PUBLIC PERCEPTIONS AND SCIENTIFIC UNCERTAINTY: THE MANAGEMENT OF RISKY DECISIONS

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As part of an overall program of managing uncertainty in environmental decision making, the Ministry of the Environment of The Netherlands commissioned Environmental Resources Limited (ERL), based in London, to undertake a detailed study of highly publicized but scientifically controversial decisions. The objective was to determine how such decisions may be better managed. Through the examination of 18 selected cases, ERL investigators developed a clear profile of what they termed risky decisions, and identified determining their acceptability as government policies. Combining lessons from the case studies with a detailed survey of management approaches and decision-making techniques, ERL devised a strategy for handling risky decisions more effectively. The Dutch government is now planning a series of risky decision workshops for senior officials, scientists, and policy advisors.

For governments around the world, the following scenario is by now familiar. It all starts innocently enough: a weekly review summarizes the preliminary results of a long-term scientific study, and speculates on the theoretical implications. These speculations are picked up by the popular press, interpreted as potential risks to the public and the environment, and loosely associated with some general trend in public health or environmental quality. The ensuing publicity creates sufficient alarm to put pressure on the Environment Ministry, which responds by instructing its scientists to review the available evidence. These scientists find "no firm evidence of risk," and the Ministry announces to the public and the press that there is no cause for public concern.

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Environmental and consumer pressure groups, already alert to the issue, counter with their own assessments which the press quotes liberally in the context of growing public apprehension. By contrast, pronouncements from the Ministry and from industry representatives sound unconcerned or circumspect. This gives rise to accusations of government complacency, and even collusion with industry. Mounting political pressure forces the Ministry to reexamine the studies and to issue a more detailed response quantifying the risk. This level of risk, the Ministry says, is negligible when compared to, for example, smoking or driving in a car. However, the pressure groups use the same figures to predict actual numbers of victims in the local population. While covering this debate, the press also searches out other expert opinions in obliquely related disciplines, and highlights several alarming and contentious statements.

Government scientists continue to say the available studies are inconclusive, and the government's report simply reiterates the need for more research. Public awareness by now is very high. The press, assuming that action is by now a foregone conclusion, begins to report on stories of hardships and economic impacts. The Ministry is asked what action is proposed. Officials are faced with a high level of public concern and considerable uncertainty about whether the action is justified. They are also aware that the action is inconsistent with the Ministry's overall stance on risk. The Minister, when the dossier arrives, knows that there is a potentially high political cost attached to almost any action that can be proposed at this stage.

This scenario captures the dilemma that has faced governments in Europe and the United States on issues such as lead in gasoline, the ozone layer, radon, acid rain, food additives, and pesticides. In a slightly different form the same set of issues has characterized decision making for radioactive waste, chemical waste, and the siting of hazardous installations, such as liquified petroleum gas storage.

Frustrated by the apparent helplessness of governments in such situations, the Ministry of the Environment of The Netherlands commissioned a study of managing uncertainty in environmental decision making. Investigators from Environmental Resources Limited (ERL) examined a wide range of highly publicized but scientifically uncertain environmental issues, and how they were managed by government. The project was designed to extract lessons that could help the Ministry deal with similar problems in the future. The conclusions of the study, completed in May 1986, are summarized in an ERL report, *Risky Decisions: A Strategy*. ERL is now working with the Ministry to develop a series of workshops for officials in The Netherlands government to put the lessons into practice.

The Study

Discussions and internal seminars with members of the Ministry revealed that officials felt that certain high profile environmental problems presented special

complications. (See Appendix 1 for ten examples.) In such a case the danger exists that the Ministry would be put in the position of responding to events rather than taking control. Forced into a defensive posture, the Ministry would find the credibility of its statements impaired.

A second problem was the predominant view, especially among analysts, that the solution to a problem depends on sifting the data. However, it was clear that many of the issues involved a high level of uncertainty, so that evidence was often controversial and, in fact, added to the uncertainty.

