OFWAT

WATER SERVICES REGULATION AUTHORITY

Environmental Economics Consultancy:
Leakage Methodology Review Project

Providing Best Practice Guidance on the Inclusion of Externalities in the ELL Calculation

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GUIDANCE

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EXECUTIVE SUMMARY

The economic level of leakage (ELL) is the point at which the cost of further leakage reduction is just equal to the additional benefit gained. It relies on two key relationships:

- The costs of the various activities for controlling leakage e.g. finding and repairing leaks, and how they vary with the level of leakage
- The impact that different leakage levels have on the costs of delivering water to customers (treatment and pumping costs) and the timing of planned new supply, treatment and demand management (including water efficiency) schemes

Water companies regularly review their ELL calculations and submit them to the Water Services Regulation Authority (Ofwat) who use these assessments at price reviews to set leakage targets for at least a five-year period. The ELL is also a fully integrated part of companies' Water Resource Plans (WRPs).

It has become increasingly recognised in recent years that if leakage levels are to fully reflect the preferences of society, the costs and benefits that are included in ELL calculations should include not just those that are borne directly by water companies (known as 'private' costs) but also the 'external' costs and benefits that arise as a result of the environmental and social impacts of leakage control activities and leakage itself. These include, for example, the environmental benefits of reduced abstraction levels resulting from a reduction in leakage, and the social costs of traffic disruption arising from leak repair and mains renewal activities. The appropriate inclusion of both private and external costs and benefits ensures that leakage targets are set at a level that is optimal for customers and broader society.

Since the last periodic review of prices in 2004 (PR04) Ofwat have identified the inclusion of external costs and benefits as an area of the ELL calculation that can be improved. In April 2007 a steering group of Ofwat, the Environment Agency (EA), Defra, CCWater and Water UK commissioned RPS Water Services to provide 'best practice' guidance for the evaluation of the external costs and benefits of leakage and how these should be incorporated in an ELL calculation. Guidance was also required for the measurement of carbon emissions associated with different leakage levels and leakage control activities. The objective of the study was to provide practical guidance on the evaluation of external costs and benefits for water companies to use in their ELL calculations for PR09.

The consultant’s report is presented in two parts:

Part 1 (Main Report) presents an overview of the research project and its key findings, and provides an introduction to the recommended methodologies described in the detailed guidance.

Part 2 (Guidance) is a self-contained, step-by-step framework for assessing the environmental, social and carbon impacts of leakage and leakage control activities and shows how these can be integrated into an ELL calculation.

Given the time available for the study, the Guidance builds on, rather than replaces existing assessment approaches in this area; collates these into a single source; and, where possible, recommends best practice. The aim has been to develop guidance that can be used by all water companies for PR09 and that will help to ensure a consistent and transparent approach across the industry.

CONTENTS

1 OVERVIEW OF GUIDANCE METHODOLOGY

1.1 AIM OF GUIDANCE

The aim of the Guidance is to provide a comprehensive framework for assessing and including leakage-contingent externalities within the ELL calculation. The Guidance builds on, rather than replaces, existing guidance in this area, and collates the range of existing assessment approaches for the different externality components into a single source.

Where both available and appropriate, up-dated data inputs are provided in certain areas and a number of minor refinements to existing processes are recommended, in order to both simplify the assessment process and increase the robustness of resulting assessments.

Application of this Guidance should thus produce valuations for PR09 that offer improved consistency, transparency and comparability across the industry relative to the assessments used in PR04.

1.2 SOURCES OF GUIDANCE

1.2.1 Environmental externalities

Based on the discussion contained in Section 4.1 of the Main Report, the main body of guidance for the determination of environmental benefit values focuses on the 'bottom-up' application of the benefits transfer approach outlined in the BAG (RPA, 2003). The aggregated project-level values derived from this appraisal can then be moderated (reconciled) with willingness-to-pay assessments that may be available from top-level customer preference surveys that are set within the context of an overall programme of potential water service investments. With respect to associated benefits transfer values, the Guidance recommends use of the data sources provided in the BAG. Practitioners should refer to the BAG for detailed guidance on assessment methods and appropriate data inputs.

1.2.2 Social externalities

Guidance on the valuation of social externalities presented in this study builds on the BAG approach (RPA, 2003), which is itself based on the earlier NERA guidance (1998). However, updated values for the social cost of traffic delays are used, and the use of up-dated, area-specific traffic flows are recommended.

1.2.3 Carbon externalities

Guidance on the valuation of carbon emissions presented in this study builds upon the following sources of information and guidance:

UKWIR guidance on the assessment of greenhouse gas emissions to provide a consistent approach to the assessment of greenhouse gas emissions associated with leakage.

The 2007 annexes to the guidance from Defra on measuring and reporting greenhouse gas emissions in order to provide up to date assumptions.

Assessment of emissions from traffic should be based on fuel consumptions converted to carbon through the application of factors recommended in the guidance and drawn from the Defra 2007 information.

In order to provide a consistent basis for the assessment of emissions from worksites and repairs a bespoke methodology was developed to estimate the likely magnitude of emissions from typical sites. These utilised data on equipment size published by Defra in 2007 and emissions factors published in 2007 as noted above.

The incorporation of a value for carbon has used the recently issued guidance (August 2007) on the Shadow Price of Carbon (SPC) from Defra which takes more account of uncertainty than the previous Social Cost of Carbon (SCC) method, is based on a stabilisation trajectory, and is in line with the marginal abatement costs of reaching the stabilisation goal. Therefore the values specified in this guidance are no longer consistent with the Environment Agency Water Resources Planning Guidelines (April 2007).

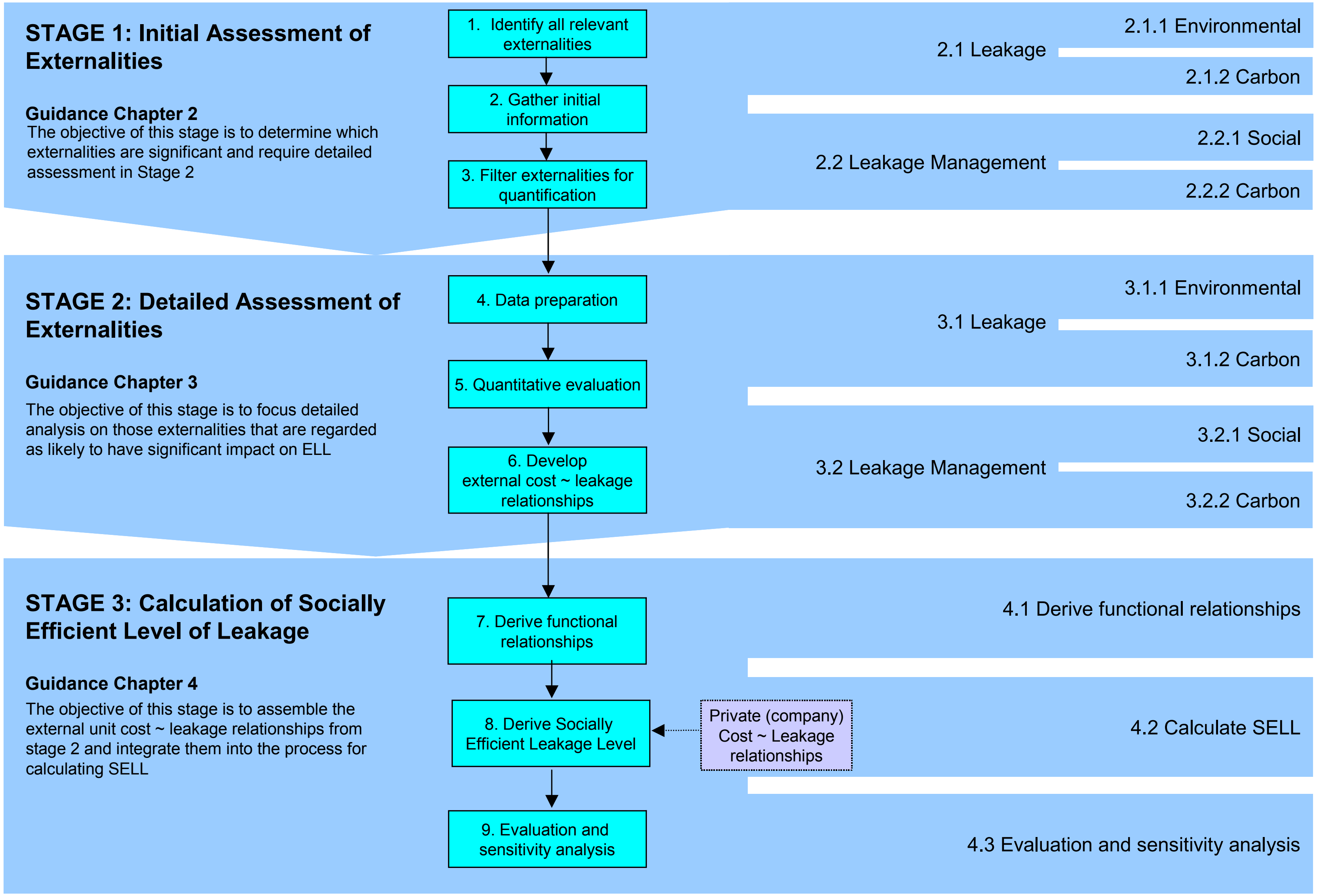


Figure 1.1: Overview Process Map

1.3 STRUCTURE OF GUIDANCE

Figure 1.1 provides an overview of the key processes required for the inclusion of externalities within the ELL. Consistent with the BAG, three distinct stages of the assessment process have been identified:

Stage 1: Initial assessment of externalities

This stage identifies the full range of externalities requiring valuation, and involves their qualitative or simplified quantitative assessment, based on minimal data requirements. Significant externalities are filtered, using objective criteria, for more detailed quantitative assessment at Stage 2.

Stage 1 is designed to (i) encourage an initial consideration of the full range of externalities in a consistent manner, (ii) minimise the data inputs associated with assessment of a large number of impacts, (iii) provide an objective means for filtering externalities, and (iv) allow more detailed assessments to focus on those externalities that are likely to be most significant in terms of their impact on the ELL.

Stage 2: Detailed assessment of externalities

The aim of Stage 2 is to produce, where possible, quantitative assessments of significant externalities and to develop a set of relevant cost ~ leakage relationships for inclusion in the ELL calculation. This is achieved through the use of established assessment methodologies, together with the collection and preparation of relevant data inputs.

Stage 3: Calculation of socially efficient leakage levels (SELLs)

This stage focuses on the development of functional cost ~ leakage relationships that may then be used within an established optimisation process, along with the more conventional private costs of leakage and leakage management, to determine leakage levels that are socially efficient.

Stage 3 also involves a sensitivity analysis and evaluation of the impacts of uncertainty. This entails the systematic exclusion of external cost categories, together with consideration of both upper and lower bound limits for individual assessments. A comparison of the resulting ELLs provides some indication of the relative sensitivity of individual impacts and the key sources of uncertainty.

1.4 LEVEL OF DETAIL AND COVERAGE

The Guidance offers a significant level of detail in terms of the number of steps involved at each stage. While appearing at first sight to be complex, the large number of proscribed processes is designed to reduce the potential for 'black holes' in the assessment that may result in misinterpretation and error.

While guidance is provided for all significant leakage-contingent externalities, guidance has not been provided for a small number of impacts listed in the classification of externalities in Section 3. These include, amongst others:

- the benefits of leakage reduction associated with commercial navigation and agricultural use
- the social costs associated with disamenity due to excavations
- the social costs associated with sewer flooding.
- fuel use associated with importing water under extreme events

Guidance on these impacts has not been provided on the basis that either

- there is no existing guidance for valuing these impacts and they are not readily assessed in monetary terms, or
- the impacts are considered to be relatively insignificant, or the impacts are associated with market-related outputs, values for which are readily available in the form of market prices.

1.5 KEY ISSUES

1.5.1 Double counting

With an assessment exercise of this nature, there exists the potential for either exclusion or double counting of relevant impacts. There are three main areas where double counting may occur:

- Impacts are included both as a benefit on one side of the cost-benefit equation and as a cost on the other. For example, for successive leakage reductions, the benefits arising from a reduction in reported leak repairs (if any) may be either netted from the costs of active leakage control, or added to the cost of leakage, but not both. Similarly, the deferral of the environmental and social costs associated with a new resource should not be included in the least cost plan both as an external benefit of leakage reduction and as an external cost of the new resource.

- The value of certain external impacts has been appropriately 'internalised', i.e. is already considered by the WSP in its private decision-making as a result of appropriate transfer payments, taxes or charges intended to reflect the social value of the externality. Even if such transfers do not wholly internalise the externality, assessment and inclusion of the full social value for such externalities amounts produces an element of double counting. Impacts that may to some extent already be internalised within WSPs private decisions are discussed below.

- Externalities for related impacts are double counted because they are not clearly separable. There may be some overlap between categories of impact; the same population may be used for different impacts; or benefits transfer values used may include more than just the specific impact being valued. Examples are provided by non-use and use categories of environmental value, where local populations may visit for informal recreation, or angling, but not both; or where benefit transfer values reflecting both recreation and non-use value are applied only to non-use beneficiaries, and additional values are applied to recreational visitors. These examples will tend to produce externality valuations that are upwardly biased. Although the BAG offers clear guidance on the avoidance of double counting, checks should be undertaken to ensure its absence.

1.5.2 'Internalised' impacts

Impacts are 'internalised' when the social value of the impact is already weighed by the WSP in its private decision-making. This occurs as a result of appropriate transfer payments, taxes or charges which are intended to reflect the social value of the externality.

In relation to the leakage calculation, there are three main categories of externality for which partial internalisation occurs:

- The social cost of domestic disruption due to supply interruptions is at least partially internalised by the Guaranteed Standards Scheme payments to water consumers, plus the additional discretionary compensation offered by most WSPs;

- The Climate Change Levy, designed to reduce carbon emissions, internalises a proportion of the true social cost of carbon;

- The proposed 'lane rental' charge for street works and related activity, which was intended to reflect to some extent the associated social cost of traffic disruption.

While the values of these transfers, taxes and charges may usefully provide some indication of a minimum bound for the related social cost, given that they typically fail to fully internalise the true social cost of the externality, an assessment of the value of the impact for inclusion in the ELL model is still required.

However, if an element of double counting is to be avoided in such cases, the financial value of the transfer, tax or charge must be 'netted out' from the social cost assessment, since this component is already reflected in the WSPs private financial costs.

It should be noted that abstraction charges are not designed to reflect the true environmental cost of abstraction, but are designed to recover a component of administrative costs.

1.5.3 Dealing with uncertainty

Uncertainty arises from a lack of information or scientific knowledge. Failure to consider uncertainty may result in sub-optimal solutions because the true value of an economic variable differs sharply from its predicted value. It is important that, however managed, uncertainty is dealt with in a consistent and systematic manner.

The scope of this study precluded the detailed development of approaches for dealing with uncertainty. Potentially, confidence assessments based on Monte Carlo analysis of probability distributions for key variables could be developed. However, given the existing difficulties of establishing reliable data inputs, associated probability distributions are likely to be relatively wide.

As a simpler alternative, the Guidance suggests the use of upper-bound, central, and lower-bound values for all key data inputs where there is a significant degree of uncertainty, and the simultaneous development of upper-bound, central, and lower-bound assessments at each stage of the valuation process.

Stage 3 of the Guidance involves a sensitivity analysis and evaluation of the impacts of uncertainty, entailing the systematic exclusion of external cost categories, together with consideration of both upper and lower bound limits for individual assessments. A comparison of the resulting ELLs then provides some indication of the relative sensitivity of individual impacts and the key sources of uncertainty.

Unless there is good justification for taking either the upper- or lower-bound values, it is recommended that the central value should be utilised in the ELL calculation.

1.6 REPORTING AND AUDIT OF ASSESSMENTS

For reporting purposes, there is a need for the findings of the assessment exercise to be well documented, with a clear audit trail provided at each stage. For consistency, the Guidance recommends use of the reporting approach outlined in the BAG, which makes use of an 'Appraisal Summary Table' (AST) for each externality valued.

The ASTs developed in the BAG relate to different water-body types. It is recommended that use of these is extended to include consideration of leakage-related carbon externalities in each zone, and social and carbon-related externalities associated with each of the three leakage management 'schemes' in each water resource zone.

ASTs should be used to record all assumptions made in an assessment as well as the results at each stage. Supplementary spreadsheets should be developed for detailed calculations.

2 STAGE 1: INITIAL ASSESSMENT OF EXTERNALITIES

The objectives of the Stage 1 analysis are to identify the full range of potential environmental, social and carbon-related impacts and to filter, from these, the sub-set of significant impacts that require more detailed quantification at Stage 2. The methodology is designed to make this process both inclusive and as objective as possible, at the same time avoiding the need to undertake a detailed quantitative evaluation of the full range of externalities.

Figure 2.1 highlights the Stage 1 steps of the overview process. These steps comprise:

1. Identify externalities
2. Gather initial information
3. Filter externalities for Stage 2

The three steps should be applied to each and every water resource zone (WRZ) within the WSP supply region and, at least initially, to the full range of leakage management and leakage-related externalities listed in Tables 3.1 and 3.2 in the Main Report.

The following sections describe in detail the application of these steps to identify significant leakage-related externalities, i.e. environmental and carbon impacts (Section 2.1) and significant leakage management externalities, ie social and carbon impacts (Section 2.2). The steps are subdivided and each sub-step is described with examples where appropriate.

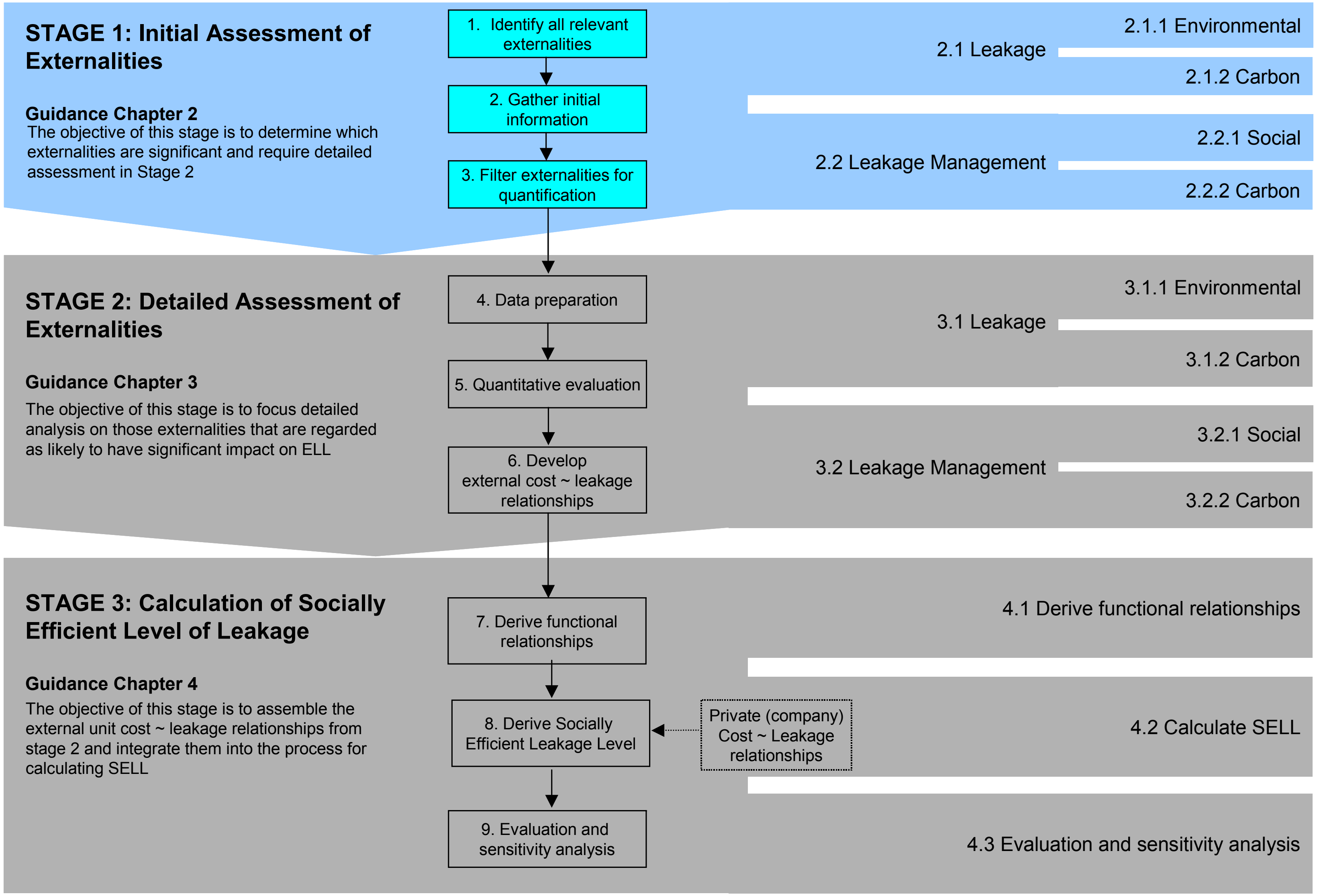


Figure 2.1: Overview Process Map – Stage 1

2.1 INITIAL ASSESSMENT: LEAKAGE-RELATED EXTERNALITIES

As discussed in Sections 2 and 3 of the Main Report, the relevant external benefits of leakage reduction that should be considered when calculating the variable operating cost SELL for a zone are the environmental and carbon-related impacts arising from associated reductions in zonal abstraction, treatment and distribution[1].

Besides leakage reduction, a number of other schemes in the least cost plan might also potentially produce flow/water level or water quality changes which, in turn, would produce a change in ecological quality and related user and non-user (biodiversity) benefits. Similarly, a source's associated carbon-footprint is also potentially affected by schemes other than leakage (much in the same way as the source's abstraction, treatment and distribution OPEX may be affected by a number of alternative schemes).

It follows that assessments of both the carbon-footprint and the abstraction-related impacts on flows / water levels for a source may be required as inputs into the cost/benefit analysis for more than one scheme. Clearly, it is important that these assessments are based on consistent characterisation of the affected source/site and use of a common set of data inputs. Ideally, to avoid duplication and inconsistencies, a source's carbon footprint and environmental characterisation should be undertaken by a WSP only once. These assessments can then be utilised and adjusted for the impacts of different schemes if relevant (i.e. if the scheme is expected to have abstraction-related impacts). Ideally, an assessment undertaken by the WSP should also be consistent with any assessment undertaken by the Environment Agency for the same source/site.

The principal source for assessing the environmental impacts of such schemes in PR04 was the Benefits Assessment Guidance (RPA, 2003), and this Guidance recommends the same source as the basis for deriving bottom-up assessments of environmental impacts.

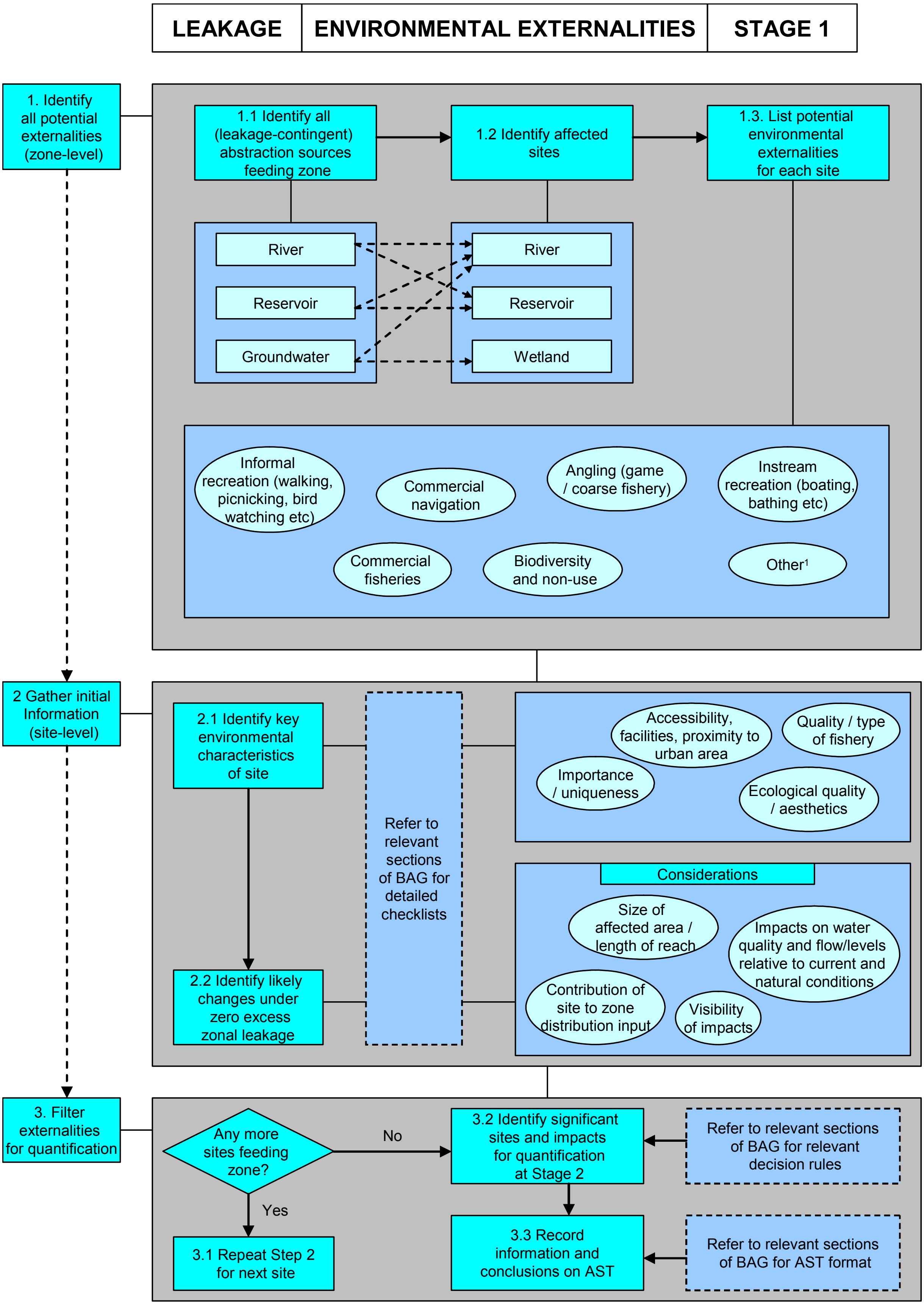
Leakage reduction clearly differs from other water resources schemes and demand management options in that incremental reductions may be considered, whereas most resource schemes, being more 'lumpy' in nature, typically offer an 'all or nothing' outcome (or at most a staggered impact or perhaps one or two intermediate alternatives). While offering a greater degree of flexibility in terms of leakage optimisation, the incremental nature of leakage reduction raises a number of additional methodological issues that this guidance attempts to address.

2.1.1 Environmental impacts

The set of relevant impacts included under 'environmental externalities' was defined and discussed in Section 3 of the Main Report.

Figure 2.2 is a process map showing the steps required to undertake an initial assessment of environmental externalities within a zone, and the subsequent filtering of significant externalities for quantification at Stage 2. The following section describes and discusses each step in turn. Boxed examples provide a practical illustration of the methodology applied to a hypothetical zone.

[1] The external (social and carbon-related) benefits arising from any reductions in the number of mains bursts and their associated repair are also relevant, but these should be 'netted out' from the external costs of leakage reduction activities.



[1] Includes agricultural use, other abstractors, heritage (archaeology and landscape), and amenity (property prices and regeneration)

Figure 2.2: Process Map for Assessing Leakage-related Environmental Externalities – Stage 1

STEP 1: IDENTIFY ALL POTENTIAL EXTERNALITIES

The aim of this step is to identify for consideration the full range of leakage-related environmental externalities that might occur within any zone. These stem from the flow/water level changes that occur as a result of changes in abstraction volumes[2].

STEP 1.1 IDENTIFY ALL (LEAKAGE CONTINGENT) ABSTRACTION SOURCES FEEDING ZONE

This step first involves the identification of all the abstraction points, large and small, which feed the resource zone, including any which lie outside the zone's boundaries. These will either be river, reservoir or groundwater sources. This information should be available from the water resources division of the WSP.

If information is available that permits the identification of any sources where abstraction volumes would be unaffected by reductions in zonal leakage (including significant reductions, i.e. down to zero excess leakage), then any such sources can be excluded from further analysis[3].

