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IRELAND**

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# **COST-BENEFIT ANALYSIS OF A RESOURCE AND ENVIRONMENTAL SURVEY OF IRELAND\***

**BY**

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MAY, 2001

## **ABSTRACT**

The Geological Survey of Ireland (GSI) has proposed that a national geochemical and airborne geophysical survey of Ireland be undertaken. Together with independent input from the Geological Survey of Northern Ireland, this would cover the whole county. The proposed survey has been termed the Resource and Environment Survey of Ireland (RESI). This paper contains an ex-ante cost-benefit analysis of the GSI's proposal. This analysis reveals a benefit-cost ratio of 5.0.

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## 1. EXECUTIVE SUMMARY

The Geological Survey of Ireland (GSI) has proposed that a national geochemical and airborne geophysical survey of Ireland be undertaken. Together with independent input from the Geological Survey of Northern Ireland, this would cover the whole country. The proposed survey has been termed the Resource and Environment Survey of Ireland (RESI). It has the potential to provide information that would have considerable policy and other public benefits, particularly in relation to mineral exploration and the pressing issues of infrastructure development and environmental management.

The Environmental Institute of University College Dublin was asked to carry out a cost-benefit analysis of the GSI's proposal. This analysis reveals that the benefits of the RESI would far outweigh the costs of undertaking the survey. Indeed, the benefit-cost ratio is far in excess of that reported in most cost-benefit analyses of environmental projects (see below).

### *Comparison of Results of RESI CBA with other Cost-Benefit Analyses*

<i>Study</i>	<i>Mid-range Benefit-Cost Ratio</i>
RESI	5.0:1
Strategic Plan for the Forestry Sector (Clinch, 1999)	0.7:1
Integrated Pollution Control Licensing (Kerins, 2000)	1.2:1

The benefits are described in detail in the sections of the report that follow and are summarised in a table at the end of each section. In some cases, the benefits are difficult to quantify precisely and we have therefore applied a familiar procedure of estimating lower, middle and upper bounds. Nevertheless, even the middle range benefits estimate of £131 million exceeds the costs of the survey by a factor of almost five to one. If public health benefits are included (including using the Value of Statistical Life methodology), especially in relation to Radon, then the net benefit increases to £292 million.

### **NET BENEFITS (Net Present Value - 5% discount rate)**

<b>Middle range estimate</b>	<b>£131 million</b>
Middle range estimate (including Value of Statistical Life)	£292 million
Upper bound estimate	£534 million
Lower bound estimate	£82 million

The most obvious benefit is the national geological data itself. No survey of such ambitious scope has yet been undertaken. Excepting geographically dispersed surveys by prospecting companies, only

around half the country has been surveyed using geophysics, and this by low resolution means. Similarly, detailed modern geochemical surveys have only been conducted in a handful of locations. Consequently, the RESI will be a modern tool of immense research value to Irish government agencies and educational institutions as well as being of considerable practical value to policy makers, planners and Irish enterprises. The level of coverage and sophistication will be comparable to any to be found elsewhere in the world.

In addition to this self-evident benefit, the RESI would provide a wide range of other benefits. These are to be found in the areas of infrastructure planning and development, water quality (surface water, groundwater and drinking water), agriculture, forestry and land management, the exploitation of minerals and aggregates, and human health. A number of these individual benefits are substantial, while others are more modest. For instance, the cost of the RESI could potentially be exceeded by the benefits of a discovery of a single new mine, or by cutting the number of radon-induced deaths by as little as 20%. Even several of the more modest benefits perform an important contribution to our understanding of the environment and together accumulate to provide a considerable net benefit.

### **Types of benefit**

The benefits of the RESI can be categorised as:

- private benefits, and
- public or social benefits.
- benefits to government or policy.

Policy benefits features strongly in this cost-benefit analysis of the RESI. These benefits are largely in the form of information that increases the cost-effectiveness of implementation. There is also a further very important benefit in that the RESI will improve the country's capacity to meet various European policy directives in the areas of environment and health. Failure to meet the requirements of these Directives could result in the imposition of considerable fines. These benefits are the subject of the next section.

As well as policy benefits, there are potentially important private and public benefits. Private benefits occur where the beneficiaries are identifiable, i.e. as individuals or types of companies. Public benefits follow where the benefits are more widely distributed through the population. These are frequently non-monetary and include benefits in the areas of environment, health and quality of life.

These benefits can further be described as being direct or indirect. In the former they would follow directly from the results of the RESI. Indirect benefits would occur where the RESI provides data that could contribute to a beneficial result. In some instances, the data provided by the RESI could be instrumental to such a result.

### **Direct and indirect benefits**

The output from the RESI would have multiple applications. The main direct benefit of the RESI occurs in the rather mainstream geological area of mineral exploration. Here the survey could contribute substantially to an expansion of private exploration activity which in itself provides an input into the economy. This exploration would increase the likelihood of a major mineral find that could have substantial economic benefits. Even under modest assumptions, the Net Present Value of such a find could be worth between £20 million (lower end estimate) and £34 million (upper end).

As well as mineral exploration, there are several instances where the RESI contributes directly to a certain goal. However, most of the benefits described in this report are of an indirect nature. In many cases, the value of information derived from the RESI is its contribution to a particular goal once combined or modelled along with other data. The information cannot resolve the problem on its own, but is no less valuable for that. The potential value of the survey data could be considerable, but for a particular goal to be achieved, further research or additional information may be needed before the full value of the RESI can be realised.

Other benefits appear modest if considered individually, but together accumulate into a very respectable net benefit figure. For example, the RESI can make a small, but significant contribution to our understanding of acidification and so enhance our ability to meet targets specified in the Gothenburg Protocol or Habitats Directive. This significance arises from the huge scale and potential cost of a problem such as acidification. By providing information to improve our understanding of environmental problems such as these, the RESI provides economic benefits which are often in the form of the avoidance of huge future costs.

Many environmental problems, e.g. acidification, impact on important habitats that are highly valued. Additional information therefore has a public benefit. This can be difficult to quantify, but because so many people or places are affected, the benefit can be very large indeed. Often, these problems impact directly on human health. Here there is the prospect of major benefits by avoiding the costs associated with groundwater pollution, radon exposure and, possibly, exposure to toxic metals. Once discounted,

these benefits could amount to between £25 million per year (lower end) and £224 million per year (upper end<sup>1</sup>).

There are further benefits which will only emerge in the course of time. There are market failures in the provision of information in that the full value of this information is shared amongst many people, impacts on future generations, or may not be fully appreciated at any one time. An example of the last such benefit is provided by the recent *foot and mouth* crisis. The need to ensure that buried carcasses do not affect water supplies has led to requests for information of the kind that would be supplied in detail by the RESI. The prior existence of such information lowers the costs and increases the effectiveness of actions such as these.

### Policy response

In all cases, for the benefits of the RESI to be realised, there will be a need for a practical or policy response to the sum of information which has been collected. This response depends on the data from the RESI being accessible. Namely, that there is the capacity for it to be interpreted at a practical level by geologists, administrators, planners and civil engineers. It is intended that the data from the RESI would be provided in a form that can be easily understood and processed by standard computer programmes, including geographical information systems.

An area to which this consideration is especially relevant is infrastructure development. In this case, the main contribution of the RESI would be to strategic or advance spatial planning. More detailed on-site surveys will usually still be needed. However, considering the rate of economic growth and proposed scale of investment in water supply, roads and built development that is specified in the National Development Plan, the RESI can contribute to faster and more informed decision-making. This is an area in which the cumulative benefits of the RESI would again be substantial.

In the table below, potential clients for RESI data are underlined. Government departments and local authorities feature frequently in this list.

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<sup>1</sup> Taking middle range estimate for avoidance of Radon deaths with Value of Statistical Life included.

## **Cost Benefit Analysis**

### Cost

Following discussions with the Geological Survey of Northern Ireland (GSNI) and British Geological Survey (BGS), the cost of the RESI is estimated at £22.4 (or £19.5 million Sterling). Allowing for closer spaced sampling, increases in the proportion of helicopter surveying, deployments of additional sensors, or contingencies, the total cost is estimated at £28.7 million (Sterling £25 million).

The cost of the airborne geophysical survey and associated data analysis is estimated to be £8.75 million. That of the geochemical survey is estimated to be £11 million. The two surveys are complementary and it is recommended that they are undertaken concurrently (see Section 1).

The airborne survey will provide the first national geophysical representation of Ireland and will complement recent commercial mapping which has been limited in scope and geographical coverage. The resultant data will have value into the far future, although inevitable technical developments will mean that renewed surveys of some areas could be considered to be desirable in twenty or thirty years time. By comparison, the geochemical survey will, in principle, be more permanent in that it will involve the comprehensive mapping of elements. However, while the composition of underlying rocks will be fundamentally unchanged, surface compositions could change in time due to agriculture, leaching and airborne deposition.

The interpretation and integration of the data from both survey components is anticipated to cost £1 million, while that of training, infrastructure and data storage will cost approximately a further £1 million. The undertaking and analysis of the survey itself will require some temporary recruitment but is not expected to lead to any increase in permanent staff costs.

Allowing for administration and outreach that is essential to ensure that the data is available in the public domain will cost £1.5 million. Income will follow from the sale of data, for instance to commercial companies involved in mineral exploration and would amount to several hundred thousand pounds per annum. However, given the need to ensure that the data is utilised, the income aspect should be regarded as being secondary to the public benefits.

### Benefits

The economic analysis reveals that the mid range estimate of the total benefits of the RESI amounts to £131 million (see table below). This provides a very positive comparison when compared against the

costs of conducting the survey, estimated at approximately £29 million, representing a benefit to cost ratio of almost 5:1.

If the upper estimates listed in the following table were adopted the benefit-cost ratio would be still higher. Recommended practice is to err on the side of caution, but even the most conservative estimate of benefits still amounts to £82 million which still far exceeds the cost of the survey. However, both this figure and the middle range figure exclude the element of Value of Statistical Life (i.e. people's willingness-to-pay to avoid premature death) which would apply to potential exposure to toxic metals or to Radon. Typically, these values are very high and, in the case of Radon, would be at least £46 million per year in total. Once multiplied by the deaths each year which are due to Radon, even the discounted figure for VoSL is over £600 million. The mid range estimate is based on the assumption that the RESI would contribute a quarter of this benefit by providing more detailed information on the geographical distribution of radon emissions.

In practice, as noted above, many benefits are extremely difficult to quantify. However, even allowing for the difficulties of estimation, the benefit-cost ratio of the RESI is a very positive.

### **Policy Benefits**

The RESI has the potential to provide numerous policy benefits in relation to strategic planning, investment in infrastructure, environmental management and public health. Some of the more sizeable benefits are in the form of damage avoidance. For instance, pressures on the environment and quality of life are increasing due to the rapid rate of economic growth and infrastructure development. By avoiding environmental losses government can avoid the substantial costs in the form of environmental rehabilitation. Similarly, the removal of avoidable threats to human health can reduce healthcare costs.

**SUMMARY OF BENEFIT ESTIMATES (VoSL = Value of Statistical Life (see Radiation chapter)).**

<i>Benefit</i>	<i>Estimate</i>	<i>Net Present Value</i>
Mining & exploration	Mid estimate Upper estimate Lower estimate Lowest estimate (no mineral or aggregate finds)	£54 mn. £73 mn. £38 mn. £7 mn.
Land management	Mid estimate Upper estimate Lower estimate	£26 mn. £42 mn. £13 mn.
Water	Mid estimate Upper estimate Lower estimate large non-quantifiable element	£12.5 mn. £52.5 mn. £8 mn ✓
Infrastructure	Mid estimate Upper estimate Lower estimate modest non-quantifiable element	£32 mn. £35 mn. £21 mn. ✓
Contaminated land	Mid estimate without VoSL Mid estimate if VoSL is included Upper estimate (if include VoSL) Lower estimate (if exclude VoSL) large non-quantifiable element	£2.62 mn. £12.25 mn. £24.25 mn £0.77 mn. ✓
Radiation	Mid estimate without VoSL Mid estimate if VoSL is included Upper estimate (if include VoSL figure) Lower estimate (if exclude VoSL) modest non-quantifiable element	4.16 mn. £155 mn. £307 mn. £1.65 mn. ✓
<u>Totals</u>	Mid estimate Mid estimate if VoSL included Upper estimate Lower estimate	£131 mn. £292 mn. £534 mn. £82 mn.

Guidance on these issues is provided by EU Directives and Regulations. These act as “drivers” for national policy and practice. Examples include standards for ambient air, waste water, water resources and drinking water, requirements for waste management or environmental performance information, and the protection of areas of conservation interest. There are also international agreements on greenhouse gasses (Kyoto Protocol) and acid precursors (Gothenburg Protocol), requirements in relation to which are likely to be assumed at European level.

The RESI will provide information that will enhance the State’s future capacity to satisfy a variety of Directives in relation to the environment. This will ensure that resources for the National

Development Plan are provided promptly under the Structural Fund and Cohesion Fund. Moreover, under the Amsterdam Treaty, the European Court of Justice has the authority to impose penalties in the event that member states fail to comply. For example, the Greek government is currently accumulating fines at a level of €20,000 day for its failure to remove an environmentally damaging landfill. These daily penalties have now amounted to €3 million.

Ireland is at risk of being fined by the EU which claims that much of the drinking water provided by group rural water schemes is of an unsatisfactory standard despite considerable recent investment by the DELG. Other potential areas of dispute concern progress made under the Waste Management Directive, the Habitats Directive, the Nitrates Directive and in relation to Impact Assessment.

In most, if not all, of these cases, the RESI can supply information that would improve environmental management in the future as well as providing the government with evidence of the most cost-effective way forward. The information would also make policy initiatives generally more effective and easier to implement. In many cases, the potential will not be appreciated as is evident from the diverse range of benefits identified in this analysis. Consequently, the GSI has already undertaken widespread consultations with various government departments and agencies in relation to the RESI.

Information provided by the RESI will be of benefit to various government departments:

*The Department of Finance* is ultimately responsible for the careful management of public resources. The Department has a central interest in ensuring that these funds provide maximum public benefit and that policies are implemented cost-effectively in a manner that minimises any possibility of misallocation of resources. It is also directed to ensure the cost-effective compliance with European Directives.

*Department of the Marine and Natural Resources:* The *Exploration and Mining Division* has a direct interest in the benefits for mineral and aggregate exploration and the exploitation of deposits in a manner which minimises risk to the environment. The *Forest Service* has plans for a major expansion of the forestry and responsibility to ensure that the most suitable areas are selected from the perspectives of productivity, timber quality and minimal environmental impact. The Department also has responsibility for inland fisheries which are threatened by acidification and eutrophication.

*Department of the Environment and Local Government* has responsibility for implementation of the Water Framework Directive, for waste management and spatial planning. In 1997, the Department prepared the National Sustainability Strategy. At local level, decisions are implemented by *local authorities* whose responsibilities include housing, water supply, wastewater treatment and land use.

Local authorities also allocate planning permission decisions which can be appealed to *An Bord Pleanála*. The RESI has a contribution to make in all areas of land use planning, infrastructure development, the siting of landfills and water supply/quality.

*The Department of Health and Children* would be interested in the contribution that the RESI could contribute to reduced public exposure to toxic metals and to radon which in turn would reduce the costs of hospitalisation, drugs and mortality.

*The Department of Agriculture, Food and Rural Development* has a direct interest in the mapping of trace elements which affect agricultural productivity and animal health. It also has responsibility for implementing cost-effective policies that will reduce the impact of nitrate leaching and ammonia emissions on health and the environment while minimising impacts on farm incomes and productivity.

*Department of Arts, Heritage, Island and the Gaeltacht* has responsibility for the built and natural environment, including wildlife habitats. It therefore has an interest in pollution factors, for instance in relation to groundwater or infrastructure development, which could affect the quality of these habitats.

*The Environmental Protection Agency* is an independent organization with responsibility for the licensing of industry and waste management facilities, and for environmental monitoring. The RESI would enhance the EPA's capacity to monitor environmental change and to recommend the most effective solutions to counter threats to environmental quality.

### **Allocation of Benefits**

The following table provides a more detailed summary of the benefits. It indicates whether the benefits are principally in the form of policy benefits and to which departments or agencies they are of interest. It also indicates whether there are additional public or private benefits. Either are a valid contribution to the net social benefit, although many public benefits may not be realised in a financial sense.

Most of the benefits are expressed in terms of a net present value (NPV), representing the balance of benefits and costs over time. In most cases these are discounted at 5% over a twenty year period. Generally "costs" in this respect are minor, for example costs of quarry development, and even many of these costs are cancelled out by the prospect that some development would occur irrespective of the survey. Rather, the relevant costs for the CBA of the RESI is the cost of undertaking the survey itself.

Overall, the analysis of the Resource and Environmental Survey of Ireland indicates a very positive benefit-cost ratio. Taking the middle range estimate, using the Department of Finance's test discount rate of 5%, benefits total £131 million compared with costs of £29 million, which is equivalent to a benefit-cost ratio of nearly 5:1. However, even this Net Benefit excludes Value of Statistical Life estimates which capture some of the very substantial public benefits to which the RESI could contribute. Under all scenarios considered (lower, middle and upper bound estimates, including and excluding VoSL) the cost-benefit analysis indicates that the investment should proceed.

<i>RESI contribution</i>	<i>Scale of RESI contribution</i>	<i>Benefits to state / policy</i>	<i>Public benefits</i>	<i>Private benefits</i>	Net Present Value of RESI
<b>MINING &amp; EXPLORATION</b>					
<i>Improved data for exploration activity</i>	Could increase exploration by 10-30%,	mainly royalties and corporation tax. Of value to <u>DoF</u> and <u>DMNR</u>	-	Leverage to profitable exploration by <u>prospecting &amp; mining co.</u>	Middle NPV = £19 mn. (upper = £24mn, lower = £14mn.)
<i>Contribution to new mineral find (probably at least one in medium term)</i>	Major contribution, as discovery is brought forward by perhaps 30 years. (if ever)	mainly royalties and corporation tax. Of value to <u>DoF</u> and <u>DMNR</u>	-	Large component, mostly in form of economic stimulus. One mine typically contributes £150mn to economy	Middle NPV £27mn. (upper = £34mn, lower = £20mn.)
<i>Contribution to new aggregate finds</i>	Modest contribution, mainly where deposits are concealed.	mainly contribution to infrastructure development & imp to <u>local authorities</u>	some local environmental costs	Mostly to road building companies/developers	Middle NPV £8 mn (upper = £15mn, lower = £4mn)
<b>LAND MANAGEMENT</b>					
<i>Acidification</i>					
Major environmental problem	Small contribution to major environmental problem (costing at least £40mn/yr.)	Increased cost-effectiveness of land use policy. Of value to <u>DELG, DAFRD, EPA</u>	Avoidance of damage to rare ecosystems with an existence value of around £40mn/yr.	Avoidance of subsequent liability to landowners.	Middle NPV = £9.78 mn (upper = £20mn, lower = £2.5mn.)
<i>Forestry planting</i>					
Major expansion planned for socio-economic and environmental benefits	Direct contribution selection of suitable land, Complementary to FIPS on which £6-8 mn is being spent.	Major expansion costing £3.7bn over 30yrs. Of value to <u>DMNR</u> (Forest Service), <u>Coillte &amp; Teagasc</u>	Avoidance of losses to existence & use value due to ecosystem damage	Benefits to private <u>forestry companies</u> due to information on land suitability and reduced liability for any environmental damage.	Middle NPV = £350,000 (also captured under acidification and in section on Water).

<b><i>Nitrification of groundwater</i></b>					
Growing environmental problem. Subject to Nitrates Directive.	Indirect contribution of Info on nitrates and aquifer vulnerability	More cost-effective policy Of value to <u>DELG, DAFRD, EPA &amp; local authorities.</u>	Savings on NVZ payments. Avoidance of health problems, esp in infants.	May exclude some farmers from restrictive nitrate regulations	Probably small, but could increase to £2 mn. (upper = £4k, lower = £500,000)
<b><i>Trace metals in agriculture</i></b>					
Losses to agricultural productivity from toxicity & deficiency	Indirect benefit adding detail to existing maps compiled by Teagasc.	Not a major policy issue, but of value to <u>DAFRD &amp; Teagasc</u>	Avoidance of some animal welfare cost.	Avoidance of income and welfare losses & to beef <u>farmers</u> around £10mn yr.	Contribution to reducing output losses of £14mn. (upper = £18.6 mn, lower = £9.4mn.)
<b><i>RESI contribution</i></b>	<b><i>Scale of RESI contribution</i></b>	<b><i>Benefits to state / policy</i></b>	<b><i>Public benefits</i></b>	<b><i>Private benefits</i></b>	<b>Net Present Value of RESI</b>
<b><i>WATER</i></b>					
<b><i>EU Water Framework Directive</i></b>					
<i>Meeting requirements of the Directive</i>	Direct benefit to assessment of nation's water resources.	<u>DELG</u> has set aside £50 mn over four years.	Use value of clean water <i>at least</i> £18-72 mn/pa.	-	Could save 5-10% of cost field assessment, ie £3.75mn
<i>Clean drinking water</i>	Small contribution to indicating aquifer vulnerability	Improved cost-effectiveness. Of value to <u>DELG</u> and <u>local authorities.</u>	Use value of clean water <i>at least</i> £18-72 mn/pa.	-	Small contribution to a major public benefit. Possibly worth £8.8mn. (upper = £45mn.)
<b><i>Aquatic resources</i></b>					
<i>Reversing decline in fish population; a major tourism resource.</i>	Contribution to research	More cost-effective protection by <u>CFB.</u>	Major benefits as fish as indicator of ecosystem health	Increased angling, which could be worth £20mn/yr.	Small non-quantifiable contribution
<i>Water-based recreation</i>	Contribution to research on eutrophication & acidification	More cost-effective management of lakes & rivers. Of value to <u>DAFRD &amp; Bord Failte.</u>	Major benefits to wide spectrum of population. Use value £18-65 mn/pa.	Increased tourism expenditure & benefits to hotels, boat owners, travel agents, etc.	Small non-quantifiable contribution
<i>Ecosystems</i>	Contribution to research on eutrophication & acidification	as above. Of value to <u>DAFRD &amp; Dúchas,</u>	High existence value of £xx mn.pa.	Some benefit to ecotourism	Important non-quantifiable contrib. to major enviro problem.

