invested heavily in wastewater treatment to the highest standards over the past thirty years - and continues to do so - and the benefits of this investment programme are confirmed by the low indices of environmental damage shown for all three basic situations. The UK, by contrast, has neglected wastewater treatment and the environmental consequences of this neglect are demonstrated by the correspondingly high "scores" awarded to British wastewater discharges and sludge disposal practices. Secondly the "All-P" option is the least damaging in environmental terms in both countries: in other words, the model shows that the best environmental option with regard to the disposal phase is to base all detergents on phosphates.

1.10 These conclusions are borne out by the Finnish, Norwegian and Danish models, whose overall results are summarised below in Table 1.2, alongside those of Sweden and the UK.

Table 1.2 Index of environmental damage for five countries

	As-is	All-P	P-free
Sweden	78	55	80
Norway	87	59	87
Finland	117	82	113
Denmark	327	183	570
UK	536	164	848

The benefits of advanced wastewater treatment are amply confirmed, as are the environmental advantages of phosphates as detergent builders: the "V-shaped" pattern, giving markedly lower values for the "All-P" situation, is repeated for all five countries, irrespective of national circumstances. The advantages of the "All-P" situation are clear in all five countries modelled, although there is, perhaps, some irony in the fact that Norway would achieve its highest environmental standards (with an index of 59 in the "All-P" column) if it were to reverse its ban on detergent phosphates and adopt a phosphates-only policy. The real key to minimising environmental damage, however, is to treat wastewaters to high standards. No matter which detergent builder system is used in the four Nordic countries, the environmental damage caused by wastewaters and sludges is significantly lower than in the UK.

1.11 The robustness of these results was tested by a series of rigorous sensitivity analyses, focussed on Sweden, in which the input values (such as detergent use, water hardness, and other basic parameters) were varied and the resulting effects in all three basic situations calculated. In every case, without exception, the "V-shaped" pattern was reproduced, with the "All-P" index registering the lowest overall environmental impact. This also held true when the concentration rates of builders in receiving waters were varied, and when a range of dilution rates was introduced. Finally, the three basic situations were calculated for each individual "judge", to determine whether the process of forging a consensus among the participating scientists had concealed or distorted an important body of opinion. This exercise showed, however, that the overwhelming majority of scientists taking part in the study (14 out of 17) agreed with the modelled results when their individual responses were analysed. We concluded, therefore, that the model results were robust and accurately reflected the consensus of opinion among the panel of water and water treatment experts. The sensitivity analyses can be found in Part 2, Tables 2.5.6 and 2.5.7.

1.12 One less than welcome result of the sensitivity analysis was to show that, under Swedish conditions, the preferred method among the scientific panel for disposing of sludge is to dump it in a landfill site. Recycling to agriculture is the second choice, closely followed by incineration, whereas sea-dumping is frowned upon and heavily penalised. The results of the sensitivity analysis for sludge disposal are shown below in Table 1.3, with the model being run on the assumption that each disposal route accounts for all the sludge produced.

Table 1.3 Sludge disposal methods in Sweden

	As-is	All-P	P-free
Landfill	70	51	63
Agriculture	86	59	99
Incineration	88	62	95
Sea	1082	233	1097

The results are unwelcome in the sense that they appear to conflict with the argument for sustainability (developed in Part 3 of this report) which holds that recycling sludge to agriculture represents the most environmentally-friendly method of disposal, by returning to the soil the valuable humus, nutrients (nitrogen and phosphorus) and trace elements in the sludge, and so completing the cycle of use and re-use. In the "All-P" column of Table 1.3, the differences between the first three disposal routes are not great, and a different result might be obtained if heavy metals were included in the calculations (they were not for this model). Sweden has succeeded in reducing the metals content in its sludges to very low levels and when this is taken into account, it may be that sludge recycling to agriculture would emerge as the preferred disposal option among the panel of scientists. There were, too, some curious results from the panel on this issue of sludge disposal, which we are unable to explain, and it would be useful to revisit this subject at a future date. For the present, however, we record the fact that landfill appears to be the favoured sludge disposal route among the scientists taking part in this study, and we discuss this issue at greater length in Part 3.

1.13 Part 3 - the final part of the report - is in eight sections, in which we discuss the significance of the Delphi study and its implications for the sustainable management of water resources in Europe. The need for higher standards of wastewater treatment and a comprehensive policy of water conservation in most European countries is not in doubt. It is the merit of the model produced here that it begins, for the first time, to quantify the environmental benefits of advanced wastewater treatment and so underlines its importance in a programme of water conservation. The European Commission has initiated moves to protect freshwaters from all forms of pollution, with two proposed framework directives on the ecological quality of surface waters and on integrated pollution control. But there are stronger forces driving Europe towards the sustainable management of water resources, as a result of widespread water shortages caused by rising demand and, in some cases, by changing weather patterns. We commend Sweden and the other Nordic countries as role models for the rest of Europe in the field of wastewater treatment and also recommend that a strategy of Clean Production be adopted by water supply companies in all European countries, to ensure that substances which are difficult to treat, such as heavy metals and organic micropollutants (pesticides, solvents etc), do not enter the wastewater stream as ingredients in domestic products or in the effluents from industrial or agricultural processes.

