assessment methods which can have a substantial influence on results.

Input 5	**Night use allowances**
Best practice	DMA-specific allowances consistent with the assessed minimum night flow and latest UKWIR methodology.

Best practice

All users which individually have a significant impact on the night line in the DMA should be continuously logged. This may include some customers whose average use throughout the year is relatively low.

Night use allowances must be consistent with the assessed minimum flow, whichever method is used for night flow analysis. For example, if the minimum night flow relates to the minimum 15 minutes each night, night use values should relate to this period; if the monthly 10 percentile night flow is used to determine the minimum night flow, night use figures should be based on the same analysis.

There is UKWIR methodology[(17)] for determining non-household night use and UKWIR methodology for household night use is shortly to report.

Input 6	Pressure adjustment factors
Best practice	DMA-specific factors based on reliable pressure leakage relationships

Best practice

Pressure adjustment (hour day) factors should be determined by pressure logging within each DMA. The factors should be based on reliable pressure leakage relationships.

Discussion

The pressure leakage relationship which is used to calculate average daily leakage can affect the resulting leakage estimate by more than 10%. Pressure leakage relationships should be reviewed in line with UKWIR report which is due to be published shortly.

Input 7	Monthly/annual leakage estimates for zones/company
Best practice	Continuous data available for all areas

Best practice

Monthly and annual leakage estimates should be produced for each DMA based on logged data. Leakage estimates for individual DMAs are added together to produce operational leakage estimates for each zone for which a leakage target is required.

Discussion

Gap filling techniques should be used if there is any loss of DMA data. Weighting up should be used to provide zonal leakage estimates if there is not complete DMA coverage.

Input 8	Measured distribution input in total Company area/resource zones

Discussion

Meters must be correctly sized and calibrated. Procedures should be in place to ensure that a minimal amount of data is lost, and that any possible data anomalies are quickly identified and investigated.

Input 13	Reconcile bottom up/top down leakage estimates
Best practice	Based on reliable information on leakage from trunk mains and service reservoirs.

Best practice

Bottom up and top down leakage estimates should be reconciled in order to produce leakage estimates for each zone and for the company. This will require reliable estimates of leakage on trunk mains and service reservoirs.

Input 14	Annual leakage estimates for use in the analysis
Best practice	Annual average values for total leakage in Ml/d

Best practice

Annual average values for total leakage should be produced for each analysis zone and for the company which are consistent with July Returns.

Discussion

Some companies base the analysis on leakage data from a single month (usually March/April). This is acceptable if large reductions in leakage have been made during the current year.

Input 15	Leakage trend
Best practice	Analysis of monthly data to understand the leakage trend

Best practice

In addition to the annual average leakage level, the trend in leakage during the year should be assessed in order to calculate transitional costs.

APPENDIX B BEST PRACTICE METHODOLOGY FOR ESTIMATING POLICY MINIMUM LEAKAGE

Figure B.1 is a process map for best practice estimation of the current policy minimum. Eleven inputs are defined in the process map, each of which is discussed below.

Input 1	**Leak detection procedures**
Best practice	i. Intensive sounding of all fittings ii. Noise logging throughout area iii. Resurvey where leaks found
More robust ↓ Less robust	i & ii above i & iii above ii & iii above i or ii above

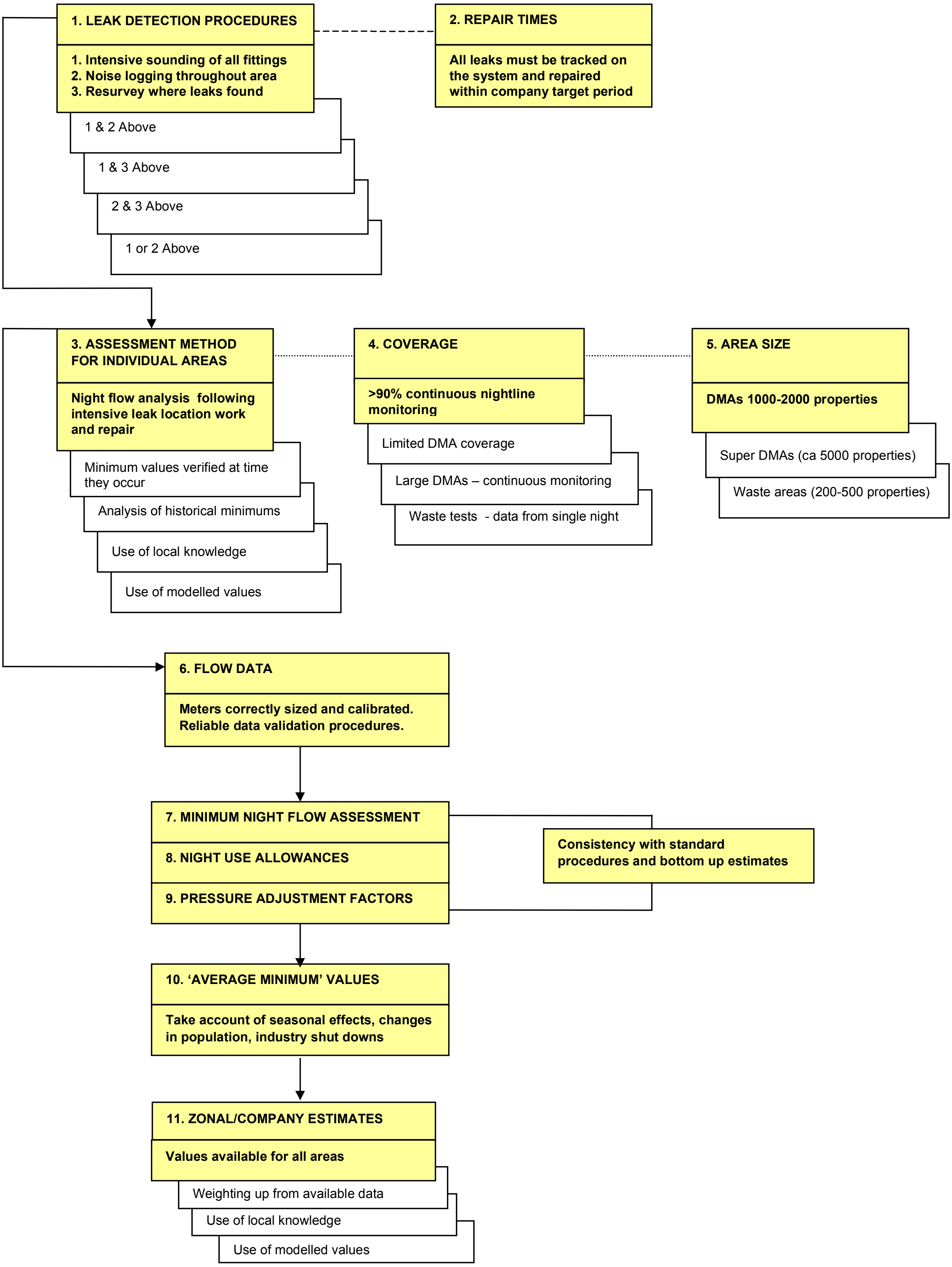
Intensive surveys to achieve the policy minimum level of leakage should be undertaken systematically in all DMAs. During the initial survey all fittings are sounded. Noise logging is then carried out throughout the area once leaks detected during the initial sounding exercise have been repaired. All locations where leaks were repaired should be resurveyed.

Input 2	**Repair times**
Best practice	All leaks must be tracked on the system and repaired within company target periods

Repair times, if long, will have an impact on the minimum levels achieved as leaks may occur between the survey and repair work.

Input 3	**Assessment method for individual areas**
Best practice	Night flow analysis following intensive leak location work
More robust ↓ Less robust	Minimum values verified at time they occur Analysis of historical minimums Use of local knowledge

Figure B.1 Process map for best practice estimation of the current policy minimum



Policy minimum levels should be assessed by the analysis of minimum night flows in individual monitoring areas immediately after systematic leak detection and repair work has been completed. Where possible, times of year with unusual night use (e.g. during hot summer weather or at times of industry shut down) should be avoided. The leakage levels achieved should be compared to historical minimums.

In cases where the current minimum is higher than the historical minimum, the historical value should be used only if it was verified at the time at which it was achieved and if the DMA has remained unchanged. Further surveys or night use investigations could be worthwhile to ensure that the historical value is still valid.

Input 4	**Coverage**
Best practice	> 90% continuous nightline monitoring
More robust ↓ Less robust	Limited DMA coverage Large DMAs – continuous monitoring Waste tests – data from single night

Night flows should be obtained from continuously monitored DMAs. The area covered by continuous monitoring should be in excess of 90%.

Input 5	**Area size**
Best practice	DMAs 1000 to 2000 properties
More robust ↓ Less robust	Super DMAs (ca 5000 properties) Waste areas (200 – 500 properties)

The average DMA size should be within the range 900 properties to 2000 properties. Where possible, DMAs containing more than 5000 properties should be subdivided. Where smaller areas are used (e.g. < 500 properties) night use allowances that take account of area size need to be used.

Input 6	**Flow data**
Best practice	Meters correctly sized and calibrated, reliable data validation procedures

In order to determine policy minimum leakage levels it is vital that district meters are correctly sized and calibrated. Ideally there should be a single boundary meter for each DMA. Procedures should be in place to ensure that a minimal amount of data is lost, and that any possible data anomalies are quickly identified and investigated.

Input 7	**Minimum night flow assessment**
Best practice	Consistent with standard procedures, in line with UKWIR recommendations

Input 8	Night use allowances
Best practice	Allowances consistent with assessed minimum flow
Input 9	**Pressure adjustment factors**
Best practice	Should be based on pressure logging in individual DMAs and reliable pressure leakage relationships

The approach used to calculate policy minimum leakage from minimum night flows should be consistent with standard 'bottom up' leakage estimation procedures. These are discussed in Appendix A.

Input 10	'Average minimum' values
Best practice	Take account of seasonal effects, industry shut downs, changes in population

The minimum 'nightline' values which are calculated for each DMA may be influenced by weekly and seasonal changes in night use. Use of the rolling 7 day 50 percentile value will overcome the problem of weekly variation. Care, however, should be taken to account for these variations in night use.

Input 11	Zonal/company estimates
Best practice	Values available for all areas
More robust ↓ Less robust	Weighting up from available data Use of local knowledge Use of modelled values

Zonal/company estimates should be based on the weighted average of policy minimum values for each of the constituent DMAs. Weighting should be carried out by DMA property counts. The value for each DMA should be determined by night flow analysis following intensive survey and repair work.

Where there is only a limited amount of data, local knowledge and comparison with similar areas may be used to provide estimates of the policy minimum in areas which have not yet been surveyed.

APPENDIX C BEST PRACTICE METHODOLOGY FOR DEVELOPING LEAKAGE COST RELATIONSHIPS

Figure C.1 is a process map for best practice evaluation of current leakage control costs and development of leakage cost relationships.