Box 2.1: Environmental externalities: Zone example

Zone X123 has 20,000 properties, and excess leakage, i.e. leakage above policy minimum leakage (L-K) = 224 l/p/d (4.47 Ml/d)

STEP 1.2 IDENTIFY AFFECTED SITES

The source from which the water is abstracted may not be the site at which the impacts of the abstraction are manifest. For example, the effects of changes in abstraction from an impounding reservoir are likely to be manifest in flow changes on the downstream river into which the reservoir feeds. Similarly, the impacts of higher or lower abstraction from a groundwater aquifer may be manifest either in nearby river flow changes or changes in wetland water levels.

This information should be available from the water resources division of the WSP.

STEP 1.3 LIST POTENTIAL ENVIRONMENTAL EXTERNALITIES FOR EACH SITE

The aim of this step is to build a complete picture of the range of human and ecological activities and circumstances which might be affected by changes in flow / water levels at the affected sites. This information will be available either from the water resources division of the WSP, or from relevant EA CAM/LEAP documentation.

The list of potential activities and circumstances for consideration should include:

- Informal recreation – walking, hiking, dog walking, picnicking, bird watching, photography, cycling etc
- Angling – coarse and game
- Commercial fisheries and aquaculture - salmon and trout farming etc
- Instream recreation – boating, yachting, sailing, canoeing and rowing
- Commercial navigation
- Amenity, property prices and regeneration

[2] These impacts will not be relevant when a leakage scheme is not expected to produce a reduction in abstraction volumes in the zone (i.e. when it is being considered as a further option in the least cost plan, beyond the attainment of variable operating cost ELL, to balance zonal-level supply and demand).

[3] The marginal environmental benefit of leakage reduction for these sources is effectively zero.

- Abstractions – impact on other abstractors besides the WSP
- Heritage, archaeology and landscape
- Agricultural use – wild fowling, willow, reed cutting etc

Several of these activities/circumstances may, for certain sites, be irrelevant, and can be disregarded. Others might be included, only to be disregarded at the next step.

Box 2.2 Environmental externalities. Step 1: Identify all potential externalities

Step 1.1: Identify all abstraction source feeding zone:
Zone X123 has two points of abstraction. The principal abstraction for the zone occurs from River Bank at Aspot, and a smaller abstraction occurs from Fair Valley Reservoir which overflows into the River Twee.

Step 1.2: Identify affected site:
The impact of abstraction from River Bank at Aspot is felt downstream for eight kilometres (Shallow Reach) until confluence with River Old at Oldtown. The impact of abstraction from Fair Valley Reservoir is felt on the River Twee for 3 km south of the point of inflow at Dove Mill (Dove Reach) to its confluence with River Bank some 10 km upstream of Aspot.

Step 1.3: List potential environmental externalities for each site:
Relevant activities and circumstances identified along Shallow Reach include informal and instream recreation, angling, abstractions, heritage, amenity and commercial navigation. Relevant activities identified along Dove Reach include informal recreation.

STEP 2: GATHER INITIAL INFORMATION (SITE- LEVEL)

The aim of this step is to gather information that will support the decision on which of the sites and impacts identified in Step 1 are significant and therefore require a more detailed quantitative assessment. This step should be completed for each site identified in Step 1.

There are two elements which should be considered at this stage. The first relates to the site's environmental attributes themselves, while the second relates to how these would be affected by a change in zonal leakage (abstraction).

The BAG (RPA, 2003) provides, on an impact by impact basis, a detailed checklist comprising a series of questions designed (a) to assist with the identification and categorisation of the key environmental attributes of the site (Step 2.1) and (b) to determine whether the impact of a scheme is likely to be significant (Step 2.2).

The BAG also provides objective categorisations for the answers to these questions which may assist with the filtering process (Step 3).

The BAG should therefore be used as a core reference for Steps 2 and 3 of the analysis.

STEP 2.1 IDENTIFY KEY ENVIRONMENTAL CHARACTERISTICS OF SITE

This step involves identification of the environmental attributes of the site which determine the significance of abstraction-related impacts. Relevant information might include:

- Ecological quality of the water resource (for example RE class)
- Quality, type and size of fishery (including carrying capacity of commercial fishery)
- Extent of agricultural use
- Educational value of any heritage/archaeological sites
- Conservation importance of the site (for example, any nature conservation designations such as SSSI, World Heritage Site, SPA etc)

- Radii within which the site is likely to draw visitors for relevant activities (eg < 15km, < 30km, or < 60km)
- Proximity to coastal or other major surface water area
- Degree of local urbanisation
- Uniqueness of the site – ie how many similar or 'better' sites exist within the relevant radius for each activity
- Accessibility (road access to different parts of the site, long distance footpaths, circular routes, local footpaths, cycle paths etc)
- Facilities (cark park, toilets, café's, information boards, clubs, rental facilities etc)
- Size of any commercial in-stream operations
- Type and number of properties close to water resource
- Number of other abstractors and magnitude of volumes taken

Data sources likely to be useful at this stage might include EA CAM and LEAP documentation, GQA data, OS maps and the WSP's GIS maps. For each impact being considered, reference should be made to the BAG for a detailed checklist[4].

Box 2.3: Environmental externalities. Step 2.1: Identify key environmental characteristics

Site 1. River Bank, Shallow Reach (affected for 8km downstream from Aspot)

Angling:

- Fishery quality: **GOOD** (RE1). The river supports a small game fishery of mainly brown trout and occasional runs of salmon and sea trout. Fishery is a good, relatively unexploited salmonid fishery. Angling opportunities are likely to be more frequent on the lower reaches of the affected river length owing to better levels of access provided by local footpaths and byways. Access to the river on the upper reaches can be gained though landowners. It is assumed that fishing can potentially occur along entire reach.
- General: the fishery is open to members of the local angling association or through the purchase of day tickets, and is generally fished by locals (within 30km radius) only. There are 25 other angling sites within a 30 km radius.

Informal recreation:

- Access: **MODERATE** accessibility to certain stretches of the river. Accessibility is poor for the 4.5km section of the upper reaches above Fair Bridge to the point of abstraction at Aspot. There is no provision of footpaths or roads giving any access to the river along this section. Below Fair Bridge, the remaining 3.5km section becomes intersected with numerous footpaths, byways, national cycle network and roads providing good access to this stretch of the river.
- Facilities: **MODERATE** (few to some facilities along affected stretch). Generally localised around the urban centres such as Newtown & Oldtown on the lower reaches of the river. Numerous camping and caravan sites along with the local facilities provided by the settlements along the affected stretch.
- Importance: **MODERATE** to **HIGH** importance in terms of informal recreation. As the river is located within Hilltops National Park, based on detail and the BAG (Part 2) Tables 2.3 & 2.7, the affected river reach is considered to be of **Regional / National** importance.
- Aesthetic value: water quality in affected stretch is **GOOD** no litter on river corridor, RE1 & designated salmonid water. The river provides an important contribution to the aesthetic quality of the area.
- General: although the site type is Regional / National, the access and facilities are rated as moderate therefore the importance is taken (from the BAG (Part 2) Table 2.7) as **LOWER,** attracting visitors up to a maximum of 10km. There are two alternative sites of similar quality within the 10 km radius.

In-stream recreation:

- General: very limited boating opportunities exist on the affected reach. The opportunity for canoeing is sporadic and only after significant rainfall is the river high enough to support this activity, and this is only likely for a very localised population. Trips to the river for the purpose of

[4] With the exception of agriculture and commercial navigation, which is not considered by the BAG

in-stream recreation are likely to be few. There are 4 alternative sites within a 30 km radius. Given the facilities and access described above, based on the information in the BAG (Part 2) Table 5.7 the assumed distance for aggregation is 8km or less.

Biodiversity and non-use:

- General: the 8.0km stretch forms part of the Bray Valley SSSI which is ecologically important for its populations of Bryophytes. The affected river also falls within Hilltops National Park, emphasising the importance of the site in terms of non-use and biodiversity. The affected river does not exhibit an extensive floodplain. Based on the BAG (Part 2) Table 9.3, the nature conservation evaluation is, due to the SSSI, **National.**

Amenity:

- Noticeable settlements located on affected river stretch: Newtown and Oldtown. The number of adjacent properties along the affected reach is relatively few, and comprise mostly housing.

Other abstractors:

- All licensed abstractors within the Bray CAM are from surface water. The two largest and most noticeable abstractions are for HEP and Potable Water Supply. Of the total volume extracted HEP accounts for 17% and Potable Water Supply some 80%. Insignificant volumes are taken for other uses such as agriculture and industrial needs.

Heritage:

- There are several scheduled ancient monuments in the area protected by law. The river forms an important part of landscape. The area is one of beauty and serene old country attractive to visitors. The importance of the area in terms of its landscape is reflected by the National Park and Special Landscape Area designation over much of the catchment. The affected river is considered to be unmodified.

Commercial navigation:

- One foot-passenger ferry operates across a relatively deep part of the reach some 0.3 km south of Aspot. This operation would not be affected by a change in flow associated with the proposed LRO. No other commercial navigation occurs along the reach.

STEP 2.2 IDENTIFY LIKELY CHANGES UNDER ZERO EXCESS ZONAL LEAKAGE

This step involves consideration of the likely impact of zonal leakage reduction on the environmental characteristics and quality of each site identified in Step 1. Also at this stage consideration should be given to whether, following a reduction in zonal leakage, any new activities might become possible.

Clearly, the impacts of zonal leakage reduction on the identified sites will depend upon the size of the leakage 'scheme', i.e., the volume of the leakage reduction being considered. For the purpose of the Stage 1 assessment, the 'scheme' is defined as a reduction in leakage to zero excess leakage. Although associated leakage management costs mean that this scenario is likely to be financially infeasible, this approach ensures consideration of the extreme 'best case' environmental scenario, i.e. the largest potential impact of leakage reduction on the site.

The magnitude of the source's reduction in abstraction that results from the zonal leakage 'scheme' is also an important consideration at this stage. Some sources may be affected relatively more than others. If information is available that indicates the expected magnitudes of changes in abstracted volumes at different sources, this information can be used in assessing the significance of resulting environmental impacts. Otherwise, these volumes can be approximated by using the percentage contribution of the source to zonal distribution input.

Other considerations include the visibility of the expected impacts, and this is partly related to both the general size of the water body, and the changes in flow /water levels that would occur relative to both current conditions and to natural flow / water levels. A large reservoir with water levels near maximum capacity is unlikely to be significantly affected by a relatively small change in abstraction associated with a reduction in leakage. Similarly, changes in flow levels are unlikely to have a significant environmental impact if, due to the confluence with another river downstream, they are only manifest along a 0.5 km reach of river.

Data likely to be useful at this stage might include EA CAM and LEAP documentation, GQA data, OS maps and the WSP's GIS maps. For each impact being assessed, reference should be made to the BAG for a detailed checklist.

Box 2.4: Environmental externalities. Step 2.2: Identify likely changes under zero excess zonal leakage

Site 1. River Bank, Shallow Reach (affected for 8km downstream from Aspot)

Contribution of Aspot abstraction to zone distribution input is 85%.
Q75 natural flows are 24.32 Ml/d and Q98 natural flows are 14.76 Ml/d.
Q75 current flows are 19.47 Ml/d and Q98 current flows are 7.98 Ml/d

The impact of the leakage reduction option (LRO) on current flows at the site is assumed to produce a 1:1 increase in flow levels. Flows will thus increase on average by 0.85 x 4.47 = 3.8 Ml/d. This produces an increase in Q75 current flows from 80% to 96% of natural flows, and an increase in Q98 flows from 54% to 80% of natural flows.

- Angling impacts: based on the angling classification identified in Step 2.1 there are likely to be some positive benefits for angling with the implementation of the LRO
- Informal recreation: based on the classifications identified in Step 2.1 there are likely to be some positive visible impacts for recreational users associated with the LRO
- In-stream recreation: based on the BAG (Part 2) Table 5.3, the impact on in-stream recreation of the LRO is categorised as **POOR** (no increase in the number of trips and value of enjoyment) to **FAIR** (slight increase in the number of trips and value of enjoyment).
- Biodiversity and non-use: based on the BAG (Part 2) Table 9.5, impacts are considered to be 'minor positive'. This equates to an expected 'small benefit' in terms of the impacts of the proposed LRO on biodiversity & conservation (theBAG (Part 2) Table 9.6).
- Amenity etc: impacts on property values and urban regeneration are considered to be negligible
- Abstractors: based on the BAG (Part 2) Table 7.2, the LRO will not result in elevation of cessation orders in the future.
- Heritage etc: based on the BAG (Part 2) Table 8.2, the LRO will cause no impact on the historic context or the landscape of the site.

STEP 3: FILTER EXTERNALITIES FOR QUANTIFICATION

STEP 3.1 REPEAT STEP 2 FOR NEXT SITE FEEDING ZONE

This step ensures that qualitative assessments are made for all sites identified in Step 1.

STEP 3.2 IDENTIFY SITES AND IMPACTS FOR QUANTIFICATION

Based on the information gathered in Step 2, Step 3.2 involves an overall assessment of the significance of both the site itself and of the environmental impacts likely to result from a reduction in zonal leakage to zero excess leakage. Reference should be made to the BAG for key decision rules relevant to each impact.

If no significant impacts for a site are identified at Step 3.2, then the entire site may be disregarded: the zero or negligible environmental impacts associated with any site should, however, be appropriately weighed in the zone-level environmental cost function at Stage 2.[5]

[5] This is achieved by downwardly adjusting (weighting) the assessed benefit valuations for each site by the associated source's expected percentage contribution to zonal leakage reduction (which, in the absence of this information, can be approximated by the percentage contribution of the site to zone distribution input). The marginal environmental cost~leakage relationships for all sites assessed at stage 2 can then be directly summed (Step 6.2).

Box 2.5. Environmental externalities: Step 3.2 Identify significant sites and impacts for quantification at Stage 2

Impact	**Stage 2 Assessment?**	
	River Bank, Shallow Reach	River Twee, Dove Reach
Angling	Yes	No
Informal recreation	Yes	No
In-stream recreation	Yes	No
Non-use and biodiversity	Yes	No
Amenity etc	No	No
Abstractions	No	No
Heritage etc	No	No
Commercial fisheries	No	No
Agricultural use	No	No
Commercial navigation	No	No
		(Site therefore not considered at Stage 2)

STEP 3.3 RECORD INFORMATION AND FINDINGS ON APPRAISAL SUMMARY TABLE (AST)

AST's are presented in the BAG as a means of summarising all the relevant information, assumptions and data sources relevant to the benefits assessment process, and the template provided by the BAG is recommended by this Guidance for use in the context of leakage-contingent externalities. AST's not only provide a detailed audit trail for final externality valuations, but also offer objective justification for the selection or elimination of sites and impacts for consideration at Stage 2.

An AST for the worked example 'Site 1 River Bank, Shallow Reach' is provided in Annex A of this Guidance.

2.1.2 Carbon emissions

Figure 2.3 is a process map showing the recommended steps and sub-steps to be taken in completing Stage 1 in relation to greenhouse gases. The purpose of Stage 1 for the assessment of greenhouse gases is twofold. First, to recommend the scope of quantitative analysis; and second, to put in place the framework around which the assessment of carbon can then occur.

Estimation of the carbon-related impacts of leakage within any zone requires an understanding of the quantity of carbon emitted during the abstraction, distribution and treatment of the existing volume of water into supply. The quantity of carbon emitted can then be converted to a monetary value thus producing a value of the carbon externality per Ml of water.

STEP 1: IDENTIFYING EXTERNALITIES

Step 1 involves identification of the full range of carbon-related externalities.

STEP 1.1 CONSIDER SOURCES OF LEAKAGE EXTERNALITY

The aim of this step is to identify, for each zone, the activities related to leakage that cause, either directly or indirectly, emissions of greenhouse gases. The leakage sources will normally include:

- Abstraction
- Distribution
- Treatment

STEP 1.2 LIST POTENTIAL SOURCES OF CO_2 EXTERNALITIES

This step should be undertaken for each relevant site, and should include (but not be restricted to) the following externalities:

- Emissions from fuel use
- Emissions from energy use
- Emissions from the water treatment process, e.g. ozonation
- Emissions from the disposal of treatment residues.

STEP 1.3 MAP INTERVENTION POLICIES TO POTENTIAL EXTERNALITIES

For the sources identified in Step 1.1 and the externalities identified in Step 1.2, a matrix identifying the relationships should be drawn up.

Externality	Interventions		
	Abstraction	Distribution	Treatment
Fuel use	√	√	√
Energy use	√	√	√
Ozonation emissions			√
Disposal of residues			√

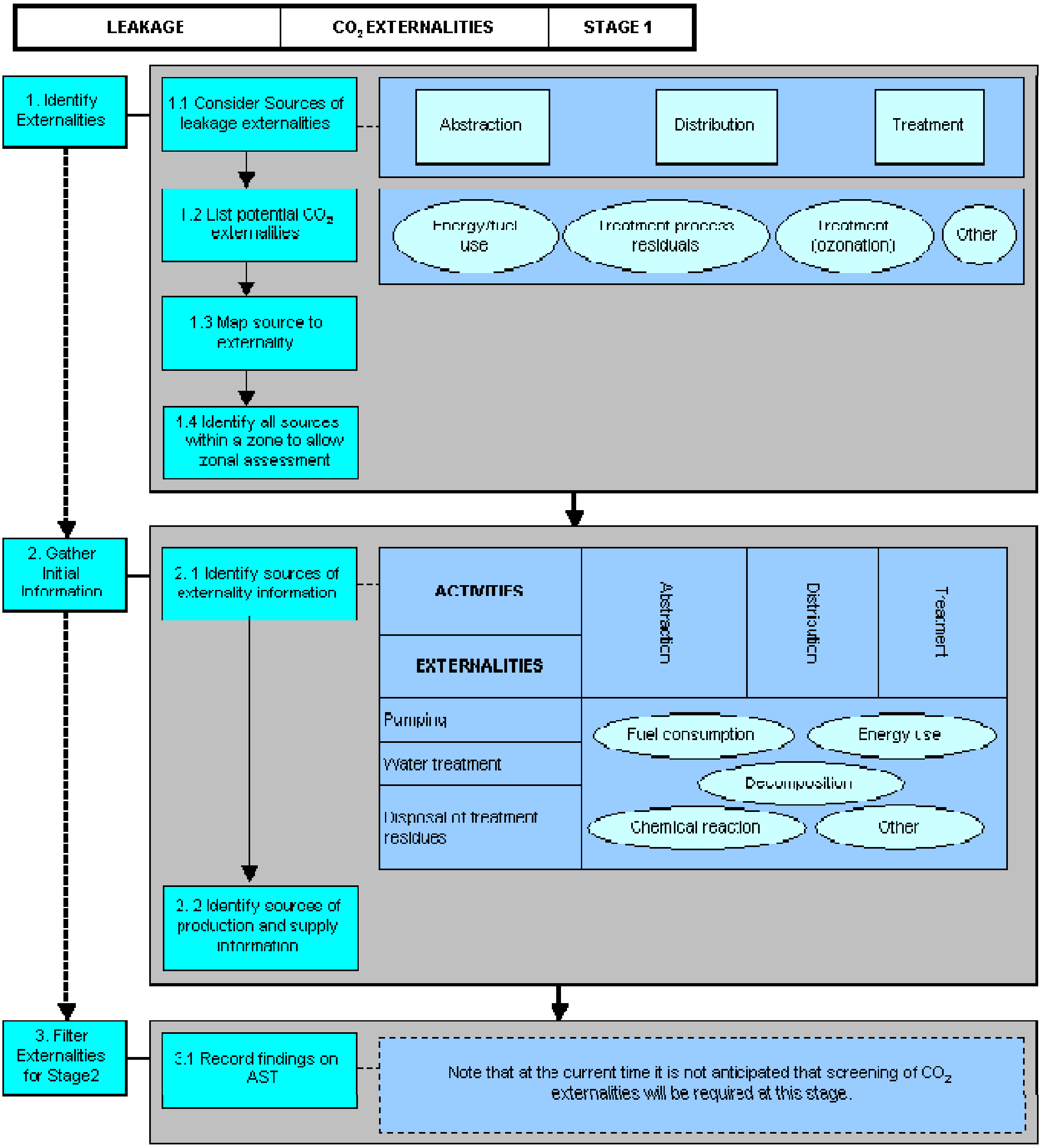


Figure 2.3: Process Map for Initial Assessment of Leakage-related CO_2 Externalities – Stage 1

STEP 1.4 IDENTIFY ALL SOURCES WITHIN A ZONE

WSPs should establish the sources of externalities within each zone. This framework will allow assessments to be made on a resource basis.

STEP 2: GATHER INITIAL INFORMATION

The objective for this step in relation to the assessment of CO_2 externalities is to establish the framework for the collection of data. The sub-steps below describe the potential data frameworks that will feed into Stage 2 of the assessment. It is important that any data framework is specifically designed to collate the necessary data to enable the calculations to be complete. This guidance recommends the form of data feeding into the assessment, however, a WSP should assess the information that they have available and try to utilise as many existing systems and data sources as possible.

STEP 2.1 IDENTIFY SOURCES OF EXTERNALITY INFORMATION

The WSP should assess the information available related to the CO_2 externalities identified in Step 1.3. The WSP should review the appropriateness of this data and collate information together to allow its manipulation during the analysis. The WSP should seek to define the following information:

Externality	Information required for calculations	Comments
Fuel use	Quantities of fuels used per annum	Should be completed for each resource zone separating out fuels consumed in abstraction, distribution and treatment.
Energy use	Quantities of energy used per annum	Should be completed for each resource zone separating out fuels consumed in abstraction, distribution and treatment.
Water treatment - ozonation	Volume of water treated by ozonation Proportion of O_3 as O_2	Should be completed for each resource zone
Water treatment - disposal of residues	Mass of drinking water treatment waste: (a) recycled to land (b) landfilled	Should be completed for each resource zone

STEP 2.2 IDENTIFY SOURCES OF WATER THROUGHPUT INFORMATION

The quantities of water abstracted, treated and distributed in the resource zone will be required for the more detailed calculations in Stage 2. Each source should be identified in order to determine/estimate the annual throughput of water.

Box 2.6: Environmental externalities: Example zone details

Zone X123 has 20,000 properties, and excess leakage (L-K) = 224 l/p/d (4.47 Ml/d)

There is 2,000 Ml of water abstracted and distributed with 2,000,000 m^3 of drinking water treated by ozonation.
In addition to this the drinking water treatment process produces 200 tonnes of waste of which 100 tonnes is recycled to land and 100 tonnes disposed of in landfill.

STEP 3: FILTER EXTERNALITIES FOR STAGE 2

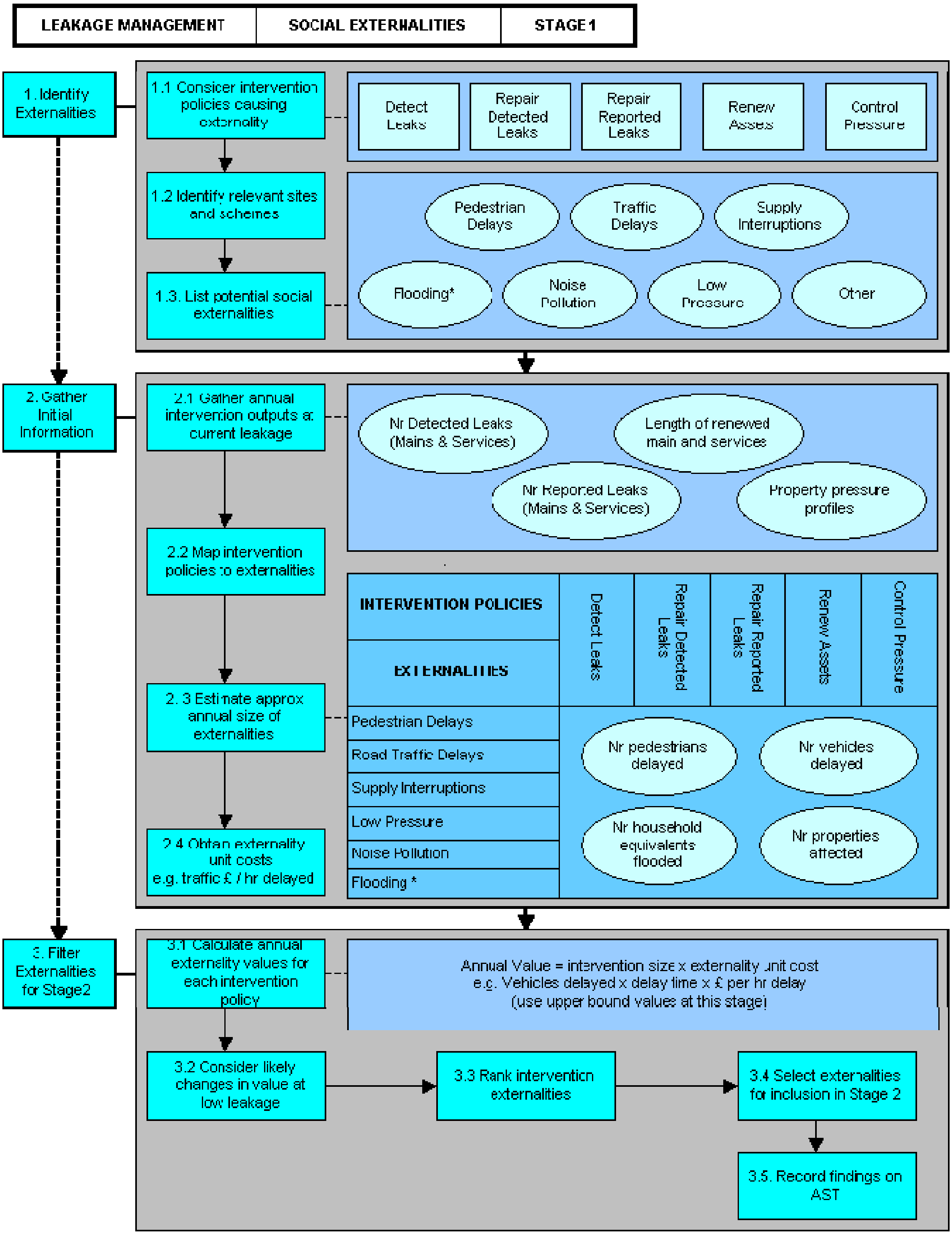
As noted above given the infancy of assessment and incorporation of CO_2 externalities into the ELL calculations it is not considered appropriate to screen elements at the current time. This step has been included in the methodology for completeness and to allow for revision in the future as appropriate.

STEP 3.1 RECORD FINDINGS ON AST

As a final step to the stage the appropriate information should be recorded on an AST together with any assumptions/justifications for decisions that have been taken.

2.2 INITIAL ASSESSMENT: LEAKAGE MANAGEMENT EXTERNALITIES

2.2.1 Social impacts



* NB Flooding due to reported mains leaks– benefit accruing to asset renewal

Figure 2.4: Process Map for Initial Assessment of Leakage Management Social Externalities

Figure 2.4 is a process map showing the recommended steps and sub-steps required for filtering those social externalities that can be discounted from further detailed analysis in Stage 2. Worked examples are provided, in boxes, where appropriate.

STEP 1: IDENTIFY EXTERNALITIES

The objective of this step is to focus the initial analysis on the relevant leakage management policies and associated social externalities. In Stage 1 the recommended focus is on those policies currently practiced, with the exception of asset renewal that may or may not have been leakage-driven.

STEP 1.1 CONSIDER INTERVENTIONS CAUSING EXTERNALITY

The leakage management intervention policies will normally include:

Active Leakage Control; Leakage-driven Asset Renewal and Pressure Control

Repair of reported leaks should also be considered.

Box 2.7
A resource zone comprises 269,244 properties and 3,356 km of distribution mains i.e. an average density of 12.5 m per connection.
Current leakage is 160 l/p/d
All leakage management policies are considered appropriate.

STEP 1.2 IDENTIFY RELEVANT SITES AND SCHEMES

Within each resource zone and in the context of each intervention policy, consider the current (or historic) levels of activity and identify the specific sites or schemes relevant to each policy.

- For ALC and Repair of reported leaks, this is likely to be DMAs across the whole or a major part of the resource zone.
- For asset renewal (whether leakage-driven or not) identify the specific scheme locations.
- For pressure management identify existing Pressure Managed Areas (PMAs) or Pressure Control Scheme locations

Box 2.8
Active Leakage Control is practiced across the whole zone (180 DMAs).
Asset renewal is undertaken at an average rate of 1% of mains per annum and includes comm. pipe renewal. Renewal is targeted at cast iron mains comprising about 25% of the zone.
About 60% of DMAs are pressure managed (162,000 properties)

STEP 1.3 LIST POTENTIAL SOCIAL EXTERNALITIES

This should include (but not be restricted to) the following externalities:

- Pedestrian and traffic delays (for example resulting from leak repair activities and asset renewal)
- Low pressure and Supply interruptions (for example resulting from leak repair activity, asset renewal, burst mains or poorly performing pressure management schemes)
- Noise pollution (for example resulting from leak repair or asset renewal activity)
- Risk of flooding from burst mains.

