

**Acid Waters in Wales:  
Appraisal of Strategic Options**

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## EXECUTIVE SUMMARY

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This work summarises the application of an appraisal methodology which evaluates, albeit at a strategic level, options which potentially begin to address the Acid waters problem in Wales. This is a logical step which follows the 1995 *Acid Waters in Wales Survey* and other scientific studies, and is a necessary precursor to the development of an information paper for the Welsh Assembly and ultimately a Strategy to tackle the problem.

This is one of the first fully documented examples of a *sustainability appraisal* carried out by the National Centre for Risk Analysis and Options Appraisal.

The method involves:-

- agreement on issues against which alternatives are to be assessed (*range of issues grouped under sensitivity, environmental, political and economic risks and benefit opportunities*).
- choice of alternatives and development of an evaluation matrix (*on one sheet of paper or overhead*) which can easily be filled in.
- convening workshop(s) involving technical specialists.
- elicitation of scores (*high, medium and low*) for each issue vs alternative.
- deciding by consensus what decision factors or criteria should be used in a trade-off analysis:-
- undertaking a trade-off analysis using a non-parametric statistical technique.
- conducting a sensitivity analysis on the results.

The conclusions of the study were not proven as statistically significant, although there is an emerging sense of priority amongst the alternatives:-

- all 11 alternatives analysed are probably much better than two (biomanipulation and genetic modification of fish) which were rejected at the outset as being far too controversial.
- possible options for further evaluation based on the analysis are SO<sub>2</sub>, NO<sub>x</sub> stationary and NH<sub>3</sub> ammonia reduction (long-term objectives) and re-introductions (short-term objectives).
- perhaps the only alternative which can be confidently rejected by the analysis is that relating to liming of agricultural land/catchments.

Sensitivity testing shows that for there to be considerable differences between options, then substantial weights would have to be applied. Above all, the process is iterative and the outcome would probably be different if alternative criteria had been selected. However, application of more sophisticated techniques could overcomplicate what is basically a strategic approach.

## 1. BACKGROUND

### 1.1 The Problem: Acid Waters in Wales

It is widely recognised that many of the soils and freshwaters in upland Wales have been acidified as a consequence of high rainfall depositing acid in solution and high deposition rates from gaseous pollutants, coupled with the poor neutralising capacity of acid soils and geology (Edwards *et al*, 1990). As much as 34% of soils may be affected, about 50% of upland watercourses may have been damaged by acidification and 43% of Sites of Special Scientific Interest (SSSI's) potentially damaged (Stevens *et al*, 1997). Acidification reduces invertebrate diversity and leads to the loss of fish stocks and other riverine species such as dippers and otters. Increased water treatment costs may also result from high acidity and concentrations of acid-soluble metals. The economic impacts of acid waters may therefore be substantial.

In 1995, a Welsh Acid Waters Survey was undertaken at the instigation of the Countryside Council for Wales, the National Rivers Authority (now part of the Environment Agency), the Forestry Authority and Welsh Office with several objectives, including:-

- describing the current patterns of acid deposition across Wales and making a comparison with a previous survey undertaken in 1984
- assessing the chemistry of acid sensitive streams and lakes in relation to observations made in 1984, to changes in atmospheric deposition, to catchment attributes and to predictions from hydro-chemical modelling
- describing the macro-invertebrate, fish and dipper populations of acid sensitive streams in relation to their current chemistry, status in 1984, and predictions from biological modelling

A detailed outline of the approach and sampling methods is given by Stevens *et al*, 1997. The most important conclusions of the survey are that:-

- atmospheric deposition of sulphur has decreased since 1984, reflecting declining sulphur dioxide emissions
- there is evidence that some chemical components of freshwaters (e.g. sulphate and pH) may be responding to reductions in sulphur deposition, but other acidification indicators (e.g. aluminium) show no improvement
- there has been no evidence that the biological indicators of acidification have responded as a consequence of a combination of factor. It is probable that suitable chemical conditions for recovery have been insufficient, sustained or widespread enough, and that biological recovery may be intrinsically slow. Furthermore the effects of reduced sulphur may have been offset by atmospheric deposition of nitrogen.

In addition to policy options for reducing emission of sulphur dioxide and nitrogen compounds, (oxides and ammonia) the influence of forestry on acidification of soils and freshwaters may be important as may other options which have been applied in Wales such as liming and reintroduction of species.

## **1.2 The Requirement for Options Appraisal**

In January 1998, the Regional Water Manager for Environment Agency Wales requested advice from the National Centre for Risk Analysis and Options Appraisal on methods for the appraisal of strategic options for the management of Acid waters in Wales. At that time the Centre was able to provide a number of examples of checklists/matrices for impact identification and evaluation which had potential for transferability to the acid waters problem.

Many of these examples form part of a *Review of Strategic Appraisal Tools* which will appear in a separate National Centre report to be published later in 1998/99. Subsequently, the Centre has assisted in the facilitation of two workshops on acid waters, one held in March 1998 in Cardiff, the other in July 1998 in Aberystwyth.

This report summarises the results of a preliminary options appraisal rather than a detailed evaluation which is anticipated to be required at a later stage, prior to the development of a Strategy to deal with the Acid waters problem.

## 2. SUSTAINABILITY APPRAISAL

The objective of the study is to evaluate potential options for solving the Acid waters problem in Wales in terms of their relative environmental, economic, technological and social implications. A broad strategic approach is demanded at this early stage of appraisal, with the aim of narrowing down the range of options and providing pointers on those options which might benefit from more detailed investigation. The approach needs to be recorded for the purposes of openness and transparency.

### 2.1 Method Selection

No universal decision-focused methodology exists for this type of sustainability appraisal. This is one of the first fully documented examples of sustainability appraisal carried out by the National Centre for Risk Analysis and Options Appraisal on behalf of the Environment Agency and there is relatively little proven UK experience to draw upon. However there is over 10 years of experience from the water industry in the UK, including the Environment Agency's predecessor organisation the National Rivers Authority. This experience is largely based on checklist or matrix approaches involving simple listings of environmental factors. There is relatively little work to draw upon involving more complex multi-criteria methods which rank or assign weights to decision factors and alternatives.

The following criteria were used to select a particular method:-

- Relatively simple and efficient with application at a strategic level within constraints of time, money and specialists (eg economists) to conduct more detailed appraisals.
- Drawing upon the technical expertise of the key stakeholders involved with the problem.
- Incorporating both factual information and value judgements.
- Covering environmental, economic and social implications.
- Providing a means of recording of long term, short term, secondary and indirect effects.

The method involves the following components:-

- Construction of an evaluation matrix which summarises a range of options from policy-level to specific project-level management approaches on as comparable and objective basis as possible.
- Use of decision workshops or conferences to elicit the views and preferences of a number of technical specialists concerned with a problem (cf Environment Agency, 1998a; Phillips, 1989, Warwick University Risk Initiative, 1998). Group dynamics and communication are important components of these workshops.

