Risks to Ireland from Incidents at the Sellafield Site

Inside This Summary

The UK's Sellafield nuclear site, located on the Cumbrian coast, is at its closest point about 180 km from Ireland's coastline. Because of the site's location, its history, and the amount and type of radioactive materials there, the Government of Ireland and the Irish people have long been concerned about how an incident at the site might impact Ireland and the Irish Sea. Therefore, the Irish Government commissioned an assessment by a team of independent experts to determine the potential risks to Ireland associated with the Sellafield Site and the Low-Level Waste Repository, located near the site.

The Sellafield nuclear site is currently a collection of facilities that process and store used fuel from nuclear reactors and other radioactive materials. The Low-Level Waste Repository stores low-level radioactive waste from all over the UK. The assessment specifically addresses incidents (for example, equipment failures, natural disasters, and accidents caused by human error or terrorist attack) that could affect current activities at Sellafield or the Low-Level Waste Repository. The scope of the commission for this study specifically excluded transportation of radioactive materials on the Irish Sea and discharges from Sellafield that result from normal operations and are within limits set by UK regulators. Levels of radioactive materials in the Irish environment continue to be monitored by the Radiological Protection Institute of Ireland.

This document briefly summarizes the detailed findings from the assessment about the potential impact of the Sellafield Site and the Low-Level Waste Repository on Ireland, the methods used to assess the potential for incidents at the two sites, and the risks to Ireland from such incidents. Note that the analysis assesses risks from Sellafield and the Low-Level Waste Repository from the viewpoint of current inventories of materials and existing processes. However, the two sites are constantly changing as facilities are dismantled and built at Sellafield and more waste is added to the Low-Level Waste Repository. The information in this analysis will help the Irish

Government better understand the risk posed by current activities at Sellafield and the Low-Level Waste Repository and provides a baseline to support understanding of future activities there.

The Legacy of Sellafield

Sellafield served several purposes since work began there in the 1940s. Nuclear reactors at the Sellafield Site previously produced plutonium for nuclear weapons or generated electricity. These reactors have all been shut down and are being decommissioned and dismantled. Tonnes of radioactive material such as used fuel from nuclear reactors in the UK and abroad are currently being processed or stored at Sellafield. Some of the Sellafield facilities date from the early days of the site; some were constructed as recently as 2011; and others continue to be built to support decommissioning.

The Low-Level Waste Repository will remain operating for many years.

Incidents at the Sellafield Site over the years have given rise to concerns in Ireland about the safety of processing and storing the radioactive materials there. Changes in operating practices and initiatives in line with international safety standards indicate that safety at the site has improved.

One of the facilities that will remain operating for many years is the Low-Level Waste Repository, which began operating in 1959. The repository is needed by the UK to support disposal of its low-level radioactive waste. Low-level radioactive waste is made up of lightly contaminated materials such as clothing, soil, and building rubble.

How the Risks Were Assessed

The risks from incidents at Sellafield and the Low-Level Waste Repository were assessed by an independent team of experts on risk assessment, nuclear facility operations, chemistry, the effects of radiation on people, and how organizations perform. This team reviewed operations at Sellafield and the Low-Level Waste Repository to answer three questions:

1. What types of incidents could cause damage that would release radioactive materials (as solid, liquid, or gas)?
2. What is the likelihood of those incidents?
3. What are the consequences to Ireland?

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The answers to these questions are provided by a probabilistic risk assessment (PRA). A PRA uses computer models, calculations, and expert judgment to consider what might happen given certain conditions such as the type of facility, the amount of radioactive material, the kinds of barriers that can prevent the material from being released, the training of the work force, and other factors.

To determine the consequences to Ireland from incidents at Sellafield or the Low-Level Waste Repository, the expert team began by reviewing volumes of existing technical information available on Sellafield, such as technical reports and results of UK audits and reviews. An information exchange agreement between the governments of Ireland and the UK provided the technical experts with access to the Sellafield Site and additional technical information. The primary information exchange occurred through discussions with site personnel via three two-week visits to Sellafield and the Low-Level Waste Repository over the course of two years.