Box 2.9
All externalities are considered relevant for Stage 1

STEP 2: GATHER INITIAL INFORMATION

STEP 2.1 GATHER ANNUAL INTERVENTION OUTPUTS AT CURRENT LEAKAGE

At current levels of leakage in the resource zone consider each of the intervention policies in turn and determine from records (or estimate) the annual outputs of each policy as follows:

- For ALC and Repair of reported leaks – numbers of mains repairs and numbers of comm. pipe and CSP repairs
- For asset renewal (whether leakage-driven or not) – length of mains and/or numbers of comm. pipe renewals
- For pressure control – the property pressure profile i.e. numbers of properties in bands of hydraulic pressure

Box 2.10
Numbers of detected and reported leaks per year by category are:

Detected mains leaks	133	Reported mains leaks	361
Detected comms leaks	154	Reported comms leaks	515
Detected CSP leaks	99	Reported CSP leaks	330

Mains and comm. pipe renewal @ 1% = 33.6km per year

Network modelling indicates that there are approximately 5% of pressure-managed properties at risk of receiving low pressure during "peak week" conditions

STEP 2.2 MAP INTERVENTION POLICIES TO EXTERNALITIES

For the intervention policies identified in 1.1 and the externalities identified in 1.3 draw up a matrix relating one to the other.

Box 2.11

Externality	Interventions				
	Detect Leaks	Repair Detected Leaks	Repair Reported Leaks	Renew Assets	Control Pressure
Pedestrian delays		√	√	√	
Traffic delays		√	√	√	
Supply interruptions		√	√	√	√
Low pressure		√	√	√	√
Noise pollution		√	√	√	
Flooding			√		

STEP 2.3 ESTIMATE APPROXIMATE ANNUAL SIZE OF EXTERNALITIES

The objective of this step is to estimate for each of the completed matrix cells in 2.2 the approximate annual numbers of events. For example:

- Numbers of pedestrians and vehicles delayed by:
  - Leak repair activity
  - Asset renewal activity

    - Burst mains
- Numbers of properties which have experienced low pressure and supply interruption events resulting from:
    - Leak repair activity
    - Asset renewal activity
    - Burst mains
    - Pressure management schemes
- Numbers of properties which have experienced noise pollution resulting from:
    - Leak repair activity
    - Asset renewal activity
- Numbers of properties, highways etc.. which have experienced (or are at risk from) flooding resulting from:
    - Burst mains

At this stage, only approximate values are required and it is recommended that “upper bound” estimates are used. WSP records should provide local sources for some of these but generic values from various guidance documents are also available and have been used in the example described.

For the assessment of vehicle impacts a preliminary step is required which defines the degree of “urbanisation” for the zone and the proportions of standard road classes by length.

Box 2.12
Vehicles and Pedestrians affected by Leak Repair and Asset Renewal Activity
Urbanisation

The WSP has developed a simple urbanisation classification system using network density (length of main per property (L/N)) as a surrogate for degree of urbanisation:

L/N	Classification
< 10	Urban
10 – 30	Suburban
30 – 50	Semi-rural
> 50	Rural

Using this system, approximately 52% of the zone is urban, 27% suburban, 12% semi-rural and 9% rural. For the purposes of Stage 1 it is assumed that most leakage management interventions are focussed on the 52% of the network that is urban.

Analysis of standard road types within predominantly urban areas of the zone gives the following proportions:

Road Class	AB	BB	CB	UB	AN	BN	CN	UN
%	5.0	2.5	6.5	76.5	4.0	1.0	3.5	1.0

Vehicle Flow Rates
The NERA guidelines (Table 4.2.1.3) give the following vehicle flow rates for each road class:

Road Class	AB	BB	CB	UB	AN	BN	CN	UN
Vehicles/hr	1600	500	300	150	1100	400	200	50

The weighted mean vehicle flow rate for the zone is 250 vehicles per hr for built up areas and 209 for non built up areas in vehicles per hr. It is assumed that the works will be largely in built-up areas.

Pedestrian Flow rates
No guidance is available for the estimation of pedestrian flow rates. Given that safe re-routing past any obstruction is normally provided as part of the works it would seem unlikely that pedestrian delays would be significant. However in order to establish an order of magnitude it is assumed that an average walking speed is 4km/hr i.e. 10% of the average vehicle speed.
Therefore assume pedestrian flow rate = 0.10 x 250 = 25 per hr

Box 2.13
Vehicle and Pedestrians impacted by Detected Leak Repairs

Detected Mains and (assumed) 50% Comm leaks = 210
Assume duration of disruption for typical mains repair = 12 hrs
Number of vehicles affected = 250 x 12 x 210 = 630,000
Number of pedestrians affected = 25 x 12 x 210 = 63,000

Vehicle and Pedestrians impacted by Reported Leak Repairs

Reported Mains and 50% Comm leaks = 619
Assume 50% increase in duration of disruption to allow for burst mains =18 hrs
Number of vehicles affected = 250 x 18 x 619 = 2,783,250
Numbers of pedestrians affected = 25 x 18 x 619 = 278,325

Vehicle and Pedestrians impacted by Asset Renewal (assume a 100m tranche of "cut and fill" mains renewal)

Assume initial 7-day period of traffic diversion for 8 hrs per day
Number of vehicles diverted = 250 x 7 x 8 = 14,000 per tranche
Number of tranches = 336 Total vehicles diverted = 4,704,000
Add further 11 days of "narrowing" for connections
Number of vehicles affected by narrowing = 250 x 11 x 8 = 22,000 per tranche
Number of tranches = 336 Total vehicles "narrowed" = 7,392,000
Number of pedestrians affected = 25 x 18 x 8 = 3,600 per tranche
Number of tranches = 336 Total pedestrians "narrowed" = 1,209,600

Box 2.14
Properties affected by unplanned low pressure and supply interruptions

Comms and CSP leak repairs (253 detected, 845 reported)

Low pressure - assume 10% of detected leaks = 25 and 50% reported = 422
Supply interruptions – assume 5% detected leaks = 13 and 20% reported = 169

Mains leak repairs (133 detected, 361 reported)

Number of detected mains leaks = 133 across 180 DMAs = 0.74 leaks per DMA
Assume 10% result in low pressure = 0.07 leaks per DMA but no interruptions
Assume 5% of DMA properties affected
Total properties affected = 0.05 x 180 x 0.07 x 1500 = 945 properties
Number of reported mains leaks = 361 across 180 DMAs = 2.0 leaks per DMA
Assume 20% result in low pressure = 0.40 leaks per DMA but no interruptions
Assume 5% of DMA properties affected
Total properties affected = 0.05 x 180 x 0.40 x 1500 = 5,400 properties

Asset Renewal (assume a 100m tranche of "cut and fill" mains renewal)

Number of properties in affected length = 100 / 12.5 = 8
Assume all properties affected by low pressure but no loss of supply
Total renewal @ 1% = 33.6 km
Number of 100m tranches = 336
Number of properties affected = 8 x 336 = 2,688

Pressure Management

Number of properties pressure managed = 162,000
Approximately 1% of properties are found to experience below standard pressure during peak week demand = 1,620

Box 2.15
Pedestrians affected by noise pollution

Leak repairs

Assume all mains and comm. pipe leak repairs necessitate the use of road-breaking equipment. The noise level of a jack-hammer is approximately 100 dB. (ambient noise levels of background traffic are about 75 dB).

Pedestrian flow rates past a leak have been estimated above as 25 per hr
Assume the duration of equipment operation is a maximum of 2hrs per leak
Number of detected mains and comm. pipe leaks = 287
Therefore number of pedestrians affected = 25 x 2 x 287 = 14,350 per yr

Number of reported mains & comm. pipe leaks = 876
Therefore number of pedestrians affected = 25 x 2 x 876 = 43,800 per yr

Asset Renewal

For a 100m tranche of mains renewal assume duration of road-breaking equipment use = 2 days (8 hrs per day)
Number of pedestrians affected = 25 x 2 x 8 = 400 per tranche per yr
Number of 100m tranches = 336
Total pedestrians affected = 336 x 400 = 134,400

Box 2.16
Flooding from Burst Mains

Assume a proportion of reported mains leaks give rise to flooding of highways and property gardens, prior to isolation.
Number of reported mains leaks = 361
Assume 5% give rise to flooding = 18
Assume two-thirds result in highway flooding = 12
And one-third gardens in property flooding = 6

For flood damage assessment, household equivalents are given in NERA Table 4.2.7.1.
Household equivalent of garden = 0.04
Household equivalent of B/C roads = 3

Total household equivalents affected by flooding = 6 x 0.04 + 12 x 3 = 36.24

STEP 2.4 OBTAIN EXTERNALITY UNIT COSTS

The next step is to determine the unit cost values to the externalities quantified in step 2.3. WSP's should use existing company-specific values for these externalities when available. It is recommended for Stage 1 that these should treated as 'upper bound' estimates.

Box 2.17
The following unit cost values have been determined from a variety of sources including generic values from guidance literature:

Externality	Units	Unit Cost (Upper Bound)
Pedestrian delays	£ per hr delayed	26.7[1]
Vehicle delays	£ per hr delayed	30.2[2]
Supply interruptions	£ per property	10.0[3]
Low Pressure	£ per property	5.0[4]
Noise pollution	£ per capita per day	1.4[5]
Flooding	£ per household equivalent	1,400[6]

1. Tag value assuming all workers
2. Tag value assuming all workers
3. Excess over internalised GSS payments (*example only*)
4. Excess over internalised GSS payments (*example only*)
5. NERA table 4.2.5.2 (£500 per yr = £1.4 per day)
6. NERA table 4.2.7.1 (*n.b. value needs repricing*)

STEP 3: FILTER EXTERNALITIES FOR STAGE 2

The objective of this step is to estimate the annual values of the externalities for each intervention and from a ranked list remove those that are considered to be insignificant and would not be taken forward to detailed analysis in Stage 2.

STEP 3.1 CALCULATE ANNUAL EXTERNALITY VALUES FOR EACH INTERVENTION POLICY

For each intervention calculate the annual values for the appropriate externalities i.e. those mapped in step 2.2 above. The calculation process is as follows:

Annual Value = annual intervention size (step 2.3) x externality unit cost (step 2.4)

For pedestrian and vehicle delays, externality unit costs are in £ per hr delayed and therefore an additional piece of information is required which is the estimated hrs of delay appropriate to the type of the intervention being considered.

Box 2.18
Delay time for leak repairs

Average vehicle speed in built-up areas = 39 km/hr (NERA)

The nature of the delay is assumed to be due to "narrowing" for which a factor of 0.25 is assumed (NERA), giving 9.75 km/hr as the speed through the works.

For mains repairs the disrupted length is taken to be 30m

The resulting delay through the works is 0.14 minutes per vehicle.

Delay time for pedestrians assuming average walking speed of 4 km/hr = 1.35 minutes

Delay time for asset renewal (per 100m tranche)

Assume diversion in place of length 400m (4 x length of works)
Delay time = 400 x 60 / (39 x 1000) = 0.62 minutes per vehicle

Assume this is followed by "narrowing" over 100m
Delay time = 0.46 minutes per vehicle

Delay time for pedestrians assuming "narrowing" throughout = 4.5 minutes

Intervention	Nr	Units	Unit Cost	Delay (hrs)	MEC £ pa
Repair Detected Leaks					
Vehicles delayed	630,000	vehicles	30.20	0.002333	44,394
Pedestrians delayed	63,000	head	26.70	0.0225	37,847
Low Pressure	970	properties	5.00		4,850
Supply Interruptions	13	properties	10.00		130
Noise pollution	14,350	head	0.06		25
(exposure time)				0.03	
Repair Reported Leaks					
Vehicles delayed	2,783,250	vehicles	30.20	0.002333	196,126
Pedestrians delayed	278,325	head	26.70	0.0225	167,204
Low Pressure	5,822	properties	5.00		29,110
Supply Interruptions	169	properties	10.00		1,690
Noise pollution	43,800	head	0.06		77
(exposure time)				0.03	
Flooding	42	house equivs	1,400		58,800
Renew Assets					
Vehicles diverted	4,704,000	vehicles	30.20	0.010333	1,467,962
Vehicles narrowed	7,392,000	vehicles	30.20	0.007667	1,711,494
Pedestrians delayed	1,209,600	head	26.70	0.075	2,422,224
Low Pressure	2,688	properties	5.00		13,440
Supply Interruptions	0	properties	10.00		0
Noise pollution	134,400	head	0.01		131
(exposure time)				0.1	
Control Pressure					
Low Pressure	1,620	properties	5.00		8,100

Box 2.19

3.2 CONSIDER LIKELY CHANGES IN VALUE AT LOW LEAKAGE

The externality sizes estimated in step 2.3 have been at current leakage levels. Consideration should be given as to how these might change if leakage was driven down to very low levels e.g. close to Background.

For example, ALC detected repair numbers may have to increase by say 50% together with a doubling of mains renewal rates from say 1% of mains per year to 2%. Repairs to reported leaks may be assumed unchanged. There may be scope to achieve further reduction in pressure through optimisation of existing pressure management schemes.

The annual externality values from step 3.1 should be multiplied by appropriate factors to reflect these assumed changes.

STEP 3.3 RANK INTERVENTION EXTERNALITIES

From step 3.2 ensure that all annual externality values are expressed in common units e.g. £ per year. For each intervention policy rank the relevant externality values.

A convenient benchmark might be the total annual pumping and treatment cost for the leakage volume in the zone against which to compare annual externality values.

Box 2.20
Annual marginal cost of leakage volume

Current leakage in zone = 160 l/p/d
Number of properties = 269,244
Volume of leakage = 43.07 Ml/d = 15,724 Ml

Marginal cost of water in zone = £50 per Ml

Annual Marginal cost = 50 x 15,724 = £ 786,192

Intervention	MEC £ pa	% Leak Val
Repair Detected Leaks		
Vehicles delayed	44,394	5.65
Pedestrians delayed	37,847	4.81
Low Pressure	4,850	0.62
Supply Interruptions	130	0.02
Noise pollution	25	0.00
Repair Reported Leaks		
Vehicles delayed	196,126	24.95
Pedestrians delayed	167,204	21.27
Flooding	58,800	7.48
Low Pressure	29,110	3.70
Supply Interruptions	1,690	0.21
Noise pollution	77	0.01
Renew Assets		
Pedestrians delayed	2,422,224	308.10
Vehicles narrowed	1,711,494	217.69
Vehicles diverted	1,467,962	186.72
Low Pressure	13,440	1.71
Noise pollution	131	0.02
Supply Interruptions	0	0.00
Control Pressure		
Low Pressure	8,100	1.03

Box 2.21

On the basis of the ranked lists prepared in step 3.3, form a judgement on whether some of the externalities can be discarded.

Box 2.22
On the basis of the ranked lists in step 3.3 for each intervention the WSP considers that annual social externality costs that are less than 1% of the marginal value of current leakage will not be taken forward to Stage 2.

The select list is therefore:

Externality	Interventions				
	Detect Leaks	**Repair Detected Leaks**	**Repair Reported Leaks**	**Renew Assets**	**Control Pressure**
Pedestrian delays		√	√	√	
Traffic delays		√	√	√	
Supply interruptions					
Low pressure			√	√	√
Noise pollution					
Flooding			√		

STEP 3.4 RECORD FINDINGS ON AST

As a final step the results of the filtering process should be recorded in an AST together with any assumptions and the basis on which filtering has been carried out.

2.2.2 Carbon emissions

Figure 2.5 is a process map showing the recommended steps and sub-steps to be taken in completing Stage 1 in relation to greenhouse gases. The purpose of Stage 1 for the assessment of greenhouse gases is two fold. First to recommend the scope of quantitative analysis and second to put in place the framework around which the assessment of carbon can then occur.

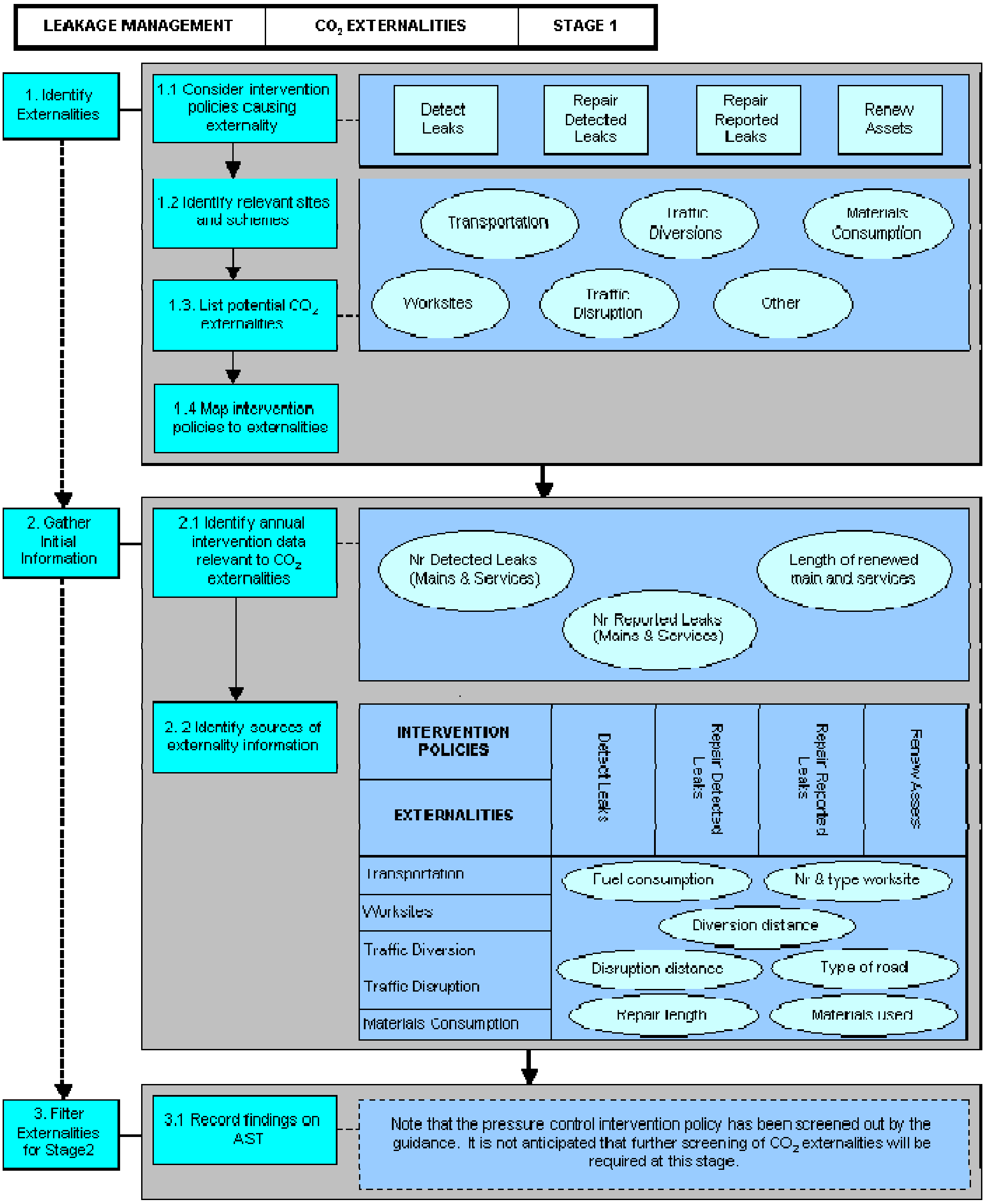


Figure 2.5: Process Map for Initial Assessment of Leakage Management CO2 Externalities

STEP 1: IDENTIFYING EXTERNALITIES

The objective of Step 1 is, as with the assessment of Social Externalities, intended to focus attention on the relevant leakage management policies and associated social externalities.

STEP 1.1 CONSIDER INTERVENTIONS CAUSING EXTERNALITY

The leakage management intervention policies will normally include the majority of those identified in Step 1.1 of the Social Externalities, namely:

- Active leakage control (detection and repair of leaks)
- Leakage-driven asset renewal
- Repair of reported leaks

Note that the leakage-driven control of pressure is not recommended for inclusion under the CO_2 externalities as typically it is not anticipated to result in a discernable impact on fuel use/emissions.

Box 2.23
A resource zone comprises 269,244 properties and 3,356 km of distribution mains i.e. an average density of 12.5 m per connection.
Current leakage is 160 l/p/d

STEP 1.2 IDENTIFY RELEVANT SITES AND SCHEMES

Note that this information is also being collected in relation to the Social Externalities.

Within each resource zone and in the context of each intervention policy, consider the current (or historic) levels of activity and identify the specific sites or schemes relevant to each policy.

- For ALC and Repair of reported leaks, this is likely to be DMAs across the whole or a major part of the resource zone.

- For asset renewal (whether leakage-driven or not) identify the specific scheme locations.

Box 2.24
Active Leakage Control is practiced across the whole zone (180 DMAs).
Asset renewal is undertaken at an average rate of 1% of mains per annum and includes comm. pipe renewal. Renewal is targeted at cast iron mains comprising about 25% of the zone.

STEP 1.3 LIST POTENTIAL SOURCES OF CO_2 EXTERNALITIES

This should include (but not be restricted to) the following externalities:

- Emissions from fuel/energy use transportation
- Emissions from fuel/energy use on worksites
- Emissions caused by traffic diversions
- Emissions caused by traffic disruption (lane narrowing)
- Emissions embedded in materials used.

STEP 1.4 MAP INTERVENTION POLICIES TO POTENTIAL EXTERNALITIES

For the intervention policies identified in Step 1.1 and the externalities identified in Step 1.3 draw up a matrix identifying the relationships.

Externality	Interventions			
	Detect Leaks	Repair Detected Leaks	Repair Reported Leaks	Renew Assets
Fuel/energy use transportation	√	√	√	√
Fuel/energy use worksites		√	√	√
Traffic diversions		√	√	√
Traffic disruption		√	√	√
Materials consumption		√	√	√

STEP 2: GATHER INITIAL INFORMATION

The objective for this step in relation to the assessment of CO_2 externalities is to establish the framework for the collection of data. The sub-steps below describe the potential data frameworks that will feed into Stage 2 of the assessment. It is important that any data framework is specifically designed to collate the necessary data to enable the calculations to be complete. The approach adopted is to recommend the data form feeding into the assessment, however, a WSP should assess the information that they have available and try to utilise as many existing systems and data sources as possible.

STEP 2.1 GATHER ANNUAL INTERVENTION OUTPUTS AT CURRENT LEAKAGE

The current levels of leakage in the resource zone will be required for the more detailed calculations in Stage 2. Each intervention policy should be assessed in order to determine/estimate the annual outputs of each policy as follow:

- For ALC and Repair of reported leaks – numbers of mains repairs and numbers of comm. pipe and CSP repairs
- For asset renewal (whether leakage-driven or not) – length of main and number of comm. pipe renewals.

Note this information is also required under Step 2.1 of the assessment of Social Externalities.

Box 2.25
Numbers of detected and reported leaks per year by category are:

Detected mains leaks	133	Reported mains leaks	361
Detected comms leaks	154	Reported comms leaks	515
Detected CSP leaks	99	Reported CSP leaks	330

Mains and comm. pipe renewal @ 1% = 33.6km per year

STEP 2.2 IDENTIFY SOURCES OF EXTERNALITY INFORMATION

The WSP should assess the information available related to the CO_2 externalities identified in Step 1.3. The assessment should review the appropriateness of this data and collate this information together to allow its manipulation during the analysis. The information should seek to define the following:

Externality	Information required for calculations	Comments
Fuel/energy use transportation	Total fuel/energy consumption by type (This should be sub-divided into leakage detection and repair)	Actual fuel consumption divided into leakage detection and repair is ideal. If not available then information on vehicle type, mileage, engine size and age should be used to derive the fuel consumption.
Fuel/energy use worksites	Number and type of worksites	Emissions factors are provided in the relevant Step
Traffic diversions	Distance of diversion Road type	
Traffic disruption (lane narrowing)	Length of disruption (m) Road type	
Materials consumption	Length of repair/replacement (m) Material	

STEP 3: FILTER EXTERNALITIES FOR STAGE 2

As noted above, given the infancy of assessment and incorporation of CO_2 externalities into the ELL calculations it is not considered appropriate to screen elements at the current time. The suggested scope above has already screened out the pressure control intervention option. This step has been included in the methodology for completeness and to allow for revision in the future as appropriate.

STEP 3.1: RECORD FINDINGS ON AST

As a final step to the stage the appropriate information should be recorded on an AST together with any assumptions/justifications for decisions that have been taken.

3 STAGE 2: DETAILED ASSESSMENT OF EXTERNALITIES

The objective of Stage 2 is to undertake a more detailed quantitative assessment of the externalities that are likely to have a significant impact on the ELL calculation. These were identified at Stage 1.

Figure 3.1 highlights the Stage 2 steps of the overview process. These steps comprise:

4. Data preparation
5. Evaluate leakage-related externalities
6. Develop zone-level external cost ~ leakage relationships

The following sections describe the steps required for the detailed analysis of significant leakage-related externalities, i.e. environmental and carbon impacts (Section 3.1) and significant leakage management externalities, i.e. social and carbon impacts (Section 3.2).

The steps are subdivided and each sub-step is described with examples where appropriate.

The output from Stage 2 is a set of data quantifying, for each set of impacts, the central, upper and lower bound assessments of the marginal external cost for a range of leakage levels.

