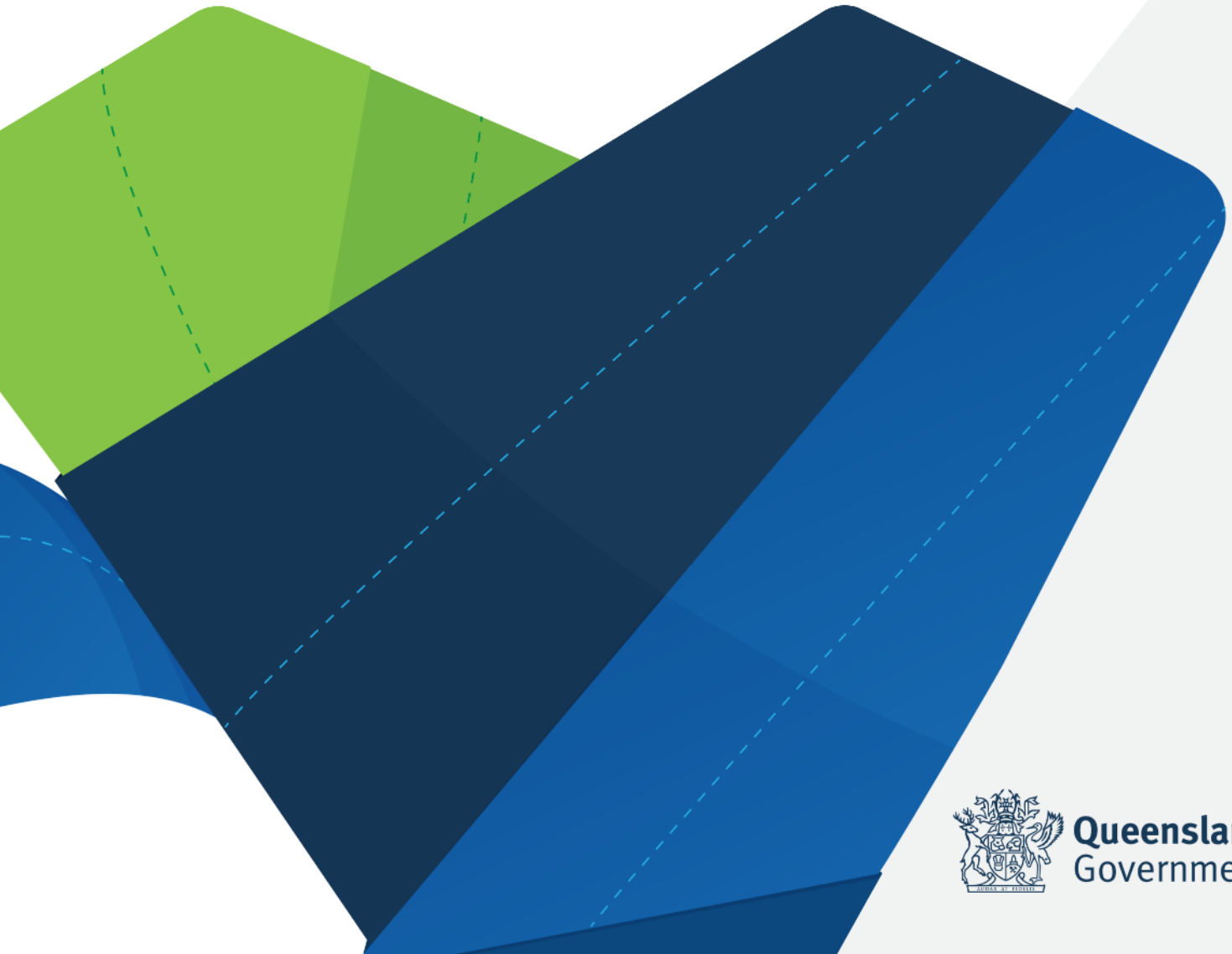
Queensland Health

Land contaminated by radioactive material

A guide to assessment, management and remediation



Queensland Government

Land contaminated by radioactive material - A guide to assessment, management and remediation

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1 Introduction

Land contamination can occur as a result of wilful, ill-informed, or accidental releases of contaminants to the environment. It may be the product of poor environmental management and waste disposal practices, or of bygone practices, allowable at the time, that are now regarded as unacceptable.

In Queensland the contamination of land by radioactive material is almost wholly an historic problem. Many properties had been affected by the use of mineral sand tailings as landfill material in the years before legislation provided for control of the disposal of naturally occurring radioactive material (NORM). Most of the affected sites are in south-east Queensland in areas where mineral sand mining or processing was carried out, or in areas serviced by such industries.

1.1 Purpose

This document explains the principles and sets the Queensland government's criteria for the purpose of ensuring radiation safety and protection of human health and the environment from the adverse effects of exposure to radiation from land contaminated by radioactive material.

Contaminated land is regulated under Queensland's environmental protection legislation, the *Environmental Protection Act 1994* (EP Act) administered by the Department of Environment and Science (DES). The EP Act contains the requirements for the notification of contaminated land and for the investigation, remediation and management of contaminated land.

This document complements the general principles, processes and guidance provided by DES and provides radiation-specific guidance for the assessment, remediation, and management of land contaminated by radioactive material. In particular it establishes reference levels for:

- the investigation and assessment of contaminated land;
- the remediation of contaminated land having regard to the principles of justification and optimisation; and
- the recording of land on the Environmental Management Register (EMR) and its on-going management.

The document is meant to assist landowners, developers, contaminated land professionals and regulators in the determination of whether land is considered contaminated and to understand what is necessary to ensure that the management or remediation of contaminated land does not adversely impact on human or environmental health.

This document replaces all previous Queensland Health guidance on the assessment of land contaminated by radioactive material.

1.2 Scope

This document applies to all land contaminated by radioactive material, but does not apply to mining or other activities that are being carried out under an active environmental authority or similar instrument.

An environmental authority or similar instrument may allow environmental harm to occur under managed conditions that result in contamination by naturally occurring radioactive material that would not be acceptable in other circumstances. The remediation of the land after the activity ceases is also managed under that authority. This document should be used as a guide in the development of conditions or requirements contained in an environmental authority or similar instrument so that when the activity ceases the land should require no, or only minimal, additional assessment or management.

This guide does not seek to be prescriptive about data sampling methods, radiation survey techniques, analytical procedures, or health and environmental risk assessments. These measurements and methods, carried out by suitably qualified people and laboratories, should be in accordance with relevant Australian or international standards, trusted guidance, and well established techniques. It is recognised that suitably qualified persons conducting investigations of a particular site are in the best position to determine the most appropriate way, consistent with this guide, to conduct those investigations and develop remediation proposals and site management plans for the site.

An important difference between this guideline and previous versions is that there is now a greater emphasis on the justification for, and optimisation of, remediation.

1.3 Exposure situations

Contamination may exist in the three exposure situations recognised by the International Commission on Radiation Protection (ICRP) [ICRP 2007]:

- Planned exposure situations;
- Existing exposure situations; and
- Emergency exposure situations

1.3.1 Planned exposure situations

Planned exposure situations are situations involving the introduction and operation of radiation sources [ICRP 2007].

There are many practices, regulated under the *Radiation Safety Act 1999* (RS Act) or other Queensland legislation, using radioactive material that have a potential to cause land contamination and subsequent radiation exposures if not properly controlled.

Practices are regulated to prevent or minimise environmental contamination, but if that were to happen it would be managed by regulatory enforcement action under the RS Act or other Queensland legislation, taking the guidance provided in this document into consideration.

1.3.2 Existing exposure situations

Existing exposure situations are situations that already exist when a decision on control has to be taken [ICRP 2007].

In Queensland, these situations have generally arisen because of activities conducted before the introduction of relevant radiation safety, environmental or planning legislation. To date, all known cases of land contaminated by radioactive material have been the result of past practices such as:

- the partial remediation of, or the abandonment of stockpiles on, former mineral sand mining and processing sites;
- the use of mineral sand tailings and residues for land fill or top dressing; or
- residual contamination being left on site by industries in which naturally occurring radioactive material was used or was accumulated as waste (e.g. foundries or abrasive blasting practices).

This document applies primarily to these existing contaminated land settings.

Existing exposure situations include those for which exposure to natural background radiation is amenable to control. In these situations, the source of the radioactivity is not regarded as contamination, so it is outside the scope of this document. However, the guidance in this document may be useful if there were ever a need to manage an area of elevated natural background radiation.

1.3.3 Emergency exposure situations

Emergency exposure situations are circumstances in which, despite all reasonable steps being taken to minimise the probability and magnitude of planned radiation exposures, an unexpected situation may arise that requires an urgent (but planned) protective response.

In such situations, radiation exposure of emergency responders and the public, and contamination of the environment may ensue. The planned protective response may include urgent measures to reduce contamination that are not within the scope of this document. However, the management of long-term environmental contamination resulting from an emergency situation is treated as an existing exposure situation [ICRP 2007] and is consequently subject to the guidance in this document.

1.3.4 Environmental protection of wildlife

This document sets an environmental reference level for wildlife. However it is not usually the case that an environmental risk assessment specifically for wildlife is required since remediation of a site to a level that protects humans from radiation exposure will typically result in environmental exposures such that an organism is not likely to receive an absorbed dose more than the relevant screening level for environmental protection of wildlife.

If, in particular circumstances, an environmental risk assessment is required the assessment of environmental impact should follow the guidance set out in the *Guide for Radiation Protection of the Environment* published by the Australian Radiation Protection and Nuclear Safety Agency [ARPANSA 2015].

1.4 Management of contaminated land in Queensland

The assessment and management of contaminated land in Queensland is regulated under the *Environmental Protection Act 1994* (the EP Act) administered by the Department of Environment and Science (DES).

DES is the lead agency for environmental management in Queensland and Queensland Health is the lead agency for matters relating to radiation safety and protection. A Memorandum of Understanding (MoU) between DES and Queensland Health, signed in 2015, sets out the strategies to address issues of common interest in the area of environmental radiation in a manner that supports ecologically sustainable development and protects human health and the environment from the adverse effects of radiation.

Under the MoU:

- DES will notify Queensland Health of any matter in relation to contaminated land that may, or would be likely to, require action to be taken under the RS Act, and
- Queensland Health will notify DES of any information about the contamination of land by radioactive material that may or would be likely to require action under the EP Act. This includes advice about the recording of land on a land register.

Queensland Health and DES will also, where relevant, share information and if appropriate undertake a joint response to contaminated land issues.

To support the EP Act, DES has published guidance material to explain the requirements for assessing and managing land contamination [DES 2020].

The DES guidance focuses on chemical contaminants but much of the general principles and processes of site assessment are relevant to radioactive contaminants. However some additional specific guidance is required in situations where there has been radioactive contamination, particularly in regard to the technical guidance for site assessment and remediation.

The DES framework is consistent with the general process for assessment of site contamination described in Australia's *National Environmental Protection (Assessment of Site Contamination) Measure 1999*, (ASC NEPM). Information about this legislation and a link to the ASC NEPM can be obtained from the National Environment Protection Council [NEPC 2020].

The ASC NEPM does not specifically deal with radioactive material: it recognises that the assessment of a site contaminated by radioactive material requires specialised forms of assessment, and that guidance should be sought from the relevant jurisdictional environmental or health authority for assessment requirements. This document provides some of that specialist guidance.

The guidance provided in this document is specific to the radiation related component of contaminated land assessment and management, and it should be used in association with the broader scope of guidance provided by DES and the ASC NEPM.

2 Guiding principles and strategies

2.1 Radiation protection principles

The following principles determine how land contaminated by radioactive material is to be assessed and managed. The principles are consistent with those described in the ICRP recommendations for radiation protection [ICRP 1991, ICRP 2007].

Principle 1 – Protection of people and the environment

People and the environment should be protected as far as reasonably achievable from unnecessary exposure to radiation from contaminated land now and into the future.

The risk of occupying contaminated land with elevated levels of radioactivity should not be out of proportion to other risks occurring in everyday living.

On land that presents a radiation health risk, its development for a more sensitive use should not proceed unless adequate measures are taken to ensure that risks to human health and the environment are reduced to an acceptable level.

Planned exposure situations

For current regulated practices, protection is about planning the practice to prevent contamination from occurring. The person responsible for the practice has the primary responsibility for the management of radiation exposures resulting from the practice.

For practices regulated under an established framework for safety and protection it is reasonable to impose strict requirements to ensure dose limits are not exceeded and to further minimise exposure through the use of dose constraints so that the effective dose received by a person is less than a fraction of the limits.

Existing exposure situations

In the case of existing exposure situations in which contamination occurred before relevant regulatory controls were in place, protection is achieved through exposure management or site remediation.

For existing exposure situations that are not amenable to strict regulatory control, although the site may be managed to keep radiation exposures within an acceptable range, it may not be reasonable to achieve the very low exposure rates that would be expected to be found in a planned practice.

When dealing with prolonged exposure situations arising from past radiation practices, reasonable and practical solutions should be applied. The word ‘reasonable’ is a key consideration. It is not reasonable to expect the current property owner to devote significant resources or bear large costs associated with remedial action if the risks are already low and the potential decrease in exposure as a result of any action the owner may take is small.

For existing exposure situations there is usually no person who can now be clearly identified and held accountable for causing the situation. It is generally the case that the present owner of the land has been left with a situation about which they are now responsible for management of exposures. Provided there is not an unacceptable health hazard, an undue burden should not be placed on the present owner of a property because of a practice that was carried out by a previous owner or occupant.

Principle 2 – Justification and optimisation

Protective actions to reduce existing radiation exposures and radiation practices that give rise to prospective radiation risks, should be justified and optimised.

Justification requires that when considering whether to conduct an action that results in radiation exposure, an assessment is made of whether the action does more good than harm.

The principle of optimisation requires that the likelihood of radiation exposure, the number of people exposed and the magnitude of the exposures should be kept as low as reasonably achievable, with economic and social factors taken into consideration.

If remediation is justified (or required) it should aim to reduce an individual's radiation exposure to at least the level at which remediation would not have been necessary and, if reasonable to do so, remediation should be continued further to a level where the exposure is trivial.

