The Application of ALARP to Radiological Risk

A Nuclear Industry Good Practice Guide

This Issue of the Nuclear Industry Good Practice Guide on The Application of ALARP was published by the Industry Radiological Protection Co-ordination Group (IRPCG) on behalf of the Nuclear Industry Safety Directors Forum (SDF) in 2012

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The Industry Radiological Protection Co-ordination Group (IRPCG) recognises that, as use and experience of this Good Practice Guide grows: there may well be comments, questions and suggestions on the content. IRPCG is committed to maintaining and updating the GPG so that it continues to represent good practice, and welcomes any such comments on the document. Comments should, in the first instance, be sent to the IRPCG secretary who can be contacted via the IRPCG website:

www.irpcg.org

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Foreword

The application of the principle that occupational exposures to risk and hence the risk of radiation exposure are required to be As Low As Reasonably Practicable (ALARP) is a fundamental requirement of UK Health and Safety legislation. This Good Practice Guide (GPG) details the principles and practices that are considered to be good practice in the nuclear industry.

It is not and should not be read as a code of practice, it solely provides a reference that can be utilised by nuclear industry practitioners. The issue of this GPG is not intended to initiate wholesale review of existing arrangements where there is no other driver to do so.

The (Nuclear) Industry Radiological Protection Co-ordination Group (IRPCG), which is a working group set up by the Nuclear Industry Safety Directors Forum (SDF), reviewed the approaches to the application of ALARP across the nuclear industry. Effective application of ALARP requires a multi facetted approach and the review found that whilst good practice could be found with all operators, there were areas where operators could learn from each other. It was also felt that although there is a vast selection of published material on this subject, nothing had been produced for the industry from the perspective of the nuclear industry practitioner.

As a direct result, the IRPCG set up a sub-group consisting of relevant experts from member organisations with the following objective:

'*Develop and make available to the Nuclear Industry a Good Practice Guide on the Application of ALARP*'

This GPG is believed to be consistent with all relevant legislation and guidance, and has so far been endorsed by the following organisations:

- Atomic Weapons Establishment
- Babcock International Group – Marine and Technology Division
- Dounreay Site Restoration Limited
- EDF Nuclear Generation
- GE Healthcare Ltd
- Magnox Limited
- Ministry of Defence
- Research Sites Restoration Limited
- Rolls-Royce
- Sellafield Limited
- Urenco Limited

This GPG has been the subject of extensive review and consultation amongst relevant stakeholders. However, as with any such document, publication may lead to a call for further advice, or for other aspects to be considered. The IRPCG will keep this GPG under review, and strongly encourages users to comment, ask questions or make suggestions on the content of this document. IRPCG undertakes to respond to any such comment and will revise and re-issue the GPG as necessary. Contact information is given on the inside front cover of this document.

Finally, the IRPCG take this opportunity to thank all of the members of the ALARP Good Practice Guide Working Group for the time and effort that they have put into producing this guide.

Revisions Sheet

Issue Number	Date	Comments
1	December 2012	New document

This publication is scheduled for review by December 2015.

Contents

1. INTRODUCTION

This Good Practice Guide (GPG) provides guidance on the approach recommended for operators of UK Nuclear Licensed Sites to discharge their statutory responsibility to ensure that doses and potential risks from exposure to ionising radiation are As Low As Reasonably Practicable (ALARP).

A considerable body of information and guidance on ALARP is available from UK and international regulatory and advisory bodies. It is not the intent of this GPG to repeat that general guidance, but instead to provide a user-guide with authoritative guidance in the particular context of operations on Nuclear Licensed Sites. The GPG does, however, provide sources of reference to assist the reader to access broader legislation, background and good practice.

Note that the term As Low As Reasonably Achievable (ALARA) is used internationally. The relationship between ALARP, ALARA and the term So Far As Is Reasonably Practicable (SFAIRP) is discussed in Chapter 2.

The intention is to address all types of work on Licensed Sites where exposure to ionising radiations may occur, including decommissioning, enduring operations such as fuel fabrication and power generation and new build. Experience from all these types of work has been drawn upon in the production of this GPG and existing good practice from industry used and applied wherever possible.

It is intended that this document should be as simple and easy to follow as possible, but in order to keep to a manageable length; the GPG assumes that the reader is familiar with the fundamental principles of safety management, including the ALARP concept.

1.1 SCOPE

The focus of this document is occupational exposure and risk. Exposure of the environment and the public is subject to Best Available Techniques (BAT), covered in the BAT for the Management of the Generation and Disposal of Radioactive Wastes (Ref. 1). BAT will not be covered in this document except where BAT considerations may impact on the ALARP process.

The application of ALARP to whole body, organ and extremity dose will be addressed, although in the UK nuclear industry, whole body exposure is generally the most significant aspect and this is reflected in this document.

In the context of occupational exposure, and specifically exposure within groups of workers carrying out similar tasks, ALARP is taken to apply to collective as well as individual dose. This is in accordance with the latest international recommendations (Ref. 2) which advocate the use of collective dose as a “key parameter for the optimisation of protection for workers”. The same publication also draws attention to the inappropriate use of collective dose, that is where individually insignificant doses are aggregated over large populations to infer a significant overall detriment.

This GPG is written primarily to assist plant managers, project managers, safety case authors and radiation protection professionals in ensuring that work is carried out in accordance with the ALARP principle. It is not designed to be an exhaustive handbook on the subject of ALARP.

Although this GPG is intended for the nuclear sector, it may be useful to the non-nuclear sector. It may not, however, always be appropriate in non-nuclear applications.

1.2 OVERVIEW

This section includes a guide to the document contents and an explanation of how to use it. Because of its scope, the document is quite long so it may be useful to read this section before proceeding further.

Chapter 2 (ALARP Theory and Concepts) includes basic ALARP background theory and essential concepts as well as an overview of the various tools, techniques and issues that may feature in an ALARP assessment. It also includes links to other sources of information that give a fuller treatment of the various topics. The information contained in Chapter 2 will be assumed knowledge for the following Chapters.

Chapter 3 (Managing for ALARP) describes the management processes that may be put in place to ensure that ALARP principles are being implemented effectively in an organisation. This covers general rather than task specific requirements, such as the use of dose review levels and investigation levels, formal review of doses and practices, training arrangements and the use of operator experience.

Chapter 4 (ALARP for Routine Operations) describes the processes that may be applied to tasks taking place in the context of ongoing operations as well as at certain stages of project work. Examples are task risk assessment, work planning and de-confliction and periodic review of practices. Examples of good practice are also given in this section.

Chapter 5 (ALARP for Projects) is split into three main parts. The first section deals with general issues that are common to all projects including the requirements to define the project correctly and the key role of Optioneering along with potential pitfalls of the Optioneering process. The second section deals with particular issues that may be of concern for short term projects, such as time at risk arguments and issues of integration with adjacent plant. The third section deals with the particular issues of enduring projects, such as through life issues and compliance with future standards. Practical examples are given in each section.

There is also a comprehensive set of Appendices that deal in detail with some of the tools introduced in the previous sections, such as Optioneering and Cost Benefit Analysis. Examples of good practice are also given as well as sources of further information.

2. ALARP THEORY AND CONCEPTS

2.1 WHAT IS ALARP?

In simple terms ALARP is an acronym that summarises the process of ensuring that risk is reduced to a level that is deemed to be as low as reasonably practicable. The concept of “reasonably practicable” is a more complex idea, that when first encountered may appear to be quite a subjective term. The ALARP processes and tools that have been developed, and are described in this guide, provide a means of qualifying and quantifying what is meant by “reasonably practicable” in a way that their use should lead to a robust demonstration that the risk is as low as reasonably practicable.

In order to determine whether the risk has been reduced ALARP requires an understanding not only of the risks involved, but also of the measures or options that are available to avoid that risk, and how practicable it is for those measures or options to be implemented. The process by which a comparison is made between the risks and the practicability of the risk avoidance measures or options is usually referred to as the ALARP Process. The ALARP process can involve various techniques and methods ranging from the simple use of a workplace risk assessment or good engineering judgement to a rigorous approach using tools such as probabilistic risk assessment.

The concept of “reasonably practicable” is widely used within the UK’s health and safety system; the actual term used in the Health and Safety at Work etc. Act (Ref. 3) and other health and safety regulations is SFAIRP (So Far As Is Reasonably Practicable). In the Health and Safety Executive’s (HSE) view the terms ALARP and SFAIRP mean the same when the latter term is applied to radiation risk reduction. This is demonstrated by the fact that The Ionising Radiations Regulations 1999 (Ref. 4) use SFAIRP rather than ALARP (as in Regulation 8(1): Every radiation employer shall, in relation to any work with ionising radiation that he undertakes, take all necessary steps to restrict so far as is reasonably practicable the extent to which his employees and other persons are exposed to ionising radiation.)

The use of the term ‘reasonably practicable’ in UK law means that it is relevant to look to guidance from the courts for what ALARP means. The key case is Edwards v The National Coal Board where the court had to determine whether or not it was reasonably practicable to expend money and effort to make the roof and sides of a road in the mine secure. The court considered that a measure should be considered as NOT reasonably practicable if there was a ‘gross disproportion’ between the risk on one side and the sacrifice involved (whether in money, time or trouble) in carrying out the measure necessary to avoid the risk – the risk being insignificant in relation to the sacrifice. Turning this around, ‘reasonably practicable’ means that measures to reduce risk should be taken unless the sacrifice is grossly disproportionate to the benefit.

The term ‘gross disproportion’ is therefore another concept that needs to be understood in relation to ALARP. Gross disproportion needs to be taken into account in deciding whether risks are ALARP when comparing the benefits of implementing a measure to

reduce risk against the 'cost' of that measure ('cost' being used to mean the 'sacrifice' involved and including factors such as time and effort, as well as money). A measure will be reasonably practicable if its 'costs' of implementation do not outweigh the benefits by a grossly disproportionate amount. The ALARP process is therefore aimed not at balancing the costs and benefits of measures but, rather, of implementing measures except where they are ruled out because they involve grossly disproportionate sacrifices.

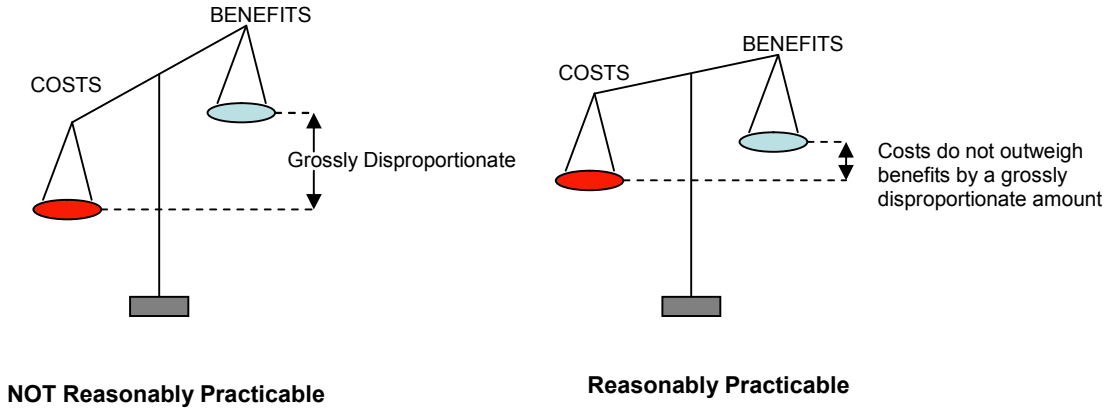


Figure 1 Illustration of relationship between grossly disproportionate and ALARP

There is no universally accepted factor for what constitutes gross disproportionality. The guiding principle is that, whilst the test of 'gross disproportion' applies at all levels of risk, more effort should be expended when risks are high i.e. the gross disproportion factor should be higher. The Office for Nuclear Regulation (ONR), in its Guidance on the Demonstration of ALARP (Ref. 5), takes as its starting point the HSE submission to the 1987 Sizewell B enquiry that a factor of up to 3 (i.e. costs three times larger than benefits) would apply for risks to workers; for low risks to members of the public a factor of 2, and for high risks a factor of 10. Other approaches may be to use a 'sliding scale' of gross disproportion factors between a low risk measure and a high risk measure, or to use slightly different discrete factors, but a factor of 10 is generally recognised as the highest value by which the costs could outweigh the risks and still be considered as reasonably practicable. HSE guidance does acknowledge that where risks are close to a Basic Safety Limit (BSL) and the consequences large then a factor larger than 10 may be appropriate. The concept of the BSL is explored further in section 2.3.2. Guidance on practical application of Cost Benefit Analysis is given in Appendix B.

In summary therefore ALARP is a process where the onus is to carry out measures to reduce risk unless it can be demonstrated that it is not reasonably practicable to do so. It's a "Why shouldn't it be done approach" rather than a "Why should it be done?" approach.

2.2 WHY IS ALARP REQUIRED?

As has already been mentioned, the principle of ALARP is implicit in the Health and Safety at Work etc. Act 1974 (Ref. 3) which places duties on employers to ensure SFAIRP the health, safety and welfare of employees, and to ensure SFAIRP that persons not in their employment are not exposed to risks to their health or safety. As has also been seen, this requirement is continued in the Ionising Radiations Regulations 1999 (Ref. 4) where, as well as the duty on the radiation employer to restrict exposure SFAIRP, there is also a similar duty on an employee to "… not knowingly expose himself or any other person to ionising radiation greater than is reasonably necessary …"

The origin of this type of concept in radiological protection derives from recommendations made by the International Commission of Radiological Protection in 1977 (Ref. 6). These recommendations introduced three principles, Justification, Optimisation and Dose Limitation as the basis for any system of radiological protection. These principles have been repeated in subsequent ICRP documents and the latest recommendations given in ICRP 103 (Ref. 2) retain the three principles as key to the control of exposure to ionising radiation. The definitions of the three principles in ICRP 103 are as follows:

- The Principle of Justification: Any decision that alters the radiation exposure should do more good than harm.
- The Principle of Optimisation of Protection: The likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors.
- The Principle of Application of Dose Limits: The total dose to any individual from regulated sources in planned exposure situations other than medical exposures should not exceed the appropriate limits specified by the Commission.