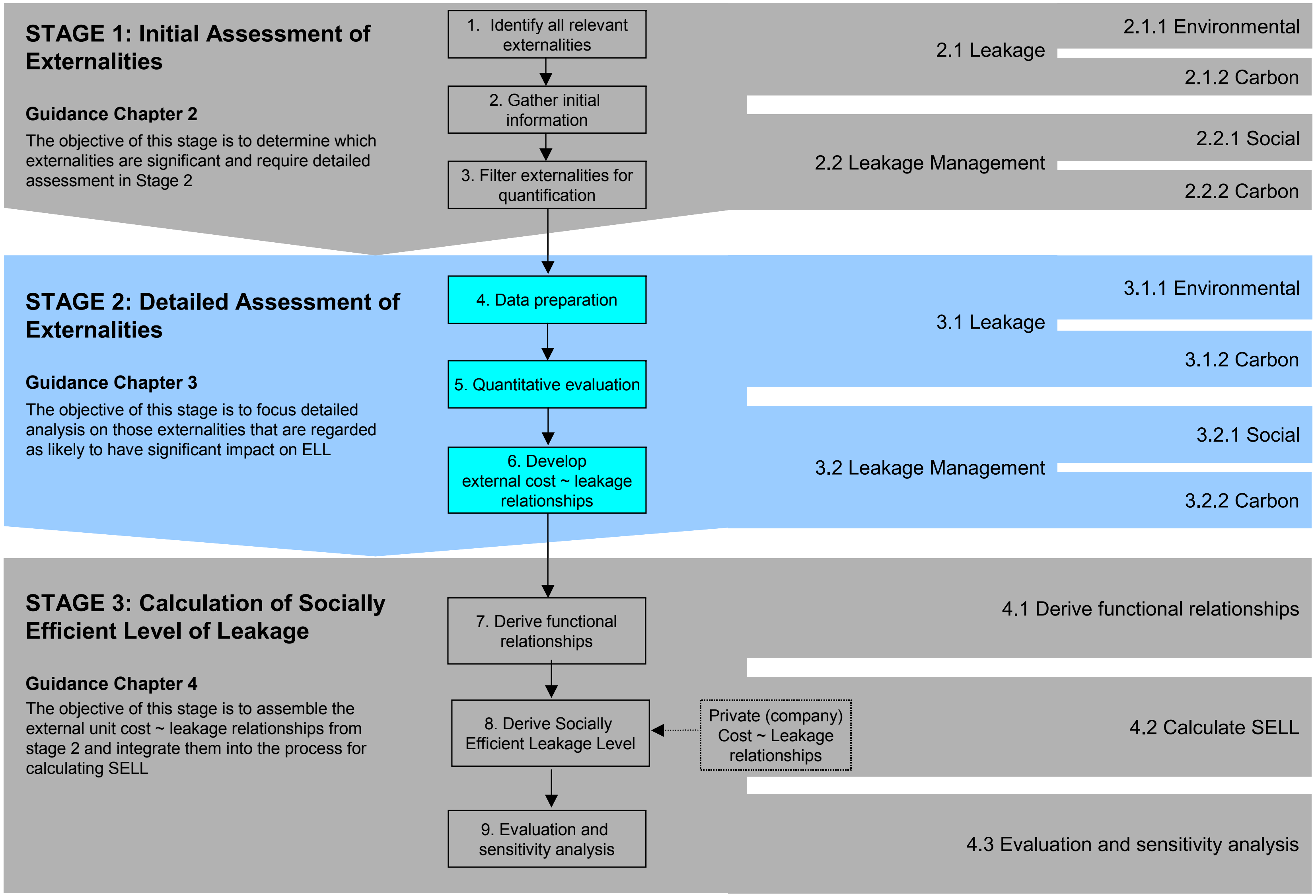


Figure 3.1: Overview Process Map – Stage 2

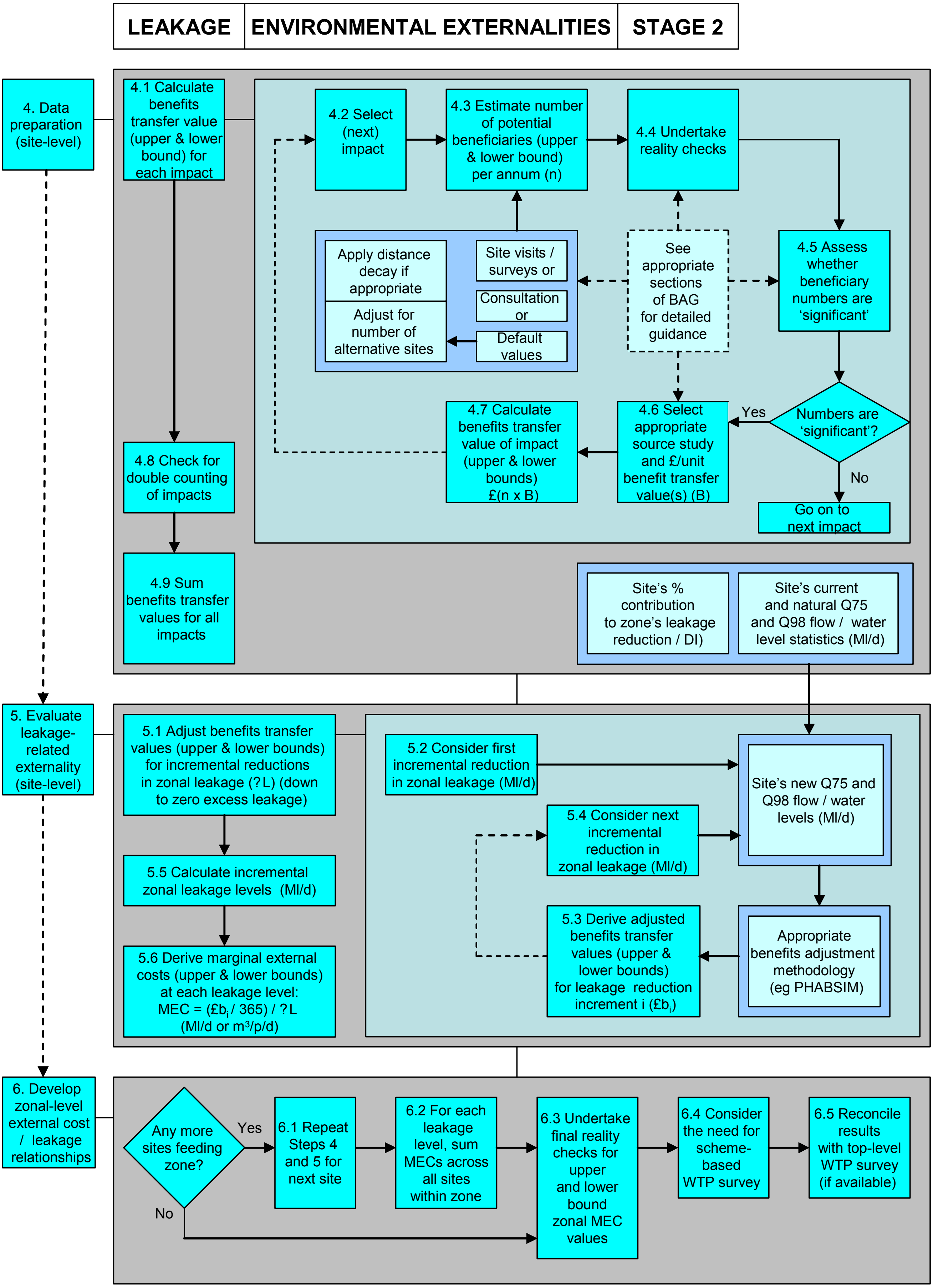


Figure 3.2: Process Map for Detailed Assessment of Environmental Externalities – Stage 2

3.1 DETAILED ASSESSMENT: LEAKAGE-RELATED EXTERNALITIES

3.1.1 Environmental Externalities

Figure 3.2 is a process map showing the recommended steps required to determine the relationship between external environmental costs and leakage.

STEP 4:	**DATA PREPARATION (SITE LEVEL)**

Step 4 uses the benefits transfer approach to derive a value which represents the total environmental benefits arising from a 'significant' flow / water level change at the identified site. At Step 5, the benefits valuation is then downwardly adjusted (moderated), using a suitable flow / water level adjustment approach, to reflect the significantly smaller changes in flow / water levels which are likely to occur given incremental changes in zonal leakage. Finally, Step 6 involves the aggregation of site-level marginal environmental costs to zone level for inclusion in the ELL model.

The Step 4 analysis draws on a considerable quantity of data that may be wholly or partly site-specific or which provides, in the absence of site-specific information, default values.

Step 4 draws heavily on the guidance provided by the BAG (RPA, 2003), which is based on application of the benefits transfer approach. Despite its well-documented shortcomings (see Section 3 of the Main Report for a review), given the costs of undertaking non-market valuation studies for a large number of sites, the benefits transfer approach offers, when used with care, a pragmatic tool for desk-based studies of this nature.

Step 4 requires that close reference is made the BAG and its relevant sections appropriately applied. A broad overview of the key elements of the approach is provided in this Guidance. References to relevant BAG data sources are provided wherever possible.[6]

STEP 4.1	**CALCULATE BENEFITS TRANSFER VALUE (UPPER AND LOWER BOUNDS) FOR EACH IMPACT**

This step involves, for each site, calculation of an environmental benefits value for each impact identified as significant at Stage 1. This is determined by estimating the number of people, per annum, likely to benefit from a flow change at the affected site (n), and multiplying this number by a (per head or per household) benefits transfer value appropriate to the impact (£B). Central, upper and lower bound values should be derived.

It should be noted that the assessment of beneficiary numbers is based on estimates of existing use and non-use populations. Reliable methods do not yet exist for predicting changes in use and non-use populations following changes in flows / water levels. Instead, the benefits of the change are expressed though the increased willingness to pay for the improvements by existing beneficiaries.

Steps 4.2-4.7 describe the process in more detail.

STEP 4.2	**SELECT (NEXT) IMPACT**

This step ensures that, for a given site, all significant impacts are considered

STEP 4.3	**ESTIMATE THE NUMBER OF POTENTIAL BENEFICIARIES PER ANNUM (N)**

[6] Although no review is planned, subsequent up-dates of the BAG may outdate these references.

This step involves assessment of the population of beneficiaries (upper and lower bounds). Following the BAG, these can be assessed using either:

- Site visits or visitor surveys: visitor counts along the affected reach or at a given site at different times of the day, week, month or year provide the basis for assessing the annual number of beneficiaries;
- Consultation-based estimates: estimates of the annual number of beneficiaries may be based on consultation with local government (District Councils), British Waterways, Wildlife Trusts, Tourist Offices, Ramblers, angling and other local clubs, boat and other hire agencies, Environment Agency Rod Licence data etc.
- Default data – involves reliance on either GIS mapping or standard (national) population density formulae, and area (Census) statistics

The choice of available methods for making this assessment is clearly dependent on the quantity and quality of available information and the cost, in terms of time and resources, of obtaining more accurate data.

The recommended best practice approach involves the collection of site specific data based on visitor counts. The next best alternative involves the use of site-specific consultation-based assessments of visitor numbers. Clearly, neither approach is valid for assessing non-use related beneficiaries. For this impact, the default method must be used.

The use of default data requires use of information gathered at Stage 1, and involves a number of additional assumptions. Estimates of the total population within a selected radius are best obtained using GIS mapping. Alternatively, the default population density formula provided in the BAG may be used, together with relevant Census data on local/regional population densities and household occupancy rates (where relevant).
If using this approach, account should be taken in this calculation of sites which are located near the coast (or other areas of significant surface water).

Default assessments of the beneficiaries for some impacts (typically bio-diversity and non-use) involve the specification of 'distance-decay'. Distance-decay occurs when people's valuations of site improvements decline as the distance from the site increases. Some valuation studies present radius-based distance-decay relationships for the benefits transfer values. Application of these values requires relevant populations to be calculated for each radius.

Default beneficiary assessments are based on the assumption that there are no alternative sites of similar or better quality within the relevant radius which compete for the assessed population of beneficiaries. To adjust for this, beneficiary assessments should be divided by the total number of available sites within the relevant radius.

The appropriate population radii relevant for different sites of varying quality, size and environmental characteristics are presented in the BAG, together with assumptions about the proportion of the total population within these radii that might be expected to benefit from improvements in flows/ water levels at the site.

Detailed calculations for the worked example (Zone A123, Site 1 – River Bank, Shallow Reach) are provided in Annex A for informal recreation (Table A.2), and biodiversity and non-use (Table A.3).

Box 3.1:Environmental externalities. Step 4.3: Estimate upper and lower bound numbers of beneficiaries per annum

Site 1. River Bank, Shallow Reach (affected for 8km downstream from Aspot)

Angling beneficiaries:

Data from local angling association:
Association membership = 513
Survey of annual non-member trips (day-ticket sales) = 388

From the BAG (Part 2) Table 3.8, the total number of trips made per annum by both members and non-members can be estimated by 388 / 45% (for a trout fishery) = 863. This provides a lower bound estimate.

Alternatively, it is assumed that members make between 3 and 11 angling trips per year (the BAG (Part 2) Table 3.10) but due to the existence of some 25 other alternative game fishing sites within a 30km radius and the relatively small size of the fishery, the lower of these numbers is more likely. Total annual visits to the site by members is estimated to be 1539. Including visits by non-members, this produces a possible upper bound assessment of total visit numbers of 1,927

Default values:
5% of the adult population within a 60km radius may be expected to visit this type of trout fishery (the BAG (Part 2) Table 3.11). Using the default population formula (the BAG Part 2 and Census data for regional population densities (= 45.54 people per km^2), the total population within this radius = 1,749,983. Multiplying by 0.8 to derive the adult population, and multiplying by 0.05 to derive the percentage that are likely to visit the site each year = 70,000. However, there are some 25 other similar sites within a 30km radius, thus anglers at this site may be limited to 70,000/26 = 2,692. This value is taken as an upper bound estimate.

Angling beneficiaries per annum:
Lower bound = 863
Upper bound = 2,692

STEP 4.4 UNDERTAKE REALITY CHECKS

The estimation of beneficiary numbers is associated with a high degree of uncertainty. Reality checks allow the analyst to establish whether the upper and lower bound assessments are of an appropriate order of magnitude, particularly when default values have been used.

A simple reality check involves calculating visitors (beneficiary numbers) per day, and an assessment of whether the value appears appropriate for the site in question. The values can also be compared with assessments from alternative sources.

Box 3.2: Environmental externalities. Step 4.4: Undertake reality checks

Site 1. River Bank, Shallow Reach (8km)

Reality checks for angling beneficiaries:
The season for this type of fishery produces around 76 weekend days of fishing, with 78% of trips occurring at the weekends (the BAG (Part 2)).
Lower bound daily number of visits = 863 x 0.78 / 76 = 8.9. With 16km of accessible bank = this implies 1 angler per 1.8 km of bank (or 1 angler per 790m of bank for 7km of the more accessible bank along lower reaches)
Upper bound daily number of visits = 2,692 x 0.78 / 76 = 27.6. With 16km of accessible bank = this implies 1 angler per 580m of bank (or 1 angler per 250m of bank for 7km of the more accessible bank along lower reaches)

For game fishing, 1 angler typically requires at least 50m of bank. Reality checks show therefore that both estimates appear reasonable, given that the site is a small but good quality, natural game fishery, with limited access over certain reaches and popular mainly with locals.

STEP 4.5 ASSESS WHETHER BENEFICIARY NUMBERS ARE SIGNIFICANT

This step allows impacts where beneficiary assessments are insignificant to be disregarded from further analysis. While there is no objective means of determining whether resulting assessments are significant or otherwise, reference to the site's size, and existing leakage levels, and comparison with assessments at other sites can provide some guidance. The BAG suggests, as a general rule of thumb, that upper bound assessments that are less than 1000 can reasonably be regarded as negligible.

Box 3.3: Environmental externalities. Step 4.5: Assess whether beneficiary numbers are 'significant'

Site 1. River Bank, Shallow Reach (8km)

Significance of angling beneficiaries:
As the upper bound number is significant (i.e. > 1,000), a quantitative valuation of impacts was completed for angling (although the beneficiary numbers are relatively low, the per unit benefit transfer values for angling are typically high).

STEP 4.6 SELECT APPROPRIATE SOURCE STUDY AND £/UNIT BENEFITS TRANSFER VALUE(S) (B)

This step involves selection of an appropriate source study for benefits transfer to the study site. The BAG reviews and presents valuations for a number of appropriate studies that were available at the time of publication. On the basis of the criteria outlined in the BAG, an appropriate value (or values) for benefits transfer should be selected from the alternatives presented in the BAG, and the value(s) inflated to current prices.

Once selected, it is important to convert either the benefits transfer value(s) or beneficiary numbers to consistent units (e.g. £/visitor household, or £/adult user etc) for aggregation at Step 4.7.

Box 3.4: Environmental externalities. Step 4.6: Select appropriate source study and £/unit benefit transfer values

Site 1. River Bank, Shallow Reach (8km)

Unit benefits transfer values for angling
There are two studies that have derived estimates of angler's willingness to pay for improvements in river flows so as to improve or maintain fishery quality. These studies are described and recommended in the BAG (Part 2) as upper and lower bound limits in this context.

Upper bound unit benefits transfer values were taken from the study by Middlesex University (1994) of the benefits of reinstating angling opportunities on the River Misbourne as a result of flow improvements.

Lower bound unit benefits transfer values were taken from the ERM study (1997) of the value to anglers (Game and coarse) of low flow alleviation on rivers in the South West Region.

Upper bound: £11.00 per visit (2001 prices)
Lower bound: £2.38 per visit (2001 prices)

Both values include consumer surplus and economic rent

STEP 4.7 CALCULATE BENEFITS TRANSFER VALUE OF IMPACT £ (N X B)

This step involves simply multiplication of relevant beneficiary numbers by the selected benefits transfer value. If two alternative benefits transfer values are available, these may be applied to the relevant upper and lower bound beneficiary assessments.

Box 3.5: Environmental externalities. Step 4.7: Calculate benefits transfer value of impact

Site 1. River Bank, Shallow Reach (8km)

Benefits transfer values for angling
Annual angling benefits transfer value for a significant flow improvement:

Upper bound = 11 x 2692 x 1.1079 (RPI) = £32,807
Lower bound = 2.38 x 863 x 1.1079 (RPI) = £2,276

STEP 4.8 CHECK FOR DOUBLE COUNTING OF IMPACTS

This step is intended as a check for the potential double counting of impact valuations.

Double counting might occur either when there is an overlap between impact categories, when the same population is used for different impacts (particularly use and non-use, or when benefits transfer values include more than just the specific impact being valued. The steps required to avoid and/or to resolve double counting under each of these circumstances are outlined in more detail in the relevant parts of the BAG.

Box 3.6: Environmental externalities. Step 4.8: Check for double counting of impacts

Site 1. River Bank, Shallow Reach (8km)

Angling:
Angler numbers were deducted from the assessed beneficiary numbers for informal recreation. This was necessary for this study because total 'user' numbers for informal recreation were derived by deducting the non-use population from the total estimated population within the relevant radius, and these therefore included angler numbers.

STEP 4.9 SUM BENEFITS TRANSFER VALUES FOR ALL IMPACTS

Once double counting has been satisfactorily resolved, the benefits transfer values for all impacts can be summed to produce a value which represents the total environmental benefits arising from a 'significant' flow / water level change at the identified site.

Box 3.7: Environmental externalities. Step 4.9: Sum estimated benefits transfer values for all quantified impacts

Site 1. River Bank, Shallow Reach (8km): All impacts

Benefit transfer values shown relate to a 'significant' improvement in flows

	Lower bound (£)	Upper bound (£)
Angling	2,276	32,807
Informal recreation	772	1,275
Instream recreation	Insignificant visitor numbers	
Biodiversity and non-use	4,704	40,341
Amenity	Negligible impact	
Abstractions	Negligible impact	
Heritage, archaeology and landscape	No impact	
Commercial fisheries	No impact	
Agricultural use	Negligible impact	
Commercial navigation	Negligible impact	
TOTAL	7,751	74,443

STEP 5: EVALUATE LEAKAGE RELATED EXTERNALITY (SITE-LEVEL)

Quantification of the flow/water level change that gives rise to the target site's assessed benefit value is extremely difficult. This is because the environmental characteristics and flow changes considered in the different source studies used in the analysis (a) vary in both nature and extent and (b) cannot be translated into a reliable equivalent for the target site.

Typically, source studies relate to a 'significant' flow improvement, often from low flow conditions to more natural flow conditions. Even when this is not the case, the flow change evaluated is still likely to be 'significant' relative to the near-negligible flow changes resulting from incremental leakage reductions.[7]

It follows that there is a need to downwardly adjust (or moderate) the benefit valuation, using a suitable flow/water level adjustment approach, to reflect the significantly smaller changes in flow / water levels which occur given incremental changes in leakage (abstraction). This is the aim of Step 5.

STEP 5.1 ADJUST BENEFITS TRANSFER VALUES (UPPER AND LOWER BOUNDS) FOR INCREMENTAL REDUCTIONS IN ZONAL LEAKAGE (ΔL) DOWN TO ZERO EXCESS LEAKAGE

Steps 5.1 - 5.4 are concerned with the adjustment (moderation) of the site's benefit valuations (obtained at Step 4) to reflect the size of the likely benefits derived from incremental changes in zonal leakage, through their impact on flow/water level changes at the site.

The range of leakage levels appropriate for consideration is defined, approximately, by current leakage levels and zero excess leakage. Leakage levels significantly in excess of existing levels are likely to be considered both politically unacceptable and environmentally unsustainable, while leakage levels at or very near zero excess leakage are likely to be economically infeasible.

STEP 5.2 CONSIDER FIRST INCREMENTAL REDUCTION IN ZONAL LEAKAGE (ML/D)

This step involves the specification of increments of leakage reduction. Note that the value of these increments does not affect the resulting marginal cost assessments, but merely determines the number of data points through which a cost ~ leakage relationship can be fitted.

Clearly, when there are two or more sources of abstraction in a zone, the full volumetric effect of a specified zonal leakage reduction will not be felt at both sites. Unless specific information on the expected reduction in the different sources' abstracted volumes is available, an assumption may be made that the reduction in abstraction at each source is directly proportionate to the source's contribution to zone distribution input.

By considering the relatively weighted impact of zone-level leakage reduction on the abstraction volumes from each source in this way, the associated marginal environmental costs derived for individual sites can be directly summed, thus the environmental impacts at each site, whether zero, negligible or significant, will be appropriately weighed in the (aggregated) marginal environmental costs for the zone as a whole.

Step 5.2 requires determination of the new flows / water levels resulting from the incremental change in leakage, together with data (gathered at Stage 1) relating to current and natural flows / water levels. These define the extent to which the water resource is functioning at relatively low flows or at more naturalised flows.

[7] The resulting benefit valuation may in this respect be regarded as the marginal external value of a 'gross' flow change increment.

An appropriate flow adjustment methodology should then be applied to estimate the percentage of the site's benefit valuation that should be taken as a measure of the environmental value of the incremental flow change. The most well-known methodology for adjusting environmental benefits valuations for different river flow changes is provided by a set of functional relationships derived from the ecological in-stream flow simulation model, PHABSIM (RPA, 1998).

The application of PHABSIM in this context was discussed and reviewed in the Tripartite Report (2002), and is also reviewed in Section 5 of the Main Report for this Guidance. Notwithstanding its shortcomings, it is recommended that PHABSIM is used for the adjustment of assessed river flow benefits valuations, unless a demonstrably superior alternative is available.

PHABSIM employs a set of equations to calculate, for a specified flow change at the target site, the percentage of the source study benefits valuation that should be applied. This percentage is derived using a set of flow/benefit relationships (for both Q75 and Q98 flows) which estimate the change in environmental value occurring given a change in river flow from current to proposed, where these are expressed as a percentage of natural flows[8].

Adjustment factors are calculated using functional relationships for both Q98 and Q75 flow, and the higher of the two factors is taken. Under the decision rules employed by the methodology, unless the relevant river is exhibiting very low flows, the Q75 relationship will be selected as the relevant one for flow adjustment purposes.

However, a key limitation of the PHABSIM methodology relates to the linearity of the Q75 flow relationship. It seems reasonable to assume that the environmental impacts of a flow improvement at relatively low flows are likely to have a higher benefit value than an equivalent flow improvement at near natural flow levels. While PHABSIM reflects this non-linearity in its Q98 functional relationship, the model assumes a linear relationship between flow levels and environmental improvements for the Q75 flow measure.

The implication arising from this restrictive functional relationship is that, frequently, the marginal environmental costs (MEC's) resulting from PHABSIM are constant for all zonal leakage levels. This restriction offers the advantage that, for inclusion in the ELL calculation, the resulting zone-level MEC may in these circumstances simply be added to the marginal operating cost of water.

STEP 5.3 DERIVE ADJUSTED BENEFITS TRANSFER VALUES (UPPER AND LOWER BOUNDS) FOR LEAKAGE REDUCTION INCREMENT i (£B_i)

This step provides the upper and lower bounds for the annual environmental benefit associated with the incremental reduction in leakage.

STEP 5.4 CONSIDER NEXT INCREMENTAL REDUCTION IN ZONAL LEAKAGE (ML/D)

This step defines the iterative process whereby the annual environmental benefit of each incremental reduction in zonal leakage is calculated, down to zero excess leakage. If PHABSIM is used, changes to both Q75 and Q98 flows should be examined and the greater of the two impacts should be taken as the environmental benefit. If the impact is found to be greater for Q75 flow changes, it should be noted that, since the relationship is linear (ie the impact of an incremental flow change is constant over all flow levels), the repeated calculation for successive leakage reduction increments is not required.

STEP 5.5 CALCULATE INCREMENTAL ZONAL LEAKAGE LEVELS (ML/D)

8 A graphical illustration of this method is provided in Part 2 of the BAG (RPA, 2003).

Step 5.5 involves calculation of the zonal leakage levels required to develop the marginal environmental cost ~ leakage relationship. This is achieved simply by deducting successive leakage increments (ΔL) from current zonal leakage

STEP 5.6 DERIVE SITE'S MARGINAL EXTERNAL COST (UPPER AND LOWER BOUNDS) AT EACH LEAKAGE LEVEL: MEC = (£B_l / 365) / ΔL

Step 5.6 is concerned with the calculation of marginal environmental costs. These are calculated by dividing the annual environmental benefit of each leakage increment by 365 to derive a daily environmental benefit, which is then divided by ΔL to produce a marginal environmental cost in Ml/d. This value may be appropriately converted to m^3/p/d or any other metric appropriate for its inclusion in the ELL model.

Box 3.7 presents a worked example demonstrating the application of Step 5 using the PHABSIM model. The mathematical relationships for the relevant Q75 and Q98 flow levels are also provided in the example. For illustration, both Q75 and Q98 impact assessments are presented, although in this case, since the % environmental benefits is greatest for the Q75 flow level, the relevant marginal environmental cost assessments are those associated with Q75 flows. It can be seen from the example that these values are constant for all leakage levels, thus reflecting the linear nature of the Q75 relationship.

Box 3.8: Environmental externalities. Step 5: Evaluate leakage-related externality (site-level)

Application of PHABSIM flow adjustment method to Site 1: River Bank, Shallow Reach

Site	River Bank, Shallow Reach	
Zone	X123	
No. properties in zone	20,000	
Site's % contribution to zone distribution input	85	
Current zonal excess leakage L-K (l/p/d)	224	
Current zonal excess leakage L-K (Ml/d)	4.47	
River RE band	1	
Incremental change in zonal leakage (l/p/d)	15	
Incremental change in zonal leakage Ml/d	0.3	
Incremental change in site flows ml/d	0.255	
	Q98	Q75
Natural flow Ml/d	14.76	24.32
Current flow Ml/d	7.98	19.47

Q75 PHABSIM formula: % environmental value = (m x percentage of natural flow) + c
Q98 PHABSIM formula: % environmental value = m x Ln (% of natural flow)

	Q 75 Band	m	c
Q75	1	2	-150
Q75	2	1	-50
Q75	3	0.67	-16.67
Q98	na	21.545	1

Value of impacts for Q75 flows

Zone excess leakage (L-K) Ml/d	Site's Q75 flow ml/d	% natural flow (Q75)	% Environmental value (from PHABSIM Q75 RE1 relationship)	% of annual benefits transfer value delivered by incremental flow improvement / leakage reduction	Annual environmental benefit of incremental reduction in leakage (= environmental cost of an incremental increase in leakage)		Marginal environmental cost of leakage (£/Ml			Zone excess leakage (L K) l/p/d
					Lower bound £b_i	Upper bound £b_i	Lower bound	Upper bound	Midpoint	
4.47	19.47	80.06	10.12							224
4.17	19.73	81.11	12.21	2.097	162.55	1,561.10	1.75	16.77	9.26	209
3.87	19.98	82.15	14.31	2.097	162.55	1,561.10	1.75	16.77	9.26	194
3.57	20.24	83.20	16.41	2.097	162.55	1,561.10	1.75	16.77	9.26	179
3.27	20.49	84.25	18.50	2.097	162.55	1,561.10	1.75	16.77	9.26	164
2.97	20.75	85.30	20.60	2.097	162.55	1,561.10	1.75	16.77	9.26	149
2.67	21.00	86.35	22.70	2.097	162.55	1,561.10	1.75	16.77	9.26	134
2.37	21.26	87.40	24.79	2.097	162.55	1,561.10	1.75	16.77	9.26	119
2.07	21.51	88.45	26.89	2.097	162.55	1,561.10	1.75	16.77	9.26	104
1.77	21.77	89.49	28.99	2.097	162.55	1,561.10	1.75	16.77	9.26	89
1.47	22.02	90.54	31.09	2.097	162.55	1,561.10	1.75	16.77	9.26	74
1.17	22.28	91.59	33.18	2.097	162.55	1,561.10	1.75	16.77	9.26	59
0.87	22.53	92.64	35.28	2.097	162.55	1,561.10	1.75	16.77	9.26	44
0.57	22.79	93.69	37.38	2.097	162.55	1,561.10	1.75	16.77	9.26	29
0.27	23.04	94.74	39.47	2.097	162.55	1,561.10	1.75	16.77	9.26	14

Value of impacts for Q98 flows

Zone excess leakage (L-K) Ml/d	Site's Q98 flow ml/d	% natural flow (Q98)	% Environmental value (from PHABSIM Q98 relationship)	% of annual benefits transfer value delivered by incremental flow improvement / leakage reduction	Annual environmental benefit of incremental reduction in leakage (= environmental cost of an incremental increase in leakage)		Marginal environmental cost of leakage (£/Ml			Zone excess leakage (L K) l/p/d
					Lower bound £b_i	Upper bound £b_i	Lower bound	Upper bound	Midpoint	
4.47	7.98	54.065	85.969							224
4.17	8.24	55.793	86.646	0.678	52.53	504.50	0.56	5.42	2.99	209
3.87	8.49	57.520	87.303	0.657	50.93	489.11	0.55	5.26	2.90	194
3.57	8.75	59.248	87.941	0.638	49.42	474.64	0.53	5.10	2.82	179
3.27	9.00	60.976	88.560	0.619	48.00	460.99	0.52	4.95	2.73	164
2.97	9.26	62.703	89.162	0.602	46.66	448.11	0.50	4.81	2.66	149
2.67	9.51	64.431	89.748	0.586	45.39	435.93	0.49	4.68	2.59	134
2.37	9.77	66.159	90.318	0.570	44.19	424.40	0.47	4.56	2.52	119
2.07	10.02	67.886	90.873	0.555	43.05	413.45	0.46	4.44	2.45	104
1.77	10.28	69.614	91.415	0.541	41.97	403.06	0.45	4.33	2.39	89
1.47	10.53	71.341	91.943	0.528	40.94	393.18	0.44	4.22	2.33	74
1.17	10.79	73.069	92.458	0.516	39.96	383.77	0.43	4.12	2.28	59
0.87	11.04	74.797	92.962	0.503	39.03	374.80	0.42	4.03	2.22	44
0.57	11.30	76.524	93.454	0.492	38.13	366.25	0.41	3.93	2.17	29
0.27	11.55	78.252	93.935	0.481	37.28	358.07	0.40	3.85	2.12	14

STEP 6 DEVELOP ZONE-LEVEL EXTERNAL COST~ LEAKAGE RELATIONSHIPS

The aim of the final step of Stage 2 is to convert the site-level marginal environmental cost relationships into zone-level relationships ready for inclusion in the ELL model.