Third, officials recognized that the statistical treatment of risk was only part of the answer. It was important to recognize that the public perceives risk at different times in different ways, while analysts using traditional tools find such apparent irrationality and inconsistency difficult to handle. For example, growth-stimulating hormones used in beef production were recently banned with the European community. Though a committee of scientists found no grounds for a ban on either natural or synthetic growth promoter, pressure from environmentalists overwhelmed the belated countercampaign mounted by industry to defend the hormones. While scientists were shocked that misinformed consumerism would be more influential in policy making than scientific evidence, European Economic Community agriculture minister Frans Andreiessen observed that it was "wholly proper" to be more responsive "to political realities than to scientific facts" (*New Scientist 1986*).

Responding to a similar set of circumstances, the British government is allowing only low level radioactive waste to be buried at dumping grounds developed by the Nuclear Industry Radioactive Waste Executive. There are no scientific grounds for banning intermediate level waste from the shallow burial grounds. The objective expressed by the decision, made in the wake of the Chernobyl disaster, was to reassure the public. Radioactive waste disposal has been an area in which the gap between scientific assessment of risk and public perception has been difficult to bridge. In this instance, the government chose to respond to community concern (*The Times*. Nuclear sites climbdown by cabinet. 1986).

Fourth, a culture gap is evident between top administrators and their scientific research teams. Administrators who must function in the world outside science are conscious of the political implications of issues and must meet the need for action (or at least for statements). Scientific research does not necessarily answer administrators' direct questions or meet administrators' timescales.

The Ministry felt the need to develop a more strategic approach to achieve widely acceptable solutions, not just adequate defenses. Scientists should find a way to think about assessing real-world options, not just state-established facts and uncertainties. The study was designed to create a process for such strategic thinking for both groups. It was based on a review of actual decision-making experiences, known management approaches, and common problem-solving methods.

The Case Studies

Eighteen environmental issues representing a range of environmental problems and situations were selected as case studies. (see Table 1). The cases included decisions in the areas of hazardous materials (e.g., liquified natural gas or LNG), uncertain environmental effects (e.g., acid rain), and environmental disasters (e.g., accidental release of dioxin). Examination of the experiences reveals seven general themes:

1. *The acceptability of decisions can be affected easily by interest group politics.* For example, in the United Kingdom an early decision about siting low level radioactive waste disposal, reached after lengthy scientific and engineering investigations, proved to be untenable in the face of effectively mobilized local opposition (case study F).
2. *Politics can easily turn a specific problem into a much wider issue.* In the United States, the expansion of a particular LNG terminal (case study I) became a much wider issue involving the Federal Power Commission in a review of existing policies on import and use of LNG.

TABLE 1. Case Studies

Title	Content
A. Wisconsin Acid Rain	state policy
B. NO_x Standards in the UK	government action on setting NOx standards for automobiles
C. NO_x Standards in the US	standard setting for NOx emissions in the US
D. Acidification in the Netherlands	government policy on acidification
E. Radioactive Waste in the Netherlands	government policy on managing wastes
F. Radioactive Waste in the UK	government policy on managing wastes
G. PCBs in the US	regulations on the use of PCBs in transformers
H. LPG Policy in the Netherlands	government policy for LPG activities
I. LNG Hazards in Boston Harbor, USA	government regualtions on operation of an LNG terminal
J. Cadmium in Sweden	government ban on cadmium
K. Dioxin emissions, USA	siting of solid waste in New York City
L. Hackensack Meadowlands, New Jersey, USA	proposals for reclamation of mercury-contaminated wetlands
M. The Sevin Crisis	control methods for gypsy moths, Massachusetts, USA
N. Platier d'Oye, France	regulations for establishing a coastal ornithological reserve
O. Release of dioxin, Seveso, Italy	clean-up methods following accident
P. Oosterscheldt flooding, the Netherlands	selection of an appropriate flood control system
Q. 2,4,5-T in Germany	regulation of the chemical
R. 2,4,5-T in the UK	regulation of the chemical