- Reaching consensus on the priorities which should be given in completing the evaluation matrix based on high, medium or low scores.
- Conducting a trade-off analysis based on pre-selected decision factors. The specific method used was the unranked paired comparison technique described by Dean and Nishry (1965) which compares each alternative relative to every alternative relative to each decision factor. The value of this method is that it involves a non-parametric statistical technique.
- Application of Friedman's Two-Way Analysis of Variance (Anova) by Ranks Test to determine if there are true differences in the alternatives selected. This involves a Chi Square calculation.
- There are a number of techniques, some mathematical, which can be used to weight alternatives and decision factors. These were not selected for this particular analysis to avoid criticism that such weights are arbitrary or biased. There is also a likelihood of false perception concerning the degree of objectivity, sophistication and precision achieved in decision making. Weights, if used, should come from a variety of sources, not just expert groups but also business or community groups or opinion surveys (DoE, 1991).
- Conducting sensitivity analysis on the results

## 2.2 Application of Method

### 2.2.1 Construction of the Evaluation Matrix

The process initially involved pre-selected categories of particular issues and options. These were chosen by the Regional Water Manager (Environment Agency Wales) from information on previous matrices supplied by the National Centre, from the literature and professional judgement. This selection was then discussed and modified as appropriate by technical specialists during two key decision workshops, held in March and July 1998.

Categories of *Sensitivity* and *Potential risks* (environmental, political and economic) and *Benefit opportunities* have been included. The specific issues within each category cover a broad spectrum from environment, to social and economic representing the types of considerations that are needed in reaching decisions on options which contribute towards an objective of sustainable development.

Table 1: Key issues and example criteria for assigning high, medium and low scores

Issue	High/moderate Sensitivity	High/moderate Risks	Benefit
Fish and aquatic ecology	Salmonoids and certain species of coarse fish.	Fish 'kills'. Loss of spawning grounds. Change in nursery grounds. Change in river 'smell' for migrating fish. Significant changes macro-invertebrate and macrophyte populations. Introduction of aliens/disease.	Increased biomass. Increased habitat diversity. Increase in number of dippers.
Terrestrial ecology	Changes in nutrient cycling. Increased biodiversity.	Impact or loss to nationally/ internationally designated site (e.g. SSSI's, ESA's and SAC's). Alien emergent vegetation.	Increased habitat diversity
Water quality	Class A river.	Fall in water quality class.	Improved water quality.
Forestry	Impacts on forested areas.	Decreased growth of trees/damage.	Improved forestry.
Agriculture	Improved land class. Restriction of farming choices.	Deterioration of land class.	Improved agricultural production. Increased stocking density.
Community Impacts - Health	Detriment to private water supplies. Air quality impacts.	Perceived and actual risks (road transport vs industry).	Improved human health.

Issue	High/moderate Sensitivity	High/moderate Risks	Benefit
Community Impacts - Amenity	Commercially important fishing. Waterbody used for contact sport. Improved access.	Fish 'kill'. Reduced transport causing inaccessibility to rural areas.	Improved amenity/recreation. Improved poor quality fishery. Improved tourism. Increased naturalist interests.
Landscape and Planning Issues	Natural areas.	Reduced natural character.	Enhanced landscape diversity.
Industry (excluding agriculture)	Technology not well developed or with knock-on effects.	New unproven technology (e.g. catalytic converters).	Benefits to industry (e.g. coal, water, quarrying, etc.).
Political	-	Extreme objection. Detrimental impact on Welsh industry and agriculture. Public perception of 'not natural' solutions and impact on conservation.	-
Economic	-	Relatively high cost solutions e.g. based on technology.	-

NB: criteria are recorded in minutes of meeting for March and July 1998 (Annex A & Annex B).  
Draft Table

Thirteen strategic options were initially selected and these can be grouped under five broad categories:-

- **S Reduction**
  - SO<sub>2</sub> Reduction
- **N Reduction**
  - NO<sub>x</sub> Stationary
  - NO<sub>x</sub> Module
  - Ammonia NH<sub>3</sub>
- **Land Use**
  - Restrictions on new forestry
  - Adopt UK standards for existing forestry
  - Agri-environment
- **Liming**
  - Direct dosing
  - Source-area
  - Agricultural/catchment
- **Bio-intervention**
  - Re-introductions at selected sites
  - Biomanipulation
  - Genetic manipulation of fish

In addition it was agreed at the first workshop (March 1998) that a split between '*All Wales*' and '*Selected Sites*' would be useful as it was a way of reaching decisions on options which may be appropriate on a limited scale rather than '*All Wales*'. In most cases, options would be applicable to either/or '*All Wales*' / '*Selected Sites*'.

Two options were dropped by consensus at the July 1998 workshop without further analysis. The first was *Bio-manipulation* which would involve additions of chemicals such as phosphate and was therefore agreed to present considerable risks to warrant further consideration. The second, *fish genetic manipulation*, was also regarded as too risky.

### 2.2.2 Decision Analysis

The minutes of these decision workshops are recorded respectively in Annexes A and B. The March 1998 workshop had an element of 'road testing' and refinement of the evaluation matrix, whilst the July 1998 workshop (over a two day period) involved taking stock of what was achieved in the first meeting and filling out the categories for the remaining 11 options. The key meeting held in July involved a comprehensive range of specialists on acid waters drawn from the Environment Agency, Welsh Office, Forest Enterprise Wales, Forest Authority Wales, Forest Research, CCW, Welsh Water and FRCA (Wales). The process was chaired by the Regional Water Manager (Environment Agency Wales) and the Environment Science Advisor (Welsh Office). The National Centre facilitated the process and served in an observer capacity.

Although sophisticated steps are available to quantify the process, this **was not** applied partly because it was not felt necessary, but also because it is a relatively specialist mathematical technique currently applied by only a few individuals. The problem of Acid waters in Wales and its potential solutions is well understood and there were no severe conflicts or unresolved disagreements arising in either workshop.

'High', 'medium' and 'low' scores were used to complete the matrix. For example, in terms of sensitivity when a small change in the option instigated a large change in the issue this equated to high sensitivity; whilst when a large change in the option elicited little or no change in the issue then this equated to low sensitivity.

In the particular application, it was agreed (in the March 1998 workshop) that timescales needed to be considered when assigning scores of 'high', 'medium' and 'low'. It was therefore agreed to annotate high and medium impacts with an 's' for short-term and an 'l' for long-term. Short-term (s) is taken to be up to 2005 when a third '*All Wales*' survey is to be carried out. Long-term (l) is taken to be up to 50 years plus (e.g. 2050).

The results are shown in Table 2.

Table 2: Comparative Sustainability Appraisal of Strategic Options

Options/ Components	Sensitivity									Potential Risks								Benefit Opportunities																	
	FE	TE	WQ	FO	AG	HT	AM	LP	IN	Environmental									PO	EC	FE	TE	WQ	FO	AG	HT	AM	LP	IN						
										FE	TE	WQ	FO	AG	HT	AM	LP	IN																	
<b>S reduction</b>																																			
A1 SO <sub>2</sub> reduction	● L	● L	●	●	●	●	●	● L	● L	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
All Wales																																			
Selected sites						●																													
<b>N reduction</b>																																			
A2 NO <sub>x</sub> stationary	● L	●	● L	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			
A3 NO <sub>x</sub> mobile	● L	●	● L	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			
A4 Ammonia NH <sub>3</sub>	● L	●	● L	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			
All Wales																																			
Selected sites		●	●																			● NH <sub>3</sub>													
<b>Land use</b>																																			
A5 Restrictions on new forestry	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			
A6 Adopt UK standards for existing forestry	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			



### 2.2.3 Trade-off Analysis

During the July 1998 workshop, consensus was achieved on four decision factors to be used in the trade-off analysis:-

- F1 Maximising the opportunity for public health
- F2 Minimising the adverse environmental risk
- F3 Best value for money
- F4 Benefit of opportunity to the aquatic environment

The *unranked paired-comparison technique* (Dean and Nishry, 1965) was then used to rank each alternative relative to every alternative relative to each decision factor. This was based on the information shown in Table 3. A value of 1 was assigned the most desirable pair of alternatives, and to the least desirable a value of 0. The results are shown in Tables 4 to 7 respectively. The assignment of 0 to a member of a pair does not denote total undesirability, but less relative desirability. A dummy alternative (A12) has been included so as to preclude the net assignment of a value of 0 to any of the alternatives i.e. to avoid skewing the process. If two alternatives were considered equally desirable relative to a decision factor then a value of 0.5 was assigned to each alternative.

