

AUSTRALIA'S IN SITU RECOVERY URANIUM MINING BEST PRACTICE GUIDE:

Groundwaters, Residues and Radiation Protection



Australian Government
Department of Resources,
Energy and Tourism

Geoscience Australia

Department of the Environment,
Water, Heritage and the Arts



Developed by officials from resources and environment agencies in the Australian Government and the South Australian, West Australian and Northern Territory Governments.

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ISBN 978-1-921672-95-8 (Web)

ISBN 978-921672-96-5 (Hardcopy)

GeoCat # 70503

Bibliographic reference: Commonwealth of Australia, 2010, Australia's in situ recovery uranium mining best practice guide, Canberra.

GA 10-4607

Front cover images

Main image: Wellfields with both injection and recovery wells, Beverley mine, South Australia (Geoscience Australia).

Bottom left: Main trunk lines between wellfields and wellhouses at the southern extension of Beverley mine, South Australia.

Bottom centre: Monitoring groundwater quality at Beverley mine, South Australia.

Bottom right: Processing plant using ion exchange technology to produce uranium concentrates, Beverley mine, South Australia

The bottom three images are courtesy of Heathgate Resources Ltd.

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Executive Summary

Introduction

This guide has been developed by officials from resources and environment agencies in the Australian Government and the jurisdictions that currently permit uranium mining. It is not a regulatory document – rather it elaborates on the Australian Government's policy to ensure that uranium mining, milling and rehabilitation is based on world best practice standards.

The guide should be considered within existing Australian legal and governance frameworks relevant to the mining sector. It sets out expectations for approval and regulation of in situ recovery uranium mining (ISR; also known as in situ leach = ISL), an internationally well established technology which accounts for almost one third of current world uranium mine production.

It has been developed to provide:

- Guidance for Australian and State/Northern Territory ministers and officials as to whether an ISR mining proposal represents world best practice environmental standards;
- A set of principles and approaches to inform all interested parties and facilitate the assessment of ISR mine proposals within multiple government regulatory processes; and
- Increased certainty for proponents in preparing ISR proposals.

The guide outlines the best practice principles and approaches that apply generally to mining in Australia, before giving more detailed consideration to best practice environmental protection and regulation for ISR mining. It draws on guidelines and regulatory practices applying to uranium mining in South Australia – the only jurisdiction currently with experience of approval and regulation of ISR projects. As other jurisdictions prepare to assess and regulate ISR uranium mining projects, they may produce documentation relating to their particular situations, which should be consistent with this national guide.

ISR mining

ISR mining technology was developed in the 1970s for recovering uranium from sandstone type deposits – a common style of uranium mineralisation worldwide. A well field is developed to circulate an acid or alkaline mining solution through mineralised zones in the sandstone aquifer to mobilise uranium from the ore body. The mining solution is extracted and pumped through a uranium recovery plant before being cycled through the well field again. ISR is selective for the recovery of uranium and does not create any radioactive rock stockpiles or radioactive tailings on the surface, although relatively small volumes of naturally radioactive residues are generated.

ISR projects and prospects in Australia are in arid regions with low topography. The natural groundwaters in the mineralised zones contain elevated concentrations of uranium and its decay products, and are more saline and slower flowing than is the case for known deposits elsewhere.

What is meant by world best practice?

'World best practice' does not amount to a universal template for ISR or any other mining, as it will be influenced by factors such as environmental conditions and government policies and approaches. This guide is based on Australian circumstances and it adopts the term 'best practice' to encompass the sentiments of 'world best practice'.

'Best practice' includes both best practice environmental standards, and best practice regulation to ensure that those standards are set and enforceable. The operational and regulatory practices and procedures should be best for the characteristics of the particular site, taking account of environmental, social and economic considerations.

In terms of regulation in Australia, which is largely the responsibility of State/Territory authorities, best practice is based on underpinning principles rather than a fixed set of practices or particular technologies. Outcome-based regulation, also known as co-regulation, has been proven effective and efficient in Australia. It involves considerable constructive discussion between the proponent and the

regulators, taking into account the views of other stakeholders, before the environmental outcomes to be achieved are set and the project approved. That said, regulations that deal with public health and safety, including radiation protection, are commonly more prescriptive.

In contrast, regulators in the United States and some other countries have used much more prescriptive approaches for all aspects of mining operations. These are not considered best practice for Australia, apart from health and safety aspects, as they transfer responsibilities for a range of matters from the operators to regulators and do not encourage innovation.