The PRA involved the review of hundreds of documents, some never previously available to Ireland; site visits; and detailed discussions with Sellafield staff.

During each visit, site staff provided presentations on all major processing systems, site infrastructure and support systems, storage systems, and site operations and planning processes that included extensive time for discussion. One-on-one discussions helped address questions about technical details raised by the expert team. During the visits, the team toured individual facilities and interviewed plant operators and managers. Finally, the team was given access to many site documents that included operations and training manuals, site procedures, process schematics, and other requested documents. The exchange gathered information that was essential to develop an objective and scientifically sound assessment of the risks to Ireland.

As anticipated at the start of the project, the UK did not disclose certain highly sensitive information related to security measures. To limit the impact this lack of security information might have on the analysis, the expert team used additional sources of information such as their own knowledge of operating history and data from similar nuclear facilities. Although many factors about the Sellafield Site are unique, individual processes have counterparts elsewhere in industry. In some areas where information was not available, the team used their experience studying other nuclear facilities around the world to make expert judgments.

The expert team used a range of PRA techniques to estimate the likelihood of radioactive materials being released from Sellafield or the Low-Level Waste Repository that may have an impact on Ireland or Irish interests. These analyses are listed in the diagram on the next page. The expert team considered scenarios involving possible accidents inside a range of facilities as well as accidents with the various systems that support those facilities. In addition, the team analyzed external events—those outside forces that can damage or destroy any kind of facility, even those storing radioactive materials. Every scenario considered the possibility of sequential failures of systems relied on for safety. Many event sequences emanating from these scenarios ended in success (normal operations being successfully restored) or simply reduced capability within a facility; others resulted in significant damage and release of radioactive material. A PRA lays out all pathways, both successful sequences of events and failures, because that is the only way to actually find the failure sequences. For this PRA, such scenarios can also provide Ireland with a means for tracking incidents in progress at Sellafield, to see where they might lead if additional problems develop.