Input 1	**Annual ALC costs for study area**
Best practice	Annual costs derived directly from company finance and job management systems

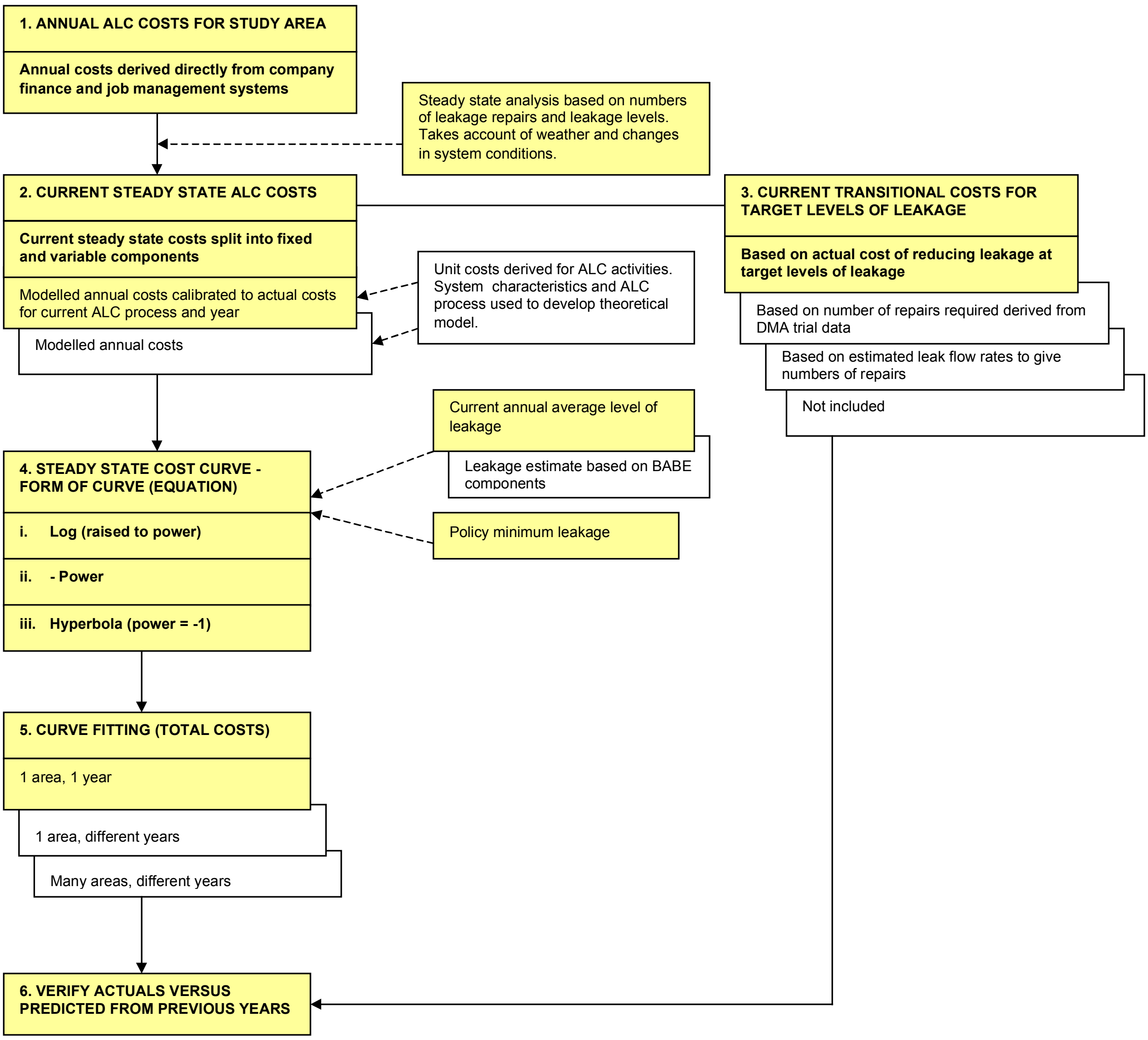
Best practice

Annual ALC costs for each study area should be derived directly from the company finance and job management systems.

Discussion

The ELL analysis should be part of the leakage management process and should be used by companies to forecast leakage budgets. This practice would provide an incentive to companies to continuously improve the accuracy of the analysis.

Figure C.1 Process map for best practice development of leakage cost relationships



Input 2	Current steady state ALC costs
Best practice	Current steady state costs split into fixed and variable components Modelled annual costs calibrated to actual costs for current ALC process and year
	Modelled annual costs

Best practice

The best practice approach requires that the proportion of current leakage control expenditure which relates to holding leakage steady should be determined by analysis historical records of leakage levels and numbers of leakage repairs. Costs should then be split into fixed and variable components.

Discussion

Assuming that under steady state leaks are repaired at the rate at which they occur and the leakage level is maintained, the average leak repair rate during periods when leakage is stable can be used to estimate the average leak occurrence rate. The average occurrence rate can then be compared to the average repair rate during the current year. As the analysis fails to take account of weather conditions, judgement should be used in the interpretation of results. It is also generally assumed that the condition of the infrastructure is unchanged, although this assumption may be adjusted if information is available.

Steady state costs should then be broken down into variable costs and fixed costs. Fixed costs, e.g. the costs of maintaining the district metering system, are independent of the level of leakage and therefore should not be included in the cost curves. It is generally assumed that monitoring costs are fixed, location costs are variable and repair costs are fixed. This is adequate for curve fitting using methods i and ii of input 4. However, the hyperbolic function is very specific and a more detailed analysis of location costs will be required, in which fixed costs are related to the number of leaks (e.g. correlation to pinpoint leaks) and variable costs are related to the number of surveys.

If costs are modelled using unit costs, the modelled costs must be calibrated to agree actual costs for the current policy and year, taking account of the split between steady state and transitional costs. Discussions have been held with a company which has developed procedures for carrying out such an adjustment. Experience from companies which do not carry out this adjustment shows that modelled values can be substantially different from actual costs. This reduces the accuracy of the ELL analysis and means that the approach cannot be used for budget setting.

Input 3	Current transitional costs for target levels of leakage
Best practice	Based on actual cost of reducing leakage at target levels of leakage
More robust ↓ Less robust	Based on number of repairs required derived from DMA trial data Based on estimated leak flow rates to give numbers of repairs Not included

Best practice

The most reliable approach for estimating transitional costs for achieving target levels of leakage is based on the actual costs of reducing leakage at the target levels.

Discussion

Costs will be heavily dependent on recent company policy. For example, if the company has concentrated on fixing major bursts rather than carrying out intensive surveys, the transitional costs of removing the backlog of leakage will be considerable.

Input 4	**Form of steady state cost curve (equation)**
Best practice	i Log (raised to power)
	ii - Power
	iii Hyperbola (power = -1)

Best practice

The form of the relationship is not important relative to the accuracy of the input data.

Input 5	**Curve fitting (total costs)**
Best practice	1 area, 1 year
	1 area, different years Many areas, different years

Best practice

The curve fitting may be based on data for one year from a single area or on historical data points for a single area.

Discussion

Where the curve is based on a single data point, the shape of the curve will be defined by the equation which is used. The use of historical data points for a single area would appear to be a more reliable approach, but any changes in the leakage policy or efficiency between years will change the shape of the curve and imply that the same savings will be made in the future.

As costs and levels of leakage are dependent on area characteristics and show considerable variation between areas, results from different areas should not be used to generate a relationship.

Input 6	Verification
Best practice	Verify actuals versus predicted from previous years

Best practice

Predicted costs and levels of leakage should be compared to actual data as these become available.

Discussion

Differences between actual values and model predictions should be investigated in order to determine if new input data should be used to generate the relationship. For example, predicted values may fail to agree with actuals if a change in policy has resulted in a reduction in the policy minimum. (Policy minimum is probably the most crucial input in the relationship.) If new policy minimum levels can be verified, they should be used in future analyses. This gives confidence in the base data and in the derived relationships.

WORKED EXAMPLES OF LEAKAGE COST RELATIONSHIPS

Base data assumptions

Policy minimum leakage (M)	60	l/prop/day
Passive level of leakage (P)	412.8	l/prop/day
Natural rate of rise of leakage (NRR)	48	l/prop/day/year
Leakage at start of current year (Lo)	156	l/prop/day
Detection costs for current year (Cdc)	2.38	£/prop
Leakage repairs for current year (Rc)	16	/1000 props/year
Average leak occurrence rate (Ro)	15	/1000 props/year

Method A

Steady state costs

Steady state detection costs for current year (Cdo) = Cdc * Ro/Rc

Average leakage in current year (Lavo) = Lo + NRR/2 = 180

Fit "cost v leakage" curve through (Lavo, Cdo) such that:

1) cost tends to infinity when leakage approaches the policy minimum,

2) cost equals zero when leakage equals the passive level.

(For simplicity, in this example the log function will be used.)

i.e.

$$\mathrm{Cd} = \frac{\left(\mathrm{Ln}\dfrac{\mathrm{P}-\mathrm{M}}{\mathrm{Lav}-\mathrm{M}}\right)^{n}}{\mathrm{A}}$$

where Cd is detection cost (£/prop/year)

Lav is annual average leakage (l/prop/day)

A,n are fitting constants

Ln is the natural logarithm

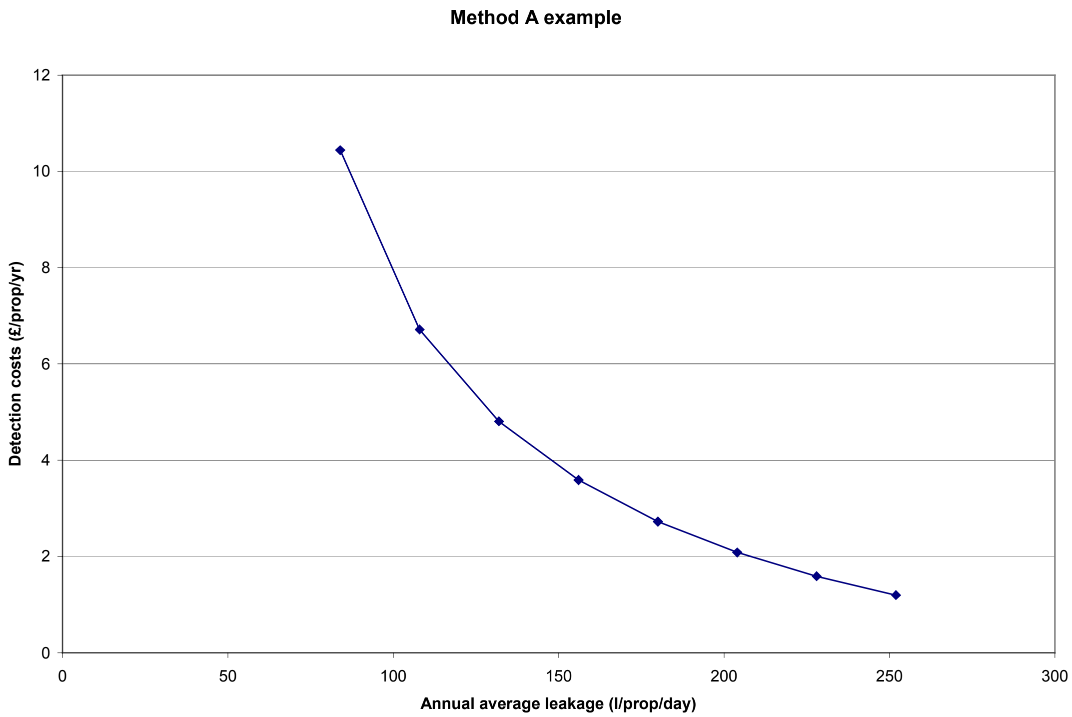
With the data given above, this becomes:

$$\mathrm{Cd} = \frac{\left(\mathrm{Ln}\dfrac{352.8}{\mathrm{Lav}-60}\right)^{1.5}}{0.43}$$

For steady state calculations using this method, it is usual to assume that repair costs are independent of leakage level and therefore do not influence the economic level of leakage.

The relationship is plotted in Figure C2.