STEP 6.1 REPEAT STEPS 4 AND 5 FOR NEXT SITE

This step ensures that the significant environmental impacts associated with the remaining Stage 2 sites feeding the zone (if any) are also considered.

STEP 6.2 FOR EACH LEAKAGE LEVEL, SUM MEC'S ACROSS ALL SITES WITHIN ZONE

Once marginal environmental costs for each relevant site have been derived, the cost ~ leakage relationships may be directly summed, as discussed at Step 5.2, to produce a zone-level MEC assessment.

STEP 6.3 UNDERTAKE FINAL REALITY CHECKS FOR UPPER AND LOWER BOUND ZONAL MEC'S

This step provides a final opportunity to assess whether resulting zonal MEC assessments are realistic relative to a priori expectations and assessments of zones/sites with comparable environmental characteristics in other zones, areas and regions within the UK.

The data inputs for any lower (or upper) bound valuations that are significantly higher (or lower) than might reasonably be expected should be closely re-appraised, and detailed sensitivity analyses undertaken in order to pin-point the source of any anomalies. The site(s) or impact(s) contributing most to the unexpected result should also be identified.

STEP 6.4 CONSIDER NEED FOR ANY SITE-SPECIFIC VALUATION STUDIES

If Step 6.3 produces individual sites or impacts that yield significantly large valuations, the need for a site-specific valuation study should be considered. Any identified need should, however, be reviewed following assessment of the impact of the results on zonal ELL (Stage 3 of the Guidance). If the impact on the ELL is considerable, this may further support the need for a valuation study, although the cost of undertaking such a study should be weighed against the benefits arising from the resulting improvement in the accuracy of the zonal ELL calculation.

STEP 6.5 RECONCILE RESULTS WITH TOP-LEVEL WILLINGNESS-TO-PAY ASSESSMENT

Step 6.5 involves reconciliation (adjustment) of the economic values derived from bottom-up application of the BAG approach with the WTP assessments derived from top-level preference surveys, assuming the latter are both available and appropriately defined in relation to flow alleviation issues. This approach is designed to satisfy the regulatory requirement that WSPs' investment programmes should be supported by customers' overall WTP, such that required tradeoffs are undertaken in line with customers' identified priorities. At the same time, the approach permits more detailed consideration of environmental impacts at the project- and zone-level, and resulting assessments can be used as a basis for defining appropriate zonal weights. Criticisms of the bottom-up approach relating to weak budget constraints and IVS are also addressed through the reconciliation of valuations with top-level survey results where these problems are significantly reduced.

A fuller justification for Step 6.5 is provided in Section 4.1 of the Main Report.

Applying the BAG approach provides a £/Ml value for the environmental benefit of reducing abstraction. In order to be able to take customer willingness to pay into account, WSPs survey results for willingness to pay for improving river quality must similarly be converted into a £/Ml value.

The way in which this can be done will depend on the nature of the question that has been asked in the top-level WTP survey. The example below illustrates an approach that might be employed.

Box 3.9: **Environmental externalities. Step 6.5: Reconcile results with top-level WTP assessment**

It is assumed in this example that the improvement assessed was an increase in the percentage of rivers assessed as 'good', in terms of their ability to support a wide range of wildlife. Customers were presented with reducing the % of rivers at risk of not achieving good status as a result of low flows, with the options being:

- From current 16% to 10% - on average, domestic customers were willing to pay £1.53 per year.
- From current 16% to 5% - on average, domestic customers were willing to pay £2.79 per year.

Multiplying by the number of customers and adding in the results from business customers gives an overall willingness to pay of £1,090,000 per year for each 1% of river length brought up to good standard.

The extent of over-abstraction is being estimated as part of Catchment Abstraction Management Strategies and for the Water Framework Directive River Basin Characterisation. The recent Defra / EA document on water resources preliminary cost-effectiveness (July 2007) quotes a range of 1,074 Ml/d to 3,560 Ml/d over-abstraction.

The following assumptions have been made:

- The WSP's share of the national figure for over-abstraction is 250 Ml/d (based on a mid-range figure for the national picture).
- There is a linear relationship between reducing the over-abstraction and achieving good status, i.e. each 1% improvement to good status is given by a reduction in abstraction of 1% / 16% (total length at risk) x 250, i.e. a 15.6 Ml/d abstraction reduction on rivers at risk of not achieving good status is needed to reduce the length at risk by 1%.
- 16% of abstraction changes as a result of leakage changes is on rivers at risk of not achieving good status.

This gives a value of reducing abstraction of 1,090,000 / 15.6 x 0.16 = £11,179 per Ml/d , equivalent to 3.1p per cubic metre.

This value can be used to moderate the bottom-up valuations derived from application of the BAG approach. A weighted average can be calculated for the BAG valuations (where weights are provided by abstraction changes), and individual zonal- or source-level results can then be multiplied by 3.1 / weighted average so that the adjusted results will then average 3.1p per cubic metre.

3.1.2 Carbon emissions

Figure 3.3 is a Process Map showing the recommended steps to be taken in determining the relationships between the CO_2 externality costs and leakage.

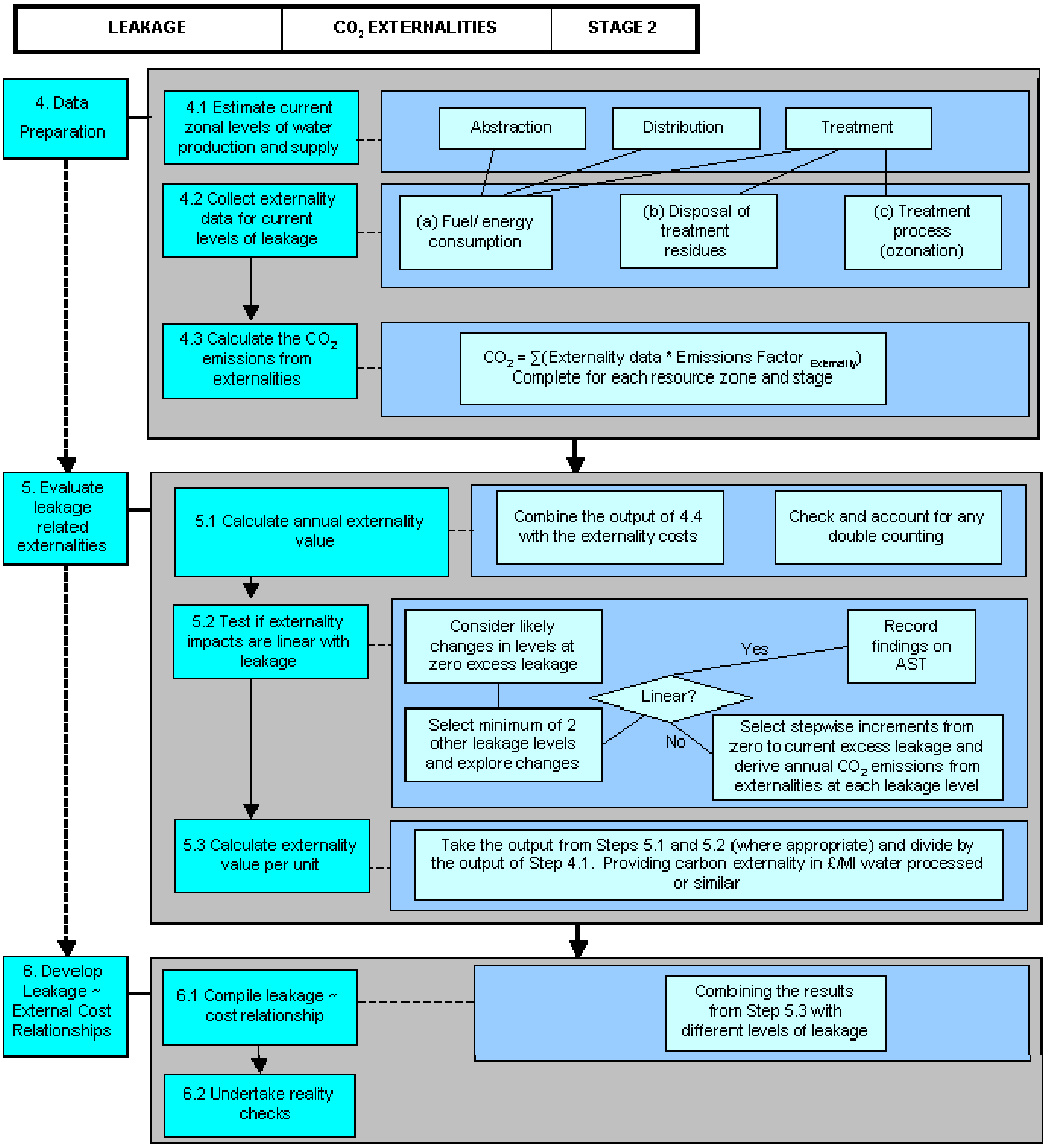


Figure 3.3: Process Map for Detailed Assessment of CO_2 Externalities

STEP 4: DATA PREPARATION

The purpose of this Step is to compile and manipulate the necessary data to calculate the CO_2 impact from each of the externalities arising from the production and supply of clean water activities.

STEP 4.1 ESTIMATE CURRENT ZONAL LEVELS OF WATER PRODUCTION AND SUPPLY

Using the outputs from Step 2.2 the WSP should, for each resource zone, calculate/estimate the annual volumes of water abstracted, treated and distributed.

STEP 4.2 COLLECT EXTERNALITY DATA FOR CURRENT LEVELS OF LEAKAGE

Step 1.2 defined the source of externality for each intervention policy while Step 2.1 set out the framework for data collection. The framework established should be followed – note that while some information may be derived from the same/similar sources it is important to maintain as much detail in the data for processes leading to the externality as this will increase the flexibility for assessment and analysis.

ABSTRACTION AND DISTRIBUTION

The sources of externality from abstraction and distribution stem from the consumption of energy and fuel. The WSP should collect the following data:

- Total electricity consumption
  - separately for abstraction and distribution
  - proportion of the electricity consumption from source – i.e. self generation (fuel), renewable, gas, coal, grid etc.
- Total fuel use by type (e.g. gas, diesel/gas oil, kerosene, LPG, biofuels etc.).

TREATMENT

The sources of externality in relation to treatment stem from energy and fuel use, the treatment process i.e. ozonation and from the disposal of drinking water treatment waste. The following information should be collected:

- Total electricity consumption
  - proportion of the electricity consumption from source – i.e. self generation (fuel), renewable, gas, coal, grid etc.
- Total fuel use by type (e.g. gas, diesel/gas oil, kerosene, LPG, biofuels etc.)
- Volume of water treated by ozonation
- Fraction of ozone generated that is generated from pure oxygen
- Mass of drinking water treatment waste
  - Proportion by disposal route i.e. recycled to land, landfilled, incinerator etc.

STEP 4.3 CALCULATE THE CO_2 EMISSIONS FROM EXTERNALITIES

ABSTRACTION AND DISTRIBUTION

Convert the fuel/energy consumption into CO_2 using the following equation:

$$kgCO_2 = \sum (\text{Fuel/Energy Consumption}_{\text{Fuel type}} * \text{Emissions Factor}_{\text{Fuel type}}) \quad \text{[Eqtn. CL1]}$$

Where emissions factors are:

Fuel	Emissions Factor*	Unit
Electricity grid	0.44	kg CO2eq/kWh
Electricity renewables	0**	kg CO2eq/kWh
Natural gas	5.44	kg CO2eq/therm
Gas/diesel oil	2.69	kg CO2eq/litre
Kerosene	2.53	kg CO2eq/litre
LPG	1.49	kg CO2eq/litre
Petrol	2.46	kg CO2eq/litre
Deisel	2.72	kg CO2eq/litre
Other (specify)	User defined record method and assumptions in AST	kg CO2eq/litre

Note: * These figures include an estimation of the CO_2 equivalent emissions of methane and nitrous oxide from the consumption of the fuels. ** Zero can only be applied where supply from renewables is guaranteed i.e. green tarrifs retiring equivalent numbers of ROCs or self-generation.

TREATMENT

Convert energy and fuel use into CO_2 by applying *Equation CL1*

Convert the volume of water treated by ozonation into CO_2 by applying the following equation:

$$kgCO_2 = \text{Volume of water}_{Ozonation} * \text{Emissions Factor}_{Ozonation} * (1 - \text{Proportion } O_3 \text{ from } O_{2\,pure}) \quad \text{[Eqtn. CL2]}$$

Where:

Emissions factor $_{Ozonation}$ = 0.0341 $kgCO_2/m^3$ treated

Proportion of O_3 *from* $O_{2\,pure}$ = WSP defined.

Convert the mass of water treatment works waste into CO_2 by applying the following equation:

$$kgCO_2 = \text{Mass of waste}_{Disposal} * \text{Emissions Factor}_{Disposal} \quad \text{[Eqtn CL3]}$$

Where:

Mass of waste $_{Disposal}$ = disposal route i.e. landfill, recycled to land or incineration.

Emissions Factor $_{Disposal}$ are as follows:

Disposal option	Emissions Factor ($kgCO_2$/tonne)
Landfill	210
Recycled to land	584
Incineration	0*

Note: * Incineration assumed zero as the waste is assumed to be biogenic and therefore converts to short-cycle CO_2 when combusted. Given short-cycle CO_2 is not typically accounted for under international guidelines the carbon emissions are therefore not included in the calculations.

Box 3.9: Carbon externalities
Step 4: Estimating carbon dioxide emissions

Total fuel/energy consumption						
	Abstraction	Units	Treatment	Units	Distribution	Units
Electricity grid	400,000	kWh	2,000,000	kWh	300,000	kWh
Electricity renewables	0	kWh	500,000	kWh	100,000	kWh
Natural gas	0	Therms	3,000	Therms	0	Therms
Gas/diesel oil	2,000	Litres	200	Litres	2,000	Litres
Kerosene	0	Litres	0	Litres	0	Litres
LPG	0	Litres	500	Litres	0	Litres
Petrol	0	Litres	0	Litres	0	Litres
Diesel	0	Litres	0	Litres	0	Litres
Other (specify)	0	(specify)	0	(specify)	0	(specify)

CO2 emissions						
	Abstraction	Units	Treatment	Units	Distribution	Units
Electricity grid	176.00	tCO2	880.00	tCO2	132.00	tCO2
Electricity renewables	0.00	tCO2	0.00	tCO2	0.00	tCO2
Natural gas	0.00	tCO2	16.32	tCO2	0.00	tCO2
Gas/diesel oil	5.38	tCO2	0.54	tCO2	5.38	tCO2
Kerosene	0.00	tCO2	0.00	tCO2	0.00	tCO2
LPG	0.00	tCO2	0.75	tCO2	0.00	tCO2
Petrol	0.00	tCO2	0.00	tCO2	0.00	tCO2
Diesel	0.00	tCO2	0.00	tCO2	0.00	tCO2
Other (specify)	0.00	tCO2	0.00	tCO2	0.00	tCO2
Sub-total	**181.38**	**tCO2**	**897.60**	**tCO2**	**137.38**	**tCO2**

Other Elements						
	Abstraction	Units	Treated	Units	Distributed	Units
Water volumes	2,000	ML	2,000	ML	2,000	ML
Water volume treated by ozonation			2,000,000	m3		

Drinking water treatment waste		
	Total	Units
Mass recycled to land	100	tonnes
Mass landfilled	100	tonnes

CO2 emissions (other elements)		
	CO2 emissior	Units
Waste disposed on land	58.40	tCO2
Waste disposed of in landfill	21.00	tCO2
Emissions from ozonation	68.20	tCO2
Sub-total	**147.60**	**tCO2**

STEP 5: EVALUATE LEAKAGE RELATED EXTERNALITIES

STEP 5.1 CALCULATE ANNUAL EXTERNALITY VALUE

The next step is to convert the CO_2 emissions derived in Step 4.4 to a monetary value.

The following figure should be used when valuing carbon emissions; note that this figure is for 2007 prices:

- £25.4/tCO_2

For calculating figures for future years which are based on 2007 prices the following figures apply, which have been increased by 2%pa to account for future inflation.

- 2008: £25.91/tCO_2
- 2009: 26.43/tCO_2
- 2010: 26.95/tCO_2
- 2011: 27.49/tCO_2
- 2012: 28.04/tCO_2
- 2013: 28.60/tCO_2
- 2014: 29.18/tCO_2
- 2015: 29.76/tCO_2

The WSP should check to ensure that costs of externalities are not being double counted when valued. It is anticipated that adjustment to account for the Climate Change Levy (CCL) will be required to non-exempt electricity, natural gas and LPG consumption. In such cases the WSP should net out the impact of the levy from the value applied to the externality – recording the approach on the AST. Any additional double counting issues identified should be treated in the same way.

STEP 5.2 TEST TO SEE IF EXTERNALITIES ARE LINEAR

It is possible that the size of the externalities at different leakage levels will be directly proportional to the leakage levels, or very close to being so. This should be tested by evaluation first at zero excess leakage then at a minimum of two other leakage levels.
If this indicates that the relationship is linear then no further assessment is necessary at this stage. If the relationship appears to be non-liner a series of step-wise levels from zero to current excess leakage valuation should then be evaluated and CO_2 emissions intervention policy and leakage level derived.

STEP 5.3 DERIVE A VALUE EXTERNALITY COST PER UNIT ~ LEAKAGE RELATIONSHIP

In this step, all the carbon externality annual MEC values for water production, treatment and distribution should be compiled:

- For each level of leakage for which externalities have been quantified and
- For mid-point, upper and lower bounds.

The summed zonal values should then be divided by the total water throughput.

Box 3.10: Carbon externalities
Step 5: Valuing carbon emissions

Carbon emissions		**Value £ (based on SPC)**		
Water production and supply	**tCO2**	**Low**	**Central**	**Upper**
Abstraction	181.38	4376.70	4607.05	4837.40
Treatment	1,045.20	25220.75	26548.16	27875.56
Distribution	137.38	3314.98	3489.45	3663.92
TOTAL	**1,363.96**	**32,912.43**	**34,644.66**	**36,376.89**

Assumed relationship	Linear	
Current levels of leakage	1.5	ML/d
Total water throughput	2,000	ML/year

Value of carbon per ML assuming linear leakage ~ carbon relationship and leakage levels at 1.5 ML/d	**Value (£)**		
	Low	**Central**	**Upper**
Cost carbon per ML	£16.46	£17.32	£18.19

STEP 6 DEVELOP LEAKAGE ~ EXTERNAL COST RELATIONSHIPS

The final step in this stage involves the transformation of the MEC per unit produced and supplied (step 5.3) to Marginal CO_2 Cost ~ leakage relationships.

STEP 6.1 TRANSFORM EXTERNALITY COST PER UNIT INTO COST ~ LEAKAGE

Multiply the outputs from step 5.3 with different levels of leakage.

Box 3.11: Carbon externalities
Step 6: Calculate cost at different leakage levels

Levels of leakage ML/d	Cost per year (£)		
	Low	Central	Upper
0.6	£3,003.26	£3,161.33	£3,319.39
0.7	£4,204.96	£4,425.86	£4,647.15
0.9	£5,405.87	£5,690.39	£5,974.90
1.1	£6,607.17	£6,954.92	£7,302.66
1.3	£7,808.47	£8,219.45	£8,630.42
1.5	£9,009.78	£9,483.98	£9,958.17
1.7	£10,211.08	£10,748.51	£11,285.93
1.9	£11,412.38	£12,013.04	£12,613.69
2.1	£12,613.69	£13,277.57	£13,941.44
2.3	£13,814.99	£14,542.10	£15,269.20
2.5	£15,016.29	£15,806.63	£16,596.96
2.7	£16,217.60	£17,071.16	£17,924.71
2.9	£17,418.90	£18,335.69	£19,252.47
3.1	£18,620.21	£19,600.22	£20,580.23
3.3	£19,821.51	£20,864.75	£21,907.98
3.5	£21,022.81	£22,129.28	£23,235.74
3.7	£22,224.12	£23,393.81	£24,563.50
3.9	£23,425.42	£24,658.34	£25,891.25
4.1	£24,626.72	£25,922.87	£27,219.01
4.3	£25,828.03	£27,187.40	£28,546.77
4.5	£27,029.33	£28,451.93	£29,874.52

STEP 6.2 UNDERTAKE REALITY CHECKS

The purpose of this step is to check to see whether the results obtained are sensible and logical.

3.2 DETAILED ASSESSMENT: LEAKAGE MANAGEMENT EXTERNALITIES

3.2.1 Social externalities

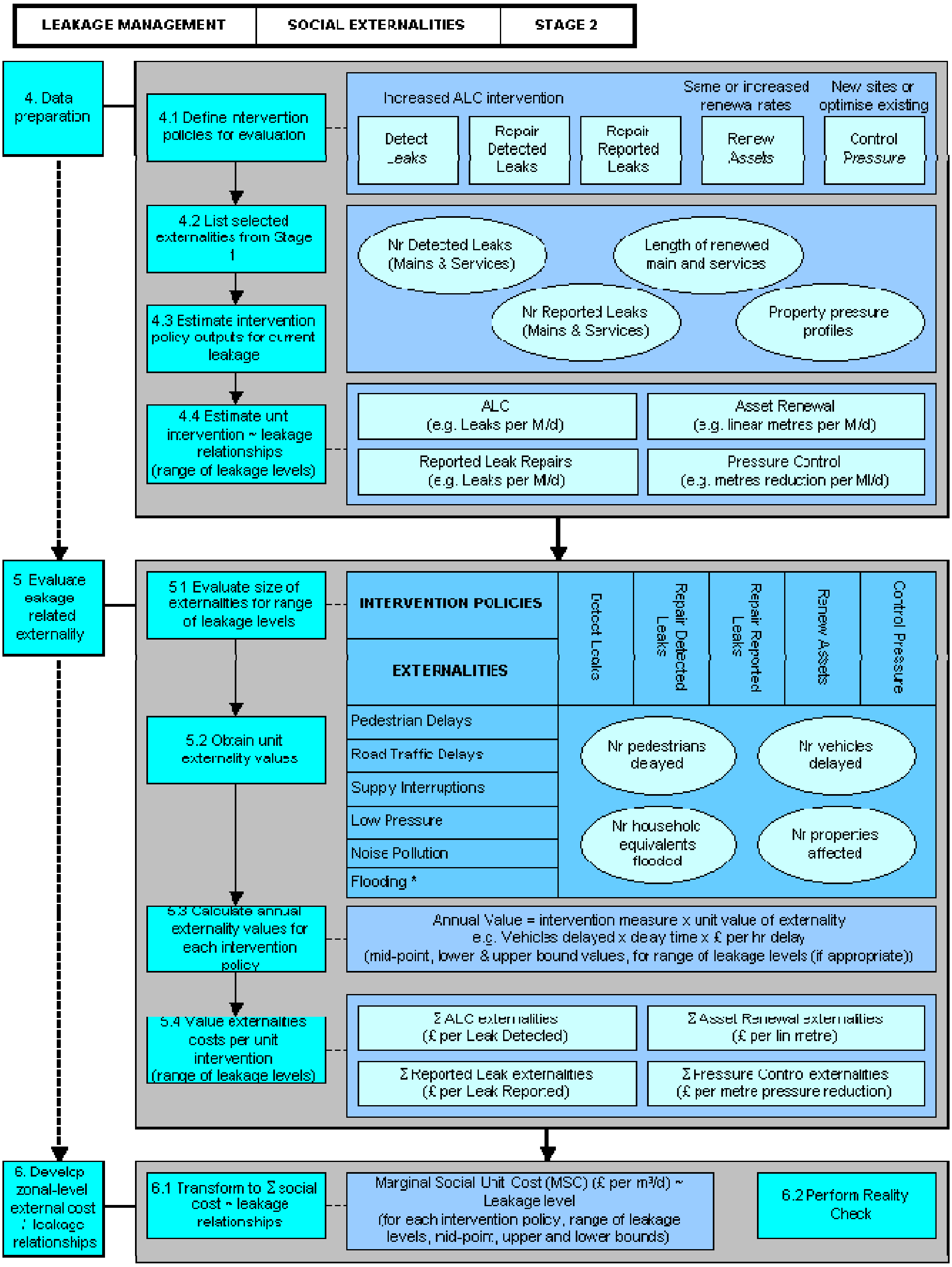


Figure 3.4: Process Map for Detailed Assessment of Leakage Management Social Externalities

Figure 3.4 is a Process Map showing the recommended steps to be taken in determining the relationships between the marginal social externality unit costs and leakage.

STEP 4: DATA PREPARATION

The objective of this step is to determine, for each intervention policy short-listed in Stage 1, the intervention outputs for a range of leakage levels.

STEP 4.1 DEFINE INTERVENTION POLICIES FOR EVALUATION

From Stage 1 remove any intervention policies from this part of the analysis that have no "significant" externality costs.

Box 3.12
All interventions (except "Detect Leaks") have been brought forward from Stage 1:

- Repair detected leaks
- Repair reported leaks
- Renew assets
- Control pressure

STEP 4.2 LIST SELECTED EXTERNALITIES FROM STAGE 1

For each intervention in Step 4.1 list the social externalities from Stage 1 that are considered to be significant.

Box 3.13

Externality	Interventions			
	Repair Detected Leaks	Repair Reported Leaks	Renew Assets	Control Pressure
Pedestrian delays	√	√	√	
Traffic delays	√	√	√	
Supply interruptions				
Low pressure		√	√	√
Noise pollution				
Flooding		√		

The WSP considers that the social costs associated with supply interruptions and noise pollution are unlikely to be significant.

STEP 4.3 ESTIMATE INTERVENTION POLICY OUTPUTS AT CURRENT LEAKAGE LEVELS

Repair detected leaks:
Quantify the numbers of detected mains, comm. pipe and CSP leaks repaired under the current ALC policy and estimate the savings achieved.

Box 3.14
In the example zone the WSP has repaired the following detected leaks in a year:

Mains leaks: 133 Comm pipes: 154 CSPs: 99 Total: 386 leaks

An analysis of average leak flow rates for each detected leak type has been carried out:

Mains leaks: 0.70 m^3/h Comm pipes: 0.42 m^3/h CSPs: 0.30 m^3/h

From these, the saving over the year from detection activity has been estimated to be:

$$133 \times 0.7 + 154 \times 0.42 + 99 \times 0.30 = 187.5 \text{ m}^3/\text{hr} = 4.125 \text{ Ml/d}$$

Repair reported leaks:

Quantify the numbers of reported mains, comm. pipe and CSP leaks repaired under the current ALC policy and estimate the savings achieved.

Box 3.15
In the example zone the WSP has repaired the following reported leaks in a year:

Mains leaks: 361 Comm pipes: 515 CSPs: 330 Total: 1,206 leaks

From its analysis of average leak flow rates the WSP has estimated the following for each reported leak type:

Mains leaks: 0.90 m^3/h Comm pipes: 0.50 m^3/h CSPs: 0.40 m^3/h

From these, the saving over the year has been estimated to be:

$361 \times 0.9 + 515 \times 0.50 + 330 \times 0.40 = 714.4\ m^3/hr = 15.717$ Ml/d

Renew Assets:

The savings in leakage from asset renewal can be attributed to:

- A proportion of the current leakage associated with the assets being renewed (depending on technique)
- A proportion of the total natural rate of rise in leakage (NRRt) associated with the assets being renewed

At the current renewal rate estimate the annual savings in leakage that have been achieved.

Box 3.16
Leakage Savings from Asset Renewal
The WSP operates a policy of renewing mains and associated comm. pipes at an average rate of 1% per year. Renewal is focussed on the worst performing assets in terms of current leakage and NRR.