3. *If opposing interest groups are brought into the decision-making process, even at a late stage, they are less likely to impede the resulting decisions.* For example in the dioxin/incineration controversy (case study K), the New York Academy of Sciences used mediation to reach agreements with affected neighborhood groups.
4. *Simple concessions, such as offers of compensation, can play a positive role in the process.* In the French Platier d'Oye Ornithological Reserve (case study N), the Regional Park Agency reduced hunters' resistance to the reserve by arranging to pay for new hunting blinds elsewhere.
5. *Formal technical assessments, if developed by the government agency or any one interest group alone, may serve to alienate other interested parties rather than attract their support.* In the Wisconsin acid rain case (case study A) an industry-sponsored analysis was suspected of being biased.
6. *Formal technical assessments can be a useful tool in a participatory decision-making process.* The Dutch Ministry of the Environment avoided an impasse in making policy for managing liquified petroleum gas (LPG) (case study H) by using various analytical devices within an interactive group process to involve all interest groups in finding an agreeable solution.
7. *Scientific uncertainty, owing to insufficient data or contradictory findings, may precipitate or aggravate controversy, but it is rarely a critical barrier to acceptable decision making.* More often, the political context is the overriding factor. In Sweden, for example, certain interest groups managed to block a decision by making a political issue out of their unwillingness to accept the economic burden of reducing the risk (case study J). In The Netherlands, the survival of a precarious coalition government was a central factor in determining the course of decision making on the Oosterscheldt flood protection scheme (case study P).

Risky Decisions

From these case studies emerged a clear profile of a particular kind of dilemma, which was termed the risky decision. As anticipated by the Dutch Ministry of the Environment, the 18 case studies showed that two key factors making a decision risky are the scientific uncertainty and public perception of the issues.

Highly charged public perceptions can make things risky for the decision maker because they result in orchestrated campaigns for immediate action (or, in the case of siting decisions, campaigns for some alternative action of a type that may seem insupportable given the available scientific evidence). This raises the risk of political damage to the government if its decision is unacceptable to the majority of interested parties. The decision maker may be further constrained by previous decisions and other precedents. In the United Kingdom, the Environment Minister, Mr. Waldegrave, has commented that the advice he often

hears on how to handle radioactive waste is that "he should not start from where he is now."

The other factor that can make a decision risky is scientific uncertainty about its consequences. In most risky environmental decisions, there is great uncertainty about whether environmental damage is actually occurring and if so what is causing it. There may be uncertainty about whether damage controls will actually work. Managers may believe that both the adverse effects and the cost of preventing them are severe. In such a case, the decision maker runs a small but significant risk of causing serious human injury or environmental damage on the one hand, or on the other of incurring totally unnecessary economic costs and hardships.

This pressure may lead decision makers to put unrealistic demands on the scientific community. In the United States, when scientists reported to the Food and Drug Commissioner, Alexander Schmidt, that they were "95 percent certain that cyclamates were not carcinogens," he is said to have replied, "I am looking for a clean bill of health, not a wishy-washy, iffy answer."

Clearly risky decisions are ones that the decision maker needs to handle strategically. After consideration of the above characteristics of risky decisions, a proposed strategy for successfully managing them was developed. The strategy incorporated the lessons of the case studies, a variety of known management approaches, and a range of available decision-making methods. In developing this strategy, the project team examined a broader range of knowledge about decision making than is normally connected with environmental issues. Psychological and anthropological, as well as sociological, perspectives were included.

A Strategy

Five principles may be applied by decision makers dealing with risky decisions:

1. *Emphasize outcomes.* Whatever analytic tools are used and whatever steps are taken to minimize risk, the focus of decision making should always be on the balance between benefits and risks. Decision makers should not allow the process of decision making or the techniques of analysis to obscure the focus on desired outcomes.
2. *Take the initiative.* Where public concern exists, the government agency must be seen to be in control. Failure to take control may result in the government being permanently on the defensive, responding to accusations of complacency or incompetence.
3. *Build legitimacy.* The coping strategies suggested in this paper include provisions for actually mitigating risks, increasing the acceptability of risks that remain, correcting misperceptions, or, most likely, a combination of these. By taking account of the concerns of all the different interest groups, a solution may be found that is acceptable to most of them.

4. *Maintain credibility*. Many of the case studies demonstrate a general public mistrust of government, and this mistrust exacerbated the difficulty of managing risky decisions. To become more credible, a government agency should be honest and open in its communications, state clearly how it plans to act, and then act as promised, give reasons for its decisions that appear reasonable to the majority, and behave as though it believes the public to be intelligent and mature.
5. *Seek consensus*. It is important to understand the concerns of the various interest groups, including their perceptions of any solution or decision. It is never sufficient simply to say that an interest group's concerns are unjustified. In particular, attention should be paid to the concerns of those who are expected to accept the greatest risk.