It is the principle of Optimisation that is relevant to ALARP. The term "as low as reasonably achievable" (ALARA) used in the optimisation principle is synonymous with ALARP, and is the term used to describe the risk reduction process outside the UK. As has been previously discussed, within the UK there is an existing practise, and a wealth of legal experience, related to the term "reasonably practicable" that has meant ALARP is used in the UK whereas ALARA is the acronym used in the rest of the world. ALARA and ALARP are considered to be equivalent in meaning and purpose.

2.3 THE OPTIMISATION PROCESS

A good starting point is to examine the process of optimisation recommended by ICRP (Ref. 2) which effectively describes a process for demonstrating ALARP. ICRP emphasises that optimisation is not minimisation of dose but rather an evaluation of both the detriment from the exposure and the resources required for the protection of individuals, and that the resultant ALARP option should be "the best option under the prevailing circumstances". Note that this is a subset of an ALARP process as laid out in section 5 that might be applied to a project. The optimisation, or ALARP, process is described as an ongoing, iterative process that involves:

EVALUATION of the dose or risk of exposure

SELECTION of appropriate dose or risk criteria

IDENTIFICATION of the possible options

ASSESSMENT and selection of the ALARP option

IMPLEMENTATION of the selected option

APPLICATION of Review Levels

The elements of this ALARP process are examined in the following sections, revealing some further important concepts and practices.

2.3.1 EVALUATION OF THE DOSE OR RISK OF EXPOSURE

An evaluation of dose may need to consider, as appropriate, doses from external exposures, internal exposures, doses to individuals, collective dose, and doses to workers, the public and specific groups of individuals. One or more of these dose parameters may be relevant for a particular ALARP case. An important consideration concerns the use of collective dose, which is a very useful parameter for comparing options, but needs to be treated with care if using it to calculate a risk to health, for examplewhen aggregating very low doses over a large population the resultant determination of cancer deaths is not appropriate and should be avoided. One approach if using collective dose in this way is to consider when, where and by whom exposures are received and assign weighting factors to the different groups so identified.

Another important consideration is to recognise that whereas most options under consideration will produce a benefit in terms of a dose saving, there may be options that

produce a reduction in risk whilst also incurring a dose exposure, in which case the evaluated dose is a detriment and needs to be included as part of the 'costs' of the risk reduction measure. An example would be where a piece of equipment is installed on the plant to reduce the risk of an accident leading to, say, a leak of radioactive coolant, but there is a dose exposure required to install, and maintain, the piece of equipment. In these cases the overall risk needs to be minimised.

An evaluation of risk may need to utilise the various tools used for risk assessment such as Hazard and Operability Studies (HAZOP), Hazard Identification Studies (HAZID), Failure Modes Effects Analysis (FMEA) and Probabilistic Safety Assessment (PSA) as appropriate, although it should be remembered that engineering judgement will always be an indispensable feature of any risk assessment process. Further information on these assessment tools is given in Appendix D. Quantitative values for risk may need to be evaluated for individual risk to particular groups of people or to society as a whole, 'societal risk'.

2.3.2 SELECTION OF APPROPRIATE DOSE OR RISK CRITERIA

The use of dose or risk criteria to define a level of exposure or risk that can be regarded as just tolerable, but cannot be exceeded, and below which the exposure or risk must be reduced to as low as reasonably practicable is described in the HSE's Tolerability of Risk document for Nuclear Power Stations (Ref. 7). In terms of applicability to the ALARP process it can be thought of as an upper bound to the evaluated dose or risk above which it is considered that an option predicted to produce such a value would be unacceptable, and for which action would need to be taken if the existing dose or risk was predicted to lie above such a value. In other words, the ALARP process is only applicable to options or measures which lie below the level of dose or risk that is deemed to be the limit of tolerability.

As has been mentioned already, the higher, or more unacceptable a risk is, the more effort, proportionately would be reasonably practicable to reduce it. Where the risk is less significant, the less effort, proportionately, would be worth expending, until a point is reached where the level of risk is considered to be broadly acceptable and it may not be worth expending effort to reduce it further.

The classic ‘carrot diagram’ used in Ref. 7 to represent these ideas is reproduced below:

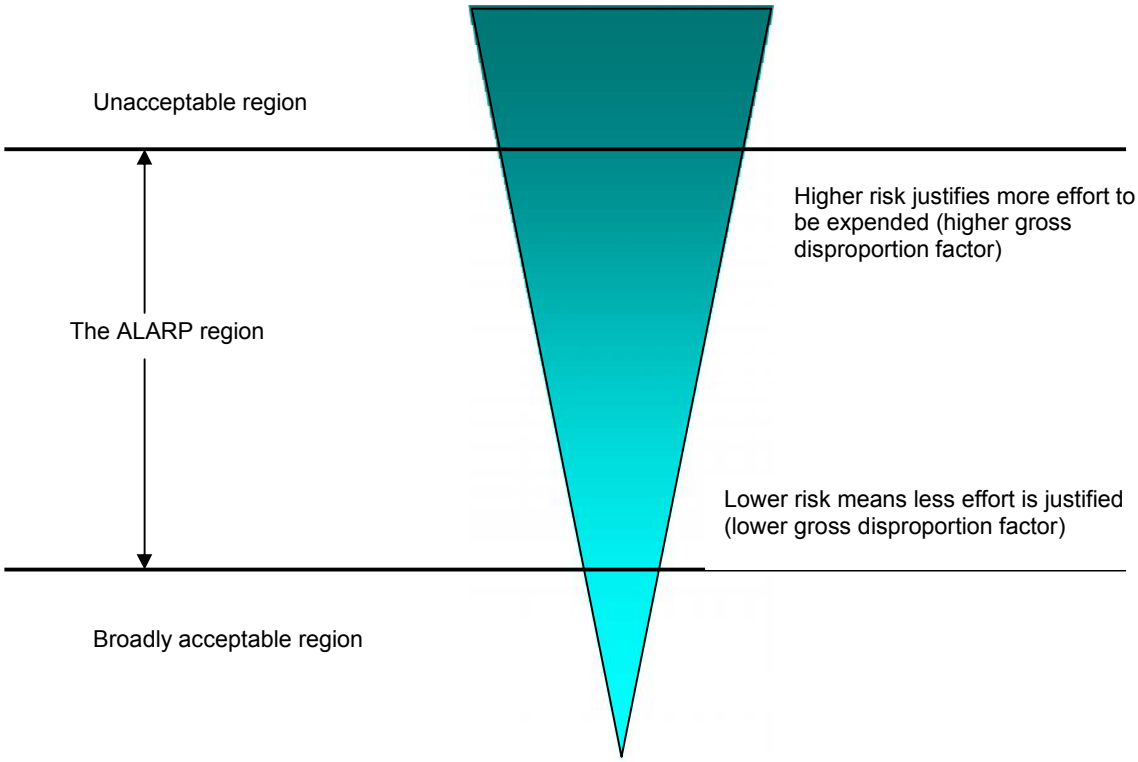


Figure 2 Levels of risk and ALARP

This approach and its applicability to all areas of health and safety, is further described in HSE’s document ‘Reducing Risks, Protecting People’ (Ref. 15).

Numerical dose and risk values for the upper ‘unacceptable’ level and the lower ‘broadly acceptable’ level for nuclear facilities are defined in the HSE Safety Assessment Principles (SAPs) (Ref. 8). The SAPs define these levels in terms of Basic Safety Levels (BSLs) and Basic Safety Objectives (BSOs). Whereas the upper BSL level represents a dose or risk value that should be met, the lower BSO level does not represent the level at which ALARP no longer needs to be considered. Rather, HSE regard the BSO doses/risks as a level where they do not consider it to be a good use of its resources or taxpayers money to pursue further safety improvements, however, nuclear facility licensees have an overriding duty to consider whether they have reduced risks to as low as reasonably practicable on a case by case basis irrespective of whether the BSOs are met.

The SAPs define nine sets of targets (in terms of BSLs and BSOs) for normal operation and fault conditions. A detailed explanation of how these dose and risk criteria have been derived, and their justification, is given in Ref. 8.

Dose and risk criteria other than those defined in the SAPs may be more relevant to consider for some ALARP cases. An example would be collective dose criteria, which are not included in the SAPs, but which may be useful to define as a target, or as a level above which a detailed ALARP process is to be followed, or in terms of upper and lower bounds of acceptability. In some cases there may need to be an apportionment of a high level criteria between various project activities, e.g. the target dose/risk for a complete outage apportioned between various activities within the outage to define 'sub-criteria'.

2.3.3 IDENTIFICATION OF THE POSSIBLE OPTIONS

In most cases there will be a number of options available to reduce dose or risk. The identification, and subsequent assessment, of such options is referred to as 'Optioneering', and is probably the most important part of the ALARP process. It is unlikely that an adequate demonstration of ALARP can be made unless it can be shown that a rigorous and structured approach has been used to identify other options.

Methods to identify options may include various techniques such as 'brainstorming' meetings attended by relevant stakeholders and Suitably Qualified and Experienced Personnel (SQEP) (Appendix A); the use of checklists of factors that can affect dose or risk; and comparison with measures and practices used elsewhere (not necessarily just within the nuclear industry). Specific activities such as HAZOPs and HAZIDs can also inform the option identification process (Appendix D).

All options should be considered and recorded, even if they can be subsequently eliminated by a simple qualitative judgement or by comparison with other options – this will provide evidence that the identification process has been comprehensive.

2.3.4 ASSESSMENT AND SELECTION OF THE ALARP OPTION

From the range of options identified, a process needs to be applied to assess each option, and to compare them with each other in order to make a decision on which can be selected as the ALARP option. In the same way as for the method of identifying options, the approach taken should be to adopt a structured process (see Appendices B and C).

This process should take into account the fact that different levels of assessment rigour may be appropriate depending on the complexity or size of the task. For some cases it may be appropriate to assess on the basis of good engineering judgement whereas other cases may need a probabilistic safety assessment, etc. Similarly, in some cases options can be satisfactorily assessed by qualitative methods, others will need quantitative assessment or a mixture of both. The overall aim is to form a balanced view on the benefits and detriments of each option, including the 'do nothing' option, and to make a decision on which to select.

A structured process will need to include consideration of the following subjects as appropriate:

- Legal requirements, standards and criteria
- Good Practice
- Operational requirements
- Risk Assessment
- Ethics
- Costs

2.3.4.1 LEGAL REQUIREMENTS, STANDARDS AND CRITERIA, GOOD PRACTICE

The ALARP assessment needs to assess each option for compliance with relevant legislation (e.g. Ref. 4), standards (e.g. IAEA standards such as Radiation Protection Aspects of Design for Nuclear Power Plants - Ref. 9) and criteria (e.g. dose and risk criteria in the SAPs).

Good practice is essentially a practice that is recognised, by the regulatory authorities or industry, as a benchmark that operators and designers should strive to achieve. Documentation defining good practice for particular activities include:

Approved Codes of Practice (ACoPs) to legislation (e.g. IRR99 Approved Code of Practice and Guidance – Ref. 10),

Government guidance and policy (e.g. Managing for Safety at Nuclear Installations – Ref. 11, Radioactive Waste Management Ref. 12),

Nuclear Industry CoPs (Refs 1, 13, 14)

If a good practice is so defined, then although not mandatory, an operator who decides to use an alternative approach would need to provide a robust justification that the measures proposed are at least as effective as the recognised 'good practice' method.

Where there is no formal document, a comparison of practices between operators, for example waste practices, can form the basis of a method for demonstrating good practice. Periodic reviews of what is good practice may be needed as good practice may change over time due to technology development and other improvements. When considering whether or not to adopt a good practice measure, account should be taken of factors that may affect its reasonable practicability such as whether a plant is a new or existing design and the expected lifetime of the measure.

Further information on documentation that needs to be considered in this context is given in Section 2.5.

2.3.4.2 OPERATIONAL REQUIREMENTS

The introduction of an ALARP measure can affect operational requirements such as performance, reliability and availability. The ALARP assessment needs to consider the impact of the measure on such operational factors. It may not be possible to quantify these aspects, and a qualitative argument may be more appropriate to address these issues.

2.3.4.3 RISK ASSESSMENT

An assessment of the risks associated with each option, be these project risks, technical risks or safety related risks will be required. The aim should be to minimise the overall risk and this may require balancing an increase in risk in some areas with a decrease in risk elsewhere.

2.3.4.4 ETHICS

Professional engineers and safety practitioners have a responsibility to consider the ethical implications of a proposed measure and to consider its benefits or detriments to society as a whole. Some option assessments may require consultation with the potentially affected public or special interest groups. Consideration needs to be given to the wider implications of the proposals, and a determination, by consensus if appropriate, of what is 'the right thing to do'.

2.3.4.5 COSTS

Although assessment and selection of the ALARP option will, in some cases, be determined without a quantitative calculation of costs, in many cases cost will be an important factor in determining reasonable practicability.

Following consideration of the above subjects and any other relevant factors, the benefits and detriments of each option should have been identified. A comparison and selection process is then required in order to judge which option or combination of options is the ALARP solution. In some cases a decision may be made based on a purely qualitative assessment; in other cases a quantitative assessment technique may be appropriate to assist the decision-making process. The two most common decision aiding techniques are:

- Decision Analysis (or Multi-attribute Analysis)
- Cost Benefit Analysis

Both of these techniques are discussed in detail later in this document. The main difference between them is that Decision Analysis can be used to 'quantify' a range of factors (by applying weightings to each factor) which otherwise could not be easily compared, whereas Cost Benefit Analysis requires all the factors to be quantified in terms of a monetary cost.