Planned exposure situations

For a planned radiation practice to be justified it needs to produce a net benefit to potentially exposed persons, or to society, to compensate for any adverse radiation risk it causes.

The principles of justification and optimisation apply to unanticipated contamination due to a planned activity. Here, in such planned exposure situations, there is a stronger case for justifying remedial and protective actions since the contamination should not have occurred if the practice was being carried out as planned.

Existing exposure situations

For existing exposure situations, a protective action to modify exposure pathways or to modify or remove the source of exposure itself is justified if the benefit of the reduced exposure outweighs the cost and disadvantage of the protective action and any exposure resulting from the action itself.

The harm arising from chronic exposures to radiation may be minimised by imposing appropriate regulatory controls. Such controls may take the form of land use management measures or intervention in the form of land remediation and should allow for judgements to be made regarding the benefits and the harm averted as a result of the controls.

The possibility of having to restrict the use of land and the cost of remedial action should be considered and compared with the benefits that may be achieved in terms of exposure reduction.

2.2 Strategies for assessment and management

2.2.1 Dose limits, constraints and reference levels

The system of radiation protection is applied in different ways depending on the type of exposure situation but the intent is always to keep radiation exposures within an acceptable range. Minimisation of radiation exposure is achieved through the use of dose limits, dose constraints or reference levels.

Planned exposure situations

Dose limit

A dose limit is the value of the effective or equivalent radiation dose to individuals that must not be exceeded.

The RS Act imposes annual radiation dose limits to restrict the exposure of a person to radiation as a result of the carrying out of a radiation practice. For a member of the public, the effective dose that a person may receive from the practice is limited to no more than 1 mSv in a year.

Regulatory action can be taken to require the person responsible for a planned practice to take corrective action (e.g. decontamination) if a dose limit is, or is likely to be, exceeded.

Dose constraints

A dose constraint is a restriction on the individual dose from a radiation source in planned exposure situations which serves as an upper bound on the predicted dose from the radiation source in the optimisation of protection for the source.

Under the RS Act the prescribed concentrations for the disposal of radioactive material to the environment are set to constrain a person's predicted annual effective dose to no more than 0.5 mSv (based on a very conservative assumption that an individual would be continually exposed to a constant rate of disposal of the radioactive material). For the planned disposal of radionuclides to the environment at concentrations above the prescribed amounts, an approval to dispose is required and the approved disposal arrangements constrain a person's predicted annual effective dose to no more than 0.3 mSv.

Although exceeding a dose constraint may not be a breach of legislation, if a practice is resulting in higher than expected radiation exposures, action is expected to be taken by the person responsible for the practice to reduce exposures so that no person will receive a radiation dose more than the planned dose constraint.

Existing exposure situations

Reference levels

The ICRP has recommended that dose limits intended for the control of exposure in planned practices cannot be used as a basis for deciding on the reduction of exposure by intervention, as they might invoke measures with economic and social costs that could be out of proportion to the benefit obtained (and then be in conflict with the principle of justification) [ICRP 1991].

Instead, reference levels are used in existing exposure situations to: set an upper bound on a person's exposure, or potential exposure to radiation; set the exposure level at which remedial action or intervention is justified; and to guide the optimisation process.

Reference levels are not limits but are used to inform decisions on a course of action when the value of a radiation quantity exceeds or is predicted to exceed its reference level. The action to be taken may range from simply recording the information through to interventional measures [ICRP 1977].

Common forms of reference levels are recording levels, investigation levels and intervention levels. A reference level may be expressed in terms of absorbed or effective dose, absorbed or effective dose rate, activity or activity concentration.

This document establishes screening (initial investigation) and action (intervention) reference levels to assist in determining whether:

- a detailed site investigation is necessary;
- remediation of a site is justified; or
- a site should be recorded on one of the environmental registers kept by DES.

Reference levels are set having regard to what is considered to be acceptable exposure. It could be argued that whatever is natural exposure (which may result in a person receiving an annual effective dose ranging from 1 mSv to 10 mSv, or more in some locations) is a tolerable exposure, but this should not be used as an argument to imply that it is then acceptable for exposure to a radioactive contaminant to result in a radiation dose within that range.

Within its land management framework, DES may establish environmental reference levels (trigger levels or quality objectives) that are not health related levels but are radiation source related levels, usually expressed as activity concentrations in water or soil, that are used in comparison to a baseline or reference value. For example, an environmental authority may state that the concentration of radionuclides in material released from a tailings dam should not exceed a reference level which is set at three standard deviations above an average baseline or reference site value.

As with a dose constraint, exceeding a reference level after completing a remedial action or implementing a management plan may not constitute a regulatory breach, but it would be a reason to review the extant radiation protection arrangements.

2.2.2 Staged process for assessment

The assessment and management of a site is based on a staged process consistent with the strategies adopted in DES guidance, and with the ASC NEPM Schedule A - *Recommended general process for assessment of site contamination*:

Stage 1	Preliminary site investigation
Stage 2	Detailed site investigation
Stage 3	Health and environmental assessment and development of remediation action plan (if remediation is required)
Stage 4	Implementation of a remediation action plan and preparation of a validation report

For some sites the preliminary and detailed site investigations may be merged into one investigation, and it may be possible at any stage to develop a remediation or management strategy. This will depend on whether there is sufficient information from the preliminary investigation to determine the amount and extent of contamination.

2.2.3 Prevention of future contamination

Planning during the establishment and operation of radiation practices is essential to prevent planned exposure situations from becoming existing exposure situations.

Under the disposal requirements of the RS Act, radioactive material may be disposed of into the environment if the activity concentrations are below levels prescribed in the Radiation Safety Regulation 2010. The prescribed levels are set so that a person should not receive an annual effective dose of any more than 0.5 mSv as a result of exposure to the continuous disposal of a moderate quantity of the radionuclide.

Current radiation safety legislation does not provide for an exposure limit or reference level for non-human biota, but it does require practices to take measures to ensure that the environment is not adversely affected by exposure to radiation. The obvious way of achieving this is only to release radionuclides into the environment if the disposal is in compliance with the RS Act and there is no other reasonable way of dealing with the material.

If a person wishes to dispose of radionuclides having an activity concentration greater than the prescribed amount, they must make an application under the RS Act for an approval to dispose of the material and must demonstrate that there is no other way of dealing with the material, and that the disposal will not result in the exposure of a person to more than an annual dose of 0.3 mSv.

Compliance with current radiation safety legislation should prevent the creation of contamination except by a failure of planned controls (whether deliberate or accidental). If this should happen there is a regulatory and societal expectation that the person responsible for the contamination should remedy the situation (usually with a desire to decontaminate to a level that returns the site back to a situation regarded as ‘normal’).

If contamination were to occur, whether by act or omission, as a result of the way a practice is carried out, enforcement action may be taken under the RS Act (by way of an improvement or prohibition notice) or under the EP Act (by way of a clean-up notice).

Remediation carried out on a contaminated site should not result in the spread of contamination on the site or in the contamination of another site unless the other site is an approved and controlled site on which the contamination can be managed.

During mining activities, protection of persons from exposure to radiation is managed under the *Mining and Quarrying Safety and Health Act 1999*, and by compliance with the DNRM Guideline *QGL 1 Guideline for management of Naturally Occurring Radioactive Material (NORM) in metalliferous mines* [DNRM 2014].

During other activities where NORM has been identified as a problem, the operator should implement measures, consistent with the Safety Guide for the Management of Naturally Occurring Radioactive Material (NORM) [ARPANSA 2008], to prevent or minimise radiation exposure and to manage radioactive waste.

Mining and exploration activities are subject to Environmental Authorities issued by DES that will have certain conditions relating to the release of contaminants and site management and rehabilitation.

Current mining and exploration activities are planned exposure situations, and as such, must be managed so that, at the cessation of those activities, the effective dose that a person may receive as a result of those activities having been carried out is no more than 1 mSv in a year.

2.2.4 Land registers

DES maintains two land registers: the Environmental Management Register (EMR); and the Contaminated Land Register (CLR).

There are regulatory requirements for contaminated land investigation documents associated with recording a site on the EMR. Site investigation reports, remediation plans, validation reports, and proposed site management plans for any land that is, or should be, on the EMR must be submitted through DES and must contain all the information required by DES.

The benefits of recording a site on the EMR are that institutional knowledge of the existence and condition of the site will be maintained and the implementation of on-going or future protective measures will be facilitated.

Having a site recorded on the EMR with an associated site management plan (SMP) not only ensures protection on the site but also enables prevention of a radioactive contaminant being taken off-site and used in a more sensitive area. Recording a site on the EMR does not necessarily mean a site is unacceptable for habitation or use.

Contaminated land recorded in the EMR is recorded on the CLR where it is necessary to take action to remediate the land to prevent serious environmental harm.

If it is determined that a site should not be on a land register it is because there is no requirement to put into place any special measures to deal with radiation now or in the future. In other words: there are no restrictions on the site.

3 Site investigation

3.1 Overview

Site investigations follow a staged assessment process that comprises:

- a preliminary or screening investigation;
- a detailed investigation; and
- a health risk and site assessment.

Whether a site investigation proceeds beyond the preliminary stage depends on the results of an initial site examination and radiation measurements.

A detailed site investigation, and the subsequent health risk and site assessment, will only be required if

- there is evidence in the site history or elsewhere to suggest contamination is possible or likely; **or**
- the preliminary radiation measurements exceed the established screening reference levels and are significantly higher than the natural background radiation levels.

The extent of any investigation will depend on the complexity of the site. For simple sites such as a residential property with a small amount of mineral sand top dressing, the investigation would be small scale, and the preliminary and detailed site investigations may be combined into one investigation. For large sites such as those where mineral sand processing occurred, the preliminary investigation would almost certainly be separate from the detailed investigation and it may serve only as a scoping study for the detailed investigation.

3.2 Triggers for investigation

There is a variety of circumstances that might be a reason for conducting a site investigation to determine whether the site is contaminated by radioactive material, and the nature, extent and magnitude of any contamination.

Following a reassessment of known contaminated sites in the late 1990s, many of those sites were recorded on the EMR. Some of these may, at some stage, be reassessed again because of a requirement of environmental or planning legislation or policy, or at a landowner's initiative.

For properties on the EMR where development is proposed or there is a planning application (such as a Material Change of Use or Reconfiguration of a Lot), a site investigation may be required under processes required by environmental or planning legislation.

A person acquiring land that is recorded on the EMR may seek information about the significance of the contamination. Many sites on the EMR were investigated during the 1980s and 1990s and there is not necessarily any documented evidence of what activities carried out since that time may have caused a redistribution of contaminants. In such cases it may be appropriate to conduct a new investigation under these guidelines.

For sites not on the EMR, an investigation may be initiated by a landowner or potential purchaser who has concerns about the site; usually based on knowledge of the site history and the activities conducted on it, observation of buried mineral sands during excavation work, or its proximity to a known contaminated site.

Current regulated practices using unsealed substances should not result in contamination except as a failure of radiation safety and protection measures. An investigation will be triggered if an unapproved release of radioactive material to the environment has been reported or is suspected.

3.3 General requirements

Site investigations should be conducted and reported with reference to any relevant DES guidance, and having regard to ASC NEPM Schedule B2 *Guideline on Site Characterisation*.

Care should be taken to not confuse the contaminant material with material that is naturally present on the site.

3.3.1 Radiation monitoring equipment

Radiation monitoring equipment used for radiation surveys should:

- have a suitable energy response to detect the suspected contaminants;
- have a minimum detectable level lower than that of natural background radiation; and
- be able to distinguish the presence of the radioactive contaminant from the naturally occurring background radioactive material.

If the contaminant is a mineral sand or other naturally occurring radioactive material (which make up the majority of radiologically contaminated sites) a suitable instrument is one that meets the following criteria:

- It should measure the air kerma rate, air absorbed dose rate or ambient dose equivalent rate of photon energies over a range of at least 30 keV to 3 MeV.
- The effective range of dose rate should be from 10 $nGy.h^{-1}$ or 10 $nSv.h^{-1}$ to at least 30 $\mu Gy.h^{-1}$ or 30 $\mu Sv.h^{-1}$.
- The linearity of the detector to dose rate should not exceed the range from -15% to +25% over the effective measurement range.
- The response to photon energy between 80 keV and 1.5 MeV should be within ±30%.
- The variation of the dose rate due to random fluctuations should be less than 20% for the most sensitive scale.

Radiation monitoring instruments should, within the previous 12 months, have been calibrated against a recognised national or international standard. In addition, the instrument should have been subject to regular consistency checks.

3.3.2 Soil and water sampling

The collection and analysis of soil or water samples should be done in accordance with national or international standards or established and accepted techniques.

All soil and water samples collected for analysis should be accompanied by chain of custody documentation.

Soil samples should be analysed by a suitable laboratory, using an appropriate analytical method, to determine each radionuclide present and its activity concentration. The method of analysis should be capable of detecting radioactivity concentrations of 5 $Bq.kg^{-1}$ or lower. Additional information about the chemical form and mobility of each radionuclide may be useful for assessing its health and environmental impact.

Water samples should be analysed by a suitable laboratory to first determine the gross alpha and beta concentration and if the relevant reference level is exceeded, to determine each radionuclide present and its activity concentration. The method of analysis should be capable of detecting radioactivity concentrations of 0.5 $Bq.litre^{-1}$ or better.

ASC NEPM Schedule B3 *Guideline on Laboratory Analysis of Potentially Contaminated Soils* may be consulted for general principles involved in the analysis of soils.

3.3.3 Investigation reports

The content and format of site investigation reports should follow DES and ASC NEPM guidance. The report should include all the outcomes of the investigation. For ease of site identification, the report should include the physical address of the site and its real property description, with the site identification number if the site is recorded on a land register.

The results of radiation surveys should be displayed on a site plan overlayed with the survey results. The results of radiological analysis (activity concentration) of soil should be treated in a similar manner to displaying the concentration of chemical contaminants.

3.4 Preliminary site investigation

The purpose of a preliminary investigation is to determine the presence of contamination and assess the need for further investigation.