A management approach has been developed to assist decision makers in implementing these principles. The approach consists of four main activities, conducted more or less in parallel, each of which deals with a different aspect of the risky decision process: program management, risk management, development and implementation of a communications policy, and focusing research. Each of these activities consists of several tasks.

Program Management

The case studies indicate that government response to risky decisions is often hampered by organizational problems. This may be overcome by establishing a working group made up of members of the relevant departments, and reporting to the relevant administrator. The structure of the group may be wholly informal. However, the case studies clearly demonstrate the importance of good coordination between administrators and analysts as well as the need to clarify where the responsibility lies. The first task of program management is to ensure proper coordination, for example, by setting up a working group involving individuals within the Ministry with relevant scientific or administrative responsibility.

The group will be directly responsible for meeting with interested and affected parties to demonstrate that the government is taking action, to listen and understand the groups' concerns in order to identify acceptable solutions, and to collect information the groups may hold, especially information that is solution-oriented rather than analysis-oriented.

The group also will direct the agency's external communications on the problem. The first job may be to issue a statement from the government saying that urgent steps are being taken to examine the problem and that a further statement of proposed action will be taken within a given period of time.

Risk Management

A central component in the group's work is the development of coping strategies. As noted, public perception of risk is based only partly on scientific evidence. Other factors include familiarity with risk, the ability to visualize its effects, catastrophic as opposed to insidious risks, the degree of voluntary control of the risk, and lack of trust in official judgments. While government officials and industrialists tend to have little sympathy for those who are more fearful than the facts support, these perceptions cannot be ignored. It is the political effects of these perceptions that ultimately will determine the success of decision makers' choices. Given these perceptions, coping strategies should be devised from three types of possible actions:

1. reduction of actual risk,
2. encouragement of acceptance of some degree of perceived risk, and
3. explanation of risk and creation of confidence through public understanding.

Risk reduction measures require technical solutions (e.g., siting facilities away from residential areas, training personnel, reducing the use of hazardous materials, spreading the risk-causing events over a greater time span, or building containment structures or other failsafes).

Measures for encouraging acceptance of risk fall into two broad groups. First, those who are affected may be allowed to satisfy themselves about the degree of the risks (e.g., access to data, joint monitoring of residues, joint management of risk). Second, those who are affected may be offered benefits to balance the risks (e.g., direct or indirect compensation, insurance or liability agreements, closing down of an unrelated activity causing a similar risk).

Measures intended to change perceptions are primarily efforts to communicate (e.g., press information campaigns, telephone hotlines, regular fact sheets). Joint measurement and monitoring can also change perceptions, especially if participants have a role to play in deciding what actions are to be taken in response to adverse results.

A combination of these measures comprises a coping strategy that will be more or less acceptable to each interested group. The coping strategy is then refined into action packages that implement the various measures over time, depending upon the availability and implications of new information. On the basis of these, the group examines the acceptability of several possible scenarios.

In general, despite scientific uncertainty, risky decisions are rarely hindered by lack of data, but commonly by lack of solutions acceptable to most groups. The coping strategies approach is designed to focus considerations on the acceptability of creative solutions.

Communications

The key to the development and implementation of a communications policy is to involve the audience in the decision process rather than having to defend the government's decisions. In many of the case studies, the groups that were being asked to accept the risk (i.e., the groups potentially subject to an adverse effect) were neither involved in the decision nor given information that they trusted. It is important that, wherever possible, all interest groups should be involved in collecting and assessing data, in reviewing coping strategies, and in monitoring the implementation of action packages.

Other aspects of good communications include the identification of trustworthy spokespersons, understanding the needs of the press and the media (i.e., for visual material, for human interest stories, and, in some cases, for exclusivity), directly answering the audience's questions in language they understand, and continually listening to the audience's concerns.

A recent study for the US EPA surveyed and assessed the literature on risk communication (Covello et al. 1986). Investigators made five recommendations to risk communicators.

1. Know your risk communication problem.
2. Know your risk communication objectives.
3. Use simple and nontechnical language.
4. Listen to your audience and know their concerns.
5. Recognize that each of these recommendations may seem obvious, but are nonetheless continually and consistently violated in practice.