Figure C2 Steady state detection cost vs Level of Leakage for Method A



Transitional costs

L_1 is leakage level at end of current year (l/prop/day)

L_2 is leakage level at the end of current year+1 (l/prop/day)

Leakage reduction (Lr) = L_2-L_1

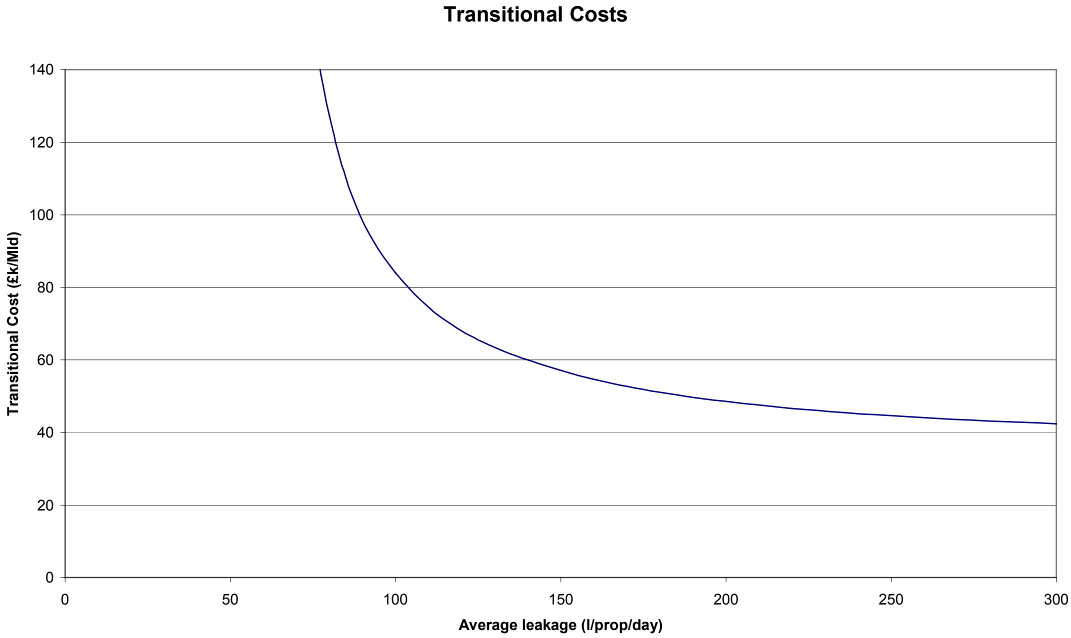
Leakage reduction costs (£/Mld) can be developed from sample areas and are dependent on the start and finish level of leakage. A typical relationship is presented in Figure C3.

The relationship is then used to predict the transitional cost to meet a target level of leakage.

Total Costs

Total Costs are calculated by adding the steady state costs + transitional costs at target level of leakage.

Figure C3 Transitional Cost vs level of leakage for Method A



Method B

The first step is to fit curves to the data for the unit cost of leakage reduction at a range of leakage levels. A relationship may be produced for each of detection cost and repair cost. (In this example, power laws will be used.)

i.e. $$Ud = a * (L - M)^{b}$$

$$Ur = c * (L - M)^{d}$$

where Ud is the unit detection cost for leakage reduction (£ per l/day)

Ur is the unit repair cost for leakage reduction (£ per l/day)

L is leakage level (l/prop/day)

a,b,c,d are fitting constants

For this example: a = 17.78, b = -1.33, c = 0.44, d = -0.45.

i.e. $$Ud = 17.78 * (L - M)^{-1.33}$$

$$Ur = 0.44 * (L - M)^{-0.45}$$

Integrating this over a year gives:

$$Cd = -53.88 * (\left(L_1 - M + NRR\right)^{-0.33} - \left(L_2 - M\right)^{-0.33})$$

$$Cr = 0.80 * (\left(L_1 - M + NRR\right)^{0.55} - \left(L_2 - M\right)^{0.55})$$

where Cd is detection cost (£/prop/year)

Cr is repair cost (£/prop/year)

L_1 is leakage level at the beginning of the year (l/prop/day)

L_2 is leakage level at the end of the year (l/prop/day)

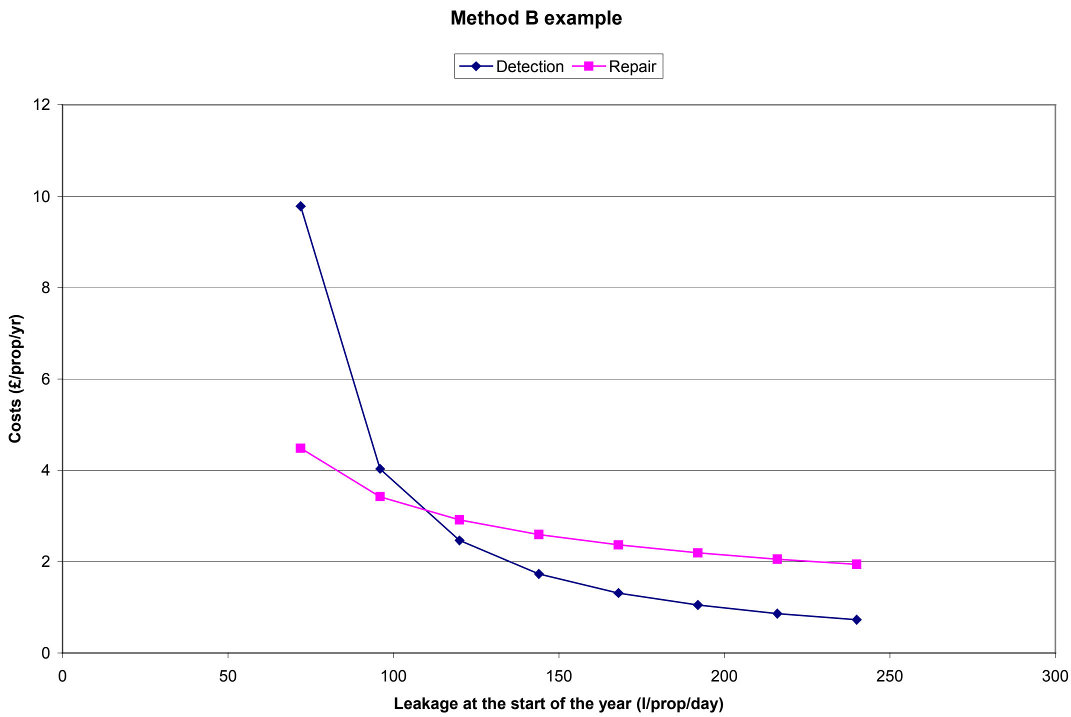
These equations explicitly include transitional costs when the leakage level changes from L_1 to L_2 over the year. With the data given at the beginning of this Appendix and assuming that $L_2 = L_1 = L$ (steady-state), these become:

$$Cd = -53.88 * (\left(L - 12\right)^{-0.33} - \left(L - 60\right)^{-0.33})$$

$$Cr = 0.80 * (\left(L - 12\right)^{0.55} - \left(L - 60\right)^{0.55})$$

The equations are plotted in Figure C4.

Figure C4 Steady state detection cost vs level of leakage for Method B



APPENDIX D PROCESS FOR INCORPORATING ENVIRONMENTAL AND SOCIAL COSTS AND BENEFITS

In this Appendix we provide in more detail our suggested process for undertaking desk based evaluations of environmental and social costs and benefits.

Our purpose is threefold. To:

1. show that values for environmental costs and costs of water derived from currently available methodologies can be related to leakage;

2. highlight how the process can be used to identify the sensitivity of the ELL to changes in the factors determining costs.

3. Demonstrate the exercise that companies should be expected to carry out in order to identify the major drivers of the external costs and benefits associated with leakage reduction that might require more sophisticated quantification.

To illustrate the suggested process, we have constructed a hypothetical "case-study" derived from company marginal costs, active leakage control costs and environmental / social costs and benefits. We emphasise that this exercise should be regarded as a demonstration of the evaluation process only.

D.1 DATA AND EQUATIONS

The following defines the data inputs necessary to implement the evaluation:

- Data / equations for the (private) marginal cost of water and active leakage control costs. These should be based on the best practice recommendations highlighted elsewhere in the report.

- Data relating to the characteristics of the environmental and social impacts identified in the relevant supply zone. For example on the former, the surface-water and groundwater sources within a supply zone, their quality, flow and accessibility. On the latter, the impact of leakage control activity on traffic disruption is required.

- The number of connected properties within a supply zone. This is used to scale some of the cost and benefit measures that are quantified in terms of "per property".

D.2 METHODOLOGY

Consistent with section 4.4, quantification of the following cost and benefits are required:

- Private costs (to the water company) of leakage (which define the private benefits of leakage reduction);

- Private costs (to the water company) of leakage reduction activity;

- Environmental and social benefits of leakage control; and

- Environmental and social costs of leakage control.

Private costs of leakage

The equation for the marginal cost of water was applied to leakage per property. Thus, if leakage control measures reduced leakage per property to 60 litres/prop/day then this equation provided the value of that losing that water. At higher levels of leakage the total cost of the water being leaked would be higher.

Private cost of leakage control repair

The leakage cost equation gives the amount of spending required to maintain leakage at any particular level. Application of the leakage cost equation gives the cost of any particular level of leakage in £/prop/yr.

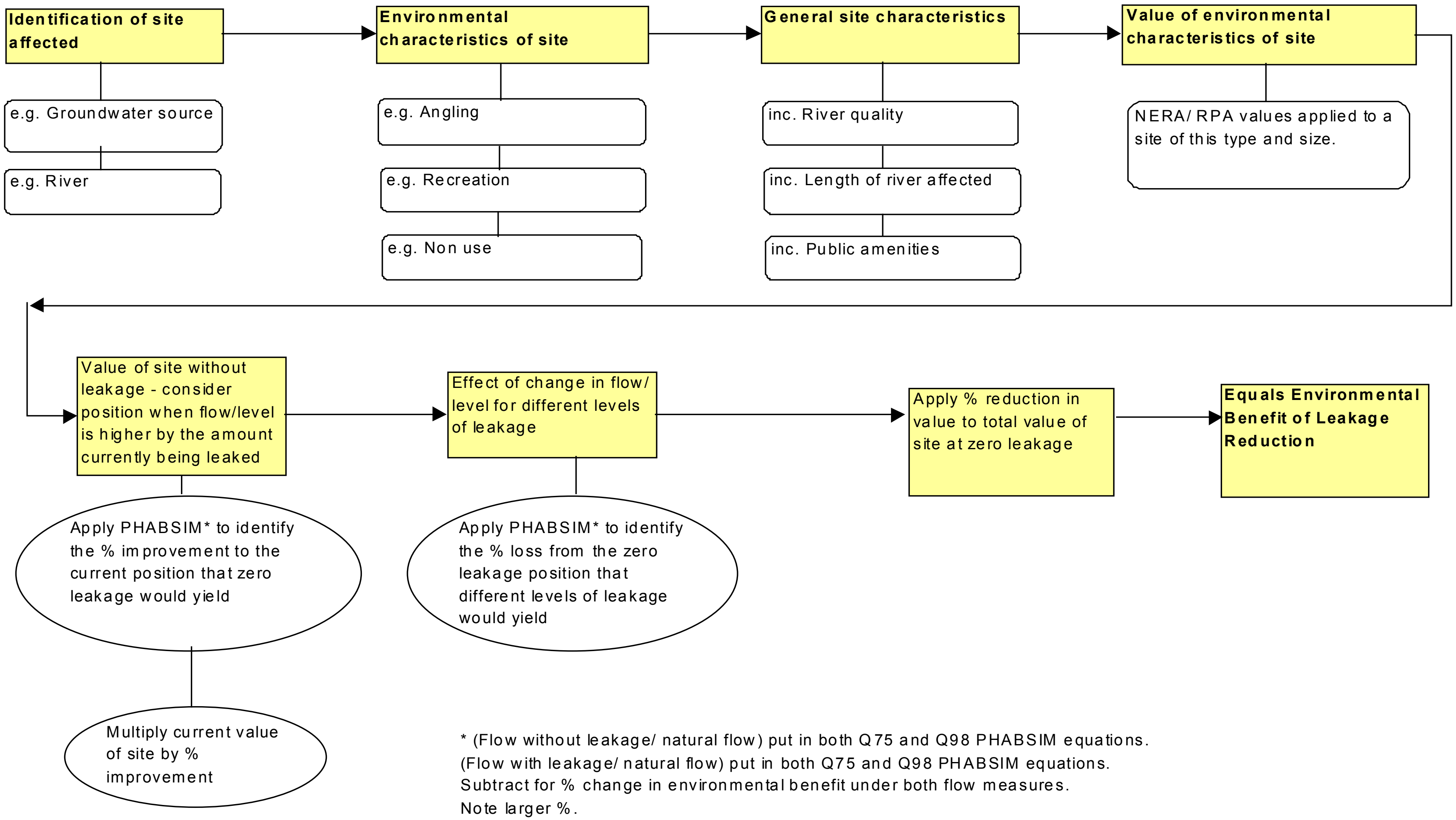
Environmental benefit of leakage control

Environmental benefits were calculated according to the RPA and NERA methodologies that use specific data on water company sources combined with standardised values for those types of river and reservoir. This value is measured in £/yr and then converted to £/prop/year.