After the assignment to each alternative of the relative-desirability value, based on the qualitative information given in Table 2, an alternative choice coefficient (ACC) was determined. The ACC is equal to the sum value for an individual alternative divided by the sum for all the alternatives. The total of the Sum column (in Tables 4 to 7) is equal to  $(M)(M-1)/2$ , where M is equal to the number of alternatives in the assignments (=11). The total of the ACC column is equal to 1.00.

Table 3: Key issues and example criteria

Alternative	Decision Factor F1	Decision Factor F2	Decision Factor F3	Decision Factor F4
A1	High sensitivity	One or more moderate risks	High cost	Considerable benefits
A2	High sensitivity	One or more moderate risks	High cost	Considerable benefits
A3	High sensitivity	Some high risks	High cost	Considerable benefits
A4	Medium sensitivity	One or more moderate risks	High cost	Considerable benefits
A5	Low sensitivity	One or more moderate risks	Moderate cost	Moderate benefits
A6	Low sensitivity	All low risks	Low cost	Minor benefits
A7	Low sensitivity	All low risks	Low cost	Minor benefits
A8	Low sensitivity	One or more moderate risks	Moderate cost	Moderate benefits
A9	Low sensitivity	One or more moderate risks	Moderate cost	Moderate benefits
A10	Low sensitivity	Some high risks	High cost	Considerable benefits
A11	Low sensitivity	Some high risks	Low cost	Considerable benefits

**TABLE 4: RANKING OF ALTERNATIVES RELATIVE TO F1**

ALTERNATIVE	ASSIGNMENT OF DESIRABILITY												SUM	ACC	
	1	2	3	4	5	6	7	8	9	10	11	12			
A1	-	0.5	0.5	1	1	1	1	1	1	1	1	1	1	10	0.15
A2	0.5	-	0.5	1	1	1	1	1	1	1	1	1	1	10	0.15
A3	0.5	0.5	-	1	1	1	1	1	1	1	1	1	1	10	0.15
A4	0	0	0	-	1	1	1	1	1	1	1	1	1	8	0.13
A5	0	0	0	0	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	4	0.06
A6	0	0	0	0	0.5	-	0.5	0.5	0.5	0.5	0.5	0.5	1	4	0.06
A7	0	0	0	0	0.5	0.5	-	0.5	0.5	0.5	0.5	0.5	1	4	0.06
A8	0	0	0	0	0.5	0.5	0.5	-	0.5	0.5	0.5	0.5	1	4	0.06
A9	0	0	0	0	0.5	0.5	0.5	0.5	-	0.5	0.5	0.5	1	4	0.06
A10	0	0	0	0	0.5	0.5	0.5	0.5	0.5	-	0.5	0.5	1	4	0.06
A11	0	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	-	0.5	1	4	0.06
A12 (dummy)	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0.00
<b>TOTAL</b>														<b>66</b>	<b>1.00</b>

**TABLE 7: RANKING OF ALTERNATIVES RELATIVE TO F4**

ALTERNATIVE	ASSIGNMENT OF DESIRABILITY												SUM	ACC
	1	2	3	4	5	6	7	8	9	10	11	12		
A1	-	0.5	0.5	0.5	1	1	1	1	1	0.5	0.5	1	8.5	0.13
A2	0.5	-	0.5	0.5	1	1	1	1	1	0.5	0.5	1	8.5	0.13
A3	0.5	0.5	-	0.5	1	1	1	1	1	0.5	0.5	1	8.5	0.13
A4	0.5	0.5	0.5	-	1	1	1	1	1	0.5	0.5	1	8.5	0.13
A5	0	0	0	0	-	1	1	0.5	0.5	0	0	1	4	0.06
A6	0	0	0	0	0	-	0.5	0	0	0	0	1	1.5	0.02
A7	0	0	0	0	0	0.5	-	0	0	0	0	1	1.5	0.02
A8	0	0	0	0	0.5	1	1	-	0.5	0	0	1	4	0.06
A9	0	0	0	0	0.5	1	1	0.5	-	0	0	1	4	0.06
A10	0.5	0.5	0.5	0.5	1	1	1	1	1	-	0.5	1	8.5	0.13
A11	0.5	0.5	0.5	0.5	1	1	1	1	1	0.5	-	1	8.5	0.13
A12 (dummy)	0	0	0	0	0	0	0	0	0	0	0	-	0	0.00
<b>TOTAL</b>													<b>66</b>	<b>1.00</b>

TABLE 6: RANKING OF ALTERNATIVES RELATIVE TO F3														
ALTERNATIVE	ASSIGNMENT OF DESIRABILITY												SUM	ACC
	1	2	3	4	5	6	7	8	9	10	11	12		
A1	-	0.5	0.5	0.5	0	0	0	0	0	0.5	0	1	3	0.05
A2	0.5	-	0.5	0.5	0	0	0	0	0	0.5	0	1	3	0.05
A3	0.5	0.5	-	0.5	0		0	0	0	0.5	0	1	3	0.05
A4	0.5	0.5	0.5	-	0	0	0	0	0	0.5	0	1	3	0.05
A5	1	1	1	1	-	0	0	0.5	0.5	1	0	1	7	0.10
A6	1	1	1	1	1	-	0.5	1	1	1	0.5	1	10	0.15
A7	1	1	1	1	1	0.5	-	1	1	1	0.5	1	10	0.15
A8	1	1	1	1	0.5	0	0	-	0.5	1	0	1	7	0.10
A9	1	1	1	1	0.5	0	0	0.5	-	1	0	1	7	0.10
A10	0.5	0.5	0.5	0.5	0	0	0	0	0	-	0	1	3	0.05
A11	1	1	1	1	1	0.5	0.5	1	1	1	-	1	10	0.15
A12 (dummy)	0	0	0	0	0	0	0	0	0	0	0	-	0	0.00
<b>TOTAL</b>													<b>66</b>	<b>1.00</b>

**TABLE 5: RANKING OF ALTERNATIVES RELATIVE TO F2**

ALTERNATIVE	ASSIGNMENT OF DESIRABILITY												SUM	ACC
	1	2	3	4	5	6	7	8	9	10	11	12		
A1	-	0.5	1	0.5	0.5	0	0	0.5	0.5	1	1	1	6.5	0.10
A2	0.5	-	1	0.5	0.5	0	0	0.5	0.5	1	1	1	6.5	0.10
A3	0	0	-	0	0	0	0	0	0	0.5	0.5	1	2	0.03
A4	0.5	0.5	1	-	0.5	0	0	0.5	0.5	1	1	1	6.5	0.10
A5	0.5	0.5	1	0.5	-	0	0	0.5	0.5	1	1	1	6.5	0.10
A6	1	1	1	1	1	-	0.5	1	1	1	1	1	10.5	0.15
A7	1	1	1	1	1	0.5	-	1	1	1	1	1	10.5	0.15
A8	0.5	0.5	1	0.5	0.5	0	0	-	0.5	1	1	1	6.5	0.10
A9	0.5	0.5	1	0.5	0.5	0	0	0.5	-	1	1	1	6.5	0.10
A10	0	0	0.5	0	0	0	0	0	0	-	0.5	1	2	0.03
A11	0	0	0.5	0	0	0	0	0	0	0.5	-	1	2	0.03
A12 (dummy)	0	0	0	0	0	0	0	0	0	0	0	-	0	0.00
<b>TOTAL</b>													<b>66</b>	<b>1.00</b>

Following the calculation of ACC's for each decision factor, these were summed to provide a total score for each alternative (Table 8).