An example reflecting the effectiveness of these principles occurred in 1980 when the US EPA proposed regulations on arsenic emissions for the Asarco plant in Tacoma, Washington, then the only high arsenic smelter in the country. At that time, EPA announced a new strategy for problem management to be based on a program of intensive communication between EPA and the community and involvement of the community in decision making. The proposed regulation had serious socioeconomic implications for Tacoma as Asarco was a major employer in a depressed area.

In his announcement of the new strategy EPA Director William Ruckleshaus said "For me to sit here in Washington and tell the people in Tacoma what is an acceptable risk would be at best arrogant and at worst inexcusable." The EPA strategy consisted of holding public workshops to inform people about the proposed regulations followed by public hearings and consultations on EPA's data, models, and conclusions. The workshops were organized to include all interest groups. A regional EPA official claims that as a result the regional office "now enjoys more credibility with environmentalists, industrialists, and the public than ever before" (Kalikov 1984).

Focusing Research

Finally, information management involves supervising the collection and selection of data from interested parties and other sources, determining in what form, when, and to whom data is presented, managing the identification and resolution of conflicts in the underlying data, and assessing the effects of decision-aiding techniques on interpreting and presenting the data. Decision makers should discuss the scope, format, and time frame for the data they need with the scientists responsible for producing it. Both decision makers and scientists must be aware that interest groups may dismiss any and all data that does not fit their perceptions, especially when the data are presented in a form incongruent to the questions they are asking.

(Appendix 2 includes two examples of the role of science in generating risk data for decision makers.)

If the outcome of research is likely to be controversial, it is important that all concerned be given the opportunity to agree upon the research program and to have access to the raw data. This will offset the perception that scientists' objectivity is being influenced by their paymasters.

The Scenario Revisited

Let us reconsider the scenario sketched at the beginning of this article as it might have unfolded using the five principles (emphasizing outcomes, taking the initiative, building legitimacy, maintaining credibility, and seeking consensus) and four activities (program management, risk management, communications policy, and information management) described above.

It all starts innocently enough: a weekly review summarizes the preliminary results of a long-term scientific study of a material suspected of being hazardous, and speculates on the theoretical implications. These speculations are picked up by the press, interpreted to suggest potential risks to the public and the environment, and associated loosely with some general trend in public health or environmental quality. The ensuing publicity creates public alarm, which is picked up by some Members of Parliament, as well as by several environmental and consumer groups.

The government takes the initiative by announcing and setting up a special Working Group, which immediately gathers information and solicits the concerns and perceptions of all interested groups, especially those who may be directly affected. The Working Group quickly establishes a program of short-term and long-term aims. Its members begin a series of individual meetings with interested parties, as well as with other departments and local authorities, with a view to identifying possible acceptable solutions. The group agrees to reconvene in seven days to develop their initial ideas on coping strategies. A press release is issued giving basic facts and promising a government proposal within 30 days.

The Ministry's External Affairs office has already started developing an in-

formation campaign, and has announced a 24 hour hotline so anyone concerned can obtain information. The next day, the Working Group representatives from the External Affairs office, other government scientists, and representatives from the Concerned Environmental Scientists Group, meet to review the information that has been collected so far, to determine what further information is required and by when, and how it should be presented and analyzed. Reports are presented to the meeting on economic impacts, risk assessment, and uncertainties. The group agrees to set up a panel for the continuing review of data from all sources.

At the next meeting, the group proceeds to identify the real choices, that is, those with some chance of acceptability. This is done through the development of two alternative coping strategies: one is based on a complete or partial ban on the suspect material, the other being no action or only delayed action. The risks and scientific uncertainties and the positions of the various interest groups are identified for each scenario, and additional conditions of acceptance are listed. Finally, options are proposed for enhancing the acceptability of each scenario.

The meeting concludes that there is no possibility of a no action scenario gaining acceptance. The other scenario is developed into an action package, incorporating a number of additional time-related actions, which are tied to the information needs identified by the data review panel, and which may help gain acceptability from the more extreme environmental groups. After the basic scenario has been presented to the Minister's office, the group members meet again with interest group representatives and with officials to iron out the details in the proposals, and to field additional suggestions for increased acceptability.