The value of benefit calculated initially is measured against some base of severe degradation. This value then needs to be adjusted using the EA's PHABSIM methodology, to relate the increase in flow from reduced leakage to the value of the improvement in river quality. We suggest, for example, the change in river flow can be established from the reduction in leakage per property per day multiplied by the number of properties.

Figure D.1 illustrates the quantification process step-by-step.

Figure D.1 Process for identification of environmental benefits of leakage control



We now illustrate the process with a hypothetical case-study. We assume the following environmental impacts:

- Environmental / non-market benefits due to increased river flows (angling, recreation, agriculture, non-use); and
- Benefits associated with improved reservoir levels.

Value of the environmental impacts

The first step is to quantify using benefits transfer the value of these impacts. We use the benchmark transfer values reported in RPA (1998). Figures D.2 and D.3 summarise the calculations.

ANGLING			
		Case Study Values	
Data required	**Source**	**Value**	**Total (£)**
km of river affected	site specific	20	
type of angling		coarse	
quality of fishery		sustainable	
/km bank/annum	RPA, 2.3	6000	120,000

Figure D.2 Estimated value of angling impacts of improved flows

AGRICULTURE			
		Case Study Values	
Data required	**Source**	**Value**	**Total (£)**
crop type		potatoes	
increase in quantity used (m3)	EA makes license available	10000	
£/m3/an	RPA, 2.4	0.13	1,300

Figure D.3 Estimated value of agriculture impacts of improved flows

RECREATION			
		Case Study Values	
Data required	Source	Value	Total (£)
km of river affected	site specific	20	
Location		urban	
Access/facilities		limited	
/annum/km	RPA, 2.2	1000	20,000

Figure D.4 Estimated value of recreation impacts of improved flows

NON USE VALUES			
		Case Study Values	
Data required	Source	Value	Total (£)
km of river affected	site specific	20	
Population		180,500	
site type		RE3 or RE4	
/km/hh/an	RPA, 2.5	0.04	144,400

Figure D.5 Estimated non-use values for improved flows

RECREATION AND ANGLING			
		Case Study Values	
Data required	Source	Value	Total
Site type		Reasonable	
Quality		Central	
/visit/yr	RPA, 4.2	6	1,500,000

Figure D.6 Estimated recreation & angling benefits of improved reservoir levels

In total the estimated benefits of leakage reduction are £1.84 million.

PHABSIM Adjustment of the Environmental Benefits

The second stage of the calculation adjusts the initial values for the flow impacts attributable to leakage reduction. Figure D.7 sets out the data inputs required to identify to compute the PHABSIM adjustment factor.:

- Assume current leakage 100 litres/prop/day above policy minimum = 18.05Ml
- Add this to current flow at Q98 and Q75 for zero leakage flow level

Data required	Source	Hypothetical value	as % of Q natural	Env benefits	change in env benefits
Leak reduction (l/prop/day)		Enter each level under consideration			
No. of HH		180500			
River band		3			
Natural flow (Q98)		30			
Current flow (Q98)		60	200%		
Zero leakage flow (Q98)		78.05	260%		
Natural flow (Q75)		100			
Current flow (Q75)		130	130%	50.871	
Zero leakage flow (Q75)		148.05	148%	50.99194	12.09%
PHABSIM equation for band Q75	0.67X + 50				

Figure D.7 PHABSIM Adjustment of environmental values

- Environmental benefits from current flow = 0.67 x (current flow/ natural flow) + 50
- Environmental benefits at zero leakage flow = 0.67 x ([current flow + current leakage]/natural flow) + 50
- Value of environmental characteristics at zero leakage = £2.065 million = 1.1209 *£1.84 million.

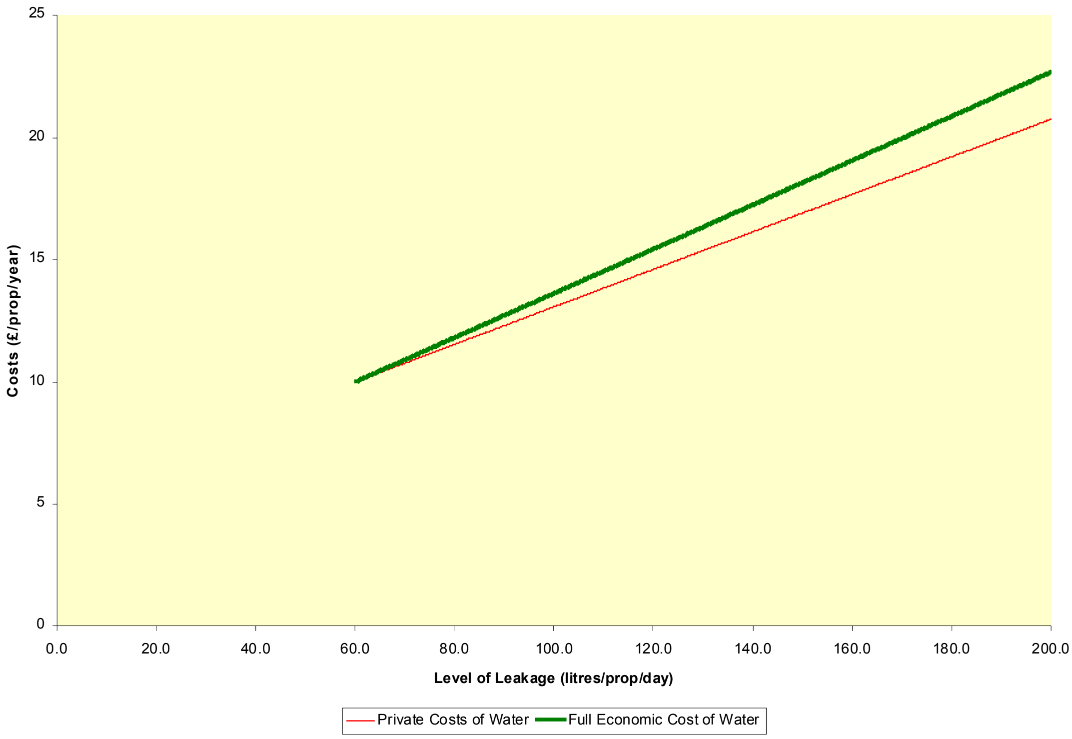
As we are quantifying the cost of leakage, we want to estimate the reduction in this benefit for different levels of leakage occurring. For the purposes of this example we looked at increments to the level of leakage of 0.2 litres/prop/day above the policy minimum of 60 litres/prop/day. Across all properties this equates to a leakage of 0.036Ml/day

We assume that this reduces the flow in the most environmentally sensitive river by 0.036Ml/day, therefore its flow is 148.05 – 0.036Ml/day. From PHABSIM the environmental benefit of this level of flow is 0.67 x (148.014/100) + 50 = 50.9917. The difference in environmental benefit from the zero leakage position = 50.9917 – 50.7719 = (-0.0002) or 0.02%

Thus the cost of leakage (policy minimum = 60) + 0.2 l/prop/day is 0.02% of £2,065,323 = £500.

Using a spreadsheet allows this calculation to be replicated for the whole range of leakage levels under consideration. Figure D.8 illustrates the schedule of environmental costs derived using this desk-top methodology.

Figure D.8 Calculated private and social costs of water



Social costs and benefits of leakage control

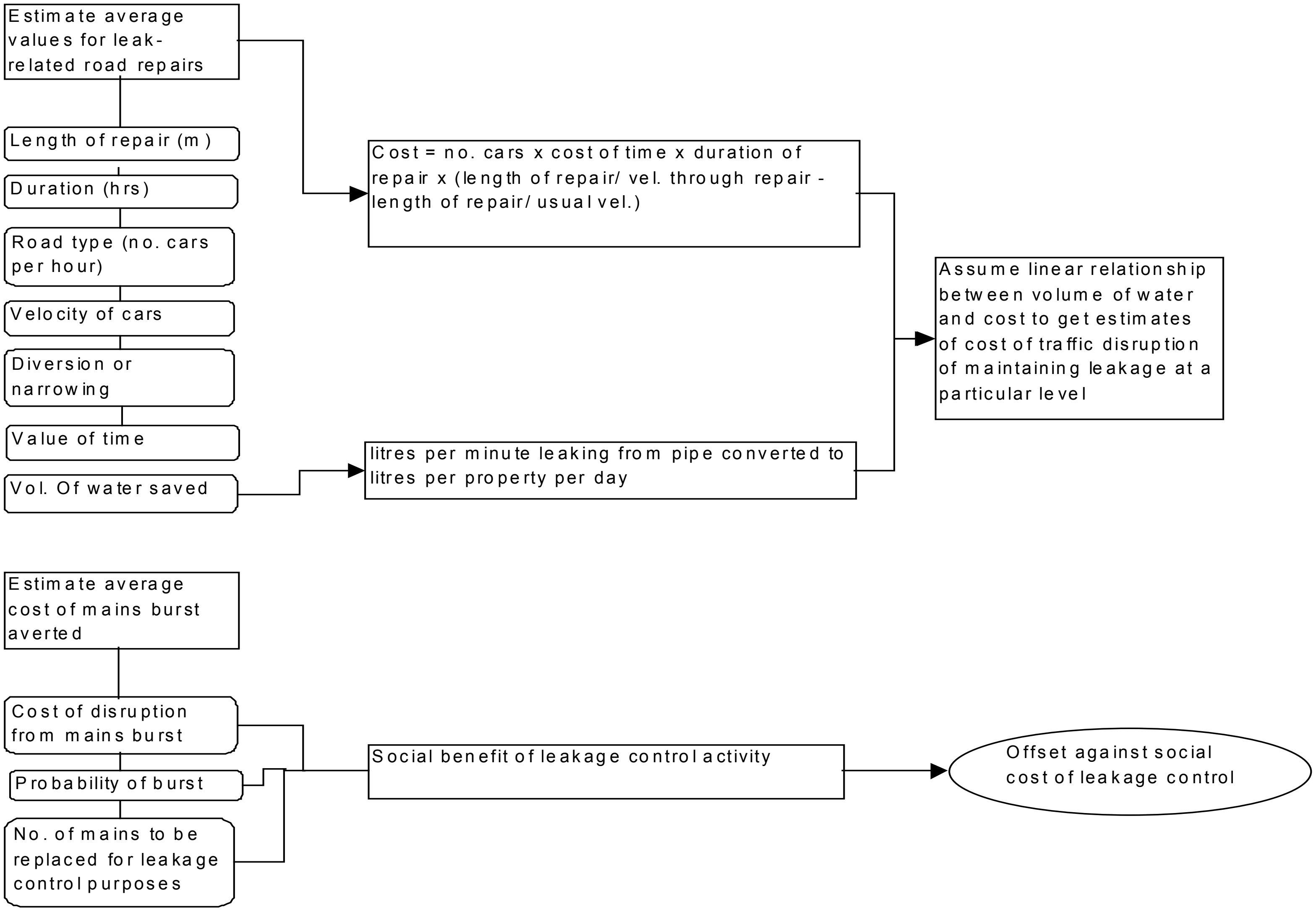
We recommend that consideration is given to the calculation of the *net* social cost. This would require offsetting the social benefit of deferred disruptions (through reduced probability of disruption).