The following general principles are considered best practice for regulation of mining generally in Australia:

- The basis for planning and approval of a mining project should be a comprehensive characterisation of the geological, environmental and social setting at and around the proposed site, involving the proponent, the regulatory authorities and local communities, including any indigenous communities. Approval and licensing should depend on the proponent satisfying government authorities that all of the potential environmental, social, economic, health and safety risks have been identified and that plans for mining, environmental management, monitoring, closure, rehabilitation and completion will result in acceptable best practice environmental outcomes and constitute best practice for mitigating these risks for the life of the operation and thereafter.
- Mining regulation in Australia should be, wherever possible, more outcome-based than prescriptive (focus on 'what' should be achieved, not 'how' it should be achieved).
- Operators should take responsibility for meeting best practice performance standards set by government regulators and are expected to pursue continual improvement where practicable. If operators do not achieve the approved outcomes, they should be held liable.
- All decision making, mining lease conditions and performance assessments should be informed, science-based, ethical, transparent, and publicly available.
- The environmental outcomes should be set by the regulators through an iterative process involving the proponent and relevant stakeholders, which identifies all of the appropriate environmental values that should be protected and considers what best practice is for that particular set of circumstances. Negative environmental impacts on land, water, air and biota should be avoided where feasible, and any impacts on environmental values should meet approved outcomes.
- Where the owner of land is not the mining company, any compensation for demonstrated economic loss caused by mining should be agreed in principle at the time of project approval.
- Mine planning should be holistic, providing for progressive rehabilitation and agreed future land uses.
- Rigorous monitoring and public reporting programs should be used to demonstrate both progress towards, and achievement of, agreed environmental outcomes, such that it will be possible to take corrective or enforcement action if the environmental outcomes may not be, or are not being, achieved. Monitoring data should be publicly available.
- Public health and safety should not be compromised.
- The mine operator should demonstrate capability through implementation of suitable management systems (including contingency plans) with adequate training and resourcing to ensure best practice is implemented on the site.
- A rehabilitation security bond or other form of financial assurance should be lodged and reviewed regularly to reflect the full third party costs of clean up of the site at any stage this may become necessary. At mine completion, the site should be fit for agreed post-closure land uses and governments should not be left with any liabilities.

With regard to radiation protection in mining, best practice is inherent in the *Code of Practice and Safety Guide on Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005)*, which reflects the more prescriptive approach to health and safety issues.

Best practice environmental protection and regulation for ISR uranium mining in Australia

This guide on best practice for ISR mining focuses on the main perceived risks relating to uranium recovery from mineralised sandstone aquifers, which relate to groundwaters; mining residues; and radiation. In essence:

- Comprehensive information is required on the current environment, particularly groundwater, aquifer systems and radiation.
- The proposed ISR mining techniques need to be justified, including disposal of residual mining solutions and residues, safety of surface storage facilities and trunklines, radiation management and mine closure strategies.
- The radioactive waste management plan should be aligned with the broader environmental management plan for the mine.

The following principles and approaches, which supplement those in the previous section, provide the basis for decisions on best practice environmental standards and regulation for ISR uranium mining (and uranium mining more generally) in Australia:

- An ISR mining proposal should be based on a full understanding of the hydrological/hydrogeological/hydrogeochemical features, the current and potential uses and values of groundwaters and natural radioactivity in the project area and environs.
- The nature of the uranium mining solution and well field design should be matched to the site characteristics, particularly the minerals and groundwaters in the uranium mineralised aquifer. Acid solutions normally represent best practice where carbonate contents are low while ores containing more than a few percent calcite or dolomite generally require alkaline leaching.
- Mining should not compromise groundwater in the mineralised aquifer to the extent that it cannot be remediated to meet the agreed post-mining use at mine completion. At no stage should mining compromise groundwater use in the mineralised aquifer outside an agreed distance (not exceeding a few kilometres) or groundwater travel time from a mined area. Other aquifers present in or around the mine lease should not be affected by ISR mining.
- The impact assessment process should determine the best option for dealing with liquid residues:
 - (i) injection into deep aquifers containing poor quality groundwaters that have no foreseeable use;
 - (ii) injection into former mining well fields for dispersion, attenuation and/or containment; or
 - (iii) evaporation to solid residues.
- Active treatment should be considered where groundwaters down flow from the mine meet the criteria for a use category under the national water quality guidelines, or the quality of the aquifer water downstream is not adequately known; or natural attenuation is not progressing at a pace that will ensure the sequential land uses can be achieved in an agreed timeframe. As active remediation can require surface infrastructure and energy use and generate waste streams, best practice is to use the active remediation technique that will achieve closure outcomes in an agreed timeframe with the minimum environmental impact.
- Monitoring wells should be located so as to demonstrate effective containment of mining solutions and liquid residues within the mining aquifer and provide early warning of any excursions. Monitoring of groundwater pressures and quality should be conducted for all other aquifers in the area to verify they have not been affected by the ISR mining. Monitoring should continue for a period agreed with the regulatory authorities to confirm the attenuation rate and containment of the mining-affected groundwaters.
- Solid radioactive residues generated at an operational ISR mine site should be managed as low level radioactive waste and disposed of in an approved waste disposal facility. Monitoring should be adequate to confirm that radionuclides in the environment and the associated potential for radiation exposures do not exceed authorised limits and will enable the site to be released from regulatory control on closure.
- For lease relinquishment, regulators should be confident that the rehabilitated site does not present any significant radiation exposure risks; impacts on groundwater quality are within agreed parameters which reflect future land uses; there have not been and will not be impacts on any other aquifers at the mining lease or beyond; and the lease and surrounding area is left in a state fit for agreed future land uses. Best practice entails being able to demonstrate that completion criteria will be achieved within an agreed reasonable period (typically less than 10 years after cessation of mining).

1. Introduction

Uranium mining proposals involve integrated consideration under both the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and State/Territory legislation. The Australian Government also has interests in uranium arising from its international responsibilities, including in relation to export controls and nuclear safeguards. In general, the appropriate level of impact assessment of a proposed uranium project is agreed by the jurisdictions involved, based on preliminary information presented by the proponent to government authorities.

This guide is not a regulatory document and it should be considered within existing Australian legal and governance frameworks relevant to the mining sector. Its purpose is to set out expectations for approval and regulation of in situ recovery uranium mining¹ (ISR), in line with the Australian Government's policy to ensure that uranium mining, milling and rehabilitation is based on world best practice standards. ISR is a widely used technology, which accounted for over a quarter of world uranium mine production in 2008. As ISR mining involves recovery of uranium from mineralisation in sandstone aquifers by circulation of a leaching solution (lixiviant), this guide focuses on the main perceived inherent risks for such mines – groundwaters, residues and radiation protection. Other aspects are common to any mining type and are adequately covered by existing publications (see below).

This guide has been developed by officials from resources and environment agencies in the Australian Government and the jurisdictions that currently permit uranium mining and have active mines or proposals (South Australia, Northern Territory and Western Australia) as a high level document to provide:

- Guidance for Australian and State/Northern Territory ministers and officials as to whether an ISR mining proposal represents world best practice environmental standards;
- A set of best practice principles and approaches to inform all interested parties and facilitate the assessment of ISR mine proposals within multiple government regulatory processes; and
- Increased certainty for proponents in preparing ISR proposals.

Where a limited field leach trial is proposed to evaluate the feasibility of an ISR operation, this should be subject to the same best practice principles outlined here for a full mine development. The site should be rehabilitated immediately after the trials if mining does not proceed. As with full mine development, limited field leach trials should also be referred under the EPBC Act for environmental assessment and, if necessary, a decision about whether the trial is approved.

1.1 Guide overview

To provide context, the guide initially discusses what is meant by best practice and the general features of ISR mining. It then outlines the general principles and approaches that should apply to all mining in Australia, before considering ISR uranium mining more specifically. In setting out a nationally agreed set of underlying best practice principles and approaches, and attaching some relevant supplementary material, it draws on guidelines and regulatory practices applying to uranium mining in South Australia – the only Australian jurisdiction currently with experience of approval and regulation of ISR projects – plus information from publications on ISR mining by the United Nations' International Atomic Energy Agency (IAEA) and from visits to ISR operations internationally.

The guide also complements leading practice guidelines produced by the Australian Government with major minerals sector contributions, such as the *Leading Practice Sustainable Development Program for the Mining Industry* (LPSDP) series (<http://www.ret.gov.au/resources/Documents/LPSDP/>). Booklets in this series provide guidance on the integration of environmental, economic and social aspects through all phases of mineral production from exploration through to construction, operation, rehabilitation and mine-site closure, and provide detail on the specifics of leading practice in areas such as: *Community Engagement and Development*; *Working With Indigenous Communities*; *Mine Closure and Completion*; and *Risk Assessment and Management*.