After a final Working Group meeting to discuss additional measures, and to consider some new information uncovered by the data review panel, an action package is proposed to a joint meeting of the three Ministers for Environment, Agriculture and Fisheries, and Economic Affairs. It includes six provisions.

1. The suspect material will be limited to agreed upon essential uses, and users will be required to change their practices to ensure that the material does not contact food or drinking water.
2. The manufacturer will make additional laboratory studies.
3. The government will support research programs up to 25 percent of costs to identify products to substitute for those containing the suspect material.
4. A joint monitoring committee will be established to include representatives from the Concerned Scientist Group, the current manufacturers of the material, the Chemical Industries Institute, and the three relevant government ministries.
5. If the data review panel of new laboratory work uncovers information to suggest that established threshold levels are too low or too high, immediate action will be taken to revise them.
6. The government states that it would like use of the material to be phased out over the next five years, and that it would like to see a reduction of

at least 20 percent in the first year. This schedule is subject to adjustment conditional upon additional risk information.

Negotiations have been held with the individual interest groups to agree upon specifics, but there remain a number of disputed details. The Working Group suggests employing a professional mediator to assist the parties in reaching a final agreement.

The Minister for the Environment holds a press conference, four days ahead of the promised 30-day limit, outlining the action the government is taking, and summarizing remaining points of disagreement. The press, which has generally ignored the issue for the past four weeks, concentrates on getting the many details right for the morning editions. Following completion of the mediated negotiations, another press conference is held, this time by the joint monitoring group, to explain what action is now being taken and why. This gets scarce coverage in the daily press, but the Ministry's handling of the issue is highlighted in a feature in the weekly scientific review that initially reported the troublesome findings.

Implementing the Strategy

Few of the controversial environmental issues discussed earlier could in practice be resolved so simply or so quickly. Many will require actions over a number of years. However, the underlying strategy and its components offer a different perspective for those responsible for managing risky decisions. In effect, the strategy requires administrators and analysts to move from the linear approach of risk assessment followed by risk management (the research-decide-announce-defend model) to a more iterative process of shaping solution, collecting relevant data, and taking step-by-step decisions.

The Netherlands Ministry of the Environment aims to bring about this change in approach through a series of in-house workshops. Each three-day workshop will introduce, in a case study, the underlying concepts about public perceptions and scientific uncertainty, which will reveal the need for a strategy. It will then cover the theory and principles of the strategy itself. Lastly, it will provide hands–on experience through practical exercises that simulate actual risky decisions. Follow-up workshops lasting about one day will be held three to six months later.

The workshop program is initially targeted towards decision makers with the Ministry of the Environment. It is intended that subsequently it will be aimed at a wider audience from both central and local government. Where appropriate, other interested parties will be invited to attend, including academics and representatives from environmental and industry groups.

One may well ask whether the proposed strategy, if implemented in countries

like The Netherlands, will overcome the difficulties that risky decisions present to governments. The answer must be that this strategy is only a framework. The framework itself can be seen to require, in effect, a cultural change: both administrators and scientists will themselves develop different approaches to their work. However, within this framework there is a requirement for the development and improvement of a variety of techniques ranging from mediation through risk assessment.

Will the strategy result in better decisions, that is, decisions which more effectively limit risks to the public and the environment, while not unnecessarily hampering the public's economic freedom and interests? This is the objective, but if the result is limited only to more effective decision making, more acceptable decisions, and more trust in decision makers, the strategy will have been a worthwhile exercise.

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Appendix 1. Ten Examples of Complex Environmental Problems

Karen Raymond and Meg MacDonald

Review of the cases described here was carried out between the autumn of 1985 and the spring of 1986. The outcomes reported reflect the status of the cases as of March 1986. Many developments have taken place since that time.

Vehicle Emissions Policy, United Kingdom

NO_x emissions from cars are believed to contribute to acid rain. The United Kingdom was coming under increasing pressure to adopt stricter emission standards. Under European Economic Community (EEC) rules these had to be agreed upon with the UK's Community partners. Some member states, notably Germany, were proposing standards requiring different control technology from that being developed by the UK motor industry. The UK government had to decide what position to adopt in negotiations with EEC partners and what concessions to accept. The United Kingdom proposed standards that could be met by UK-developed technology arguing that these would, in the long run, achieve lower emissions and at a lower cost. A compromise has been reached that requires use

of US/German technology on large cars, which form only a small proportion of the UK market, but allows UK technology on small cars. The decision on medium-sized cars has been delayed until more information is available.