1.14 In the case of detergent builders, however, we consider that the evidence of this study, combined with the experimental results of microcosm studies carried out by three European universities and the long-term observations of Lake Zürich, Zürichobersee and Lake Walenstadt by scientists from the Zürich Water Supply Authority (described in sections 3.6 and 3.7), are sufficient to persuade all European countries to reconsider their attitudes to detergent phosphates.

1.15 We make a number of formal recommendations in the final paragraph of the report, as follows:

- a review of the bans and restrictions on the use of detergent phosphates
- the reformulation of detergents to exclude other polluting ingredients
- the adoption of Clean Production programmes by water supply companies in Europe to eliminate "hard" or recalcitrant pollutants from the wastewater stream
- advanced wastewater treatment as part of a sustainable strategy for managing freshwater resources in Europe and ensuring future supplies
- application of the principle of sustainability to sludge disposal, to ensure the beneficial recycling to agriculture of sludges with low metals content
- the adoption of Sweden as a role model for other European countries in the treatment of wastewaters to high standards and the production of sludges with low metals content for recycling to agriculture.

Executive Summary

1. The Swedish Phosphate Report completes the analysis of detergent builders which began with "The Phosphate Report", published in 1994. It assesses the fate in the environment of phosphates and zeolites-PCA after use, within the context of advanced wastewater treatment as widely practiced by Sweden and the other Nordic countries.

2. Seventeen senior scientists with expertise in wastewater treatment and sludge disposal from eight European countries took part in the Delphi study to evaluate the impact of the two builder systems upon a range of receiving waters and in four disposal situations for sludge. Response curves for each scenario were constructed on the basis of the scientific consensus which emerged from the Delphi consultation process. These were used to model each of the four Nordic countries and the UK.

3. The study finds that advanced wastewater treatment is highly effective in preventing pollution, as measured by the indices of environmental damage for each of the modelled countries. Sweden and Norway, which have invested heavily in wastewater treatment, show very low indices of environmental damage by comparison with the UK, which has not. The study also finds that phosphates are less environmentally damaging than zeolites-PCA under all modelled conditions.

4. Finally, the study discusses the necessary conditions for the sustainable management of freshwater resources in Europe. It concludes that wastewater treatment to high standards, coupled with methods to remove and recycle phosphates, are essential components of such a sustainable régime.

PART 2

The Delphi study and model of environmental impacts arising from the disposal of laundry detergent builders

2.1 Introduction

The Phosphate Report[1] examined the life cycle of the three principal laundry detergent builders used in the UK: sodium tripolyphosphate (STPP), zeolite A and polycarboxylates (PCA). The study covered all phases of the life cycle: raw material extraction, raw material processing, builder production, use of the detergent and disposal through the wastewater treatment system. The disposal phase was evaluated by five wastewater treatment experts who were asked to compare the following two wastewater streams entering a treatment works:

Wastewater	A	B
	mg/l	mg/l
Phosphate (as P)	20	15
Zeolite A	0	25
Polycarboxylates	0	3

Wastewater A represented a hypothetical wastewater in which all detergents were phosphate-based, whereas wastewater B represented the estimated concentrations if all laundry detergent builders were to be replaced by zeolite/PCA at a rate of 0.7 kg STPP to 1 kg Zeolite A/PCA - an equivalent performance ratio in water of average UK hardness which was established by a series of washing tests. The evaluation covered four types of wastewater treatment plants ranging from primary treatment only through to tertiary treatment; with the plant discharging into five types of standing waters - classified according to the OECD trophic status; five classes of river (NWC scheme); as well as estuarial and coastal locations. Sludges produced as a consequence of the various treatments were also evaluated depending on their subsequent disposal route, which ranged from agriculture to incineration.

Although only five senior scientists out of 27 accepted invitations to participate in the study, the evaluations of those participants had a consistent pattern with regard to the ratio of the valuations given for each influent wastewater. Overall the panellists considered that, on average, wastewater A would be 6% more environmentally damaging than wastewater B with respect to treated water discharges, and 1% more damaging with respect to sludge use. These figures were used in subsequent calculations aimed at comparing the environmental impacts of the two builder systems over their life cycles, although it was accepted that the number of judges used, five, was not really sufficient to give reliable readings. The study also did not give the judges any opportunity to compare their responses with other judges, and to amend their answers where appropriate, as happens in the Delphi approach. The evaluations were also very much aimed at UK conditions.

It was therefore decided that the current study should re-examine the disposal phase of detergent builders, but with the following differences to the study described above:-

- adequate numbers of judges (at least 8)
- able to evaluate any number of levels of different wastewater composition, rather than two.
- able to evaluate wastewater in any European country, rather than just the UK, particularly the four Nordic countries: Denmark, Finland, Norway and Sweden.
- the judges should have feedback to enable them to compare their values with those of other judges.

The following sections describe the methodology aimed at meeting these requirements and the results obtained.