The preliminary investigation should include:

- a brief description of the site history, and current and past uses of the site;
- a description of the current condition of the site, identifying areas of actual or potential contamination;
- a description of the current and past potentially contaminating activities;
- one or more of the following types of radiation monitoring (as appropriate to the site and the suspected contaminant)
  - external radiation dose rate survey
  - surface contamination survey
  - soil or water sample analysis;
- an assessment of natural background radiation levels if required; and
- an assessment of the need for further investigation, with a description of what investigative work is necessary.

For sites potentially affected by chemical contaminants, soil or water sampling and analysis is an accepted way of determining whether contamination is present. For suspected radioactive contaminants, the accepted way of obtaining preliminary information is usually via a gamma dose rate survey across the site.

The site history may provide an indication of the radionuclides likely to be contaminating the site. This may be useful in determining the type of preliminary radiation monitoring to be undertaken.

For some of the sites investigated by Queensland Health in the 1980s, the Radiation Health Unit may be able to provide historical information (including old radiation survey results) to the site investigator.

There may be sufficient information obtained during the preliminary site investigation to determine whether the site should be notified to DES under the EP Act.

3.4.1 Radiation dose rate survey

The aim of the preliminary radiation survey is to gain a representative view or profile of the radiation dose rate around a property and it may delineate areas that exceed the screening reference level specified in Table 1. This is usually a principal determinant of whether further investigation or action needs to be taken. A walk-over survey (screening survey) may be sufficient, particularly if the dose rates are high enough to easily identify the presence of a radioactive contaminant. A screening survey may not yield conclusive results, but combined with the site history may indicate whether a more detailed investigation is required.

If the screening survey shows the radiation dose rate to be uniform over the site, the average dose rate may be used when comparing results with screening reference levels.

If there are localised areas exhibiting higher radiation dose rates, it is not appropriate to use the average dose rate over the site. The maximum dose rate should then be used when comparing results with screening levels.

3.4.2 Surface contamination survey

For alpha or low energy beta emitters which are not associated with a significant gamma activity component, the gamma radiation dose rate survey would not be appropriate. Instead, a surface contamination survey, using specialist monitoring equipment (e.g. tritium contamination monitor for contamination by ^{3}H) and the analysis of a representative number of soil samples is likely to be preferable.

3.4.3 Soil and water sampling

Soil or water sampling is not a requirement for the preliminary site investigation but may be conducted if there is an obvious and easily accessible volume of radioactive contaminant.

For alpha or low energy beta emitting radionuclides, analysis of soil and water may be an important source of preliminary information.

If the site conditions or history or the results of the screening survey indicate that soil or water sampling is warranted or will provide useful information for a subsequent health or

environmental risk assessment, that sampling should form part of a detailed site investigation.

3.4.4 Screening reference levels

The results of the preliminary radiation monitoring should be compared with the relevant screening reference levels in Table 1. If the monitoring results for any particular screening parameter are greater than its screening reference level, an assessment should be made to determine whether a detailed investigation is required.

It is not a requirement that an assessment is made against each of the screening reference levels – only those screening parameters related to the radiation monitoring that was conducted need to be tested.

If the value of the radiation quantity measured is less than the screening reference level, there is no requirement for further investigation unless there is evidence to suggest otherwise.

If the value of the radiation quantity measured is greater than the screening reference level, a comparison should be made with the local natural background value to assess the need for a further investigation.

Table 1 Screening reference levels to assist in determining the need for a detailed investigation

Screening parameter	Quantity measured	Screening reference level
External dose rate [1]	Gamma dose rate	0.15 $\mu Gy.h^{-1}$
Radionuclides in soil [1]	Activity concentration ($Bq.kg^{-1}$) of individual radionuclides	Refer to Appendix 2
Radionuclides in water [1]	Gross alpha or gross beta concentration	0.5 $Bq.litre^{-1}$
Environmental exposure [1]	Absorbed dose rate considering internal and external exposure pathways	10 $\mu Gy.h^{-1}$
Derived environmental exposure [2]	Gamma dose rate	3 $\mu Gy.h^{-1}$

1. Screening reference levels for external dose rate, radionuclides in soil and water, and environmental exposure include natural background radiation. The external dose rate includes both the terrestrial and cosmic components.
2. The derived environmental exposure is provided as a directly measurable radiation quantity to supplement the absorbed dose rate which requires an assessment of the effect of exposure on an organism. See Appendix 1 for the derivation of this screening level,

Screening reference level for external dose rate

External dose rate is the radiation quantity that largely determines the annual dose for human exposure. The screening reference level of 0.15 $\mu Gy.h^{-1}$ is a level above which further investigation is justified.

The further investigation may be as simple as ascertaining that the ambient natural radiation level in the vicinity is consistent with the measured external dose rate at the subject location. However, if this is not shown to be the case, a more detailed investigation may be required.

Screening reference levels for activity concentration in soil

The screening reference levels for a selection of radionuclides with a half- life greater than 30 days, and most commonly in the possession of Queensland licensees are listed in Appendix 2.

These screening reference levels are reproduced from NCRP Report No. 129 *Recommended screening limits for contaminated surface soil and review of factors relevant to site-specific studies* [NCRP 1999].

If the activity concentration of radionuclides in soil are above the screening reference levels, then an assessment of the natural background concentrations should be made.

Screening reference level for activity concentration in water

The screening reference level for radionuclides in water is based on the Australian Drinking Water Guidelines [NHMRC, NRMMC 2011] and for irrigation and livestock drinking water [ANZECC, ARMCANZ 2000].

The screening reference level for gross beta activity is 0.5 $Bq.litre^{-1}$ and excludes the contribution from potassium-40.

If the gross alpha or gross beta activity concentrations exceed the screening reference levels, specific radionuclides should be identified and their activity concentrations determined as part of a more detailed site investigation.

Environmental screening reference level

The environmental screening reference level is that proposed in the *Guide for Radiation Protection of the Environment* [ARPANSA 2015] where it is suggested that exposure at that level is below regulatory concern.

An environmental screening assessment is not a requirement for residential, commercial and industrial sites at the preliminary investigation stage. For other sites that may support a population of wildlife, the site investigator will need to make a judgement about whether there is a potential for wildlife to be affected and the need to carry out a screening assessment to determine if the absorbed dose to a selected organism exceeds the screening level of 10 $\mu Gy.h^{-1}$

Deciding whether the environmental screening reference level is exceeded is more complex than basing the decision on a simple measurement. The absorbed dose rate is not a directly measurable quantity. It requires knowledge of the radionuclide concentrations in soil or water, the organisms present in the environment, the dose coefficients for internal and

external exposure for each organism, and the biochemical behaviour of the chemicals containing the radionuclides in the environment.

An environmental screening assessment should be conducted if:

- the activity concentrations of radionuclides in soil or water have been measured and they exceed their relevant screening reference level; or
- the average external dose rate over the part of the site that supports a wildlife population has been measured and it exceeds the derived environmental screening reference level of 3 $\mu Gy.h^{-1}$.

The environmental screening assessment should be done within the scope of the detailed site investigation. Note that an external gamma dose rate above the derived screening reference level is cause for a detailed site investigation.

3.4.5 Comparison with natural background radiation levels

If the screening reference level for any screening parameter is exceeded, then an assessment should be made of what the natural background radiation level of that parameter is, and whether the measured radiation quantity is significantly different from the natural background.

Natural background may be assessed by measuring the dose rate or soil/water activity concentration in areas near the site that are not suspected of being contaminated.

If it proves difficult to delineate potentially contaminated and definitely uncontaminated areas, then a default value for the natural background radiation level may be used. If this is the case, then the site investigation report should include an explanation of why background could not be measured and a justification for using the chosen default value.

For external dose rate the preferred default value for (terrestrial plus cosmic) background radiation dose rate is 0.08 $\mu Gy.h^{-1}$. Appendix 1 contains a discussion about the derivation of this value.

If some other default value for natural background radiation is chosen it should be relevant to the area being investigated and based on a reputable published source.

3.4.6 Assessment of the need for further investigation

Whether a detailed site investigation is necessary depends primarily on:

- the results of the preliminary radiation monitoring, and a comparison with local natural background; and
- the site history, and whether any potentially contaminating activities were carried out on the site.

It is unlikely to be the case that environmental exposure screening will trigger a detailed site investigation without some other screening level having already been exceeded.

When a detailed investigation is not required

A detailed investigation is not required if:

- there is no evidence in the site history or elsewhere to suggest contamination is likely; **and**
- there are no localised areas exhibiting elevated radiation dose rates; **and**
- the preliminary radiation monitoring results are
  - less than the relevant screening reference levels, **or**
  - consistent with natural background radiation levels.

When a detailed investigation is required

A detailed investigation is required if:

- there is evidence in the site history or elsewhere to suggest contamination is possible/likely; **or**
- there are localised areas with dose rates significantly higher than those over other parts of the site; **or**
- the preliminary radiation monitoring results
  - exceed the screening reference levels, **and**
  - are significantly higher than the natural background radiation levels.

This process is displayed in Figure 1.

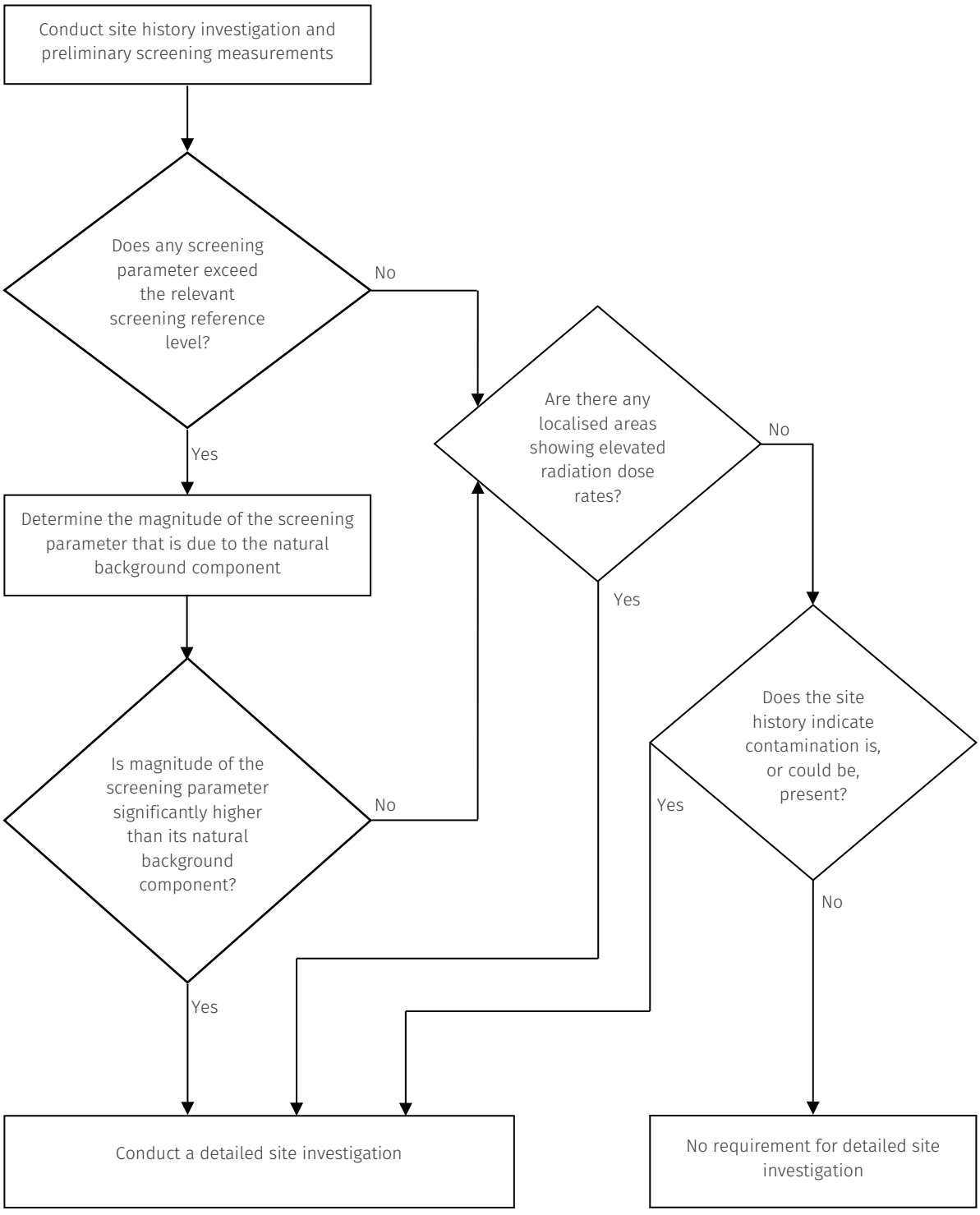

Figure 1 Deciding on the need for a detailed investigation

3.5 Detailed site investigation

A detailed site investigation is required if the results of the preliminary investigation indicate actual or potential contamination. The strategies used to conduct the detailed investigation (where to look, what to look for, and what analyses to conduct) should be informed by the outcome of previous investigations.

The detailed site investigation should build upon the preliminary investigation and provide sufficient information to characterise:

- the natural background radiation level;
- the lateral and vertical extent of the contamination;
- the contaminant radionuclides present, their activity concentration, and leachability; and
- the potential for off-site migration of contaminant radionuclides though soil, water or air movement.

The detailed site investigation should provide sufficient information to enable a health risk assessment to be conducted and for a site management plan or remediation plan to be developed.

The proposed methodology for data collection or sampling programs should be statistically planned and based on the investigator's knowledge of the site and results of investigations to date.

3.5.1 Radiation dose rate survey

The following guide to the surface densities and borehole depths at which external radiation dose is measured should be followed unless the site history and conditions, or the preliminary investigation, suggests otherwise. If there is any variation from this guidance, an explanation and justification for this should be provided in the site investigation report.

Above ground survey

If the screening survey was not conducted at closely spaced intervals, a more detailed above ground radiation dose rate survey may be required to more clearly delineate contaminated areas and identify localised hot-spots.

As a guide to measurement density, the radiation dose rate survey should be conducted using a 2 m grid pattern for residential properties or other properties at which the occupancy of particular individuals is or could be high, and a 5 m grid for all other properties.