Acidification Policy, The Netherlands

SO_2, NO_x, and NH_3 emissions from many sources are recognized contributors to damage attributed to acidification. The Dutch government agreed that reductions in emissions should be sought and wished to establish appropriate targets and define how these targets should be achieved. A wide range of studies were carried out and interim targets of 70 percent, 30 percent, and 50 percent reductions of SO_2, NO_x, and NH_3 between 1980 and 2000 were defined. Optimization studies to identify the most cost-effective and feasible ways of achieving these interim targets were carried out. The targets were lowered slightly to take account of difficulties in implementation and a program of research was set up to review progress and revise the targets by 1988.

Radioactive Waste Disposal Policy, United Kingdom

The UK government was prevented from continuing its policy of disposal of radioactive waste at sea by the action of concerned groups. This together with plans for expanding the nuclear industry, including waste reprocessing, led to the establishment of a program of work to investigate the Best Practicable Environmental Option (BPEO) for disposal of radioactive waste. The government had to decide which storage or final disposal route(s) to adopt. Having selected underground disposal as the preferred route for low level wastes, the government now faces the decision of where to locate the disposal site. Four possible sites have been identified by the nuclear industry and final selection and approval by the government is pending. Local opposition groups have been set up and are active in hindering site investigations.

Radioactive Waste Disposal Policy, The Netherlands

The Netherlands Government also has had to make decisions on how to manage radioactive waste. Following the decision to stop ocean dumping in 1982, the waste has been temporarily stored. The Government has (recently) delayed making a decision on final disposal of waste by adopting a policy based on "interim storage" for the next 50 to 100 years. The Government is currently in the process of selecting a site for the storage facilities. In March 1986, three sites were being considered; selection of one site has been made by COVRA (the organization responsible for radioactive waste management). The Government is now awaiting

completion of a site-related environmental impact statement before giving approval for the facilities.

Platier d'Oye Nature Reserve, France

A coastal area in northern France was identified as an important site for migratory birds. The Park Agency proposed to extend a planned nature reserve over an area presently used for hunting, and a national agency had to make a recommendation on the proposal to the Council of State for its approval. Decisions then had to be made on what level and type of use should be permitted subsequently in the reserve: closed or restricted access or recreational use. Approval has been granted for the already planned reserve area and negotiations are being held with the hunting lobby on the extension. A final decision is pending.

LPG Policy, The Netherlands

LPG supply and use was expected to increase in The Netherlands and new facilities were planned for transshipment, storage, transport, and fueling, all of which presented risks to public safety. Government decisions on policy guidelines for siting and operation of these facilities required judgments about acceptable levels of risk. Agreements were reached on acceptable levels of risk between relevant government departments and decisions were made about siting of major facilities and transportation. Standards were set for siting and operation of smaller facilities. Subsequently the expected growth in LPG did not materialize and new facility plans were abandoned. However, the standards set for acceptable levels of risk have subsequently served as a basis for other policy.

Accidental Release of Dioxin, Seveso, Italy

The accident at the ICMESA plant at Seveso released toxic dioxin into the surrounding area. The authorities were faced initially with decisions on what action, if any, should be taken, and later with decisions on how large an area should be evacuated around the plant and on the measures that should be taken to decontaminate and reclaim the area. Two zones were defined: Zone A was evacuated completely and in Zone B, pregnant women and children were evacuated. A standard for acceptable levels of contamination was set and measures were implemented to decontaminate areas to this level before crop cultivation and return of residents was allowed.

Flood Protection Scheme, Oosterscheldt, The Netherlands

In 1953 severe flooding caused huge loss of life and property in the coastal areas of The Netherlands. A dam closing off the Oosterscheldt estuary was proposed

as the last element in a national flood protection plan. When work started in the early 1970s the dam was opposed by fishermen and environmentalists because of loss of the estuarine ecosystem and fisheries. The government had to decide whether to proceed with the dam and, if not, whether some other scheme could be undertaken to protect the population. A decision was made not to create an impermeable barrier and a large number of options for part-closed schemes were examined together with a scheme for inland protection works. A storm surge barrier design was finally selected and implemented.