The calculation of this value is closely associated with the method of leakage repair under consideration. For example, find and fix policies are more likely to be associated with a net social cost since they are reactive by definition. Conversely, programmes of planned mains replacement may be associated with social benefits in excess of social costs given the reduction in the likelihood of mains bursts in the future. It can be expected that these benefits will be correlated with the importance of any given highway. For example, the consequences of a mains burst on a major "A" road or dual carriageway will be higher than for a smaller "B" road.

The likely number of roadworks, their location, duration and length will be required as inputs to the calculation. If large amounts of roadworks are anticipated then average or mean values will produce a fairly reliable estimate. If it is observed that the distribution of roadwork impacts is skewed in any of the dimensions (e.g. duration, length) then the median will provide a more robust measure. The cost per hour of a road work is multiplied by number of roadworks and number of hours to obtain the total cost per year.

Figure D.9 illustrates the quantification process in more detail.

Figure D.9 Process for quantifying social costs and benefits of leakage control



The following details provide an example benefits transfer calculation using the process map detailed above. NERA (1998) provides the original transfer values. Note that this calculation does not include any offsetting benefit of active leakage control methods such as mains replacement. The example calculates the cost of a road diversion.

Figure D.10 Data inputs to calculate social costs of road disruption

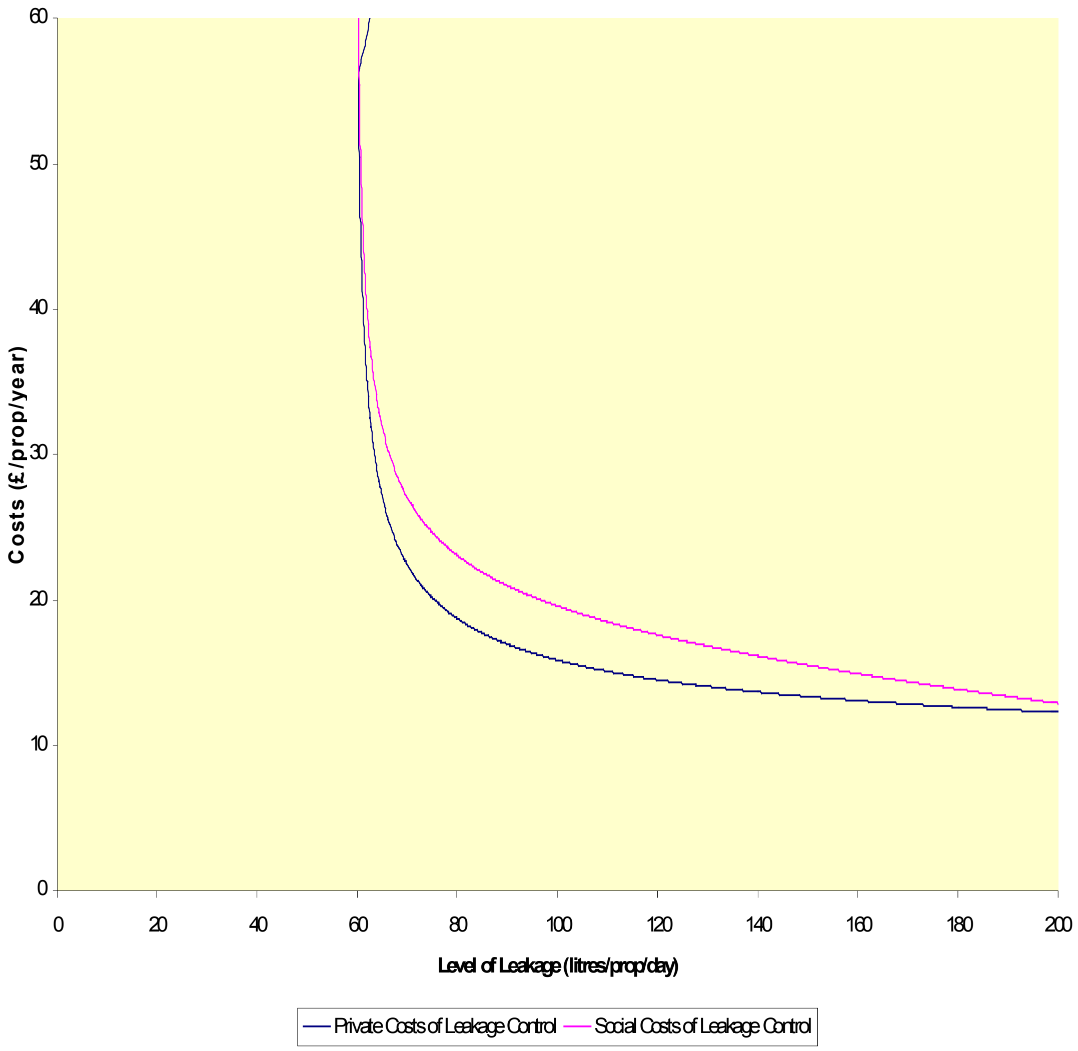
		Hypothetical values		
Data required	Source	Value	Total	
Road type	site specific	A, built up		
vehicles/hr	NERA, box 1	300		
ave. speed (km/h)	NERA, box 1	39		
disruption type	site specific	narrowing		
length of diversion /disruption (km)	site specific	0.2		
Hours of disruption	site specific	6		
time cost per vehicle	NERA, box 1	9.217		
regional weight	NERA, box 1	1	28.36	=300*6*9.217*1*(0.2/(39*0.75)-0.2/39)

- Change in speed due to road narrowing = 0.25 x 39 = 30km/h
- Additional time to get through disruption = (0.2/30 – 0.2/39) = 0.0015hrs
- Cost per vehicle = 0.0015 x 9.217 = 0.094
- Total cost = 0.094 x 300 = £28.36

This is the cost per hour of one road work on a road with these characteristics. We now need to find the likely number of road works and their duration that are likely to be required with any leakage reduction scheme. Thus the total cost will be a function of (Number of roadworks x duration of roadworks x 28.36), where the numbers and duration can be computed for each level of leakage or leakage reduction.

Figure D.11 illustrates the private and social costs of leakage control computed for the illustrative case-study.

Figure D.11 Private and social costs of leakage reduction



APPENDIX E THE USE OF BENEFITS TRANSFER IN ENVIRONMENTAL VALUATION

E.1 INTRODUCTION

In quantifying the monetary impacts of leakage on the environment it is necessary to apply environmental values. The pragmatic approach we have taken in this study is to propose that companies make rough estimates of the environmental costs of their leakage via a desk based study. This will demonstrate the major cost drivers which companies can then quantify more accurately using more sophisticated techniques.

Whilst there are limitations to environmental valuation, techniques such as hedonic pricing, travel cost and contingent valuation are well established and a great deal of work has been done examining and refining these techniques. Environmental valuation techniques are the only way of estimating the monetary value of environmental impacts which are not traded in the market and money is the standard unit used for comparing diverse costs and impacts. Best practice approaches to environmental valuation can be found in DEFRA guidance on environmental valuation (forthcoming).

Environmental valuation techniques underlie the values presented in the NERA (1998) and RPA (1998) reports. A desk study of the type proposed in this report entails applying the technique of benefits transfer of environmental values, from the original study, to the company site under examination. At present many academics and practitioners are questioning the validity of benefits transfer. Below we discuss the concerns with, and the limitations of, benefits transfer.

This annex has the following structure:

- Section E.2 describes the basic methods of transfer available and the method being applied when using RPA and NERA work;
- Section E.3 presents studies that have revealed the lack of robustness of the technique;
- Section E.4 discusses the reasons why transfer may have failed. Also in section E.4 we look at ways of improving benefits transfer; and finally
- Conclusions are presented in section E.5.

E.2 TYPES OF BENEFITS TRANSFER

This section describes the basic methods for benefit transfer and explains how these are used when applying the values presented in the RPA(1998) and NERA(1998) reports. There are two basic types of benefit transfer;

- Naïve transfer, and
- Naïve transfer with adjustment.

Naïve transfer involves taking a Willingness to Pay (WTP) value directly from an existing study and applying it to the site under review. Although this has the benefit of simplicity, the values may not represent a good proxy for WTP at the new site for the following reasons:

1. Differences in socioeconomic characteristics of the relevant population,

2. Differences in the physical characteristics of the site,

3. Differences in the level of change that is being valued at each site,

4. Differences in the market conditions applying to the sites (e.g. existence of substitutes).

Naïve transfer with adjustment uses quantifiable characteristics of both sites as proxies for these general characteristics. Values from the existing study are adjusted according to the quantifiable characteristics. Adjustment for income differences is the most common adjustment.

$WTP_R = WTP_E (Y_R/Y_E)^e$

Where R is the site under review, E is the site with an existing study, Y is income and e is the elasticity of Willingness to Pay (similar to demand) with respect to income.

Both RPA(1998) and NERA(1998) outline the benefits of original studies to obtain environmental values but, for practical purposes, contain values to be used for benefit transfer. The method of benefit transfer for these values differs depending on the characteristic under valuation. In some cases, such as the estimation of recreation value the site is first of all characterised according to some of its qualitative attributes, then a value for a site with such attributes is applied directly to the site. It can be assumed that by choosing the description that fits the site best, the researcher is actually choosing the most suitable valuation study from which to transfer values through a naïve transfer approach. Other cases start with a value, such as the value of time, and adjust for relative characteristics of the site (number of vehicles and average speed of vehicles in this case). This approach would be regarded as naïve transfer with adjustment, although it does not go so far as to use income estimates of people near the site.

E.3 VIDENCE ON THE FAILURE OF BENEFITS TRANSFER

In recent years the robustness of benefits transfer has been the subject of much scruntiny. Two major studies that call the methodology into question are Downing and Ozuna (1996) and Kirchohoff et al (1997).

Downing and Ozuna use contingent valuation methodology (CVM) to estimate a function for the WTP for angling in eight contiguous sites. The average function of WTP for angling was compared with the function estimated for any one of the sites, based on the same data. It was found that the estimates of welfare based on these functions were significantly different so using the average function would not have provided a reliable estimate of the site specific welfare. Kirchhoff et al compared the compensating variation (a measure of WTP) estimated through a primary valuation of certain environmental sites with the estimate of the compensating variation that would have been obtained for these sites if this had been calculated through benefits transfer rather than original research. Various statistical tests were then carried out to establish whether the values were significantly different. Of 24 comparisons made, 2 involved errors of over 100% and 6 involved errors of 50% to 100%. Kirchhoff et al then identified the characteristics of the less reliable transfers. This analysis led to the rejection of the more simple benefit transfer measures.

E.4 REASONS FOR FAILURE OF BENEFITS TRANSFER

In order to assess the reliability of benefits transfer of any type it is important to identify the reasons for, or the circumstances of failure. The main reasons for failure are as follows:

1. The original WTP study was not designed with the intention that its results would be applied to other situations. Therefore the site data and socio-economic data collected, whilst being sufficient to model WTP for the site, are not sufficient for adjusted benefits transfer. An original study may have been to value a change in the environment that was not well enough defined for use in other circumstances. For example, an “improvement” in a river.

2. The site used for benefit transfer was not sufficiently similar; different attributes, different socio-economic status of local population, different welfare function.

3. Different forms of WTP study (dichotomous choice, WTP, WTA etc.) tend to give rise to slightly different answers and therefore the choice of study which was selected for the original research might be less applicable to the new site.

4. The magnitude or level of the environmental change being measured could be different between studies, e.g. Applying results from a noise study that valued the cost of a rise in noise from 50 decibels to 60 decibels to circumstances causing a rise from 10 db to 20 db would not give a correct result unless WTP for noise reduction was independent of the existing level of noise. Similarly the cost of increasing noise from 50db to 80db would not necessarily equal three times the cost of 50 to 60db.