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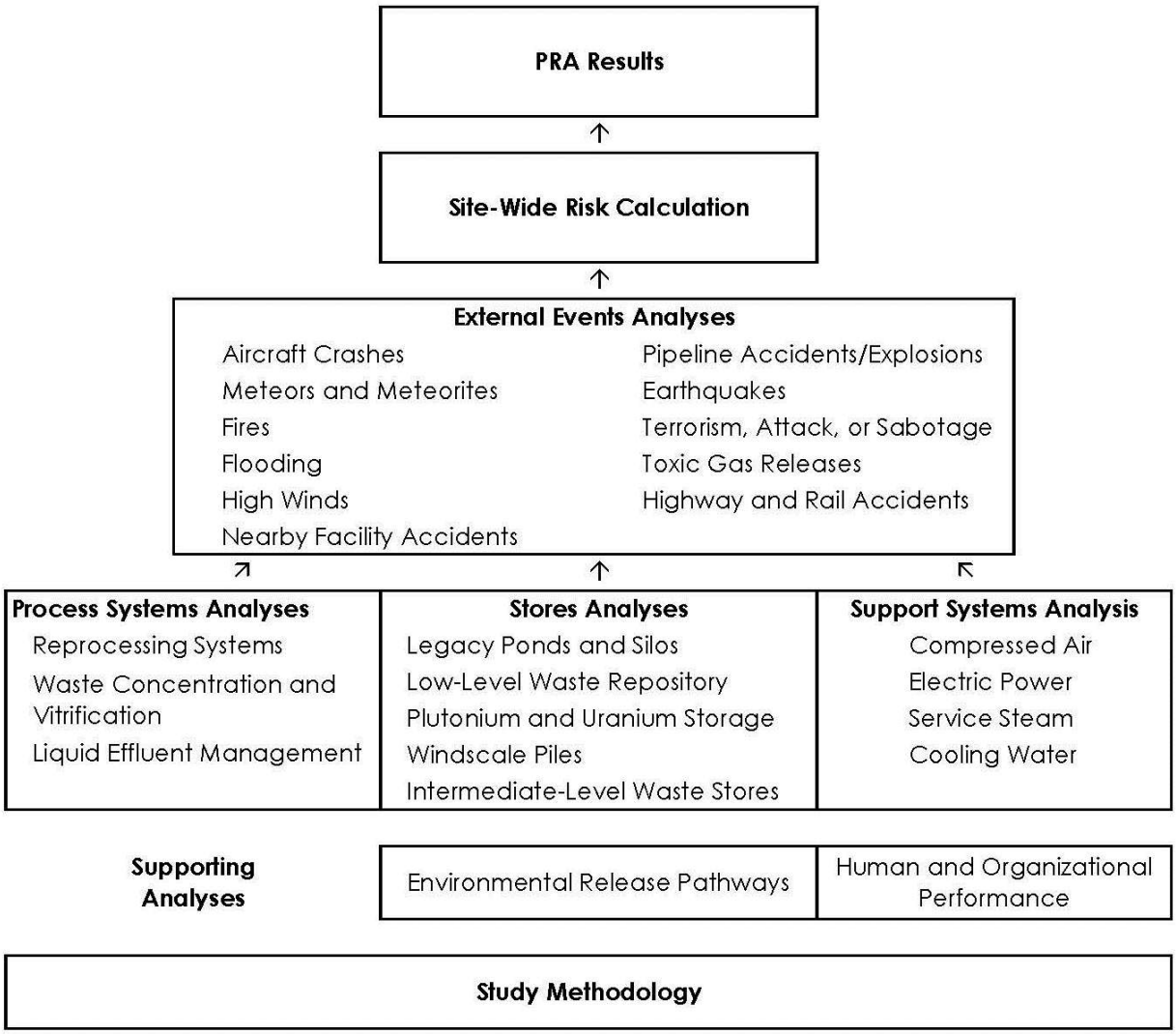
To ensure the analysis was thorough, the PRA team identified a broad range of potential initiating events that represent starting points of an incident. Some examples include human errors, mechanical equipment failures, loss of support systems such as electrical power, environmental events such as severe storms, and external events such as aircraft crashes, meteorite impacts, and deliberate attacks. Some initiating events, such as a strike by a meteorite, were extremely rare but still possible. Others, such as human error, have been seen more often at nuclear facilities around the world. The team was able to rule out some incidents because the configuration of Sellafield facilities or the natural environment would make them nearly impossible or no radioactive materials would be involved.

The expert team then looked at the possible sequences of actions that could happen after the initiating event—for example, what might happen if a pipe failure or human error is not detected immediately, or for a long time, or measures to prevent the release of radioactive material are unsuccessful. The team used site-specific information and gathered performance data from similar facilities for structures, systems, components, and human actions. They



Overview of the PRA Process

then calculated how often such incidents might occur and estimated the range of possible releases of radioactive material that could impact Ireland. They made sure to address incidents that have the ability to simultaneously affect multiple facilities.

How Incidents at Sellafield Could Impact Ireland

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The PRA calculated the consequences from three different realistic release scenarios with varying capability to loft radioactive materials high in the air so that the materials could be transported significant distances beyond the site boundary. For each of these three scenarios, the team then calculated how the materials could be dispersed in the atmosphere and potentially deposited in Ireland. A companion calculation considered a release of a portion of the contents of a storage tank containing among the most highly concentrated radioactive materials at Sellafield. The analysis showed that some radioactive materials could reach Ireland but at levels far below the dose levels that could cause observable health effects and well below the level of background radiation people normally receive each year. For all other PRA scenarios, doses would be much lower. While radioactive materials from the release could be detected using sensitive measurement equipment, the levels would not be enough to cause observable health effects in Ireland.