Savings in current leakage
Average leakage = 160 l/p/d = 43.1 Ml/d
Leakage is disaggregated between assets using the relative proportions of average leak flow rates.
For detected leaks this gives: Mains 49.3 %; Comms 29.6 % and CSPL 21.1 %
For reported leaks this gives: Mains 50.0 %; Comms 27.8 % and CSPL 22.2 %
Averages across the zone are: Mains 49.7 %; Comms 28.7 % and CSPL 21.6 %

Disaggregated current average leakage values are therefore:
Mains: 0.497 x 43.1 = 21.42 Ml/d equivalent to 6.38 m^3/km/d
Comms: 0.287 x 43.1 = 12.37 Ml/d equivalent to 45.94 l/p/d
CSPL: 0.216 x 43.1 = 9.31 Ml/d equivalent to 34.58 l/p/d

The effectiveness of mains renewal in reducing leakage has been taken as 75% giving average net savings of 4.79 m^3/km/d
The effectiveness of comm. pipe renewal in reducing leakage has been taken as 90% giving average net savings of 41.35 l/p/d

Savings from reduction in NRR
The total natural growth for the zone over a year (NRRt) has been estimated to be 19.8 Ml/d pa.
Assuming the same proportions by asset as above, the disaggregated NRRt values are:
Mains: 0.497 x 19.8 = 9.84 Ml/d equivalent to 2.93 m^3/km/d
Comms: 0.287 x 19.8 = 5.68 Ml/d equivalent to 21.10 l/p/d
CSPL: 0.216 x 19.8 = 4.28 Ml/d equivalent to 15.90 l/p/d

The effectiveness of mains renewal in reducing leakage has been taken as 75% giving net savings of 2.20 m^3/km/d
The effectiveness of comm. pipe renewal in reducing leakage has been taken as 90% giving net savings of 19.0 l/p/d

Since these are increases over a year the average annual values are half these i.e.
Mains: 1.10 m^3/km/d and Comm pipes 9.50 l/p/d

Total savings rates from current leakage and NRRt are therefore:
Mains: 5.89 m^3/km/d and Comm pipes: 50.85 l/p/d

Box 3.17
Current savings from Asset Renewal

For a 1% asset renewal rate the total length of mains renewed = 33.56 km
The WSP has focussed on the renewal of the worst performing DMAs.

The total comm. pipes renewed = 33,560 / 12.5 = 2,685

The WSP has found that the worst performing DMAs have savings rates that are 3x the average, giving savings rates of:

Mains: 17.67 m^3/km/d and Comm pipes: 152.55 l/p/d

Projected savings are therefore:

17.67 x 33.56/1000 + 152.55 x 2685/1000000 = 0.593 + 0.410 = 1.00 Ml/d

Control Pressure:

Assess the savings achieved from current pressure management schemes.

The relationship between pressure and leakage is well established and can be expressed by a number of formulae of which one example is the power-law:

$$\text{Leakage Index (LI)} = AZNP^{N1}$$

Where AZNP = average zone night pressure (m)
N1 is an infrastructure factor (a typical value is 1.12)

The ratio of the LI's for AZNP's before and after pressure reduction gives the ratio of the minimum night flows in a zone.

Box 3.18
Approximately 108 DMAs are currently pressure managed in the zone (about 162,000 properties).

The average AZNP in the pressure managed DMAs is currently 25m.
Prior to pressure management the AZNP was 40m.

LI before pressure management = 40^1.1 = 57.8
LI with current pressure management = 25^1.1 = 34.5
The average leakage in the pressure managed DMAs is 155 l/p/d
Estimated leakage before pressure management = 57.8 x 155 / 34.5 = 259.7 l/p/d
Estimated saving = (259.7 – 155) x 162,000/1000000 = 17.0 Ml/d

STEP 4.4 ESTIMATE UNIT INTERVENTION ~ LEAKAGE RELATIONSHIPS

Repair detected leaks:

As a starting point assume that the numbers of detected leaks to achieve and maintain a given leakage level is non-linear, i.e. numbers will increase disproportionately as leakage is reduced towards background leakage.

Estimate the numbers of detected leaks that need to be repaired per unit saving for a range of leakage levels.

Box 3.19
The WSP has developed a relationship for leaks per Ml/d saved at different leakage levels:

From step 4.3 the estimated saving achieved from detecting 386 leaks was 4.125 Ml/d

At current leakage levels (160 l/p/d) the leaks required to save 1 Ml/d are therefore 93.6

From an analysis of the numbers of leaks required at different leakage levels the WSP has developed the following non-linear relationship:

$$\text{Leaks per Ml/d} = 7498 \,.\, L^{-0.8637}$$

Where L = average zone leakage (l/p/d)

The following table gives the leaks per Ml/d for a range of leakage levels:

Leakage level		Leaks per Ml/d
l/p/d	**Ml/d**	
170	45.8	88.8
160	43.1	93.6
150	40.4	99.0
140	37.7	105.0
130	35.0	112.0
120	32.3	120.0
110	29.6	129.4
100	26.9	140.5
90	24.2	153.8
80	21.5	170.3
70	18.9	191.1

Repair reported leaks:

For the purposes of this analysis it is recommended that the numbers of reported leaks can reasonably be assumed constant for the range of leakage levels (see comments elsewhere).

Box 3.20
Reported leaks per unit saving

From step 4.3 the estimated saving achieved from detecting 1,206 leaks was 15.72 Ml/d

At current leakage levels (160 l/p/d) the leaks required to save 1 Ml/d are therefore 76.7

There is assumed to be no change at different leakage levels

Renew Assets:

Assess the extent of asset renewal required to achieve a 1 Ml/d reduction in leakage for a range of leakage levels.

This will depend on a whole range of factors such as renewal rate, targeting policy etc.. However, for a given renewal rate as leakage is reduced, so the savings at that rate will reduce and the proportion of the total saving from NRRt will increase. This produces a non-linear effect with Length per Ml/d saved increasing as average zone leakage decreases.

Box 3.21
Leakage Savings from Asset Renewal

The WSP has developed a relationship for leaks per Ml/d saved from mains and comm. pipe renewal at different leakage levels.

From step 4.3 the estimated saving achieved from renewing 33.56km of mains and associated comm. pipes is 1.0 Ml/d

At current leakage levels (160 l/p/d) the extent of the asset to be renewed to save 1 Ml/d is 33.6 km

From a detailed analysis of the amount of asset renewal required to save 1 Ml/d at different leakage levels for a 1% renewal rate the WSP has developed the following non-linear relationship:

Km renewal per Ml/d = 2252 . L^ -0.8288

Where L = average zone leakage (l/p/d)

The following table gives the leaks per Ml/d for a range of leakage levels:

Leakage level		Km per Ml/d
l/p/d	Ml/d	
170	45.8	31.9
160	43.1	33.6
150	40.4	35.4
140	37.7	37.5
130	35.0	39.9
120	32.3	42.6
110	29.6	45.8
100	26.9	49.5
90	24.2	54.1
80	21.5	59.6
70	18.9	66.6

Control Pressure:

Estimate the relationship between the pressure reduction (m) per unit leakage saving at different levels of leakage.

Box 3.22
Approximately 108 DMAs are currently pressure managed in the zone (about 162,000 properties).

From step 4.3 the WSP has assessed the savings attributable to the current pressure management arrangements as 17.0 Ml/d from a pressure reduction of 15m i.e. 0.88 metres reduction per Ml/d saving.

Through network modelling and appraisal work the WSP has concluded that there is no potential for new pressure management schemes. However the WSP believes that there is some potential for optimisation of existing schemes by retrofitting advanced pressure control devices.

The average AZNP in the pressure managed DMAs is currently 25m
The WSP believes it can reduce the average AZNP across the DMAs by an average of 5m
The average leakage in the pressure managed DMAs is 155 l/p/d
This is estimated to be equivalent to 7 l/p/h at night

Current LI = 25^1.1 = 34.49
Post reduction LI = 20^1.1 = 27.0
Ratio of min night flows = 27.0/34.49 = 0.783

Estimated night leakage after pressure reduction = 0.783 x 7.0 = 5.48 l/p/h

Estimated saving = (7.0 – 5.48) = 1.52 l/p/h for say 6 hrs
Daily saving = 1.52 x 6 x 162000 / 1000000 = 1.48 Ml/d

Therefore pressure reduction for 1 Ml/d reduction = 5/1.48 = 3.38m

Pressure reductions (PR) in metres per Ml/d saving for a range of zone leakage levels is given below:

Leakage level		PR per Ml/d
l/p/d	Ml/d	
170	45.8	3.1
160	43.1	3.3
150	40.4	3.5
140	37.7	3.7
130	35.0	4.0
120	32.3	4.3
110	29.6	4.7
100	26.9	5.2
90	24.2	5.8
80	21.5	6.5
70	18.9	7.4

Through the implementation of APC the WSP has shown that further leakage savings can be achieved by lowering night pressures to achieve a flatter diurnal profile. Using flow modulation the WSP also believes it can reduce the risk of low pressure to properties during peak demand conditions.

It is therefore considered that the social costs associated with the risk of low pressure can be removed.

STEP 5: EVALUATE LEAKAGE-RELATED EXTERNALITIES

The objective of this step is to cost the short-listed externalities (step 4.2) for each type of intervention for a range of leakage levels. These are then converted to cost per unit of intervention for the range of leakage levels. This is to be carried out for mid-point, upper and lower bounds.

STEP 5.1 EVALUATE SIZE OF EXTERNALITIES FOR RANGE OF LEAKAGE LEVELS

This is essentially a repeat of Stage 1 step 2.3 but applied to the matrix of intervention – externalities short-listed in step 4.2. The opportunity should be taken at this stage to review and if appropriate, refine the values used in Stage 1 e.g. a more detailed analysis of road classifications and vehicle numbers. Upper and lower bound estimates should also be assigned at this stage.

It is possible that the size of the externalities at different leakage levels will be directly proportional to the intervention levels. This should be tested by evaluation at low levels of leakage. If necessary valuation should then be extended to intermediate leakage levels.

Box 3.23
The WSP has reviewed its evaluation of annual externality values at current leakage levels in Stage 1and estimates that upper and lower bounds of + / - 15% can be applied to the estimates.

A review of the valuations at low levels of leakage indicates that the externalities at different leakage levels are directly proportional to intervention levels. It has therefore considered it unnecessary to evaluate externality sizes at different leakage levels.

STEP 5.2 OBTAIN UNIT EXTERNALITY VALUES

Determine the unit cost values for each of the short-listed externalities and identify mid-point, upper and lower bounds.

Box 3.24
The WSP has determined the following unit cost values for the short-listed externalities in step 4.2 from local information, where this is available, or from guidance documents.

Externality	Units	Unit Cost		
		Low	Mid	High
Pedestrian delays[1]	£ per hr delayed	5.00	9.90	26.7
Vehicle delays[2]	£ per hr delayed	5.74	11.28	30.2
Low Pressure[3]	£ per property	3.78	4.35	5.0
Flooding[4]	£ per household equiv.	1,217	1,400	1,610

1. TAG (low = non-workers, high = workers, mid-point estimated)
2. TAG (low = non-workers, high = workers)
3. Excess over internalised GSS payments (*example only*)
4. NERA Table 4.2.7.1 (n.b. value needs repricing)

+/- 15% applied to 3 and 4 for upper and lower bounds

STEP 5.3 CALCULATE ANNUAL EXTERNALITY VALUES

If appropriate, for a range of leakage levels (otherwise current leakage level), evaluate the mid-point, upper and lower bound annual externality costs.

As in Stage 1, the calculation process is:

Annual value = annual intervention size (step 5.1) x externality unit cost (step 5.2)

For pedestrian and vehicle delays, the annual values should also be multiplied by the appropriate delay times (hrs).

Box 3.25
The WSP has evaluated Mid–Point, Upper and Lower Bound annual costs for current leakage levels only.

Intervention	Annual Social Cost £ pa		
	Lower	Mid	Upper
Repair Detected Leaks			
Vehicles delayed	7,172	16,582	51,053
Pedestrians delayed	6,024	14,033	43,524
Repair Reported Leaks			
Vehicles delayed	31,685	73,255	225,545
Pedestrians delayed	26,615	61,997	192,284
Low Pressure	18,706	25,326	33,477
Flooding	43,447	58,800	77,763
Renew Assets			
Vehicles diverted	237,158	548,298	1,688,156
Vehicles narrowed	276,503	639,260	1,968,219
Pedestrians delayed	308,448	898,128	2,785,558
Low Pressure	8,637	11,693	15,456
Control Pressure			
Low Pressure	5,205	7,047	9,315

In this step, aggregate all the social externality annual cost values for a given intervention type:

- for each level of leakage for which externalities have been quantified and
- for mid-point, upper and lower bounds.

The summed values should then be divided by the unit intervention outputs e.g. detected leaks for ALC, linear metres for asset renewal etc. to give externality costs per unit intervention

Box 3.26
From the annual cost summary in step 5.3 the WSP has calculated externality costs per unit intervention. These have been calculated for current leakage only and are assumed to be applicable to all leakage levels.

Intervention	Total Annual Cost(£ pa)			Intervention outputs		Cost per unit intervention		
	Lower	Mid	Upper	nr	units	Lower	Mid	Upper
Repair Detected Leaks	13,197	30,615	94,577	386	detected leaks	34.2	79.3	245.0
Repair Reported Leaks	120,453	219,378	529,069	1,206	reported leaks	99.9	181.9	438.7
Renew Assets	830,746	2,097,379	6,457,388	33,560	metres renewal	24.8	62.5	192.4
Control Pressure	5,205	7,047	9,315	N/A		-	-	-

It is noted that pressure control has not been calculated because future implementation of advanced pressure control will remove the risk of low pressure at peak demand.

STEP 6: DEVELOP ZONE-LEVEL EXTERNAL COST ~ LEAKAGE RELATIONSHIPS

The final step in this stage involves the transformation of the Social Costs per unit interventions (step 5.4) to Marginal Social Unit Cost ~ leakage relationships.

The output from step 4.4 is a set of tables that give the intervention outputs per unit saving in leakage for a range of leakage level e.g.

Repair detected leaks: leaks per Ml/d saved at a range of leakage levels

From step 5.4 the Social Cost per unit intervention for "Repair detected leaks" is £ per leak

Multiplying the two values gives the marginal social unit cost (MSC) in £ per Ml/d

STEP 6.1 TRANSFORM EXTERNALITY COSTS PER UNIT INTERVENTION TO COST ~ LEAKAGE

Multiply outputs from step 4.4 by outputs from step 5.4

Box 3.27
Repair detected leaks:

		MSC (£ per m^3/d)		
	leaks per	Lower	Mid	Upper
l/p/d	Ml/d	34.2	79.3	245.0
170	88.8	3.0	7.0	21.8
160	93.6	3.2	7.4	22.9
150	99.0	3.4	7.8	24.2
140	105.0	3.6	8.3	25.7
130	112.0	3.8	8.9	27.4
120	120.0	4.1	9.5	29.4
110	129.4	4.4	10.3	31.7
100	140.5	4.8	11.1	34.4
90	153.8	5.3	12.2	37.7
80	170.3	5.8	13.5	41.7
70	191.1	6.5	15.2	46.8

Box 3.28
Repair reported leaks:

		MSC (£ per m³/d)		
	leaks per	Lower	Mid	Upper
l/p/d	Ml/d	99.9	181.9	438.7
170	76.7	7.7	14.0	33.6
160	76.7	7.7	14.0	33.6
150	76.7	7.7	14.0	33.6
140	76.7	7.7	14.0	33.6
130	76.7	7.7	14.0	33.6
120	76.7	7.7	14.0	33.6
110	76.7	7.7	14.0	33.6
100	76.7	7.7	14.0	33.6
90	76.7	7.7	14.0	33.6
80	76.7	7.7	14.0	33.6
70	76.7	7.7	14.0	33.6

Box 3.29
Renew assets:

		MSC (£k per m³/d)		
	km per	Lower	Mid	Upper
l/p/d	Ml/d	24.8	62.5	192.4
170	31.9	0.8	2.0	6.1
160	33.6	0.8	2.1	6.5
150	35.4	0.9	2.2	6.8
140	37.5	0.9	2.3	7.2
130	39.9	1.0	2.5	7.7
120	42.6	1.1	2.7	8.2
110	45.8	1.1	2.9	8.8
100	49.5	1.2	3.1	9.5
90	54.1	1.3	3.4	10.4
80	59.6	1.5	3.7	11.5
70	66.6	1.6	4.2	12.8

nb. MSC units in £'000 per m^3/d

STEP 6.2 PERFORM REALITY CHECK

As a final step before proceeding to Stage 3, review the results obtained and carry out a "reality check".

3.2.2 Carbon emissions

Figure 3.5 is a Process Map showing the recommended steps to be taken in determining the relationships between the marginal CO_2 externality costs and leakage.

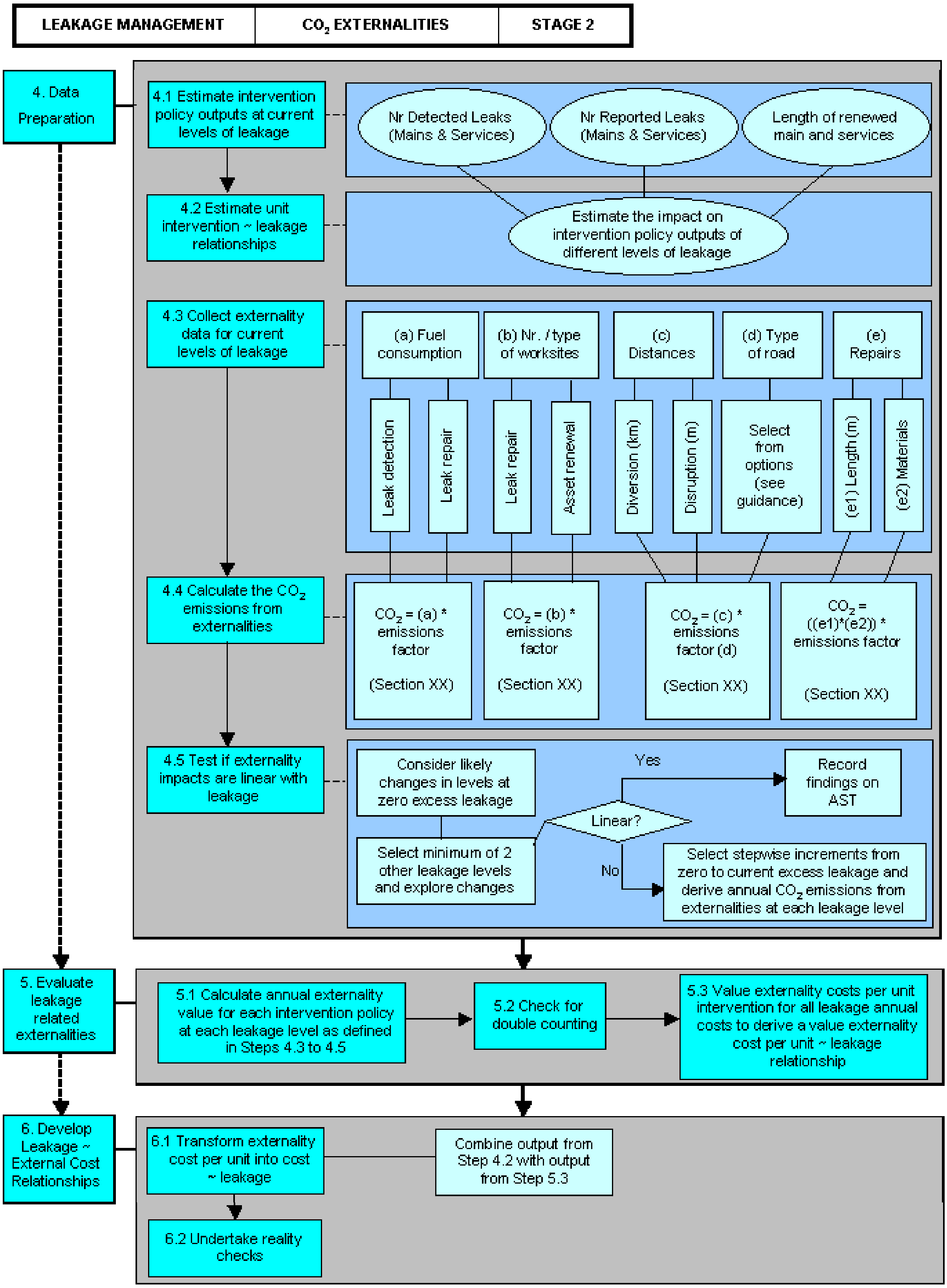


Figure 3.5: Process Map for Detailed Assessment of Leakage Management CO_2 Externalities

STEP 4: DATA PREPARATION

The purpose of this Step is to compile and manipulate the necessary data to calculate the CO_2 impact from each of the externalities arising from the intervention policies.

STEP 4.1 ESTIMATE INTERVENTION POLICY OUTPUTS AT CURRENT LEVELS OF LEAKAGE

For the relevant intervention policies follow the guidance set out in Step 4.3 of the assessment of social externalities. The data required for the assessment of CO_2 is the same. The intervention policies of interest for CO_2 are as follows:

- Repair detected leaks (note that for the purposes of these calculations the number of repairs of detected leaks and the number of detected leaks are assumed to be equal)
- Repair reported leaks
- Renew assets.

Box 3.30

Example data as social externalities Step 4

STEP 4.2 ESTIMATE UNIT INTERVENTION ~ LEAKAGE RELATIONSHIP

For the relevant intervention policies follow the guidance set out in Step 4.4 of the assessment of social externalities. The data required for the assessment of CO_2 is the same. The intervention policies of interest for CO_2 are as follows:

- Repair detected leaks
- Repair reported leaks
- Renew assets.

STEP 4.3 COLLECT EXTERNALITY DATA FOR CURRENT LEVELS OF LEAKAGE

Step 1.4 defined the source of externality for each intervention policy while Step 2.2 sets out the framework for data collection. The framework established should be followed – note that while some information may be derived from the same/similar sources it is important to maintain the distinctions between the intervention policies.

Leak detection

The total fuel consumption related to leak detection for a given year should be estimated. Ideally this should be derived from records of fuel consumption by the vehicles associated with leak detection i.e. perhaps through fuel card data. If such data is not available then the fuel consumption associated with leak detection should be estimated using an appropriate methodology (recorded/justified on the AST).

Box 3.31

There were 386 detected leaks in the example the identification of which consumed 7,720 litres of diesel.

Repair of leaks

In terms of the assessment of CO_2 externalities the type of information requiring collection does not differ between the repair of detected or reported leaks. However, the WSP should maintain a distinction between the two areas when collecting the data so that the different intervention policies can be evaluated.

The WSP should identify and estimate the following information on an annual basis:

- Number of repairs by type (estimated under Step 4.1)
- Proportion of repairs by type of roads associated with repairs – should be quantified using standard DfT road types:
- Fuel consumed during transportation to and from the repair site
- Total length of repaired pipes.

Box 3.32

Category	Number of leaks	Category	Number of leaks
Detected mains leaks	133	Reported mains leaks	361
Detected comms leaks	154	Reported comms leaks	515
Detected CSP leaks	99	Reported CSP leaks	330
Detected total	**386**	**Reported total**	**1206**

Road type	Proportion
AB	60%
BB	10%
CB	2%
UB	20%
AN	5%
BN	1%
CN	1%
UN	1%

7,000 litres of fuel were used travelling to and from the repair sites.

5,600m of plastic pipes and 10,000m of ductile iron pipes were repaired.

Asset renewal

The WSP should identify and estimate the following information on an annual basis:

- Number of asset renewals (by site) (estimated under Step 4.1)
- Total length of mains asset renewals (estimated under Step 4.1), and proportions by material e.g.:
- UPVC and other plastic
- Ductile iron
- Total length of comm. pipe renewals (estimated under Step 4.1)
- Proportion of renewals by type of roads associated with the renewal – should be quantified using standard DfT road types
- Fuel consumed during transportation to and from the renewal site.

Box 3.33
33.56km of mains were renewed with 15km of comm pipes across 500 worksites.

Materials	Percentage replaced
UPVC/plastic	10%
Ductile iron	90%

Road type	Proportion
AB	60%
BB	10%
CB	2%
UB	20%
AN	5%
BN	1%
CN	1%
UN	1%

8,000 litres of fuel were consumed getting to and from the worksites.

STEP 4.4 CALCULATE THE CO_2 EMISSIONS FROM EXTERNALITIES

Leak detection

Convert the total fuel consumption into CO_2 using the following equation:

$$kgCO_2 = \sum (Fuel\ Consumption_{\ Fuel\ type} * Emissions\ Factor_{\ Fuel\ type})$$ [Eqt C1]

Where emissions factors are:

Fuel Type	Emissions Factor (kg CO_2 equivalent/litre)*
LPG	1.49
Petrol	2.46
Diesel	2.72

Note: * These figures include an estimation of the CO_2 equivalent emissions of methane and nitrous oxide from the consumption of the fuels.

Box 3.34

7720 litres of diesel = 21 tCO_2

Leak repair

There are four steps to the calculation of emissions associated with leak repair activities (remember to separately calculate emissions for reported and detected leaks):

- Fuel consumption
  Completed as set out in Equation C1

- Emissions from traffic disruption

$$kgCO_2 = Number\ of\ repairs_{\ Leak\ type} * Emissions\ Factor_{\ Disruption}$$ [Eqtn C2]

Where:
Leak type = relates to whether leaks are detected or reported
Disruption = weighted emissions factor derived as follows:

$$Emissions\ Factor_{Disruption} = \sum (Proportion\ of\ leaks_{Road\ type} * Emissions\ Factor_{Road\ type}) \quad [Eqtn\ C3]$$

Where: Emissions Factors by road type are as follows:

Road type	Disruption road type emissions factor (kgCO_2/repair)
AB	138
BB	41
CB	26
UB	13
AN	97
BN	34
CN	17
UN	4

- Emissions from the worksite

$$kgCO_2 = Number\ of\ repairs_{Leak\ type} * Emissions\ Factor_{Repair\ site} \quad [Eqtn\ C4]$$

Where: *Emissions Factor* $_{Repair\ site}$ = 286 kgCO_2/repair

- Embedded emissions

$$kgCO_2 = Total\ length\ of\ repair_{Leak\ type} * Emissions\ Factor_{Weighted\ material} \quad [Eqtn\ C5]$$

Where:
Weighted material = weighted emissions factor derived as follows:

$$Emissions\ Factor_{Material} = \sum (Proportion\ of\ repairs_{Material} * Emissions\ Factor_{Material}) \quad [Eqtn\ C6]$$

Emissions Factor $_{Material}$ as follows:

Material	**Emissions factor materials (kgCO_2/m)**
UPVC other	1
UPVC main	19
Ductile iron main	91

Box 3.35

Litres of diesel	7,000			
Tonnes CO2 from transportation	**19**	tCO2		
Road type	Proportion	Disruption road type emissions factor (kgCO2/repair)	Weighted emissions factor (kgCO2/ repair)	
AB	60%	138	82.8	
BB	10%	41	4.1	
CB	2%	26	0.52	
UB	20%	13	2.6	
AN	5%	97	4.85	
BN	1%	34	0.34	
CN	1%	17	0.17	
UN	1%	4	0.04	
Total	**100%**	n/a	**95.42**	
Repairs	Number			
Reported	1,206			
Detected	386			
Tonnes CO2 from disruption	**152**	tCO2		
Emissions per worksite	286	kgCO2		
Tonnes CO2 from worksite	**455**	**tCO2**		
Material	Emissions factor materials (kgCO2/m)	Length pipe repaired	Weighted emissions factor (kgCO2/m)	Total tCO2
UPVC other	1	3,000	0.2	
UPVC main	19	2,600	3.2	
Ductile iron main	91	10,000	58.3	
Total	n/a	**15,600**	**61.7**	**962**
Overall CO2 emissions	**1,589**	**tCO2**		

Asset Renewal

There are four steps to the calculation of emissions associated with asset renewal activities (remember to separately calculate emissions for reported and detected leaks):

- Fuel consumption
  Completed as set out in Equation C1

- Emissions from traffic diversion

$kgCO_2 = Number\ of\ renewals * Emissions\ Factor_{Diversion}$ [Eqtn C7]

Where:

Diversion = weighted emissions factor derived as follows:

Emissions Factor $_{Diversion}$ = ∑ *(Proportion of leaks* $_{Road\ type}$ ** Emissions Factor* $_{Road\ type1}$*)* [Eqtn C8]

Where: Emissions Factors by road type 1 are as follows:

Road type	Diversion road type emissions factor ($kgCO_2$/renewal)
AB	621
BB	188
CB	115
UB	58
AN	338
BN	120
CN	61
UN	15

- Emissions from the worksite

*$kgCO_2$ = Total renewed length (m) * Emissions Factor* $_{Renew}$ [Eqtn C9]

Where: *Emissions Factor* $_{Renew}$ = 61 $kgCO_2$/m renewed

- Embedded emissions

Follow the equations C5 and C6 inputting the total renewed length as opposed to repaired length.