<b>INFRASTRUCTURE DEVELOPMENT</b>					
<i>Water supply</i>	Direct benefit through more precise info on groundwater location and savings on excessive borehole drilling.	More cost effective distribution of water & conformance with Water Framework Directive. Of value to <u>DELG</u>	-	Could benefit 60+ <u>rural communities</u> .	Major contribution of at least £8.14 + £9.76 mn. (upper = £21 mn, lower £14mn.)
<i>Road development</i>	Direct benefit through info on ground conditions	Savings to <u>national agencies</u> (eg NRA) & <u>local authorities</u> . Delays currently cost £2-4mn/yr.	Improved info for public enquiry and accelerated activity leading to reduced inconvenience.	Input of <u>civil engineering companies</u> to routing design	Minor contribution when routing alternatives being considered. Not quantifiable/
<i>Built development</i>	Direct benefit by avoiding geohazards	Of benefit to strategic planning by <u>local authorities</u>	-	Info on ground conditions for <u>developers</u> .	Minor contribution at strategic planning level. Not quantifiable.
<i>Landfill siting</i>	Indirect benefit by revealing risk to groundwater.	Again, at strategic level to <u>local authorities</u> . Reduced cost of alternative site investigation	Reduced short-term anxiety and property blight. Possible avoidance of unexpected enviro probs	-	Small contribution at strategic planning level. £11.4mn.
<i>Electricity transmission</i>	Direct benefit for siting of substations	-	-	Contribution to <u>ESB</u> multiplied by amount being invested (£500m)	Minor contribution along with other factors. £2.5mn.

<i>RESI contribution</i>	<i>Scale of RESI contribution</i>	<i>Benefits to state / policy</i>	<i>Public benefits</i>	<i>Private benefits</i>	Value of RESI
<b>CONTAMINATED LAND</b> (VoSL = Value of Statistical Life (see Radiation chapter).					
Impact of trace elements on human health (toxic metals & deficiencies).	Indirect benefit by revealing population at risk.	Reduced cost of health care probably offset by cost of mitigation. Value to DoH & regional health authorities	Reduced mortality possibly worth £500,000 per yr represented as VoSL.	-	Full value dependent on policy response. With VoSL = £12 mn. (upper = £24mn, lower £520,000).
Identification of extent of contaminated land	Direct benefit by revealing location of such land & through baseline info	Of value to EPA & local authorities & in allocating clean-up liability (some of which could be public cost)	Avoidance of possible health costs.	Essential to EIA and therefore of interest (if not necessarily value) to <u>developers</u> .	Major contribution, mainly in terms of baseline data. Not quantifiable.

Sewage sludge	Direct benefit through improved info on trace metal levels. Contribution is at strategic level rather than to final site selection.	Improved site selection by local authorities & DELG as part of £650mn waste element of NDP.	-	-	Possible resource savings of £250,000 to County Councils by avoiding unnecessary site examination.
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<b>RADIATION</b> (VoSL = Value of Statistical Life (see Radiation chapter).					
Radon (a cause of 150-300 deaths per year).	Indirect benefit by mapping radon emissions	Reduced morbidity costs of around £1.8 mn/yr. More cost-effective policy.	Reduction in lost economic contribution of around £0.85 mn/yr	Lower personal mortality expressed as VoSL of at least £46mn/yr	Imp contribution, if small relative to remedial action. £4.16mn (£155 if VoSL is included) (upper = £307mn, lower £77 mn.)
Caesium (Chernobyl).	Mapping of baseline levels.	Will reveal continuing contamination and provide baseline data for response to future incidents.	-	-	Large, non-quantifiable contribution.

## **2. THE RESOURCE AND ENVIRONMENT SURVEY OF IRELAND**

Much of the data currently available on Ireland's geology is an interpretation based on surface outcrops and borehole data. However, modern geochemical and geophysical techniques can provide far more high resolution information about geological resources which are concealed beneath surface layers of soil, peat and glacial debris.

The RESI includes both geochemical and geophysical surveying. Modern geochemical surveying is based on multi-element geochemical analysis of water, soil and sediment samples. High resolution geophysics can reveal much about structure, mineral content and overlying subsoils based on local variations in magnetic and electromagnetic fields.

There are advantages in undertaking a comprehensive survey using geophysical and geochemical techniques simultaneously. In this way, the survey will provide the first detailed national database on subsurface geology. It will be applied at a single time using a consistent resolution to provide a thorough baseline database that informs us of the current state of the environment as well as acting as a foundation from which to analyse change. There may also be economies of scale in the simultaneous processing and analysis of geochemical and geophysical data. These approaches will complement one another, providing for a greater sophistication of analysis and added value products.

### **2.1 The geophysical survey**

Around half the country was surveyed using aeromagnetics in the early 1980s, but the technology used was very low resolution by today's standards and neither radiometrics or electromagnetics were not included. More recent geophysical surveying has been undertaken by mineral prospecting companies. However, the cost and prospects of success have restricted commercial exploration activity to the more promising exploration areas. Consequently, the data is geographically discontinuous, inconsistent and of various vintage.

The RESI will apply airborne geophysics to overfly the whole country using parallel lines spaced at 200 to 400 metres. Closer spaced surveying will be carried out in areas of special interest. The instruments would ideally include a magnetometer, radiometric equipment, electromagnetic equipment, and GPS positioning. This instrumentation has the capability to indicate precisely boundaries between rock types, depth to bedrock, fracture and fault zones (including those where minerals may be found or through which groundwater flows more rapidly) and, in some cases, directly reveal the presence of mineral ores. The final selection of techniques such as time domain or

frequency domain electromagnetics will depend on the resources available, the detail required and the rating of economic benefits to which they best contribute respectively. The airborne survey will take 2-3 years to complete.

## **2.2 The geochemical survey**

The observation in relation to existing geophysical data applies to geochemical data too. Again, much past geochemical surveying has been undertaken by the mineral prospecting companies. The data has widespread geographical coverage, but again is discontinuous, inconsistent, of varying vintage and often restricted to a few elements of interest to the sponsor. Only around 15% of the country has been surveyed using multi-element analysis with some of the most detailed surveying having been undertaken by the GSI in the south-east of the country and by GSNI in the North.

Modern geochemical techniques have the capability to test for the full suite of elements. The RESI will employ systematic ground based sampling of soils and stream waters. The survey will involve the collection and analysis of approximately 150,000 samples and will inevitably involve more time to complete than an airborne survey, i.e. around five years. It is proposed to undertake more intensive surveys in urban areas at a coverage of around four samples per km<sup>2</sup>.

## **2.3 Integration and delivery**

The data from both surveys will be analysed and entered into a Geographical Information System. This database will combine information from the RESI with other information on topography, soils and water.

It is intended that the survey be accompanied by an outreach and promotional programme to ensure that there is a high level of awareness of the survey work amongst educational institutions, researchers, commercial enterprises, policy makers and international institutions. Its full value can only be realised if the data is provided in a manner that can be interpreted and made accessible to a range of users.

### 3. METHODOLOGY

The following format is used in the individual sections of the report:

- Description of the nature of the problem or issue;
- An economic assessment;
- The contribution of the RESI.
- A table summarising the contribution of the RESI

The Summary Table is followed by an estimate of the benefits where these are quantifiable. Lower, middle and upper bound estimates are given of the assumed contribution of the RESI to the total economic benefits. This RESI contribution is expressed as a proportion (tentative in most cases) where 1.0 = 100%, or 0.2 = 20%, etc. The middle-bound estimate is then discounted over a 25 year period from the commencement of the survey to provide a Present Value estimate of the benefit flow. The sum of these Present Values can be compared with the short-term costs of undertaking the survey.

The call for a cost-benefit analysis (CBA) of RESI is in line with recommended policy where public expenditure is concerned (DoF, 1994, 1999). The purpose of CBA is to measure, as far as is practicable, a project's efficiency in terms of its net benefits to society's economic welfare.

The calculation of net benefits takes into account both a project's private benefits as well as its societal benefits. Private benefits will accrue to the GSI in terms of a level of employment and enhanced data availability. Benefits will also accrue to private organizations, for instance developers, mineral prospecting or mining companies, as they can potentially benefit from the greater information provided by the RESI.

However, the primary benefits are to society. It is these benefits that are of interest where public expenditure is concerned, namely

- reduction in the costs of environmental management;
- benefits to public welfare;
- benefits for education and research;
- more cost-effective policy.

The direct benefit provided by the RESI is information. This corrects for a market failure in the provision of information that provides a diversity of benefits, none of which are individually of a scale or nature that would merit the provision of the same information by an entity other than the state itself.

Furthermore, the information can be used to correct other market failure problems. Action, or inaction, taken in the absence of such information leads to a misallocation of resources and a loss of economic welfare. The RESI will, for instance, contribute to the better management of environmental risk associated with a variety of developments. This will contribute to a potential improvement in environmental management as well as a reduction in the costs of such management, for example those associated with groundwater pollution, acidification and other topics considered in this report. Indeed, the RESI goes far to satisfy the requirements for economic efficiency in that it can contribute to economic growth (e.g. by revealing new mineral deposits) while also reducing market distortions which arise due to lack of information and which result in environmental costs. The calculation of net benefits must also include non-market valuation of these environmental costs as they affect public welfare. Examples include reduced risks to public health or the removal of threats to environmental assets which are highly valued by society.

At a practical level, better information will allow for the more accurate targeting of environmental amelioration measures, for instance by identifying areas subject to the highest levels of natural radon risk. This means that public spending can be more cost-effective. There will be a saving of resources and greater *efficiency*, while the better information and targeting will ensure that policy can be more *effective*. This would make it easier for government to satisfy national environmental requirements and European Directives. The consequent exchequer savings are a social benefit as they can be redirected to other areas of public expenditure or used to reduce distortionary taxation.

### **3.1 The calculation of Net Social Benefits**

An investment is a positive addition to economic welfare if its benefits exceed its costs. The benefits, and usually the costs, occur as a flow over time and must be discounted back to the present (see below). Where possible, they must also be converted into the same monetary terms, the main tasks in this procedure being:

- the identification of costs and benefits;
- the estimation of opportunity costs and non-market costs/benefits;
- the relative valuation of costs and benefits at different times. This valuation can include an assessment of risk and uncertainty.

The first preference is to measure the full consumer or producer surplus associated with the investment. It is for this reason, and because so many of the potential benefits of the RESI are not directly priced by the market, that the CBA makes reference to the public's willingness-to-pay.

The RESI has a unique value in that it will provide national baseline data on soil, water and rock geochemistry and geophysics. For most of the country, this data does not currently exist. Furthermore, the information from the two types of survey will be mutually complementary. There are benefits of added value and possibly economies of scale (for instance in data analysis) by undertaking both types of survey. Similarly, there are obvious benefits in undertaking both surveys simultaneously in that the data will belong to the same baseline period.

The survey will provide a detailed and comprehensive description of the country's geochemical characteristics and the geophysics of its rocks and soils. Without doubt, it will be an invaluable resource for research. Its full social value, however, can only be realised if the information is utilised in public policy, for example if the information contributes to fewer radon-induced lung cancer deaths, to reduced ecosystem damage or to employment and additions to national income from the sustainable development of natural resources. In some cases, the benefit of the RESI will be direct or substantial (e.g. groundwater and trace metals). In others, it may be but a single link in a long chain of actions required to achieve an environmental gain (e.g. reductions in eutrophication).

A quantification of the private and social benefits is therefore difficult and is bound to be incomplete. Morgenstern (1997) remarks that:

*“almost anything can be quantified if the requirement that the results be convincing and methodologically sound is abandoned. Requiring the quantification of all effects is an invitation to shoddy analysis and would likely provide no more information ... than a careful attempt to qualitatively consider the effects in question”.*

This CBA therefore lists and categorises the benefits of the RESI as private, social or policy related. Where possible, an indication of the total benefits is given and an argument made for the relative contribution likely to be supplied by the RESI. As noted this may be large or small, but, in accordance with the precautionary principle, the benefits will be greatest where environmental risks are irreversible or uncertain.

### **3.2 Other considerations**

#### a) Discounting

The present value of future costs and benefits is estimated by discounting these to the outset of the project. A rate of 5% is advised for public projects (DoF, 1994).

The costs are limited to the survey itself, the input of data into a GIS, and its primary analysis. They therefore relate to a short initial period.

The benefits are more long-term. For the most part, the benefits will be realised shortly after the completion of the survey itself and persist into the distant future. As many of the benefits are of an annual nature they can accumulate to a respectable sum even after discounting.

Some of the benefits are very long-term, e.g. in relation to reducing the risk posed by the accumulation of trace metals in environments which are currently not at risk. Generally, given the prominence of long-term public benefits due to the RESI, any discount rate should reflect the social rate of time preference. This rate should not overly diminish distant benefits. Nevertheless, a sustainability constraint should be considered in that actions to remove widespread land or groundwater contamination, even if required only in the distant future, could be so expensive as to be effectively irreversible.

Within this time frame, aspects will change. In particular, elements identified in the soil geochemistry will vary greatly over time. Many inorganic compounds will also be supplemented or depleted by agriculture. However, the benefits are not limited to these factors alone and the value of having an initial baseline survey is not diminished. The RESI provides the comparative baseline by which to study the relationship between human activity and natural processes over time.

Of more practical relevance is the durability of the data itself. Geological information has a long shelf-life. Much use is still made of maps which were compiled over a century ago. The geochemical database should be useful for at least 50 years. On the other hand, advances in geophysical surveying, mean that the practical value of the geophysical survey could be superseded in 10-20 years (as was true of the low resolution survey conducted in the eighties). In this CBA, a time frame of 25 years is applied (typically 20 years following completion of the RESI) as is commonly used in accounting. The only exceptions are health related issues due to radon or toxic metals where improved mitigation measures might not have an impact for a further 20 years due to the long time period before the onset of cancer.. In these cases, the discounting period has been extended to 2050. Although the 25 year discounting period could be regarded as short, it is remarkable how benefits that could be viewed as being modest on a “per year” basis, can amount to a substantial sum despite the discounting factor.

b) Alternatives

No alternative project is available for consideration. The 'do nothing' scenario would mean that any new geochemical or geophysical data would only become available in a geographically patchy and inconsistent way and to satisfy varied objectives. Its public availability cannot be relied upon. Furthermore, it would tend to be of a specific nature (with respect to private investments) and not the general baseline information envisaged in the RESI.

There is a strong argument for possessing data which will be publicly accessible and have long-term value for future resource and environmental management. The comprehensiveness of a national survey permits these benefits to be maximised.

The survey will complement existing data in the possession of the GSI, universities or commercial companies. Likewise, it will complement, and not substitute for, sampling currently being undertaken by agencies such as the Environmental Protection Agency (EPA) or the Radiological Protection Institute of Ireland (RPII). This complementary role is discussed in the individual sections which follow.

c). Deadweight

The RESI is intended as a public resource and the benefits which it will secure will principally be public rather than private. There is very little deadweight as no other organization has plans to undertake a similar survey and, as noted above, the data will be complementary to surveys carried out by the EPA, RPII or others. Where private benefits are identified, the GSI could consider recouping some of the cost through user fees. This private sector investment in mineral exploration, engineering work or development would still require more detailed local surveys to provide a satisfactory environmental impact statement. There are therefore no significant deadweight losses.

There is, however, a deadweight cost associated with public funds raised through taxation. This factor can be added to the survey cost. A weighting of 1.25 is now recommended to reflect the distortionary effect of public taxation (Barry *et al*, 2000).

d). Uncertainty

It is impossible to predict benefits with certainty, particularly where the future is concerned. Therefore the estimates which appear in the CBA include an upper, lower and middle bound. As discussed earlier, the middle bound figure is favoured.

### **3.3 Linkages implicit in the RESI**

Although the benefits of the RESI are discussed under certain heading, each possesses numerous linkages to economic development, social infrastructure, the environment and human health as well as to the benefits listed under other headings.

#### **MINING**

##### **MINING - MINERALS**

Principal issue = Economic development

Linkages = Contaminated Land

##### **AGGREGATES**

Principal issue = Economic development

Linkages = Roads, Built Development, Environment

#### **LAND MANAGEMENT**

##### **AGRICULTURE & Trace Elements**

Principal issue = Economic development (agriculture)

Linkages = Trace Elements, Sewage Sludge.

##### **AGRICULTURE & Groundwater**

Principal issue = Trade-off between human health & agri output.

Linkages = Clean water

##### **FORESTRY**

Principal issue = Economic development

Linkages = Acidification, Ecosystem, Fish, Recreation.

##### **ACIDIFICATION**

Principal issue = Environmental health

Linkages = Ecosystem, Fish, Recreation, Forestry growth.

#### **WATER**

##### **WATER FRAMEWORK DIRECTIVE**

Principal issue = Human and environmental health

Linkages = Agriculture & groundwater, Ecosystem, Trace Elements, Sewage Sludge.

## FISH

Principal issues = Economic development & environment

Linkages = Ecosystem, Recreation, Forestry, Water Directive.

## RECREATION

Principal issues = Social infrastructure & economic development

Linkages = Ecosystem, Fish.

## AQUATIC ECOSYSTEM

Principal issue = Environment

Linkages = Recreation, Fish, Water Framework, Agriculture & groundwater, Forestry, Roads.

## **INFRASTRUCTURE**

### WATER SUPPLY

Principal issue = Social infrastructure

Linkages = Water Framework, Agriculture & groundwater.

### ROADS

Principal issue = Economic development

Linkages = Aggregates, Ecosystems.

### BUILT DEVELOPMENT

Principal issue = Economic development

Linkages = Aggregates, Water supply, Brownfield Sites

### LANDFILL

Principal issue = Environment

Linkages = Water Directive.

### ELECTRICITY TRANSMISSION

Principal issues = Economic development & social infrastructure

Linkages = no major ones.

## **TRACE ELEMENTS**

### TRACE ELEMENTS

Principal issue = Human health

Linkages = Agriculture & trace elements, Sewage Sludge, Contaminated Land.

### CONTAMINATED LAND

Principal issue = Human health

Linkages = Trace Elements, Mining, Water Directive.

### BROWNFIELD SITES

Principal issue = Economic development

Linkages = Built Development, Contaminated Land.

### SEWAGE SLUDGE

Principal issue = Environment

Linkages = Agriculture & trace elements, Water Directive.

## **RADIATION**

### RADON

Principal issue = Human health

Linkages = Built Development

RADIATION (Other)

Principal issue = Human health

Linkages = Built Development, Agriculture, Contaminated Land.

## 4. MINING AND EXPLORATION

The Irish mining and quarrying sector is comprised of base metal extraction, the mining of industrial minerals such as gypsum, quarrying for aggregates and the output of hydrocarbons.

### *METALS AND INDUSTRIAL MINERALS*

Ireland is well-endowed with mineral resources. It is the world's sixth largest producer of zinc and output includes lead and silver as associated minerals. In 2000, 289,000 tonnes of zinc concentrate were produced. In the preceding year, 39,000 tonnes of lead concentrate and 10 tonnes of silver were also produced. In addition, 500,000 tonnes of gypsum were mined.

Production is dominated by a few major mines:

- Outokumpo-Tara Mines at Navan: Production of around 2.2 million tonnes of zinc ore (grading 7.23%) and lead (grading 2.00%);
- Galmoy mine in Co. Kilkenny owned by Arcon Mines Ltd: Production of over 500,000 tonnes zinc ore (grading 10.46%) and lead (grading 0.80%);
- The recently opened Lisheen mine in Co. Tipperary owned by Anglo-American and Ivernia West: Output currently over 700,000 tonnes zinc ore (grading 11.11%) and lead (grading 4.26%), but expected to increase to 1.5 million tonnes at full production.
- Irish Gypsum's open cast Knocknacran mine in Co. Monaghan: Production of 500,000 tonnes.

### *QUARRYING*

Quarrying is undertaken for sand, gravel and rock. Crushed rock now represents more than half of quarry output. Natural sand and gravel is fundamental to concrete manufacture. Despite the relevance to infrastructure and built development, the extraction sector is less capital intensive and of a smaller scale than mining. Nevertheless, there are some major players including CRH, Readymix and Tarmac.

### *HYDROCARBONS*

Geophysical surveys have helped to reveal deposits of oil and gas in many parts of the world. In Ireland, most future development opportunities are to be found offshore. However, geophysical surveys would provide a better understanding of onshore oil and gas reserves, including the potential for commercial exploitation.

## 4.1 EXPLORATION

### 4.1.1 METALS AND INDUSTRIAL MINERALS

Mining companies typically spend around 5% of their turnover on exploration. Up to £2 million is spent each year on exploration by Tara Mines, of which about 20% is actual survey work. Unlike dedicated prospecting companies, mining companies can offset exploration costs against corporate taxation.

Prospecting licenses are issued for six years. Fees are nominal. A standard prospecting license costs £2,500 over three years for an area of around 30km<sup>2</sup> (between 10-100 km<sup>2</sup>). However, to encourage continued exploration activity, firms must demonstrate minimum expenditure of £36,000 over three years for standard licenses, £14,000 for licensed areas, or £9,000 for open ground.

Licenses are held by a mixture of companies, including the major mining interests and smaller prospecting companies. In 1999, a total of £7.27 million was spent on exploration, of which £2.35 million was accounted for by exploration drilling costs. An indication of how much of the remainder was spent on other geological work is given in Table 4.1.

**Table 4.1 EXPLORATION EXPENDITURE 1999**

<i>prospecting</i>	<i>base metals</i>	<i>gold</i>	<i>other minerals</i>	<i>total</i>
geology	970,183	85,202	57,500	1,112,885
geochemistry	368,961	30,202	64,100	463,706
geophysics	746,101	6,050	4,000	756,151
airborne geophysics	985,460	0	56,410	1,041,870

*source:* DMNR (2000)

In the early nineties, it was predicted that there was an 80% chance of at least one major new discovery in the next ten years (GoI, 1995). In fact, there have been no major new finds since that time and exploration has been held back by low international metals prices. Towards the late 1990s, there was a renewed amount of exploration, largely as a consequence of more facilitatory state policy and the cyclical trends in the industry. In 1999, 463 prospecting licenses were in issue, a slightly higher number than in recent years. These cover an area of around 14,500km<sup>2</sup>. Much of the exploration has been for zinc, but also for nickel in the west. In addition, there is a continuing search for gold and, more recently, gemstones.

### **4.1.2 Quarrying**

Exploration for aggregates tends to be more low key than that for minerals. Around 1% of companies' turnover is believed to be spent on exploration. Acceptable sand and gravel deposits are usually small and often revealed by a mixture of geological mapping, geomorphological interpretation and local knowledge. However, the stakes are rising due to the emergence of major international companies, demand for high quality PSV aggregates for road-building, and interest in coastal deposits suitable for bulk export. Economic growth has caused increased demand. For example, it takes between 300 and 400 tonnes of aggregates to build a typical house (EPA, 2000).

## **4.2 Economic assessment**

### ***4.2.1 Metals and industrial minerals***

Mining for metals contributes around £300 million each year to the economy, of which the value of base metal output is over £100 million. Although a fall from the late seventies when mining contributed 2.4% of net industrial output, its output is still a respectable 0.6% of GDP. Employment, has fallen somewhat due to increased mechanisation, but still accounts for more than 1000 people directly. Downstream development is limited to the processing of gypsum and imported alumina.

Once a commercial sized deposit is found, it will take at least two years for a full assessment to be made. In the case of Lisheen, nine years passed before extraction began. Known deposits can lie undeveloped for many years until planning permission, higher market prices or a company's situation ensure that the deposit is ready for exploitation.

Nevertheless, once a mine is opened, production may continue for twenty years or more. Reserves at Navan amount to 28 million tonnes and could sustain the mine for at least a further 10-15 years. Galmoy has reserves of at least 10 million tonnes, and Lisheen 19 million tonnes, each being enough for production for at least 15 years. If these reserves continue to be exploited, then these three mines will turnover a billion pounds in the next ten years.