The PRA also found that some unlikely incidents at Sellafield or the Low-Level Waste Repository have the potential to create significant socioeconomic impacts in Ireland. These impacts may include loss of tourism and markets for Irish seafood and farm products because of concerns that radioactive materials may be present, despite monitoring data confirming that all food for sale or export complies with the limits set to protect consumer health. The likelihood of such incidents ranges from very low (less than a 30% chance anytime over the next 100 years for the more modest releases that remain near the Sellafield Site) to extremely

unlikely (less than a 0.05% chance over the next 100 years for the more extreme cases with the potential to release materials well beyond the site boundary). These very rare severe incidents are largely associated with extreme environmental events such as severe earthquakes and very strong winds (greater than 165 mph) or incidents originating outside the Sellafield Site that can impact it, such as strikes by meteorites or by aircraft or missile crashes.

Lesser incidents are much more likely, but these would not lead to significant releases of radioactive materials. These lesser incidents primarily involve failures of individual pieces of equipment and human errors that reduce facility and safety capability, or incidents that release radioactive materials from their normal boundaries but still contain such materials within the facility. The risk of releases of radioactive materials that could impact Ireland from these incidents originating within facilities at Sellafield is low because of the design of the processing systems there. Processing facilities are designed with multilayered protection—redundant equipment and diverse physical means of protection. Therefore, single or even multiple failures of equipment do not disable safety functions. It takes a severe incident, such as the ones listed in the preceding paragraph, to defeat the design features—redundancy, diversity, and containment—that protect the Sellafield facilities.

Redundancy, diversity, and containment in Sellafield facilities keep equipment failures from leading to more severe events. Extremely rare severe incidents such as an earthquake that damages multiple facilities could defeat such protection.

The expert team examined similar kinds of incidents for the Low-Level Waste Repository. Of the range of incidents examined, only an unlikely one in which an aircraft crashed directly into the waste materials had the potential for any releases in the short term. Such a release would result in no observable health effects in Ireland.

The expert team also examined a very long-term event: Hundreds of years from now, rising sea levels and severe coastal storms could cause the entire contents of the Low-Level Waste Repository to be released into the Irish Sea. Radioactive materials decay predictably over time, in this way becoming less harmful to human health and the environment. If in the far future the radioactive material in the repository does empty into the Sea, the radioactive materials will have reached less harmful levels by that time. In addition, the materials would be diluted by seawater and currents. Based on calculations that overestimate the consequences of such a release, the increase in radioactivity levels in seawater would be barely detectable anywhere near the coast of Ireland.

Summary of Results

The impacts, then, to Ireland, of incidents at the Sellafield Site and the Low-Level Waste Repository can be summarized as follows:

Incident	Impact on Ireland
Problems such as minor equipment malfunctions or human error possibly leading to releases of radioactive materials that remain inside a facility	No observable health effects in Ireland; continued vigilance by the Irish Government to understand the implications of problems at the site
More serious equipment malfunctions or compounded human errors leading to significant releases contained inside a facility, with potential injuries to site personnel	No observable health effects in Ireland; continued vigilance by the Irish Government to understand the implications of problems at the site
Explosions, fires, and other incidents that result in significant releases within the Sellafield Site and possibly injuries or death to site personnel	No observable health effects in Ireland; possibly perception by the public that risks to Ireland have increased
Incidents such as earthquakes that affect only one facility and release limited quantities of highly concentrated radioactive liquids or concentrated radioactive materials; effects limited to areas near the Sellafield Site; possibly injuries or deaths among site personnel and adjacent populations in the UK; possible runoff to the Irish Sea	No observable health effects in Ireland; possibly significant socioeconomic impact for Ireland in terms of tourism and perception of contamination of food supplies and fisheries; possibly significant increased radiation level monitoring by Irish authorities
Severe incidents such as earthquakes that damage multiple facilities and that release highly concentrated radioactive liquids or moderate quantities of intermediate-activity materials; protective measures required near the site to prevent health effects there; contamination of the Irish Sea near the UK	No observable health effects in Ireland; possibly significant socioeconomic impact for Ireland in terms of tourism and perception of contamination of food supplies and fisheries; possibly major increased radiation level monitoring by Irish authorities
Very rare severe incidents such as impacts by meteorites that disperse highly concentrated radioactive materials or release large quantities of intermediate-activity materials; health effects in the UK adjacent to the site, including fatalities; releases into the atmosphere, with subsequent dispersion and dilution	No observable health effects in Ireland; possibly major socioeconomic impact for Ireland in terms of tourism and perception of contamination of food supplies and fisheries; possibly prolonged major increased radiation level monitoring by Irish authorities