5. It has been noted that referendum CVM will give different results depending on whether it takes places ex ante (how much are you WTP to avoid a potential threat) or ex poste (how much are you WTP to not suffer a particular impact). The use of an ex ante value for an ex poste valuation could be a source of error.

6. The substitutes available differ between sites and the proximity of good substitutes will alter people’s valuation of a particular site.

Suggested refinements

There are a number of ways in which benefits transfer can be improved to give more reliable results. These are as follows:

- Benefit Function transfer
- Verbal protocols
- Choice experiments
- Meta analysis

Function transfer

Instead of transferring the WTP estimate (adjusted or otherwise) to a different study site, there is intuitive sense in transferring the function that provides the estimate of WTP based on characteristics of the site and the respondents. This is effectively a much more thorough adjusted transfer. However, a recent study by Ready et al (1999) that compares transfer methods finds that the average transfer error in predicting average willingness to pay was as large for value function transfer as for either type of naïve transfer.

Verbal Protocols

Verbal protocols can give an indication of how respondents formulate their valuation and therefore how amenable this valuation is to application to another site. For example, if respondents have well-formed and articulated views prior to a survey, then they are less likely to be led by survey information, thus their valuation may be applied elsewhere. Linked to this, if respondents are consistent in their approach to analysing a problem of this nature, values are more likely to be transferable. In certain circumstances valuation responses may be liable to change so the value elicited from the original study may not even remain applicable to the original study site for long. If it is found that respondents answer differently depending on the procedure for asking a question then this should be factored in when applying the response to another study.

Choice experiments

Choice experiments are a survey based method of eliciting WTP for environmental goods that differ from Contingent Valuation by their use of scenarios. Instead of stating their WTP for a fixed bundle of environmental goods, the respondent is asked to rank a series of scenarios in order of preference. These scenarios feature different levels of the attributes that are associated with the environmental site, as well as some payment level. There are two apparent benefits of using a CE study for benefit transfer. Firstly, the model generated for a CE study will include levels of environmental attributes as explanatory factors of WTP therefore the levels of each attribute arising at the site under discussion can be put into the model and the WTP calculated. This should go some way to overcoming the risk of applying values to dissimilar sites. Secondly, it is thought that the CE approach causes respondents to think more carefully about substitutes (Adamowicz et al, 1996) and makes these more explicit. If a researcher is aware of the value of substitutes in the original study he/she will have some idea of the relative impact of substitutes in the site under review. However, more work needs to be to done to assess whether the functions estimated from choice experiments are more suitable for transfer.

Meta Analysis

Instead of basing the transfer value on the value of WTP estimated for one particular site an average value could be obtained from a series of WTP studies. This would prevent an unusual value or study having too great an influence on the estimate of WTP. The “average” value used could be a simple average, a weighted average or an average obtained through more sophisticated analysis of the original study.

Meta analysis is currently being used to examine the differences in results in WTP studies to improve these further.

PHABSIM

Most of the existing studies concerning the environmental value of rivers are based on the benefit of improving a low flow river. In order to apply the results of these studies to rivers which do not have flow problems, PHABSIM was applied by RPA (1998). This hydrological modelling tool relates current and proposed flows to the natural flow of a particular river. The change in the ratio from current:natural to proposed:natural is fed into an equation that translates the change into the change in environmental benefit/ cost arising from the flow change. The output of the equation is a percentage change in the environmental benefit that needs to be applied to the total change in environmental benefit.

Without primary studies on normal flow rivers which can a) be used to test how reliable PHABSIM is and b) be used as a source of benefit estimates which can be transferred, there is no alternative but to use PHABSIM. However, there are two important limitations to the application of PHABSIM to adjust benefit transfer values:

1. The PHABSIM equation for at least one river band is linear which means that the environmental benefit of an additional litre of flow is the same whether the river is suffering a flow problem or whether the flow is close to its natural level. This implies that people are indifferent between improving the flow of a “problem” river and an almost normal river. It seems more likely that the worse the condition of a river the more people would be prepared to pay to improve it.

2. Environmental benefits are made up of various attributes such as numbers of fish, recreation value and non-use value. PHABSIM implicitly assumes that a change in river flow will have the same percentage value change in each of these, i.e. that they are all equally responsive to river flow.

The worked example in the text uses PHABSIM as a way to estimate the benefits of different levels of flow change, as well as applying low flow valuations to non low flow rivers. This practice begs a question of the original studies. When people were asked to value the benefits of an improvement in the flow, what volume of flow improvement was actually being suggested? The absence of this piece of information does not jeopardise the original study, provided that respondents were all envisaging the correct level of flow change, but it does make it quantification of the benefits of a different flow change more difficult.

Population

Once average willingness to pay estimates are derived for a non-use good, either through original study or through benefits transfer, these need to be applied to the relevant number of people in order to estimate the total cost of a particular change. The size of the population to which WTP estimates are applied can alter the total valuation of the site completely. Earlier suggestions on appropriate population included, counting everyone in the water company area, and counting everyone within a 60km radius. The former of these two approaches is particularly arbitrary because it would lead to the conclusion that rivers in small water company areas were less valuable than those in large water company areas. The use of 60km is a pragmatic approach but risks overstating the benefits of changes in unknown, unimportant rivers and underestimating the benefits from sites of national interest.

If original research is being carried out it is possible to survey people who live at a range of distances from the site and note whether,

a) there is a decline in response further from the site,

b) there is a lower incidence of WTP > 0 further from the site, and

c) whether WTP, where positive, is lower further from the site.

From this information it is possible to build up a more robust picture of distance decay.

In the situation that original research was not being carried out there might be a need to transfer the distance decay function, provided that information had been provided on sites such that an appropriate site could be selected for comparison. Currently the EA is sponsoring research work on the statistical derivation of distance-decay functions for the River Mimram.

E.5 CONCLUSION

From the arguments presented above it is obvious that benefits transfer is a hazardous exercise. For the purposes of calculating the efficient level of leakage, carrying out original studies on all possible environmental impacts and savings would be expensive and time consuming. For this reason we recommend the desk study, based on benefits transfer, as the initial approach, followed up by original research work on the environmental values that make a significant difference to the ELL.

APPENDIX F TRADEABLE PERMITS FOR LEAKAGE CONTROL

F.1 INTRODUCTION

There is considerable work in the environmental economics field concerning the use of tradable permits as instruments to achieve specific policy goals in an economically efficient manner. The UK Government is currently planning to use tradable permits in three areas of environmental policy. These are in reducing the amount of waste going to landfill, reducing emissions of greenhouse gases and reallocating abstraction rights from rivers. The purpose of this paper is to examine the practical issues relating to tradable permits and discuss how these issues were resolved for the three cases discussed above, then outline the options for a leakage permit trading scheme.

- Section 2 of this annex describes the purpose and status of the three tradable permit schemes currently under development.
- Section 3 discusses the major issues arising in tradable permit schemes and how each scheme under development proposes to deal with them.
- Section 4 puts the debate into the context of leakage.

This annex aims to give a high level guide to tradable permits for leakage. Further work and consultation on the issues raised would need to be undertaken to develop the scheme more fully.

F.2 EXPECTED TRADABLE PERMIT SYSTEMS

The theory behind using tradable permits as a way to securing environmental goals has featured in Government literature for some time. The Department of the Environment paper, “Economic Instruments for the Environment” (1995) and the follow up paper by Department of the Environment, Transport and the Regions (2000) both present the advantages and disadvantages of tradable permits. To date there are no Government schemes using these sort of instruments but there are three which are in various stages of development. These relate to greenhouse gas emissions, water abstraction and landfilling.

UK Emissions Trading Scheme

In August 2001 the Department for the Environment, Food and Rural Affairs published its “Framework for the UK Emissions Trading Scheme”. The purpose of this scheme is to achieve reductions in the six greenhouse gases which, under the Kyoto Protocol, the UK has agreed to reduce by 12.5% on 1990 levels by 2010. As the Government is introducing the scheme in advance of targets needing to be met, it is to operate on a voluntary basis.

The objective of the Emissions Trading Scheme is to reduce emissions in an economically efficient manner. This is achieved by providing an incentive to all those who produce greenhouse gas emissions to reduce emissions whilst permitting those with high costs associated with reduction to purchase allowances from those who have made reductions instead of making reductions themselves.

> "Emissions trading is a unique instrument that allows the market to reduce emissions by stimulating cost effective innovation and investment." - M. Meacher (Minister for Environment)

The initial auction of allowances is to take place in January 2002 and the scheme is to come into operation in April for a compliance period to run from January 2002 to December 2002.

Tuning Water Taking

Tuning Water Taking was published in June 2001 to present the Government decisions following the consultation on the use of economic instruments in relation to water abstraction. As a result of the consultation process, the Government decided to pursue a policy that allows abstraction licences to be traded. The purpose of the consultation was to determine how the abstraction authorisation system could "contribute to sustainable development by protecting and, where possible, enhancing the aquatic environment whilst facilitating economic growth and higher living standards with minimum impact on water consumers' bills" (Taking Water Responsibly, DETR, March 1999). Tradable abstraction permits offer more rational use of water by allowing water users with high economic costs of reducing water consumption to take advantage of the reductions which can be made by another user who places a lower value on the water in use.

The Government's view, as set out in Economic Instruments In Relation to Water Abstraction: A Consultation Paper, is that,

> "… in principle, abstraction licence trading should be promoted as an effective means of achieving the optimal distribution of water resources within and between different sectors of use and thus contributing to sustainable development"

Legislative changes required to allow the licence trading envisaged are included in the draft water bill. At present the Environment Agency (EA) is charged with holding consultations on the new charging scheme for abstraction licences and on how it should assess "reasonable need" as required for determining who should be allowed to hold licences. The EA is also to prepare its staff for further developments in Licence trading and to establish a precursor licence trading web site.

Tradable Landfill Permits

From March 2001 to June 2001 the DETR/ DEFRA held a consultation on the trading of permits that would constrain the landfilling of Biodegradable Municipal Waste by Waste Disposal Authorities. The Government is committed to reducing the amount of waste going to landfill by 35% of the 1995 level by 2020 under The Landfill Directive[4] (1999). Such a system would also assist in meeting the UK's own domestic targets.

Tradable permits were chosen as the preferred approach because they give certainty in meeting the targets whilst generating low compliance and administration costs and little transfer of wealth in or out of the Local Authority system. Tradable permits were considered to be consistent with the principles of transparency, consistency of application, ease of administration and enforcement, proportionality of effect and accountability.

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[4] 75/442/EEC

The details of the trading system are currently under development.

F.3 ISSUES ARISING IN TRADABLE PERMIT SCHEMES

The main issues generic to tradable permit schemes are the following:

1. Determining who can participate.
2. The initial allocation of permits.
3. The duration of a permit.
4. The method for transferring permits.
5. The reduction of permits to meet tighter environmental targets.
6. The monitoring and sanctions for permits.
7. The effects on competition.
8. The banking and borrowing of permits.

Each of these issues is discussed in turn and some conclusions for the permit schemes discussed above are noted.

Who can participate?

For most tradable permit schemes there are a group of people who can be identified as contributing to the environmental impact and a wider group of people who experience the impact. The intention of most trading schemes is to issue permits to the level of environmental impact that is "acceptable" and then allow those who have difficulty in reducing their environmental impacts to purchase permits for the quantity of impact they will continue to produce. However, public and environmental groups who experience the impact may wish to purchase permits as well with the intention of keeping them out of circulation so that the level of the environmental impact is reduced further. Determination as to whether such groups can participate in trading depends on the risk of excessive permits being withdrawn such that companies are forced into extremely expensive environmental constraints, relative to the benefit of groups with environmental preferences being able to reflect these in a market.