Box 3.36

Litres of diesel	8,000			
Tonnes CO2 from transportation	**22**	tCO2		
Road type	Proportion	Disruption road type emissions factor (kgCO2/repair)	Weighted emissions factor (kgCO2/ repair)	
AB	60%	621	372.6	
BB	10%	188	18.8	
CB	2%	115	2.3	
UB	20%	58	11.6	
AN	5%	338	16.9	
BN	1%	120	1.2	
CN	1%	61	0.61	
UN	1%	15	0.15	
Total	**100%**	n/a	**424.16**	
	Number	Distance (m)		
Asset renewals	500	33,560		
Tonnes CO2 from disruption	**212**	tCO2		
Emissions per worksite	61	kgCO2/m		
Tonnes CO2 from worksite	**2,047**	**tCO2**		
Material	Emissions factor materials (kgCO2/m)	Length pipe repaired	Weighted emissions factor (kgCO2/m)	Total tCO2
UPVC other	1	15,000	1.0	
UPVC main	19	3,356	4.1	
Ductile iron main	91	30,204	176.2	
Total	n/a	**48,560**	**181.2**	**8,801**
Overall CO2 emissions	**11,082**	tCO2		

STEP 4.5: TEST TO SEE IF EXTERNALITIES ARE LINEAR

It is possible that the size of the externalities at different leakage levels will be directly proportional to the intervention levels, or very close to being so. This should be tested by evaluation first at zero excess leakage then at a minimum of two other leakage levels.

If this indicates that the relationship is linear then no further assessment is necessary at this stage. If the relationship appears to be non-liner a series of step-wise levels from zero to current excess leakage valuation should then be evaluated and CO_2 emissions intervention policy and leakage level derived.

Box 3.37

		Value (£)		
Valuation of Car	**tCO2**	**Low**	**Central**	**Upper**
Detected leaks	**406**	**£9,801.37**	**£10,317.23**	**£10,833.10**
Reported leaks	**1203**	**£29,339.74**	**£30,568.15**	**£32,096.55**
Asset renewals	**11,082**	**£267,407.81**	**£281,481.30**	**£295,556.00**

STEP 5: EVALUATE LEAKAGE RELATED EXTERNALITIES

STEP 5.1: CALCULATE ANNUAL EXTERNALITY VALUE FOR EACH INTERVENTION POLICY AT EACH LEAKAGE LEVEL DEFINED IN STEPS 4.3 TO 4.5

The next step is to convert the CO_2 emissions derived in Step 4.4 to a monetary value.

The following figure should be used when valuing carbon emissions; note that this figure is for 2007 prices:

- £25.4/tCO_2

For calculating figures for future years which are based on 2007 prices the following figures apply, which have been increased by 2%pa to account for future inflation.

- 2008: £25.91/tCO_2
- 2009: 26.43/tCO_2
- 2010: 26.95/tCO_2
- 2011: 27.49/tCO_2
- 2012: 28.04/tCO_2
- 2013: 28.60/tCO_2
- 2014: 29.18/tCO_2
- 2015: 29.76/tCO_2

Box 3.38

	Value (£)			Intervention		Value (£) per unit intervention		
	Low	Central	Upper	analysis	Units	Low	Central	Upper
Detected leaks	£9,801.37	£10,317.23	£10,833.10	386	Number	£25.39	£26.73	£28.07
Repaired leaks	[illegible]	[illegible]	[illegible]	[illegible]	Number	[illegible]	[illegible]	[illegible]
Asset renewals	[illegible]	[illegible]	[illegible]	[illegible]	metres	[illegible]	[illegible]	[illegible]

STEP 5.2: CHECK FOR DOUBLE COUNTING

The WSP should check to ensure that costs of externalities are not being double counted. It is not anticipated that any adjustment will be required to the above figures, however, should a double counting issue arise the WSP should net off the costs of such double counting then calculate the residual values.

STEP 5.3 DERIVE A CO_2 COST PER UNIT ~ LEAKAGE RELATIONSHIP

In this step, all the CO_2 externality annual cost values for a given intervention type should be added:

- For each level of leakage for which externalities have been quantified and
- For mid-point, upper and lower bounds.

The summed values should then be divided by the unit intervention outputs e.g. detected leaks for ALC, linear metres for asset renewal etc.

Box 3.39

Detected Leaks

		Value (£) per unit intervention		
		Low	Central	Upper
l/p/d	**Leaks per Ml/d**	£25.39	£26.73	£28.07
170	88.8	£0.71	£0.74	£0.78
160	93.6	£0.75	£0.79	£0.82
150	99	£0.79	£0.83	£0.87
140	105	£0.84	£0.88	£0.92
130	112	£0.89	£0.94	£0.99
120	120	£0.96	£1.01	£1.06
110	129.4	£1.03	£1.09	£1.14
100	140.5	£1.12	£1.18	£1.24
90	153.8	£1.23	£1.29	£1.35
80	170.3	£1.36	£1.43	£1.50
70	191.1	£1.52	£1.60	£1.68

Reported leaks

		Value (£) per unit intervention		
		Low	Central	Upper
l/p/d	**km per Ml/d**	£24.08	£25.35	£26.61
170	76.7	£0.61	£0.64	£0.68
160	76.7	£0.61	£0.64	£0.68
150	76.7	£0.61	£0.64	£0.68
140	76.7	£0.61	£0.64	£0.68
130	76.7	£0.61	£0.64	£0.68
120	76.7	£0.61	£0.64	£0.68
110	76.7	£0.61	£0.64	£0.68
100	76.7	£0.61	£0.64	£0.68
90	76.7	£0.61	£0.64	£0.68
80	76.7	£0.61	£0.64	£0.68
70	76.7	£0.61	£0.64	£0.68

Asset Renewal

		Value (£) per unit intervention		
		Low	Central	Upper
l/p/d	**km per Ml/d**	£7.97	£8.39	£8.81
170	31.9	£0.25	£0.27	£0.28
160	33.6	£0.27	£0.28	£0.30
150	35.4	£0.28	£0.30	£0.31
140	37.5	£0.30	£0.31	£0.33
130	39.9	£0.32	£0.33	£0.35
120	42.6	£0.34	£0.36	£0.38
110	45.8	£0.36	£0.38	£0.40
100	49.5	£0.39	£0.42	£0.44
90	54.1	£0.43	£0.45	£0.48
80	59.6	£0.47	£0.50	£0.52
70	66.6	£0.53	£0.56	£0.59

STEP 6: DEVELOP LEAKAGE ~ EXTERNAL COST RELATIONSHIPS

The final step in this stage involves the transformation of the CO_2 cost per unit interventions (step 5.3) to Marginal CO_2 Unit Cost ~ leakage relationships.

STEP 6.1: TRANSFORM EXTERNALITY COST PER UNIT INTO COST ~ LEAKAGE

Multiply outputs from step 4.4 by outputs from step 5.4

Box 3.40

		Value (£) per unit intervention		
Detected Leaks		Low	Central	Upper
l/p/d	**Leaks per Ml/d**	£13.20	£24.97	£48.21
170	88.8	£0.37	£0.70	£1.34
160	93.6	£0.39	£0.73	£1.42
150	99	£0.41	£0.78	£1.50
140	105	£0.43	£0.82	£1.59
130	112	£0.46	£0.88	£1.69
120	120	£0.50	£0.94	£1.82
110	129.4	£0.54	£1.01	£1.96
100	140.5	£0.58	£1.10	£2.13
90	153.8	£0.64	£1.21	£2.33
80	170.3	£0.71	£1.33	£2.58
70	191.1	£0.79	£1.50	£2.89

		Value (£) per unit intervention		
Reported leaks		Low	Central	Upper
l/p/d	**km per Ml/d**	£12.52	£23.68	£45.72
170	76.7	£0.32	£0.60	£1.16
160	76.7	£0.32	£0.60	£1.16
150	76.7	£0.32	£0.60	£1.16
140	76.7	£0.32	£0.60	£1.16
130	76.7	£0.32	£0.60	£1.16
120	76.7	£0.32	£0.60	£1.16
110	76.7	£0.32	£0.60	£1.16
100	76.7	£0.32	£0.60	£1.16
90	76.7	£0.32	£0.60	£1.16
80	76.7	£0.32	£0.60	£1.16
70	76.7	£0.32	£0.60	£1.16

		Value (£) per unit intervention		
Asset Renewal		Low	Central	Upper
l/p/d	**km per Ml/d**	£4.14	£7.84	£15.13
170	31.9	£0.13	£0.25	£0.48
160	33.6	£0.14	£0.26	£0.51
150	35.4	£0.15	£0.28	£0.54
140	37.5	£0.16	£0.29	£0.57
130	39.9	£0.17	£0.31	£0.60
120	42.6	£0.18	£0.33	£0.64
110	45.8	£0.19	£0.36	£0.69
100	49.5	£0.21	£0.39	£0.75
90	54.1	£0.22	£0.42	£0.82
80	59.6	£0.25	£0.47	£0.90
70	66.6	£0.28	£0.52	£1.01

STEP 6.2: UNDERTAKE REALITY CHECKS

The purpose of this step is to check to see whether the results obtained are sensible and logical.

4 STAGE 3: CALCULATION OF SELL

The objective of Stage 3 is to assemble the marginal external unit cost ~ leakage relationships from Stage 2 and integrate them into the process for calculating the Socially Efficient Level of Leakage (SELL).

Figure 4.1 is a reproduction of the overview process map with the Stage 3 steps highlighted. These comprise steps 7, 8 and 9:

7. Derive functional relationships
8. Derive SELL
9. Evaluation and sensitivity analysis

This chapter describes these steps in detail in relation to the marginal external cost ~ leakage relationships developed as part of Stage 2 for the following externalities:

- leakage-related externalities, ie environmental and carbon impacts, and
- leakage management externalities, ie social and carbon impacts

The steps are subdivided and each sub-step is described with examples where appropriate.

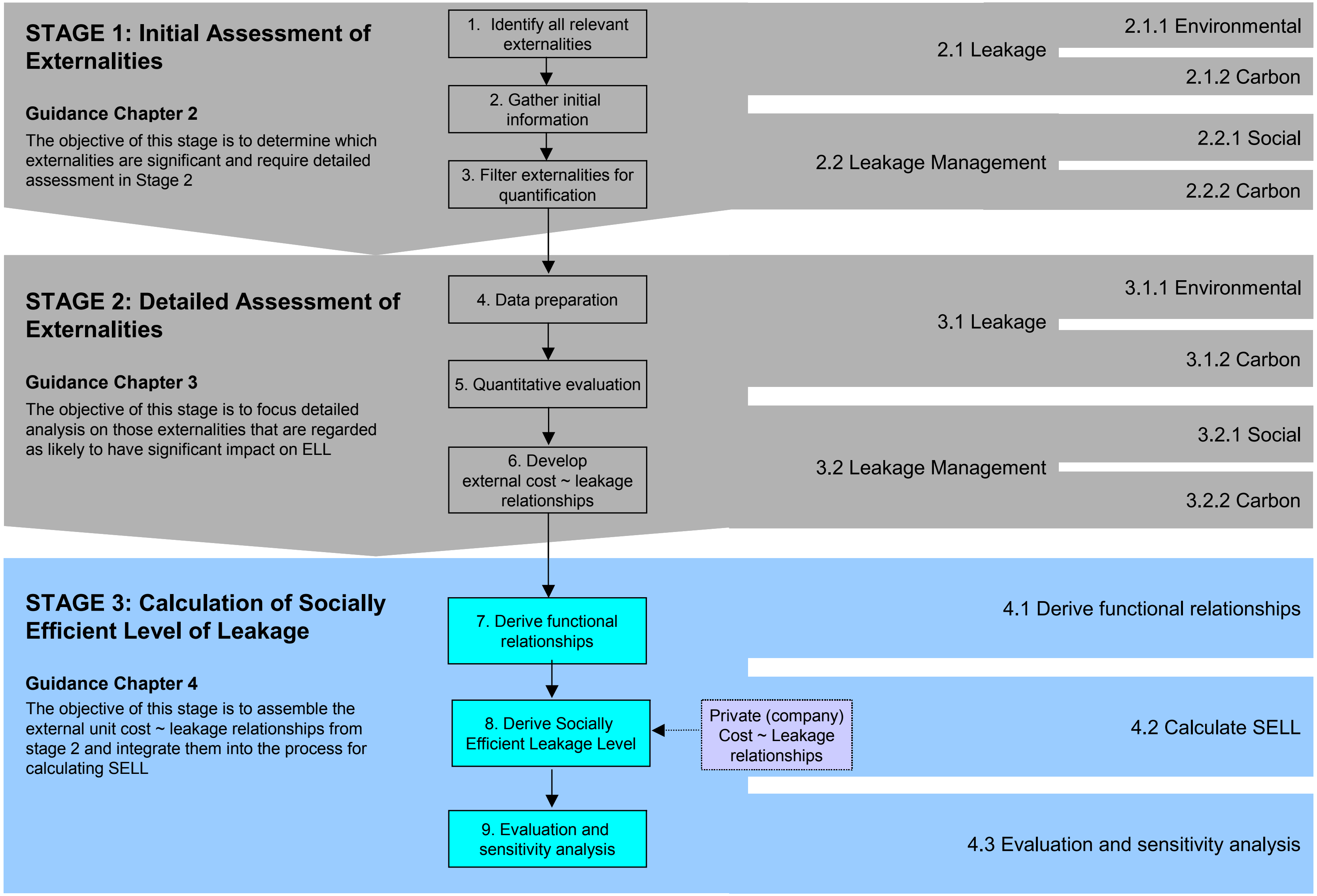


Figure 4.1 Overview Process Map - Stage 3

Figure 4.2 is a Process Map showing the recommended steps and their inter-relationships.

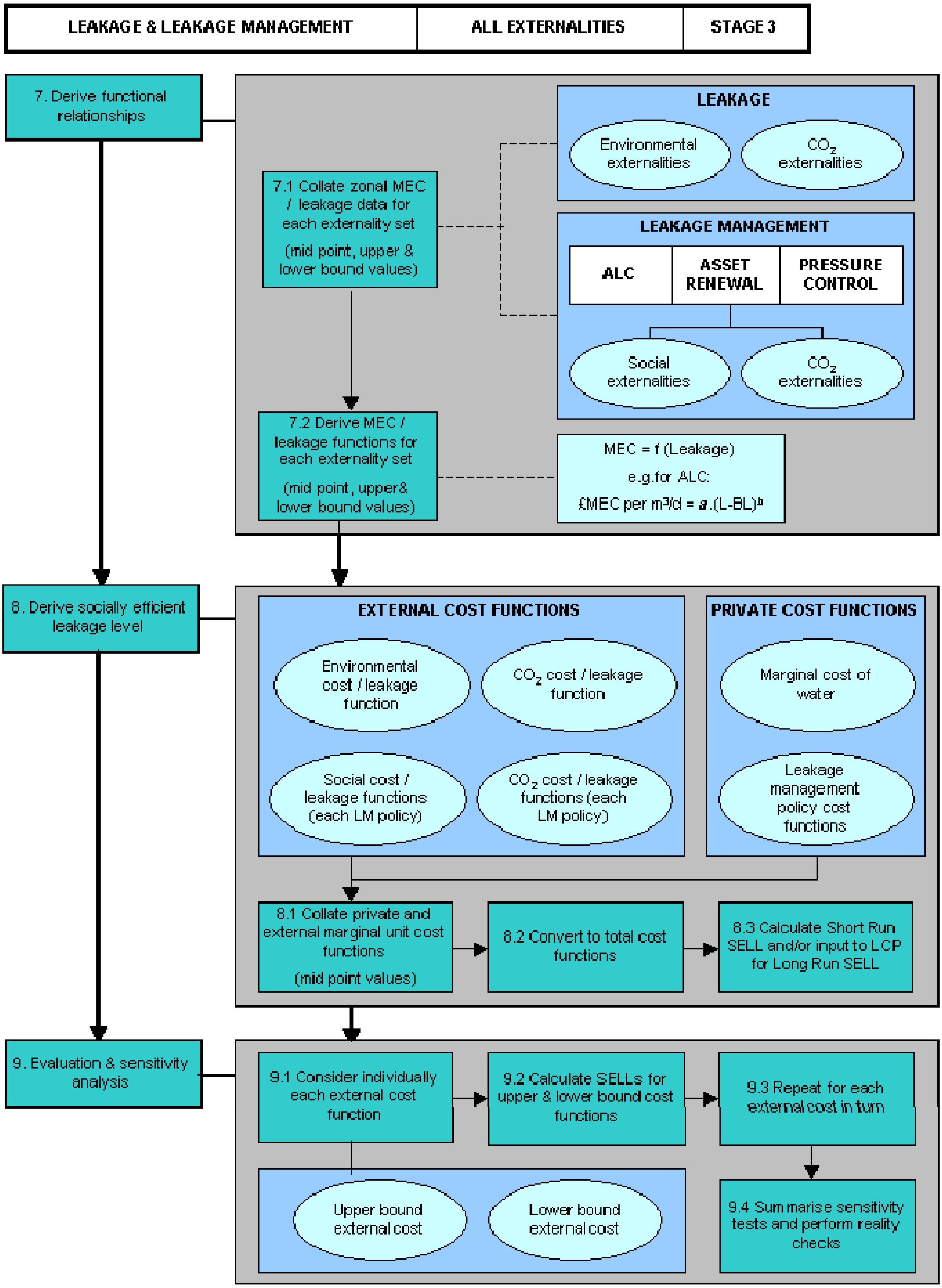


Figure 4.2: Process Map for Integration of Externalities and Derivation of SELL

4.1 DERIVE FUNCTIONAL RELATIONSHIPS

STEP 7 DERIVATION OF MEC FUNCTIONAL RELATIONSHIPS

The objective of Step 7 is to calculate a functional form for each of the four externality data sets for each resource zone:

- leakage-related environmental externalities
- leakage-related carbon externalities
- leakage management social externalities
- leakage management carbon externalities

relating marginal unit cost to leakage.

STEP 7.1 COLLATE ZONAL EXTERNALITY COST ~ LEAKAGE DATA FOR EACH EXTERNALITY SET

For each externality set, assemble the data tables from Stage 2 (Step 6), that relate the appropriate marginal external unit costs to leakage levels, for each of the mid-point, upper and lower bound conditions.

Leakage-related externalities

For each resource zone there should be 6 tables as shown in the following checklist:

Externality type	Leakage-related externalities		
	Lower	Mid	Upper
Environmental	6 tables: marginal external unit cost ~ leakage level		
Carbon			

Leakage management externalities

For each resource zone and each intervention type (ALC, asset renewal etc.) there should also be 6 tables:

Externality type	Leakage management externalities		
	Lower	Mid	Upper
Social	6 tables: marginal external unit cost ~ leakage level		
Carbon			

STEP 7.2 DERIVE EXTERNALITY COST ~ LEAKAGE FUNCTIONS FOR EACH EXTERNALITY SET

Most leakage economic modelling packages and least cost planning tools require the intervention cost ~ leakage relationships to be defined in a particular functional form (see Chapter 2 of Main Report). Functional forms may vary from model to model but nevertheless it is considered appropriate that externality cost ~ leakage relationships should also be expressed in a compatible functional form where possible.

From the data tables in 7.1 derive an appropriate functional form for each marginal unit cost relationship.

In the examples provided below, externality costs are expressed in a consistent way as the unit cost: £ per m^3/d saving in leakage at a range of leakage levels. Alternatives such as p per m^3 are equally valid.

Leakage-related externalities

Box 4.1
A WSP has assembled data tables for leakage-related environmental externalities for a resource zone. From Stage 2 (step 6) the externality marginal unit cost values based on Q78 conditions are constant across all leakage levels:

Lower bound: £ 1.81 per Ml (equivalent to £5.0 per m^3/d)
Central value: £ 9.31 per Ml (equivalent to £25.5 per m^3/d)
Upper bound: £16.82 per Ml (equivalent to £46.1 per m^3/d)

For low-flow rivers the Q98 values are used which produce a non-linear relationship (decreasing with decreasing leakage level). An exponential functional form has been fitted to this data:

$$\text{£ per } m^3/d = a \, . \, e^{b. LE}$$

where LE = excess leakage, a and b are coefficients

Box 4.2
Similarly, the WSP has assembled data for leakage-related CO_2 externalities for the resource zone. From Stage 2 (step 6) the CO_2 marginal unit cost values are:

Lower bound: £ 8.56 per Ml (equivalent to £23.5 per m^3/d)
Central value: £16.18 per Ml (equivalent to £44.3 per m^3/d)
Upper bound: £31.25 per Ml (equivalent to £85.6 per m^3/d)

These are constant across all leakage levels.

Leakage Management Externalities

Box 4.3

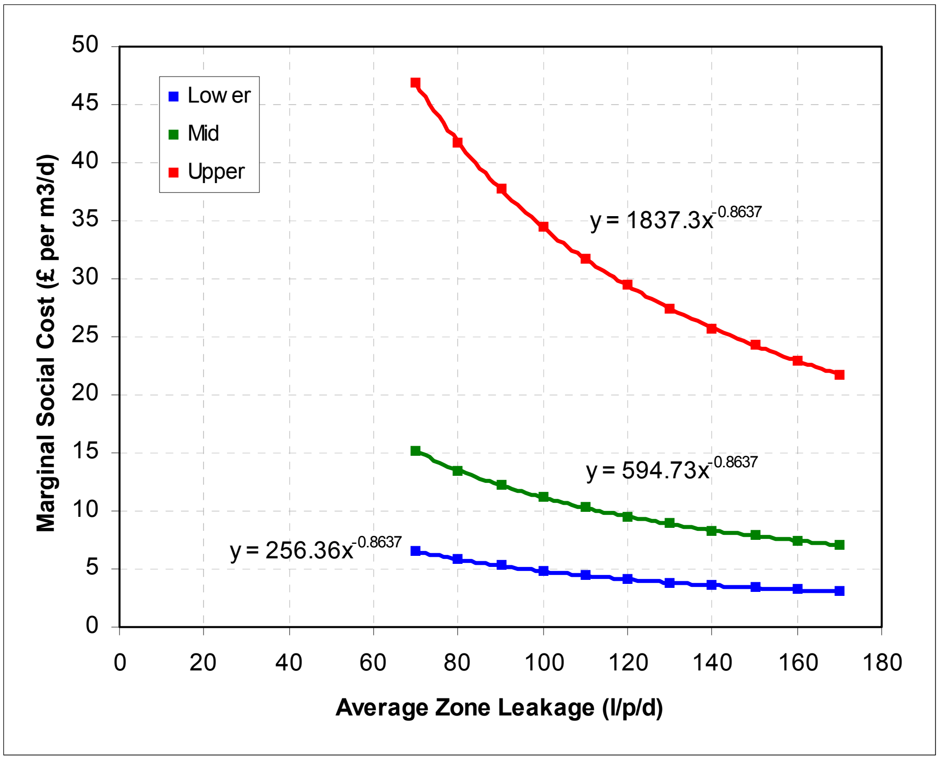
The WSP has also assembled data tables for the social externalities associated with leakage management interventions. From Stage 2 (step 6) the data table for repair of detected leaks in a zone is given below:

		MSC (£ per m³/d)		
	leaks per	Lower	Mid	Upper
l/p/d	Ml/d	34.2	79.3	245.0
170	88.8	3.0	7.0	21.8
160	93.6	3.2	7.4	22.9
150	99.0	3.4	7.8	24.2
140	105.0	3.6	8.3	25.7
130	112.0	3.8	8.9	27.4
120	120.0	4.1	9.5	29.4
110	129.4	4.4	10.3	31.7
100	140.5	4.8	11.1	34.4
90	153.8	5.3	12.2	37.7
80	170.3	5.8	13.5	41.7
70	191.1	6.5	15.2	46.8

This has been fitted to the power function:

$$\text{Marginal Social Cost (MSC)} = a \cdot L^{b}$$

This is illustrated in the following graph:



MSC functions for Repair of detected Leaks

The WSP has developed similar social cost relationships for all other leakage management externalities.

Box 4.4
The WSP has also assembled data tables for the CO_2 externalities associated with leakage management interventions. From Stage 2 (step 6) the data table for repair of detected leaks in a zone is given below:

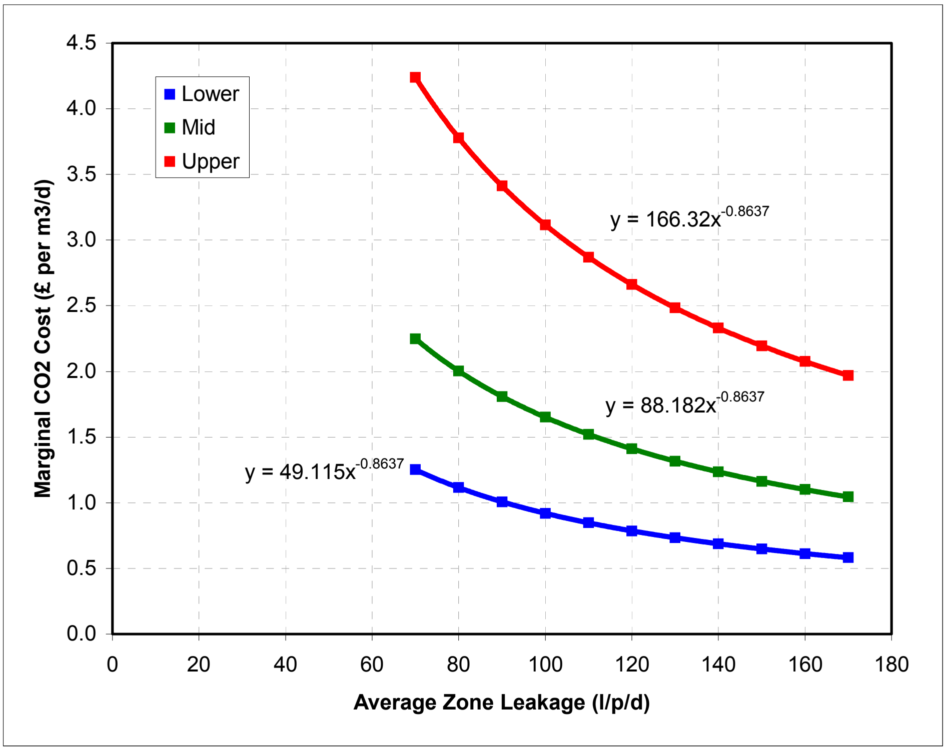
Repair detected leaks:

		MSC (£ per m³/d)		
	leaks per	Lower	Mid	Upper
l/p/d	Ml/d	6.6	11.8	22.2
170	88.8	0.6	1.0	2.0
160	93.6	0.6	1.1	2.1
150	99.0	0.6	1.2	2.2
140	105.0	0.7	1.2	2.3
130	112.0	0.7	1.3	2.5
120	120.0	0.8	1.4	2.7
110	129.4	0.8	1.5	2.9
100	140.5	0.9	1.7	3.1
90	153.8	1.0	1.8	3.4
80	170.3	1.1	2.0	3.8
70	191.1	1.3	2.2	4.2

This has been fitted to the power function:

$$MSC = a \cdot L^{b}$$

This is illustrated in the following graph:



The WSP has developed similar CO_2 cost relationships for all other leakage management externalities.

4.2 CALCULATE SOCIALLY EFFICIENT LEAKAGE LEVEL

In this step the marginal external unit cost functions for the 4 externality groups are integrated with private cost data from which the socially efficient leakage level is calculated. At this stage only the mid-point functions are used.

STEP 8.1 COLLATE PRIVATE AND EXTERNAL MARGINAL COST FUNCTIONS

For each resource zone assemble the mid-point marginal external unit cost functions:

- leakage-related: environmental and CO_2
- leakage management: social and CO_2 (all intervention types)

Ensure that the MEC values are in consistent units e.g. £ per Ml, £ per m^3/d, p per m^3 etc.

For each resource zone also assemble the private cost functions used for calculation of the private ELL's:

- leak detection }
- repair detected leaks } Active leakage control
- repair reported leaks
- asset renewal
- pressure control

STEP 8.2 CONVERT LEAKAGE MANAGEMENT FUNCTIONSTO TOTAL COST FUNCTIONS

These guidelines recommend that externality cost functions are defined initially as marginal unit cost functions and Stages 1 and 2 have followed this convention. Some modelling approaches use Total Cost and these can be determined by integration of the appropriate unit cost functions between appropriate start and end leakage levels. Leakage-related external costs (environmental and CO2) should be kept as marginal unit costs e.g. £ per Ml, in line with units for the marginal cost of water.

Box 4.5
A WSP uses the MELT total cost function for modelling the relationship between Active Leakage Control and Leakage:

$$\text{Leak Detection (£ per property per year)} = c \,.\, [(L_0 + NRRd - BL)^d - (L_1 - BL)^d]$$

Where:
L_0 = leakage at start of year, L_1 = leakage at end of year
NRRd = detectable proportion of NRR
BL = background leakage
c,d are coefficients

Repair of detected leaks, has a similar functional relationship.

Repair of reported leaks is assumed to be a constant.