The grid spacing may be closer as informed by the site history. However, there may be little benefit in conducting a survey at closely spaced intervals if it has become clear that the site needs to be remediated and that very large areas of the site will be excavated during that process.

Depth survey

The above ground radiation survey may not necessarily give any indication of contaminated soil at depth. Experience with some contaminated sites has shown that even though surface

radiation dose rates may indicate acceptably low levels, there could have been sub-surface contamination.

The depth of the contaminant can be determined by core sampling or logging a borehole. The advantage of core sampling is that it allows for both the determination of the depth of contamination as well as providing samples of soil for analysis.

As a guide to sampling density, holes may be drilled on a regular grid of 10 m or closer as informed by the site history or surface dose rate. Holes may also be drilled at locations within the grid if the surface dose rate indicates the presence of localised elevated concentrations of radioactive material.

As a guide to sampling depth, an initial survey depth of 3 m may be reasonable for industrial sites and 1 m for residential sites. The depth should be varied in view of the site history, results of radiation measurements, and observations.

If the site history or above ground radiation survey suggest there may be deep pockets or trenches of contaminated soil, additional measurements should be taken at appropriate locations and depths.

If there is still evidence of contamination at the base of a borehole, the survey should continue downward until contamination is not evident.

3.5.2 Soil analysis

Soil analyses are required to determine the activity concentration of radionuclides in contaminated soil and to test for leachability of the radionuclides.

Soil samples should be collected at the surface and at regular depths at locations and at a sampling density appropriate to the size of the site and informed by the above ground and depth radiation dose rate surveys.

Soil samples should be analysed by a suitable laboratory, using appropriate physical or chemical analysis methodologies, to determine each radionuclide present, its activity concentration, mineral form and mobility. The method of analysis should be capable of detecting radioactivity concentrations of 5 $Bq.kg^{-1}$ or lower.

Leachability

A sufficient number and range of soil samples should be tested to determine the potential for leachability of radionuclides. The appropriate test is a Toxicity Characteristic Leaching Procedure (TCLP), as mentioned in the Radiation Safety Regulation 2010, to test for gross alpha and beta concentration in the leachate.

Radon

Consideration should be given to testing for radon particularly if there are elevated concentrations of uranium, thorium, or radium on or near the surface.

3.5.3 Water analysis

If surface water (e.g. in a pond or creek) is present on the site it should be tested for gross alpha and beta concentration. If any drinking water supplies are sourced on site, the drinking water should also be tested for gross alpha and beta concentration.

When there is reason to believe that contaminants may leach into water, or there is a potential for off-site migration of contaminants, consideration should be given to testing off-site groundwater or surface water to determine if the site has impacted other areas.

3.5.4 Environmental screening assessment

The environmental screening assessment is conducted to determine if the absorbed dose to selected organisms living within the environment on the site will exceed the environmental screening level of 10 $\mu Gy.h^{-1}$.

The assessment requires soil or water sampling and analysis to have been completed.

The environmental screening assessment should be made with reference to documents and models from trusted sources.

Examples of suitable tools for carrying out an environmental screening assessment are:

- RESRAD Biota [ANL 2020]
- ERICA assessment tool [ERICA 2020]

If the environmental screening reference level is exceeded a more detailed environmental assessment should be performed. The *Guide for radiation protection of the environment* [ARPANSA 2015] provides further information about this.

4 Health risk and site assessment

If contamination has been found on a site through a detailed investigation and the site has been characterised in terms of radiation dose rate and radionuclide activity concentrations, a health and environmental risk assessment can be made. The assessment will be used to determine the site status and what action, if any, should be taken to deal with potential radiation exposures.

4.1 Health risk assessment

4.1.1 Preferred approach to assessment

There are two approaches to the risk assessment. The first is to only consider a person's exposure to the current circumstances (which implies only considering exposure to surface contaminants).

If this first approach is taken, adequate measures can be put in place for protection in current circumstances. However, taking this approach will provide insufficient confidence to ensure that future generations will remain protected, and therefore the site should be managed to ensure a reassessment can be made in the future if circumstances change. This requires that the site be recorded on the EMR. This is particularly the case if the assessment did not consider buried radioactive material.

The second approach is to consider current and likely future circumstances including the circumstance in which buried material is brought to the surface.

Since protection of persons and the environment into the future is a key principle of protection, the preferred approach is the second one and the guidance given here is based on that approach.

The health and environmental risk assessment should be made with reference to documents from trusted sources such as the IAEA, ICRP, and NCRP. A selection of relevant documents is listed in the bibliography.

Examples of suitable tools for health or environmental assessments are:

- RESRAD and RESRAD Biota [ANL 2020]
- ERICA assessment tool [ERICA 2020]
- RCLEA [UKEA 2020]

As the science in this area is developing, care should be taken to ensure that the chosen modelling tool uses up-to-date values for dose coefficients and habit data.

It is difficult to determine what future exposure circumstances might be, so it is usual to assume a hypothetical critical group composed of individuals with extreme characteristics. This provides for a conservative estimate of dose - usually more than any real critical group would possibly receive.

4.1.2 Desired outcome of assessment

The outcome of the assessment should be an estimate of the potential annual effective dose received by a person occupying or using the site (and if relevant, off-site) in each of the applicable exposure circumstances. The outcome of the assessment should be included in the site investigation report.

The health risk assessment and the estimation of annual dose to a person should consider:

- current and reasonably foreseeable exposure circumstances and site conditions;
- all likely potential pathways for exposure, land use, and occupancy of the site;
- exposure to all environmental media containing the contaminants (soil, water, sediment, and air);
- potential for radionuclides to leach into the environment (in particular, groundwater);
- on-site and off-site exposures;
- external surface radiation dose rates (for most sites this is the predominant mode of exposure);
- dose due to ingestion or inhalation of radioactive material; and
- the potential dose contribution from subsurface radioactive material should it be excavated and redistributed on the ground.

4.1.3 Environmental assessment

A special risk assessment for wildlife is not required unless the environmental screening level is exceeded. In most of those situations it is likely that the site would require some remediation for the protection of human health – this is likely to reduce the radiation dose to a level that also provides protection for the wildlife inhabiting the area.

However, there may be situations in which the likely human occupancy approaches zero and measures for human health protection may not be implemented, so an environmental risk assessment for protection of wildlife should be conducted.

There is not enough information to support generic conclusions about the impact of different types of radiation on wildlife and it is not yet possible to define a radiation protection quantity specific for protection of wildlife [ARPANSA 2015].

There is no generic reference level above which remedial action should be taken to protect wildlife. The need for protective action depends on the absorbed dose to the organism (which varies for different organisms) and the effect of that dose to the organism.

Guidance for environment assessment may be found in in the *Guide for radiation protection of the environment* [ARPANSA 2015].

4.2 Assessment of site status

Following the calculation of an annual effective dose due to exposure to contaminants on the site, the site status needs to be determined and what, if any, action needs to be taken.

4.2.1 Matters to consider

The assessment of the actual or potential annual dose to a person due to a contaminated site should be made considering current and reasonably foreseeable uses of the land.

In assessing the site and determining its status and what action should be recommended to reduce or manage exposure, consider the following questions:

- Is the site acceptable for its current use in its current condition?
- Will the site be acceptable for use if it were to change to a more sensitive use (e.g. a childcare centre)?
- Should the site be on the EMR or CLR?
- Does the site need to be remediated?
- If remediation is needed, how much remediation is required, and does it have to be done now or can it wait until a future development or a change of use?
- Does the site need to be controlled now, or only if it is put to a more sensitive use?
- If the site does need to be controlled now, what is the most effective way of optimising exposure?

In addition to radiation exposure, it should be acknowledged that there may be the potential for harmful effects from other (non-radioactive) contaminants on a site. When making an assessment of a site and preparing site investigation reports, remediation plans, or management plans, attention should be given to exposure to all forms of contamination on the site.

4.2.2 To remediate or manage?

Measures that may be used to deal with contaminated land that poses an unacceptable health risk, or where intervention is justified, are either, or both of the following:

- Remedial measures – remediate the site to prevent unacceptable current or future exposure.
- Protective measures – record the site on the EMR; determine acceptable uses for the land; implement a site management plan to control activities, and optimise exposures.

Radiation exposure due to a contaminated site can be reduced by dealing with the radioactive contaminant itself (source control) or by changing the way the site is used (exposure control).

The radioactive contaminant can be excavated and removed from the site, or it can be treated on-site in such a way that contains the contaminant and provides radiation shielding (e.g. placing the material in a lined cell and covering it with a layer of concrete).

If a site requires on-going management, this is achieved by recording it on the EMR and having a site management plan. The site management plan should contain measures, either physical or administrative, to restrict the current or future use of the site and modify the pathways for exposure.

4.3 Reference levels for deciding a course of action

Action reference levels are used to guide decisions about what action to take in response to contamination in the situations of existing exposures or planned exposures.

Where the estimated annual dose to a person fits in relation to the action reference levels will determine:

- whether the exposure is acceptable or not;
- the need for recording a site on the EMR; and
- the justification for remediation of a site.

4.3.1 The setting of action reference levels

For existing exposure situations, the ICRP and IAEA have recommended that action reference levels are set at an annual effective dose to a person between 1 mSv and 20 mSv and that the main factors to be considered in setting these reference levels is the practicability of controlling the situation and on experience in managing similar situations [ICRP 2007, IAEA 2014]. The action reference levels established in this guideline have been set after considering both those main factors.

The *Guide for Radiation Protection in Existing Exposure Situations* [ARPANSA 2017] adopts the IAEA recommendations for selection of reference levels and suggests an intermediate reference level of 10 mSv per year as an appropriate starting point for remediation of legacy and post-accident sites.

The Queensland experience is that most sites contaminated by radioactive material (in existing exposure situations) would have resulted in radiation doses to individuals of between 1 mSv and 10 mSv per year and that it has been, or would have been, readily achievable to remediate to a level where the annual dose is less than 5 mSv.

Consequently, action reference levels are set at 1 mSv, 5 mSv and 10 mSv per year as shown in Table 2 which provides a guide to the actions that should be taken when the estimated annual radiation dose to a person due to the radioactive contaminants on site exceeds the stated action reference level.

From a historical perspective (in existing exposure situations):

- The action reference level of 5 mSv has evolved from a level (set in 1983) at which remediation was required, through to a level (set in 1998) at which a site would be recorded on the EMR and remediation recommended.
- The action reference level at which remediation was required was set at 5 mSv in 1983, amended to 7.5 mSv in 1998, and is now set at 10 mSv (i.e. the requirements have been relaxed).

Further information about previous Queensland Health guidance is in Appendix 3 which also shows that its guidance is consistent with international and national changes.

The reference levels set for planned exposure situations are of two types:

- dose constraints used in planning a practice to ensure dose limits are not exceeded; and
- reference levels to guide the regulatory enforcement action that will be taken should a planned practice result in a release of a contaminant to the environment.

Table 2 Action reference levels for radioactive contamination and guidance for action [1,2]

Action Reference Level [3] (mSv/year)	Existing exposure situations	Planned exposure situations
	Consider environmental assessment on sites that support a wildlife population. Enforcement action may be taken to ensure remediation is undertaken. Remediation is necessary.	Enforcement action taken under the RS Act, or other Queensland legislation, may require an environmental assessment on sites that support a wildlife population. Remediation is necessary.
10		
	Consider implementing a site management plan. Remediation is almost always justified. Site should be recorded on EMR.	Enforcement action taken under the RS Act, or other Queensland legislation, may require a site management plan. Remediation is always justified. Site should be recorded on EMR.
5		
	Remediation is likely to be justified. Under some circumstances the land should be recorded on the EMR – refer to Section 4.4.1.	Remediation is almost always justified. Enforcement action taken under the RS Act or other Queensland legislation. Site may be recorded on EMR
1		
	Remediation may be justified if it is reasonably easy to achieve. No need for further investigation or action if estimated dose is not significantly different from natural background.	Remediation is likely to be justified. Contamination or unapproved release of radionuclides dealt with under the RS Act or other Queensland legislation.
~0.3		
		Contamination or unapproved release of radionuclides dealt with under the RS Act or other Queensland legislation.

1. This describes the action that may be taken if the estimated actual or potential annual effective dose to a person (arrived at after a health risk assessment considering the current or a reasonably foreseeable land use) exceeds the stated action reference level.
2. When remediation is conducted it should be optimised to reduce the annual dose to a person to as low as reasonably achievable. The preferred endpoint is an annual dose to a person in the order of 0.3 mSv to 1 mSv. Refer to Section 5 for guidance on remediation.
3. The action refence level is the annual effective dose to a person as a result of exposure to the radioactive contaminants on the site.

The annual effective dose of ~0.3 mSv in Table 2 is:

- equivalent to a dose constraint for planned practices i.e. the consequences of disposal of radionuclides to the environment should not exceed this level; and
- approximately the level at which the radiation dose to a person due to radioactive contamination on the site starts to become significantly and noticeably different from the dose contribution from natural background levels of radioactive material.

4.4 Application of action reference levels

The estimated annual effective dose to a person (actual or potential) should be compared with the action reference levels shown in Table 2 to determine the status of the site and what action, if any, needs to be taken.

The action reference levels should be regarded as an upper bound. It may be justifiable in some circumstances for remediation or protective measures to be taken at a level lower than the relevant action reference level. For example, the site may be recorded on the EMR if the estimated annual dose to a person is 4 mSv (rather than 5 mSv), but it should never be the case that a site resulting in an annual dose to a person of more than 5 mSv is not recorded on the EMR.

4.4.1 Existing exposure situations

For estimated annual doses of up to 5 mSv

Actual or potential annual doses to persons up to 5 mSv are within the tolerable range for existing exposure situations.

Recording land on the EMR

If there is no possibility, under any reasonably foreseeable situation (in the current or a future land use), that surface or buried radioactive material existing as is, or being redistributed or concentrated on site, could result in an annual dose to a person above 5 mSv, then it is unlikely that remediation of the site or recording the presence of a contaminant on the EMR is justified on solely radiological grounds.