Control of Cadmium Levels, Sweden

In the 1970s evidence of the harmful effects of cadmium was growing and monitoring suggested that cadmium levels were increasing. The Swedish government considered what measures should be taken to prevent harmful effects to man and the environment and decided to implement controls on products containing cadmium. Key uses of cadmium were identified and regulations were drawn up on specific products. Implementation of bans on these products proved difficult because substitutes were not available and the government was forced to grant exemptions. Evidence suggested that in fact bans on these products would have little effect on overall levels of cadmium in the environment and a decision was made not to implement further bans beyond those already in force.

Regulation of 2,4,5-T in Germany

In the 1950s, 2,4,5-T was introduced as a herbicide and approved by the regulatory authorities. In the 1970s, 2,4,5-T was identified as potentially harmful to man and animals, and pressure mounted for the approval to be withdrawn. In a sequence of decisions various licenses were revoked and later reissued. A general permit was then issued but with stricter controls on contamination of the product by dioxin, but by this time production of 2,4,5-T in Germany had stopped. In response to public pressure other authorities had implemented regulations concerning waste disposal and transport of dioxin and the use of the herbicide effectively ceased.

Appendix 2. The Role of Science and Risk Data

This appendix gives three examples of how science and risk data can influence environmental decision making. The first two, which demonstrate uncertainties in major hazard assessment and uncertainties in health risk assessment, are excerpts from recent studies of risk assessment and risk control. The third, which shows how values can affect an assessment, is drawn from the authors' experience with the case.

Uncertainties in Major Hazard Assessment

From: F. Warner (1981), The foundations of risk assessment, in R. F. Griffiths (ed.) *Dealing with Risk.*

Taking an example from the Canvey Island Study (*Health and Safety Executive*, 1978), the effect of releasing 1000 tonnes of liquefied anhydrous ammonia as the result of a catastrophic failure of the pressure vessel is represented as the worst case. Taking category D weather conditions (the most prevalent in the United Kingdom) with a windspeed of 3 meters per second, the distance within which fatal concentrations would be experienced is calculated to be in the range of 5 to 8 km. That is the consequence of such a release resulting from the failure of the pressure vessel, but the likely vessel failure rate computed from historical data is 13 per million per year, with 95% confidence limits of 60 and 2.8 as the upper and lower estimates about 13. That is quite a range, and when combined with all the other sources of uncertainty the result is very far from what I would call a hardedged figure.

Uncertainties in Health Risk Assessment

From: Conservation Foundation (1985) *Risk Assessment and Risk Control.*

The impact that such choices have on risk estimates is illustrated by a study of perchloroethylene (PCE), a solvent used in dry cleaning. The study looked at three crucial steps in assessing the risks of cancer from PCE: 1) the choice of which test animal to use (mice or rats), 2) the choice of methodology for extrapolating from animals to humans (by body surface area or body weight), and 3) the choice of a dose-response model (linear or quadratic) to extrapolate risk from high doses of the chemical to low doses. For none of these choices is the state of scientific knowledge sufficient to offer guidance as to which option should be picked. If the risk assessment used mice, surface area extrapolation, and a linear model, the risk from PCE was assessed to be 347 cancer cases annually. If the assessment used rats, body weight extrapolation, and a quadratic model, the risk was assessed to be 0.01 cases annually. Thus a set of choices for which science could provide little or no guidance changed the assessment of risk by a factor of approximately 35,000.

The Implications of Using Value-Dependent Data

An example of how values may affect an assessment is given by the New York dioxin problem (case study K). In this case two separate groups carried out health risk assessments for the proposed development of municipal waste incineration

facilities. Each group considered the same basic data, but came to different interpretations of the data and thus used different modeling assumptions in their assessments. These differences later became the focus for debate.

The "Commoner Report," commissioned by environmental groups, was completed first and provided an estimate of 1430 cancer deaths per million exposed to the facility's dioxin emissions (Barry Commoner and Associates 1984). The "Hart Report," commissioned by the authorizing agency, estimated only six deaths per million—a dramatically lower figure (Fred C. Hart and Associates 1984). This range of estimates generated a great deal of public concern and confusion.

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