**Table 8: Summation of ACC's**

ACC's by Alternative	Decision Factor F1	Decision Factor F2	Decision Factor F3	Decision Factor F4	Total Score
A1	0.15	0.10	0.05	0.13	0.43
A2	0.15	0.10	0.05	0.13	0.43
A3	0.15	0.03	0.05	0.13	0.36
A4	0.13	0.10	0.05	0.13	0.41
A5	0.06	0.10	0.10	0.06	0.32
A6	0.06	0.15	0.15	0.02	0.38
A7	0.06	0.15	0.15	0.02	0.38
A8	0.06	0.10	0.10	0.06	0.32
A9	0.06	0.10	0.10	0.06	0.32
A10	0.06	0.03	0.05	0.12	0.29
A11	0.06	0.03	0.15	0.12	0.36

It is important to ask the question *Are the total scores shown in Table 8 indicative of true differences in the 11 alternatives?* A non parametric statistical test, Friedman's Two-Way Analysis of Variance (Anova) by Ranks Test was applied to the data to obtain an answer:-

- *Step 1* Involved assigning rank-order numbers to each of the alternatives for each decision factor (1 = worst, 11 = best). The numbers are shown in Table 9.
- *Step 2* Summary the rank-order numbers for each alternative (see Table 9).
- *Step 3* Chi-square  $Xr^2$  calculation, where:

$$Xr^2 = \left[ \frac{12}{n(k)(k+1)} \sum_{j=1}^k R_j^2 \right] - 3n(k+1)$$

where  $n$  = number of rows (decision factor)  
 $k$  = number of columns (alternatives)  
 $R_j$  = sum of rank order numbers in  $J$ th column

$$Xr^2 = \left[ \frac{12}{(4)(11)(12)} \sum_{l=1}^{11} \begin{matrix} 29^2 + 29^2 + 24.5^2 + 27^2 \\ + 21.5^2 + 26^2 + 26^2 + 21.5^2 \\ + 21.5^2 + 15.5^2 + 22.5^2 \end{matrix} \right] - (3)(4)(12) = 5.42$$

- *Step 4* The critical value of  $Xr^2$  at the 0.05 significance level is less than the calculated value. Thus the reported value exceeds the calculated level and it can be concluded that the alternatives depicted in Tables 8 and 9 are not significantly different from each other.

Table 9: Ranks assigned to alternatives (based on scores in Table 8)

Rank Order	Decision Factor F1	Decision Factor F2	Decision Factor F3	Decision Factor F4	Sum (overall rank)
A1	10	6.5	3	9.5	29.0
A2	10	6.5	3	9.5	29.0
A3	10	2	3	9.5	24.5
A4	8	6.5	3	9.5	27.0
A5	4	6.5	7	4	21.5
A6	4	10.5	10	1.5	26.0
A7	4	10.5	10	1.5	26.0
A8	4	6.5	7	4	21.5
A9	4	6.5	7	4	21.5
A10	4	2	3	6.5	15.5
A11	4	2	10	6.5	22.5

### 2.3 Results

The Ranks Test shows there to be no statistically significant differences between the alternatives analysed reflecting the types of alternatives chosen for analysis and the decision factors. However, an order of priority does begin to emerge from the analysis.

Table 10, below, depicts the 'top' alternatives for any one of the chosen decision factors.

**Table 10: Desirable alternatives for any one decision factor**

Decision Factor		Most desirable alternatives	
F1	Maximising opportunity for public health	A1	SO <sub>2</sub> reduction
		A2	Reduction of NO <sub>x</sub> stationary
		A3	Reduction of NO <sub>x</sub> mobile
F2	Minimising adverse environmental impact	A6	Adopting UK standards for existing forestry
		A7	Agri-environment
F3	Best value for money	A6	Adopting UK standards for existing forestry
		A7	Agri-environment
		A11	Re-introductions at selected sites
F4	Benefit of opportunity to the aquatic environment	A1	SO <sub>2</sub> reduction
		A2	Reduction of NO <sub>x</sub> stationary
		A3	Reduction of NO <sub>x</sub> mobile
		A4	NH <sub>3</sub> Ammonia reduction

Looking across all decision factors, with the exception of re-introductions at selected sites, all of the desirable alternatives are those which become effective in the long-term (i.e. 50 years +). During the July 1998 workshop, the group eluded to F1 as being the most important decision factor. Table 11 provides an overall ranking of the alternatives.

**Table 11: Overall Ranking of Alternatives**

Overall Sum	Ranking (high = 1)	Alternative		Long Term / Short Term
29	1.5	A1	SO <sub>2</sub> reduction	Lt
29	1.5	A2	NO <sub>x</sub> stationary reduction	Lt
27	3	A4	NH <sub>3</sub> ammonia reduction	Lt
26	4.5	A6	Adopt UK standards for existing forestry	Lt
26	4.5	A7	Agri-environment	Lt
24.5	6.5	A3	NO <sub>x</sub> mobile reduction	Lt
22.5	6.5	A11	Re-introductions	St

Overall Sum	Ranking (high = 1)	Alternative		Long Term / Short Term
21.5	9	A5	Restrictions on new forestry	Lt
21.5	9	A8	Direct dosing	St
21.5	9	A9	Source-area	St
15.5	11	A10	Agricultural/catchment	Lt

An option which can be confidently rejected is A10, the liming of agricultural land/catchments.

All 11 options evaluated by the process are probably far more preferable than the two options initially rejected at the July 1998 workshop i.e. *genetically modified fish* and *bio-manipulation*. The latter were considered as highly contentious.

## 2.4 Limitations and Assumptions

Whilst the author has confidence in the particular method selected, ideally at such an early stage of development of sustainability appraisal tools a range of techniques should be applied to the same problem to provide sensitivity testing. This would be an extremely time consuming and complex process.

The method which has been applied is based on a number of limitations and assumptions. One of the significant problems of sustainability appraisal at a strategic level is the general lack of information and substantial uncertainty involved.

### 2.4.1 Sensitivity testing

Weighting could be undertaken for the four decision factors included in the analysis. For example, the consensus might be that F1 (public health) and F4 (best value for money) are the most important decision factors. However, using the unranked paired-comparison technique for the four existing decision factors would not lead to a different ranking of the alternatives.

Sensitivity testing using water quality rather than fish and aquatic ecology as indicative of 'benefit of opportunity to the aquatic environment' would lead to the same result (i.e. the same scores) in all cases except 're-introductions at selected sites'. Re-introductions would obviously not directly benefit water quality and in this instance would be ranked lower.