2.3.5 IMPLEMENTATION OF THE SELECTED OPTION

The next stage in the ALARP process will be to implement the selected option. It will be important to record how successfully this is carried out, any issues which arise that were not considered in the ALARP assessment and how the operation of the measure compares to the assumptions that were made. This feedback will be invaluable for subsequent reviews of the measure and as feedback into future ALARP assessments.

2.3.6 APPLICATION OF REVIEW LEVELS

Following the Optimisation process, review level values should be applied to individual exposure situations to limit the maximum dose to individuals carrying out the operation. The use of review levels is an essential part of the ALARP process, ensuring that risk to individuals is limited and a balance between individual and collective risks is achieved. Further information on the application of review levels in a broader context is given in Chapter 3.

2.4 PRACTICALITIES OF APPLYING ALARP

It is easy to be swamped by the wide range of information and documentation on ALARP theory and concepts. By the nature of the judgemental process inherent in demonstrating ALARP, there are many different approaches and practises across the nuclear industry. In addition, it always needs to be recognised that an ALARP case should be fit for purpose; for example, an ALARP assessment of a new nuclear power plant design will require a different methodology than assessing options for installing a ventilation system in a contaminated area.

ALARP should not be seen as something separate from the overall design or implementation process, something that is ‘added on’ at the end of a project, but rather an integratal part of the overall design or process strategy.

Existing plants may meet the ALARP requirement at higher risks than new ones, as the cost of bringing the plant up to modern standards may not be reasonably practicable, perhaps due in part to the remaining lifetime of the plant.

In any ALARP assessment, cost will undoubtedly have to be taken into consideration in determining if an option is reasonably practicable. If it is demonstrated that the costs of the measure are reasonable compared to the benefits gained (using gross disproportion factors as applicable), then this will be an ALARP solution. Affordability cannot be considered as part of the ALARP argument (Ref. 5).

If, after carrying out an ALARP assessment, more than one option is shown to be practicable (after taking all relevant factors into account) then the option that gives the lowest risk/dose should be chosen, even though it may cost more than other options.

2.5 ALARP IMPLEMENTATION GUIDANCE

The implementation and/or development of an ALARP program will be dependent on the complexity and magnitude of the potential hazards associated with the work. The following elements will need to be considered at a level commensurate with the radiological and non–radiological hazards associated with the project.

2.5.1 ONR GUIDANCE ON THE DEMONSTRATION OF ALARP (TAST005)

T/AST/005 (Ref. 5) is a Technical Assessment Document (TAG) which is written against the background of Reducing Risks Protecting People (R2P2) (Ref. 15) and the supporting documents published by the HSE which give guidance to inspectors on ALARP

It is likely that all ALARP assessments will have to meet the T/AST/005 expectations.

2.5.2 SAFETY ASSESSMENT PRINCIPLES (SAPS)

The SAPs (Ref. 8) were developed against the background of the legal requirements and the TOR philosophy, and have been benchmarked against the IAEA Safety Standards. They contain engineering and operational principles, safety analysis requirements and numerical targets and legal limits. SAPs expect that a safety case (see T/AST/051 (Ref. 16)) should provide an analysis of normal operation, fault analysis covering Design Basis Analysis, Severe Accident Analysis and a Probabilistic Safety Analysis (PSA), and analysis of the engineering design and operations.

The Tolerability of Risk (Ref. 7) philosophy has been translated in certain specific cases into numerical targets in the form of Basic Safety Levels (BSLs) and Basic Safety Objectives (BSOs).

2.5.3 BASIC SAFETY LEVELS

It is HSE's policy that a new facility or activity should at least meet the BSLs. However, in meeting the BSLs the risks may not be ALARP. The application of ALARP may drive risks lower. Deciding when the level of risk is ALARP needs to be made on a case-by-case basis. A graduated approach should be used so that the higher the risk, the greater is the degree of disproportion needed before being considered ALARP, and a more robust argument would be needed to justify not implementing additional safety measures.

2.5.4 BASIC SAFETY OBJECTIVES

The BSOs form benchmarks that reflect modern nuclear safety standards and expectations. The duty holder, however, is not given the option of stopping at this level. ALARP considerations may be such that the duty holder is justified in stopping before reaching the BSO, but if it is reasonably practicable to provide a higher standard of safety below the BSO then the duty holder should do so.

2.5.5 ‘GOOD’ AND ‘BEST’ PRACTICE

Good practice is the generic term for those standards for controlling risk which have been judged and recognised by the HSE as satisfying the law when applied to a particular relevant case in an appropriate manner. Best practice usually means a standard of risk control above the legal minimum.

All ALARP demonstrations should consider first and foremost factors relating to engineering and design, operation of the facility and safety management. This approach is often referred to as “good practice” and has been identified by the HSE as the basis for new design and where there is the potential for major accidents application of “best practice” is required.

Compliance with relevant good practice alone may be sufficient to demonstrate that risks have been reduced ALARP. For example, recognised standards provide a realistic framework within which equipment designers, manufacturers and suppliers (including importers) can fulfil their general duties under HSWA S.6 (Ref. 3).

However, depending on the level of risk and complexity of the situation, it is also possible that meeting good practice alone may not be sufficient to comply with the law. For example, in high hazard situations (those with the potential to harm large numbers of people in a single event), where the circumstances are not fully within the scope of the good practice, additional measures may be required to reduce risks ALARP.

2.6 DOCUMENTING THE ALARP CASE

In order to demonstrate the legal requirement for doses to be ALARP, the ALARP case needs to be written down and retained. There is no specified minimum retention period for this, however it should be for as long as it is needed to form part of the justification, argument or supporting evidence for the operation of the plant or process.

3. MANAGING FOR ALARP

Corporate procedures should highlight the responsibilities at various levels in the organisation and identify the relevant radiation protection objectives, standards and procedures consistent with the Ionising Radiation Regulations 1999 and current good practice. There should be a commitment to ALARP at all levels within the organisation.

To achieve this, control of radiological exposure and dose reduction should be firmly on the agenda of management and this should lead to a firm commitment to radiological protection and safety throughout the organisation.

The establishment of well considered and articulated safety policies where responsibilities are properly defined and allocated and organisational arrangements set out are key to promoting a high-quality safety culture.

3.1 DOSE MANAGEMENT

Dose management tools have an important part to play in ensuring doses are kept ALARP.

3.1.1 DOSE REVIEW LEVELS

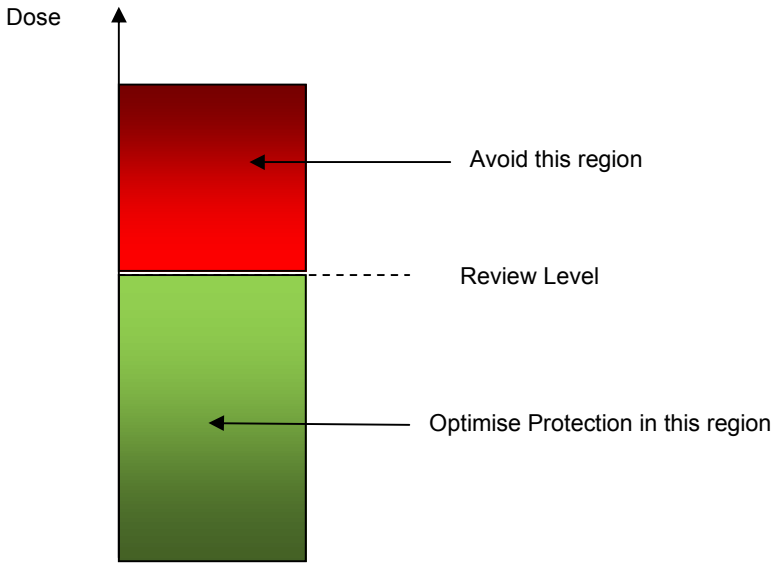
ICRP 103 (Ref. 2) outlines the recommendation to set dose constraints when considering a planned exposure to radiation. Without these, the optimisation process described in Chapter 2 may emphasise the protection of the exposed population as a whole over limitation of risk to individuals. Their purpose therefore is to ensure that some individuals within an exposed group are not put at disproportionate risk to the others.

In the UK nuclear industry, the use of the word “constraint” is generally avoided as it has been found to be widely associated with the concept of fixed limits and hence its meaning misinterpreted. Other terms are used instead with equivalent meaning and use such as “objectives” and “review levels”, the exact terminology varying between operators. For the purposes of this document, the term “review level” is used.

Review levels should be set for occupational exposures and should be used at the planning or design stage as one of the tools for helping to restrict exposure. It is not acceptable to just work within the dose limits set out in the Ionising Radiations Regulations 1999.

Setting a review level at the planning stage will provide a boundary which individual exposures from a single, specific source should not exceed and below which optimisation of protection should take place. This may be set as a result of previous experience or as a result of benchmarking carried out with other operators and may be informed by the regulators expectations.

Use of a review level in this context is demonstrated in the figure below.



Further review levels may also be set following the optimisation process. In this context, the review level provides a ceiling to the values of individual doses from a source, practice or task which could be determined to be acceptable in the process of optimisation for that source, practice or task. In setting a review level the distribution of individual doses that is reasonably achievable in the particular circumstances should be determined with a view to setting the review level in the region of the upper end of the distribution.

The definition of ‘source’ relative to a review level may be interpreted in different ways. For example, a ‘source’ could be a sealed source with several kBq or TBq of activity, a nuclear power plant in its entirety or even individual activities within the plant such as the replacement of a valve. It is widely accepted in industry however that the term ‘where appropriate’ must be applied to the requirement to set review levels.

Review levels are an important tool for improving optimisation in practical radiation protection and for facilitating communication between operators, employers and regulatory authorities.

Options resulting in doses greater in magnitude than the identified review level should be rejected at the planning stage. If, following the implementation of an optimised protection strategy, it is subsequently shown that the value of the review level is exceeded, the reasons should be investigated as this may indicate that planning assumptions were incorrect or that workplace controls may have deteriorated.

It is important to recognise however that setting a review level must not take away the emphasis of what the application of the ALARP principle is aiming to achieve at a

practical level. The review level does not represent a “safe” level below which optimisation can be disregarded. Setting a review level helps to focus the attention on good management of the exposure of personnel in the design of facilities and in the planning of operations.

3.1.2 INVESTIGATION LEVELS

Regulation 8(7) of the Ionising Radiations Regulations 1999 (IRR) (Ref. 4) outlines the requirement to set a formal investigation level for the purpose of determining that effective doses are being restricted. The regulation specifies that a formal investigation must be undertaken when an employee exceeds an effective dose of 15mSv (or such other lower effective dose as the employer may specify) in a calendar year.

The duty to carry out the investigation is placed on the actual employer of the person whose recorded dose has exceeded the investigation level. This must also include contracting staff (e.g. scaffolding contractor or cleaning company) working on various sites occupied by different radiation employers, noting the requirements for co-operation between employers set down in the IRR. The investigation may have to take account of work with ionising radiation undertaken at all these different sites throughout the calendar year.

A formal investigation should include for example:

- The work pattern of the individual and immediate work colleagues.
- Whether the individual was involved in any known incident in which they may have received an unusual exposure.
- Comparison of dose with work colleagues doing similar work.
- Results of radiological surveys undertaken in the work area to identify any deterioration in physical control measures, including airborne activity levels, even if just to eliminate the likelihood of internal doses.
- Discussion with the Radiation Protection Supervisor, individual concerned and colleagues to ensure all local rules and dose reduction measures have been adhered to, or deficiencies in those rules in light of changes to work practices.
- A dose reduction plan for continued work for the individual or group.
- Whether there is a need for further control measures or better application of current controls.

The investigation report should be reviewed jointly by the employer and the RPA.

Where groups of employees are engaged in essentially similar work in the same type of environment, only one investigation may be needed if two or more individuals receive doses above the investigation level.

Copies of formal investigation reports should be kept for at least two years, but good practice will be to keep the investigation for the same length of time as the dose records for the employees concerned, ideally with the dose records.

In addition to the formal investigation level required under Regulation 8(7) employers will generally find it appropriate to set additional local investigation levels which are set at much lower dose levels to trigger more routine reviews of working practice. These may range in frequency e.g. daily, monthly, quarterly or annual such that when triggered they act as a means of early notification to management that the actual exposure is at variance to the planned and hence some form of local ALARP review is warranted to restrict further exposure..

In setting appropriate local investigation levels the profile of doses of employees as a whole (or particular groups) should be considered. The Radiation Protection Adviser should be consulted when setting such levels, appointed safety representatives or the established safety committee may also be consulted as appropriate.

3.1.3 PREDICTED DOSE –V- PROGRAMME

Realistic dose estimates for the likely occupational exposure for a package of work should be undertaken prior to the commencement of work. The dose estimate should provide a guideline on the expected dose accrual.

The actual dose accrual must be monitored on an appropriate frequency commensurate with the length of the work package, levels of expected doses and risk of unexpected events and compared with the estimate. As a guide, for longer term and lower risk projects monthly is sufficient, whereas for short term work or work with high dose accrual then a weekly or even daily review may be more appropriate. If there is a large discrepancy between the two, either below or above the dose estimate, the estimate should be reviewed for any future work. If it is necessary to recalculate the dose estimate during the work package a record of any changes made should be held.

It should be noted that the maximum possible frequency of review will be determined by the nature of the radiation hazard. For example, it is possible to monitor exposure to external beta and gamma radiation on a real time basis using electronic personal dosemeters. This is not generally possible for exposure to neutrons or when monitoring internal exposure for example.

The comparison of dose estimates against actual doses could provide an indication of the effectiveness of ALARP measures.

It is important that the findings of any discrepancies should be brought to the attention of relevant management groups so that pertinent factors can be considered when planning future work.