Additional Technical Details

The following three tables provide more detail on the types of scenarios that could lead to releases of radioactive material from Sellafield. Each line of the tables represents many even more detailed individual event sequences calculated in the PRA. None of these events would cause observable health effects in Ireland.

Incidents that release limited quantities of highly concentrated radioactive liquids or concentrated radioactive materials; effects limited to areas near the Sellafield Site; possible injuries or deaths among site personnel and adjacent populations in the UK; possible runoff to the Irish Sea			
Incident	**Best Estimate Frequency, event per year**	**Probability that the incident will occur at some time in the next 100 years**	
		Best Estimate	**Range of Uncertainty**
Earthquake damage to a facility that contains concentrated radioactive materials	$1x10^{-3}$	12%	4% to 26%
Large unconfined leak from a historic storage pond for radioactive materials	$2x10^{-4}$	2%	0.02% to 6%
Very strong winds (greater than 165 mph) that damage a facility containing concentrated radioactive materials	$8x10^{-5}$	0.8%	0.004% to 3%
Unconfined leak from a processing pipe holding concentrated radioactive liquids	$7x10^{-5}$	0.7%	0.2% to 2%
Aircraft crash, test missile crash, or meteorite impact into a facility that contains concentrated radioactive materials	$2x10^{-5}$	0.2%	0.01% to 0.6%
Unconfined leak through a cooling coil in a tank storing highly concentrated radioactive materials	$1x10^{-5}$	0.1%	0.01% to 0.5%
Any of the above incidents	**$1.6x10^{-3}$**	**16%**	**6% to 32%**
A 16% probability that one of these incidents may occur at some time during the next 100 years equivalently means that there is an 84% probability that none of these incidents will occur during the next 100 years.			

Severe incidents that release highly concentrated radioactive liquids or moderate quantities of intermediate-activity materials; protective measures required near the site to prevent health effects there; contamination of the Irish Sea near the UK			
Incident	**Best Estimate Frequency, event per year**	**Probability that the incident will occur at some time in the next 100 years**	
		Best Estimate	**Range of Uncertainty**
Severe earthquake damage to multiple facilities that contain intermediate-activity materials	$4x10^{-5}$	0.4%	0.1% to 0.8%
Very strong wind damage to multiple facilities that contain intermediate-activity materials	$3x10^{-6}$	0.03%	0.002% to 0.1%
Severe earthquake damage to a facility that contains highly radioactive liquids	$2x10^{-6}$	0.02%	0.006% to 0.06%
Very strong wind damage to a facility that contains highly radioactive liquids	$1x10^{-6}$	0.01%	0.00002% to 0.03%
Meteorite impact into a facility that contains highly radioactive liquids	$4x10^{-7}$	0.004%	0.00005% to 0.02%
Aircraft or test missile crash into a facility that contains highly radioactive liquids	$3x10^{-7}$	0.003%	0.0005% to 0.008%
Any of the above severe incidents	**$5x10^{-5}$**	**0.5%**	**0.2% to 0.9%**
A 0.5% probability is a one-half of one percent probability that one of these severe incidents may occur at some time during the next 100 years. This equivalently means that there is 99.5% probability that none of these incidents will occur during the next 100 years.			