Different results would also be obtained by modifying the classification in Table 3 for decision factor F2 (minimising environmental risk). For example, if it was deemed that one moderate risk was acceptable (i.e. thereby placing this in the lowest 'risk' category then this would improve the overall ranking for SO<sub>2</sub>, NO<sub>x</sub> stationary and NH<sub>3</sub> ammonia reduction). They would all have a higher overall sum in Table 10.

Looking at the 'All Wales' and 'Selected sites' categories (Table 2) in terms of human health, there are likely to be locally high benefit opportunities due to the sensitivity of this issue to SO<sub>2</sub> reduction. In terms of environmental risks, there are likely to be locally high impacts on the terrestrial ecology as a consequence of changes in land use practices. This was not taken into account in the analysis but would tend to suggest that these options are less desirable than indicated in Table 10, for example.

Finally in Section 2.1 the difficulties of applying weighting to the decision factors in a complex issue such as Acid waters in Wales, involving many stakeholders, was eluded to. Weighting could be agreed by the technical specialist group but may then have to be agreed by consensus with outside groups and organisations. This might prove very difficult and controversial. However, it is worth noting that for the purposes of sensitivity testing, what orders of weighting would be required to bring some of the other alternatives to the top of the list. For example, to make A5 (restrictions on new forestry), A8 (direct dosing), and A9 (source-area liming) more preferable, might require extremely large weights, applying to decision factor F2 (minimising environmental risk) and even then these allocations would all fall behind A6 (adopting UK standards for existing forestry) and A7 (agri-environment). Equally, applying a high weight to decision factors (F1) (say 90 on a scale of 1 to 100) would maintain SO<sub>2</sub>, NO<sub>x</sub> (stationary) and NO<sub>x</sub> (mobile) as the top alternatives and would probably result in statistically significant differences from the 11 options.

### 3. WAY FORWARD

#### 3.1 Iteration of the preliminary options appraisal

Choosing different decision factors, or combinations of decision factors, may lead to different outcomes i.e. clearer 'front runners' in terms of preferred options. However, this should only be undertaken if it is genuinely felt that these are better decision factors.

Paired-comparison techniques can also be used for importance weighting of the decision factors. However, choice of different decision factors and the decision to assign weights should only be done through consensus of the technical specialist group. Iterations of the process may be required. For example, between the March 1998 and July 1998 workshops, the assignment of the score for political risks of SO<sub>2</sub> reduction were re-evaluated. A final score of 'high' was adopted in July 1998 because it was felt that taking into consideration the Department of Environment, Transport and Regions *Energy Sources Document* (published early summer), the implications for Welsh coal/power generation could be high.

It may also be worth revisiting some of the basic assumptions made in the preliminary appraisal. For example, was it correct to reject biomanipulation outright? There is considerable experience from the Norfolk Broads which shows the benefit of some types of biomanipulation. Also A11 (reintroductions at selected sites) could be a much more expensive option than already envisaged if this was necessary at many sites rather than selected sites.

#### 3.2 More prescriptive work

It is anticipated that the final results will feed into a draft document to be produced by December 1998 following further political/economic screening. More detailed work could involve some input from specialists from within the Centre, including the Social Issues Officer. There will then be consultation with key stakeholders early in 1999 and it is recommended that the learning lessons from the Environment Agency (1998b) approach to *Consensus building for sustainable development* may be useful in this process. A final report is likely to be produced by the summer of 1999 as an influencing document for the Welsh Assembly. A detailed options appraisal may subsequently accompany the full Strategy.

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**ANNEX A:**

**WELSH ACID WATERS STRATEGY WORKSHOP**

**Monday 23rd March 1998 Rivers House, St Mellons, Cardiff 14.00 -17.00hrs**

**Attendees:**

Dr Havard Prosser	Environment Science Advisor, WO (HP)
Trefor Owen	Forest and Environment Manager, Forest Enterprise Wales (TO)
Huw Davies	Operations Manager, Forestry Authority Wales (HD)
Dr Tom Nisbet	Hydrologist, Forest Research (TN)
Simon Bareham	Pollution Impacts Advisor, Countryside Council for Wales (SB)
Dr Alun Gee	Regional Water Manager, EA Wales (AG)
Wendy Merrett	Environment Scientist, EA Wales (WM)
Dr Dafydd Evans	Regional Fisheries Officer, EA Wales (DE)
Dr Andrew Brookes	Options Appraisal Manager, EA National Centre for Risk Analysis and Options Appraisal (AB)
Adam Mactavish	Secondee from WS Atkins to National Centre (AM)

**Apologies:**

Alan Broughall      Upper Severn Area, EA Midland Region

**1. INTRODUCTION - AG**

A brief résumé of the history of the acid waters problem in Wales was given, summing up with the conclusions drawn for the Welsh Acid Waters Survey conference in November 1997. This identified the objective of a need to 'commission a risk based assessment of future options for policy makers'. This assessment needs to consider the following:

Implications of Deposition Reduction:

Sulphur and Nitrogen

Regional response:

Where will recovery be earliest/fastest

Processes /modelling:

Identify gaps where more research/modelling is required

Land Use:

Consider the full range management practices and future developments

Biology:

Ability of watercourses to be repopulated.

Risks/Weighting factors:

Uncertainty; costs; logistics; political constraints.

## **2. INTRODUCTION TO RISK ASSESSMENT (AB)**

Copies of overheads circulated. This was followed by a discussion which included the following:

Timescales needed - AB suggested that on average 2 days would be required to complete a spreadsheet of this complexity.

It was noted that it was important that all 'experts' were involved so that the consensus would be accepted outside of the group.

SB -suggested that implementation of the strategy would require broader involvement.

HP - raised the use of technical experts to enable the input on which decisions are based to be validated before decisions are made. Therefore a technical panel may be required to support the present group which represents the major decision makers/stakeholders on this issue.

AB - stated that the optimum number for the group is 8 - 15.

DE - suggested that the present group should initially go through the matrix, and identify the gaps for the experts to provide information on. However this would be risky in that the group may feel it is in a position to make a decision, as it may not be aware of the existence of further information which may be of use.

AG - suggested that we may be able to scope the process initially, and then widen once we feel that this is an appropriate method to use.

Once the strategy has operational implications, it would have to be consulted on by a wider audience, such as EA committees. It was agreed that this should be done collectively by the respective organisations, to avoid divergence from the strategy and loss of consensus. Therefore a targeted consultation is required, but options are needed for consultation

AB - Raised the point that there was not a 'Do Nothing' Option. SB suggested that this was because we all agreed that this was not an option - we had to be seen to be doing something. Reduction in Sulphur was considered to be the 'baseline' option, as this was being done already.

AM - Raised the point that in order to assess the options and their success we need to have clear targets, or at least a range of targets which could then be formalised once it was known what was achievable.

### 3. MATRIX COMPLETION

It was agreed that a trial run at filling in part of the matrix would be useful.

The matrix has five groups of options:

1. Sulphur Reduction
2. Nitrogen Reduction
3. Land Use
4. Liming
5. Bioremediation

The group of liming options (4) had been put together as the most contentious options.

Group 5 - Bioremediation, was pointed out as being a way of achieving the end result rather than ameliorating acidification

The split between All Wales and Selected Sites was agreed to be useful as it was a way of building consensus for options which may be appropriate on a limited scale rather than all Wales. In most cases options would be applicable to either/or All Wales/Selected Sites.