3.1.4 DOSE REPORTS

Dose Reports can be a useful tool, providing dose information which can be used by Health Physicists, managers, team leaders and RPS as well as the individual to work towards keeping doses ALARP. Timely provision of dose information allows prompt investigation or intervention as required.

Examples of dose reports may be used as follows:

- Daily dose report giving individual and collective doses for specific work areas and/or groups of workers, with weekly summaries to assist with comparing accrued doses to predictions as necessary.
- Monthly dose reports giving collective and individual doses for their team. This allows them to monitor the team's performance, compare individual doses and discuss the data at team meetings to explore ways to improve.
- Monthly dose reports giving collective dose data as performance indicators for monitoring the department and location business plans, this allows for comparison of actual performance against the budget.

In order to ensure the production of dose reports are used effectively the 'customers' must be identified, the requirements agreed and checked frequently to confirm they are getting the dose information they need to ensure their staff keep their radiation exposures ALARP.

3.1.5 INDIVIDUAL AND GROUP DOSE CONTROL

The doses accrued must be monitored to avoid disproportionate dose accrual. Techniques for doing this may include real time dosimetry with facility for remote reading. This applies to individual and collective dose accruals.

The most effective method of dose control must be considered when monitoring doses. There may be, for example, circumstances where it is prudent to authorise higher shift/weekly dose accruals to achieve a more efficient overall dose accrual leading to a lower collective dose.

Sufficient numbers of people in each trade group for example are to be authorised and trained for work to enable dose targets to be met.

Dose sharing is unacceptable as a primary strategy used to comply with planning constraints and as an alternative to a robust optimisation process. However, in the context of an operation that has been demonstrated to be ALARP, it may be necessary in order to avoid disproportionate dose accrual by individuals.

3.2 ESSENTIAL ELEMENTS OF A RADIATION PROTECTION PROGRAMME

In addition to arrangements for the control of dose, there are a number of other essential elements of a good radiation protection programme. These are outlined in this section.

3.2.1 TRAINING AND FAMILIARISATION

Radiation protection training should be provided at all management and operational levels in the organisation. The training should cover basic radiation protection, in particular the importance of minimising occupational exposures and of establishing an ALARP culture throughout the workforce, including training in conducting ALARP assessments for appropriate sections. Refresher training should also be provided. The level of knowledge of senior management about the occupational exposure strategy and how it is achieved is a useful indicator.

The planning of all operations must include consideration of training.

In addition to the general training on occupational exposures and ALARP, there should be effective planning and training on specific tasks to be carried out. For example the use of mock-ups in order to familiarise workers with potential problems and to improve their skills in carrying out the tasks. In this way, tasks can be carried out more efficiently in a radiation environment thus reducing occupational doses.

Training should make workers aware of the simple actions they can take to minimise their doses and the doses received by others, which can be more effective when combined with individual direct reading dosemeters. It enables all those concerned to contribute to the reduction and control of doses.

3.2.2 MONITORING THE WORKPLACE

All equipment used to measure radioactivity needs to be calibrated in line with legislation and appropriate standards. A dosemeter calibration plan will ensure that occupational doses to plant workers and contractors are accurately measured. Calibration of radiation survey instruments used ensures that existing dose rates within the plant are accurately measured in order to avoid workers being exposed to excessive radiation fields. Whole body counters and equipment for the analysis of bio-assays need to be calibrated to ensure that potential intake of radioactive material is properly measured.

When it has been assessed that there is a risk of airborne activity then appropriate measurements of the airborne activity will be required. In some cases this may include personal air samplers (PAS), for example when work patterns are variable or the potential source of contamination could be localised. In many cases general area, or static air sampler (SAS), measurements may suffice.

If it is determined that there is a significant risk of the breakdown of controls, leading to a potential for significant airborne radioactive material, then alarming air samplers may be used to mitigate this.

3.2.3 CONTAMINATION CONTROL POLICY

The risk to personnel from radioactive contamination compared to external whole body dose will vary considerably with different isotopes present in a plant. It is generally the case, however that control of contamination is important to prevent the build-up of radioactive contamination in clean areas. A balanced approach to contamination control is necessary to properly control total dose. Protective measures put in place to control contamination or mitigate the hazard may increase the external doses (by increasing the time to conduct the work) or increase other risks (such as additional Personal Protective Equipment (PPE) when working at height or with rotating machinery). These potentially conflicting aspects must be carefully assessed.

It is useful to have criteria for trigger levels, to review surface contamination levels in low contamination areas so that any long-term build-up of contamination (where the "background" level gradually increases over a long period of time) does not go unnoticed and lead to small changes in plant conditions.

Radioactive contamination controls strive to minimise the contamination of areas, equipment and personnel. The primary means of preventing the spread of contamination are to contain contamination at its source, and to minimise the extent of contaminated areas and the amount of loose surface radioactivity contained in the contaminated areas.

3.2.4 CONTROL OF RADIOACTIVE MATERIAL

Radioactive material, such as calibration, test and radiography sources and radioactive material from all stages of the nuclear fuel cycle, need to be properly controlled.

Companies specialising in radiography are normally used for radiography in the nuclear industry. It should not be assumed that contract radiographers provide their own radiological protection coverage and oversight. Instead the plant radiological protection department should provide oversight of all radiography operations performed.

Strict control must be kept of any radioactive source being brought on to the site and they should be kept in a designated storage facility, with an inventory of sources being maintained. These arrangements need to be integrated with the arrangements used by radiographers to ensure that compliance with legislative requirements for holding radioactive material, safe working practices and contingency plans.

3.2.5 MANAGEMENT OF SOLID RADIOACTIVE WASTE

Management of radioactive waste will be addressed by an effective BAT process (Ref. 1) which will aim to minimise high, intermediate and low level radioactive waste. This is important in order to limit the environmental impact of the plant and make it acceptable to the public. Minimising the generation and volumes of solid radioactive waste reflect good work practice and in many cases reduces radiation dose. Furthermore, the less waste generated, the lower the dose received by personnel in packaging and loading shipments of waste for disposal.

3.3 MONITORING EFFECTIVENESS OF ARRANGEMENTS

Monitoring the effectiveness of arrangements is important to ensure that doses accrued are in accordance with the ALARP principle. It should be a formalised ongoing process which is carefully planned to obtain maximum benefit.

Evaluation provides a good opportunity to assess whether established standards of good practice are still in date. New developments, for example better knowledge of the risks involved and advances in technology may indicate that a higher standard would be more appropriate to control the risk.

The following provides examples of how arrangements can be monitored.

3.3.1 RADIATION DOSE REDUCTION COMMITTEE / WORKING GROUPS

Dose Reduction Committees / Working Groups should be set up to identify improvements in plant and its operation in order to restrict occupational doses, including doses to the public, to ALARP levels.

There should be clearly defined Terms of Reference for the Committee / Working Group. The groups should involve relevant stakeholders from the plant operations, management, safety representatives, Health Physicists, appointed Radiation Protection Supervisors etc and would usually be specific to a facility or operational area.

The organisation structure must also be clear i.e. who does the committee report to.

A Dose Reduction Committee / Working Group should undertake the following:

- Review and monitor the effectiveness of any measures implemented.
- Review of individual and collective dose accrual.
- Review Investigation Reports.
- Review Radiological events and incidents, in particular to consider lessons learnt.
- Provide a forum for concerns to be raised.
- Provide a forum for new ideas, particularly for operators.

3.3.2 OPERATING EXPERIENCE FEEDBACK

A record of incidents including near misses which have radiological consequences or the potential for such consequences is a measure of how well occupational exposures have been managed. The types of incidents/near misses are also relevant e.g. contamination incidents where the actual doses may be very small but the potential doses may be large.

The nature and thoroughness of the investigations should be commensurate with the actual or the potential radiological consequences. The actions to prevent incidents recurring should be taken without undue delay and should be effective. Root cause analyses of the information should also be carried out by the licensee.

Trends of certain events / incidents may be identified which will enable the evaluation of the effectiveness of dose reduction efforts in certain areas.

3.3.3 ANNUAL REPORTS

An annual report summarising the ALARP achievements or areas for improvement from work undertaken in the previous year can be extremely useful. It can collate information from all areas of an organisation and be distributed to a wide audience.

Producing an annual report provides an opportunity to consider what changes have had a beneficial effect with regard to radiation dose. Continued effort is required to ensure that any improvements are consolidated into normal work practices throughout the company as a whole.

3.3.4 AUDITS

Audits can be used to provide a strong indicator of the effectiveness of arrangements in place. Consideration should be given to the depth and frequency of audit required, for example Department/Facility on a quarterly basis and Executive Management annually.

Examples of areas which could be considered during an audit to identify ALARP practices are given below:

- Equipment
- Facilities and design based safety factors, such as inherent protection, safety and warning systems
- Methods, workloads, procedural safety
- Maintenance work – what, when, where and by whom
- Attitude of Personnel
- Training
- Dose accrual

3.3.5 METRICS

Ideally the plant should look for three or four metrics for each of the elements of the Radiation Protection (RP) program. Metrics should be easily measureable and not subjective.

Once a set of metrics have been agreed the plant can establish an ALARP Committee. A function of the committee would be to assess and approve ALARP reviews for routine or non-routine work where the individual or collective dose exceeds a threshold set by the plant. In addition the ALARP committee should set annual dose targets for the main work groups and the facility as a whole. The ALARP committee can then engage in regular reviews of the facility's performance against targets and identify areas of concern and address remedial actions. On a less frequent basis the ALARP Committee should review the dose performance of the plant against modern standards, undertake a gap analysis and then question whether gaps are justifiable and ALARP.

4. ALARP FOR ROUTINE OPERATIONS

4.1 RISK ASSESSMENT

The IRR Regulation 7(1) differs from the Management of Health and Safety at Work Regulations 1999 (MHSWR99) (Ref. 17) in that a prior risk assessment for new activities must be completed before work with ionising radiation can commence. How does this relate to routine work where the work with ionising radiation is already ongoing? No task should be considered so routine that some degree of risk assessment is not required. At the very least the work will need to consider impact of any other work in the immediate area and changes to plant conditions.

It must be stressed that radiological risk must always be considered in the context of other risks that may be present and may be more significant and immediate. Significantly increasing risks from conventional hazards in order to achieve a minor reduction in a small long term radiological risk, must be guarded against. An integrated approach to the assessment of all risks, including radiological, is recommended as best practice in order to achieve this.

Within the context of an overall approach to risk assessment, it is important to establish a framework for a graded approach to radiological risk assessment for what can be considered routine operations. Routine plant operation is a clear candidate as should routine preventative maintenance work, housekeeping and surveys be considered routine. Breakdown maintenance should be considered routine if the nature of the failure does not lead to unusually elevated radiological hazards for the facility or require other than routine maintenance tasks to be performed. Another aid to deciding if a maintenance task is routine is to ask if the breakdown was considered during the design stage and if engineered features were incorporated to work the repair during construction. If the answer to this is yes then the maintenance activity will have been subjected to a risk assessment and the significant hazards identified dealt with during design and construction. If the answer is no then a new risk assessment commensurate with the scale of the task must be considered.

When it has been determined that the work is routine in nature it may be appropriate to divide the work into three categories from a risk assessment point of view as follows:

- The radiological hazards associated with the activity are minimal and well understood and not likely to change during the period of the activity. A basic risk assessment carried out to meet the requirements of MHSWR99 may be adequate in this instance without a requirement to assess the radiological risk in any further detail.

- The radiological hazards associated with the activity are well understood but have the potential for change during the period of the activity and may require some mitigation e.g. use of shielding or enhanced PPE. In this instance, the requirement for a radiological risk assessment specifically carried out to meet the requirements of IRR Regulation 7(1), may be identified. If an integrated approach to risk assessment

is being adopted, this may be in the form of a specialised assessment driven from and identified by the overall MHSWR99 assessment.

- The radiological hazards associated with the activity are already significant or have the potential for significant change during the period of the activity. In addition to a radiological risk assessment, a pre-job ALARP assessment and brief is necessary to ensure that all members of the relevant work party are aware of the potential hazards and required precautions.

Once it has been established that a task or series of tasks are routine in nature then a risk assessment appropriate to the category listed above can be applied. Periodic review of the risk assessments should be carried out at a suitable frequency. Guidance can be found in paras 52 – 54 of the Approved Code of Practice (Ref. 10). For activities in the highest category it may be appropriate to identify a hierarchy of dose ranges such that at each successive dose range the work requires a higher level of approval before it can proceed.

The aim of these risk assessments should be to identify the hazards and to assess the severity of the resulting risks and then to formulate precautions to eliminate or reduce the risk. An appropriate method for identifying the risk is a simple checklist to identify if certain risks exist and their severity. Although it is tempting to focus on effective dose to the whole body care must be taken to ensure that dose to the lens of the eye or other extremities is not overlooked for special situations. The precautions specified should follow a hierarchy as shown below, where the highest precautions are always preferable to precautions lower down the list. This is an example of what is often called the "Hierarchy of Controls" which is a requirement of Regulation 4 of MHSWR99.

- Eliminate or Reduce Hazard at Source: Examples - removal of a pump to allow refurbishment in a low doserate area, flushing a line with heavy contamination to remove sources of radiation, removal of material stored in a glovebox to allow maintenance to be carried out and reducing the spread of contamination by decontamination at the start of work and as new surfaces are exposed. A beta shield or safety spectacles is effective at controlling beta dose to the lens of the eye.

- Remove person from hazard by the use of engineering controls, for example from remote operation of shielded enclosures using Master Slave Manipulator (MSM) equipment and robotics to long handled tools there are many ways in which the principle of distance and shielding can be used to reduce the external radiation hazard.