The land should be recorded on the EMR if:

- under a foreseeable more sensitive land use, the radioactive material might lead to an annual dose to a person of above 5 mSv;
- the health risk assessment did not consider likely future land use circumstances, in particular a more sensitive land use;
- buried radioactive material is confirmed or suspected but its impact has not been assessed.

Remediation

Although annual doses to a person of up to 5 mSv are tolerable, it should be kept in mind that dose optimisation is a key principle. Remediation is more likely to be justifiable as the annual dose to a person approaches 5 mSv, whereas an annual dose to a person in the region of 1 mSv may only be justifiable if easy to achieve.

Remediation of land, on purely radiological grounds, where annual doses to persons are less than 1 mSv would be difficult to justify unless it is very easy to achieve (e.g. by removing a small stockpile on the surface).

However, remediation should always be suggested as an option to the landowner in terms of cost versus benefit.

Reassessment of sites already assessed or registered

Many of the known contaminated sites were previously assessed in the mid-1980s as having surface dose rates less than the relevant action level at the time and were not recorded on the EMR during the reassessment program of the mid-1990s. These sites are not likely to be reassessed unless concern is raised by a landowner in the future.

There are also contaminated sites within this range that were previously assessed in the mid-1980s as having tolerably low surface dose rates (giving rise to annual doses to persons of less than 5 mSv), but were recorded on the EMR because of the nature of the activities that occurred on the site or the likelihood of buried material being brought to the surface, thereby resulting in unacceptable doses.

These sites are likely to remain on the EMR and may only be reassessed if triggered under environmental or planning legislation, or if a landowner seeks to have the site reinvestigated.

For estimated annual doses of between 5 mSv and 10 mSv

Although annual doses to persons between 5 mSv and 10 mSv are within the tolerable range, they are elevated enough to justify some level of remediation or management.

Recording land on the EMR

It is expected that sites resulting in, or having the potential to result in, annual doses to a person of between 5 mSv and 10 mSv, will be recorded on the EMR. These sites should therefore have a site management plan to ensure measures to minimise exposure as far as reasonably achievable are in place for current and future land uses.

Remediation

If annual doses of between 5 mSv and 10 mSv are indicated, remediation (rather than simply relying on site management) should be considered as an option since it is almost always justified in this dose range.

Reassessment of sites already assessed or registered

Some contaminated sites assessed in the mid-1980s as having surface dose rates greater than the action level at the time (a level that would result in an annual dose to a person of 5 mSv) were recommended or required to be remediated. The contamination status of these sites is not clear since there was no regulatory means to enforce remediation or to require notification that remediation had occurred.

During the reassessment program of the late 1990s, all these sites were recorded on the EMR and are only likely to be reassessed if triggered under environmental or planning legislation, or initiated by a landowner.

For estimated annual doses of 10 mSv or more

Actual or potential doses to a person of above 10 mSv are not acceptable, and remediation and management in all cases is justified. If circumstances warrant it, enforcement action under Queensland legislation can be taken to ensure some level of remediation is undertaken.

Recording land on the EMR

Sites resulting in, or having the potential to result in, an annual dose to a person above 10 mSv should be recorded on the EMR. If actual or potential annual doses to a person are well above 10 mSv, consideration should be given to recording the site on the CLR, particularly where it is necessary to take regulatory action to remediate the land.

These sites should also have a site management plan which details the measures in place to minimise exposure or restrict access to the site before remediation is carried out.

Remediation

Remediation must be carried out as it is always justifiable in this dose range. For such sites, regulatory action may be taken to enforce remediation.

Environmental assessment

An annual dose greater than 10 mSv may indicate the presence of a large quantity of radioactive material such that, if the land supports a wildlife population, an environmental assessment should be considered.

4.4.2 Planned exposure situations

Current radiation practices are planned and regulated - these are 'planned exposure situations'. Annual public doses are limited to 1 mSv and are generally constrained to an annual effective dose of 0.3 mSv or less. Any disposal of radioactive material to the environment allowed under the RS Act is planned so that it should not exceed the dose constraint (and will not be regarded as contamination).

The contamination of land due to a disposal that is not allowed is not acceptable, so responses to remedy the consequences of such disposals are always justified. It is a regulatory and societal expectation that any newly contaminated land be dealt with in a way that restores the environment to a condition similar to that before the contamination occurred. However, if contamination did occur, it is recognised that restoration to the original condition may not be achievable in practice.

Nevertheless, the person responsible for the contamination will be held accountable for decontamination and site management, and the matter may be dealt with under the RS Act or other relevant Queensland legislation.

As part of any enforcement action under the RS Act, it will be a requirement that all site investigations, assessment and decontamination activities be done in consultation with the Radiation Health Unit in Queensland Health. This includes activities that result in the preparation of contaminated land investigation documents which must be submitted to DES.

Recording land on the EMR

If decontamination of a site is not possible, or not carried out within a reasonably short time following the contamination, the site may be recorded on the EMR if the estimated actual or potential annual dose to a person is of the order of, or greater than, 1 mSv. Recording the site on the CLR will be considered if the estimated annual dose to a person is above 10 mSv.

Remediation

The justification for remediation depends on the level and nature of contamination. For any given annual exposure there is greater justification for decontaminating a site contaminated by a planned practice than there is for remediating an existing exposure situation.

Where the potential annual dose to a person is:

- less than 1 mSv, remediation is likely to be justified if it is simple to achieve;
- from 1 mSv to 5 mSv, remediation is almost always justified;
- greater than 5 mSv, remediation is always justified.

If the contaminant is a short-lived radionuclide, an acceptable alternative to remediation is that the site is managed, or its access restricted, until the level of radioactivity has reduced to an acceptably low level.

Environmental assessment

If radioactive contamination occurs on land that supports a wildlife population, it may be a requirement of any enforcement action that an environmental assessment is undertaken.

4.4.3 Case study

The following case study is a simplified one that serves to illustrate how the results of an assessment can be used to determine what should happen with a site.

Current site condition:	Vacant *unimproved* urban land
Exposure situation:	An existing *exposure* situation caused by a past practice contaminating the surface with radioactive material that gives rise to an above ground radiation level of 2.5 µGy.h^{-1}.
Exposure pathway:	The critical *exposure* group is commuters who walk over this land while going to and from work, being exposed for a total *of 10 minutes per day.*
Predicted annual dose:	0.1 mSv per person

An annual dose of 0.1 mSv to a person is acceptable for existing exposure situations and would not, by itself, be cause for a site to be recorded on the EMR nor for any protective measures to be implemented.

However, the assessment should consider reasonably foreseeable exposures and site conditions - the intended use of the site may change to the more sensitive use of residential.

Future site condition:	*Residential*
Pathway for exposure:	A person occupies a ground floor residence for 10 hours for each working day and 18 hours each weekend day. The person is away from the site for 4 weeks per year
Predicted annual dose*:*	10.3 mSv to the person

This potential dose is unacceptable.

The potential dose is unacceptable, and it may be argued that even the radiation dose arising from the current site condition is able to be reduced. Reasonable measures that may be taken now to prevent or minimise current and future exposures are:

Remedial measures:

Remediate the site to a level where foreseeable future exposure is acceptable. Since it is found that the contamination is only on the surface, it is justifiable to remediate the vacant land and it would be reasonable to optimise the remediation so that the foreseeable annual dose to a person due to the contaminant is less than 0.3 mSv and approaches a trivial dose of 0.01 mSv.

Protective measures:

Fence or vegetate the site to act as a control barrier (a reasonable measure to prevent or optimise exposure).

Record the site on the EMR with a site management plan to maintain the exposure controls and restrict the use of the site to no more than its current use (i.e. vacant unimproved) until such time that remediation does occur.

Restrict the unauthorised removal of the radioactive contaminant to prevent it from ending up on land which has a sensitive use.

5 Site remediation

The aim of remediation is to reduce the potential radiation doses to exposed persons or wildlife to as low as reasonably achievable (optimisation). The scale and type of remedial action will depend on the desired endpoint and on the realities of what is reasonably achievable in each situation.

Any remediation or disposal activity (including the transport of radioactive material) is a planned activity and hence is subject to current environmental and radiation safety legislation. In regard to radiation safety, there are requirements for occupational and public radiation dose limits, storage and handling of radioactive material, and the final disposal of radioactive material.

Remediation must be carried out in a way that ensures no member of the public receives an annual radiation dose in excess of 1 mSv as a result of the remediation.

Remediation and disposal activities should not cause radioactive material to contaminate other sites, or to adversely affect persons or the environment on or off site.

5.1 Remediation strategies

Remediation methods should be chosen with regard to the scale of contamination and how well optimised it can be. There is little or no justification for remediation of one site by removal of its radioactive contaminant if that contaminant ends up causing a radiation health problem at another site.

Any material brought onto the site (for example, fill used to replace contaminated soil removed from the site) should be 'clean'; it should not give rise to an annual radiation exposure any more than that of the site's natural background.

5.1.1 Remediation technologies

If remediation is required it may be undertaken using the following technologies:

- on-site treatment or containment of the contaminated material;
- on-site dilution and dispersal of the contaminated material;
- removal of the contaminated material to an off-site approved landfill or other disposal facility; or
- management and decay.

Management and decay

For short half-life radionuclides, an alternative to physical remediation is to manage the site until the radionuclides have decayed to a level where remediation would not be justified.

Beneficial re-use

Instead of merely excavating a contaminant and disposing of it, there may be more useful ways of dealing with it, particularly in the case of mineral sands.

At the time when mineral sand contamination happened there may have been little commercial value in dealing with it in a more beneficial way. That may not be the case now, and if a site is contaminated by large amounts of mineral sand it may be worth reprocessing the material, creating a useful product to be taken off-site for beneficial use, and leaving leftover material remaining on-site or removed for disposal.

Reprocessing contaminated material may result in a situation somewhere between the following extremes depending on what the useful product is:

- The useful product contains most of the radionuclides and the leftover material is of sufficiently low concentration that it can remain on site as 'clean' material.
- The useful product is clean and the leftover material is more highly concentrated, in a reduced volume, and must now be disposed of at an approved location.

5.1.2 Remediation target levels

Before remediation begins, its desired outcome should be established. This should include measurable end-points such as the target radiation dose rates or soil activity concentrations of radionuclides.

If remediation is carried out it should aim to reduce the radiation dose rate or activity concentration to at least the level at which remediation would not have been required. If it is reasonably achievable, the site should be remediated further to a level where the dose is trivial.

For sites that have, or could foreseeably have, a sensitive use, the preferred endpoint for remediation is that sufficient radioactive contaminant is removed so that a person's annual exposure due to the contaminant is no more than about 0.3 mSv to 1 mSv. If that preferred endpoint cannot be reasonably achieved there should be sufficient explanation to demonstrate why that is the case.

The target endpoint for remediation may not be complete rehabilitation or the return to environmental conditions existing before the contamination occurred. It may be the case that radiation exposure will remain elevated but low enough to be acceptable without having to place restrictions on the use of the site. In other cases the endpoint may be a tolerable level but one that requires the site to be on the EMR and subject to a site management plan.

5.1.3 Optimisation

Optimisation requires that the radiation risks are as low as can be reasonably achieved, taking into account social and economic factors.

There may be a trade-off between radiation dose levels and use of the site: a high residual dose rate should imply restrictions on land use; a low residual dose rate would indicate the site is suitable for unrestricted use.

The ICRP says that optimisation is not the same as minimisation of dose – optimised protection is the result of an evaluation, which carefully balances the detriment from the exposure and the resources available for the protection of individuals. The best option is not necessarily the one with the lowest dose [ICRP 2007].

The IAEA, in TECDOC 987 [IAEA 1998] notes that:

> One particular issue that may be relevant in implementing optimisation is whether options involving restrictions on use of land should be treated on an equal basis to those that would allow unrestricted use. In this context, sustainability may be an important additional factor to be considered in carrying out the optimisation – short term restrictions on the use of small areas are unlikely to be of major concern, but a situation in which large areas are subject to long term restrictions may not be sustainable, and the expected value of assumed benefits will therefore be reduced. There may be social and equity considerations associated with passing uncertainty in the level of protection to future generations.

5.1.4 Consideration of adjoining sites

Remediation activities on the subject site should not adversely affect adjoining sites. If adjoining sites are also contaminated, an assessment should be made of whether contaminated material on the adjoining site is capable of re-contaminating the remediated subject site (through leaching or soil transport mechanisms). This is a particular problem at site boundaries and consideration could be given to extending remediation work onto the adjoining site if the adjoining site owner is amenable to that.

The assessment of the subject site and any decision about recording it on the EMR should be based on the radiation exposure due to material on the subject site. Radiation exposure that is due to a contaminant on an adjoining site should not adversely affect the assessment of the subject site – that should be a matter for the management of the adjoining site.

5.2 Development of a remediation action plan

The remediation action plan should include:

- a description of the intended remedial work (e.g. the technology to be used) and of the fate of the radioactive contaminant;
- the desired measurable outcomes including the target radiation dose rates or radionuclide activity concentrations;
- a description of any expected residual contamination;
- details of the persons who will be involved in the remediation;
- a program for the conduct of radiation monitoring surveys while the remediation is being carried out to verify that remediation is proceeding effectively;
- measures for contamination control (e.g. measures for control of dust and soil and water run-off) and prevention of public exposure; and
- radiation safety and protection measures for the protection of persons carrying out the remedial work (e.g. the use of safety devices, personal protective equipment, and personal radiation monitoring devices).

A suitably qualified person should be on-site often enough to ensure that the remediation is being carried out according to the plan and should always be available for radiation safety related advice and guidance.

5.3 Disposal of contaminated material

Disposal of contaminated material must be in accordance with relevant requirements of the RS Act and EP Act. Contaminated material removed from a site must only be disposed of at an approved place, such as a controlled landfill approved by DES, or a place approved in accordance with an Approval to Dispose issued under the RS Act.

Note that an approved landfill may have conditions on its operation that restrict the volume or concentration of radioactive material that it may accept.

Removal or disposal of contaminated material from a site must be done in a way that ensures no person receives an annual radiation dose in excess of 1 mSv from exposure to the material following its removal or disposal.