In the case of the Landfill Permit Trading proposals, only Waste Disposal Authorities can own permits. Whilst these Authorities are not responsible for the waste that goes to landfill (in the same way that water companies do not produce the effluent they have to discharge safely to water-courses), they have the power to encourage waste minimising behaviour and facilitate diversion to other waste management routes. Under the rules developed for the Environment Agency's Catchment Abstraction Management Strategy process, only those who can demonstrate a need for water can obtain an abstraction licence. This regulation, which is designed to prevent water users from holding extra Licences which could then be brought into use without warning, would prevent non water users from buying up Licences with a view to keeping them out of circulation. Participation in the Air Emissions Trading Scheme covers all those who emit greenhouse gases either directly or indirectly. As it is commencing on a voluntary basis there is no obligation for any organisation to become involved. However, participation is open to organisations that emit greenhouse gases as part of their activities or consume electricity (the production of which results in the emission of greenhouse gases). Households amongst others are specifically excluded so there is little scope that permits will be hoarded.

Debate in the US concerning emissions trading has focussed on whether greenhouse gas reducing “carbon sinks” should be able to create permits. This would open the door to participants from industries whose production offset the environmental impacts that were being targetted.

Initial allocation

Permits can be allocated based on historical levels of environmental impact (“Grandfathered”) or can be allocated afresh through some allocation procedure, frequently an auction. The basic advantage of grandfathering is the smooth transition it allows participants as the allocation of permits will be closely related to their current performance so participants will not be faced with an abrupt need to reduce impacts or purchase permits. However, grandfathering disadvantages those who have already reduced their environmental impacts.

Auctioning permits indicates that the property right for the environment is with the party that gains the revenue resulting from the auction. Auctioning can be seen as a fair way of allocating permits as participants with high previous levels of impact pay a price reflective of this. However, an auction could also result in some participants facing a sudden shift in their targets and financial power rather than need could drive this allocation.

Where generation of the environmental impact relates to providing goods or services to a particular customer base, eg. individuals or households, there may be justification for allocating permits according to the number of customers being served. This has the advantage of fairness and not disadvantaging those who have already taking impact-reducing action. However, the unconstrained occurences of environmental impact must be similar across all customers for this to offer a level playing field to participants.

The schemes currently under development show a variety of approaches to this problem. The emissions trading scheme, because it is voluntary, requires that participants bid the reductions they are able to achieve in an initial auction. For water abstraction the consultation found divided views about the method of allocation. As abstractors already hold Licences there was no question of removing and reallocating these therefore the debate centred on the method for allocation of new Licences. The Government is of the view that in general the EA should undertake to issue these on a basis of need, though the option of auctioning is available for specific circumstances. For landfill permits the Government was clear from the outset that these would be grandfathered. However, the consultation allowed for discussion as to whether the allocation should be based on current landfilling rates or rates in 1995, the date upon which the 2020 target is based.

Duration of a permit

In determining the duration of a permit the policy maker makes a judgement about risk to the environment relative to risk to the permit holder. If permits only allow an activity for a short period of time then it is easy to change the overall quantity of permits or the terms of permits in response to a change in the environment (or improved information on an existing environmental problem). However, permits with a short lifespan create risks for companies which try to plan their business activities over a long time horizon. A major investment may be written off if supporting permits are unexpectedly unavailable. Such risks force businesses to insure or undertake more expensive investment options which raise costs to business consumers or effect international competitiveness.

The Environment Agency has recently proposed that all abstraction licences are to have a life span of five years. Some water companies are arguing that because the development of an abstraction source is an expensive and long term investment this time constraint could add significantly to their costs.

Method of transferring a permit

A permit may be bought or sold by any eligible party. For monitoring purposes a register needs to be kept of which organisation holds permits. An electronic permit can meet the requirements. The schemes under proposal distinguish between a trade and a transfer of a permit. A trade refers to a financial transaction concerning an allowance to create a certain amount of environmental impact. Depending on the sophistication of the market futures trades are possible. A transfer refers to the explicit movement of the permit to another participant and this is the transaction of importance in the eyes of the monitoring agency. All three schemes allow for electronic trading and transfer.

Trades and transfers may be carried out bilaterally or through a broker. Depending on the volume of trade in the market a broker may be very useful in bringing together parties with a trading interest who might not be able to find a suitable partner otherwise. Brokerage also allows anonymity, which may be regarded as desirable under certain circumstances.

Reduction of permits to meet environmental targets

In many situations a permit system is being introduced as a vehicle for reducing environmental impacts. If permits were only issued to the level of the final target at the outset, organisations would face a very high cost of complying with the new targets immediately. It is more efficient to introduce a quantity of permits that is similar to the existing level of impact, then reduce the amount of impact permitted over time. The three main ways of doing this are by either,

- Programming the allowance associated with the permit to reduce by x% automatically each year to meet the final target.
- Holding an auction for a reduced number of permits each year.
- Setting targets for individual participants that are reduced over time.

The landfill permit scheme uses the third approach such that the Government gives each participant its own target for reduction which it may either meet directly or purchase permits to cover. In this case interim targets are also set for which will gradually decrease, meanwhile the same permits, representing the same allowance, remain in circulation. A variation of this is to be used for the emissions trading scheme with the refinement that participating organisations' initial targets are based on levels offer to set themselves. (These levels will be determined through an auction process in which participants will offer to reduce their emissions over a 5 year period, thus giving themselves a lower cap, in return for money.)

Tradable permits for abstraction will work differently because a reduction in abstraction is not the fundamental objective being pursued; the objective is to minimise environmental impacts from abstraction. The scheme gives an incentive to participants to reduce their overall abstraction but the EA will use its powers of Licence issue and revocation to control the actual quantity of licences in circulation.

Monitoring and Sanctions

Where permit schemes are introduced to meet international agreements the Government has a responsibility to carry out at least high level monitoring of the scheme to ensure that the UK will not fail to meet its obligations. However, a high quality monitoring system is always desirable to ensure the credibility of the scheme in place. The monitoring body would have responsibility for maintaining a record of permit ownership. It would need to reconcile permit ownership with actual environmental impacts, e.g. for the landfill permit scheme the EA will need to cross check the records held by landfill operators which identify the quantity of waste disposed of by different authorities, with the permits held by these authorities. It would be responsible for taking action against participants who do not comply with the rules of the scheme. In the case of the emission permit trading scheme the Government intends to set up an Emissions Trading Authority as an independent statutory body to carry out this role.

It is desirable that price information is available to participants in the market in order that a competitive price for permits can be established. Economic Instruments for Abstraction proposed that the EA should regulate, broker through its website and publish aggregate price information. For schemes with more participants this obligation on a monitor might be particularly onerous and participants might agree to set up a market independently that carries out the trading and price reporting but is subject to the scrutiny of the legal monitor.

Penalties are important in ensuring the scheme is not abused, which would render it ineffective and non-credible. Penalties should give the incentive to adhere to the rules of the scheme without being disproportionate to the offence. The Government has not decided the type of sanction to apply for those who fail to comply with the rules of the landfill permit scheme. The standard options of fining or criminal charges are supplemented in this case by “Intervention through Best Value.” The latter is a scheme that applies only to local authorities that would fine them for non- compliance but provide means of assistance in future years to help the achievement of compliance.

Primary legislation needs to be passed before statutory penalties can be set up for non-compliance with the emissions trading scheme. At present the only sanctions available to Government are the non-payment of incentive payments and the public stigma for participants failing to make their targets.

Effects on competition

The introduction of a tradable permit system can have impacts both in terms of competition for permits and inter-business competition in product markets. We discuss these in turn.

Competition for permits

A competitive market requires a large number of buyers and sellers such that an individual participant cannot influence price and the free flow of information concerning the product and its going price. Through the monitoring/ market system information on the price and availability of permits (which are standardised) should be available to interested participants. However, there is a risk that the market has a low number of participants. Under these circumstances it might be possible for player to buy a large number of permits and control their distribution, keeping prices high. If other participants are effectively using the permit as an input to production then they must either pay a higher cost to obtain permits or adjust their production process such that they no longer need the permit. Either option would impose high costs on participants.

This sort of behaviour is already a risk in markets of long standing, such as the diamond market or the aluminium market. However, given the regulated nature of the scheme these risks can be reduced by the intervention of the regulator; either the one responsible for the operation of the scheme or the Office of Fair Trading, which deals with market failures in otherwise unregulated markets.

Competition within product markets

It may be the case that all producers of certain goods or services will generate the same environmental impact. If there are producers of other goods and services who also generate that environmental impact then permits will be traded over a wider base and the risk that permit holding activities would constrain producers in a particular product market is reduced. There are many activities that result in the production of greenhouse gases so there is little chance that one producer will try to enhance its position in the product market through strategies in the permit market. However, if the environmental impact being traded only arises as the result of production of one product or service then there may be scope for some companies pushing up the price of permits in order to force up the production costs and hence prices of their competitors.

Again, bodies like the OFT would have powers to deal with such situations should they arise, though if the likelihood of this problem was great, it might act against the idea of a tradable permits scheme in the first place. Rules might be introduced that time limit the holding of unused permits so a participant purchasing extra permits to gain competitive advantage would be forced to sell them or see them forfeited. However, such time limits would need to be introduced with care because additional permits might be held to insure against uncertainty in impacts rather than as an anti-competitive action. There has been a great deal of debate on this issue with regard to water abstraction licence trading.

Banking and Borrowing Permits

Scheme rules must make it clear how unused permits are to be treated. A participant that does not use its permits in a particular year has the option of trading them at year end to assist other companies with their reconciliation. However, it may not wish to do this if it expects that its own environmental impacts will be higher in the next year or if it anticipates an increase in the price for permits. Allowing permits to be banked gives the participant the flexibility to hold onto permits. However, if the UK is committed to achieving particular targets in every year a significant quantity of banked permits may cause impacts to exceed the target in a future year. Banked permits must also be subject to the same rules as existing and newly allocated permits, in particular if the allowance associated with a permit is to decline over time.

Borrowing permits against the future allocation postpones actions required from participants. Although this may allow participants to set their own timetable for compliance it creates a risk that a significant number of participants will all borrow permits and then will find they have a very large obligation to meet when they need to start "repaying" these. It is conceivable that the Government could come under pressure to relax the targets and allow them a more gentle transition.

The Emissions Trading Scheme permits the banking of permits (with the proviso that they could be subject to an x% cut in value at some point in the future) but will not allow borrowing. As abstraction licences currently state the rate of abstraction permitted there is no presumption that these will be changed to allow higher abstraction than this level following a period of low abstraction thus no type of banking is possible (and the only way to allow for greater abstraction in a subsequent year is through obtaining another licence).

F.4 OPTIONS FOR LEAKAGE PERMIT TRADING

Leakage permit trading could be used as an alternative to setting leakage targets. Instead of requiring that individual companies achieve a certain level of leakage reduction, a permit trading system could be set up with the total number of permits issued equalling the total amount of leakage allowed. Water companies would then either reduce their leakage or purchase permits within the framework. Leakage permit trading would ensure that a specific level of leakage reduction was achieved either nationally or at each catchment area without prescribing the leakage permitted by individual companies.

Advantages of the approach

One of the advantages of this approach is that the same level of leakage reduction is achieved but in a manner that is responsive to the differing costs of leakage control between companies. Hence companies with low costs of leakage control can reduce their leakage significantly and create leakage credits which can then be purchased by those with higher costs of leakage reduction. The overall leakage reduction can therefore be achieved at lower cost.

The price of traded leakage permits would reveal how much companies were willing to pay to avoid carrying out leakage control. They would be willing to pay for permits so long as the price of these was below the company's cost of leakage control. Hence the cost of leakage control activity for different companies would be revealed to the regulator in a much more effective fashion than the placing of information requirements on companies.