- Contain the hazard by the use of engineered enclosures for examples carrying out work in a fumecupboard or glovebox rather than on an open bench, use of a tent to contain the contamination hazard and protect other workers in the vicinity, small plastic enclosures that form glove box type enclosures around a valve or pump that can contain any release and protect the operator. This is illustrated below.

- Reduce employee exposure: Example - this may range from the application of time saving techniques such as use of a battery operated screwdriver through to rehearsing the task, work planning, deconfliction and sharing a task between employees.

- Safe systems of work: Example - these are written procedures that have steps or hold points to ensure that work place hazards are minimised. They may also include training and supervision requirements, specify hold points and detail any radiation and contamination monitoring requirements. For work in very high doserate areas it might be appropriate to apply a dose review level which is controlled by stay time calculations or telemetric dosimetry which is being monitored by a control person in audio contact with the worker(s).

- Personal Protective Equipment (PPE): - Example - ranging from simple gloves to pressurised air line fed suits, PPE should be the last line of defence used when all other controls have failed to reduce the hazard to acceptable levels. However, PPE can also be used to mitigate the risks of engineering or control measures failing.

Although the primary concern of the risk assessment is the protection of the worker performing the task, the assessment must also consider downstream risks to other workers and the public by ensuring that waste is minimised or produced in a manner that facilitates easy handling and processing and results in minimal discharges to the environment.

In addition to optimising the exposure the risk assessment should identify methods by which the effectiveness of the controls may be demonstrated. This can be addressed by the specification of suitable survey strategies, air sampling or alarming radiation or contamination detection equipment.

4.2 PLANNING

Planning of tasks is an important part of ensuring that exposures are ALARP. For simple tasks the planning may be as simple as ensuring that the activity takes place at an optimal time based on other plant activities. But for more complex series of tasks such as a routine plant outage the planning will need to include vertical slices to review the interactions with other activities and ensure that tasks are performed in the correct sequence with hard holds to prevent the start of some activities that require the completion of a prior activity before the optimal radiological conditions can be realised.

Activities should be sequenced to ensure that they occur in a logical order to prevent unnecessary exposure or rework. For example an access scaffold should not be removed until the maintenance has been completed and tested.

Parallel activities should be reviewed to remove conflicts such as avoiding other work in an area where radiography is planned. Such conflicts will only become apparent when detailed planning of all the events takes place and are unlikely to have been identified during the initial risk assessment. The review will require input from RP personnel, planners as well as representatives from each work party who will be required to justify the relative priorities of each task before decisions can be made on what order to perform the tasks.

Where work involves freshly irradiated items a significant dose saving can be achieved by delaying the work to allow short lived nuclides to decay. The older the material the less effective this technique becomes unless the program is able to withstand significant delays. For operational areas delaying preventative maintenance too long can have the adverse effect of causing plant failures through lack of maintenance and this will often incur more dose to recover than that which was saved from not performing the maintenance. There may also be conflicts with production schedules if the delay period extends beyond the window of opportunity and further delay would mean a delay to resumed operations.

Plant status and configuration is an important consideration that must be reviewed when determining the optimum time to undertake routine work. That is routine tasks should be planned to coincide with periods when the plant is in an optimal configuration for performing the task with minimal doserates present or following plant clean up to minimise contamination hazards.

Where practicable, decontamination should precede maintenance activities. Ideally this will be accomplished remotely by draining, flushing and filling with clean fluid. For major activities it may even be appropriate to use chemical decontamination of the plant prior to work starting. When normally sealed surfaces are exposed it is equally important to take an opportunity to remove loose contamination prior to further work. This will minimise the likelihood of a spread of contamination throughout the work area. Such spreads due to poor housekeeping will challenge containment of the contamination every time a person or items move across the work area boundary.

4.3 PERIODIC ALARP REVIEW

An important part of any routine ALARP practice is the periodic review of ALARP performance. It is important to realise that collective dose is not the only measure of a good ALARP performance. A strong Radiological Protection program will incorporate many facets and the review should include measurements for each of these to demonstrate that they are being successfully implemented. This may include an implementation of the full process described in section 2.3.

5. ALARP FOR PROJECTS

5.1 INTRODUCTION

The demonstration that activities involving the exposure of persons to ionising radiation are ALARP is fundamental and has to be carried out in many situations from the construction of new facilities to the decommissioning of old and redundant ones.

This section discusses the ALARP demonstration required for projects. It must be borne in mind that the requirement to demonstrate ALARP is all embracing and continuous. There is an ongoing requirement for ALARP demonstration under all work activities involving radioactive material.

This section deals with ALARP applied to “projects” In this context we are considering the following types of processes, or example;

- New build including major refurbishment of existing parts of a facility.
- Modifications to existing plant.
- Decommissioning of an existing facility (including disposal of waste).

ALARP for routine operations is discussed in Chapter 4.

Due to the complex nature of many projects a combination of radiological and non-radiological hazards may be encountered. Identification of non radiological hazards is important because efforts to apply the ALARP process may inadvertently increase risks from non-radiological hazards. An integrated safety management approach that optimises worker protection from all hazards must be considered in the ALARP process.

A schematic representation of the ALARP approach to projects is shown in Figure 5.1.

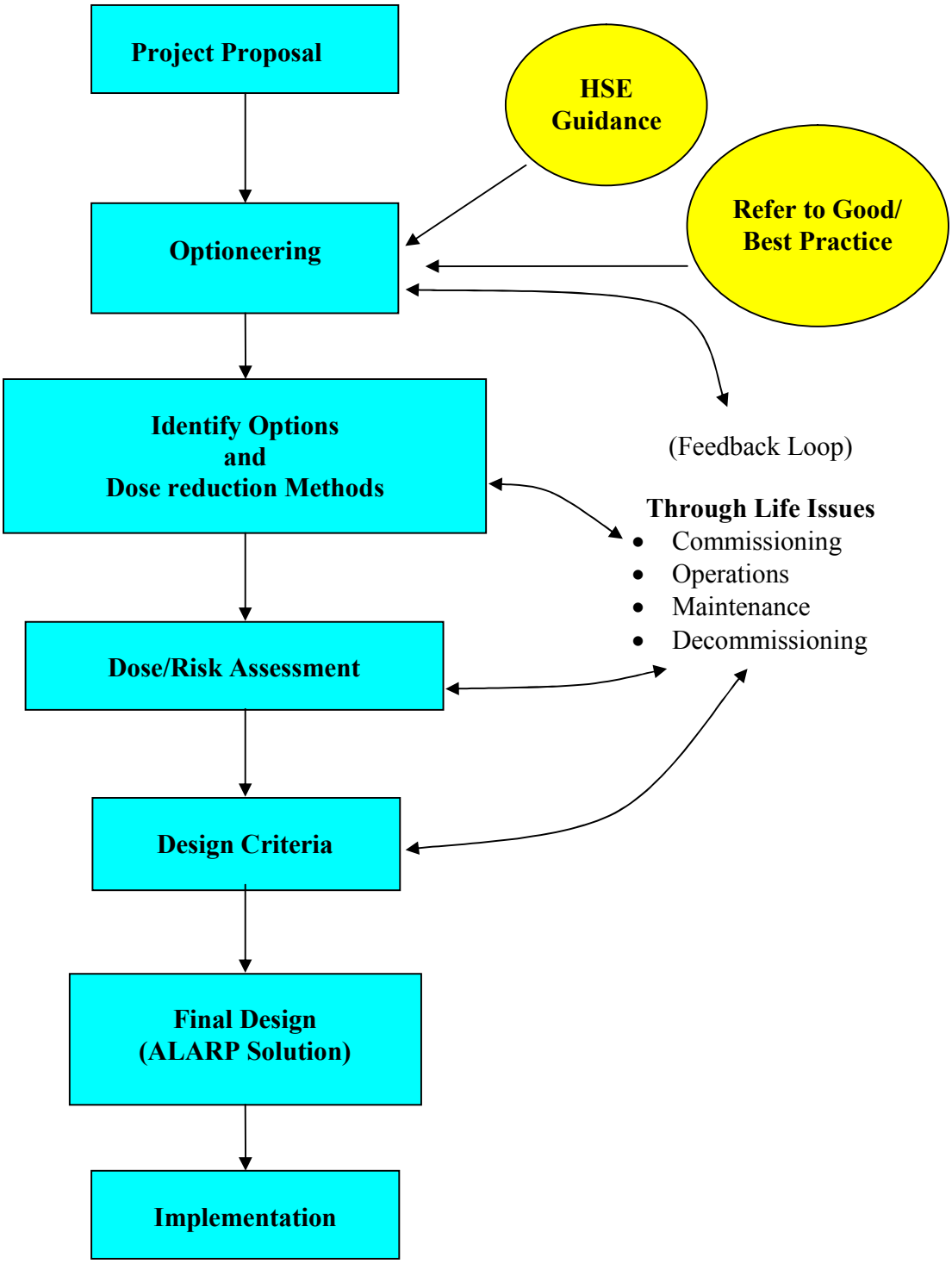


Figure 5.1: Illustrative ALARP process

5.2 OPTIONEERING

Having identified the benefits and detriments of each of the ALARP options, a comparison and selection process is required in order to choose between different options, or to judge whether a particular individual measure or group of measures should be implemented. The approach followed and depth of rigour in the process will vary depending on the individual case, but fundamentally the ALARP principle requires the following to be demonstrated:

- Each option, or combination of options, should be considered to determine whether the 'detriments' of applying the option are 'grossly disproportionate' to the benefits gained.
- Options should only be rejected if the associated detriments are 'grossly disproportionate' to the benefits that would accrue from their implementation.

All options that are considered should be documented and where they are rejected there should be a record of the rationale for their omission.

Where claims of gross disproportion are made, evidence of costs and benefits must be provided.

Further background information on Optioneering is given in Chapter 2, with information on the practical application in the Appendices.

5.3 PROJECT DURATION

The detail and the degree of rigour that is in an ALARP assessment the depends on factors such as the time duration of the project, the magnitude of the risks, whether a modification to an existing facility is being carried out or if it is a completely new facility.

When conducting the assessment it is worth considering whether the project is either:

a) A long term enduring project.
b) A short term discrete project.

<u>Examples of long term projects</u>

New Build facilities (power station, waste repository)
Operation of a nuclear power station
Operation of a radioactive waste repository
Radioactive waste packing and handling facility
Operation of a nuclear fuel reprocessing plant
Decommissioning of a major facility
New medical treatment facilities

Examples of short term projects

Decommissioning of a minor facility
Short duration decommissioning project (less than 1year)
Minor modifications
Minor land remediation

5.4 LONG TERM ENDURING PROJECT – SPECIFIC ISSUES TO CONSIDER

Although a facility or installation may be expected to exist for a long time it must be borne in mind that it is a liability that future generations will have to deal with. Projects associated with radioactive waste management and some decommissioning, will run over many years, and the risks that result may affect future generations of workers and the public as well as the present generation. For such cases the risks should be assessed in an holistic manner and not restricted to part of the overall time period or part of a process. ALARP principles must be applied over the whole life cycle of the facility. Any new build or major modification is within this category.

Therefore, in this type of project the new installation or facility must be designed and built to minimise decommissioning and associated waste management operations and costs. For example a ventilation system that is modular in design so that it can be removed in sections will be easier to decommission than one which is entirely of welded sections.

The primary methods used for maintaining ALARP exposures should be by engineered controls, e.g. confinement, ventilation, remote handling and shielding. Managerial controls must only be incorporated only as supplemental methods and for specific activities where engineered controls are demonstrated to be impractical.

In addition, for longer timeframes, the erosion and loss of corporate knowledge relating to plant design, modification and operation can have a significant impact on risks later in the project. Hence there is the need to carefully and accurately document changes and to retain this information in a retrievable form.

5.5 PRINCIPLES FOR SHORT AND LONG TERM PROJECTS

The following principles are likely to need consideration:

1) **Design criteria** – The appropriate ALARP design features should be incorporated into modifications of existing facilities and/or equipment and designs of new facilities as early as possible in the engineering and design process. From early in the design phase and throughout the project a RPA should be involved in the process. The following elements will need to be considered in any design review:

- Selection of building materials. How easy is the installation to decontaminate?
- Maintenance.
- Is there adequate space around it for ease of decommissioning? How is the facility structured? Facility layout may also have an influence upon the ability to meet the duty to reduce radiation doses to ALARP and can be a factor in providing means of preventing unauthorised access.
- Traffic Patterns - Layout can also affect consequences of incidents, particularly Internal and external hazards, and the access conditions following an incident.
- Location and size of change facilities and adequacy of decontamination facilities
- Location of monitoring equipment.
- The design of the containment and ventilation systems must provide the required level of protection from airborne contamination, paying particular attention to airflow patterns and the locations of air inlets, penetrations and exhausts. The velocity of air flow at containment barriers also needs to be carefully considered.
- The adequacy of specific control measures for reducing occupational doses such as shielding, fume cupboards, glove boxes, containments, interlocks, cells, posting arrangements will need to be reviewed and documented.
- Assess the suitability of installed radiological monitoring and nuclear criticality safety instrumentation and determine whether the proposed instrumentation is appropriate for the radiation types, levels and energies to be encountered, and whether there is sufficient redundancy and capability for operation under normal operating conditions and during emergency situations.

2) **Through life issues** – It is not appropriate to declare a plant design as ALARP and then forget about it. The plant is likely to need maintenance and this may require a change in state for a short time. In this instance the plant must still be protected and an ALARP demonstration required for this changed state. Areas where ALARP requirement is at risk of not being met and where focus should be applied are:

- Existing ongoing procedures that may no longer be suitable due to changes to original assumptions e.g. changes in plant condition or unintended consequences of changes in other related procedures or working practices etc.
- New procedures that have been introduced.
- Changes to the radioactive material or source term.
- Deployment of new or inexperienced workers.