'Sensitivity' was defined as follows:

When a small change in the 'Option' instigates a large change in the 'Category' this equals high sensitivity, while when a large change in the 'Option' elicits little or no change in the 'Category' this equals low sensitivity.

'Risks' included where adverse effects may be due to over reaction of the 'Category' to the change.

'Benefits' take into account the overall impact of sensitivity and risks as well as the favourable impacts.

SB - commented on the fact that timescales were needed to be considered when making the assessment of high/medium/low impact. It was therefore agreed to annotate high/medium impacts with a 's' for short term and a 'l' for long-term. Where discussion was needed to achieve a consensus with the scoring, additional notes were made to explain the decision.

Better defined timescales would be expected to be identified as part of the detailed options appraisal, for example - 2005, 2025, 2050 etc. In the short term, the target of 2005, when a third All Wales survey could be carried out, was identified as a point at which it was felt that some improvements were required. Therefore short-term targets needed to be realisable and realistic. Longer term targets could be identified through the strategy.

**Notes:**

*A Direct Dosing*

**4.1 Sensitivity - Communities**

Considered to be medium due to effects on drinking water and anglers.

**4.2 Sensitivity - Landscape**

Medium - depending on site.

**4.3 Environmental Risks - Fish & Aquatic Ecology**

Medium due to risks of under/over dosing.

**4.4 Environmental Risks - Industry**

Depends on scale of operation - currently the lime used is a byproduct, but sustainability and transport issues should be considered.

**4.5 Political Risks**

Medium due to unsustainability and 'interfering with nature'.

**4.6 Economic Risks**

Depends on scale - medium compared to source area/agricultural liming.

**4.7 Benefits - Fish & aquatic ecology/water quality**

Limited by target area required - not suitable for most 1st/2nd order streams, effective lower down catchments.

*B Source Area Liming*

**4.8 Sensitivity - Fish/Aquatic ecology**

Assuming dosage is correct.

**4.9 Sensitivity - Terrestrial ecosystems**

Even if dosage is correct, this will depend on the conservation value of the respective source area and the dose of lime required. However in terms of the whole terrestrial ecosystem of the catchment only a low proportion is dosed, and only parts of the system are highly sensitive, therefore medium score. (NB: Ref - Steve Ormerod's work on source areas).

**4.10 Sensitivity - Communities**

Scored for conservationists etc.

**4.11 Sensitivity - Landscape**

Medium taking into account effects of quarrying/transport etc.

4.12 **Political Risks**

Group (inc CCW) consider medium, but could be high due to sensitive conservationists.

4.13 **Benefits - Fish & Aquatic Ecology**

If assumed to be working properly.

4.14 **Benefits - Terrestrial Ecology**

Negative.

4. **REVIEW - WHAT NEXT?**

It was agreed that HP should approach colleagues in WOAD and/or ADAS, Industry and Public Health departments of WO to provide expertise in Land use and other issues.

*HP to identify contacts, and their availability (see below)*

It was agreed that the group should reconvene to complete the matrix, via an overnight stay followed by a full day meeting end of April/May. A 'premeeting' will be held 16.00hrs-18.00hrs? before dinner, followed by a full days meeting the next day. Suggested venue - Pencerrig Hotel, nr Builth Wells.

*ALL to inform WM (or Sue Alwan) of availability for the following dates asap*

May - 7th pm - 8th  
14th pm - 15th  
18th pm - 19th

June - 3rd pm - 4th  
or 4th pm - 5th

WJM 25.3.98

**ANNEX B:**

**WALES ACID WATERS STRATEGY MEETING**

**9-10th July 1998 Aberystwyth (Draft)**

**Attendees:**

Dr Havard Prosser	Environment Science Advisor, Welsh Office (HP)
Trefor Owen	Forest and Environment Manager, Forest Enterprise Wales (TO)
Huw Davies	Operations Manager, Forestry Authority Wales (HD)
Dr Tom Nisbet	Hydrologist, Forest Research (TN)
Simon Bareham	Pollution Impacts Advisor, Countryside Council for Wales (SB)
Dr Norman Lowe	Chief Scientist, Dwr Cymru Welsh Water (NL)
Katie Metcalfe	FRCA Wales (KM)
Ronnie Alexander	Chief Environmental Health Advisor, WO (RA)
Dr Alun Gee	Water Manager, EA Wales (AG)
Wendy Merrett	Environment Scientist, EA Wales (WM)
Chris Bower	Inspector, EA Wales
Dr Dafydd Evans	Fisheries Officer, EA Wales (DE)
Dr Andrew Brookes	Options Appraisal Manager, EA National Centre for Risk Analysis and Options Appraisal (AnB)
Alan Broughall	Upper Severn Area, EA Midland Region(AIB)

**1. INTRODUCTION**

AG - Covered the history of the acidification problems in Wales and the background to the strategy (see previous papers etc.).

Discussion covered where the Strategy should be taken and it was agreed that the first stage would be to produce an influencing document for presentation to the Welsh Assembly when functioning, before work commenced on detailed options appraisal for the full strategy.

NL raised the point that huge investment has already been made to bring about environmental improvements, for example by DCWW, and such figures should be used to put any future expenditure in context.

SB also highlighted the importance of protecting and improving quality in upland areas, due to their conservation importance as SSSI's, ESA's and SAC's etc.

RA stated that there is currently a WO Green Consultation paper on Public Health issues in Wales - and that some aspects of the strategy may be relevant to this - and an opportunity to respond in this light to the paper should be taken.

HP suggested that as drivers for the strategy - health issues are likely to be stronger than environmental issues. Also air quality would also be important - both the effects of point and diffuse sources.

NL - suggested that other interest should also be flagged up - eg Dippers to attract the interest of specialist groups.

**2. RECAP OF ASSESSMENTS CARRIED OUT ON 23/3/98**  
(see minutes for earlier notes)

A discussion followed on the interpretation of 'community'. It was agreed that there were actually two areas of interest here - Public health and Amenity/leisure (including angling, tourist industry, naturalist interests). For both of these categories there could be actual and perceived impacts. It was agreed that the 'Community' column would be divided into 'Health' and 'Amenity', and accompanying notes would discriminate between actual and perceived risks where appropriate.

**OPTION 1 - SULPHUR DIOXIDE REDUCTION**

**a) Second Sulphur Protocol (revised to Sulphur Dioxide Reduction)**

The following amendments were made:

**Sensitivity - Community**

Column was split into **Health** - High, especially at selected sites/ locally, and also as both a 'real' and 'perceived' effect on health; **Amenity** - medium

**Environmental Risks** - of S reduction - to **Health** - low; **Amenity** - low.

**Benefits** - **Health** - high; **Amenity** - medium

**Political risks**

This was debated on two occasions during the meeting. Initially (from 23/3) the rating was high - but it was reassessed to medium on 9/7 to take into account the fact that the 2nd S protocol was agreed and therefore this option was not politically risky in international terms. However it was noted that from a Welsh point of view, taking into consideration the DETR Energy Sources document, the implications for Welsh coal/power generation could be high. In the final review of 10/7 the 'Welsh' factor was considered to be more important, and the political and economic risks were re-evaluated to high. Site specific sensitivities and benefits will depend upon the level of exceedence of critical loads - marginal sites will benefit sooner.

TO - made the point that the interests of industry and the community were not fully represented by the group membership - and it was agreed that a consultation paper would be produced to gather the views of these groups at the appropriate time.