At present the net economic value of employment and the wage bill is more restricted to peripheral geographical areas due to the economy being close to full employment. However, mines have a long operating life and national economic fortunes can change over such a period. Furthermore, the scale of output produces a substantial pay-back in terms of purchasing of inputs and additional secondary expenditure, even allowing for the capital intensity of the industry and repatriation of profits. Companies currently pay royalties and corporation tax of 25%. The former are individually negotiated

depending of the nature of the deposit. For Galmoy they have been set at 3%, and for Lisheen, at 4.5%. However, total receipts are modest at £1.03 million (1999). The opening of a mine is also no guarantee of profitability. For example, low international prices for zinc and lead have been problematic for Tara Mines whose mine is high cost due to the deepness of the remaining deposit.

The external cost of mining has diminished due to tighter environmental regulation and monitoring. However, as a high risk activity, mining is heavily regulated as far as the environment is concerned and planning applications are carefully assessed. Some mine drainage water carries sulphate in solution which requires stringent treatment to remove threats to groundwater or the environment.

#### *4.2.2 Quarryings*

The quarrying sector is worth £200 million annually and employs around 3,000 people. Exploration for sand, gravel and rock is driven by market demand. At present, this is extremely strong due to the country's rapid economic growth. In 1998, 35 million tonnes of hard rock and 15 million tonnes of sand and gravel were quarried. These amounts will have increased as the construction materials industry has doubled its output in the last six years. The National Development Plan (NDP) foresees a need for 500,000 new houses over the next ten years, each of which consumes between 300 and 400 tonnes of aggregates (EPA, 2000). In addition, £4.4 billion has been earmarked for road construction, an annual increase of 100% compared with 1999.

In practice, the relevant market for aggregates is often local due to transportation costs. However, this situation is changing due to demand for specific products such as high quality aggregates (e.g. PSV) for road surfacing. In addition, the emergence of major international aggregate companies and planning restrictions on new quarrying activity abroad, presents a potential for export.

As with mining, quarrying has external costs which need to be considered by planners when considering permission for new operations. Environmental impacts include noise, HGV traffic, dust, visual intrusion, habitat damage, groundwater pollution risks and depression of the water table. In the UK, these costs have been estimated to average STG£4.60 per tonne (£9 sand/gravel & £3 for hard rock) (London Economics, 1998). The prominence given to property impacts meant that stated external costs were least for superquarries which are located in less inhabited areas.

### 4.3 Contribution of the RESI

#### 4.3.1 *EXISTING DATA*

To date, much of the exploration for base metals has been undertaken in the Lower Carboniferous rocks which straddle the middle of the country. Quite a large area, around 30% is currently covered by prospecting licenses. In total, around 50% of the country has been explored for minerals, about 30-40% in the recent past. Around half the country was surveyed using low resolution geophysics in the early 1980s. Large areas remain where the underlying geology is obscured by layers of peat, glacial drift or other surface deposits. These areas have only recently begun to be explored by companies using airborne geophysics.

There is poor geographical information on near surface Quaternary deposits which are the principal target of the quarrying sector. As noted above, deposits tend to be small and are located through a mixture of geological, geomorphological and local information.

#### 4.3.2 *THE RESI*

##### a). Metals

The RESI will provide a direct private benefit to mining and prospecting companies, and an indirect benefit to the state if new mineral deposits are found. It will provide several specific benefits:

- a *consistent* database which will assist usability, analysis and processing;
- continuous coverage in areas which have been surveyed, but not subjected to continuous geochemical or geophysical mapping;
- encourage exploration in new areas where underlying geology is concealed;
- data for the assessment of the environmental suitability of land for mining activity;
- data with which to avoid the sterilisation of hidden deposits by surface development.

The geophysical survey will be able to *see* beneath the surface layers and to detect variation in underlying rock types and faulting. Modern high resolution airborne magnetics is of most value for this purpose. This technique can provide information on the location of fault zones, including those which may be associated with minerals. Modern techniques can even, in some cases, directly detect concentrations of minerals through the presence of magnetic minerals.

Geochemical surveys are able to detect very small traces of metals and associated secondary products in soils, water and sediment. These techniques are especially useful for detecting near-surface small or dispersed deposits of minerals, including gold (although they can provide secondary evidence to

complement geophysical methods in relation to deeper reserves). To date, the GSI have carried out stream and soil sample geochemical surveys over 15% of the country.

In both cases, mineral exploitation would require that follow-up intensive surveys be undertaken by mining companies, particularly in relation to deep deposits. Evidence provided by the RESI would encourage such follow-on activity.

The data is also of value for assessing environmental risk. It will reveal areas where groundwater could be threatened by pollution. For existing mines, the high conductivity of polluted groundwater will be revealed by the RESI (*see Contaminated Land*), although this information has less applicability to operating mines which are already closely monitored by the EPA.

#### b). Quarrying

For quarrying, benefits relate to sand or gravel extraction and to hard rock sources. If an electromagnetic technique is included in the RESI it will provide information on the:

- boundaries between the more distinctive rock types;
- depth of the over-burden (overlying deposits) which must be removed during quarrying;
- depth to basement, i.e. the depth of the deposit (most workable deposits being up to 30m);
- location of groundwater (management on inflows or analysis of aquifer threat).

This information will contribute to the business of locating potential deposits and, specifically, to determining the best location to commence quarrying and where to negotiate permissions. It could prove especially valuable in reducing the risk that deposits become *sterilised* by permanent above-ground development.

As with the mining companies, the RESI will improve the cost-effectiveness, and possibly the sophistication, of aggregate companies' exploration strategy. It will also benefit local public authorities who are among the main users of aggregates. The data will be of relevance to *planning decisions*, i.e. to eliminate risk of *sterilisation*, or as supplementary information by which to judge any risk to aquifers. Its full relevance also depends on the availability and *suitability* of this data for planners and for the smaller companies involved in quarrying.

### 4.3.3 COMPLEMENTING COMMERCIAL EXPLORATION

Widespread surveying has been undertaken by commercial companies, but only in areas liable to have surface deposits (i.e. around 15% of Ireland). Commercial survey data and drilling records become publicly available once companies relinquish their licenses. Private airborne geophysical data is only now about to enter the public domain five years after the first modern surveys were undertaken.

Surveying is expensive. A company might spend around £200,000 on geophysical mapping of a 20km<sup>2</sup> area. Moreover, due to the small prospects of a discovery, most exploration is unsuccessful. Consequently, companies have focused their attention on the most promising sites, even within the prospecting license areas. Much of the survey coverage is therefore discontinuous and geographically patchy. Moreover, data from different companies is not consistent. It may also be of low resolution or have focused on a limited number of minerals. Many recent surveys have been conducted in the vicinity of existing mines where the probability of success is greater and where capital investment has already been made.

The availability of a public database should therefore encourage new commercial exploration by *reducing the risk* that this will be unsuccessful. It will increase the *cost-effectiveness* of exploration. Companies will be encouraged to undertake further exploration:

- within current prospecting areas where unexpected anomalies are revealed by the new data,
- in unexplored terrain where bedrock geology is concealed over large areas.

A new *discovery* is only one of the reasons why a company might invest in exploration. The RESI would therefore result in *little displacement* in the short/medium term because companies would not be able to justify the additional surveying costs against the prospects of a new discovery. Much private airborne surveying also tends to be the more expensive Time Domain EM which is not being included in the RESI. There would also be little displacement in relation to exploration undertaken by the larger aggregate companies.

Rather, the RESI acts as *leverage* for subsequent commercial intensive surveying where interesting anomalies are found. Over time, companies will themselves investigate new areas, but would be unlikely to do without the RESI in those areas where the underlying geology is concealed beneath surface layers and would not justify a commercial investment.

A CBA is justified as the public sector does not have to demonstrate a profitable return on investment in the same manner as commercial companies. It is not itself responsible for the development of new

resources and can make data available to a range of parties. Furthermore, there is the secondary advantage that the RESI could provide advance strategic and independent data with which to make a preliminary judgement on environmental impact.

#### 4.3.4 Probable outcome based on past experience

In the UK, the British Geological Survey's Mineral Reconnaissance Programme now covers 80% of the country. It has been instrumental in providing new data on a variety of potentially economic deposits and in locating a valuable baryte deposit near Aberfeldy which is now being exploited. The deposit produces around 50,000 tonnes each year and will have produced output valued at £35-40 million over its 16 year lifespan. In Devon, the Programme located gold deposits in area not previously considered to be promising.

In Australia, mineral exploration in Victoria increased by 60% and petroleum more than doubled after the state government launched a A\$16.5 million (IR£8 million) minerals initiative (VIMP) including a major geophysical survey (Robin & Spencer, 1997). An important factor was that the initiative encouraged exploration in new unexplored areas. The same was true of South Australia where a A\$21.4 million state initiative (SAEI) led to an additional A\$33.5 of commercial investment in exploration.

However, a comparable boost of exploration activity in Ireland is unlikely because of the existing understanding of the country's geology. Nevertheless, consultees in the DMNR believe that the RESI could still encourage an increase in activity of up to 30%. and this could be worth £2.4 million. The GSI argue that it would strengthen the case for companies to stay in Ireland. Follow-on exploration could reveal reserves under surface layers which would be workable in the short-term. It could also reveal strategic reserves which would be suitable for future development and which could underpin a continued mining industry in the country.

The country's near surface mineral deposits are already largely known. Six major base metal deposits have been worked since 1960, of which only Lisheen was initially located at more than 200m. depth. Clearly, shallow deposits represent only a fraction of Ireland's total mineral endowment (Finlay, 1981). The industry therefore believes that there are probably another two or three 10-20 million tonne deposits at economically workable depths of less than 500m. Such deposits would be of scale comparable to Lisheen or Galmoy.

The commercial response to available public data could be gradual, but possibly also sudden following an initial lag. A major geochemical survey undertaken by the GSI in the eighties in the south-east of Ireland initially encouraged a limited amount of exploration activity. Commercial exploration for tungsten has now recommenced. Typically, the smaller exploration companies have limited resources with which to respond to new data. The larger international mining companies' exploration effort is more conservative. These companies have investments elsewhere in the world and will inject resources in new exploration when they consider it to be appropriate given cycles in world metal prices and the lifetime of their existing mines. Interest in zinc is currently high given Ireland's reputation as a major producer and there is potential for a commercial gold mining in Northern Ireland. However, demand for lead is depressed and development of Connemara's nickel reserves would require an economic find.

#### **4.4 Summary contribution of the RESI**

Where mineral and aggregate reserves are concerned, the RESI would provide *direct benefits* for exploration activity. It would enhance the prospect of locating commercially viable deposits. In the short-term, the displacement factor is low. In the longer term, benefit streams from new mines would be subject to a discounting effect. Eventually, future exploration benefits too will be truncated by the emergence of new mapping technology (e.g. airborne gravity measurements) which might supersede elements of the RESI.

Nobody can predict precisely the difference the RESI would make to the chances of a major mineral find. Indeed, this type of information is arguably part of infrastructure that national governments are expected to provide if they wish to advance mineral exploration. Even if we assume that:

- a) just one new mine is opened (that would not otherwise be located for several decades),
- b) that this is largely as a consequence of the new RESI data,
- c) that it makes a conservative contribution to national income

this single mine could have a net present value (NPV) of at least £34 million, i.e. sufficient on its own to outweigh the full costs of the RESI.

Table 4.2a. Metals and industrial minerals

<i>Benefit</i>	<i>Nature of benefit</i>	<i>Economic value of end result</i>	<i>RESI contribution</i>
Improved exploration data	A direct benefit	Major companies have exploration budgets of between £0.5-2 mn/yr.	Could lead to a 30% increase in exploration, worth up to £2.4 mn/yr. Over 20 years.
Data on new mineral deposits in unexplored areas	An indirect benefit once new mine is opened. Assumption is that one major new mine opens in a new area within 15 years.	Mine contributes £150mn to national economy at present prices.	Major contribution as find would otherwise not have occurred for 30 years (if at all) even given use of other survey techniques.

Assumption used for CBA  
a). Mine opens 2015, operates for 10 years, annual revenue £15mn. Annual value due to RESI truncated at 2035 on the assumption that the mine would have been located privately by this time. (NPV = £34mn.)

More optimistic scenarios  
b). second mine opens 2020 (NPV = £76mn).  
c). two mines' lifetime values £100mn (NPV = £51mn.)  
d). two mines' lifetime values £200mn (NPV = £156mn)

Table 4.2b. Quarrying

Benefit	nature of benefit	economic value of end result	RESI contribution
Data on new aggregate (main) and hard rock (lesser) deposits.	A direct benefit realised once new quarry is opened.	High net value given current strong demand for sand and gravel. Allowing for environmental costs.	An important contribution in combination with other data. Most obvious contribution where deposits are well concealed below surface.

***Net Present Value of RESI***

Exploration: Middle bound. Contribution @ 0.8 = £19 mn

Upper @ 1.0 = £24 mn.

Lower @ 0.6 = £14 mn.

Minerals: Basic assumption. Middle bound. Contribution @ 0.8 = £27 mn.

Upper @ 1.0 = £34 mn.

Lower @ 0.6 = £20 mn.

Lowest: no new discoveries

Aggregates: Middle bound. Contribution @ 0.1 = £8 mn.

Upper @ 0.2 = £15 mn.

Lower @ 0.05 = £4 mn.

Lowest: no new discoveries

## 5. LAND MANAGEMENT

The RESI will assist policy makers, county councils and land managers with decisions in relation to the environmental impact associated with land use. The geochemical survey will map the inherent chemical composition of rock and soil. Together with geophysical data, it will provide evidence of the suitability of land for agriculture, forestry, sewage sludge application, built development and the sourcing of drinking water. In addition, the survey will be a potential source of information on the distribution of nitrates and phosphates in the environment.

### 5.1 Nature of the problem

#### 5.1.1 Acid pollution

Acid deposition occurs when certain chemicals (acid precursors) are released into the atmosphere where they are converted into acid and subsequently deposited through either dry deposition or acid rain. This can result in the biological 'death' of lakes which are susceptible to changes in acidity, the release of toxic metals from soils and damage to crops or forests.

Acid precursors can be carried long distances and across national boundaries. Consequently, international agreements have been negotiated over the years to restrict emissions. In late 1999, negotiations were completed under the United Nations Economic Commission for Europe which will restrict emissions of sulphur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>) and ammonia (NH<sub>3</sub>). Under this agreement, Ireland will reduce its acid emissions by 10,000 tonnes to 116,000 tonnes by 2010.

*Table 5.1 IRELAND'S ACID PRECURSOR EMISSIONS AND CEILINGS*

Year	Sulphur (kt SO <sub>2</sub> )	NOX (as kt NO <sub>2</sub> )	Ammonia (kt NH <sub>3</sub> )
1980	222.4	76.8	n/a
1990	177.9	114.6	126
1997	164.9	124.3	131
Ceiling for 2010	42.0	65.0	116
Percentage reduction required by 2010 (base year 1990)	76%	65%	8%

*Sources: Lehane, 1999; UN/ECE, 1999.*

In Ireland, agriculture is the principal source of acid emissions and, together with forestry, accounts for around half of acid precursor emissions, mainly in the form of ammonia.<sup>2</sup> On the ground, agriculture is a major source of the nitrates which quickly find their way into surface and ground water bodies (see relevant section). In 1994, power production was the second largest source of acid precursors at 26%, followed by industry at 10% and transport at 9%. Since these figures were compiled, the contribution of power output has fallen due to switching to other fuels, while those of agriculture, industry and, especially, transport have continued to increase.

### *Acid precursors*

#### **1. Sulphur Dioxide**

Most of Ireland's SO<sub>2</sub> emissions (60%) are from power plants, notably the coal-fired plant at Moneypoint in Co.Clare. However, this plant has already switched to low sulphur coal and is due either to close or be transferred to natural gas by 2008 under the National Climate Change Strategy.

The highest concentrations of SO<sub>2</sub> are found in the Wicklow Mountains and originate from imported pollution. The high levels of SO<sub>2</sub> in wet upland western areas are considered to be close to background levels (EPA, 2000).

#### **2. Nitrogen Dioxide**

NOx emissions now represent a more pressing problem than SO<sub>2</sub>. Half of total nitrogen emissions are due to transport. Total emissions are low in comparison with larger European states, but rising car ownership and use means that Ireland is now the third largest polluter on a per capita basis. The European Directive 1999/30/EC has set an average limit of 40 µg/m<sup>3</sup> to be achieved by 2010 and current concentrations are close to this level in many areas affected by heavy traffic. However, only around 10% of NOx deposition originates from within Ireland and concentrations are again highest in the east (EPA, 2000). Acidification of lakes in some afforested areas has occurred due to the filtering effect of trees on atmospheric acid pollutants.

#### **Ammonia**

NH<sub>3</sub> is a more home-grown problem than SO<sub>2</sub> or NOx. Over 80% of NH<sub>3</sub> deposition originates from within Ireland. Almost all of these NH<sub>3</sub> emissions are due to agriculture and derive mainly from the application of nitrogenous fertiliser and from animal waste. Emissions have increased from 112,000 tonnes to 126,000 between 1990-98 and are now by far the highest in the EU (EPA, 2000).

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<sup>2</sup> 48% in 1994.

### 5.1.2 Forestry

Acid rain is a serious problem in Western and Central Europe where it is severely damaging forests and has caused considerable losses to the few remaining areas of natural heathland. In Ireland, its impact has been less manifest, but still significant. On the one hand, Ireland has been protected by relatively low domestic emissions of SO<sub>2</sub> and NO<sub>x</sub> and by prevailing westerly winds. However, there are problems of acidification in upland eastern areas mostly due to imported SO<sub>2</sub> and NO<sub>x</sub> pollution. In the west, many sensitive and important ecosystems are at risk from relatively small changes in acidity largely due to the presence of all three sources of acid precursors in heavy rainfall. There is an economic risk to forestry, but the principal threat is the replacement of rare ecosystems with more common types.

The environmental pollution risk from commercial forestry occurs at two stages, during planting and during tree growth. Preparatory deep ploughing releases silt which can suffocate fish spawning streams. Where planting is undertaken on peat, as was commonplace in the past, organic matter and trace elements are released which could respectively encourage eutrophication or be toxic to fish. Other external costs are documented in detail by Clinch (1999).

Once grown, coniferous trees intercept air-borne acid precursors arising from air pollution and these contribute to the acidification of water bodies. Serious acidification problems have been reported at Roundwood in Co. Wicklow which experiences high atmospheric pollution due to its eastern location and altitude (Farrell *et al.*, 2000). In addition, this same scrubbing of acid precursors by trees can lead to the release of metals, particularly aluminium, to watercourses following certain soil/water interactions (Hornung & Adamson, 1991). Aluminium is highly toxic to fish. The problem is greatest on acid soils over mineral poor rocks and has been observed in Ireland (Giller *et al.*, 1993). The EPA adds that many forest soils throughout Ireland have been depleted in copper and zinc (EPA, 2000) and that over 400 tonnes of nitrogen are lost annually to water from plantation forestry (EPA, 1999).

The Forest Service has ambitious plans to increase the area of forest from 9% to 17% over thirty years. As there is a risk that the external environmental cost of forestry could multiply, the programme has been preceded by a major mapping exercise as part of a Sustainable Forest Management strategy. The mapping will evaluate the suitability of land for forestry based on six criteria relevant to Sustainable Forest Management including landscape quality, soil productivity and the risk to water quality. Important factors in relation to water quality are depth to bedrock and the characteristics and chemical composition of rock, subsoil and soil. Measurement of these factors will reduce the threat from acidification and aluminium leaching.

The strategy represents a reversal of the previous selection of poor quality land in favour of better quality land with the objective of good timber and lower environmental damage. In the past, upland peatlands were frequently ploughed for forestry leading to problems of siltration and acidification of water courses. The strategy also includes requirements that harvesting should not involve clear-felling but rather be phased. This should reduce the risk of siltration.

### 5.1.3 Agriculture

Agriculture can have positive impact on the rural landscape, but also produces a variety of external costs including acid emissions and nitrate leaching, eutrophication, methane emissions and pesticide damage. The first three of these have relevance to the RESI and arise from:

1. Release of acid precursors into the atmosphere leading to either dry deposition or acid rain.
2. Direct release to surface water as run-off or to groundwater.

NH<sub>3</sub> emissions are the most serious cause of atmospheric pollution and deposition arising from agriculture in Ireland. Most NH<sub>3</sub> is deposited within short distances and presents a particular problem where intensive agriculture is practised close to sensitive ecosystems. The problem is mainly associated with the increasing intensity of livestock production, both directly from the animals themselves and from the application of slurry. A contribution is also made from inorganic fertiliser applications, especially in tillage areas.

As well as NOX and NH<sub>3</sub> emissions, nitrates and phosphates are rapidly lost to run-off. These substances pose particular problems for surface water quality and natural ecosystems in the form of acidification and eutrophication. These problems are further supplemented by direct acid deposition from the atmospheric. Nitrates may also reach groundwater and aquifers where they can become a problem for human health.

Due to the intensification of agriculture, the existing level of phosphate on much farm land is surplus to pasture or crop needs. The EPA estimates that the annual net loss of surplus phosphate is 4,600 tonnes, equal to 8% of applications (Tunney *et al*, 2000). In the case of nitrogen, a similar surplus exists. This represents an entirely unnecessary burden on the carrying capacity of the environment as well as an avoidable cost to farmers.

The question of how to reduce the problem largely relates to agricultural policy. As a form of non-point pollution, acid emissions, and phosphate and nitrate pollution are difficult to police and represent

an almost intractable problem. Various measures are being promoted to deal with the problem, including grants provided under the Control of Farmyard Pollution Scheme, nutrient management plans contained within the Rural Environmental Protection Scheme (REPS) and the proposed nitrate vulnerable zones. Tentative suggestions by the Department of the Environment that the national herd could be reduced by 10% is but one way of dealing with the problem.

**Table 5.2 Water Pollution attributable to agriculture, by intensity, 1995-97**

<i>Degree of pollution</i>	<i>% of cases attributed to agriculture</i>
Slightly polluted	47
Moderately polluted	46
Heavily polluted	25

*Source:* EPA (1999)

#### **5.1.4 Trace element deficiency and toxicity**

Trace element deficiency and toxicity can adversely affect both human and animal health (the former is discussed in Chapter 8). Deficiencies can result in crop failure or losses of productivity. Excesses of some elements can be toxic if ingested in herbage. In either case, the availability of trace elements is greatly increased where drainage is poor. However, except in some extreme cases, e.g. mining tailing ponds, these elements are frequently filtered out by the plants themselves. Although, for some elements, the difference between levels which are beneficial or toxic is extremely fine.

Natural trace element deficiencies continue to be a problem for livestock, especially where animals are largely dependent on a single source of forage. Deficiencies of elements such as I, Cu, Se, Co, Fe, Mn, Ni, and V can cause health problems for livestock such as anaemia and immune system deficiency. For example, copper deficiency can cause weight loss and iodine deficiency can lead to still-births. In Scotland, Berrow & Reaves (1985) found that 79% of soils contains insufficient Cu to support grazing (<3 mg kg<sup>-1</sup>).