3) **Adaptability of the design** – how easy is the design to modify for future requirements? If for example in the future, the facility requires increased ventilation or to handle greater quantities of radioactive material, how difficult would it be to effect this change? Can this requirement be built in to the original design?

4) **Compatibility with the existing facility** – If the work is installation of a new piece of equipment to carry out a process within an existing facility facility; then the adequacy of the existing plant and equipment to allow its safe use must be demonstrated. For example if a new glovebox is to be installed in a facility, is there sufficient capacity in the ventilation system to allow its safe operation.

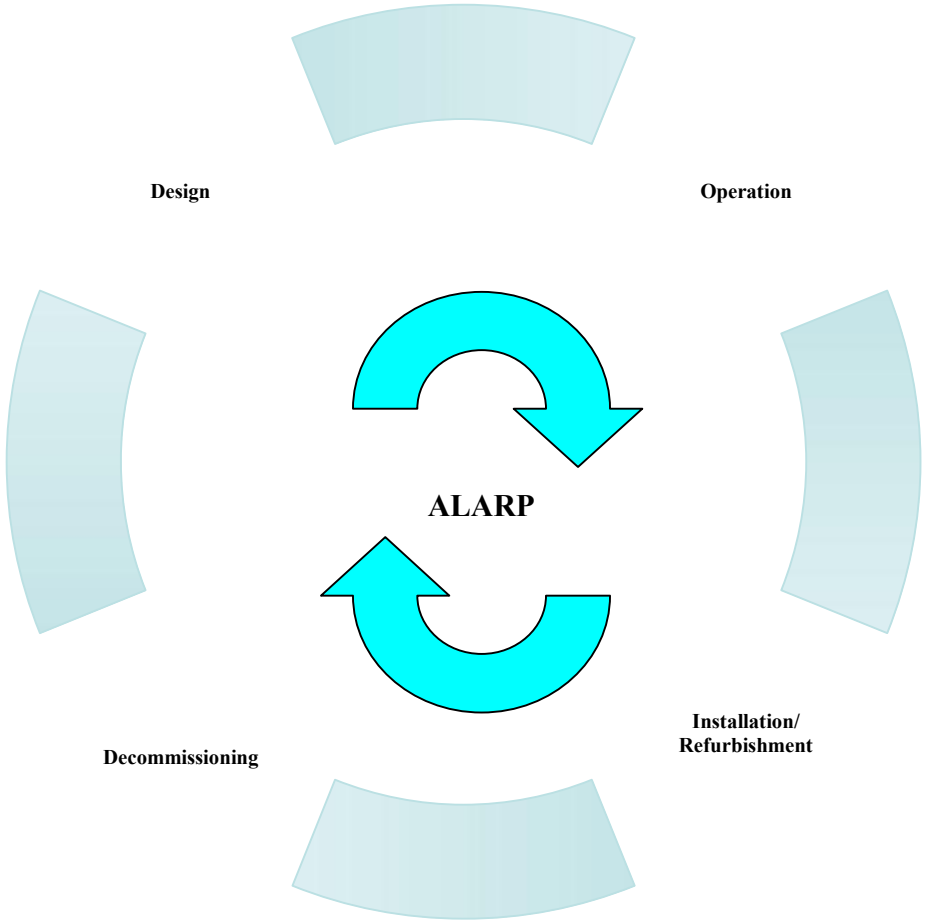


Figure 5.2: ALARP over the lifecycle of a project

5.6 SHORT TERM DISCRETE DECOMMISSIONING PROJECTS – SPECIFIC ISSUES TO CONSIDER

In this type of project there is a known end state (physical and radiological) for the work. If the work is to decommission a facility, the end state is likely to be complete removal of the facility.

Decommissioning is by its nature different in that it is transient and there may be short term increases in risk which lead to a long term risk reduction overall. This is provided that the risk increase itself is ALARP and the period of increased risk is kept as short as reasonably practicable. Consequently it can be legitimate to use time at risk as part of a decommissioning ALARP argument. The extent of the time for which the risk is increased should not be the sole argument for acceptability that a situation is ALARP.

There may be uncertainty as to the precise nature and magnitude of the hazards to be encountered, and the physical condition of some areas of the plant. For many decommissioning projects there is incomplete information about the state of the plant internals (level of contamination, condition of plant services, waste category and quantities etc.) and therefore reduced or limited ability to plan precisely how to mange dismantling and clean up. This makes the production of a detailed and reliable safety justification, in advance of any activities, very difficult.

In order to progress work that contains uncertainty of risks and therefore a “problem area” for demonstrating ALARP the following approach is recommended.

- There must be defence in depth – the decommissioning safety case should identify a safe decommissioning envelope based on declared bounding assumptions.
- The safety case must set out explicitly the argument for how ALARP has been satisfied.
- The work must follow the hierarchy of control measures as described in the Ionising Radiations Regulations 1999 (Ref. 4).
- The work must not be subdivided into a series of small tasks without an overarching ALARP case, as there is a potential for the overall risk of the project to be under assessed. The decommissioning safety case must be categorised in accordance with the highest hazard potential of all the activities.
- Each decommissioning task should be capable of being halted without additional hazards in case unexpected hazards come to light.
- The succession of activities should be planned so that earlier ones provide information that assists in managing the later ones. For example do not start decommissioning the most contaminated or hazardous facility first; practice decontamination techniques, size reduction on less hazardous facilities.

It is important that facilities are not left in care and maintenance regimes for longer periods than necessary before beginning decommissioning, because knowledge and experience of the plant may be lost, and these attributes are paramount to straightforward, safe and cost effective decommissioning.

Wherever possible the people who operated the plant should play a major role in its decommissioning, especially during Post Operative Clean Out (POCO) and the development or validation of the decommissioning plan. This has the advantages of:

- Plant knowledge (of spills, incidents and inventories) and experience being retained.
- Utilising site knowledge.
- Retaining the motivation and continuity of workers.

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GLOSSARY OF TERMS USED

ACERA	Australian Centre of Excellence for Risk Analysis
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
BAT	Best Available Techniques
BSL	Basic Safety Level
BSO	Basic Safety Objective
CBA	Cost Benefit Analysis
FMEA	Failure Modes Effects Analysis
GPG	Good Practice Guide
HAZID	Hazard Identification Studies
HAZOP	Hazard and Operability Studies
HSE	Health and Safety Executive
HSWA	Health and Safety at Work Act
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IRPCG	Industry Radiological Protection Co-ordination Group
IRR	Ionising Radiations Regulations 1999
MAUA	Multi Attribute Utility Analysis
MCDA	Multi-criteria Decision Analysis
MHSWR99	Management of Health and Safety at Work Regulations 1999
MSM	Master Slave Manipulator
P&ID	Process and Instrument Diagrams
PAS	Personal Air Sampler
POCO	Post Operative Clean Out
PPE	Personal Protective Equipment
PSA	Probabilistic Safety Assessment
R2P2	Reducing Risks, Protecting People
RP	Radiation Protection
RPA	Radiation Protection Adviser
RPE	Respiratory Protective Equipment
RPS	Radiation Protection Supervisor
SAP	Safety Assessment Principles
SAS	Static Air Sampler
SDF	Safety Directors Forum
SFAIRP	So Far As Is Reasonably Practicable
SQEP	Suitably Qualified & Experienced Personnel
TAG	Technical Assessment Document
TOR	Tolerability of Risk

APPENDIX A GENERATING ALARP OPTIONS AT THE CONCEPT STAGE

An essential part of the ALARP process that is particularly relevant for new projects is that of specifying suitable risk, dose and consequence reduction options to inform the concept design or process. Options arising may then be subject to cost benefit analysis (Appendix B) and options assessment process (Appendix C) to determine the best option and apply tests of reasonable practicability.

It should be stressed that this section is applicable to the concept stage of a project. ALARP measures that are prescribed by Radiological Risk Assessments for inclusion in specific safe system of work are not considered at this stage. These include aspects such as training (including the provision of mock ups for non radiological learning), supervision, PPE selection, monitoring and dose management.

A suggested guided brainstorming procedure for generation of options is shown below.

A1. PROCEDURE

A baseline option needs to be identified to provide a starting point to generate alternatives. Typically, baseline options may be the cheapest option that meets the project requirements, the option that would be pursued in the absence of significant radiological risk or the solution that seemed most obvious to the project engineer.

Keywords are then applied in turn and any options arising are identified for future evaluation. Note that options are not considered practicable unless they are technically feasible and are compliant with basic legal requirements.

A2. SUGGESTED KEYWORDS

Some suggested keywords are given in this section but it is advised that these are added to or amended to fit the particular application.

Eliminate / Reduce

Keywords	Comments
Do nothing / less	Is there a net benefit in carrying out the full project scope? Would a smaller scope have a greater net benefit?
Delay	Would the net benefit be greater if the project was delayed?
No / less size reduction	Are there artificial packaging or assay constraints?
Eliminate / reduce radioactive source term	Decontaminate / use inert material instead.
Reduce throughput / scale	Can the material to be processed be reduced in volume or activity at source?
Disposal routes	Can the category of waste be reduced by improved sampling or segregation? Are there alternative disposal or recycling routes?

Isolate

Keywords	Comments
Robotics / remote control devices	Use of devices that function remotely from the operator e.g. robotic arms, demolition robots.
Remote handling	Remote handling from a shielded location e.g. use of MSMs.
Handling aids	Use of reachers, tongs etc. May be used in conjunction with shielding.
Stand off devices	Devices set to work manually and then supervised remotely e.g. band saws. Low dose waiting areas.
Shielding	Best material vs. source term. Has the radiation field been characterised? Flexible, permanent, shielding of hot spots, shielding of operator position.
Containment	Extracted enclosures, glove boxes, ventilated enclosures. What standard of filtration is required? Do discharges require monitoring?

Process Issues

Keywords	Comments
Process elsewhere	Can processing take place on a different site / plant / location within plant?
Combine operations	Can plant be shared to reduce costs?
Batching	Can efficiency be improved by processing batches of material with common features or tooling etc?
Sequencing	What is the best order to do the work? Is there a risk of having to repeat activities? Have potential interferences been eliminated?
Handling time	Has handling, moving and disposing time been minimised?
Access	Can access risk and time be reduced for people and plant?

Other

Keywords	Comments
Good / best practice	Have we learned all we can from other operators? Are design standards or codes of practice applicable?
New facilities vs. refurbishment	Which solution gives lower cost and risk over the plant lifetime?
Sampling / Measurement	Would more / better information help make the right decision?
Waste conditioning requirements	Are they appropriate?
Construction / installation	Are there significant risks and waste arisings?
Through life costs / risks	Have these been minimised?
Dismantling, decommissioning and disposal	Do designs consider future dismantling, decommissioning and disposal? Have these costs and risks been minimised?

APPENDIX B – COST BENEFIT ANALYSIS

Cost Benefit Analysis (CBA), associated with modifications and continued operation justifications, may be used to support an assessment of whether the cost of an improvement is justifiable or is grossly disproportionate.

B1. MONETARY EQUIVALENCES

The following monetary value equivalences between cost and risk are to be assumed:

- The value of preventing a fatality from cancer is £2.7M from the HSE Cost Benefit Analysis (CBA) Checklist (Ref. 18). This value was quoted for 2003. HSE principles for Cost Benefit Analysis (CBA) in support of ALARP decisions (Ref. 19) gives guidance on updating this value in line with annual per capita growth in GDP.
- When considering risk reduction, this equates to £27 per 10^{-5} reduction in the risk of an individual fatality.
- When considering radiation exposure, assuming a fatality risk of $4.1 * 10^{-2}$ / Sv for individual doses up to 100 mSv (Ref. 2), this equates to £111 per man mSv reduction of dose.

B2. GROSS DISPROPORTION TEST

An option is considered to be reasonably practicable if it satisfies the gross disproportion test, i.e.

CI < (DR * MV * D)

Where:

CI = Cost of implementing the option, (money, time and trouble of implementing the option including other safety factors)

DR = Dose (Sv) or Risk averted by implementation over the life of the plant

MV = Appropriate monetary value per unit dose/risk

D = Disproportion factor

The following Disproportion factors, recommended by T/AST/005 (Ref. 5), may be used:

Dose / risk level	Disproportion factors	
	Workers	Public
Dose / risk nearing the BSL (Just Tolerable)	10	10
Dose / risk near the BSO (Broadly Acceptable)	3	2

APPENDIX C – MULTI ATTRIBUTE SCORING

ICRP Publication 55 on 'Decision Making' includes a process known as Multi Attribute Utility Analysis (MAUA) which applies an analytical rigor to decision making, modelling the thought process which goes into adding in all relevant factors into the decision making process. Other aligned methodologies are Multi Attribute Decision Analysis or Multi-criteria Decision Analysis. Decision analysis has also been used to make business decisions particularly where risk is an issue.

This technique assigns an overall score (total utility) to each option considered - the optimum solution is that with the lowest overall score. Each option is given a score (called a factor utility) based on its performance with respect to all of the relevant factors, and the total utility is then a weighted sum of these factor utilities such that:

Total Utility = $\Sigma_n(kF_n \times uF_n)$

Where kF is the weighting of each factor depending on their perceived importance (conventionally, the sum of all kF values is 1);

And uF is a score assigned to each option to describe "how well" it does in reducing the various factors (this might be data such as actual doses or a subjective measure of the discomfort caused by each option).

C1. MAUA PRACTICAL EXAMPLE

In this simplified example, three options have been identified for a job involving significant handling of radioactive material. The options involve wearing different kinds of gloves. The factors used to choose between these options involve loss of dexterity and finger dose (discomfort when wearing the gloves, heat etc. might also be included, but for the purposes of this example only dexterity is used).

Three different options might be given values $uF_{(dext)}$ = 1.0, 0.5 and 0 respectively for the factor of dexterity because option 1 involves wearing thick leaded gloves (high dexterity loss), option 2 involves wearing leather gloves (moderate dexterity loss) and option 3 involves wearing no gloves.