5.4 Validation of remediation

Validation is the process of assessing whether remediation has been successful and whether the potential annual doses to persons have been reduced to the intended level.

The effectiveness of any remedial action and the contents of the site investigation report and validation report will determine the status of the site following remediation.

5.4.1 Validation survey and report

A radiation survey, similar to the survey carried out in the detailed site investigation, should be conducted in order to validate the site.

As a guide, validation of the surface dose rate should be measured on a 2 m grid across the whole of the site after remediation has taken place.

Validation may be carried out progressively. As one part of a site is remediated and radiation levels reduced to the target levels, it can be validated provided that it can be ensured that the validated area is not subsequently contaminated by remediation activities carried out on the remainder of the site.

The external gamma radiation dose from a contaminated adjoining site (shine) should be accounted for when measuring the gamma dose rate on the subject site.

The actual or potential radiation exposure from the remediated site should be reassessed and compared with the action reference levels in Table 2 to determine the continued need for the site to be recorded on the EMR, or to have a site management plan.

The validation report should include a description of the success, or otherwise, of any remediation, and a revised health and environmental risk assessment with an estimate of the actual or potential annual effective dose to a person from exposure to residual radioactive material on the remediated site.

5.4.2 Criteria for removal of a site from the EMR

The purpose of most remediation activity is to make a contaminated site suitable for a particular use.

Removal of land from the EMR requires the site to be suitable for any use, in addition to radiological, environmental and administrative criteria having been met.

If remediation is required, it must be optimised to minimise exposure to as low as reasonably achievable, with economic and social factors being taken into consideration, in addition to meeting the purpose of having the property removed from the EMR.

The radiological criteria to be met for removal of a site from the EMR is that:

- the radiological condition of the site following remediation is such that it would not be recorded on the EMR if it were to be assessed as a new site; and
- no person should receive an annual dose in excess of 1 mSv from exposure to any radioactive contaminant remaining on the site; and
- remediation is such that radiation levels are as low as can be reasonably achieved.

6 Site management plans

If a site is recorded on the EMR it may also require a site management plan (SMP).

The purpose of the SMP is to ensure the site is managed in a way that minimises radiation doses to its occupants. In some cases, the SMP may be written to ensure material is not disturbed, in others it may be to establish procedures while the site is being disturbed during remediation.

A basic SMP should contain a description of the existing and potential radiation hazards on the site, and measures to:

- prevent or minimise exposure to radioactive contaminants; and
- prevent the spread of contamination and the off-site movement of the radioactive contaminant (by wind, water, human action).

For a small site, such as a residential owner-occupier block, the site management plan may simply be that the radioactive material is not to be disturbed – the owner will easily be able to ensure the plan is followed.

A large or complex site may require more advanced measures and the SMP may also include:

- a detailed characterisation of the nature and extent of the radioactive contaminant;
- administrative procedures for site access and the activities conducted on site;
- measures for the maintenance of any engineered physical structure or landscaping designed and built to control or limit access to the radioactive material;
- provision for an on-going radiation monitoring program (external, groundwater, air monitoring);
- consideration of long-term chemical changes to residual contaminants; and
- consideration of the potential for changes to exposure pathways over time.

Appendix 1 Supplementary assessments

Assessment of natural background radiation

External gamma dose rate

If during the preliminary site investigation (described in Section 3) it is found that the measured external gamma dose rate is greater than the relevant screening reference level, an assessment should be made of what the natural background radiation level is.

The preferred method is to measure the background dose rate in the close vicinity of the subject site at a place which is known not to be, or is very unlikely to be, contaminated.

If that is not possible or reasonable to do, then a default value may be used. Table 3 shows the results of Australian studies of background radiation. The default value is derived from these values.

It is proposed that, for the purpose of applying this guideline, the default external background radiation dose rate is 0.08 μGy.h^{-1}.

The total default background dose rate is comprised of:

- 0.05 μGy.h^{-1} for the terrestrial component, and
- 0.03 μGy.h^{-1} for the cosmic component.

Table 3 Natural background radiation level

Parameter	Value	Reference
Proposed generic Queensland terrestrial air kerma rate	49 ± 69 nGy.h^{-1} Values range up to 120 nGy.h^{-1}	[Kleinschmidt & Watson 2016]
Average annual gamma dose rate in Queensland homes [1]	740 ± 265 μSv Values range up to 1,535 μSv	[Langroo et al,1991]
Cosmic radiation at sea level for latitudes 10° to 30°	0.030 μSv.h^{-1}	UNSCEAR 2000

1 This includes both the terrestrial and cosmic components.

Environmental screening assessment

Deciding whether the environmental screening reference level is exceeded is more complex than basing the decision on a simple measurement. The absorbed dose rate is not a directly measurable quantity. It requires knowledge of the radionuclide concentrations in soil or water, the organisms present in the environment, and the dose coefficients for internal and external exposure for that organism.

To simplify this, at least at the preliminary site investigation stage, some derived easily measurable quantity is required – the easiest being external gamma dose rate.

A simple assessment using the ERICA assessment tool [ERICA 2020] was carried out in an effort to derive a measurable screening level that can be used to give an indication of whether or not an environmental screening assessment is warranted.

The assessment was a Tier 2 assessment using three selected organisms (small mammal, bird, and shrub) exposed to typical concentrations of thorium-232 and uranium-238 in soil.

The soil activity concentrations were 30 $Bq.kg^{-1}$ for ^{232}Th, and 35 $Bq.kg^{-1}$ for ^{238}U [UNSCEAR 2000].

The output of the assessment showed the absorbed dose rates to be:

- small mammal 4.7 $nGy.h^{-1}$
- bird 1.3 $nGy.h^{-1}$
- shrub 93 $nGy.h^{-1}$

By comparison the external dose rate would be expected to be about 25 $nSv.h^{-1}$ (using the dose coefficients 0.604 $nGy.h^{-1}$ per $Bq.kg^{-1}$ for ^{232}Th series, and 0.462 $nGy.h^{-1}$ per $Bq.kg^{-1}$ for ^{238}U series).

It would require the soil to contain about 100 times the concentration of Th & U for the environmental screening level to be reached in the case of the shrub.

At that elevated concentration the external gamma dose rate is expected to be about 3 $\mu Gy.h^{-1}$. This would appear to be a reasonable derived screening level at which to require an environmental screening assessment to be carried out.

In the situation of environmental exposure, radiation protection is applied to populations rather than to critical individual organisms. The effect on a particular individual organism that happens to live in a localised area with elevated concentrations of radionuclides is of less concern. For this reason, the average dose rate over the entire part of the site that supports a population of wildlife is to be used when making a comparison with the derived environmental screening level.

Appendix 2 Screening reference levels

Screening reference levels for radionuclides in soil

The screening reference levels in Table 4 are selected from NCRP Report No. 129 *Recommended screening limits for contaminated surface soil and review of factors relevant to site-specific studies* [NCRP 1999].

Table 4 Screening reference levels for radionuclides in soil

Radionuclide	Activity concentration ($Bq.kg^{-1}$)	Radionuclide	Activity concentration ($Bq.kg^{-1}$)
Am-241	330	Pm-147	8,900
Ba-133	280	Po-210	44
Cd-109	120	Pu-238	320
Cf-252	340	Ra-226	3.7
Co-57	540	S-35	27
Co-60	23	Se-75	82
Cs-137	110	Sr-89	190
Gd-153	4,200	Sr-90	8
Ge-68	5.6	Tc-99	17
I-125	220	Th-232	2.3
Ir-192	450	Tl-204	140
Na-22	30	U-238	620
Pb-210	14		

For each radionuclide, the screening reference level is the most conservative value from the range of land-use scenarios presented in the NCRP report. The screening levels are designed to restrict the total annual dose to any exposed person from a single contaminated site to no more than 250 µSv.

The radionuclides listed here are those with a half-life more than 30 days and are the more common radionuclides in the possession of Queensland licensees.

Appendix 3 A short history of contaminated land management and the basis for setting reference levels

The current screening and action reference levels presented here have evolved from past Queensland Health guidance and are based on established national and international radiation protection standards and recommendations.

The reference levels applied in this guide are consistent with the approach taken in the past by Queensland Health, and have been shown to be achievable and practicable.

This appendix describes the evolution of Queensland's guidance for assessing and managing land contaminated by radioactive material and incudes an annotated bibliography of the relevant national and international standards upon which that guidance has been based.

Table 5 displays the reference levels proposed by the ICRP and the IAEA in comparison to the reference levels adopted by Queensland Health.

Pre 1980 and early 1980s

International & national standards

ICRP 26 - Recommendations of the International Commission on Radiological Protection [ICRP 1977]

ICRP 26 described the principles of justification and optimisation within planned practices, and the setting of dose limits and reference levels based on tolerable risks. The recommended annual dose limits for members of the public were:

- 5 mSv (one-tenth of the occupational limit) in situations where exposures are planned and optimised, recognising that the application of a 5 mSv annual dose limit provides the necessary degree of safety and would most likely result in annual doses to individuals in the order of ~0.5 mSv provided that the practices exposing the public are few and cause little exposure outside of the critical group used to assess exposures; and
- 1 mSv as a prudent limit for other circumstances and in those situations where the annual dose to individuals is found to approach the 5 mSv limit over a prolonged period.

ICRP 26 described the use of reference levels to determine a course of action when the value of a certain radiation quantity exceeds its reference level.

NHMRC RHS No.1 - Recommended radiation protection standards for individuals exposed to ionising radiation [NHMRC 1981]

The NHMRC in its recommended radiation protection standards adopted the dose limits described in ICRP 26 for use in Australia.

Queensland measures for management of contamination

Prior to the early 1980s radioactive residues from the mining and milling of mineral sands were used as land fill on various residential and commercial properties, and public spaces, in southeast Queensland. This resulted in the potential for elevated radiation doses due to exposure to the radioactive material present. It was also found that some sites on which abrasive blasting media containing elevated levels of radioactive material had been used, were also contaminated.

This was not a problem confined to Queensland and discussions about how best to deal with this matter were held at the national level between the governments of the States and the Commonwealth.

In Queensland, following radiation surveys to determine the location and extent of contamination, a program of remediation was initiated by the responsible agencies, the Department of Environment and Heritage and the Department of Health. The program was only partially successful, mainly due to the lack of legislation to enforce remediation.

The assessment and remediation of sites contaminated by radioactive material was outside the regulatory scope of the *Radioactive Substances Act 1958* and there was no environmental legislation to deal effectively with contaminated land. Owners of affected properties were advised of the radioactive contamination and of suggestions for remediation. Although a number of properties were remediated by excavating and removing contaminated soil to approved disposal sites, many owners did not carry out remediation.

Despite the lack of a specific legislative mechanism, the Department of Health provided comment and advice on all land related radiation safety issues in the interest of public health and it was in this role that the Department commenced keeping records of land affected by radioactive material.

It was noted at the time that the future use of radioactive materials from existing and future dry mills used to process mineral sands was subject to control under the *Mines Regulation Act* then administered by the Department of Mines.

1983

Queensland measures for management of contamination

Action levels for radiological control and remedial measures – Mineral sand practices [QH 1983]

This document described the action levels (reference levels) that had been developed for application to two types of exposure situations related to contamination by radioactive mineral sand. It was assumed that the ALARA principle would be applied to remediation so that final radiation levels should be below the action levels.

Sources 'under control'

Practices associated with mineral sand mining and processing capable of being controlled and complying with an appropriate radiation protection program were regarded as being 'under control'. For those practices it was required that the concentration of radionuclides in any material disposed of offsite from operational practices be limited so that the external

effective dose rate due to the radioactive material should not exceed 0.1 µSv/h in areas used, or likely to be used, for residential, school, commercial or industrial purposes, and not exceed 2.5 µSv/h in other areas accessible to the public.

The 0.1 µSv/h action level had the effect of limiting the annual effective dose to no more than 1 mSv, the dose limit for members of the public stated in the 1981 NHMRC recommendations for situations where exposure to the same individuals could result in annual doses approaching 5 mSv over a prolonged time (as it could be in some 'out of control' situations).

Sources 'out of control'

Situations where sites were no longer under the control of operators (such as decommissioned processing plants, old stockpile sites) and sites where the deposition of radioactive mineral sand residues for landfill or top-dressing had already taken place, were termed 'out of control'. The action level for instituting counter-measures on sites where radioactive mineral sand residues were already deposited was an external dose rate of 0.6 µSv/h (inclusive of natural background radiation).

This action level was set to restrict the annual dose to a person from the contaminant to less than 5 mSv, the same level as the annual dose limit for members of the public recommended by the NHMRC, and a level that was reasoned to be acceptable considering the social and other costs of remedial action. It was also consistent with the action levels in counter-measures for sand mining practices in Western Australia and New South Wales.

The preferred method of dealing with the contaminated material was its removal from the site and its disposal at a place where the long term impact on the environment would be acceptably low. An alternative, short term, measure was to place restrictions on the use of the site.

At the time of first determining the 0.6 µSv/h action level, it was based on the conservative assumption that for exposure to the complex spectrum of radiation emitted by the radionuclides in mineral sand, exposure was equivalent to effective dose.

1984

Australian guidelines

Guidelines for remedial action in areas where residues from mineral sand mining and processing have been deposited [NHMRC 1984]

The aim of the NHMRC guidelines was to minimise exposure to radiation from mineral sands residues which had been deposited in areas occupied by members of the public.

The guidelines set action levels based on the occupancy, or likely occupancy, of contaminated areas, above which, remediation was required. The action levels were expressed in terms of derived limits based on the annual member of public dose limit of 5 mSv recommended in ICRP26 and adopted by the NHMRC in its 1981 recommendations.

The proposed action levels for remedial action (inclusive of natural background) were:

- 0.7 µGy/h on sites where occupancy by the same individuals occurs regularly on a day by day basis (e.g. dwellings, schools, businesses, factories);
- 1.0 µGy/h in areas where occupancies are for a few hours per week by individuals (e.g. public gardens, places of entertainment); and
- 2.5 µGy/h in areas with intermittent occupancy (e.g. roads, paths).