Amendments were also made on 10/7 to the sensitivities and benefits of sulphur reduction when considered in the **long term**.

**Sensitivity - Fish and Aquatic Ecology** - High in the long-term

**Sensitivity - Water quality** - High - (both short and long-term)

**Benefits - Fish and Aquatic Ecology** - High in the long-term

**Benefits - Water quality** - High - (both short and long-term)

Whether to consider 'Sulphur reduction' or the 'Second sulphur protocol' was also rediscussed. Second sulphur protocol has a target of 80% reduction by 2010, but greater reductions of 90% by 2005 have also been consulted upon. It was considered that the evaluation system was not sensitive enough to score these targets differently. Therefore it was agreed to retitle this option as Sulphur reduction rather than Second Sulphur Protocol, and that the text of the strategy document should expand on this issue.

#### **OPTION 4 - LIMING**

##### **a) Direct Dosing**

This method was assumed to be using the latest technology, computer controlled etc. It could be that dosing could have implications for water supply treatment - this was considered under health.

##### **Sensitivity - Health**

For all Wales, limited occurrence, - low; selected sites could be high as private water supplies could be sensitive, and also could assist treatment of public water supplies.

**Sensitivity - Amenity** - medium due to improvements in angling etc.

NB - Effects of lime supply - as the lime is a byproduct and not quarried specially, and the amounts used are small when compared with other uses, sensitivity to industry is low.

**Risks - Aquatic Ecology/fish** - medium due to overdosing/dosing failure

**Risks - Landscape** - amended to medium from low, but mostly site specific

**Risks - Health** - low

**Risks - Amenity** - medium - (risk of fish kill)

##### **Political risks**

Unsustainable and 'not natural' but 'better than doing nothing' - medium.

##### **Economic risks**

Not as costly as eg S reduction - medium

**Benefits - Water quality** - high (negative effects negligible)

**Benefits - Health** - low

**Benefits - Amenity** - medium.

**b) Source Area Liming**

i.e. Liming a relatively small part of the catchment - targeting the stream sources ('boggy bits').

**Sensitivity - Terrestrial** - medium, but high at selected sites

**Sensitivity - Health** - low

**Sensitivity - Amenity** - medium (as includes interest groups, conservationists etc)

**Risks - Health** - low

**Risks - Amenity** - medium

**Risks - Landscape** - medium - (increased from low)

**Economic Risks** -

Medium - if comparing with eg sulphur reduction. The 'economic damage' will depend on the scale of the operation.

NB Costs of source area liming are greater than direct dosing - but if only at a few sites then low.

**Benefits - Health** - low

**Benefits - Amenity** - medium

**Benefits - landscape** - revised to low

**NEW ASSESSMENTS**

NB - Notes are given where discussion took place on impact ratings. Where assessment was clear cut - refer to matrix for score.

**OPTION 2 NITROGEN REDUCTION**

**a) Stationary NOx (Power Stations)**

**Sensitivity - Fish/Aquatic ecology** -high, but location sensitive, in the long term

**Sensitivity - Terrestrial Ecology** - Medium .

The exact mechanisms within the soil are not clear, especially the effect of increased N deposition has had in soils which previously where nutrient poor. N deposition could contribute 25-30kg N/ha/year. Therefore this may have lead to changes in nutrient cycling and biodiversity.

**Sensitivity - Water quality** - high in the long term

As influenced by terrestrial system. Likely to get N 'breakout' from N saturated soils at some sites.

**Sensitivity - Agriculture** - low (compared to other sources of N)

**Sensitivity - Health** - High

Although stationary NOx considered to be less significant than mobile in real terms, public perception is high for both. Effects of NOx and Ozone are the same for stationary and mobile NOx.

**Sensitivity - Industry** - High

Would effect mainly the energy producers. Technology is less well developed than for S reduction, and gas turbine stations also produce NOx.

**Environmental Risks** -as for S reduction ie all low, except industry medium

**Political Risks** - medium - more support due to human health aspects

**Benefits - Forestry & Agriculture** - low

Depends on the balance between acidifying effects and the benefits of N as a fertilizer.

**Benefits - Industry** - low as no benefits to swapping fuels in contrast to S reduction.

b) **NOx - mobile**

NB Most assessments as for NOx stationary

**Sensitivity - Agriculture** - low

Assuming exemption for any limitations on transport in rural areas etc

**Sensitivity - Amenity** -high, due to transport implications

**Sensitivity - Industry** - high - transport, fuel industry, catalytic converter manufacturers etc.

**Risks - Health** - Small reductions in NO may give rise to higher ozone in urban areas

**Risks - Amenity** - medium, assuming majority of restrictions would be 'in city'

**Risks - Industry** - medium - due to transport

**Benefits - Amenity** - low (possibly negative due to public perception)

*(Friday July 10th - (A Broughall, H Davies not present))*

c) **NH<sub>3</sub> - Ammonia**

Originally this was intended to be from agricultural sources, although 87% is agricultural, 13% sewage. So both sources are considered in the assessments - but as aerial deposition/diffuse sources. (i.e. Not direct discharges to water from Sewage Treatment works etc.). There may also be significant inputs from catalytic converters - but the scale of these is not yet known so not considered for now.

It is assumed that there will be ways of reducing NH<sub>3</sub>, although methodology or amounts cannot be defined.

**Sensitivity - Fish/Aquatic ecosystems** - high, in the long term, especially locally

**Sensitivity - Terrestrial** - medium - can be very significant locally

**Sensitivity - Water Quality** - high, in the long term, especially locally

**Sensitivity - Forestry** - low, though could be significant locally.

NB It may be possible to do more to reduce 'local' NH<sub>3</sub> in Wales, and tackle this in the short term at selected sites.

**Sensitivity - Agriculture** - High from the industry point of view.

**Sensitivity - Amenity** - medium, locally high eg Anglesey

**Sensitivity - Industry** - low (excluding agriculture and point sources e.g. Sewage Treatment Works)

**Risks - Agriculture** - Medium, but available evidence may not be applicable to Wales (e.g. intensive farming in Europe). Also queries as to how effective reductions can be.

**Risks - Industry** - low (Excluding agriculture)

**Political risk** - high - due to agriculture

**Economic risk** - high - due to agriculture

**Benefits - Fish/Aquatic ecology** - high in the long term

**Benefits - Terrestrial** - medium, but may be high at specific sites

**Benefits - Water Quality** - high in the long term

**Benefits - Agriculture** - low, may be negative

**Benefits - Health** - medium

But don't know enough about the effects of ammonia on secondary particles. - important re air quality in Wales.

**Benefits - Amenity** - medium

## LIMING

### c) Agricultural Liming

As part of long term agricultural improvement - applied at agricultural rates as per liming subsidies.

**Sensitivity - Fish/aquatic ecology** - medium,

Assumed to be in the long term if application rates correct and over a large enough area, but not targeted /controlled as direct dosing, and needs repeating every 10 years. Even though soil pH may fall over time, water quality remains protected and aluminium is not leached from the soils.