If the associated hand doses for a given task are 1, 3 and 15 mSv for these options, $uF_{(hand)}$ values might be assigned at:

$uF_{(hand)}$ = 0 for dose = 1 mSv and

$uF_{(hand)}$ = 1 for dose = 15 mSv, with doses in-between the two values calculated on a pro rata basis between 1 and 15 mSv such that half way between the two (i.e. 8 mSv) would score 0.5.

In this case, $uF_{(hand)}$ = 0.14 for hand dose of 3 mSv.

If it is decided that hand dose is 9 times as important as dexterity, the kF values chosen will be:

$kF_{(dext)} = 0.1$

$kF_{(hand)} = 0.9$

This is represented in the table below:

Gloves	$uF_{(dext)}$	Weighted dexterity score ($uF_{(dext)}$ x $kF_{(dext)}$)	$uF_{(hand)}$	Weighted hand dose score ($uF_{(hand)}$ x $kF_{(hand)}$)	Total Utility (sum of weighted scores)
Leaded	1.0	0.1	0	0	0.1
Leather	0.5	0.05	0.14	0.126	0.176
None	0	0	1	0.9	0.9

The optimum solution is the option with the lowest value of the sum of each of these scores after weighting by the kF values, in this case the use of leaded gloves.

This enables the decision maker to take account of other issues analytically for example:

- Dose (or Dose rate for example in transport issues)
- Intakes of radioactive material
- General Safety (i.e. by implementing the option does this increase/decrease the other Health and Safety risks)
- Respiratory Protective Equipment (RPE) factors (e.g. is the airborne concentration likely to challenge the choice of RPE)
- Discharges to plant, environment or outside facility (LC 34 process to be considered see references)
- Stakeholder issues
- UK Best Practice
- Moral issues
- Company Standards & Initiatives
- Local Custom and Practices
- Employee Relations

Some of the above can be used at a higher level e.g. when considering BAT vs. operational dose exposure vs. risk issues with wounding when discussing options during decommissioning or as part of optimising company strategies at a corporate level.

As part of the sensitivity analysis or as part of the main analysis options can also be eliminated as a result of the initial limits and conditions sometimes called 'tombstones'.

C2. MAUA WEAKNESSES AND PITFALLS

In some Multi Attribute Analysis carried out, criticism has been made that the weighting factors or utility factors are chosen in such a way as to favour a particular option. The scope for doing this is clear from the example given above, where reversing the weighting (kF) values factor in favour of dexterity would result in no gloves being worn. As part of the sensitivity analysis some analysts carry out a weighted vs. unweighted score to review the difference as to understand why this difference occurs in order to better underpin the recommendations.

In addition the Australian Centre of Excellence for Risk Analysis (ACERA) recently carried out a review of MCDA and the review 'identified that the final decision or ranking of options depends on the choice of performance scoring scales, even when the criteria weights are held constant. The report evaluates the "sensitivity" of results to the choice to performance scales. It concludes that it is possible to change the final ranking of options just by recalibrating the scoring scales for the criteria.

This arbitrariness is not a feature or a fault of the MCDA model. It is a misuse of the weighted average decision method. To address the issue, the report recommends that analysts ensure that the weights for numerical criteria reflect the relative importance of the criteria, and that they are conditioned on the way in which the performance-scoring scales for the criteria are calibrated.'

In short, even if the weighting chosen remains the same, how the individual factors are rescored affects the outcome.

APPENDIX D - THE USE OF HAZARD AND RISK TOOLS

A number of hazard and risk tools are available to aid the production of a safety case that demonstrates that the risks associated with the operation of a plant are tolerable and ALARP.

There are a number of tools available such as Hazard and Operability Studies (HAZOP), Hazard Identification Studies (HAZID), Failure Modes Effects Analysis (FMEA) and Fault Tree Analysis.

The end point of the use of these tools is to identify hazards and then to assess them using either a qualitative approach or attempting a quantitative assessment where required. Tools such as FMEA and Fault Tree Analysis focus on hazards caused by faults and the effects of multiple simultaneous faults

These tools can have value as part of an overall ALARP case, but cannot demonstrate ALARP in isolation. Particular points to note are:

- The use hazard and risk tools are not a substitute for optioneering.
- Safety cases and hence the use of these tools in support of a safety case may often focus on the consequence of failures and may not address the risks posed by expected operations, such as planned occupational exposures.
- These tools may be used to demonstrate that risks are below a particular threshold such as the BSO for a chosen option, rather than necessarily demonstrating that risks are ALARP or that the chosen option is the optimum solution.

Further information is given below on the HAZOP methodology due to its prevalence in the production of safety case arguments.

D1. HAZOP GENERAL METHODOLOGY

The HAZOP technique is a method of structured systematic examination of processes or designs aimed at identifying potential hazard and operability problems. The technique requires a detailed description of the object being studied, such as process flow sheets, Process and Instrument Diagrams (P&ID), plant layout drawings or procedural documentation. It is carried out by a multi-disciplinary team including process, engineering and maintenance specialists as well as health physicists and safety specialists.

The systematic process of hazard identification is carried out by applying keywords in turn to sub-systems (or nodes) within the whole plant or process. The keywords enable the team to discuss and question possible hazards and operability problems associated with each operation, stage or item of equipment. Potential problems can then be identified.

The HAZOP technique may be applied at different levels of examination from the conceptual or high level examination stage to the detailed design examination stage and may also be applied to operating plant.

D2. HAZOP EXAMPLE KEYWORDS

The following is an example list of applicable keywords for a concept design. The actual list used will depend on the application and should be agreed by the team before the study starts.

- Fire
- Explosion
- Radiation/Loss of Shielding
- Airborne/Surface Contamination/Loss of Containment
- Wounding
- Criticality
- Operations
- Maintenance Errors
- Impact/Dropped Loads
- Loss of Services - air, cooling, electrics, ventilation
- Control failures
- Domino effects
- Adjacent facilities
- External events

D3. ROLE OF HAZOP APPLICATION IN THE ALARP PROCESS

The application of a HAZOP process is not a substitute for an ALARP study; however it may be used to inform or underwrite that process.

At the commencement of a project, an options study may yield a number of options which require examination to determine those which have better safety performance. Applying the HAZOP approach can determine which of the options may lead to initiating events or hazardous situations which may require further consideration and inform the decision making process.

During the detailed design process, HAZOP techniques may be applied to identify hazards that may arise with the chosen design, aiding optimisation of that design.

APPENDIX E - Example ALARP Documentation

E1. RADIOLOGICAL RISK ASSESSMENT

The following proforma is an example of a type that may be used to carry out a radiological risk assessment of the type required by IRR Reg 7(1).

Example questions are:

Radiological hazards	Expected levels based on previous or pre-work survey results etc.	Expected levels during execution of task.
Alpha Contamination (loose)		
Alpha Contamination (fixed)		
Beta/Gamma Contamination (loose)		
Beta/Gamma Contamination (fixed)		
Airborne Contamination		
Beta/Gamma Radiation		
Gamma Radiation		
X Rays (Bremsstrahlung or other)		

The values entered into the table should be compared with local limits for clean, controlled and restricted areas.

Further consideration should be given to the types of persons who may be required to perform the work or more particularly any groups who should be restricted from performing the task. Typical examples are given below:

Persons at Risk	Y/N	How/When
Classified Workers		
Non-Classified Workers		
Trainees		
Pregnant women		
Breast Feeding women		
Persons approaching dose limits or levels		
Persons outside the working party		
Visitors		
Others		

Based on the expected radiological conditions and the expected work duration, approval for the work to commence may require escalation to the site ALARP committee or even off-site approval. The collective dose required to trigger each level of authorisation should be predefined in local procedures.

E2. EXAMPLE ALARP CHECKLIST

Supporting evidence is required against each of the questions in this checklist, yes or no answers are not acceptable.

ID	Operation	Justification/Recommendation
1	**General:** • Have the hazards identified in the Risk Assessment (RA) been adequately identified and addressed? • Has ALARP advice been incorporated into the Work/LOI's? • Are all operatives Suitably Qualified and Experienced Persons (SQEPs)? • Is the workplace adequately monitored? i. HP support ii. Air Sampling iii. Extract Discharge monitoring iv. Routine area monitoring requirements v. Personal monitoring requirements	
2	**Can the exposure of personnel to external sources of radiation be reduced by:** **Source reduction:** • Can isotopes be allowed to decay? **Shielding:** • Can a more effective shielding material be used? • Can shielding be applied to the source of radiation? • Can shielding be applied to the working space? • Can shielding be applied to the person carrying out process? • Can other sources of exposure be avoided from adjacent plant or processes? • Any other method? **Time:** • Does the SSoW ensure as much work as possible is done without the source present (e.g. setting up for the process)? • Can the work be practised in low / no dose rate areas? If not why not?	

ID	Operation	Justification/Recommendation
	• Can a more efficient means of working be identified? • Can the process frequency be reduced (or can the process be avoided altogether)? • Does the SSoW avoid unnecessary handling to reduce exposure? • Can power tools be used to reduce exposure time (e.g. power tools Vs hand tools)? • Can quality be improved to avoid re-working? • Application of exclusion areas? • Any other method? **Distance:** • Has the distance between the process worker and the source been maximised? • Can warning notices be erected or monitoring results posted to raise awareness? • Are non-essential personnel excluded from the area? • Can remote handling devices be used? • Any other method? **Interlocks, safety features & warning devices:** • Are safety interlocks fitted? • Have suitable safety features been designed into the system? • Are automatic warning devices fitted?	
3	**Can the exposure of personnel to internal sources of radiation be reduced by:** **Airborne:** • Using a containment system? • Increasing the use of ventilation or extract systems? • Using tie-down coatings? • Using personal protective equipment? • Any other method? **Surface:** • Can the work be restructured to reduce the generation of contamination? • Can tie-down / strippable coatings be used to reduce the loose source term?	

ID	Operation	Justification/Recommendation
	• Is tooling and/or item decontamination appropriate? • Can the extent of contamination spread be reduced by real-time monitoring? • Any other method? **Source Term:** • Can less material be used? • Can contamination be removed or reduced? • Can isotopes be allowed to decay? • Any other method? **Tooling:** • Can tooling which minimises the production of sharp edges be used? • Can tooling which minimises the production of airborne contamination be used? • Can remote handling equipment be used? • Any other method? **Containment:** • Has the number of HEPA filters between the glovebox / temporary enclosure / containment and the isolation point been optimised? • Are active service lines being broken on the clean side of any filtration? • Is a secondary containment required before breaching the primary (e.g. constructing a tent around a glove box)? • Are breaches in containment planned at the point with the lowest potential for material 'hold-up'? • Any other method? **Wounds:** • Are appropriate tool guards fitted? • Can the Operative be isolated from the wounding hazard? • Is there alternative cutting method that would reduce the number of sharp edges produced? • Are sharp edges covered where practicable? • Any other method?	

ID	Operation	Justification/Recommendation
4	**Contingency Arrangements:** • Do all the potential incident scenarios, identified in the RA, have a corresponding contingency arrangement?	

Prepared by	**Name**	**Signature**	**Date**
Endorsed by Health Physicist or RPA	**Name**	**Signature**	**Date**

APPENDIX F: Example of ALARP Case

F1. Options Assessment for Early vs. Late Reactor Decommissioning

Note that this would form part of an overall assessment which could also include cost benefit analysis for example.

Reactor Decommissioning Option Assessment

General

1. "Early" and "Late" decommissioning are assessed against the SAP DC3 criteria. A summary of the conclusions is shown in Table 1.

Worker and Public Safety

2. Worker and Public (radiological) safety are addressed within the ALARP Review – see Section 3.

3. With respect to radiological hazards, it is concluded that there is a significant advantage in minimising operational doses (to workers) for Late Decommissioning.

4. There is concluded to be no significant advantage between Early and Late decommissioning for minimisation of normal off-site doses, or accident risks.

5. Conventional hazards to workers and members of the public are concluded to be very low. There is probably a slight advantage for Early Decommissioning of eliminating ongoing conventional hazards associated with Care and Maintenance (C&M).

6. Overall it is concluded that Worker and Public Safety favours Late Decommissioning.

Environmental Impact

7. Environmental Impact is qualitatively assessed, including the following aspects:

   - Visual Impact
   - Noise; dust/ disturbance; nuisance
   - Consumption of energy and resources

8. Note that other key environmental aspects, in particular "waste" and "radioactively contaminated land" are separately considered in other sections below.

9. Visual impact is concluded as being improved by the removal of the main facilities, in particular the main Secondary Containment structure. Thus Early decommissioning and removal of these structures is concluded to be beneficial.

10. Noise: There is little or no noise from the facility in Care & Maintenance. There will be some noise during the final demolition of the Secondary Containment Structures, though this will not vary significantly with the timescale of this task. Noise is thus concluded as having no significant variation or advantage between Early and Late decommissioning. Dust/ disturbance and nuisance are concluded to be of low impact and similar for Early and Late decommissioning.

11. Consumption of energy and resources. The decommissioning work is concluded to require approximately the same consumption of energy and resources whenever it

occurs. Ongoing Care & Maintenance will require a continued consumption of energy and resources [20.5 TJ of energy for the whole site 2001/11]. It is possible that energy consumption may be reduced to a minimum by maintaining the facility in a cold/ dark status for the majority of the C&M period, including switching off of the ventilation extraction system. However, overall consumption of energy and resources will be minimised by Early Decommissioning.

12. Overall it is concluded that benefits with respect to Environmental Impact favour Early Decommissioning.

Security

13. The facility will remain within the licenced site as long as it remains a categorised facility, and the licenced site will retain the security/ access arrangements as required by the Office of Civil Nuclear Security (ONCS).

14. The facility is a relatively low security risk, as the vast majority of its remaining radiological inventory is inaccessible and non-mobile (activated components of the core).