The action levels were to be measured one metre above the areas of concern. The value for natural background radiation was given as 0.1 µGy/h.

1985

International & national standards

ICRP Statement from the 1985 Paris meeting of the International Commission on Radiological Protection [ICRP 1985]

The ICRP issued a supplementary statement to its 1977 recommendations (ICRP 26). Its revised view was that the principal dose limit for planned practices is 1 mSv in a year but that it was permissible to use a subsidiary dose limit of 5 mSv in a year for some years provided the average annual effective dose over a lifetime does not exceed the principal limit of 1 mSv in a year.

1989

Queensland measures for management of contamination

Queensland Health was authorized to provide to the Registrar of Titles, particulars relating to properties having dose rates above 0.6 µSv/h and request the entry of these particulars on the Administrative Advice file maintained by the Department of Freehold Titles.

1991

International & national standards

ICRP 60 - 1990 Recommendations of the International Commission for Radiological Protection [ICRP 1991]

ICRP 60 describes the principles of justification and optimisation within planned practices, and the setting of dose limits and reference levels based on tolerable risks. For exposure to radiation from planned practices the recommended annual dose limit for members of the public was set at 1 mSv.

The recommended system of protection applied to practices in which prospective doses are limited and constrained, and to interventions in which existing doses are reduced through intervention.

NHMRC RHS No. 33 - Interim statement on Australia's radiation protection standards (1991) [NHMRC 1991]

The NHMRC issued a statement adopting the recommendations contained in ICRP 60.

1992

Environmental & radiation safety legislation

The *Contaminated Land Act 1991* commenced on 1 January 1992 providing a framework for identifying and managing contaminated land and preventing further contamination. The Act established a Contaminated Sites Register. The Act dealt with land contaminated by hazardous substances but did not apply to land on which radioactive substances were stored or used, and radioactivity was not explicitly identified as a property that would cause a substance to be a hazardous substance.

The Council of Australian Governments (COAG) signed an Intergovernmental Agreement on the Environment, establishing the National Environment Protection Council with responsibility for developing national environmental protection measures to ensure a nationally consistent approach to environmental protection.

Australian guidelines

Australian and New Zealand guidelines for the assessment and management of contaminated sites [ANZECC, NHRMC 1992]

The Australian and New Zealand Environment and Conservation Council (ANZECC) and the National Health and Medical Research Council (NHMRC) published the Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites. The purpose of the guidelines was to provide a framework for the proper assessment and management of contaminated sites.

Some of the key principles of the guidelines were:

- Contamination, or further contamination, of a site should be prevented and appropriate precautionary measures need to be taken when decommissioning practices.
- The fundamental goal of remediation is to render the site acceptable for long-term continuation of its existing use or proposed use, and to maximize to the extent practicable its potential future use.
- Clean-up of a site should not proceed if the process is likely to create a greater adverse effect than leaving the site undisturbed.

Queensland measures for management of contamination

Queensland Health started providing information about properties known to be affected by radioactivity in mineral sands to the Department of Environment and Heritage for inclusion in its contaminated sites register with a classification of 'restricted'.

Design and action levels adopted by the Queensland Department of Health for practices involving technically enhanced sources of radiation from mineral sands deposited on the ground [QH 1992]

Queensland Health issued a statement about its derived design and action levels applying to sites where the radiation dose pathway from mineral sands is via external gamma radiation.

Practices under regulatory control at the time ('under control' practices) were to be designed and managed in a way such that no member of the public received more than an annual dose of 1 mSv.

The derived design levels (which did not include natural background radiation) were:

- 0.1 µSv/h on sites where the occupancy factor was 'total' i.e. occupancy by the same individuals occurs regularly on a day by day basis; and
- 0.2 µSv/h in areas where occupancies were 'partial' i.e. a few hours per week.

Derived action levels for use in 'out of control' practices were based on an annual dose to a person of 5 mSv and calculated for sites with 'total', 'partial' and 'intermittent' occupancy. Sites having a dose rate more than the applicable action level were required to be remediated to below the action level with the possibility of restricted future use.

The derived action level of 0.6 $\mu Sv.h^{-1}$ including background applying to sites with a 'total' occupancy was retained and the action levels for sites with partial or intermittent occupancy described in the 1984 NHMRC guidelines were adopted. It was noted that for sites on which the higher action levels were applied would have their future use restricted to partial or intermittent occupancy.

- 0.6 µSv/h on sites where occupancy by the same individuals occurs regularly on a day by day basis (e.g. dwellings, schools, businesses, factories);
- 1.0 µSv/h in areas where occupancies are for a few hours per week by individuals (e.g. public gardens, places of entertainment); and
- 2.5 µSv/h in areas with intermittent occupancy (e.g. roads, paths).

Guidelines for the assessment of contaminated land [CHEM 1992]

The Chemical Hazards and Emergency Management Unit (CHEM Unit) within the Bureau of Emergency Services issued guidelines for the assessment of contaminated land, based on the 1992 Australian and New Zealand guidelines published by ANZECC & NHMRC.

1993

Environmental & radiation safety legislation

A regulation under the Health Act 1937 was implemented in 1994 to regulate levels of radioactivity in abrasive blast media. This regulation was intended to prevent future contamination of those sites where abrasive blasting was practised.

1995

International & national standards

NHMRC RHS 39 - Recommendations for limiting exposure to ionizing radiation [NHMRC 1995]

The NHMRC in its 1995 recommendations for limiting exposure adopted the general principle and dose limits described in ICRP 60. It also contained a discussion about the setting of reference levels for intervention in situations where sources of radiation exposure were already present but did not give specific guidance on what those levels should be.

Environmental & radiation safety legislation

The *Environmental Protection Act 1994*, commenced on 1 March 1995. Its objective was to protect Queensland's environment while allowing for ecologically sustainable development. The EP Act made it an offence to cause environmental harm due to a contaminant unless the harm is authorised under an environmental authority or similar instrument.

Queensland measures for management of contamination

Radiation dose levels for properties where mineral sand residues are deposited on the ground [QH 1995]

Queensland Health updated its 1992 contaminated land guidance to describe in greater detail how the radiation dose levels were to be applied. The derived design and action levels for remediation remained unchanged.

Key points clarified in the update were:

- Removal of radioactive contaminant from a site is classified as an 'under control' practice and subject to an annual dose limit of 1 mSv.
- Properties requiring remediation may require a site history and a radiation hazard assessment which, together with the remediation program, will determine the contamination status of the property following the remediation.
- If, after remediation to below the relevant action level, there is still potential for enhanced radiation levels if radioactive material were to be disturbed or redistributed, then a management plan is required.
- Radioactive contaminants removed from a site may only be disposed of at sites approved by Queensland Health.

1997

International & national standards

IAEA TECDOC 987 - Application of radiation protection principles to the cleanup of contaminated sites [IAEA 1997]

This report proposed an approach to developing radiation related criteria for use in decisions about the cleanup of contaminated areas.

The report discusses in some detail the principles of justification and optimization as they apply to practices and interventions (in relation to past practices).

The report proposed six exposure bands (increasing in decades) of annual dose to persons, discussing the acceptability, or otherwise, of exposures in those bands and providing guidance for the justification of cleanup of contaminated areas giving rise to those exposures.

The exposure bands and the key elements within them are shown in Table 5.

Two of those bands are worthy of noting:

- Annual doses in the range 1 mSv to 10 mSv are not normally considered to be acceptable if they are deliberately imposed on the public, but are low enough that they would be tolerable in a range of other situations, including individuals living in areas of naturally elevated background radiation. Radiation risks of this magnitude are routinely accepted from natural sources, and variations in the magnitude of levels of background radiation do not appear to influence people's behaviour or have demonstrable health effects. Decisions about the cleanup of a contaminated site are to be based on justification and optimization. For practices subject to dose limits and dose constraints, cleanup is almost always justified; for interventions in past practices, cleanup is usually justified.
- Annual doses > 10 mSv are unacceptable and a contaminated site must always, or almost always, be remediated and have its use restricted or prevented.

Queensland measures for management of contamination

Radiation Health began a program of reassessing the known existing contaminated sites to determine whether they should be subject to continuing management or remediation.

1998

Environmental & radiation safety legislation

In July 1998 the *Environmental and Other Legislation Amendment Act 1997* repealed the *Contaminated Land Act 1991* and incorporated its contaminated land provisions into an amended *Environmental Protection Act 1994* (EP Act). Radioactivity was also included within the definition of a hazardous contaminant thus allowing it to be regulated under the contaminated land provisions. The updated EP Act also established the two land registers: the Environmental Management Register (EMR) and the Contaminated Land Register (CLR).

Queensland measures for management of contamination

Policy on land affected by radioactive materials due to past practices [QH 1998]

Radiation Health reviewed its previous guidance and published a new policy to enable assessment and management of land contaminated by radioactive materials to be consistent with the new legislative framework for contaminated land then managed by the Department of Environment and Heritage.

The policy described how Queensland Health was to assess and classify sites and make recommendation to DEH about inclusion or removal of sites from the new EMR. The policy only applied to existing exposure situations caused by past practices.

The reference level at which remediation was required increased from 5 mSv to 7.5 mSv per year. This was chosen as an acceptably conservative but optimised level that was:

- above the NHMRC level of 5 mSv per year which by then was thought to be unnecessarily restrictive; and
- less than the generic reference level of 10 mSv per year which was at that time being proposed by the IAEA as an upper level for tolerable chronic exposure situations [IAEA 1998].

The derived action level based on an annual dose to a person of 5 mSv was raised to 0.7 µGy/h (inclusive of natural background radiation). This is consistent with the action level in the 1984 NHMRC guideline and accounts for a more appropriate dose conversion coefficient than had previously been used.

A site was to be included on the EMR in the following circumstances:

- where average radiation levels were between 0.7 $\mu Gy.h^{-1}$ and 1.0 $\mu Gy.h^{-1}$, (inclusive of natural radiation background of 0.1 $\mu Gy.h^{-1}$); or
- where there was confirmation or a reasonable suspicion that radioactive material was buried on site (regardless of the surface dose rate); or
- where surface radiation dose rates were below the action level for remediation, but for which future activities on the land needed to be monitored in case of redistribution or disturbance of contaminated soil.

A site was required to be remediated, if the average dose rate on the site were greater than 1.0 $\mu Gy.h^{-1}$ (inclusive of natural radiation background of 0.1 $\mu Gy.h^{-1}$).

A remediated site was to be cleared from the requirement for further action if:

- no person could receive an annual dose of more than 5 mSv (calculated for full occupancy of the site); and
- the extent of contamination was known, and no potential existed for a person's annual dose to exceed 5 mSv following any disturbance or re-distribution of any contaminated material remaining on the site

Draft guidelines for the assessment and management of contaminated land in Queensland [DoE 1998]

The Department of Environment (DoE) published draft guidelines for the assessment and management of contaminated land to establish best practice for managing land contamination through the planning and development control practice.

The draft guidelines included mechanisms to manage contamination and reduce the environmental impact of remediation activities, and procedures for identifying, reporting, investigating assessing and remediating contaminated land.

1999

International & national standards

ICRP 82 Protection of the public in situations of prolonged radiation exposure [ICRP 1999]

This report provides guidance on the ICRP's system of protection as it applies to prolonged exposure to radiation in the exposure situations of practices and interventions.

Key points of this report are:

- An annual dose to a person above 100 mSv is intolerable.
- Intervention may be necessary at annual doses greater than 10 mSv and is almost always justified as the dose rises toward 100 mSv.
- Protective actions are justified at annual doses greater than 10 mSv.
- An existing annual dose approaching ~10 mSv may be used as a generic reference level below which intervention is not likely to be justifiable for some prolonged exposure situations.
- Between 1 mSv and 10 mSv per year intervention might be justified if the protective action is fairly simple or is the result of optimisation.
- Protective action is not necessarily applicable below 1 mSv per year.
- Dose constraints for practices (planned exposures) should be set at about 0.3 mSv per year, and at about 0.1 mSv for the prolonged exposure component.

Environmental & radiation safety legislation

National Environment Protection (Assessment of Site Contamination) Measure 1999 [NEPC 2020]

The *National Environment Protection (Assessment of Site Contamination) Measure 1999* (the ASC NEPM) is made under the Commonwealth's *National Environment Protection Council Act 1994* and was given effect in Queensland by *National Environment Protection Council (Queensland) Act 1994* and the DES guidelines.

The NEPM for the assessment of site contamination (ASC NEPM) does not specifically deal with radioactive material: it recognises that the assessment of a site contaminated by radioactive material requires specialised forms of assessment, and that guidance should be sought from the relevant jurisdictional environmental or health authority for assessment requirements.

Queensland measures for management of contamination

The Department of Health and the Department of Environment and Heritage sign a Memorandum of Understanding for the purpose of describing the anticipated roles, responsibilities and obligations of each of the parties with respect to the administration and enforcement of the provisions of the EP Act as they related to land contaminated by radioactive substances.

Following its reassessment of contaminated sites Radiation Health was in a position to notify DES of sites that should be recorded on the EMR.

2002

Queensland measures for management of contamination

Guidelines for the assessment and management of land contaminated wth radioactive material [QH 2002]

Queensland Health replaced its 1998 policy with updated guidance intended to be used in conjunction with the 1998 DoE Draft Guidelines. At the time it was proposed that technical guidelines for land contaminated by radioactive material be included as an appendix in a future amended DEH Guideline.

Although the 1998 DoE Draft Guidelines catered for radioactive contamination in general terms, there was no radiation-specific guidance (similar to the ASC NEPM). The updated QH guideline was designed to provide specialist input to supplement DEH and ASC NEPM documents.

The updated guidelines:

- retained the radiation dose levels at which sites where past practices occurred would be recommended for remediation and recording on the EMR;
- contained guidance to deal with sites where current regulated practices take place; and
- introduced an investigation level (derived from an annual dose to a person of 0.3 mSv) that was used as a trigger for a detailed site investigation; a target for remediation and a criteria below which remediation was not required.

2007

International & national standards

ICRP 103 - The 2007 Recommendations of the International Commission on Radiological Protection [ICRP 2007]

ICRP 103 evolved from the previous process-based approach of practices and interventions as described in ICRP 26 and ICRP 60, to an approach based on the characteristics of exposure situations (i.e. planned exposure, existing exposure and emergency exposure situations).