In practice, deficiency problems are readily countered by supplements such as COSECU, but frequently go undiagnosed because the effects are indirect, sub-clinical or even non-clinical (no evident impact). In the rather capital intensive dairy sector, the direct relationship between animal health and milk productivity means that supplements are widely used. Deficiencies are a more serious problem in the less intensive beef sector. Although iodine deficiency is a problem for both the dairy and beef sectors due to its short-cycle retention in livestock.

Other elements such as Al, Se and Mo, are harmful in excess concentrations. The last of these, is known to be problem on calcareous soils where it is associated with scouring and growth retardation due to reduced copper absorption (Suttle, 1988). For cattle, selenium deficiency is a thousand times more prevalent than toxicity, but can be a serious problem where it occurs. It is a particular problem for horses.

Crops too are vulnerable to deficiencies that reduce productivity. For example, without supplements, the productivity of cereal crops in much of Counties Carlow and Cork would be poor due to low Cu or Zn counts in soils. Zinc deficiency also leads to stunting or poor uptake of nitrogen by potatoes and beet, while boron is essential to the production of the latter. Forestry too requires manganese to ensure that bark is suitable for mulching if the full value of the timber crop is to be realised. Land managers might mistakenly attribute problems with crops, especially more minor problems, to other causes such as fungal diseases, pests or insufficient fertiliser. Once recognized though, problems can quickly be put right through the use of appropriate fertiliser.

The availability of many trace elements to both livestock and plants is determined by the presence of other elements, soil pH and Eh. Thus, high concentrations of certain compounds such as iron oxides, Mn and Mo can also affect the capacity of plants to utilise elements such as Cu, Zn or P. The relationships are often complex. For instance, copper deficiency is determined by high manganese which can induce deficiencies even where the level of copper is high. Similarly, high soil pH reduces the availability of Mn, B and Zn, but increases that of Mo and Se. Fertilisers can remedy deficiencies, but excess applications can also be harmful. For instance frequent lime dressings can lead to losses of Cu, Zn and Se. Deficiencies of copper <2 mg/kg are common in Ireland and a problem for cereals. They can be easily supplemented, but copper will become toxic at concentrations greater than 20 mg/kg.

## **5.2 Economic assessment**

### **5.2.1 ACID POLLUTION**

There are three fundamental costs associated with acid pollution.

1. Changes to chemical composition of soils and water (and hence ecosystem impacts);
2. Damage to vegetation;
3. Material damage to buildings.

Due to the relative scale of its pollution and to the prevailing winds, Irish acid emissions have not had the same impact as in other European states. The greatest problems are vegetation and ecosystem damage. This damage has been less prevalent than in other countries, but Ireland does possess some sensitive and rare ecosystems which are highly vulnerable to any change in acidity. Acidification has become a problem in forested catchments such as upper Glendalough and Roundwood in Co. Wicklow. It is believed to have wiped out the rare native population of charr in Lough Dan. Damage of this kind will be difficult to reverse without major changes in fossil fuel use and agricultural policy. Moreover, given the practical difficulties of restoring ecosystems, together with the rarity of some of the ecosystems involved, the phenomenon has the potential to be irreversible.

In cases where ecosystems are unique or threatened with irreversible damage, economics asserts that they are likely to have a high existence value (Krutilla & Fisher, 1975). As such, it has been argued that they should be protected by a sustainability criterion (Pearce *et al.*, 1989). No studies have been conducted in Ireland to establish the total economic value of ecosystems threatened by acidification. However, given the rarity of the ecosystems, an approximation is provided by Hanley and Craig (1992) for the unique peatland Flow Country of Northern Scotland. Although the 400,000 plus hectare Flow Country is threatened directly by afforestation as much as by acidification, the study revealed a total present use and non-use value of up to £4.1 million figure based on the values held by the Scottish population alone.

#### ***EU regulations and international agreements***

In addition to the direct economic cost of the impact of acid pollution, there is a cost involved in meeting European regulations and the requirements of international agreements. Current EU policies propose that the share of ecosystems receiving acid deposition in excess of their critical load should fall to 5% by 2010 (from 25% in 1990). There is also an accelerated policy scenario which calls for a "50% gap closure", i.e. that the area of ecosystems not protected should be reduced by at least 50% compared with 1990 levels. At a Community level, the cost of meeting these targets will be high given the extent of damage in much of continental Europe.

Ireland is further bound to reduce its output of acid pollutants by the Convention on Long Range Transboundary Air Pollution. The Convention forms the basis for the recently agreed Gothenburg Protocol which aims to use a co-ordinated approach to tackle a range of air-borne pollution including acidification, ozone and carbon dioxide emissions. It provides the basis for the EU National Emissions Ceiling Directive which is the first to set limits on total emissions for each Member State (EPA, 2000). In the baseline scenario, the EU's output of SO<sub>2</sub> and NO<sub>x</sub> is expected to be 44% higher than current levels. That for NH<sub>3</sub> is expected to increase dramatically by 36 times due to the currently weak controls in the agricultural sector. Existing policies to reduce these outputs would cost €67 billion per year (1997 prices). Although Ireland's share of these costs is small due to its lower total emissions of SO<sub>2</sub> and NO<sub>x</sub>, the accelerated policy scenario calls for more stringent controls, including of NH<sub>3</sub>. It is expected to cost €43 billion more than the baseline (EEP, forthcoming).

The marginal cost for NO<sub>x</sub> control ranges up to €13,000 per tonne. No figure is available for NH<sub>3</sub> although much reduction could be achieved at little cost as mostly it is changes in agricultural practices rather than output that are required (EEP).

### 5.2.2 FORESTRY

The Forestry Service plans to invest £3.7 billion over the next thirty years in an ambitious plan to increase the area of forest cover to 17%. A total of £580 million has been budgeted for the duration of the NDP 2000-06, most of which will be co-funded under the CAP Rural Development Plan. It is intended that this will increase the amount of planting to 20,000 hectares per year.

The strategy is predicted to have socio-economic benefits in preserving rural livelihoods which are threatened by the increasing marginality of small farming. It will also contribute significantly to efforts to reduce CO<sub>2</sub> emissions in line with Ireland's Kyoto obligations. In addition, the objective of planting more broadleaves and on better quality of land, could increase the productive value and add opportunities for more value-added processing.

### 5.2.3 NITRATE POLLUTION

Nitrate pollution is dealt with in greater detail, along with phosphates, in the chapter on Water. While there is some uncertainty over the health risks, European regulations in relation to nitrate contamination of drinking water could result in groundwater being classified as unsuitable for drinking, necessitating costly replacement with alternative supplies. In addition, there is a risk of acidification of surface water.

The EC Nitrates Directive consequently sets a maximum admissible concentration of 50mg/l of nitrates and a recommended limit of 25mg/l. The Directive also requires that Member States establish nitrate vulnerable areas where agricultural activity must follow certain codes of practice.

Designation of nitrate vulnerable zones (NVZs) depends on the permeability of the underlying strata, the importance of aquifers and the nature of land use. The Government is being required to establish NVZs. In the UK, where the problem is worse, large sums are being spent on compensation for output losses incurred by farmers residing in vulnerable areas in return for average reductions of 33kg/ha. Compensation varies between £65 per hectare for the basic grassland option to £250 per hectare for premium grassland and up to £550 per hectare for good arable land, although a recent evaluation indicates that these payments have been excessive by around one third (MAFF, 1998).

No economic analysis has yet been undertaken by the DAFRD of the implications of NVZs in Ireland. According to Teagasc, 13 aquifers are being considered for protection in 2001. Initially, at least, these will cover only a small area (Regan, *pers comm*). The bill could amount to IR£80 million if 1,000 farmers are compensated at levels similar to the grassland options in UK.

#### **5.2.4 Trace element deficiency and toxicity**

Due to the complex interactions between different elements, Teagasc argue that it would be extremely difficult to demonstrate the implications of trace element deficiencies and toxicity on arable output beyond farm level. The same is true of livestock where deficiencies may cause reproduction problems or poor performance which are difficult to quantify in cumulative economic terms. In many cases, deficiencies have no discernible impact on productivity. For example, of 52 cattle herds revealed as having a “serious” copper deficiency, only 14 showed any evidence of production loss (P.Rogers, *pers.comm*). Consequently, there have been no efforts to demonstrate the economic cost to Irish agriculture. However, the costs are likely to be significant, not least in terms of financial losses and inconvenience to individual farmers together with the implications for animal welfare, i.e. malnutrition.

Similarly, it is difficult to diagnose problems with crops. This occurs not least because the soil status is constantly changing. Efforts to increase productivity will result in extra biomass and may lead to deficiencies where previously none were apparent. Acidification will also affect the availability of trace elements in the future. Fertiliser applications will also change the soil composition. Indeed, changes in the type or ingredients of the fertiliser itself may also expose deficiencies because compounds are no longer available or included in the formulas due to toxicity fears.

In the main, the greater continuing agricultural loss is to livestock rather than to tillage crops. Amongst livestock farms the losses on dairy farms have been minimised. Selenium and copper deficiencies have been reduced from 7% in the seventies to less than 1% today, and only iodine deficiency continues to be a problem. Generally, on the more specialised and intensive farms in the east and south-east, any deficiencies will quickly be picked up by farm advisors. Elsewhere, smaller farms abandoned dairy and tillage crops in favour of beef or sheep.

It is the extensive livestock farms in the west where most problems now persist. Due to their smaller size, these farms also support the majority of the farming population. Furthermore, many livestock farms are being encouraged to reduce their dependence on housing and concentrates and to extend their grassland systems for environmental and organic reasons. This could expose trace element problems.

An indication of the economic cost of trace element deficiency is available using the example of copper. Of animals not receiving nutritional supplements, 60% had a deficiency in copper. Of the

affected sample analysed by Rogers, this was revealed as a production loss in 19% of cases. Typically this loss would result in around a 15% loss of liveweight gain per day. If we assume that 80% of the nation's sucker animals are not receiving supplements, then copper deficiency could be causing a loss of agricultural output of £13 million per year out of a total value of farm gate output of £926 million (before allowing for transfers).

It may not be unreasonable to assume that the combined effect of deficiencies in I, Se, Co and other elements could be causing a loss equivalent to that of copper. Toxicity is a lesser problem, but would also involve an economic cost.

### **5.3 The Contribution of RESI**

Currently, the EPA monitors air quality, an effort which is supplemented by some monitoring by local authorities and universities. Ten research stations monitor acid deposition and modelling of these records are used to draw deposition maps. In addition, the EPA regularly undertakes biological sampling of river water quality, together with some less extensive chemical sampling, although only a small proportion of the country's lakes are sampled and a national groundwater sampling programme began in 1995.

The RESI cannot provide a baseline map of dry acid deposition. It can potentially provide once-only data on surface nitrate levels which could be overlain on maps of land use and soil vulnerability. The detectability of these nitrates and phosphates in rivers is less precise and greatly influenced by large seasonal and diurnal variations. The levels of biologically available nitrates in lakes are more stable.

Rather the RESI would provide the following benefits:

- Data on the composition of sub-soils and bedrock which can be used to indicate weathering and thereby to model acidification;
- Evidence of vulnerability to nitrate leaching with which to improve the cost-effectiveness of agricultural policy;
- Data on toxic metal leaching due to land uses such as forestry;
- Evidence of the structural suitability of land for various uses;
- Data on trace element distribution of relevance to all land uses;
- Data on surface waters.

### **5.3.1 Acid pollution**

The RESI will provide information on the nature of sub-soils and bedrock. This can be used to indicate weathering rates and thereby to predict the local environment's susceptibility to acidification. The nature of the bedrock, particularly the presence of Ca and Mn will indicate the buffering capacity of the environment in relation to acid contamination. Levels of aluminium in water reported by the geochemical survey will provide an indirect indication of acidification in forested catchments.

### **5.3.2 Land suitability**

The survey would reveal background levels of trace elements in soils and underlying rock, particularly those released in water. Together with other information, such as soil pH, this could be used to indicate where certain land uses could pose an environmental hazard as, for example, in the case of forestry and aluminium leaching. Similarly, a mixture of geophysics and ground-based measurements can be used to indicate levels of soil moisture. The rates of growth of Scots Pine and Norway Spruce react very differently to variations in soil moisture (Hyvonen *et al*, 1998).

It will be possible to incorporate the data from RESI in the Forestry Inventory Planning System (FIPS) currently being prepared by Teagasc Kinsealy and the Forestry Service. Together with other information contained in the GIS, the RESI will indicate where forestry presents a risk of acidification or of the leaching of metals. For the purposes of the Indicative Forest Strategy, the geophysical and geochemical surveys will provide more detail on the nature of the bedrock and its therefore its capacity to buffer acid pollution. It would therefore complement existing FIPS data on the same area, but would need to be supplemented by intensive soil samples before planting actually takes place.

In addition, the geochemical survey will indicate the presence of elements essential to productivity such as manganese. The geophysical component of the RESI will provide indicative information on the depth to bedrock and therefore on the appropriateness of planting on soils which could be shallow, vulnerable to waterlogging or erosion, or important to the protection of an aquifer from nitrification.

### **5.3.3 Nitrate contamination of groundwater**

The RESI would indicate the vulnerability of groundwater to nitrate contamination from agriculture or forestry (see also section on Water). Appropriate codes of practice could therefore be imposed where the risks are highest and in a manner which would be more cost-effective than the mapping of

geological strata alone. Soil tests are currently performed by Teagasc and private surveyors, often in response to applications from farmers themselves. However, no national inventory currently exists or is updated. Regular soil tests are only performed in the nitrate vulnerable zones subject to Cork County Council bye-laws.

The RESI would provide a picture of background nitrate levels as well as on the vulnerability of groundwater to nitrate pollution. This would contribute to ensuring that policy is cost-effective. For example, when demarcating NVZs, policy makers need to know which farmers would be required to reduce stocking or nutrient applications. This may involve a reduction in the intensity of farming which could affect private profitability, although public resources would be needed to implement the regulations, to monitor the situation and to cover compensation for agricultural losses. Inevitably, implementation of the Nitrates Directive will involve a raised level of spending, but expenditure in locations where there is no environmental hazard would be a deadweight loss.

#### ***5.3.4 Trace element deficiency and toxicity***

In relation to trace element deficiency or toxicity, the RESI would provide a more detailed baseline maps than are currently available from soil samples taken by Teagasc.

The maps would reveal where farmers could be at risk of productivity losses and should be advised to apply fertiliser or nutrient supplements. Furthermore, by defining precise fertiliser needs, the RESI could potentially reduce the physical quantity of fertiliser applied to our soils (often in ignorance of trace element deficiencies) and this would potentially help to reduce the external environmental costs associated with farming. To meet this requirement, the RESI would provide an indication of the availability of trace elements for uptake by plants.

Ultimately, the contribution of the RESI to improved agricultural productivity depends on the willingness of the DAFRD to provide complementary resources. Currently, trace element analysis is a problem that is perceived as having a low priority in relation to other policy needs.

## Summary contribution of the RESI

<i>Benefit</i>	<i>nature benefit</i>	<i>Economic value of end result</i>	<i>RESI contribution</i>
Acidification	Direct benefit re suitability of land for forestry. Indirect benefit by indicating areas at risk from acidification.	Damage to rare ecosystems. Can be irreversible. Existence value transfers on basis of overseas studies suggest possibly £40 mn/yr.	Small (0.01-0.05), but important contribution by indicating buffering capacity and risk of metals. Minor contribution by measuring AI and metals in streams. Of value to <u>DoE</u> , <u>DAFRD</u> & <u>EPA</u> .
Acidification policy	More cost-effective policy action	Avoidance of an aggravated problem through poor land use decisions. Not quantifiable	Baseline data for land use decisions and monitoring. Of value to <u>DMNR</u> & <u>DAFRD</u> .
Location of forestry	Direct benefit. Info on acidification and risk of heavy metal leaching.	£3.7 bn being spent over 30 yrs. £6-8 mn is being spent on indicative forest strategy. Avoiding acidification and poisoning of fish by AI (captured above & in Water section).	Important, contribution complementary to FIPS for use in the indicative forest strategy. Of value to <u>DMNR</u> , <u>Coillte</u> , <u>Teagasc</u> & private <u>forestry companies</u> .
Groundwater pollution due to agriculture.	More cost-effective demarcation of NVZs.	Savings in unnecessary compensation payments. Initial annual policy expenditure likely to be £800,000 /yr., but these payments could increase.	Would indicate nitrate levels, location of aquifers and depth to groundwater. Important to <u>DoE</u> & <u>DAFRD</u> , <u>EPA</u> . & <u>county councils</u> .
Trace elements and agriculture	Indirect benefit. Avoidance of deficiency and toxicity.	Highest in beef sector, perhaps £13mn pa. Avoidance of personal and animal welfare costs.	Would add detail to existing maps compiled by Teagasc. Value depends on follow-up action being taken (perhaps 01-0.2 over 10 yrs). <u>DAFRD</u> & <u>Teagasc</u> .

### *Net Present Value of RESI*

Discounted over 20 years from completion of survey:

Acidification & forestry siting: Middle bound. RESI contribution @ 0.025 = £9.78 mn

Forest inventory: Estimate. RESI contribution @ 0.05 = £350,000

Savings on NVZ payments: Middle bound. RESI contribution @ 0.25 = £2 mn.

Toxicity and deficiency in beef output: Middle bound. Contribution @ 0.15 over 10yrs= £14 mn

Note: Benefits are largely public benefits. True also for beef production as this is largely subsidised.

## 6. WATER, GROUNDWATER AND DRINKING WATER

The long awaited Water Framework Directive which has now been approved by the EU Conciliation Committee will incorporate previous water related directives issued by the Commission, including the Nitrates Directive and Drinking Water Directive. It sets a target for water quality of “good status” which is to be achieved by 2015.

To satisfy the requirements of the Directive, a considerable effort will be needed to describe and categorise surface and groundwater. This database will provide the baseline for future monitoring. The information required will go far beyond anything already possessed and will involve the application of multidisciplinary expertise within a geographical information system (GIS).

The RESI can provide a considerable amount of the information required in terms of surface water composition and groundwater composition and flow. This will have two benefits. Firstly, it will contribute to more *effective* environmental management. Secondly, it will ensure that policy is more *efficient* in its use of public funds and, therefore, is more cost-effective.

### 6.1 Nature of the problem

#### 6.1.1 Nitrates

Levels of nitrates are increasing in many Irish river catchments and groundwater aquifers. At present, the incidence is low with 80% of groundwater sampled by the EPA having a NO<sub>x</sub> level below the 25mg/l guideline level. Only 2.6% of sites had nitrate levels above the critical 50 mg/l level (equivalent to 5.65mg/l N).

#### **High nitrate levels in drinking water have been associated with the following impacts:**

- Concentrations above 50mg/l have been linked to an increased risk of methaemoglobinaemia, or ‘blue baby syndrome’, a life threatening disease in infants.
- Alleged cancer risks due to reactions with stomach compounds to form products known to be carcinogenic.

## **POLICY**

Official efforts to monitor water quality in Ireland commenced with the Local Government (Water Pollution) Act of 1977 which provided for water quality management plans. Since this time, 15 plans have been prepared by local authorities, mostly in the Midlands. These plans have mainly been directed at surface water and have focussed on pollution threats from point sources. Consequently, groundwaters have been rather neglected, while diffuse source phosphate and nitrate pollution have increased considerably. According to the EPA, the resulting eutrophication is the principal reason for the decline in the number of “unpolluted” length of river from 84% in 1971 to 51% in 1997. Although, the proportion of seriously polluted rivers has continued to decline from 6% in 1971 to less than 2% today (EPA, 2000).

In recent years there has been a surge of policy initiatives related to water quality. These have been precipitated by European Directives including those for Urban Waste Water Treatment, Nitrates, and Integrated Pollution Prevention and Control.

The new Water Framework Directive transcends previous policy in that it will integrate surface and ground water management. The Directive also provides a basis for the design of strategies for the sustainable management of water resources and for the protection of ecosystems, including fish populations. Specifically, it aims to:

- prevent any further deterioration in aquatic ecosystems;
- promote sustainable water use;
- reduce discharges and emissions of polluting substances;
- reduce groundwater pollution;
- contribute to the mitigation of the effects of floods and droughts.

In the majority of cases, a target of “good ecological status” is sought. In Ireland’s case, this will probably require an improvement in the 20% of rivers currently described by the EPA as being “moderately” or “seriously polluted”.

The Directive requires an analysis of the characteristics of all major aquifers, including their chemical status, the impact of human activity and economics of water use. For surface waters, information on flow rates as well as chemical and ecological status is required. The Department of the Environment has until 2004 to undertake this task for which it has set aside a sum of £50 million.

The analysis will go towards the preparation of River Basin Management Plans which will aim to maintain good water quality and will involve controls on abstraction and discharges. Continuous monitoring of water quality will follow. The Directive itself states that a failure to meet the general requirements of the Directive will attract penalties which are “effective, proportionate and dissuasive.”

The EU has placed great importance on a reduction in nitrate levels, although the nature of the health risk and its exact relationship with nitrate levels is rather contentious. In surface waters, high nitrate levels certainly do cause enrichment leading to eutrophication, particularly in estuarine environments, although surface water nitrate levels in Ireland are not a major cause of eutrophication and levels are generally less than in many other EU states. However, levels in both surface and ground water in the south-east are high and rising.

Agriculture is the major source of nitrates and ammonia (which converts ultimately to nitrates). The problem is discussed further in the section on Land Management. N and NH<sub>3</sub> are leached directly from surface applications of organic and inorganic fertiliser into streams and groundwater. The EPA (2000) estimates that the annual net loss of N not taken up by plants to be 103,000 tonnes which is equivalent to 25% of N applications. Forestry too has been estimated to release 410 tonnes of N to water (EPA, 1999).

The rate of increase is a concern. If this increase remains unchecked, eutrophication could become more widespread and some drinking water supplies could exceed the maximum acceptable threshold. Considerable state expenditure would then be needed to provide the infrastructure for alternative drinking water supplies. Consequently, the EU requires the establishment of nitrate vulnerable zones. These zones will be selected largely on the basis of the permeability of surface layers and the importance of underlying aquifers to water supply.

### **6.1.2 Phosphorous**

The Department of the Environment and Local Government (DELG, 2000) describes the most pressing threat to the Irish rural environment as being the eutrophication of water sources. Nitrates are a contributory factor, but the principal cause of the problem in Ireland is elevated phosphate levels. As well as being unsightly, the pollution causes excessive algal growth which reduces dissolved oxygen levels and leads in turn to loss of biodiversity, including fish stocks. Serious declines in river quality have been reported by the Lough Derg and Lough Ree Catchment Management and Monitoring System and the Three Rivers Project (Liffey, Boyne and Suir) amongst other river systems. A study by the Cork Institute of Technology has reported toxic cyanobacteria blooms linked to eutrophication in one fifth of rivers and lakes, including some used for drinking water (Irish Times, 5/1/00).