Very rare severe incidents that disperse highly concentrated radioactive materials or release large quantities of intermediate-activity materials; health effects in the UK adjacent to the site, including fatalities; releases into the atmosphere, with subsequent dispersion and dilution			
Incident	**Best Estimate Frequency, event per year**	**Probability that the incident will occur at some time in the next 100 years**	
		Best Estimate	**Range of Uncertainty**
Meteorite impact into a facility that contains highly radioactive materials	$7x10^{-7}$	0.007%	0.00009% to 0.03%
Severe earthquake damage to a facility that contains used nuclear fuel	$6x10^{-7}$	0.006%	0.002% to 0.01%
Test missile crash into a facility that contains highly radioactive materials	$2x10^{-7}$	0.002%	0.0002% to 0.006%
Aircraft crash into a facility that contains highly radioactive materials	$2x10^{-7}$	0.002%	0.00003% to 0.007%
Severe site-wide earthquake damage	$5x10^{-8}$	0.0005%	0.00002% to 0.002%
Any of the above very rare severe incidents	**$2x10^{-6}$**	**0.02%**	**0.003% to 0.05%**
A 0.02% probability is a two one-hundredths of one percent probability that one of these very rare severe incidents may occur at some time during the next 100 years. This equivalently means that there is 99.98% probability that none of these incidents will occur during the next 100 years.			

The Expert Team

The independent team of experts who assessed the risks to Ireland from Sellafield and the Low-Level Waste Repository brought knowledge and expertise to the project which the Irish Government felt was not readily available within its own system. They are internationally respected for their understanding of the risks posed by nuclear facility activities. These experts do not work for the UK government, the site license companies, the respective parent organizations, or any person or business associated with either Sellafield or the Low-Level Waste Repository.

- **Dr. Dennis C. Bley**, PRA principal investigator: doctorate in nuclear engineering, Massachusetts Institute of Technology; an internationally recognized risk assessment professional for over 30 years who has developed methods for risk assessment being used worldwide; member of the US Nuclear Regulatory Commission's Advisory Committee on Reactor Safeguards and former member of a number of US National Research Council committees, including one that examined the transportation of radioactive waste; author of more than 300 papers and reports on risk assessment issues.

- **Dr. Jimmy Bell**, physical chemist: doctorate in physical chemistry; retired from more than 30 years at Oak Ridge National Laboratory as chemist and later head of the section in charge of process developments; recipient of the prestigious Glenn T. Seaborg Actinide Separations Award for outstanding and lasting contributions to the development and application of actinide separations processes and methodology.

- **Dr. Michael T. Ryan**, consultant in radiological health physics: doctorate in health physics from Georgia Tech; member of the US Nuclear Regulatory Commission's Advisory Committee on Reactor Safeguards, distinguished emeritus member of the US National Council of Radiation Protection and Measurements, and Editor-in-Chief of the journal *Health Physics*.

- **John Stetkar**, risk assessment and facility consultant: consulting engineer with three degrees from the Massachusetts Institute of Technology in electrical, nuclear, and environmental engineering; has held lead technical responsibilities in more than 15 major nuclear power plant risk assessments in the US and Europe, including reviews of several in the UK; Vice-Chair of the US Nuclear Regulatory Commission's Advisory Committee on Reactor Safeguards.

- **John Wreathall**, consultant on human reliability analysis and organizational performance: Chartered Engineer (UK) with bachelor's degree in nuclear engineering and master's degree in systems engineering; internationally recognized expert who helped develop internationally accepted methodologies for human performance modeling; has led or participated in safety-related projects for NATO, the World Bank, the International Atomic Energy Agency, and the US Nuclear Regulatory Commission as well as private companies around the world.

The team was assembled and engaged by Egan, Fitzpatrick, Malsch & Lawrence, PLLC, a US law firm that specializes in nuclear energy, nuclear fuel cycle, nuclear waste, and related risk-assessment matters. The firm also engaged other legal experts, such as Ambassador John Norton Moore, and obtained the US regulatory approval necessary for the experts to participate in the assessment. The analyses and conclusions of the assessment, however, are solely those of the expert team.

The information contained in the report is highly sensitive. Its release in full would add to the risks to both Ireland and the UK.