**Sensitivity - Terrestrial systems** - high, immediately

**Sensitivity- Water Quality**-medium in the long term (as for fish)

**Sensitivity - Forestry** - low

As not actually proposing to lime forested areas. -(NB Effects on trees - decreases growth increases nitrate leaching)

**Sensitivity - Agriculture** - high -

Restricting activity to improved/reverting grassland, not semi natural

**Sensitivity - Amenity** - medium - more fish, (but possibly less heath)

**Sensitivity - Industry** - medium (will use more lime than direct dosing or source area liming)

**Risks - Fish/aquatic ecology** - low - as lower chance of overdosing/acute changes

**Risks - Water quality** - low, but may effect non-target streams

**Risks - Forestry** - low (Some risk of damage, but unlikely if not liming directly)

**Risks - Landscape** - high - considering all Wales (and beyond re quarrying)

**Political risks** - high in conservation terms

**Benefits - Fish/Aquatic Ecology** - (low to) medium depending on scale

**Benefits - Terrestrial** - low (negative)

But putting into a historical perspective - much of the land improved in 50s-70s is now reverting, and liming may be used to maintain biodiversity in these areas, where flora and faunal communities have developed in a response to liming. However this must be balanced against reducing biodiversity in semi-natural areas which have not been previously limed.

**Benefits - Agriculture** - high, -

But for full benefit N fertilisers have to be added. NO effects would be buffered by the lime, but increased stocking densities could lead to increased ammonia releases. (If N fertilizers not added, then benefit would be medium)

**Benefits - Amenity** - low (med to fish v medium risk)

**Benefits - Industry** - medium, for quarrying/transport sectors

NB this could be suitable for local effects in Wales - and can be influenced. Compared to NOx/S reductions driven externally to Wales and NH<sub>3</sub> influenced by IPPC control of intensive livestock units.

### **OPTION 3 LAND USE**

New Forestry- ie forestry where no trees currently - As the current forestry policy is to expand planting - the option was defined as the 'Implications of Restricting New Planting'.

Existing Forestry - 'do nothing' - ie manage and replant according to the current UK Forestry Standards as are applied at the moment.

#### **a) Restricting New Forestry**

Applied to new planting on sensitive sites, including farm woodland.

**Sensitivity - Fish /Aquatic Ecology** - low (all Wales)

Selected sites - high - i.e. where critical loads are exceeded. However, with emission reductions, areas with exceedence will be decreasing. But - new forestry is likely to be associated with areas of existing forestry - so it may just be enough to take levels over the critical point.

**Sensitivity - Terrestrial** - high as significant change in land use

**Sensitivity - Water Quality** - Low (All Wales), selected sites - high . NB what about water quantity issues

**Sensitivity - Agriculture** - medium

Generally, as restricting farmers choices, may be high at specific sites

**Sensitivity - Industry** - low (excluding forestry and associated industries)

**Risks - Fish/Aquatic ecology** - Medium for Wales (if got wrong/guidance not followed ) high at selected sites

**Risks - Terrestrial** - Medium for Wales , high at selected sites

**Risks - Water Quality**- Medium for Wales , high at selected sites

**Risks - Agriculture** - medium - based on ease of returning to agricultural use.

**Economic Risks** - medium, for forestry industry

**Benefits** - low generally, high at specific sites which are protected from acidification by not planting

**Benefits - Terrestrial** - low, as not 'improving' land of low value

**Benefits - Water Quality** - low generally, high at specific sites

**Benefits - Forestry** - negative, as restricting industry

#### **b) Existing Forestry**

Use of UK Forestry Standard for sustainable forest management - restructuring, increasing biodiversity, open space, access etc. - important that audit process in place.

**Sensitivity - Fish/Aquatic ecology** - medium long term , high at selected sites

**Sensitivity - Terrestrial** - medium , increasing biodiversity

**Sensitivity - Water Quality** - medium long term , high at selected sites

**Sensitivity - Amenity** - high - improved access and biodiversity

**Risks** - all low

**Benefits** - Forestry high - sustainable

#### **c) Agri-environment Schemes**

Includes all existing schemes - Habitats etc, and AWAES: (NB Antagonistic to agricultural liming).

As applied to acidified areas:

**Sensitivity - Fish / aquatic ecology** - low, but useful where acidification overcome already - improved habitats etc.

**Sensitivity - Terrestrial** - medium - 'more environmentally friendly'

**Sensitivity - Water Quality** - low - for acidification, (but other WQ benefits would occur)

**Sensitivity - Forestry** - low, though limited scope for woodland expansion

**Risks** - all low

**Political risk** - low - as following EC directive

**Economic risks** - low - EC funded

**Benefits** - as for sensitivities

## **OPTION 5 BIOINTERVENTION**

NB Only applicable at selected sites, and for short - medium term intervention.

### **a) Re-introductions**

Targeted to sites where water quality recovered enough to sustain populations. Fish, invertebrate, plants - all could be transferred from adjacent/equivalent watercourses to promote biorecovery.

**Sensitivity - Fish /Aquatic Ecology** - high, short term

**Sensitivity - terrestrial** - medium - (e.g. Dippers, emergent vegetation)

**Sensitivity -Amenity** - medium - angling/wildlife etc.

**Risks - Fish/Aquatic ecology** - high - Don't know enough, may introduce 'aliens', disease etc.

**Risks - Terrestrial** - medium - alien plants (Japanese knotweed)

**Political Risks** - medium - interfering with nature

**Economic Risks** - low - relatively low cost

**Benefits** - see matrix

### **b) Biomanipulation**

This would involve additions of for example phosphate, but risks considered to be too high to warrant further consideration.

### **c) Fish Genetic manipulation**

Again risks considered to be too high to warrant further consideration.

## **DISCUSSION**

The matrix was briefly 'quality assured' by looking at the evaluations for all the options for each category. The changes that were made are incorporated within the preceding notes.

### **A Brookes - view of Assessment**

Considered to be fairly simplistic, as was necessitated by the time frame. Now that the information is gathered, it is possible to attempt ranking the options - either within the meeting, or outside of the meeting once given basic ranking criteria. Raised the difficulty of comparing apples with pears (and the odd banana thrown in!).

Need to identify the key policies driving the decisions - 'no risk', sustainability, 'low cost', etc to enable trade offs between the options.

Present qualitatively - though it may be possible to determine the rankings using numeric scoring - eg score options on scale of 1 - 11 - but this would not be presented in the final document.

Also need to assess relative importance - e.g. if risks low except one - do 8 'low risks' nullify one high?

Could this be agreed by correspondence?

### **Initial ideas:**

Benefit to Aquatic Environment (linked to Water quality).

Minimise environmental risks across all categories.

Maximise benefits to public health.

Costs : value for money/cost effectiveness.

These could all be linked into the principles of sustainable development (Social, Environment, Economics). Long and short term implications - need to divide for all criteria to give two separate strategies - so that ultimately the long term will take over from the short term, but initial improvements can be accelerated 'artificially'.

Cost benefits of extending short term (10 years) to more long term (50+years) - model in some way to find the point of equality.

## **WAY FORWARD**

Colour spread sheet plus notes to Andrew Brookes asap.... **Action WM**

A Brookes, plus Social Affairs Officer, (plus WM/AG/HP) to carry out provisional options assessment using criteria above, initially screening on technical grounds (followed by political/economic).

Circulate to team members - and decide whether a further meeting is required to consolidate, agree the next stage and to identify information gaps, which if necessary can be fed into R&D programmes for next year.

## **TIMETABLE**

Phase one - Options Appraisal - complete by beginning of September.

This will feed into draft strategy document to be produced Sept - Dec.

Consultation with key stakeholders early in 1999. Following this an outline paper for the strategy can be produced, including appropriate case studies, as an influencing document for the Welsh Assembly by summer 1999.

WJM 20.7.98