The EPA has singled out agriculture to be the greatest source of phosphate pollution, at least along water courses it describes as being “slightly or moderately polluted” (EPA, 2000). According to Scott (1999), 62-72% of ‘eutrophication potential’ is due to agriculture. The other major causal factor, urban and domestic sewage, can be more easily sourced and hence is gradually being dealt with through more stringent environmental regulations. A more minor contribution is made by peatland workings. Operations in the Brosna River catchment are believed to contribute 8% of the total P load entering the river (EPA, 2000).

### **6.1.3 Bacteriological contamination**

Bacteriological pollution represents the most immediate threat to groundwater. In tests conducted by Lucey *et al* (1999), one third of samples have elevated contamination, most especially of faecal coliforms. Given that many of the group water schemes sampled rely on groundwater, this suggests there has been insufficient disinfection and protection of water sources. The high incidence of contamination is one of the major reasons why Ireland has been threatened with punitive fines by the EU for failing to improve water quality.

### **6.1.4 TOXIC METALS**

Surveys by the EPA suggest that the risk of elevated toxic metal levels in water is small. There are indeed problems related to some old mining sites such as those at Avoca and Silvermines where water acidity is low and metal levels are high. However, in much of Ireland, the risk of more widespread natural contamination is reduced by the buffering effect of surface carbonate deposits. The coverage of surveys to date has, though, been limited and there are certain to be pockets of high natural contamination which are currently unknown. The G-BASE survey conducted by the British Geological Survey found high concentrations in many locations, such as levels of arsenic in Snowdonia. While, contamination is probably localised, the prevalence of water sourced from individual wells and small group schemes in rural Ireland does increase the risk to health.

Soluble nitrates themselves help release heavy metals into water where the water itself is naturally acidic. Forestry scrubs polluted air of nitrates which releases aluminium from soils into water. As a result, some rivers in forested catchments such as upper Glendalough are known to have high levels of acidity.

Similar land use/water interactions will release other heavy metals into ground and surface waters. These could pose a local threat to people and livestock. As with aluminium, small increases in metal levels are highly toxic to fish.

## 6.2 Economic Assessment

### 6.2.1 DRINKING WATER INCLUDING GROUNDWATER

Three quarters of the country's drinking water is abstracted from surface sources and one quarter from groundwater sources, of which public authority supplies represent 15%. The proportion taken from groundwater is lower than in many other European countries, although many rural households source their water directly from individual wells and group water schemes.

A sum of £2.495 billion has been earmarked for water and waste water investment under the Economic and Social Infrastructure Programme for the period of the NDP. This huge amount of expenditure is a response to tighter environmental regulation and the existing poor state of the country's infrastructure. The figure includes a sum of £380 million for water supply (quality, treatment & distribution) and £550 million for management and rehabilitation (including reduction of leakages). A further challenge is presented by the need to keep pace with the current rapid rate of urbanisation, provision for which has been included in a further £463 million budget.

The proposed expenditure is far higher than the £605 million spent under the previous Plan 1994-99, 75% of which was funded by the EU. This sum included investment in 128 water or sewerage schemes and phosphorous reduction facilities on eutrophic rivers and lakes. For instance, around £50 million was spent in the Lough Derg and Ree catchment where it apparently achieved an 80% reduction in the amount of phosphorous in waste water. Further substantial investment is needed nationally, given that only 22% of waste water receives secondary treatment.

The proposed expenditure also includes £420 million to improve rural water supplies, particularly group water schemes. Much of the expenditure represents the government's response to the criticism of the lack of previous investment needed to raise water quality to European standards. Now that much lead piping has been replaced, the next most serious threat to clean water supplies is perceived to be from nitrate levels. Although levels are currently low, Nitrate Vulnerable Zones will have to be designated to prevent a further rise in areas at risk. Without such action, decontamination or sourcing of alternative supplies would be needed and this would involve phenomenal cost, albeit in the distant future.

Whilst the proposed amount of public expenditure is substantial, an indication of the importance that people attach to clean drinking water is evident from sales of bottled water. Further evidence of the extent of the consumer surplus is available from some overseas studies in which people have been asked how much they would be prepared to pay to avoid pollution of groundwater. For example, Stenger & Willinger (1996) asked people in eastern France how much they were willing-to-pay to

protect the quality of the Alsatian aquifer. Although the amounts were quite low on a per person basis at FF150-180 per year, this still amounts to FF 386 million per year (£45mn) once aggregated to the total population of the region. Transferred to just the proportion of the Irish population drawing on groundwater, this would amount to £18 million per year. North American studies (see McClelland *et al*, 1992) would suggest much higher values.

### 6.2.2 FISH AND ANGLING

Angling is a major economic activity in Ireland. In 1987, Whelan & Marsh estimated that annual expenditure associated with game species was nearly twice that for coarse, although there has since been some fall off in visits by foreign anglers and the Central Fisheries Board now believe that values are about equal. Whelan & Marsh also estimated that total expenditure by domestic and visiting anglers was £29 and £28 million respectively, amounts which would now be worth around £42 and £40 million (before allowing for the fall in foreign visitors). The Marine Institute (1996) believe that 190,000 Irish nationals are involved in angling and claim that £68 million is spent by up to 97,000 visitors. Game fishing is expensive. There are salmon rivers where a half-day's fishing can cost as much as £200. To this can be added the multiplier effect of anglers' spending in the local economy.

Another way by which to illustrate the economic value is through the capital value of the fishing rights. For example, around 800 salmon are caught each year along twelve kilometres of the River Erriff which is valued at a rate of between £2,000 and £4,000 per fish. Parts of the River Moy could possibly claim an even higher value of £6-8,000. These figures equate to around £500,000 per kilometre, a figure similar to those at which sections have recently sold on the estate market.

Trout and coarse fishing are not as lucrative given that access in Ireland is less restricted, but have a substantial economic value given their popularity. Many more rivers and lakes once had excellent game and coarse fishing, but their current and future economic value is well below its potential. If restored, their individual value would probably not equal those of the Erriff or Moy because they would act as substitutes for these rivers. Indeed, the value of the Erriff or Moy could even diminish if enough new alternative quality angling became available. Nevertheless, while impossible to quantify, the potential value would be substantial, not least because catches on rivers in other angler destinations, such as in Scotland and Scandinavia, have collapsed.

The reasons for declining catches are many and controversial and include overfishing at sea, commercial netting, sea lice, loss of bankside habitat and toxic pollution. Eutrophication is certainly a factor and acidification is known to have affected fish populations such as those of charr in Lough Dan. Raised levels of toxic elements due to increased acidity in the environment represent another

threat, for instance aluminium in the presence of forestry plantations (see Land). When asked about their principal dislikes, not surprisingly anglers referred to pollution and to poor fish stocks (Marine Institute, 1996). Possibly as a consequence, the numbers involved in game fishing have fallen in recent years. The CFB has responded with an initial investment of £12.5 million over five years on improving 400 km of channel. While principally directed at bankside and spawning habitat, this rehabilitation also helps to reduce phosphorous run-off.

### **6.2.3 BOATING AND AQUATIC ECOSYSTEMS**

In addition to angling, the Marine Institute (1996b) claims that residents and a further 140,000 foreign tourists spend between £65 million each year on inland water-based recreation. Direct expenditure on boating is estimated at between £18-46 million, of which a third is by Irish nationals (Marine Institute, 1996a,b). Many more people have either an active or passive interest in wildlife, including wildfowl and other water species. Birdwatch Ireland has a membership of over 5,000, but at least the same number again could be expected to list informal birdwatching as one of the main reasons for visiting rivers and lakes for recreation.

These activities could easily be deterred by ecological damage, particularly highly visible algal growth and blooms. Eutrophication has a serious impact on wildlife populations and, therefore, on the utility of people interested in nature studies. Nitrification, pollution of groundwater and abstraction also threaten many lakes and wetland ecosystems.

Studies have been conducted in the UK in which people have been asked how much they would be willing to pay to preserve rivers or wetlands. In the case of canals and waterways, Adamowicz, Garrod and Willis (1999) reported figures of between £23-£39 per year in average, but far higher figures for active users. In other cases, the existence value component of aquatic wildlife species and habitats is much greater. For example, Bateman *et al* (1992) reported a once-off figure of up to £20 million to protect the Norfolk Broads from coastal floods. No studies have been carried out in Ireland, but an average value for wetlands has been estimated from a number of European studies at €35 (IR£27.5) per person (EFTEC *et al.*, 2000). This assumes that people are being asked about the future protection of ecosystems from acidification, etc.

This could represent an absolute minimum given the widespread use and interest in waterways such as the Shannon. While Ireland has no wetlands comparable in ecological status to the Norfolk Broads, it does have a higher overall number of lakes and wetland edges than almost all other European countries. Furthermore, these habitats could benefit tremendously from good wildlife management

which would increase their value. In economic parlance, their future *option value* perhaps exceeds their current *use value*.

Moreover, the state is required to maintain the status of sites of ecological value under the Water Framework Directive, the forthcoming Wildlife Act and various specific designations. Planned expenditure and sustainable management by the Department of the Environment and the Forestry Service of the Department of Marine and Natural Resources is testament to the importance now attached to the preservation of natural ecosystems.

## **6.3 Contribution of the RESI**

### 6.3.1 Provision of data

The geochemical survey will involve systematic surface based sampling of soils at kilometre intervals together with stream and lake water and sediment sampling. As such it will have a particular value in providing data on trace element and metal content and could provide baseline information of the level and distribution of nitrates and phosphates in both groundwater and lakes. These substances are included in the “core parameters” of the Water Framework Directive and national baseline measurement will complement the continual sampling by the EPA. In addition, the geophysical survey will add to the results of the geochemical survey in relation to describing the characteristics of aquifers and groundwater movement. Geophysics have also been used to map the presence of contaminated groundwater, for example from mine workings and landfills (Lerssi *et al*, 1998).

### 6.3.2 Drinking water including groundwater

The RESI will provide data to meet the requirements of the Water Framework Directive, namely:

- information on the geographical extent and depth of aquifers;
- evidence of the thickness and characteristics of capping materials, i.e. subsoil;
- hydrogeological characteristics of rocks and overlying soils, including:
  - levels of trace metals
  - nitrate levels and background fluoride levels
  - natural occurring or leachate toxic metals such as arsenic, cadmium or lead.
- contamination of water by trace metals.

One of the principal benefits of the RESI in relation to groundwater will be the provision of information on the thickness of the overlying subsoil or deposits. The thickness and permeability of this capping are vital to protecting an aquifer from surface contamination, e.g. from bacteriological contamination or nitrates. The GSI is currently assisting with the mapping of the vulnerability of the country's aquifers.

The RESI can be used to help map aquifer boundaries. While this information is of less importance to the regional mapping required by the Framework Directive, it is of value at a local level for drilling boreholes (see Infrastructure). In addition, geophysics will reveal fault zones and fracturing where groundwater could be expected to flow more easily. It would also provide some information on clay content in subsoil as well as the height of the water table (i.e. saturation).

The Framework Directive emphasises water quality. The geochemical survey will indicate the trace metal content of soils, sediment and surface waters. It will also provide baseline evidence of soil nitrate levels which could be modelled along with information on land use and aquifer vulnerability after allowing for seasonal variations in fertiliser application.

Further ground based analysis and borehole data would be needed to model environmental hazards. Nevertheless, in the area of water management, the contribution of the RESI will be considerable. Mapping is essential if groundwater vulnerability is to be related to human activity. It is also essential for policy to be cost-effective and to minimise both the public and private costs of conformance with regulations such as the Nitrates Directive (see Land).

### **6.3.3 Ecosystems**

The RESI will be of value to ecosystems dependent on groundwater recharge. For instance, it will reveal where abstraction or civil engineering work could affect the quality of availability of groundwater to valued ecosystems.

Where nutrient enrichment is concerned, geochemical measurements are of limited direct value given that only a tiny proportion of total phosphorous is available to plants. Likewise, the survey's contribution to nitrate induced eutrophication and to acidification is limited due to the rapid removal of nitrates in soils as well as the huge annual and seasonal variations in nitrate levels. It would, however, provide data on rock mineralogy with which to model weathering rates and therefore to predict the buffering capacity of the environment. Other than on deep peat, and depending on the parent material, high weathering rates will neutralise acids in the long-term, slowing or preventing the accumulation of nitrates.

The survey will be of less value for measuring phosphorous unless it is extended to lakes where there is a closer relationship between available molybdate-reactive phosphorous and total phosphorous. However, by providing information on weathering rates, the RESI could provide an input to sophisticated environmental modelling of eutrophication. In the final analysis, so serious is the problem of eutrophication and, in the long-term, of acidification, that any contribution to its reduction is of tremendous value.

#### **6.3.4 Fish populations and angling**

The trace element analysis within the RESI will also contribute to the preservation of fish populations. The survey will reveal areas where metals, including aluminium, present a risk of toxicity to fish. It will ensure that fish management is more cost-effective by indicating just how much clean-up or buffering of metals would be required to restore populations of fish and dependent species. As a baseline for monitoring, subsequent surveys could indicate when trace metal concentrations rise above this baseline. This would reveal pollution incidents and possibly their source.

The RESI would make a further valuable contribution to mapping fish migration. Salmon are believed to have an instinctive awareness of their birth river's chemical profile when returning to spawn. The trace element analysis could be compared with that within fish scales to determine which tributaries are of principal value in the salmon life cycle. Resources can then be concentrated on the tributaries which are of most importance.

## 6.4 Summary contribution of RESI

<i>Benefit</i>	<i>nature of benefit</i>	<i>economic value of end result</i>	<i>RESI contribution</i>
Meeting Water Framework Directive	Direct benefit. Assessment of nation's water resources.	Govt has set aside £50 mn over four years. Failure to satisfy Directive will result in severe penalties.	Important component, perhaps saving 5-10% of field assessment otherwise needed. In particular, re capping. Of value to <u>DELG</u> .
<u>Water supply</u> : More precise data on location and depth of groundwater	A direct benefit. Would increase success of borehole drilling.	Could be of benefit to 60+ communities over ten years, i.e. £2.5mn/yr. (captured in Infrastructure section).	Major contribution in combination with other survey techniques. Indicate location and provide data on zones of groundwater flow . Of value to <u>local authorities</u> .
Clean water	Welfare value of protection.	Use value of <i>at least</i> £18mn. on basis of overseas studies for groundwater. Possibly £72mn. overall.	Small indirect, but important contribution, mainly by indicating vulnerability of aquifers.
Fish and angling	Research for more cost-effective protection. (acidification captured above)	Rehabilitated rivers. Increased expenditure of perhaps £20 mn pa. by sport fish anglers.	Significant, but too indirect to quantify.
Water-based recreation.	Research towards better understanding of eutrophication and acidification.	Reduced visible ecosystem damage. Current use value is substantial at £18-65 mn pa. An improvement would increase this by perhaps 25%.	Important contribution, but impossible to quantify.
Ecosystems	as above	High existence & option value Value of improvement perhaps worth £27.5 pp/pa. (i.e. £70mn if multiplied by the adult Irish population).	Important, but difficult to quantify. Partly captured in acidification

### *Net Present Value of RESI (discounted over 20 years from completion of survey)*

Water Framework Directive: Middle bound. Contribution @ 0.075 = £3.75 mn.

Clean water: Middle bound Contribution @ 0.05 of £18 mn/yr. = £8.8 mmn.

Upper bound based on 0.05 of 72 mn = £44.85 mn.

Note: most benefits are public benefits.

## **7. INFRASTRUCTURE**

One consequence of the rapid economic growth of the last five years has been a phenomenal increase in construction activity and capital investment by both the private and public sectors. In addition, tighter environmental regulations due to national and European legislation or directives are being enforced through local authorities and the EPA. Many projects are subject to environmental impact assessment. Strategic environmental assessments are also beginning to be prepared by government, regional and local authorities.

An understanding of the properties and behaviour of the ground is essential for the construction of safe and economical structures. Unforeseen ground conditions can result in delays, remediation costs, environmental impacts and other external costs.

### **7.1 Nature of the problem**

In the case of roads and buildings, common geotechnical hazards include hard rocks, saturated rocks, soft ground, slope instability, caverns and sink holes. Shrinkable clays or corrosive sulphide bearing rocks are less of a problem in Ireland than in some other countries, but karstic ground does present a particular hazard across much of the country. In particular, failure to take account of groundwater is a major factor, especially given that the water table in Ireland is so close to the surface.

These types of hazards result in additional costs of drilling, etc., or problems such as differential settlement, flooding or pumping requirements. Ultimately, these type of costs are often borne by the commissioning body, e.g. county councils or agencies such as the National Roads Authority (NRA).

The RESI can contribute to better information on ground conditions. Its most unique contribution could be realised at a strategic level when determining the siting or routing of various construction projects. Benefits are mostly in the form of damage avoidance. In addition, however, the RESI could provide some direct benefits as with the case of more precise information on the location of aquifers.

### **7.2 Economic assessment**

The Site Investigation Steering Committee (1993) quotes figures from various sources which demonstrate the economic cost of unforeseen ground conditions in the UK:

- Reports by the National Economic Development Office (1983, 1988) which reveal that half of industrial building projects, and one third of commercial building projects, had overruns of more than one month. In respectively 37% and 50% of sampled cases these delays were caused by unforeseen ground conditions;
- The National House Building Council (1990) reports that total annual insurance claims of £5-11 million, over half of which were due to geotechnical problems;
- The National Audit Office (1989) noted that geotechnical problems on eight road and six bridge projects resulted in extra work costing £18 million;

The Committee adds that site investigation as a proportion of project cost has fallen in real terms over the years. Only 16% of site investigations were managed by geotechnical specialists.

No figures appear to be readily available for Ireland. The Comptroller and Auditor General (GOI, 1999) does report that 32 major projects were, in total, £180 million (23%) over budget and that this was more than can be explained by inflation. Of these costs, the amount due to unforeseen ground conditions in Ireland is not recorded. It is likely to be substantial for at least four reasons, namely:

- a surge in infrastructure investment which is placing pressure on contractors and civil engineering consultants, including the small number of experienced geotechnicians;
- fragmented decisions between central and local government combined with inadequate personnel or financial resources within the County Councils commissioning many such projects;
- widely reported evidence of delays in projects partly due to serious design oversights, as well as other factors (e.g. legal objections), resulting in the Government's recent promise to speed up approvals for infrastructural projects;
- the prevalence of poor quality environmental impact assessments, many of which lack objectivity.

A substantial amount of investment is now proposed in the National Development Plan 2000-06 to eliminate the country's infrastructural deficit. For instance:

- £4.4 billion is to be invested in national roads (£620 million in 2000);
- a contingency of £500 million for the underground section of LUAS, on top of existing capital provision of £430 million for the surface element;
- capital investment of £960 million in water and waste water services (of a total of £2.5 billion);
- £650 million on all forms of waste management, including landfill;

- land and infrastructure provision for a projected 500,000 new houses over the next ten years.

In addition, to this planned public expenditure are some major civil engineering projects such as the proposed £200 million Bord Gáis cross-country pipeline, the Spencer Docks development (whatever scheme finally gains acceptance) and public/private partnerships such as the reincarnated Dublin Port Tunnel.

In the case of all these projects, a thorough understanding of ground conditions will be essential. The economic benefit is realised as a reduction in uncertainty surrounding civil engineering work. This leads to the avoidance of economic losses arising from the mitigation of unforeseen hazards, project delays and environmental damage.

Accurate geological maps are essential for these purposes. The RESI can make a major contribution along with other geological data drawn from maps, borehole or geophysical data. Any contribution would still need to be supplemented by detailed local surveys, but the RESI will help to reduce uncertainty and provide strategic information to both developers and county planners.

#### 7.2.1 Water supply

The NDP includes a massive £2.495 billion budget for water and waste water. This comprises £380 million for water supply and £463 million for infrastructure, including the servicing of newly developed land. In addition, £420 million is included under the Regional OPs for improving rural water schemes. A more detailed breakdown is not yet available.

The section on Water, Groundwater and Drinking Water provides information on the value of the RESI to ensuring good water quality. In addition to this, the RESI can make a contribution to engineering work directed at ensuring a reliable supply of quality drinking water.

The location of important aquifers is already known from existing geological maps. However, the boundaries of these, and those of local minor aquifers, are not known precisely because the geology is concealed. The RESI can:

- provide more precise data on geological boundaries, at least where adjacent rock types are distinct;
- indicate fracture zones where flow rates are likely to be highest;

- provide data on capping, i.e. the depth to bedrock, which protects groundwater from surface contamination.

A large amount of the proposed spending under the NDP is intended to improve rural water quality supplies. This expenditure has been prioritised because the EU has threatened Ireland with fines in response to continued poor rural water quality, particularly in relation to coliform contamination.

One response would be an “engineering fix” whereby rural households would be linked to water supply networks of guaranteed quality. Between 1994 and 1999, 827 km of such pipeline were constructed. More extensive water pipeline projects are being proposed under regional Strategic Rural Water Plans. This pipeline construction would itself benefit from an enhanced knowledge of ground conditions. However, pipeline construction is costly as is subsequent treatment (Lanne *et al*, 1999). In many cases, water could be supplied more *cost-effectively* from local sources. The problem at present is knowing where to drill. Exploratory drilling is expensive and soon becomes impractical financially where there is a high risk of failure.

***Example 1 – Rural water supplies***

In County Laois, the Portarlinton Water Supply Scheme is to be funded by the Department of Environment at a cost of £3.5 million. The water is to be taken from the River Barrow and will require treatment before being potable. Arguably, an improved understanding of groundwater could have revealed alternative water supplies. Around £100,000 had initially been spent on unsuccessful exploratory drilling in the absence of precise geological data.

In County Limerick, an improved water supply for small rural communities is being considered within its Strategic Rural Water Plan. As part of this plan, some communities might be connected to the Limerick municipal water main. Other more remote rural households with their own wells will be connected to group water schemes. The County Council is aware that it has to consider the cost-effectiveness of constructing pipelines to supply small rural communities. In some cases, water could be obtained from local groundwater sources at far less cost.

For instance, a 200mm diameter 5km pipeline spur to link an existing village network would cost almost £500,000. If, instead, clean groundwater supplies could be obtained from a local source, as might be the case in one community examined, the cost including a local link pipeline to the borehole would be in the region of £85,000. This saving of over £400,000 can possibly be multiplied by similar communities across the country. Allowing for the cost of pumping stations, the national savings would be considerable.

Of course, in many cases, continued dependence on local groundwater sources might be at odds with environment objectives. Pipelines also have the advantage that they can remove waste water and this is of particular benefit where drinking water or ecosystems are vulnerable to pollution. Nevertheless, if the savings in the example above were extended to 5% of villages, assuming that villages include half the 1.2 million homes already dependent on groundwater, the savings would amount to around £24 million. To this can be added the savings on exploratory drilling which has been avoided.