This function is derived from the marginal cost functions for leak detection and repair by integration of the function:

$$\text{Marginal Unit Cost (£ per } m^3\text{/d)} = a \,.\, (L^*-BL)^b \qquad \text{where } L^* = \text{average leakage}$$

The WSP has converted all leakage management marginal cost functions from step 8.1 to total cost functions.

STEP 8.3 CALCULATE SHORT-RUN SELL AND PREPARE INPUTS TO LEAST COST PLAN

Short-run SELL

The short run SELL may be calculated using the marginal cost of water approach (see Main Report chapter 2).

In the short term it is usual to assume that the current leakage management policy of Active Leakage Control will be dominant. However the marginal unit costs of other options (Pressure Management and Asset Renewal) should be compared and schemes implemented which have lower marginal unit costs.

The short-run socially efficient level of leakage is defined as the level of leakage at which the total present value cost of leak detection, detected leak repairs and the value of the water lost through leakage is a minimum over a given planning period, provided that both private and external costs are incorporated.

The value of the water lost in this case is based on the marginal cost of water produced and delivered and is calculated largely from electricity and chemical costs. Repair costs of reported leaks is assumed to be constant. No supply or demand management costs are included.

- For a range of target leakage levels calculate the total present value cost of achieving the target over a short-term glide path and then maintaining the target thereafter.
- Calculate the present value cost of the water lost through leakage over the period for the range of target leakage levels.
- For each leakage target add the pair of PV costs

The short-run SELL is the target leakage level at which the total PV cost is a minimum provided that both private and external costs are included i.e.

Cost of leak detection = private detection costs + external costs (social and CO_2)

Cost of leak repair = private repair costs + external costs (social + CO_2)

Cost of leakage = private marginal unit cost of water x leakage + external marginal unit cost of water (environmental + CO_2) x leakage

An approximation of the long-run SELL may be made by using the long-run marginal unit cost of water calculated using production costs and the capital cost of the next resource. However “best practice” recommends that this should only be carried out as part of interim reviews and is not a substitute for the Least Cost Plan method.

The short-run SELL is useful in its own right for interim reviews of ELL and short term target setting without the need to undertake a full least cost plan. It is also useful as a precursor to an LCP study by using the SELL as the leakage component of the LCP base demand forecast. For zones which have a positive supply demand balance through the planning period the long run SELL will be equal to the short-run ELL.

Least Cost Plan

The recommended “best practice” approach to the calculation of the long run SELL is through the development of a Least Cost Plan (see Main Report chapter 2). In this case the optimal mix of supply, demand management and leakage control interventions is identified which will achieve a supply - demand balance (including headroom) over the planning period at least cost.

The EBSD Guidance provides a description of the LCP approach and includes a summary of techniques for selection of options. The most common approach to option selection is to use Average Incremental and Social Costs where options are selected in order of increasing AISC until the target headroom is met. This approach is simple to apply but has a number of disadvantages not least of which is its inability to consider any inter-relationships between options. Optimality is therefore not guaranteed. A number of more complex optimisation methods are now available using for example linear programming or genetic algorithms (GA) and these are being increasingly used by WSPs.

Whichever LCP approach is favoured by a WSP it will be necessary to prepare the private and external cost functions into a compatible format, either as AISCs or total cost functions for a range of leakage levels.

4.3 EVALUATION AND SENSITIVITY ANALYSIS

In Step 8, the short-run SELL is evaluated using central estimates of external cost ~ leakage relationships. The aim of step 9 is to examine the effects of uncertainty on the values used and test the sensitivity of the SELL estimates to changes in parameter estimation. The establishment of SELL confidence limits could be developed using Monte Carlo techniques for example. However it is considered that the simpler alternative of using lower and upper bound external cost estimates is adequate as a means of illustrating the sensitivity of SELL.

The initial step is to evaluate SELL values using first the lower and then upper bounds with all externality cost functions included. Externality cost functions are then systematically removed and the process repeated until only private costs are used.

STEP 9.1 CONSIDER INDIVIDUALLY EACH EXTERNAL COST FUNCTION

STEP 9.2 CALCULATE UPPER AND LOWER BOUND SELL'S

STEP 9.3 REPEAT FOR EACH EXTERNAL COST

STEP 9.4 SUMMARISE SENSITIVITY TESTS AND PERFORM REALITY CHECK

The final step is to evaluate the results and define upper and lower bound estimates of SELL. From the results rank the externality costs in order of their impact on SELL levels. This will provide valuable information on the key externalities and provide a focus for future data improvement.

ANNEX A

Environmental Benefits Assessment: Details of Worked Example (River Bank, Shallow Reach)

Table A1. Appraisal Summary Table

Site Name	River Bank, Shallow Reach (Zone No. X123)					
Scheme Description	Leakage Reduction Option (LRO): From existing leakage levels to zero zonal excess leakage					
Site Specific Assumptions	Length of Affected Stretch of River: 8.0 km (abstraction to outflow to sea)					
Category	Angling					
Likely impact?	Yes					
Category Specific Assumptions	**Stage 1 Assessment: Steps 2 and 3**	**Stage 2 Quantitative Assessment: Steps 4.3-4.5 (beneficiary numbers 'n')**	**Step 4.6: Transfer Value Taken ('B')**	**Reason for Taking Transfer Value**	**Step 4.7: Monetary Valuation (n x B) (Annual Benefits)**	**Step 4.8: Check for double counting of impacts**
Qualitative description based on BAG2 Tables 3.2 & 3.3 Fishery Information sourced from: EA's CAM Consultation documents / OS Maps / Company GIS / Various internet Sources	Angling opportunities are likely to be more frequent on the lower reaches of the affected river length owing to better levels of access provided by local footpaths and byways. Access to the river on the upper reaches can be gained though landowners. It is assumed that fishing can potentially occur along entire reach. The fishery is open to members of the local angling association or through the purchase of day tickets. The river supports a small game fishery of mainly brown trout and occasional runs of salmon and sea trout. Fishery is a good, relatively unexploited salmonid fishery. Classified as **Good (RE1).** Generally fished by locals only. Contribution to zone distribution input is 85% There are likely to be minor positive benefits for angling with the implementation of the LRO On the basis of this information, , a Stage 2 assessment of angling benefits is justified	*Data from local angling association:* *Association membership = 513* *Survey of annual non-member trips (day-ticket sales) = 388* *From BAG2 Table 3.8, the total number of trips made per annum by both members and non-members can be estimated by 388/ 45% (for a trout fishery) = 863. This provides a lower bound estimate* *Alternatively, if it is assumed that members make between 3 and 11 angling trips per year (BAG2 Table 3.10), but that, due to the existence of some 25 other alternative game fishing sites within a 30km radius and the relatively small size of the fishery, the lower of these numbers is likely, then total annual visits to the site by members is estimated to be 1539. Including visits by non-members, this produces a possible upper bound assessment of total visit numbers of 1,927* *Default values:* *5% of the adult population within a 60km radius may be expected to visit this type of trout fishery (BAG2 Table 3.11). Using the default population formula (BAG2), 1,749,983 x 0.8 x 0.05 = 70,000. However, there are some 25 other similar sites within a 30km radius, thus anglers at this site may be limited to 70,000/26 = 2,692. This value provides an upper bound estimate.* *Angler visits per annum:* *Lower Bound = 863* *Upper Bound = 2,692* *Reality checks:* Season for this type of fishery produces around 76 weekend days of fishing, with 78% of trips occurring at the weekends. *Lower bound: daily number of visits = 863 x 0.78 / 76 = 8.9; with 16km of accessible bank = this implies 1 angler per 1.8 km of bank (if considering only 7km of more accessible lower reaches only, 1 angler per 790m of bank)* *Upper bound: number of visits = 2,692 x 0.78 / 76 = 27.6; with 16km of accessible bank = this implies 1 angler per 580m of bank (if considering 7km of more accessible lower reaches only, 1 angler per 250m of bank)* For game fishing, 1 angler typically requires at least 50m of bank. Reality checks show therefore that both estimates appear reasonable, given that the site is a small but good quality, natural game fishery, with limited access over certain reaches and popular mainly with locals.	Upper Bound Middlesex University (1994) River Misbourne (BAG2): £11.00 per visit (Game) Lower bound: ERM (1997) South West Region fisheries (Game/coarse) (BAG2): £2.38 per visit	Considers a WTP for an additional angling day as a result of improved river levels & flows Recommended by BAG2 as upper and lower bound values Values include economic rent and consumer surplus	Annual angling benefits transfer value for 'significant' flow improvement: Lower bound = 2.38 x 863 x 1.1079 (RPI) = £2,276 Upper bound = 11 x 2692 x 1.1079 = £32,807	Angler numbers need to be excluded from informal recreational users (since in this case study these 'user numbers' are derived by total population minus non-use population).

Site Name	River Bank, Shallow Reach (Zone No. X123)					
Scheme Description	Leakage Reduction Option (LRO): From existing leakage levels to zero zonal excess leakage					
Site Specific Assumptions	Length of Affected Stretch of River: 8.0 km (abstraction to outflow to sea)					
Category	Informal recreation					
Likely impact?	Yes					
Category Specific Assumptions	**Stage 1 Assessment: Steps 2 and 3**	**Stage 2 Assessment: Steps 4.3-4.5 (beneficiary numbers)**	**Step 4.6: Transfer Value Taken**	**Reason for Taking Transfer Value**	**Step 4.7: Monetary Valuation (Annual Benefits)**	**Step 4.8: Check for double counting of impacts**
Qualitative description based on Table 2.3 (BAG2) Information regarding site quality sourced from: EA CAM consultation documents / OS Maps / Company GIS maps / EA GQA data	Overall, access is rated as **MODERATE** accessibility to certain stretches of the river. Access is poor for the 4.5km section of the upper reaches above Fair Bridge to the point of abstraction at Aspot. There is no provision of footpaths or roads giving any access to the river along this section. Below Fair Bridge, the remaining 3.5km section becomes intersected with numerous footpaths, byways, national cycle network and roads providing good access to this stretch of the river. Provision of facilities rated as **MODERATE** (few to some facilities along affected stretch). Generally localised around the urban centres such as Newtown & Oldtown on the lower reaches of the river. Numerous camping and caravan sites along with the local facilities provided by the settlements along the affected stretch. As the river is located within Hilltops National Park, based on detail and BAG2 Tables 2.3 & 2.7, the affected river reach is considered to be of **Regional / National importance.** The river provides an important contribution to the aesthetic quality of the area and as a result the site is rated, overall, as **MODERATE** to **HIGH** importance in terms of informal recreation. Although the site type is Regional / National the access and facilities are rated as fair therefore based on BAG2 Table 2.7 the importance is taken as **LOWER** attracting visitor up to a maximum of 10km Water Quality in affected stretch is **GOOD** no litter on river corridor, RE1 & Designated salmonid water. Contribution to zone distribution input is 85% There are likely to be some minor positive visible impacts associated with the LRO. On the basis of this information, , a Stage 2 assessment of informal recreation benefits is justified	No site-specific survey data available, so default data used: Although designated as a 'Regional/National' site, it is however of lower importance as access moderate and facilities fair. Likely to draw people from at most 10km (unlikely to be any further owing to the location of more favourable sites within the extended area that people could visit). Two methods were used to determine total population numbers within the 10km radius. **Method 1** - Distance Polygon using Company GIS mapping system: population = 20,354 **Method 2** – BAG2 default formula: population = 22,061. These formed upper and lower bound assessments for total population. **% visiting site(s):** % visiting site(s) is assumed to be 98% for those living within 0.5kmof site; 70% for those living 0.51 – 3km from site; and 26% for those living 3-10km away (BAG2 Table 9.12) **Adjustment for double counting (angler visitors)** – see final column of AST **Alternative Sites:** There are 2 alternative recreational sites within the 10km radius, which can be considered to offer equal or better recreational activities for those visiting the area. **Estimated visitor households per yr :** Lower Bound = 651 Upper Bound = 1059 **Reality check:** Upper bound: 71 visits per day / 16km = 4.4 visits per km of bank per day**.** Lower bound: 33 visits per day /16km = 2 visits per km of bank per day. (If considering 3.5 km of 'good' accessibility only, upper bound = 10 visits per km per day, and upper bound = 5 visits per km per day) Visit numbers do not seem unreasonable given access, facilities and availability of alternative sites. Site can also support such numbers. Upper bound visits however appear somewhat high, thus lower bound values may be more accurate	Jacobs Gibb (2002) (from BAG2 Table 2.10): <0.5km: £0.34 0.51 – 3km: £0.25 3-12km: £0.07 12-60km: £0.03 Units: per household per km per year	Considers a WTP for flow improvements on River Mimram: to move from low flows every 4-5 years out of 20 to full restoration (low flows once every 20 years). BAG2 recommend these values if separate estimates for angling are to be made	Annual informal recreation benefits transfer value for 'significant' flow improvement: Upper bound = £1275 Lower bound = £772	Visitor numbers are derived, using the default method, by considering total population within relevant radius and deducting percentages assumed to be non-users. Anglers will therefore form part of the residual number of 'use' visitors, and thus angling numbers must be deducted from these assessments to avoid double counting. The lower bound angling assessment (863) has been deducted from the upper bound assessment of 'user' numbers (, while the upper bound angling assessment (2692) has been deducted from the lower bound assessment of 'user' numbers.

Notes/Comments on assessment:
1. Alternative sites*:* visits per year adjusted by dividing by 4 (3 plus 1 for the site in question) *although it is of Regional / National importance (as located within NP) there are several other sites which offer equal of better recreational opportunities which could attract visitors within 10km of the site. Furthermore as the river is located within Hilltops NP visits maybe for this resource than the actual river itself.*
2. Detailed calculations for informal recreation benefits transfer values (steps 4.3 – 4.7) may be found in Table A.2.

Site Name	River Bank, Shallow Reach (Zone No. X123)					
Scheme Description	Leakage Reduction Option (LRO): From existing leakage levels to zero zonal excess leakage					
Site Specific Assumptions	Length of Affected Stretch of River: 8.0 km (abstraction to outflow to sea)					
Category	In-stream recreation					
Impact Likely?	Yes					
Category Specific Assumptions	**Stage 1 Assessment: Steps 2 and 3**	**Stage 2 Quantitative Assessment: Steps 4.3-4.5 (beneficiary numbers 'n')**	**Step 4.6: Transfer Value Taken ('B')**	**Reason for Taking Transfer Value**	**Step 4.7: Monetary Valuation (n x B) (Annual Benefits)**	**Step 4.8: Check for double counting of impacts**

Qualitative description based on Table 5.2, 5.3, 5.5, 5.6 and 5.7 (RPA Guidance, 2003) Information sourced from: EA CAM consultation documents / OS Maps / GIS maps / various internet Sources	No boating and very limited canoeing opportunities exist on the affected reach. The opportunity for canoeing is sporadic and only after significant rainfall is the river high enough to support this activity . Furthermore this is likely to be only a be used by a very localised population. Therefore trips to the river in terms of in stream recreation are likely to be few. Based on the facilities and access and BAG2 (Table 5.7) it is assumed that the river will be used by locals only therefore the assumed distance for aggregation is 8km. Although it is suspected that the distance will be far lower due to the sporadic nature of the opportunities and other alternatives within the region. Based on BAG2 (Table 5.3), with the implementation of the LRO, the impact to canoeing is most likely to be **POOR** (no increase in the number of trips and value of enjoyment) to **FAIR** (slight increase in the number of trips and value of enjoyment) There are considered to be 4 other alternative sites within 8km radius.	***DEFAULT DATA:*** ***THE ASSUMED DISTANCE FOR AGGREGATION IS 8KM.*** ***LOWER BOUND: USING BAG2 (TABLE 5.5), CANOEING REPRESENTS 0.8% OF TOTAL VISITOR NUMBERS, THUS 0.8% X 6,721 = 54. WITH FOUR ALTERNATIVE SITES, THIS YIELDS 54/5 = SOME 11 CANOEING VISITS PER YEAR*** ***UPPER BOUND: USING THE DEFAULT POPULATION DENSITY FORMULA (BAG2) PRODUCES AN ADULT POPULATION WITHIN AN 8 MILE RADIUS OF 11,761X 0.8 = 9,408. USING BAG2 TABLE 5.6, THE NUMBER OF TRIPS MADE BY THE ADULT POPULATION PER YEAR IS 0.18, THUS THERE ARE 1,693 CANOEING VISITS MADE BY THE LOCAL ADULT POPULATION. WITH FOUR ALTERNATIVE SITES, THIS YIELDS 1693/5 = 340 ADULT VISITS PER YEAR TO THE SITE IN QUESTION.*** ***LOWER BOUND: 11*** ***UPPER BOUND: 340*** Reality check: These estimates seem reasonable given the sporadic canoeing opportunities on the reach and its local nature. As these numbers are not significant (i.e. < 1,000) no further quantitative evaluation was undertaken for in-stream recreation.	Impacts not significant therefore further quantitative and monetary valuation not necessary

Site Name	River Bank, Shallow Reach (Zone No. X123)
Scheme Description	Leakage Reduction Option (LRO): From existing leakage levels to zero zonal excess leakage.
Site Specific Assumptions	Length of Affected Stretch of River: 8.0 km (abstraction to outflow to sea)
Category	Biodiversity and non-use

Impact Likely?	Yes					
Category Specific Assumptions	**Stage 1 Assessment: Steps 2 and 3**	**Stage 2 Assessment: Steps 4.3-4.5 (beneficiary numbers)**	**Step 4.6: Transfer Value Taken**	**Reason for Taking Transfer Value**	**Step 4.7: Monetary Valuation (Annual Benefits)**	**Step 4.8: Check for double counting of impacts**
Qualitative description based on BAG2 Table 9.2 Impacts based on BAG2 Tables 9.3, 9.4, 9.5 & 9.6 Conservation information etc sourced from the EA CAM consultation documents / OS Maps / Company GIS/ various internet sources	The 8.0km stretch forms part of the Bray Valley SSSI which is ecologically important for its populations of Bryophytes. The affected river also falls within Hilltops National Park, emphasising the importance of the site in terms of non-use and biodiversity. The affected river does not exhibit an extensive floodplain. The Nature conservation evaluation is 'National' (owing to the SSSI) (BAG2 Table 9.3). The Biodiversity impact is considered to be 'minor positive' (BAG2 Table 9.5) This equates to an expected 'small benefit' in terms of the impacts of the proposed LRO on Biodiversity & Conservation (Table 9.6). The site contributes 85% of zone distribution input. On the basis of this information, a Stage 2 assessment of biodiversity and non-use benefits is justified	The nature conservation evaluation is 'National' (BAG2 Table 9.3), but the benefit is defined as 'minor positive'. Therefore the relevant distance decay radii are taken as 60km (upper bound) with 30km being examined as a lower bound. (NB the distance-decay relationship defined by Jacobs Gibb (2002) becomes zero after 60km). Two methods were used to determine total population numbers within these two radii. **Method 1** - Distance Polygon using Company GIS mapping system: population = **Method 2** – BAG2 default formula. The upper bound assessment (BAG2 default, 60km radius) = 1,749,983, and the lower bound assessment (GIS, 30km radius) = 149,451 **% population who are non-users:** % non-users (as opposed to users) is assumed to be: 2% for those living within 0.5km of site; 30% for those living 0.51 – 3km from site; 74% for those living 3-12km away ; and 98% for those living > 12km away (BAG2 Table 9.12) **Alternative sites**: There are 3 sites of similar (or better) ecological importance within a 30km radius of the site, and a further site in the 30-60km radius. Thus the upper and lower bound beneficiary assessments (corresponding to 60km and 30km radii) were adjusted accordingly **Non-use households:** Upper bound = 250,835 Lower bound = 22,379 **Reality checks:** No reality checks undertaken for this impact	Jacobs Gibb (2002) (from BAG2 Table 9.11): <0.5km: £0.22 0.51 – 3km: £0.22 3-12km: £0.04 12-60km: £0.03 Units: per household per km per year	Considers a WTP for flow improvements on River Mimram: to move from low flows every 4-5 years out of 20 to full restoration (low flows once every 20 years). BAG2 recommendation of greatest reliability. Figures already adjusted for income effects	Annual non-use benefits transfer value for 'significant' flow improvement: Upper bound = £40,341 Lower bound = £4,704	It is assumed that non-users do not visit the site for any purpose, thus non-users exclude all types of visitors included elsewhere in externality evaluations
2. Detailed calculations for biodiversity and non-use benefits transfer values (steps 4.3 – 4.7) may be found in Table A.3						

Site Name	River Bank, Shallow Reach (Zone No. X123)
Scheme Description	Leakage Reduction Option (LRO): From existing leakage levels to zero zonal excess leakage
Site Specific Assumptions	Length of Affected Stretch of River: 8.0 km (abstraction to outflow to sea)
Category	Other
Impacts likely?	No

Category	Impact Likely?	Category Specific Assumptions	Stage 1 Assessment: Steps 2 and 3	Stage 2 Quantitative Assessment: Steps 4.3-4.5 (beneficiary numbers 'n')	Step 4.6: Transfer Value Taken ('B')	Reason for Taking Transfer Value	Step 4.7: Monetary Valuation (n x B) (Annual Benefits)	Step 4.8: Check for double counting of impacts
Amenity	No		Noticeable settlements located on affected river stretch: Newtown and Oldtown Qualitative description based on BAG2 (Table 6.2) As the changes in flows/levels under consideration are relatively small it is assumed that there will be no impacts on property values or urban regeneration	Impacts not significant therefore quantitative and monetary valuation not necessary				
Abstractions	No	Information regarding abstractors obtained from the EA's CAM consultation documents	All licensed abstractors within the Bray CAM are from surface water. The two largest and most noticeable abstractions are for HEP and Potable Water Supply. Of the total volume extracted HEP accounts for 17% and Potable Water Supply some 80%. Insignificant volumes are taken for other uses such as agriculture and industrial needs Qualitative description based on table BAG2 (Table 7.2). Descriptions of abstractions are based on CAM / LEAP reports covering the area containing the affected river. As the changes in flows/levels under consideration are relatively small this will not result in elevation of cessation orders in the future. In most cases impacts are unlikely to be sufficient to cause noticeable change for abstractors	Impacts not significant therefore quantitative and monetary valuation not necessary				
Heritage, archaeology & landscape	No	Information regarding Heritage, Archaeology & Landscape has been obtained from the EA's CAMS & LEAP reports.	There are several scheduled ancient monuments in the area protected by law. The river forms an important part of landscape. The area is one of beauty and serene old country attractive to visitors. The importance of the area in terms of its landscape is reflected by the National Park and Special Landscape Area designation over much of the catchment. The affected river is considered to be unmodified. Qualitative description based on BAG2 (Table 8.2) As the changes in river flow/levels are relatively small it is assumed that this will not cause any significant impact to the historic context or the landscape of the site.	Impacts not significant therefore quantitative and monetary valuation not necessary				
Commercial Fisheries	No	No commercial fisheries exist within the site		Impacts not significant therefore quantitative and monetary valuation not necessary				
Agricultural use	No	No agricultural activities exist within the site that might be affected by a change in flow levels		Impacts not significant therefore quantitative and monetary valuation not necessary				
Commercial navigation	No		One foot-passenger ferry operates across a relatively deep part of the reach some 0.3 km south of Aspot. This operation would not be affected by a change in flow associated with the proposed LRO. No other commercial navigation occurs along the reach.	Impacts not significant therefore quantitative and monetary valuation not necessary				

Table A.2: Detailed Calculation of Beneficiary Numbers for Informal Recreation

	Site: River Bank, Shallow Reach		Impact: Informal recreation								
	Step 4.3: Assessment of potential beneficiary numbers (n)						Step 4.4	Step 4.6: Deriving B		Step 4.7: n x B	
Parameter	Distance from site	Total population within each 'distance ring'	Informal recreation visitor population	Adjustment for double counting	Site visitor population (adjusted for number of alternative sites)	Annual visitor households to site	Total number of visits to site per day	Unit benefits transfer value for non-use (2001 prices)	Benefits transfer value for whole river reach (2001 prices)	Total informal recreation benefits transfer value (2001 prices)	Total informal recreation benefits transfer value (2005 prices)
Explanatory information	Represents distance decay (up to 10km)	Upper bound: default population density formula (for 'sausage')[1] Lower bound: Company GIS Polygon	Proportion of population visiting (may decline with distance from site)	Number of anglers deducted from total user numbers	Number of similar recreational sites within radius (=2)	Benefits transfer values are per visitor household	Reality check	Unit non-use value of a 'significant' flow change	x by length of affected reach (8km)	Total non-use value for a 'significant' flow change	Inflated to present value
Source of data	Jacobs Gibb (2002) (BAG2 Table 2.10)	Upper bound: BAG2 and census data (population densities for local authority or region)[2]	x by relevant % of population who visit (BAG Table 9.12)	Numbers of anglers derived from angling assessment (assumed to all come from within 10km radius)	Divide by (number of other sites + 1)	/ by household occupancy rates (census data for local authority or region[2])	No. visitors to site x number of annual visits /365 (BAG2 Table 2.7)	Jacobs Gibb (2002) (BAG2 Table 2.10)	Stage 1 assessment	Unit BT value x no. households	RPI
Units	km	No. people	No. visitors	No. visitors (informal recreation)	No. visitors to site	No. visitor households per year	No. people visiting site per day	£ per household per km	£ per household	£	£
Upper bound assessment	0 - 0.5	409	401	354	118	57	6	0.34	2.72	156	172
	0.51 - 3	3,140	2,198	1,942	647	314	30	0.25	2.00	628	696
	3.01 - 10	18,512	4,813	4,253	1,418	688	35	0.07	0.56	385	427
	TOTAL	22,061	7,412	6,549	2,183	1,059	71			1,169	1,295
Lower bound assessment	0 - 0.5	320	314	188	63	30	2	0.34	2.72	83	92
	0.51 - 3	2,723	1,906	1,143	381	185	9	0.25	2.00	369	409
	3.01 - 10	17,311	4,501	2,698	899	436	22	0.07	0.56	244	271
	TOTAL	20,354	6,721	4,029	1,343	651	33			696	772

1. Population = 3.14 x radius^2 + (2 x radius x reach length) x relevant (regional or local authority) population density
2. For radii < 30km, local authority values used (from census data). For radii > 30km, regional values used.

Table A.3: Detailed Calculation of Beneficiary Numbers for Biodiversity and Non-use

	Site: River Bank, Shallow Reach		Impact: Biodiversity and non-use							
	Step 4.3: Assessment of potential beneficiary numbers (n)						Step 4.6: Deriving B		Step 4.7: B x n	
Parameter	Distance from site	Total population within each 'distance ring'	Total households within each 'distance ring'	% households with non-use only	Non-use Households	Adjusted No. Households	Unit benefits transfer value for non-use (2001 prices)	Benefits transfer value for whole river reach (2001 prices)	Total non-use benefits transfer value (2001 prices)	Total non-use benefits transfer value (2005 prices)
Explanatory information	Represents distance decay	Upper bound: default population density formula (for 'sausage')[1]. Lower bound: Company GIS polygon	Population x average household occupancy rate for local authority or region[2]	Remaining % assumed to be users, therefore need to eliminate double counting		Adjustment for number of similar sites within non-use radius (4)	Unit non-use value of a 'significant' flow change	x by length of affected reach (8km)	Total non-use value for a 'significant' flow change	Inflated to present value
Source of data	Jacobs Gibb (2002) (BAG2 Table 9.11)	Upper bound: BAG and census data (population densities for local authority or region)[2]	Census data	BAG2 (Table 9.12)		Divide by (number of other sites + 1)	Jacobs Gibb (2002) (BAG2 Table 9.11)	Stage 1 assessment	Unit BT value x no. households	RPI
Units	km	No. people	No. households	%	No. households	No. households	£ per household per km	£ per household	£	£
Upper bound assessment	0 - 0.5	409	198	2	4	1	0.22	1.76	1	2
	0.51 - 3	3,140	1,523	30	457	91	0.22	1.76	161	178
	3.01 - 12	26,431	12,820	74	9,487	1,897	0.04	0.32	607	673
	12 - 60	1,720,002	757,710	98	742,556	148,511	0.03	0.24	35,643	39,489
	TOTAL	1,749,983	772,252		752,504	250,835			36,412	40,341
Lower bound assessment	0 - 0.5	320	155	2	3	1	0.22	1.76	1	2
	0.51 - 3	2,723	1,321	30	396	99	0.22	1.76	174	193
	3.01 - 12	24,520	11,893	74	8,801	2,200	0.04	0.32	704	780
	12 - 30	121,888	59,119	98	57,937	14,484	0.03	0.24	3,476	3,851
	TOTAL	149,451	73,661		67,137	22,379			4,246	4,704

1. Population = 3.14 x radius^2 + (2 x radius x reach length) x relevant (regional or local) population density
2. For radii < 30km, local authority values used (from census data). For radii > 30km, regional values used.