15. It is concluded that the maintenance of the security of the facility is relatively straight-forward and no problems would be expected for either Early or Late decommissioning. However, the requirement to maintain adequate Site security would entail significant ongoing costs.

16. It is concluded that for minimisation of security requirements and costs, Early Decommissioning is favoured.

Progressive Hazard Reduction

17. The most important early stages of hazard reduction for the facility, including removal of fuel, fuel handing equipment and the emptying of the ponds, have already been completed. In addition, most of the Secondary Containment has been cleared of equipment and materials associated with the reactor operations.

18. The ongoing stages of hazard reduction are the planned operations for the deplanting of the Primary Containment, through to the decommissioning of the core. These stages are necessary for hazard reduction for the facility as a whole, thus to achieve Progressive Hazard Reduction, Early Decommissioning is favoured. However, this general objective for the facility as a whole must be weighed against the associated issue of Worker and Public Safety.

Technical Practicability

19. Decommissioning of the facility is likely to require some engineering development. However, it is expected that this will be based on sound and established engineering practices. There are no aspects of decommissioning of the facility that are currently perceived to have no practicable engineering solutions.

20. It is thus concluded that neither Early nor Late decommissioning is preferred on the basis of the technical practicability of the decommissioning methodology.

Radionuclide Decay or in-growth

21. Radionuclide decay of the main inventory is continuing progressively (see Section 3.1).

22. As the proportion of actinides present in the inventory is very small, radionuclide in-growth is concluded not to be significant.

23. It is thus concluded that Late decommissioning is preferred on the basis of radionuclide decay (see also Section 3).

Aging of Facilities

24. No major structural deterioration of the facilities is expected within the timescales of Early or Late decommissioning, within the timescales as defined. However, some ongoing maintenance costs may be expected, including some which may be substantial (e.g. re-roofing or refurbishment/ replacement of major equipment – e.g. 60t crane). Such maintenance may be required even within the timescales for Early decommissioning.

25. Overall it is concluded that Early decommissioning is preferred on the basis of Aging of Facilities.

Decommissioning Wastes

26. The full criterion is: "The Volume and Categories of Decommissioning Wastes and the Availability of Waste Management Routes".

27. The overall volumes of solid wastes have been estimated [Ref. [1]]. Not including radioactive decay, these estimates are likely to change with the recent implementation of the Environmental Permitting Regulations (2011 amendment) – which should reduce the quantities of Low Level Waste (LLW) and Very Low Level Waste (VLLW) due to tritium (increasing the proportion of Out-of-Scope waste). Other changes to nuclide limits may result in some slight increases in LLW, though these are likely to be small (for) in comparison with the effect of the change in the tritium limit.

28. Only small quantities of Intermediate Level Waste (ILW) are likely to be produced prior to decommissioning of the Reactor core. Even for Early decommissioning, this will not occur until around 2017 at the earliest.

29. The effect of radioactive decay decreases with time, with the inventory becoming dominated by Ni-63 (Co-60 decays much more rapidly). The decrease in total activity between 2017 and 2057 (40 year delay), is approximately 50% (see Table 2). This is expected to result in a reduction in ILW volumes. This reduction will not be as great as 50%, as only a small proportion of the ILW would be in a region that it will be brought below the ILW/LLW boundary. It is estimated that the reduction in ILW volume (2057 c.f. 2017) may be around 10%, with a smaller reduction in the volume of LLW. This assumes that the criteria for consignment of wastes remain the same. Note that delay of decommissioning for the 10 year period between 2007 and 2017 will have reduced the quantity of ILW and LLW decommissioning wastes by a larger percentage, for this period.

30. In addition to the reduction in the volume of decommissioning ILW, it is likely that a 40 year delay will also simplify the storage and transportation requirements for ILW, in particular the requirements for shielding during storage/ transportation (either by self-shielding containers, or a shielded temporary store/ container) will be reduced.

31. Relatively small quantities of LLW are produced from C&M operations. These would be eliminated by Early Decommissioning. These wastes mostly arise from surveillance and monitoring operations on and around the plant with relatively few major maintenance operations. However, these quantities are not separately recorded amongst the total waste masses from the plants together, which over 2010-2011 ranged up to ~150Te/y. Based upon the period since the secondary containment was deplanted and cleared, it is

estimated that a quantity of only a few m^3/y has been produced from C&M operations and no major changes in these volumes are anticipated up to 2017.

32. Routine airborne and liquid discharges from the facility are low, and will decrease with the completion of decommissioning of the effluent facility (from which liquid wastes were routed through the facility). Liquid discharges from the facility alone over the past year have averaged $5m^3$/y and are expected to reduce further in the coming years with the termination of processes generating liquid wastes. Gaseous discharges of mainly Tritium and Carbon-14 have remained low over the past two years and below 10% of the Facility Annual Investigation Limit for each isotope. Routine discharges from C&M operations would be eliminated by Early Decommissioning.

33. Waste management routes are currently available for LLW and Out-of-Scope (formerly Exempt) waste. Routes for VLLW are currently less accessible – these may become more (or less) accessible in the future.

34. There is currently no waste management route for ILW. The Nuclear Decommissioning Authority (NDA) Geological Disposal Facility is not expected to be available until approximately 2040[2]. There is currently no designated interim store for any ILW produced, though this is recognised as a requirement for a number of facilities which will produce ILW during decommissioning. This is a significant dependency for the decommissioning programme.

35. Overall it is concluded that "decommissioning wastes", including minimisation of the quantities of active wastes, favours Late Decommissioning.

Radioactively Contaminated Land

36. The full criterion is: "The presence of radioactively contaminated land, its potential impact on the site and wider environment, the possibility of dispersion during the decommissioning stage and any threat this may pose to the achievement of the assumed end-state for the facility or site."

37. Trace levels of ground contamination have been detected around the facility believed to be associated with the effluent facility and pipeline. It is possible that other areas of ground contamination will be discovered during the final stages of decommissioning of the facility, including any excavation of the foundations. As the vast majority of potentially mobile activity has now been removed from the facility (e.g. the sludge tanks emptied, ponds emptied) the potential for further significant escape of contamination is limited.

38. There is a small potential for dispersion of contamination during final decommissioning of the main building structures. However, with a precautionary approach during decommissioning, and maintenance of the Secondary Containment structure during decommissioning of the Primary Containment and core, this potential is very small for both Early and Late decommissioning.

39. Overall it is concluded that the small potential for contaminated land is the same for either Early or Late decommissioning.

[2] A review is currently underway considering the viability of accelerating the availability of the GDF for emplacement of waste by 2029, [Review of Options for Accelerating Implementation of the Geological Disposal Programme, NDA Report NDA/RWMD/083, December 2011.].

Interactions and Dependencies with Other Facilities

40. The facility interacts will a number of other facilities and services on the site, including the liquid effluent system, waste services, and other departments providing support services. The availability of these services becomes less certain with the passage of time.

41. The other key dependency for decommissioning is a temporary store for ILW. This must be available by the time significant production of ILW occurs.

42. The availability of the current facilities favours Early Decommissioning. As the requirement for an ILW store is recognised as a key dependency, and could be required for Late Decommissioning as well as Early decommissioning, the overall conclusion is that interactions and dependencies with other facilities favours Early Decommissioning.

The Maintenance of an Appropriate Safety Management Organisation Structure

43. The licensee maintains an appropriate Safety Management Organisation structure, that meets the requirements of the regulatory bodies (HSE/ONR and EA), its government sponsors (NDA) and its own procedures. An appropriate safety management structure will be maintained as long as is required.

44. Maintenance of an appropriate Safety Management Organisation Structure is concluded to be equal for Early or Late Decommissioning.

The Maintenance of Site Infrastructure

45. The maintenance of Site Infrastructure is concluded to be similar to “interactions and dependencies with other facilities” as in 2.11 above. It is thus concluded that this criterion favours Early Decommissioning.

The Maintenance of Corporate Memory and Records

46. The licensee has established systems for the maintenance of key facility records. The importance of such records for a major facility such as this is well understood, thus it is considered unlikely that key records could be lost during a relatively short period (40 years). However, as none of the original staff would be available after this period of deferral, knowledge of the plant is likely to be somewhat reduced.

47. The maintenance of corporate memory and records thus favours Early Decommissioning.

The Availability of Suitably Qualified and Experienced Personnel

48. The UK nuclear workforce is aging, with most of the operational staff > 45 years old (Nuclear Industry Association). With the potential increase in demand due to New Build, a significant increase in staffing levels (and thus new recruits to the nuclear industry as a whole) is likely to be required over the next 10 – 20 years. This thus applies to both Early and Late Decommissioning.

49. The site currently has >200 SQEP staff, based in the area, and spending a proportion of their time supporting the site nuclear C&M and Decommissioning operations. This level of locally available SQEP staff is likely to be maintained or increased for Early Decommissioning.

50. In the event of Late Decommissioning, the site (nuclear) staffing requirements would be significantly decreased, and it is unlikely that a sufficient core of SQEP staff would be initially be available locally to commence decommissioning operations. Also, none of the original facility staff would be available.

51. The availability of suitably qualified and experienced personnel favours Early Decommissioning.

Costs, including Care & Maintenance and Infrastructure Costs

52. Decommissioning costs (for all of the nuclear facilities) were estimated in the 2006 Strategy Business Case. Though not precisely the same as “Early” and “Late” decommissioning as defined in this document, Options 1 and 2 could roughly be defined as “Early” and options 3 and 4 “Late”. The undiscounted costs were significantly lower (> £170M) for Options 1 & 2 (Early), though the discounted costs, at 3.5%, were virtually the same between Early and Late.

53. Overall it is concluded that minimisation of costs favours Early Decommissioning.

Future Uncertainties, including Climate Change

54. It is unlikely that climate change will have a significant physical effect on the facility during either the Early or Late timescales. The facility is not vulnerable to possible increases in sea level.

55. It is quite possible that the UK economic position could deteriorate significantly (or improve) over the timescales being considered – both for Early and Late decommissioning. This could affect the availability of government funding to support the substantial cost of decommissioning the reactor core.

56. As uncertainty inevitably increases with time, future uncertainty is concluded as favouring Early Decommissioning.

The Precautionary Approach

57. There are a number of definitions of the Precautionary Approach (or Principle) including the following from the February 2, 2000 European Commission Communication on the Precautionary Principle:

58. "The precautionary principle applies where scientific evidence is insufficient, inconclusive or uncertain and preliminary scientific evaluation indicates that there are reasonable grounds for concern that the potentially dangerous effects on the environment, human, animal or plant health may be inconsistent with the high level of protection chosen by the EU".

59. The requirements for decommissioning of the facility are well understood; the facility is well characterised, and there are no perceived significant inadequacies in information, or potential consequences of decommissioning (or deferral of decommissioning), which give rise to significant concerns for potentially dangerous effects on the environment, human, animal or plant health. It is thus concluded that the Precautionary Approach favours neither Early nor Late Decommissioning.

Possible Burdens on Future Generations

60. Deferral of decommissioning for 40 years represents approximately 1.5 generations. Though not an excessive deferral period, this still represents placing the burden of the main decommissioning activities on a future generation.

61. The possible burdens on a future generation favours Early Decommissioning.

The Potential for Reuse

62. The buildings/ facilities are used for some functions in support of company operations, including storage and waste services. However, these functions will not be required

beyond the timescales of Early Decommissioning. The buildings/ facilities do not have a long term potential for reuse.

63. The site has a possible potential for reuse, though it is unlikely that a future commercial nuclear reactor will be sited there. It is the current site strategy that the site will be returned to heath-land.

64. The potential for reuse is concluded to favour neither Early nor Late Decommissioning.

Interim Storage Facilities

65. As already discussed, an interim storage facility (which does not currently exist) will be required for ILW, for Early Decommissioning. (It is possible that an interim storage facility could also be required for Late decommissioning.)

66. The criterion Interim Storage Facilities favours Late Decommissioning.

Discussion of Options Assessment

67. Four criteria were judged to favour Late Decommissioning (LD) but in three out of four cases a weighting factor above 1 was proposed, totalling 8 overall. These concerned safety (a), radioactive decay (f), waste issues (h) and interim ILW storage (t).

68. Of the eleven criteria that were judged to favour Early Decommissioning (ED), three were weighted above one, comprising environmental impact (b), progressive hazard reduction (d) and availability of SQEP (n). Here the weighting factors totalled 14, suggesting that ED was favoured overall.

69. Five of the criteria in the table (e, i, k, q and s) were judged to favour neither option.

Table 1. Options Summary

Criterion	Early Decommissioning		Late Decommissioning	
	Fav/Unfav	Weighted Result	Fav/Unfav	Weighted Result
a) worker and public safety;	-		+	3
b) environmental impact;	+	2	-	
c) security;	+	1	-	
d) progressive hazard reduction;	+	2	-	
e) technical practicability;	0	0	0	0
f) radionuclide decay or in-growth;	-		+	1
g) ageing of facilities;	+	1	-	
h) the volumes and categories of decommissioning wastes and the availability of waste management routes;	-		+	2
i) radioactively contaminated land	0	0	0	0
j) interactions and dependencies with other facilities;	+	1	-	
k) the maintenance of an appropriate safety management organisational structure;	0	0	0	0
l) the maintenance of site infrastructure;	+	1	-	
m) the maintenance of corporate memory and records;	+	1	-	
n) the availability of suitably qualified and experienced personnel;	+	2	-	
o) costs, including care and maintenance and infrastructure costs;	+	1	-	
p) future uncertainties including climate change;	+	1	-	
q) the precautionary approach;	0	0	0	0
r) possible burdens on future generations;	+	1	-	
s) the potential for re-use;	0	0	0	0
t) interim storage facilities.	-		+	2
TOTAL (Nett for Fav/Unfav)	7 +	14	7 -	8