The report reinforced that the principle of optimisation of protection should be applicable in a similar way to all exposure situation with restrictions on doses achieved by the use of dose constraints on planned exposure situations and reference levels in existing exposure situations.

Some relevant key points in ICRP 103 are that:

- Annual exposure greater than 100 mSv is not justified.
- Intervention is almost always justified if the annual dose to a person is between 20 mSv and 100 mSv.
- For existing exposure situations, reference levels should be set within the exposure range of 1 mSv to 20 mSv per year, determined according to the situation.

- The main factor in setting the reference level is the practicability of controlling the situation and on past experience in managing similar situations.
- For planned exposure situation, reference levels should be set below about 1 mSv per year, with the typical public dose constraint for prolonged exposure set at about 0.3 mSv or less, and set at about 0.1 mSv for the prolonged component from long-lived radionuclides.

2014

International & national standards

IAEA GSR Part 3 - Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [IAEA 2014]

These Standards represent the international benchmark for radiation safety requirements and are based on the recommendations of the ICRP.

Some of the points reaffirmed by the IAEA in GSR Part 3 are:

- Dose >100 mSv over a short period or in one year is unacceptable except under specific circumstances relating to the planned exposure of emergency workers.
- Reference levels for exposure of the public in emergency exposure situations should be in the range 20 mSv to 100 mSv.
- Reference levels for annual exposure of the public in existing exposure situations should be set in the range from 1 mSv to 20 mSv.
- The actual value of the reference level depends on the feasibility of controlling the situation and on experience in managing similar situations.
- All reasonable steps shall be taken to prevent doses from remaining above the reference levels.
- Dose constraints or reference levels for exposure to planned exposure situations should be set below about 1 mSv per year.

2017

International & national standards

Guide for Radiation Protection in Existing Exposure Situations [ARPANSA 2017]

The Guide is derived from ICRP and IAEA recommendations and in particular it aims to promote, within Australia, the relevant requirements of the 2014 IAEA Standards.

Key points of the Guide are:

- Reference levels for annual exposure of the public in existing exposure situations should be set in the range from 1 mSv to 20 mSv.
- An annual dose to a person of 10 mSv is an appropriate starting point as a reference level for the remediation of legacy and post-accident sites.

Table 5 Summary of reference levels, dose limits and constraints for public exposure to land contaminated by radioactive material

Reference level Annual dose to a person (mSv)	Natural background	IAEA - TECDOC 987 - Application of radiation protection principles to the clean-up of contaminated areas, 1997 Exposure bands & principles applying to • Practices with constraint (Planned exposures) • Practices without constraint (Existing exposures)	ICRP 82 - Protection of the public in situation of prolonged radiation exposure, 1999 Principles applying to: • Practices (Planned exposures) • Interventions (Existing exposures)
100		Exposure Band 6 Existing dose >100 mSv - (Intolerable risk) Clean-up or prevent use Always remediate regardless of whether a constraint is applied Not suitable for release	Annual dose above 100 mSv is intolerable Intervention (remediation) almost always justifiable Protective action justified
20		Exposure Band 5 10 mSv < Existing dose < 100 mSv (Unacceptable risk) Clean-up or restrict use No constraint - Almost always remediate With constraint - Always remediate Not suitable for release	Intervention may be necessary at annual doses greater than 10 mSv and is almost always justified as the dose rises toward 100 mSv Protective action justified
10	Elevated background (UNSCEAR, 2000)	Exposure Band 4 1 mSv < Existing dose < 10 mSv (Risk is not normally acceptable if deliberately imposed. Tolerable risk in certain situations e.g. natural exposure) Clean-up decisions are based on justification & optimisation. Clean-up is more likely as 10 mSv is approached. No constraint – Usually remediate; With constraint – Almost always remediate Release may be possible subject to regular review of situation	An existing annual dose approaching ~10 mSv may be used as a generic reference level below which intervention is not likely to be justifiable for some prolonged exposure situations Between 1 mSv and 10 mSv per year intervention might be justified if the protective action is fairly simple or is the result of optimisation. Protective action optional
5	Global average (2.4 mSv) Australian average (1.2 mSv)		
1		Exposure Band 3 0.1 mSv < Additional dose < 1 mSv (Tolerable risk from justified and optimised practices) Clean-up decision are based on justification & optimisation No constraint - Sometimes remediate; With constraint - Usually remediate Release possible – situation may need occasional review	Public dose limit for practices = 1 mSv Protective action is not necessarily applicable below 1 mSv per year
0.3			Dose constraint for practices ~0.3 mSv
0.1		Exposure Band 2 0.01 mSv < additional dose < 0.1 mSv (Acceptable risk from planned justified actions) Clean-up unlikely to be necessary on the basis of radiological risks: No constraint - Rarely remediate; With constraint - Sometimes remediate; Release likely - review only if problem is apparent	Dose constraint for prolonged exposure component of practices ~0.1 mSv
0.01		Exposure Band 1 (trivial risk) No clean-up necessary; Can be released without controls	

ICRP 103 - The 2007 Recommendations of the International Commission on Radiological Protection, 2007	IAEA - GSR Part 3 - Radiation protection and safety of radiation sources: International basic safety standards, 2014	QH - Land contaminated by radioactive material -A guide to assessment, management and remediation, 2020	
Exposure bands applying to : • Planned exposure situations • Existing exposure situations	Reference levels applying to: • Planned exposure situations • Existing exposure situations	**Existing exposure situations (Past practices)**	**Planned exposure situations (Current practices)**
Doses above 100 mSv are not justified	Dose >100 mSv over a short period or one year is unacceptable except under specific circumstances relating to the planned exposure of emergency workers		
Band 3 (annual dose >20 mSv to 100 mSv) An annual dose rising toward 100 mSv will almost always justify intervention	Reference levels for exposure of the public in emergency exposure situations to be in the range 20 mSv to 100 mSv.	Consider environmental assessment on sites that support a wildlife population. Enforcement action may be taken to ensure remediation is undertaken Remediation is necessary.	Enforcement action taken under the RS Act, or other Queensland legislation, may require environmental assessment on sites that support a wildlife population. Remediation is necessary.
Band 2 (annual dose >1 mSv to 20 mSv) Reference levels, above which remediation is justified, for existing exposure situation should be set within the 1 mSv to 20 mSv band Main factors for setting reference level is feasibility of controlling the situation and past experience in managing similar situations Requirement for remediation in existing exposure situations is determined according to situation.	Reference levels for exposure of the public in existing exposure situations – used when the exposure situation (but not necessarily the exposure itself) usually benefits individuals The actual value of the reference level depends on the feasibility of controlling the situation and on experience in managing similar situations in the past. All reasonable steps shall be taken to prevent doses from remaining above the reference levels.	Consider implementing a site management plan. Remediation is almost always justified. Site should be recorded on EMR.	Enforcement action taken under the RS Act, or other Queensland legislation, may require a site management plan. Remediation is always justified. Site should be recorded on EMR.
		Remediation is likely to be justified. Under some circumstances the land should be recorded on the EMR.	Remediation is almost always justified. Enforcement action taken under the RS Act, or other Queensland legislation.
Public dose limit for planned exposure situations = 1 mSv Band 1 (annual dose <=1 mSv) Reference levels set (usually) in this band for planned exposures.	Dose constraints or reference level for exposure to planned exposure situations set below ~1 mSv	Remediation may be justified if it is reasonably easy to achieve. No need for further investigation or action if estimated dose is not significantly different from natural background.	Dose limit for planned exposures = 1 mSv Remediation is likely to be justified. Contamination or unapproved release of radionuclides dealt with under the RS Act or other Queensland legislation.
Dose constraint for members of the public in planned exposure situation are set at ~0.3 mSv			Dose constraint for planned exposures ~0.3 mSv Contamination or unapproved release of radionuclides dealt with under the RS Act or other Queensland legislation.

Abbreviations

ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
CLR	Contaminated Land Register
DES	Department of Environment and Science The department responsible for regulating environmental protection has had several names since the early 1980s: • Department of Environment and Heritage Protection, • Department of Environment; • Department of Environment and Heritage; • Department of Environment and Resource Management; • Environmental Protection Agency. For the sake of convenience these are all referred to as DES
EMR	Environmental Management Register
EP Act	*Environmental Protection Act 1994*
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
NCRP	National Council on Radiation Protection and Measurements
ASC NEPM	*National Environment Protection (Assessment of Site Contamination) Measure*
NHMRC	National Health and Medical Research Council
RS Act	*Radiation Safety Act 1999*

Glossary

Contamination	of the environment is the release (whether by act or omission) of a contaminant into the environment.
Contaminated land	Land contaminated by a hazardous contaminant (a contaminant can be a radioactive contaminant
Contaminated land investigation document	A site investigation report, draft site management plan or validation report
Critical group	An individual or group of individuals whose exposure to a radioactive contaminant is such that they will receive the greatest personal dose from exposure to the contaminant.
Dose	A generic term that may mean absorbed dose or effective dose depending on the context.
Dose constraint	A prospective and source-related restriction on the individual dose from a source, which provides a basic level of protection for the most highly exposed individuals from a source, and serves as an upper bound on the dose in optimisation of protection for that source. For occupational exposures, the dose constraint is a value of individual dose used to limit the range of options considered in the process of optimisation. For public exposure, the dose constraint is an upper bound on the annual doses that members of the public should receive from the planned operation of any controlled source.
Environment	A collective term for all of the physical, chemical, and biological conditions within which wild animals and plant normally live. Under the EP Act 'environment' includes: • ecosystems and their constituent parts, including people and communities; and • all natural and physical resources; and • the qualities and characteristics of locations, places and areas, however large or small, that contribute to their biological diversity and integrity, intrinsic or attributed scientific value or interest, amenity, harmony and sense of community; and • the social, economic, aesthetic and cultural conditions that affect, or are affected by, things mentioned in the above paragraphs.
Environmental exposure	The exposure of wildlife to ionising radiation including the exposure of animals, plants and other organisms in the natural environment.

Existing exposure situation	A situation of exposure that already exists when a decision on the need for control needs to be taken. Existing exposure situations include exposure to natural background radiation that is amenable to control; exposure due to residual radioactive material that derives from past practices that were never subject to regulatory control; and exposure due to residual radioactive material deriving from a nuclear or radiological emergency after an emergency has been declared to be ended.
Exposure	The circumstance of being exposed to radiation.
Hazardous contaminant	A contaminant that, if improperly treated, stored, disposed of or otherwise managed, is likely to cause serious or material environmental harm because of its radioactivity
Justification	For a planned exposure situation, the process of determining whether a practice is overall beneficial; i.e., whether the expected benefits to individuals and to society from introducing or continuing the practice outweigh the harm resulting from the practice.
Natural background radiation	Radiation occurring naturally at the site. It includes a component from terrestrial sources of radiation and from cosmic radiation.
NORM	Naturally occurring radioactive material - containing no significant amounts of radionuclides other than naturally occurring radionuclides. NORM may be a contaminant if it is not normally natural to the site or is in a modified or concentrated form as a result of human activity.
Optimization	The process of determining what level of protection and safety makes exposure, and the probability and magnitude of potential exposures, as low as reasonably achievable taking economic and social factors into consideration.
Past practice	A practice that is no longer occurring and was not subject to regulation under environmental or radiation safety legislation at the time the practice was carried out
Planned exposure situation	Situations where radiation protection can be planned in advance, before exposures occur and where the magnitude and extent of exposures can be reasonably predicted. Planned exposure situations may give rise both to exposures that are anticipated to occur (normal exposures) and to exposures that are not anticipated to occur (potential exposures) but may do so. Radioactive contamination arising from a planned activity is not anticipated to occur but it may dos so by act or omission. For clarity, the remediation of a contaminated site is a planned activity.

Practice	An activity in relation to a radioactive material that may result, whether or not intentionally, in exposing anyone to radiation.
Public exposure	Exposure incurred by members of the public from the radioactive contaminant on a site. It excludes any occupational or medical exposure, exposure to the site's natural background radiation, and exposure from authorised sources and practices.
Radioactive material	is material that spontaneously emits ionising radiation as a result of the radioactive decay of a radionuclide in it.
Radioactive contaminant	means a contaminant that contains radioactive material Examples of a radioactive contaminant on a site: • A stockpile of monazite remaining on a former mineral sand processing site. • Radioactive mineral sand residues brought on to a site as fill or top-dressing. • Radioactive material disposed of on a site in a way that does not comply with the *Radiation Safety Act 1999*. • Radioactive material released onto a site as a result of an accident or malicious act. Examples of what is not a radioactive contaminant: • Radioactive material disposed of in a way that complies with the *Radiation Safety Act 1999*. • Soil containing typical activity concentrations of naturally occurring radioactive material or typical activities of anthropogenic radionuclides that has not been modified in any way by human action.
Remediation	Any measure such as clean-up, rehabilitation, restoration or other action to prevent or minimise radiation exposure caused by a radioactive contaminant. Under the EP Act, 'remediate contaminated land' means: • rehabilitate the land; or • restore the land; or • take other action to prevent or minimise serious environmental harm being caused by the hazardous contaminant contaminating the land. Remediation includes decontamination of sites contaminated in a planned exposure situation, and rehabilitation or restoration of land contaminated in existing exposure situations.
Screening assessment	An assessment to determine if the measured value of a radiation quantity exceeds its relevant screening reference level.

Sensitive use	A use in which the same individual occupies the site on a regular basis. This includes, for example: • residential and accommodation places • workplaces • schools, child care centres • health care facilities.
Site investigation report,	A report about an investigation of the land to scientifically assess whether the land is contaminated land.
Site management plan	A plan for managing the environmental harm that may be caused by the hazardous contaminant contaminating the land by applying conditions to the use or development of, or activities carried out on, the land.
Source	A source of radiation leading to the radiation exposure of a person or wildlife.
Validation	A process of assessing the success of remediation and whether the potential annual doses to persons have been reduced to the intended level.
Validation report	A report about work carried out to remediate the land.

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