As other States and the Northern Territory prepare to assess and regulate ISR uranium mining projects, they may produce regulatory and related information relating to their particular situations, which should be consistent with this national guide.

¹Also known as in situ leach (ISL) and solution mining.

1.2 Guide outline

This guide covers in order:

- Overview of ISR mining
- What is meant by world best practice?
 - Best practice environmental management
 - Best practice regulation of mining in Australia
 - Best practice radiation protection
- Best practice environmental protection and regulation for ISR uranium mining in Australia
 - Principles for best practice
 - Aspects of the existing environment to be considered
 - Aspects of the proposed mine techniques to be considered
 - Best practice environmental standards
 - Best practice in monitoring of environmental and radiation standards
 - Best practice management of ISR uranium operations
 - Best practice mine closure, rehabilitation and completion

Attachment 1 provides more detailed information on what a proponent should take into account in preparing integrated plans for best practice mining. It develops the links between best practice principles and best practice regulation. **Attachment 2** provides definitions and abbreviations.

2. Overview of ISR Mining

ISR mining was developed independently in the 1970s in the former Soviet Union and the United States (US) for extracting uranium from sandstone type uranium deposits that were not suitable for open cut or underground mining. Many sandstone deposits are amenable to uranium extraction by ISR mining, which is now a well established technology that accounted for more than 28% of the world's uranium production in 2009. The basic requirement for ISR mining is that the mineralisation is located in water-saturated permeable sands within sediments that allow effective confinement of mining solutions (commonly confined between impermeable clay-rich strata).

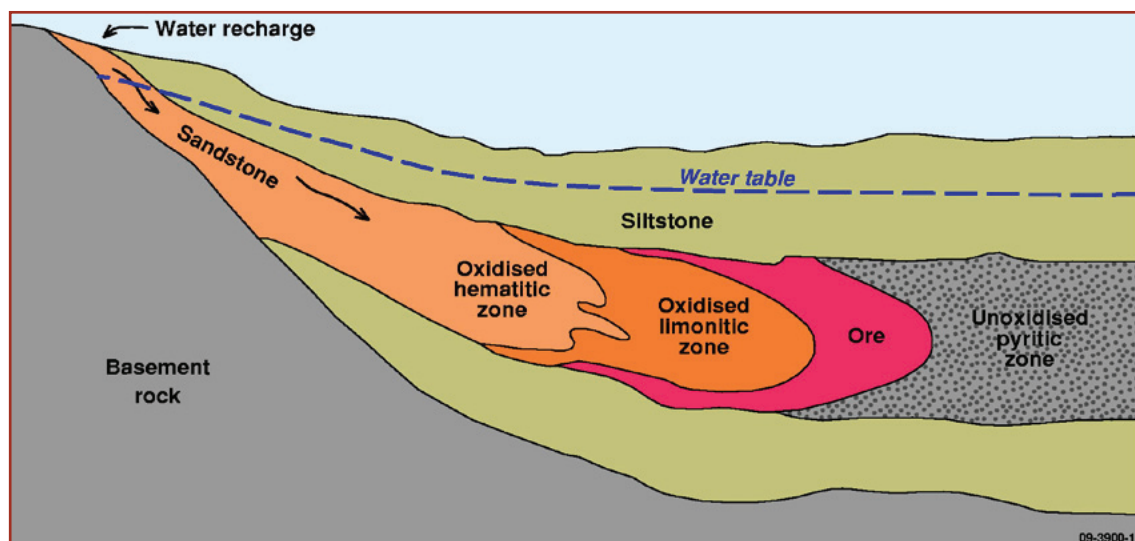


Figure 1. Diagrammatic cross-section of a roll front sandstone uranium deposit in a semi-regional/regional aquifer. Sandstone deposits can exhibit a range of other forms, including tabular, sinuous and disseminated.

Sandstone deposits are one of the most common styles of uranium mineralisation. This is because uranium is soluble in oxidised waters typical of the Earth's surface – weathering of naturally uranium-rich source rocks (particularly granites) can mobilise uranium into aquifers, where it precipitates under reducing conditions (Figure 1). In geologically young sandstone deposits, which are common in Australia, the mineralisation can be 'dynamic' – migrating slowly down flow as oxidised waters continue to flow in the aquifer, generating 'roll-front' uranium mineralisation.