### ***Example 2: Midland power station***

Another instance where a precise knowledge of water availability would have saved resources, is provided by the example of a power station in the Midlands. The new power station needed a water source for operational purposes and for cooling. Although, standard geological maps indicated a nearby rock boundary, no water supply of satisfactory quantity or quality could be located. After much negotiation over access, a 4km pipeline and pumping station were constructed at a cost of around £750,000. However, the water quality, especially in winter, proved unsatisfactory. The power station managers were forced to consider bringing in water by tanker at considerable extra expense. This option also caused local anxiety which delayed the commissioning of the station.

In fact, detailed investigation proved that a cheap and highly satisfactory groundwater supply was available on-site. The construction of the pipeline and delays had together cost millions of pounds. Furthermore, given the current delicate balance between national electricity generation and demand, possible supply failures were averted. The RESI would have provided a far clearer indication of the location of the rock boundary and its fractured state.

## 7.2.2 Road construction

Problems due to “unforeseen ground conditions” frequently cause delays and additional costs to road construction projects. Delays are caused by hydrogeological problems and other geotechnical factors, including the presence of sink holes and unstable ground conditions. To reduce this threat, civil engineering companies should ideally undertake ground geophysical surveys within a 5km corridor of the intended route. However, the evidence from the UK suggests that many contractors have been tempted to reduce the amount of geotechnical investigation.

A report by the Comptroller and Auditor General (CAG) on the national road network (GOI, 1999) comments on the frequency of delays during the road design phase. National Road Authority (NRA) guidelines note that the final cost of a road scheme should not be 50% more than the first estimate and no more than 25% above that presented at the completion of the preliminary design phase. The CAG report remarks that “ambiguity about the way the guidelines are phrased .. suggests that cost increases up to the limits of [these] margins of error would be acceptable”.

Much of the cost of delay is currently borne by local authorities and passed onto the NRA. A further social cost is endured by motorists in the meantime. In the near future, around 50% of projects could be in the form of Design and Build Projects in which contractors will bear a much higher proportion of such costs and this could lead to better site analysis.

As of 1999, the CAG identified twelve Major Road Projects as being ongoing at a combined cost of £70 million. It did not specify the extent to which delays had been caused by unforeseen ground conditions. In the UK, the Public Accounts Committee (1993) has reported an average cost overrun

on major road projects of 28% due largely due to poorly researched ground conditions. If applied to Major Road Projects in Ireland, a similar proportion would imply costs of between £10-20 million over a typical five year design and construction period.

The RESI would provide information on concealed geology, i.e. the hydrogeology or the nature of bedrock. It would be of obvious benefit to the routing of major roads and tunnels. Together with environmental and socio-economic data, it could improve the strategic consideration of alternative routing options. Intensive on-site surveying would still be needed, but potential problems may have been identified in advance.

*Example: Kildare by-pass*

The long-running delay to the construction of the £60 million Kildare by-pass could have been mitigated by a better initial understanding of hydrology. Although the 4km cutting proposed for the by-pass had the benefit of removing a visual intrusion from the Curragh Plain and of minimising an alleged hazard to horses based at the National Stud, the threat to the sustainability of the Pollardstown Fen National Nature Reserve initially went largely unnoticed. The depth of the cutting presents a potential barrier to the movement of groundwater to the Fen. In addition, the proximity of the water table to the surface of the Curragh, would require pumping of up to 25 million litres per day to allow construction.

A better understanding of the hydrology would have facilitated an improved design. In this instance, the type of data to be supplied by the RESI would make only a minor contribution as the nature of the Curragh aquifer and its relationship with Pollardstown Fen should already have been understood well enough to justify preliminary research and appropriate engineering design. Nevertheless, it is indicative of the type of problem associated with *unforeseen ground conditions* to which the RESI can often make a contribution.

As a rare and valued ecosystem, Pollardstown Fen will be protected under the Habitats Directive. This protection will be reinforced by requirements in relation to groundwater contained in the new Water Framework Directive. The Fen is also a major supply of water to the Grand Canal. Although the road has now received the go-ahead following the inclusion of a novel “tanking” system in its design, the delay of seven years has cost a considerable sum due to redesigns and enquiries. Politically, it has been an embarrassment as the EC had threatened to withdraw its support. Potentially, the external cost in terms of continued vehicle congestion over that time could also be quantified. In itself, this would run into millions of pounds

### 7.2.3 Built development

The risk of flooding due to a rise in the water table, or of subsidence, are factors that need to be considered by planners and developers before undertaking any built development. The Site Investigation Steering Group (1993) believes that a detailed site investigation generally costs between 0.1-0.3% of construction costs. However, it adds that this investigation is often inadequate. In part, this is because foundations work generally accounts for just 10% of final costs and delays can often be

made up later. Unresolved problems can lead to subsequent structural problems. In 1990, insurance claims in the UK totalled between STG£5-11 million, half of which were due to geotechnical problems.

Problems are most acute in countries with an industrial past, as in the UK where there are many mine workings and old undocumented dumps, or in countries with serious risk of earthquakes or landslides. For areas subject to gypsum subsidence risk, Cooper & Calow (1998) have estimated the direct costs of subsidence at STG£90,000 or STG£200,000 once all costs (including housing blight) are taken into account. Using an example of a 500 house development, they go on to show that geological data (at a cost of e.g. £250,000) leads to a net benefit of STG£127,000 if a risk free alternative site is selected as a result, or STG£48,000 if building takes place in a risk zone but incorporates countermeasures.

In Ireland, the Insurance Information Service believes that subsidence is “not a major issue”. The main problems relate to karst features, such as sink holes. There can, however, be unforeseen problems associated with the water table which is often close to the surface in Ireland. Of the latter, for example, questions were raised about the risk of local diversion and raising of the water table due to the substantial underground car-park planned for the giant Spencer Dock development. Given that so many major new developments are currently underway, the benefit of hazard reduction is likely to be significant even though Ireland has a smaller population density than other European countries and fewer serious geohazards.

7.2.4 Landfills

The issue of waste management has become a highly contentious one in recent years. Local authorities across the country are being required to prepare integrated waste management plans. Government has made available £650 million for waste management and is seeking a 50% diversion of waste away from landfill to other options such as incineration and recycling. Nevertheless, there will be a continued reliance on landfill to deal with the increasing amount of waste being produced (see Table 7.1). In 1998, 91% of municipal waste went to landfill (EPA, 2000).

*Table 7.1. SOURCES OF WASTE 1998* (excepting agriculture)

Manufacturing	4.9 million tonnes
Mining & quarrying	3.5 mt.
Municipal	2.1 mt.
Construction & demolition	2.7 mt.

source: EPA (2000)

Now that stricter licensing and controls are being enforced by the EPA under the Waste Management Act 1996, local authorities are having to contemplate the closure of older landfills and to consider the establishment of new and larger sites. Typically several options get considered by councillors who are acutely aware that landfills are highly unwelcome with constituents. Campaigns have been organised against local landfills in Counties Galway, Tipperary, Fingal and elsewhere.

Traditional style “dumps” with their associated environmental problems of surface pollution, leachate, smells and vermin are no longer acceptable. Instead, better managed options are being considered which make use of impermeable linings or compaction. However, even with modern precautions, there is still a risk that leachate could escape into groundwater.

Most notably these concerns were raised by the residents of Silvermines in relation to Waste Management Ireland’s proposal to use an abandoned mining pit to receive municipal waste. Residents were concerned that old mine workings could act as a conduit for leachate in the event of any failure of the lining. Although the risk is minor and the aquifer is not important regionally, any such outcome would become irreversible and be a considerable economic burden on future generations. For instance, in the US, the EPA has found that landfills expected to operate for just 20 years present a continued risk of cancer *over 300 years* due to groundwater pollution (Rasmussen, 1997).

Bernknopf *et al* (1993) demonstrated that better geological maps could be used to refine the areas considered suitable for landfill in Loudoun County, Virginia. By using property prices as an indicator, they showed that geological information would produce a benefit of \$376,000 per km<sup>2</sup> by removing potential losses in property value.<sup>3</sup> As there are roughly 153 people per km<sup>2</sup> and an average house price was \$150,000, this might suggest an average loss avoided of 6.5% given an average household size of four.

The American EPA has estimated property losses of between \$300 and \$15,000 (Rasmussen 1997). It has also quantified the cancer risk (noted above) and cost of replacement wells as well as assessing “non-quantifiable” factors such as the value of clean groundwater, ecosystem impacts and gains in public confidence.

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<sup>3</sup> Given variations in property values, the loss varied from \$39,241 to \$124,791 per 250m<sup>2</sup> cell. The authors do not provide respective information on household density. Perceived losses were based on risk of groundwater pollution.

### **7.2.5 Electricity transmission**

In line with other aspects of the infrastructure, electricity generation and transmission is expanding rapidly to satisfy economic growth. New private generation companies are also entering the market. The RESI could potentially identify substation sites where conductivity is low. Fifty new substations are planned over the next ten years at a cost of around £500 million. However, pre-site selection survey costs are not a major expense.

## **7.3 Contribution of the RESI**

For civil engineering projects, much of the benefit of the RESI would be realised at a strategic level when proposing alternative options for roads, built development, landfill and electricity cables. However, the RESI can provide a direct benefit in relation to the more accurate identification of groundwater sources. In all cases, though, more detailed on-site investigation would be required. Greater benefits will often be realised through more satisfactory use of geophysical data at this stage.

### **7.3.1 Water supply**

The NDP has budgeted for very considerable sums for water supply over the next six years. For this reason, any additional information that can be utilised in the planning of capital investment has a significant dividend.

The contribution of the RESI to the mapping of groundwater is discussed further in the section on Water. Here, though, the issue is how to supply water most cost-effectively. The RESI can provide resource savings in relation to increasing the success rate of borehole drilling (see Farr *et al*, 1982). In addition, there is the avoidance of unnecessary construction of pipelines, pumping stations and water treatment plants. Using the examples given earlier, access to reliable local water sources could reduce piping costs by £25 million over ten years. Avoidance of excessive drilling might save £1 million per year.

The geophysical survey can effectively map depth to bedrock and fractures with high water flow rates. In many cases, with specialist interpretation, it can also indicate the exact location of rock boundaries. Further on-site investigation would still be needed, e.g. ground-based geophysics and drilling. However, significant benefits can be realised if the data is interpretable by users such as county councils, power stations, industrial plants, developers and even individual householders especially if supported by expert assistance.

### 7.3.2 Road construction and built development

Adequate site investigation should make use of an assortment of data including geological maps, geophysical surveys, hydrological data, borehole records and archival sources. In the US, Bernknopf *et al* (1993) estimated that good geological maps led to a better prediction of slope failure along road cuttings leading to savings of \$11,000 per 250m<sup>2</sup> of embankment by avoiding the construction of unnecessary length of retaining wall.

At a more strategic level, more detailed geological data, including airborne geophysical data, would be very valuable. It would speed up the planning process and limit the number of site or routing alternatives under consideration. As such, the RESI would provide a significant benefit to county councils and agencies such as the NRA and An Bord Pleanála. It would also reduce the temporary property blight in locations being considered for motorways or airports, noise from which would be an external cost. These organizations would be interested in evidence of:

- ground contamination;
- ground instability, sink holes or subsidence risk; or
- interference with local groundwater which could lead to pollution, habitat damage or project delays.

### 7.3.3 Built development

The RESI has a modest contribution to make in relation to avoiding geological hazards. However, in combination with existing geological data, it would help to indicate the location of rocks, sink hole risks or faults which present a risk of subsidence or a raising of the watertable. Given the amount of new development now underway, including some substantial proposals such as that for Spencer Dock, this modest contribution can potentially be multiplied by the amount invested in new structures.

### 7.3.4 Landfills

The RESI would identify fracturing in rock that could indicate where there is a risk of groundwater contamination. In principle, a geophysical survey would provide a *direct benefit* by reducing the risk of future contamination of groundwater associated with leachate. Were such contamination to occur, the impact cost would depend on the extent of the contamination and the importance of the aquifer. This would represent something of a conundrum for economic analysis as the impacts would be long-

term, even irreversible, but be diminished by standard discounting procedures. These would need to be set against the costs of clean-up (if possible) in the short-term

However, final site selection requires detailed on-site surveying. Rather, the benefits of the RESI are realised at an earlier stage and not directly from reducing actual groundwater pollution risk. These benefits are interrelated and include:

- a) Reducing the cost of unnecessary site investigation;
- b) Removing unnecessary housing blight;
- c) Increased public confidence.

Once again, the RESI would assist in providing data to support a preliminary selection of suitable landfill locations at a county level. Site investigation is costly. In the US, the investigation of an individual site has been estimated to cost over \$1 million (Bhagwat & Berg, 1991). Although an preliminary site investigation in Ireland comprising 15 trial pits and five boreholes might be possible for just £20,000 (Brinkmann, *pers comm.*). The principal clients for such information would be local authorities. For example, no less than eight possible landfill sites are currently being considered by councils in the greater Dublin area.

Site investigation can also provoke property blight. The avoidance of losses to property values identified in the study by Bernknopf *et al* (1993) cannot easily be transferred to Ireland. It is, though, reasonable to assume that a proposed site could cause a 10% loss of value for properties within a 1km radius (perhaps a 5% loss for those just outside this area). For all but the chosen site, the loss is temporary, lasting perhaps 2-5 years. Nevertheless it causes resale problems and anxiety in the interim. Moreover, it is reasonable to assume that landfill alternatives are being considered by one fifth of county councils at any one time. If the RESI led to the exclusion of just one alternative at an early stage, there would be a continual avoidance of unnecessary blight of over £1.5 million per year given average population densities and house prices. In addition, there would be a contribution to total savings of up to £1 million on site investigation costs.

The issue of anxiety is another factor worthy of economic consideration as identified by the EPA in the US. Manifested in the NIMBY (Not-In-My-Back-Yard) syndrome, this presents considerable problems for local authorities trying to achieve an objective assessment of the merits of alternative sites. Public opposition causes delays and indecision which has an associated cost. This cost is clearly not insignificant given the current impasse in several County Councils and the powers consequently being considered by the Minister for the Environment to speed up the decision-making process.

### 7.3.5 Electricity transmission

Resistivity is not a major factor for locating either overhead and underground electricity transmission lines. Indeed, other aspects of the geophysical survey indicating depth to bedrock may be more important. However, ground-based resistivity surveys are undertaken by the ESB when locating substations. Generally, many factors have to be considered in such cases. Although, where resistivity is low is it more worthwhile to select an alternative location than to invest in mitigating groundworks. The RESI would assist in providing wider geographical information on resistivity, but local ground based studies are not a major expense in relation to other construction costs.

#### *Net Present Value of RESI from 2005*

Water supply: Middle bound. RESI contribution @ 0.5 = £1.25 mn/yr. over 10 years = £8.14 mn.

Upper bound 0.8  
Lower bound 0.25

Borehole drilling: Estimate RESI contribution £1 mn/yr. over 20 years = £9.76 mn.

Landfills: Middle bound. Contribution @ 0.5 = £1.25 mn/yr. over 20 years = £11.39 mn. Upper bound 1.0

Lower bounds 0.1

Electricity: Middle bound. Contribution @ 0.01 = £2.5 mn.

## 7.4 Summary contribution of the RESI

<i>Benefit</i>	<i>nature of benefit</i>	<i>economic value of end result</i>	<i>RESI contribution</i>
<u>Water supply</u> : more precise data on location and depth of groundwater	A direct benefit. Would increase success of borehole drilling and avoid construction of unnecessary pipelines, pumping or treatment stations.	Could be of benefit to 60+ communities over ten years, i.e. £2.5mn/yr. Avoidance of excessive drilling worth >£1mn/yr.	Major contribution in combination with other survey techniques, but could need specialist interpretation. Of value to <u>local authorities</u> and to <u>industrial projects</u> or <u>other development projects</u> .
<u>Roads</u> : strategic info for routing decisions	Avoids time and money being spent considering unsuitable alternatives.	Delays due to unforeseen ground condition at least £2-4 mn/yr. Savings multiplied by amount of current investment activity.	Main contribution at strategic level, which cannot be represented as a proportion of figure (left), but of significant value to <u>local authorities</u> and <u>national agencies</u> . Possibly also to <u>civil engineering companies</u>
<u>Built development</u> : strategic info for planning decs.	Avoidance of built development on areas subject to geohazards. Avoidance of damage to structures.	Resource savings of at least £5mn/yr multiplied by amount of current investment activity.	Most contribution at strategic planning level, which cannot be represented as a proportion of figure (left). Of most value to <u>local authorities</u> and <u>major developers</u> .
<u>Landfill siting</u> : strategic info for site selection.	Avoids consideration of unsuitable sites, thereby avoiding housing blight and local opposition.	Savings difficult to quantify as are at level of strategic decision-making, but could amount to £2.5 mn/yr.	Most contribution at strategic planning level. Of great value given current waste debate. Of most use to <u>local and regional authorities</u> .
<u>Electricity transmission</u>	A direct benefit to the strategic location of substations	£500mn to be invested over ten years, but survey cost small.	A minor benefit as there are other location factors to consider and ground based surveys are not expensive.

## **8. TRACE ELEMENTS AND CONTAMINATED LAND**

Modern geochemical methods are capable of collecting information on a comprehensive range of elements. High levels of potentially harmful elements (PHEs) can represent a threat to human or animal health. Similarly, low levels could be indicative of dietary deficiencies. In rural areas, high or low concentrations are usually natural and a consequence of the underlying geology. In such circumstances the impact of agriculture or of the application of sewage sludge needs to be considered.

High levels of certain elements can also result from land contamination due to past mining or industrial activity. Such contamination can be localised, but become dispersed by wind, surface water or groundwater. Exceptionally high levels could also be revealed by airborne geophysics (GSF & EM).

### **8.1 Nature of the problem**

#### **8.1.1 Naturally occurring deficiencies and toxicity**

Acid igneous rocks such as granite typically contain lower levels of certain trace elements than basic igneous rocks or shales. However, the availability of trace elements for intake by humans, animals and plants is highly dependent on the hydrology, base rock composition, overlying soils and temperature.

Where trace element deficiency and toxicity does occur it can adversely affect both human and animal health. The impact on livestock and plants is dealt with in the section on Land Management. The risk to human health is smaller than in the past as the population is now more mobile and food sources are more diverse. Nevertheless, problems can still go undetected. For some elements the difference between beneficial and harmful effects can be extremely narrow.

Many trace elements are vital to health, including 'first row transition elements' such as iron (Fe), manganese (Mn), nickel (Ni), copper (Cu), vanadium (V), zinc (Zn), cobalt (Co), chromium (Cr), molybdenum (Mo), as well as selenium (Se), iodine (I) and fluorine (F). Deficiencies of these elements can retard growth and have harmful effects on human health. Zinc deficiency has been linked to foetal abnormalities (Fleming, 1988). Cancers of the colon or rectum have been associated with deficiencies of Mo or Se, but it is difficult to standardise the data against age and sex ratios especially in areas of low population density (Aggett *et al*, 1988).

On the other hand, all trace elements are toxic if ingested or inhaled at sufficiently high levels. PHEs include arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg) and lead (Pb). Along with some organic compounds such as dioxins, PAHs and PCBs, these elements act as carcinogens, neurotoxins or irritants. Children are at particular risk as they are developing physically and may also ingest toxins directly from soil. Worldwide, 400,000 people are believed to die from arsenic poisoning, much of this due to natural concentrations (Salminen, *pers comm.*). Often, however, the link is indirect as fluorosis arising from the use coal for cooking in China (Zheng & Hong, 1988).

PHEs can cause a variety of health problems. For example, selenium has been linked to cardiovascular disease in Ohio (Schlamberger, 1980) and zinc to stomach cancers in Wales (Stocks & Davies, 1964). However, it has proven to be difficult to demonstrate statistically significant associations with disease even close to old industrial sites or mines. Such pollution can be obscured or matched by high naturally occurring levels of PHEs.

Fortunately, the mobility of PHEs is often restricted by environmental chemical conditions. Plants also have a remarkable capacity to filter out various elements. Toxic elements can, though, be ingested from unwashed hands or from dust. Excesses can also be concentrated in products such as milk. There is an obvious risk from groundwater sourced from private wells or small water schemes.

There is also a risk from mineral deficiencies, for example iodine and goitre. These were common in the past and continue to be so in much of the developing world. Consumption of home-grown produce is now supplemented by varied diets and food from other sources, although deficiencies could continue to be a problem on self-sufficient farmsteads.

Aside from existing levels of naturally occurring contaminants, there is also a risk that acidification could lead to changes in pH that could increase the mobility of PHEs in the environment. Coniferous plantations, for example, remove acid precursors from the atmosphere and these are known to react with aluminium which is a major toxin particularly for fish. The effect is discussed in more detail in the section on Land Management. However, the availability of other elements such as lead can be similarly increased. Forest soils have also become depleted in Cu and Zn (EPA, 2000). Natural metal levels which are currently considered to be safe or borderline, could therefore be replaced by more toxic levels as soil pH falls. Consequently, there is a need for continual monitoring.

Furthermore, a Dutch study by Guinée *et al* (1999) claims that the continuing increase in use of toxic metals in the economy is gradually increasing the concentration of PHEs, in some cases to levels that would be hazardous 100 years hence. Closed-loop agricultural systems are one reason for this potential increase, e.g. Cu and Zn found in animal feed (especially pig feed) or Cd in some fertiliser.

Inputs from landfill or from incineration products are also increasing. In a business-as-usual scenario, they argue that emissions into sensitive environmental pathways could increase by 30% for Cd, Pb and Zn, and 100% for Cu. The study is based on the Netherlands which has a larger industrial sector and more intensive agriculture than Ireland, but does nevertheless demonstrate the presence of a potential risk and the need for monitoring.

### **8.1.2 CONTAMINATED LAND**

#### *Power stations and peat workings*

Plumes of ground contamination can occur downwind of power stations. Livestock and crops are at greater risk, but contaminants could also be ingested by humans. Usually, the stack collects most polluting compounds, but high concentrations of elements such as Li, As and Cd can be found in the fly-ash. Coal fired power stations represent the greatest risk, but Moneypoint, the only example in Ireland is expected to be transformed to natural gas to meet the country's Kyoto obligations. There could be some risk downwind of peat-fired stations, two of which are due to be commissioned. This risk, including that from older stations, does not appear to have been examined. However, experts based at TCD believe the risk to be small.

#### *Mining*

More obvious is the risk from past mining activity. Although less of a problem than in Britain with its longer industrial legacy, mining has nevertheless occurred throughout much of Ireland for centuries. In the past, smelting tended to be carried out close to ore deposits, frequently contaminating nearby land with heavy metals such as Cu, Pb, Zn, Cd and As. The distribution of mine waste and flue dust has also led to the contamination of wider areas. In the UK, old mineral workings have been associated with cereal losses from Zn and Cu, and the poisoning of livestock by Pb. High lead levels in blood samples taken from children in old industrial areas of England have also been associated with the lead content of garden soils (Bartrop *et al*, 1975).

However, contamination can sometimes be difficult to distinguish from background levels. Similarly, the extent of any contamination around the Tara Mines site near Navan is masked by wider distribution of lead due to the past prevalence of leaded fuel (DAFRD, 2000).