There is an incentive to companies to reduce their leakage further because they can sell permits. In other words out-performing against an initial leakage target can become profitable for those water companies where the marginal costs of leakage control are below the selling price of the leakage permit

Existing issues the approach does not address

Leakage permit trading does not reduce many of the problems associated with the setting of leakage targets. In particular, the following problems remain;

1. Determining the quantity of permits – this needs to be calculated based on the private, environmental and social cost of leakage for the market as a whole in a similar way to the calculation of the ELL for each company. It therefore depends on companies revealing their costs accurately.

2. Monitoring leakage and leakage control activity – any policy that requires costly activity to be undertaken must be monitored as participants have the incentive to cheat. Under a tradable permits scheme the monitor must ensure that each company is controlling leakage at the level allowed by the permits they hold, under a leakage target scheme the monitor ensures that the target is not being exceeded.

Potential disadvantages of the approach

If a trading scheme is properly set up with regard to the issues discussed in Section F.3 then, from an economic perspective it should be at least as effective as a leakage target approach. (A trading scheme in which no one trades equates to a leakage target on each company.)

One potential outcome of trading, however, is that some companies may buy permits and increase their levels of leakage. Whilst this might be an economically efficient outcome there might be political issues with such an increase, even if leakage is being reduced overall. This problem could be overcome by limiting the permit market in some way. For example, water companies could be limited in the number of permits they were allowed to buy so that they could not allow leakage to rise above a certain level. Such a cap could be imposed across the board or at different levels for different companies.

Issues for the implementation of leakage permit trading

There are many aspects of a leakage permit trading system that would require careful consideration before a scheme was set out. This section examines a few leakage-specific issues.

Geographical scope of permit market

A leakage permit market could be established at a national level or at some more localised level. A national market would have a large amount of scope for trading and the national level of leakage would be controlled according to the quantity of permits that the regulator allowed. However, if it is the case that leakage constitutes a greater environmental or social problem in some areas then the regulator would want to limit the leakage occurring in that area. It seems quite likely that environmental problems are likely to arise at the level of the catchment area, thus it might be appropriate to have trading schemes operating within catchments. Alternatively, some hybrid scheme could be developed that adjusts the value of a permit according to the environmental sensitivity of the catchment in which it is being used. I.e. a permit with a face value of 1 l/prop/day is only worth 0.6 l/prop/day in a more sensitive catchment area. Such a hybrid would allow nationwide trading with responsiveness to local circumstances, though would not limit the national level of leakage.

Quantity of permits issued

As the quantity of permits issued control the amount of leakage occurring at a national or catchment level they must reflect the costs and benefits of leakage control activity. If the regulator issued a very large number of permits, very little leakage control activity would be undertaken and environmental benefits would be lost. However, if very few permits were issued then most companies would have to carry out a high level of leakage control activity at a high cost that might exceed any environmental benefits of leakage control. Hence, as with target setting the quantity of permits issued needs to reflect the costs and benefits of leakage and leakage control activity. Two possible ways of deciding the quantity of permits to be issued are presented below:

1. Calculate the ELL for each company within the scheme and issue permits for the sum of these ELLs. The total amount of leakage control is therefore the same as it would have been under leakage targetting but trading between low cost and high cost companies would reduce the total cost burden of achieving this level of leakage control.

2. Calculate the ELL for the scheme area as a whole based on the marginal environmental benefit of leakage control and the marginal cost of leakage control for the modal (or least cost) water company. This option may reallocate some of the gains from trade towards the environment rather than towards the water companies.

Regulatory Issues

In regulating the water industry, Ofwat would use evidence of a company operating at something other than a calculated “efficient level” as a sign of inefficiency hence any “gains” from operating at this level would not be allowed for in prices. However, in a trading system of this nature there may be genuine gains through companies being more efficient than others at leakage control for justifiable reasons and thus such gains are evidence of allocative efficiency at a super-company level (though this is more difficult to square with the concept of comparative competition).

Aside from the “greater allocative efficiency” argument, there are grounds for a company operating at something other than the “efficient level” in this case. The ELL that could be used to determine the total supply of permits will be different to the level of leakage that efficient companies would maintain on their own because the ELL reflects social and environmental consequences of leakage as well as private costs. When Ofwat requires companies to act efficiently it expects them to balance all commercial considerations and an efficient company will determine its level of leakage control based on these. An additional requirement to reduce leakage will increase leakage control activity above the privately efficient level and efficient companies would identify the cheapest way of doing this.

APPENDIX G: SUMMARY OF VALUATION METHODS

General Description

The Contingent Valuation Method (CVM) is used to value goods or attributes when monetary values of such goods or attributes are not observed through market transactions. CVM estimates values by asking questionnaire respondents about their willingness to pay (WTP) or willingness to accept (WTA) a change in the level of the good or service.

There are three broad elicitation methods using a survey scheme, which are classified as:

- the direct bidding approach (a traditional WTP/WTA approach);
- the dichotomous choice approach; and
- the choice modelling approach.

Each approach is described below.

Description of Different Survey Methods

CVM with Direct Bidding Elicitation

In a direct bidding approach, respondents are asked to bid the price they wish to pay for a particular good, an attribute or a bundle of attributes. In the questionnaire, respondents are asked to bid WTP or WTA or both on several options for the bundle. In general, it is thought that WTP is used to value a potential benefit, while WTA is more appropriate when valuing a cost. Some existing research studies (e.g. Cummings, Brookshire and Schulze 1986), however, ask respondents both their WTP and WTA a specific change, and statistically proved that the respondents had a tendency to claim higher WTA.[5]

[5] One reason for this outcome is so-called "loss aversion". That is, individuals reveal a psychological tendency to value more highly a potential loss than potential gain.

Box 1: Method of Analysis

The data from the CVM survey can be analysed using a simple Ordinary Least Squares (OLS) regression model, in which the bid price information serves as an independent variable and the attributes (and other exogenous socio-economic variables, such as income level) comprise the explanatory variables. The coefficient of each attribute variable is interpreted as a marginal willingness to pay or willingness to accept associated with a unit increase in each attribute (or socio-economic) parameter. For instance, the coefficient for the "number of shortfalls" variable indicates that the price that average respondents wish to accept (WTA) to compensate the utility loss caused by a unit increase in the number of shortfalls. The coefficients of socio-economic variables are interpreted in an analogous way. The coefficient for the "income level" variable refers to the WTP increase associated with a unit increase in income level, being the values of other variables unchanged.

CVM with Dichotomous Choice Elicitation Method

In a dichotomous choice approach, respondents are presented with a choice set ("scenario"), consisting of the attribute information and asked if the presented price associated with the choice set is acceptable or not. Hence, the WTP information has a dichotomous nature. The dichotomous choice approach has an advantage over the direct bidding approach in that the information processed by respondents is simpler and thus requires less cognitive ability by respondents. It is known, however, that the values obtained based on dichotomous choice approach tend to be larger than those obtained based on a direct bidding approach, presumably because it is easier for respondents to accept the price by simply saying "yes" than bidding on the maximum acceptable price.

Box 2: Method of Analysis

The values of the attributes can be estimated either by logit regression utilizing the fact that the data on WTP is dichotomous or by simply using OLS. In the case of the logit regression model, the independent variable of the model is the log likelihood of a respondent accepting the presented price as opposed to rejecting it. Similar to the previous case, explanatory variables consist of the attributes and can include other exogenous socio-economic variables. The coefficients of the logit regression are interpreted as the change in the log likelihood of a respondent accepting to pay the presented price driven by a unit increase in each attribute or socio-economic variable. For instance, the coefficient of the "environmental quality" variable denotes the change in log likelihood of a respondents accepting to pay the presented price (one time fee, annual or monthly fee depending on how you specify the variable) associated with the unit change in the "environmental quality" variable. The typical approach to obtain valuations from logit model is to determine the fee or price corresponding to a *Prob[yes]* = 1. That is, the fee or price that an average respondent would find agreeable to pay.

CVM with Choice Modelling Elicitation Method

Although cojoint analysis has been used in experimental psychology for some time, Choice Modelling is a comparatively new technique for use in applied economic analysis. It has earned attention recently because its statistical results are reliable and because it achieves greater consistency in the preferences revealed by respondents than normal CVM methods. It involves identifying the attributes of an environmental site or good and then examining how respondents' preferences change when the attributes are changed. In the questionnaire for a choice modelling experiment, respondents are presented with a series of choice sets ("scenarios") and asked to rank these according to their order of preference. A respondent may be asked to repeat the ranking process several times for different combinations of scenarios. There are four main ways to present respondents the choice sets, namely:

- **Choice Experiments** – Respondents are asked to choose their most preferred option in each set. Each set also includes a baseline (or the "status quo") option used as a reference when measuring the utility level.

- **Contingent Ranking** – Respondents are asked to rank the options in each set. The contingent ranking method can be exercised as a repeated process of choice experiments. The respondents first identify their most preferred choice, then after eliminating that option from the choice set, identify their most preferred choice out of the remaining set and so on. A drawback of this technique is that it requires a higher level of respondents' cognitive ability. In some studies, it was found that the logical structure in forming preferences can change for less preferred options.

- **Contingent Rating** – Respondents are asked to rate/score each option. Thus, this method does not involve comparison between two or more options at the same time. The contingent rating method provides more information about preference than the two techniques mentioned above, as it asks respondents to reveal how much more they prefer any particular option over other options.

- **Paired Comparisons** – Respondents are asked to choose their preferred alternative out of a set of two choices and to indicate the strength of their preference in a numeric or semantic scale. The paired survey method also provides more information about preference than Choice Experiment or Contingent Ranking methods. For the revealed preferences to be consistent, the baseline option must be assigned.

Responses can be analysed to estimate the total value of the good and the marginal value of each of the attributes. This is particularly useful where there is some uncertainty or choice over the levels of each attribute which are possible as variations in the scenarios can be assessed. The CM approach can explicitly include levels of substitutes as an attribute. This ensures the respondent takes these into account in selecting a choice set, which overcomes a problem with CVM.

Box 3: Method of Analysis

Valuations obtained from a choice modelling approach are often estimated using logit/tobit regressions or multinomial logit regressions. The description of the logit regression model and the interpretation of the coefficients are as described above. When a multinomial logit model is used, the independent variables consist of attribute and socio-economic variables, while the independent variable is the log-likelihood of a particular choice set being preferred over the baseline (or "status quo") choice set. The coefficients of the multinomial regressions are interpreted as the change in the probability of a respondent preferring a particular choice set over the baseline choice set driven by the fact that any particular attribute has a certain category or level instead of the baseline category or level. For instance, the coefficient on a "water pressure" variable would be interpreted as the change in the log-likelihood that Scenario 2 is chosen (over the baseline) when the quality of water is High instead of Low (which is assumed as the "baseline category"). Similar to the dichotomous modelling approach, the fee or price that an average respondent would find agreeable to pay is derived for each scenario (or, equivalently, each water supply scenario).

APPENDIX H **Changes to original Best Practice Principles in the Economic Level of Leakage Calculation document published March 2002**

- Page 1, paragraph 4: "…concerned **with** reviewing…"

- Page 17, paragraph 2: "…that a more ~~appropriate term~~ **useful concept** is 'policy minimum' leakage. **However component based calculations of a base level such as expressed in UKWIR report 97/WM/08/10 can sensibly be used as a sense check to actual recorded policy minimum levels**…"

- Page 37, last paragraph: "…**For water mains**, ~~T~~**t**he sensor is…" and "…~~However an important criteria is the 'pigability' of the main. This could render the technique impractical on older mains, where the pig could be obstructed by internal corrosion~~…"

- Page 44, paragraph 1: "…"~~Economics of the Supply/Demand Balance~~"…" now reads "…"**Economics of Balancing Supply and Demand**"…"

- Page 57, paragraph 2: "…context **and** are 'transferred' to…"

- Page 60, paragraph 1: "…Estimation of the ~~Efficient~~ **Economic** Level of Leakage without…"