Since the 1970s, this method has been used for mining sandstone deposits in a number of eastern European and central Asian countries. Kazakhstan has had major ISR mines since the 1980s, and currently dominates world ISR uranium production.

In Australia, ISR mining experience is currently limited to Beverley mine, which commenced production in 2001. The Honeymoon and Four Mile projects in South Australia have been approved and are expected to commence production in 2010. Field leach trials have been approved for the Oban project, South Australia. Extensive alkaline leach trials were carried at the Manyingee deposit in Western Australia in 1986 to 1987.

As a general observation, ISR projects and prospects in Australia are in arid regions with low topography, where the uranium mineralisation is largely within water-saturated permeable sands in buried palaeochannels. The natural groundwaters in the mineralised zones contain minor enrichments of uranium and daughter radionuclides, and they are variably more saline and slower flowing than for many deposits in other countries, which typically occur in regions of higher relief.

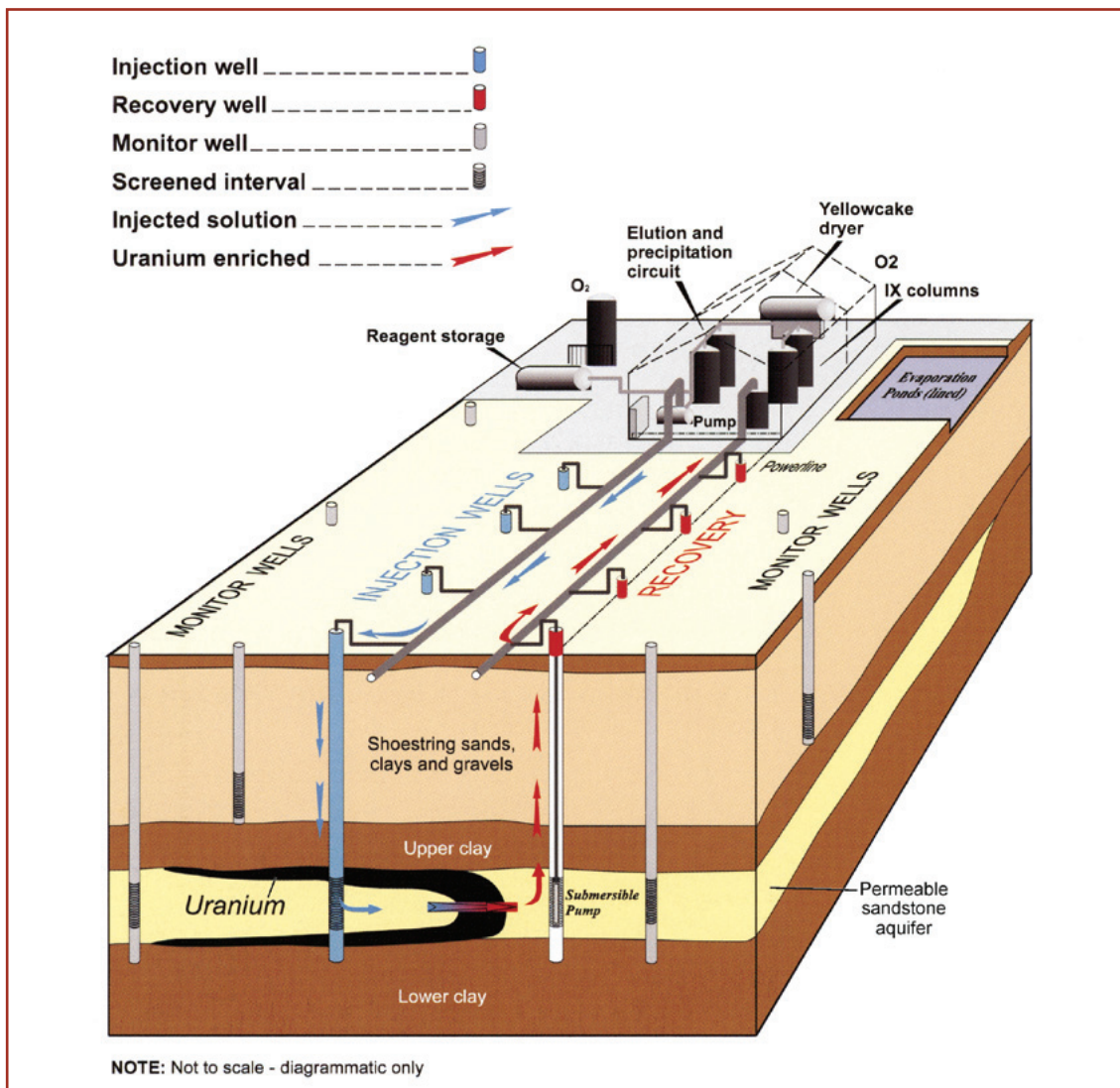


Figure 2. Schematic block diagram of ISR uranium mine, based on figure from the Beverley EIS (after Heathgate Resources Ltd, 1998).

Sandstone uranium mineralisation is typically low grade – commonly averaging below 0.25% uranium oxide (U₃O₈) – and recoverability of the uranium by ISR is commonly 60–90%. This is comparable with recovery rates for conventional mining of ores with complex uranium mineralogy.

A schematic block diagram of an ISR uranium mine is shown in Figure 2. Uranium is extracted by means of a leaching solution (lixiviant) which is pumped down injection wells into the permeable mineralised zone to mobilise uranium from the ore body. The uraniferous solution is pumped to the surface via nearby recovery wells and the uranium is recovered by hydrometallurgical processing, typically ion exchange or solvent extraction (particularly for highly saline waters). The mining solution is regenerated and recycled.

ISR mining results in much less surface disturbance than conventional open cut or underground mining methods: it does not involve tailings, waste rock dumps, or open pits, and the processing plant is small and easily removed after completion of mining.

The best documented ISR mines have been in the US, mainly in Wyoming, Nebraska and south Texas. Currently several US companies are planning to develop new ISR projects or expansions to current operations. These US deposits formed in regional to semi-regional aquifers confined by relatively impermeable units which inhibit leakage above and below (Figure 1). There is active flow of groundwaters downstream from the uranium mining areas, where they are used for livestock, crop irrigation and, in some cases, as potable water sources.