## Silvermines

In September 2000 the EPA published a report on the risk from lead posed by disused mining facilities in the vicinity of Silvermines, Co.Tipperary. The report stated that tailings in the area “represent a perpetual risk to human health and the environment. Thus it requires structured, comprehensive, active, and continued management”. The report was followed by the establishment of an Inter-Agency Group to investigate the risk. Although the EPA’s report had been precipitated by the death of three cattle from lead poisoning, it was concluded that the risk to human and animal health could be managed at a low level so long as certain precautions were taken (DAFRD, 2000). However, It did reveal that:

- contamination from lead and other metals was extremely high in several localities, and that one of these localities was the school playing ground in Silvermines village;
- one-third of the area’s soils had lead levels which exceeded 1,000 mg/kg;
- high heavy metal concentrations in sediments of the Yellow River had produced a toxic effect on local ecology.

The report recommended active monitoring of blood lead levels, water, animal and food products. For the most part the recommendations were restricted to behavioural responses, but some activities were required that involved direct costs including resurfacing of the school playground, pumping of water for animals and liming.

As part of an EU study on The Management of Wastes Resulting from Mining, Quarrying and the Treatment of Minerals (DGXI), the GSI undertook a survey of 31 old mining sites. The GSI believes that apart from two well-known sites, pollution from mine waste is not widespread. However, it acknowledges that there is insufficient data given that past surveillance was poor.

Amongst the report’s findings are:

- Toxic elements (Pb,As,Cd,Hg,Sb) are present in 13 locations, but are predominant at five of these, while elements which are toxic in excess predominate at 12 locations;
- AMD/leachate potential is high at one minesite, while six have medium-high potential.
- There was a high suspension of solids in runoff at six locations, and this was moderate for eight others.
- Five locations are underlain by Regional aquifers, while the remainder are local or poor aquifers.
- Reports of pollution incidents have not been common, but at one site pollution is ongoing and ten other sites have had pollution incidents.

The Avoca copper and pyrite mine in Co.Wicklow has received attention under the Fifth Environmental Action Programme and been the subject of EU LIFE funding. Avoca has almost 50km of underground workings and these have lowered the local watertable with the effect that water flows into the mine from the surrounding area. The effect is aggravated by the large degree of fracturing of

rocks at higher levels. The pH of streams and rivers has been lowered sharply and the Avoca River is biologically dead below the minesite (Gallagher *et al*, 1998).

#### *Brownfield sites*

In the UK, the government has recently set a target that 60% of new houses should be built on brownfield sites. There is consequently a need for information on any prior contamination. The Geological Survey in Northern Ireland receives around 300 enquires each year about site conditions. Callers are typically interested to know if levels of PHEs such as lead or arsenic are higher than background levels. Developers and local authorities then have to ensure that a more thorough on-site survey is conducted.

In Ireland, one of the better known instances of a development being proposed on a site known to be contaminated were the apartments planned by Zoe Developments for the site of the old gasworks at Barrow Street. However, due to the current considerable interest in urban regeneration, there is an increasing need for analysis of contaminated land, particularly in the Dublin Docklands Development Area. Intensive surveys need to be funded by developers, in relation to both heavy metals and organic compounds. Developers would be liable for any contamination discovered subsequently. In most cases, the removal of contaminated top-soil is sufficient, although some sites will require more thorough clean-ups.

#### **8.1.3 SEWAGE SLUDGE**

In 1998, 37,377 tonnes of dry solids were recovered from urban wastewater, of which over 16% was spread on agricultural land, 41% went to landfill and 41% was disposed of at sea. A further 507 tonnes was produced by small scale treatment plants. A total of 708,000 tonnes of organic sludge was produced by industry, largely the food and beverage sector, of which over 80% was used for landspreading (EPA, 2000).

Dumping at sea has been banned under the Urban Waste Water Directive and landfill is considered to be an inferior option given increased regulatory standards and pressure to find reduce waste. In addition, new wastewater treatment plants are being commissioned in the major cities, increasing the quantity of sludge produced. The Department of the Environment has therefore been promoting the application of sewage sludge to farmland. Although the quality of sludge is just 1% of that of

farmyard slurry, sludge is highly regulated and local authorities will need to select land banks at least five times that which will eventually be needed.

A knowledge of background trace element concentrations is essential where application of sewage sludge is being considered. Sludge can improve the physical properties of soil, add valuable trace elements and replace P or N fertilisers. The problem is that it can also add undesirable substances and these can be very persistent (Berrow & Burrige, 1979) and limits are therefore set (see Table 8.1). Even the small quantities of heavy metals found in the sludge can accumulate over time to cause toxicity. One quarter of the state has soil trace metal levels that would disqualify land for sludge application (McGrath & Murphy, 1998).

Heavy metals are just one of a range of factors that need to be considered. In a risk assessment process applied by Towers (1994) trace metal levels were the final category used to judge the land's suitability to accept sludge, following factors such as nitrate or phosphate vulnerability. Teagasc maps are being used for these purposes and combined with an analysis of existing river nutrient levels. However, the coverage of the Teagasc soil survey is only partial and the final selection of suitable sites will require on-site soil sampling.

**Table 8.1 LIMITS AND TYPICAL PHE CONCENTRATIONS IN SLUDGE AND SOIL (MG/KG)**

PHE	EC Directive sludge content	Typical sludge content	EC Directive soil quality	Typical soil content
Cd	20-40	2.8	1-3	0.52
Cu	1000-1750	641	50-140	17
Ni	300-400	54	30-75	13
Pb	750-1200	150	50-300	30
Zn	2500-4000	562	150-300	70
Hg	16-25	0.6	1-1.5	0.12
Cr	-	165	-	49

source: Fehily Timoney, 1998

## 8.2 Economic Costs

### 8.2.1 Human health

In much of Ireland the mobility of PHEs is restricted by the prevalence of carbonate rocks and so the risk to public health is greatest in remaining areas. In the Republic a large proportion of rural households depend on either small group water schemes or private wells (there is less dependence in the North). There is therefore a real risk that some rural communities are already being subjected to excessive levels of PHEs.

This study has found no evidence of work on the economic cost of either trace element deficiency and even toxicity. It is known that contaminated land presents a risk of cancer. However, it is difficult to demonstrate a statistically significant relationship between levels of PHEs and disease. For example, in parts of North Wales, levels of zinc and arsenic are high as is the incidence of stomach cancers are known to be high, but the cluster is too small to conduct a statistical analysis that can demonstrate an unambiguous connection. Similarly, except for some consequences of toxicity or deficiency due for instance to iodine deficiency, symptoms can be non-specific and difficult to diagnose without expensive blood testing.

In addition, the nature of research funding has not favoured an analysis of these two different sources of data. Moreover, data on disease is usually related to health authority areas or hospitals rather than the place of residence of the sufferer. This situation may change given the increasing application of GIS.

It is probably not unreasonable to suspect that PHEs in the wider environment cause tens of deaths each year as well as other health problems. The number is not high, when measured against other factors including radon. Nevertheless, it could be costed in terms of EU estimates of the 'value of statistical life' (VoSL) of £2.4 million (Pearce, 1998).<sup>4</sup> On the other hand, the risk from PHEs may be perceived by the public to be similar to other environmental factors such as the risk from radon, in which case, a smaller figure of £300,000 (Soderqvist, 1995ab) could apply. Either figure excludes the cost of medical care.

Where a problem is suspected the *precautionary principle* could be applied. A possible application would be to locally high levels of natural fluoride in water. Excessive fluoride causes dental discolouring and more serious bone problems (Bølviken, *pers comm.*). Indeed, fluoride has been the subject of one of the few epidemiological studies conducted in Ireland (McKay, 1974). There has also been recent disquiet over levels of naturally occurring fluoride in County Clare. The precautionary principle could imply the cessation of supplementary fluoride to local water supplies.

### **8.2.2 Contaminated land**

Contaminated land represents a localised health threat that is similar to natural contamination. The only difference is that most contaminated sites are known to the EPA and precautions are taken to protect agriculture and groundwater. There are potentially large costs. At Silvermines, the state and

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<sup>4</sup> See section on Radiation

mining company has had to accept the cost of stabilising the tailing pond and cleaning-up contaminated land in the village.

Smaller, older and less well-known sites are a risk. There is also a possibility that land which is nearby, but not necessarily adjacent to mines or factories, could be contaminated from past events or practices. A particular problem has been past use of furnace or mining slag as fertiliser. Geochemical maps produced by the BGS reveal several areas of widespread contamination off-site of mining areas or industrial areas, such as high chromium contamination in a heavily populated area around a chrome plant in Teeside.

Site investigation is expensive. Thompson (1992) estimated that it would cost £15,000 per hectare to properly investigate a site. At this rate it would cost £600 million to investigate all the 40,000 hectares identified in the 1988 Derelict Land Survey. The UK Environment Agency (1999) believes that there are over 300,000 hectares affected in the UK.

### **8.2.3 Sewage sludge**

A large amount of activity is currently underway as a consequence of the Waste Management Act. Local authorities have been examining the suitability of sites for the application of sewage sludge by undertaking soil sampling rather than geochemical analysis. Large amounts have also been invested in waste treatment, notably in Limerick and in Dublin (£200 million). According to Cockburn (1993), STG£200 million will be needed to deal with the growing sludge mountain in the UK. However, the quantities involved in Ireland are smaller and there is more suitable rural land available. Just 50 farmers in Leinster have been applying products from 12,000 tonnes of sludge distilled by Dublin Corporation from 1.8 million litres of waste water.

## **8.3 Contribution of the RESI**

No high resolution national geochemical survey has been undertaken to date combining stream water, sediment and soil analysis together with records of stream pH and eH. The GSI has conducted geochemical surveys, notably in the south-east ten years ago, but these were less comprehensive than are now possible and were principally directed at mineral exploration. In Northern Ireland, detailed geochemical surveys have only been conducted in the south-west. There has been no survey in Ireland of a coverage comparable to the BGS's Geochemical Baseline Survey of the Environment (G-BASE).

The trace element content of soils is mapped by Teagasc, but largely in response to requests from farmers themselves. Consequently, the coverage is incomplete except in the more intensive agricultural areas. Except for Ca, P and K, the number of sample points used is frequently below this minimum needed for accuracy.

The RESI would complement the existing level of soil and stream testing. The geochemical survey will provide baseline information on background trace element levels. The geophysical survey, in particular the EM component, can be used to detect the location of mining waste, and contaminated groundwater. Surveys undertaken by the Geological Survey of Finland (GTK) have used airborne geophysics backed by ground-based calibration to detect subterranean plumes contamination from landfills, pulp mills and agricultural waste (Lerssi *et al*, 1998).

### **Baseline information**

Information on baseline levels is important for planning purposes. New industrial development or brownfield site development requires an analysis of ground composition for the purposes of environmental impact assessment. Currently, information on baseline levels is seldom available, although such information is needed to judge whether emissions would exceed critical loads. If, for instance, a local authority were to offer planning permission for a development that was inappropriate for a location given existing background contamination, then it could be liable for any subsequent damages.

Baseline information on trace element levels is also needed to judge the suitability of land for sewage sludge application. More intensive local surveys would still be needed. However, the RESI would provide information to county councils at a strategic level on the amount and location of suitable land.

By providing detailed information on trace element levels, the RESI would also greatly assist future epidemiological studies. The data can be held in a simple database and presented using GIS. Such modern storage and presentational mediums make it easier to combine geochemical data with medical records. This will provide an ability to investigate links between environmental contamination and public health which could improve preventative techniques, reduce deaths and lead to health expenditure savings. Given the current absence of data, these benefits cannot currently be quantified, but the information can be used to select appropriate action such as the fixing of arsenic through the inexpensive precipitation of hydrous oxide.

## Monitoring

The RESI will provide baseline data by which to monitor changes in trace element levels. Both geochemical and geophysical techniques will provide baseline data to improve the monitoring of contaminated sites such as old mines and landfills. The conductivity of pyrites and sulphides contaminating groundwater around old mines may readily be detected by electromagnetic techniques. These results can be confirmed by geochemical analysis.

For planning purposes, baseline data, would confirm whether any increase in contamination at a particular site was subsequent to a development being allowed. This would assist in allocating liability for any clean-up required as well as indicating the extent of decontamination required to return the site to baseline levels.

The same baseline data can also be used to judge changes in the wider environment. The data will be of particular value for monitoring the effects of acidification and global warming on the mobility of trace elements, including any increase in toxicity which could affect human or animal health. Using GIS, this data can be combined with data on organic compounds, atmospheric pollution and land use in a similar manner as is currently monitored through the Environmental Change Network in the UK.

### *Net Present Value of RESI*

Due to gestation period of cancer, figures are discounted over 20 years from 2015.

Human health: Middle bound. NPV of RESI contribution @ 0.25 = £2.62 mn/yr.

Middle bound with VoSL included NPV @ 0.25 = £12 mn/yr.

Upper bound @ 0.5 including VoSL estimate of £24 mn /yr.

Lower bound @ 0.1excluding VoSL = £520,000 mn/yr.

Sewage sludge: Estimate Contribution £250,000.

## 8.4 Summary contribution of the RESI

<i>Benefit</i>	<i>nature of benefit</i>	<i>economic value of end result</i>	<i>RESI contribution</i>
<u>Human health:</u> distribution of PHEs	A direct benefit. Would reveal population at risk, particularly those dependent on private wells or own crops.	Significant, but lack of epidemiological studies linking actual PHE exposure to disease. Could be tens (e.g. 20) deaths each year. The cost of mortality and lost economic contribution would be at least £840,000pa. (taking treatment costs at £12,000pp), but £6.84mn if VoSL is included).	Major contribution, but requires policy response. Of interest to <u>individual communities, health authorities.</u>
<u>Contaminated land:</u> a) Background contamination	Direct benefit.	Inadequate information on extent of contaminated land. Info vital to EIA.	Would contribute info on background levels. May also reveal previously unknown contamination. Of value to <u>developers, local authorities enviro consultants and EPA.</u>
<u>Contaminated land:</u> b) Baseline contamination	Direct benefit.	Baseline information on contamination from mining sites, industrial sites and power plants. Could be used to allocate liability for clean-up costs, typically >£100,000/ha.	Indicate where is a need to collect detailed baseline data or monitoring data. Of value to <u>local authorities and EPA.</u>
<u>General environment:</u> Baseline information	Indirect benefit to policy. Not quantifiable.	Baseline information for policy on air pollution and land use.	Baseline data for monitoring of acidification & forestry. Of interest to <u>DELG, Duchas DAFRD &amp; DMNR.</u>
<u>Sewage sludge:</u>	Direct benefit.	Selection of sites suitable for application £650m set aside for waste management in NDP.	Info at a strategic level for <u>DELG &amp; local authorities,</u> potentially saving latter £10,000s. Preliminary selection would have been completed by 2004 using Teagasc data.

## **9. RADIATION**

The airborne radiometric surveying proposed in the RESI will provide an accurate baseline map of ground radiation levels. The principal radiation risk is presented by Radon gas produced by the decay of naturally occurring uranium, long term exposure to which can cause lung cancer. Radon has also been implicated as a cause of multiple sclerosis (Bølviken, *pers comm.*). In addition, the survey will be able to detect radiation deposition, in particular Caesium 137 remaining from the Chernobyl Disaster, but also deposition from nuclear power stations such as Sellafield. Radiation from these sources also presents a possible threat to human and animal health.

### **9.1 Nature of the Problem**

#### **9.1.1 Radon**

Radon is a naturally occurring radioactive gas arising from the decay of uranium in rocks and soils. Once Radon reaches the atmosphere it is rapidly dispersed to harmless concentrations but, where background levels are high, Radon can accumulate to unsafe concentrations. In enclosed spaces such as an unventilated house.

The individual risk is largely determined by conditions within the house. As noted above, Radon levels will be highest in poorly ventilated houses (as evidenced by winter peaks of indoor radiation concentrations). These concentrations can be eliminated by the inclusion of a plastic membrane together with an air space (sump) beneath the house from where the gas can be vented out. New constructions within vulnerable areas must include these precautions, but many people in older houses might regard the cost of installing a membrane, or even an extractor fan, as prohibitively expensive.

The acceptable reference level for safe exposure has been set at 200 Bq/m<sup>3</sup>. On the basis of a widespread national survey conducted between 1992-99, the Radiological Protection Institute of Ireland (RPII) has estimated that 8.8% of households in the country receive an annual dose in excess of this level. Taking the county breakdown provided by the RPII, this would imply that 220,000 people are at an elevated risk.

This latest figure is higher than that calculated on the basis of an earlier survey by McLaughlin (1991). He also estimated that 40% of the population who are at elevated risk could actually be receiving

double the reference level of radiation. If extrapolated to the latest estimate, this high level would apply to 88,000 people.<sup>5</sup> Moreover, children have an elevated risk.

The small number of cases involved means that the actual number of fatalities is notoriously difficult to estimate. To date, most projections have assumed that a linear scale of risk applies at radiation levels below the high levels experienced by uranium miners. Others argue that the relationship between radiation and cancer cases may not be linear and that a risk may only emerge above some threshold. Furthermore, estimates are based on lifetime risk which makes further assumptions about the amount of time people spend indoors or residing in an area with elevated radon emissions.

By way of illustration, Soderqvist (1995a) claims that the risk of cancer from smoking one pack of cigarettes per day, corresponds to a Radon exposure of 750 Bq/m<sup>3</sup>. He provides a table that indicates that exposure to Radon at 200 Bq/m<sup>3</sup> over sixty years would result in a 2.4% risk of lung cancer above the baseline risk of 3%.<sup>6</sup> More conservative estimates of 1.5-2% are favoured by researchers in Ireland. A synergistic relationship means that the risk associated with Radon is much higher for smokers (Nazaroff & Teichman, 1990).

In Ireland, people experience an average radiation dose of 89 bq/m (i.e. 2.2 msv). Previously the RPII had predicted that over 150 lung cancer deaths per year were due to radon (McGarry *et al* 1997-99), the new national survey could be interpreted to imply that a higher estimate could actually apply, perhaps 150-300 deaths (equivalent to or 5-8 per 100,000). Although bad, this is small compared with those due to smoking. The actual number of deaths in 1997 were 1,388 (averaging 50 per 100,000).

There is considerable geographical variation in radiation levels. In Co.Wicklow for example, an estimated 15% of the housing stock has elevated indoor Radon concentrations. The RPII 10km survey grid square centred on Salthill (which includes Galway City) revealed that over 30% of properties had Radon levels in excess of the reference level. Indeed, one house had a radiation level of 2,399 Bq/m<sup>3</sup> per annum which would involve a dose to the occupants of 60 mSv, equivalent to three times the maximum permitted dose for workers in the nuclear industry (Madden *et al*, 1994).

### **9.1.2 Caesium**

Fall-out from Chernobyl was deposited on high ground in rain experienced during the week following the accident in 1986. For people living in Ireland the threat of radioactive contamination from the Chernobyl disaster was extremely low even at the time of the incident. Exposure to iodine 131 was

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<sup>5</sup> This extrapolation is provided by the authors of this report and is not provided by official reports.

the immediate threat, but this isotope has a short half-life. By comparison, caesium isotopes have a longer half life and are rather immobile in the soil. The risk of direct contamination was low, if protracted. Radionuclides can concentrate in livestock products, fish or eventually in groundwater (NEA, 1995).

Detectable levels of radioactivity in sheep were observed in Ireland and Britain, but could be greatly reduced by grazing on uncontaminated pasture before slaughter. Restrictions on sheep movement and slaughter were imposed by the authorities in Britain and Northern Ireland. These remained in place until recently. In Ireland, action was limited to the sampling of domestic and imported produce. It was estimated that cancers arising from the disaster would be too small to be observed against background levels and would amount to just one fatality (Cunningham *et al*, 1987).

By 1990, levels of caesium-137 in the diet of EU citizens had fallen to pre-accident levels (NEA, 1995). There is a ever-present risk of another disaster. In addition, there is a continuing level of public and political concern over discharges from Sellafield.

## **9.2 Economic assessment**

### **9.2.1 Radon**

There are three main types of cost associated with Radon-induced lung cancer:

- a) a morbidity cost in terms of hospital and medical care;
- b) social costs arising from reduced capacity to work due to sick days;
- c) personal costs to the families of those diagnosed with cancer, including the *mortality cost* of premature death.

In addition, there are direct costs to the state which will meet a proportion of the costs of Radon protection up to £800. There is also the cost, including liability, arising from any exposure of children while in school. To the extent that reduced Radon exposure reduces these social costs, precautionary action provides an economic benefit.

#### **a) Morbidity**

Exposure to Radon imposes a treatment cost for patients diagnosed with lung cancer. Savings in these resources could be utilised elsewhere in the health sector. In Ireland, the most common form of

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<sup>6</sup> Soderqvist (1995) provides a rather high figures of 1.4 and 8.4 fatal lung cancer cases per 1000 people over ten and sixty years respectively. For exposures of 500 Bq/m<sup>3</sup> the corresponding figures are 10 and 60 respectively.

treatment is radiotherapy, but around one third of patients are considered suitable for chemotherapy or surgery. Usually, there is no prospect of a cure and palliative care is provided only to prolong quality of life. Sadly, this is short lived. Only 13% survived beyond four years following diagnosis (National Cancer Registry Board, 2000).

In theory, it should be possible to measure the public health costs by means of the Hospital In-patient Enquiry (HIPE), but treatment does not generally require the prolonged hospitalisation typically captured by the HIPE figures. Moreover, the database is far from comprehensive as it excludes private hospitals, out-patient care and nursing homes.

More detailed figures are available for the UK based on full-cost accounting including overheads. On the basis of the study by Wolstenholme & Whynes (1999), the mean cost discounted over four years of treatment was STG£6,150 for non-small cell lung cancer (the most common form) and STG£5,668 for small cell cancer (1993 prices). Updated to present prices, the cost is equivalent to an average of IR£7,862. Multiplied by the number of cases diagnosed each year this cost amounts to between IR£1.2-2.4 million.

b). Loss of economic contribution

Given that the economy is close to full employment, a direct social cost is imposed on society from the loss of the economic contribution of people unable to work due to illness or whose working lives are cut short by disease. This loss would apply at least to the 16% of people who suffer lung cancer deaths below the age of 65 (NCRB, 2000). In a US study by Ford *et al* (1999) the cost has been put at \$85,196 per fatality. Given the proportion of Radon induced deaths, this figure would amount to around £1.7 million per year if the same values were transferred to Ireland.

However, the cancer risk from Radon exposure is probably more delayed than that due to the biggest causal factor, smoking. The gradual accumulation in exposure means that a greater proportion of Radon-induced deaths would occur amongst people of post-retirement age. As a consequence, it is probably less appropriate to measure the cost of Radon-induced cancer in terms of a loss of direct economic contribution, although certainly there would be some loss.

c) Personal and mortality costs

As well as the care provided by the families of those diagnosed with cancer and the personal costs they must endure, there is also a social cost in terms of 'reduced activity days' and the premature death of the sufferers themselves.

*Reduced activity days* occur when sufferers are unable to engage in their normal preferred activity. Cost-utility analysis is commonly used in health economics to measure this diminished quality of life. However, for most lung cancer sufferers, this period is short as so few survive beyond five years following diagnosis.

Premature death is a yet more serious personal tragedy which could never be fully estimated. However, part of this personal cost can be captured and quantified by individuals' willingness to pay to avoid Radon induced lung cancer. This willingness to pay has been obtained from public surveys using the contingent valuation method (CVM). Estimates are vulnerable to the public's notoriously poor appreciation of risk in situations where this risk is perceived as being small or distant.

A CVM survey was conducted in Sweden where people were asked for their willingness-to-pay to avoid Radon induced cancer risks to their household's occupants (Soderqvist, 1995ab).<sup>7</sup> The results indicated that the average Swedish household (3 persons) would be willing-to-pay a once only amount of SEK 64,000 for a reduction in Radon exposure from 500 Bq/m<sup>3</sup> to 70 Bq/m<sup>3</sup>. Respondents with one or two children were willing to pay half as much again. On the basis of responses from the region of Sollentuna, the author estimates a value of saving a (statistical) life (VoSL). This is not to be interpreted as a value of life, but rather is the sum of individuals' own valuation of reducing risk of premature death. Based on the actual risk reduction (rather than the *perceived* reduction) the VoSL is SEK 3.3 million.

CVM is vulnerable to a *hypothetical bias* in which people state a readiness to undertake an action that, in reality, they will not. Indeed, people can pay for their own precautions by installing radiation proof membranes or simply extractor fans. However, whether or not people voluntarily choose to take precautions does not deny the total potential benefits of doing so. Market failures are present in many instances where people would be advised to take a certain action, but do not, e.g. household heating insulation.

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<sup>7</sup> The figures are Soderqvist's estimate for the national population adjusted for (less concerned) non-respondents.

Accepting these reservations, were Soderqvist's figures to be transferred to Ireland, the benefits would be IR£310,000 per person or at least £46 million per year taking the RPII estimate of total fatalities.<sup>8</sup> Together with the morbidity benefits, this represents the potential benefit of eliminating the Radon risk.

### 9.3 Contribution of the RESI

#### 9.3.1 Radon

The total quantifiable benefit from eliminating the Radon risk is comprised of savings in medical treatment and the value of statistical life (VoSL). The RESI would contribute to achieving these benefits along with information campaigns, advice from the RPII and investment in Radon-proof membranes, etc. It would provide a direct benefit by avoiding costs which are currently incurred. A realisation of this benefit depends on the willingness of policy makers to respond to this data and of existing householders to make expenditure that averts the risk.

Whether these requirements are realised or not, the potential contribution of the RESI is significant. Variations in Radon concentrations in the home are due to indoor factors such as ventilation or exterior meteorological factors. However, geological conditions exert the primary influence. Most obviously, this is due to uranium in underlying rocks and soils. The porosity and moisture content of rocks and soils are also factors. Due to the short half-life of Radon, most radiation reaches the indoor environment from a depth of one metre, but radiation can be received from much deeper levels where there is fracturing of the underlying rock. In these instances, there can be local hot-spots of high radiation.

The RESI could map such hot-spots. Householders in these locations could then be approached directly and advised to take precautionary measures. This would contribute significantly to reducing the risk of Radon-induced cancer. It would also ensure national efforts to reduce the risk are most *cost-effective*. In the US, Ford *et al.* (1999) have found that targeted campaigns are cost-effective. While they admit that an assumption of full-compliance by the targeted householders is unlikely, this would result in a cost per life saved of 60% compared with an across-the-board awareness campaign.

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<sup>8</sup> This estimate is lower than those associated with other risks, for instance a figure of £2.4m. (updated to 1997) has been proposed for the EU (*see* Pearce, 1998). Typically, these figures are related to the risk of accidents (e.g. road traffic accidents) for people of around 40 years of age. With Radon, the risk emerges in later life and people likely apply some mental discounting to a distant mortality risk. On this basis, it is arguably more appropriate to adjust the figures to represent the additional years of life gained due to reduced risk (i.e. value of statistical life years), rather than simply the risk of premature death. Discounted at a utility Discount rate of 0.3% as proposed by Pearce (1998), the annual VoSY to somebody of age of 40 would be around £13,000.

Given that the need for 500,000 new houses has been identified in the NDP, there is straightforward capacity to ensure that adequate precautions are taken in zones where there is a high Radon risk. Builders are already required to incorporate Radon protection measures. The state is responsible for ensuring the safety of children in schools and therefore for ensuring that precautions have been taken. The RESI data would provide more accurate information of where precautions are necessary and how substantial these should be.

### **9.3.2 Caesium**

The RESI is capable of detecting caesium-137 and other radionuclides. As such, it would provide a once-only indication of the current extent of contamination from the Chernobyl disaster. This could reveal hot-spots where radiation is much higher than realised and where there is a continuing risk that might merit precautions being taken in relation to food products. The survey would also provide a baseline from which to assess any future contamination due to a nuclear incident.

The results could also provide a baseline map of the extent of radioactive contamination from British nuclear reactors, including Sellafield. Maps produced by the BGS clearly reveal high, if acceptable, levels of contamination in coastal sediment, for example along the Dee Estuary.

## **9.4 Summary contribution of the RESI**

The estimate of total costs is very dependent on that of Radon-induced cancer deaths. Lower figures would apply to the RPII's own estimate of 150 deaths per year. Whereas the maximum estimate of 300 deaths is crudely extrapolated from the RPII's revised figure showing an increase in the numbers of people at risk. All figures are subject to error as there is not yet conclusive evidence of levels of lung cancer due to Radon, or the age at which the disease strikes.

Morbidity costs are of major concern to the state, and to private health organizations, as they must directly fund health care. Society loses the contribution of people whose working lives are shortened. Both these costs are reduced by the short survival period of people diagnosed with cancer. Costs are also a small fraction of those incurred due to smoking. The highest absolute cost is borne by sufferers themselves, and of their families, and is measured in terms of Value of Statistical Life (VoSL).

<i>Benefit</i>	<i>nature of benefit</i>	<i>economic value of end result</i>	<i>RESI contribution</i>
<u>Radon</u>	Indirect benefit: a) reduced morbidity costs to the state, b) avoid cost of lost economic contrib. c) reduce personal mortality cost measured as VoSL.	Mortality costs of £1.8m/yr (av £1.2- 2.4).  Lost economic contribution around £850,000 (i.e half Ford <i>et al</i> figure for US).  VoSL cost is very high at least £46 mn/yr.  Median estimate = £2.65mn/yr or £48.65mn/yr. if VoSL is included).	Important contribution, but small in relation to the benefits of remedial action expressed against total benefits ( <i>left</i> ).  Main benefit is increased cost-effectiveness of policy and of building regulations.  Of most interest to <u>state</u> (RPII). Also <u>individual communities</u> , and <u>health authorities</u> .
<u>Caesium:</u>	Indirect benefit.	Not quantifiable. Would improve effectiveness of response to future contamination. Also reveal continuing contamination from nuclear reactors.	Baseline information. Of value to <u>state</u> (RPII) and <u>communities along Irish Sea</u> .

#### *Net Present Value of RESI*

In the case of Radon the NPV figures are largely dependent on the long gestation period of Radon-induced cancer. Even if there is a prompt policy response, mitigation measures may not begin to have an impact on mortality for a further 20 years. The discounting period has therefore been extended by 20 years to reflect this (without which the benefits would be zero). The exception, however, is VoSL, whereby people are being asked now how much they would be willing to pay for a prolongation of their lives. The present value of the benefit therefore largely rests on whether it is considered appropriate to include VoSL in the CBA.

Mortality	Middle bound NPV of RESI Contribution @ 0.25 = £4.16 mn.
& lost economic contribution (over 20 years from 2015)	Upper bound 0.5 Lower bound 0.1
VOSL	Middle bound NPV of RESI contribution @ 0.25 = £151.57 mn.
(over 20 years from 2015)	Upper bound 0.5 Lower bound 0.1

## REFERENCES

- Aggett, P.J., Mills, C.F., Morrison, A., Callan, M., Plant, J., Simpson, I.R., Dingwall-Fordyce, I., Halliday, C.F. & Stevenson, A. (1988) A Study of Environmental Geochemical and Health in North-east Scotland, in Thornton, I. (ed) Geochemical and Health (1988) - Proceedings of the 2<sup>nd</sup> International Symposium. Science Reviews Limited.
- Bartrop, D., Strehlow, C.D., Thornton, I. & Webb, J.S. (1975) Absorption of lead from dust and soil. *Journal of Post-graduate Medicine*, 51, pp.808-4.
- Barry, F., Murphy, A., Strobl, E. & Walsh, B. (2000) A Review of the Economic Appraisal System for Industrial Projects, Unpublished draft, University Industry Centre, University College Dublin.
- Bateman, D.W., Langford, I.H., Willis, K.G., Turner, R.K. & Garrod, G.D. (1993) The impacts of changing WTP question format in contingent valuation studies. CSERGE Working Paper GEC 93-05.
- Bernknopf, R.L., Brookshire, D.S., Soller, D.R., McKee, M.J., Sutter, J.F., Matti, J.C. & Campbell, R.H. (1993) Societal Value of Geological Maps. U.S. Geological Survey Circular 1111.
- Berrow, M.L. & Burrige, J.C. (1979) Sources and distribution of trace elements in soils and related crops, Proceedings of International Conference on Management and Control of Heavy Metals in the Environment, London, Sept. 1979, CEP Consultants, Edinburgh.
- Berrow, M.L. & Reaves, G.A. (1985) Extractable copper concentrations in Scottish soils, *Journal of Soil Science*, 36, pp31-43
- Clinch, J.P. (1999) Economics of Irish Forestry. COFORD, UCD, Dublin.
- Cockburn, A. (1993) The Urban Waste Water Directive, A local government perspective. *Scottish Envirotec*, 1 (3) pp25-35.
- Convery, F. and Roberts, S. (2000) Farming, Climate and the Environment in Ireland, paper presented at the AGMET Conference, Geological Survey of Ireland, Dublin, Feb 29<sup>th</sup>, 2000.
- Cooper, A.H. & Calow, R.C. (1998) Avoiding Gypsum Geohazards: Guidance for Planning and Construction. BGS Technical Report WC/98/5.
- Coulter, B.S., McDonald, E., MacNaeidhe, F.S., Parle, P.J., Blagden, P., Fleming, G.A. and Gately, T.F. (1999) Nutrient and Trace Element Status in Grassland and Tillage Soils, Teagasc, Wexford.
- Cunningham, J.D., MacNeill, G. and Pollard, D. (1987) Chernobyl – Its effects on Ireland. Nuclear Energy Board, March 1987.
- Department of Agriculture, Fisheries and Rural Development (2000) Report of the Investigation into the Presence and Influence of Lead in the Silvermines area of County Tipperary. IAG, June 2000.
- Department of Finance (1994) Guidelines for the Appraisal and Management of Capital Expenditure Proposals in the Public Sector, July 1994.
- Department of Finance (1999) Proposed Working Rules for Cost-Benefit Analysis, CSF Evaluation Unit, July 1999.

Department of the Marine and Natural Resources (DMNR) Current state mining and prospecting facilities and areas open for application under competition. Exploration and Mining Division, 1 November 2000.

Economic and Social Research Institute (1998) National Investment Priorities for the Period 2000-2006. edited by Fitzgerald, J., Kearney, I., Morgenroth, E., Smyth, D. in association with DKN, Peter Bacon & Consultants and NUI, Maynooth.

Ecotec (1993) A cost-benefit analysis of reduced acid deposition: UK natural and semi-natural ecosystems. Ecotec, B'ham.

Environment Agency (1999) Contaminated Land Issues. <http://www.environment-agency.gov.uk>

Environment Agency (2000) Information on Land Quality in the UK. Summary R&D Report 25 prepared by British Geological Survey & LGC.

Environmental Protection Agency (2000) Ireland's Environment, EPA Wexford.

Environmental Protection Agency (1999) Water Quality in Ireland 1995-97, EPA, Wexford.

European Environmental Priorities (EEP): An Environmental and Economic Assessment, Draft report (Dec 1999) prepared for the European Commission by RIVM, EFTEC, NTUA and IIASA.

The European Parliament and Council of the European Union (2000) Directive for establishing a framework for Community action in the field of water policy, Brussels, 18 July 2000.

Fanning, A., Crowe, M., Carty, G. & Clenaghan, C. (1999) Water Quality Management Planning in Ireland, EPA, Wexford.

Farr, J.L., Spray, P.R. & Foster, S.S.D. (1982) Groundwater Supply Exploration in Semi-arid Regions for Livestock Extension - a Technical and Economic Appraisal. *Water Supply and Management*, 6 (4), pp343-353.

Farrell, E.P., Aherne, J., Boyle, G.M. & Nunan N. (2000 forthcoming) Long-term monitoring of atmospheric deposition and the implications of ionic inputs for the sustainability of a forest ecosystem. Department of Environmental Resource Management, UCD.

Fehily Timoney & Company (1998) Inventory of Non-hazardous Sludges in Ireland. Prepared for Dept of Environment and Local Government in association with WRc.

Finlay, S. (1981) Probability theories as applied to further base metal discoveries in Ireland. pp.19-25. in Mineral Exploration in Ireland, Progress and Developments 1971-1981. Eds. A.G. Brown and J.F. Pyne.

Fleming, G.A. (1988) Aspects of Agricultural and Environmental Trace Element Research in the Republic of Ireland, in Thornton, I. (ed) Geochemical and Health (1988) - Proceedings of the 2<sup>nd</sup> International Symposium. Science Reviews Limited.

Ford, E.S., Kelly A.E., Teutsch, S.M., Thacker, S.B. & Garbe, P.L. (1999) Radon and Lung Cancer – A Cost-effectiveness Analysis, *American Journal of Public Health*, 89 (3), pp351-357.

Gallagher, V., O'Connor, P., Good, J., Kilkenny, B., O'Suilleabhain, D. & Prescott, T. (1998) Environmental Problems and Rehabilitation Trials at Avoca Copper Mine Ireland, *Chronique de la Recherche Miniere*, No. 533.

Giller, P.S., O'Halloran, J., Hernan, R., Roiche, N., Clenaghan, C., Evans, J., Kiely, G.K., Morris, P., Allott, N., Brennan, M., Reynolds, J., Cooke, D., Kelly-Quinn, M., Bracken, J., Coyle, S. & Farrell, E.P. (1993) An Integrated Study of Forested Catchments in Ireland, *Irish Forestry*, 50 (10) pp70-83.

Government of Ireland (1999a) National Development Plan 2000-2006.

Government of Ireland (1999b) Development of the National Roads Network, Report on Value for Money Examination by the Comptroller and Auditor General. Report No. 29, March 1999.

Government of Ireland (1995) A New Minerals Policy. Report of the National Minerals Policy Review Group, for Minister for Transport, Energy and Communications. April 1995.

Guinée, J.B., van den Bergh, J., Boelens, J., Fraanje, P.J., Huppés, G., Kandelaars, P., Lexmond, Th.M., Moolenaar, S.W., Olsthoorn, A.A., Udo de Haes, H.A., Verkuijlen, E., van der Voet, E. (1999) Evaluation of risks of metal flows and accumulation in economy and environment, *Ecological Economics*, 30, pp.47-65.

Hanley, N. & Craig, S. (1992) The economic value of wilderness areas: an application of the Krutilla-Fisher Model to Scotland's 'Flow Country', Research paper, University of Stirling.

Hornung, M. & Adamson, J. (1991) The Impact of Forestry Expansion on Water Quality and Quantity, Forestry Commission Occasional Paper 42, Forestry Commission, Edinburgh.

Hyvonen, S.R., Hanninen, P., Maikitalo, K., Penttinen, S., Siira, M. & Sutinen, M-L. (1998) Classification of forest soils using dielectric and gamma-ray moisture detection. Journal paper provided by GTK, Finland.

Irish Times (Kevin O'Sullivan) "Danger of toxic microbes in Irish lakes highlighted", Jan. 5<sup>th</sup>, 2000.

Irish Times (Frank McDonald) "Plastic wrap for Kildare by-pass cutting proposed", Aug 16<sup>th</sup>, 1999.

Kerins, D. (2000). A Cost-Benefit Analysis of Integrated Pollution Control Licensing, unpublished Master of Science (Environmental Policy) thesis, University College Dublin.

Krutilla, J.V. & Fisher, A.C. (1975, 1985) The Economics of Natural Environments, Baltimore, John Hopkins Press.

Lanne, E., Vaisanen, U., Forss, H., Ruotsalainen, A. & Lehtimäki, J. (1999) Geophysical prospecting of bedrock aquifers in Finland. Proceedings of the Fifth Meeting of the Environmental and Engineering Society (ed. Vero, L.) Sept 6-9, 1999, Budapest.

Lehane, M. (1999) Environment in Focus – A Discussion Document on Key National Environmental Indicators, EPA.

Lerssi, J., Kurimo, M., Jokinen, T., Lanne, E. & Puranen, R. (1998) Environmental applications of airborne geophysics in Finland. Proceedings of the Fourth Meeting of the Environmental and Engineering Society (ed. Casas, A.) Sept 14-17, 1998, Barcelona.

Lucey, J., Bowman, J.J., Clabby, K.J., Cunnigham, M., Lehane, M., MacCarthaigh, M., McGarrigle, M.L., & Toner, P.F. (1999) Water Quality in Ireland 1995-1997. EPA, Wexford.

Madden, J.S., Duffy, J.T., Mackin, G.A., Colgan, P.A. & McGarry, A.T. (1994) Radon in Dwellings in Selected Areas of Ireland, Radiological Protection Institute of Ireland.

- Marine Institute (1996a) A National Survey of Water-based Leisure Activities, prepared by the ESRI.
- Marine Institute (1996b) Investment Programme 2000-2006 for the Water-based Tourism and Leisure Sector in Ireland.
- McClelland, G.H. (1992) Methods for measuring non-use values: A contingent valuation study of groundwater cleanup, Centre for Economic Analysis, University of Colorado.
- McGarry, A.T., Fennell, S.G., Mackin, G.M., Madden, J.S. & O'Colmain, M. (1997-99) Radon in Dwellings – The National Radon Survey (regional reports 1997-99), Radiological Protection Institute of Ireland.
- McGrath, D. & Murphy, W.E. (1998) Geochemical Survey of Soils in the Republic of Ireland, Poster presented at meeting of Soil Science Society, Belfast, Sept 6-8, 1998.
- McKay, C. (1974) A dental epidemiological study in a high fluoride area of County Fermanagh. *Ulster Medical Journal*, 43, pp 41-44.
- McLaughlin, J.P. (1991) Radon and Indoor Air Quality: Its Measurement, Extent and Significance. In J.Feehan (Ed.), *Environment and Development in Ireland*, Environmental Institute, UCD.
- Ministry of Agriculture, Fisheries and Food (UK) (1998) Economic Evaluation of the Nitrate Sensitive Areas Scheme.
- Morgenstern, R.D, (Ed.) (1997) Economic Analyses at EPA – Assessing Regulatory Impact. Washington DC, Resources for the Future.
- National Cancer Registry Board (2000) Cancer in Ireland, 1997: Incidence and Mortality.
- Nazaroff, W.W. & Teichman, K. (1990) Indoor Radiation, *Envir, Sci Tech*, 24, pp775-782.
- Nuclear Energy Agency (1995) Chernobyl Ten Years On: Radiological and Health Impact. OECD.
- Pearce, D., Howarth, A. Gordon, F., Ozdemiroglu, E. and Hett, T. (1998). Benefit Analysis per PEEP: Background Document for Programme “Economic Assessment of Priorities for a European Environmental Policy Plan, Brussels: European Commission DG XI.
- Pearce, D. (1998) Valuing Statistical Lives, Background Document for Programme “Economic Assessment of Priorities for e European Environmental Policy Plan, European Commission DGXI.
- Pearce, D., Markandya, A. & Barbier, E. (1989) *Blueprint for a Green Economy*. London, Earthscan Publications.
- Plant, J., Baldock, J., Haslam, H. & Smith, B. (19xx) The Role of Geochemistry in Environmental and Epidemiological Studies in Developing Countries. *Episodes*, 21 (1).
- Rasmussen, S. (1997) Municipal Landfill Management, in Morgenstern, R.D, (ed.) (1997) Economic Analyses at EPA – Assessing Regulatory Impact. Washington DC, Resources for the Future.
- Robin, D. & Spencer (1997) *Exploration Geophysics*, 28 pp296-298.
- Scott, S. (1999) Pilot Environmental Accounts, Dublin, Central Statistics Office.
- Site Investigation Steering Group (1993) Site Investigation in Construction – Without site investigation ground is a hazard (1). London, Thomas Telford Group.

Soderqvist, T. (1995a) The Value of Saving a Statistical Life in the case of Residential Radon Risks: Estimates and Determinants, Beijer Discussion Paper Series No. 59, Beijer International Institute of Ecological Economics.

Soderqvist, T. (1995b) Property Values and Health Risks: The Willingness to Pay for Reducing Residential Radon Exposure, *Scandinavian Housing and Planning Research*, 12, pp141-153.

Stenger, A. & Willinger, M. (1996) Preservation value for groundwater quality in a large aquifer: a contingent valuation study of the Alsatian aquifer. Centre de Recherche en Sciences Economique et de Gestion, Strasbourg.

Suttle, N.F. (1988) Relationship between the Trace Element Status of Soils, Pasture and Animals in relation to Growth Rate in Lambs, in Thornton, I. (ed) *Geochemical and Health (1988) - Proceedings of the 2<sup>nd</sup> International Symposium*. Science Reviews Limited.

Thompson, H. (1992) *Nat West Quarterly Economic Review*, November 1992, pp20-33.

Thornton, I. & Plant, J. (1980) Regional Geochemical Mapping and Health in the United Kingdom, *Journal of the Geological Society of London*, 137, pp. 575-586.

Towers, W. (1994) Towards a strategic approach to sewage sludge utilisation on agricultural land in Scotland, *Journal of Environmental Planning and Management* 37 (4), pp 447-460.

Tunney, H. (1990) A Note on a Balance Approach to Estimating the Phosphorus Fertiliser Needs of Agriculture, *Irish Journal of Agricultural Research* 29, No. 2, 149-152.

United Nations Economic Commission for Europe (1999) Draft Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification and Ground Level Ozone. <http://www.unece.org/environment/wgs/eb991e.pdf>

Wolstenholme, J.L. & Whynes, D.K. (1999) The Hospital Costs of Treating Lung Cancer in the United Kingdom, *British Journal of Cancer*, 80 (1/2) pp.215-218.

Zerbe, R. & Dively, D. (1994) *Benefit-Cost Analysis in Theory and Practice*, Harper Collins, New York

Zheng, B. & Hong, Y. (1988) The Geochemical Environment related to Human Endemic Fluorosis in China, in Thornton, I. (ed) *Geochemical and Health (1988) - Proceedings of the 2<sup>nd</sup> International Symposium*. Science Reviews Limited.

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