In the US, operators are required to remediate affected groundwater within the mine site to the pre-mining average constituent concentrations (restoration standard) or drinking water maximum contaminant levels (whichever is higher), regardless of sequential land uses. Experience to date has shown that the operator is not able to achieve these levels in practice without excessive use of water and energy. If the operator can demonstrate after concerted efforts they are unable to meet standards requirements, they can apply for alternative concentrations, which are protective of public health and environment.

The largest currently producing ISR uranium mines are in Kazakhstan, in two regional aquifers which flow from the mountainous uranium-rich source areas in the east towards the Aral Sea in the west. There is an ambitious program underway to increase the number of ISR uranium production centres. There are generally fewer regulatory requirements in Kazakhstan; for example, there has not been any requirement to rehabilitate the aquifers – however, carbonate minerals in the aquifers neutralise the acidic residual mining solutions.

In contrast, the uranium at Beverley (South Australia), occurs in isolated sand lenses that are surrounded by impermeable clay-rich strata and contain naturally poor quality saline, radioactive and stagnant groundwater. As the Beverley aquifer had no use before and has no foreseeable use after recovery of uranium, natural attenuation was considered appropriate rehabilitation for the situation at Beverley; there is an extensive monitoring program to measure the progress of natural attenuation.

3. What is Meant by World Best Practice?

'World best practice' does not amount to a universal template for ISR or any other mining, as it will be influenced by factors such as environmental conditions and government policies and approaches. This guide is based on Australian circumstances and it adopts the term 'best practice' to encompass the sentiments of 'world best practice'.

The term 'best practice' encompasses a number of different facets in relation to uranium mining, including:

- A comprehensive understanding of the current environment (particularly groundwater and aquifer systems);
- Justification for the mining techniques proposed, including proposed practices and procedures to be undertaken by the uranium miner, including mine closure strategies;
- The regulator setting and enforcing appropriate environmental outcomes and radiation safety standards (including long term outcomes for post mine closure);

- Demonstration of the capability of the uranium miner to manage the operations on the site; and
- Monitoring of the operation and the environmental and health effects, to demonstrate that the environmental and radiation standards are being met (this includes public access to all monitoring results).

3.1 Best practice environmental management

The widely used definition of 'best practice' in the *Best Practice Environmental Management in Mining* series published by Environment Australia in 2002 captures the essence of how the term 'best practice' is generally understood in the context of protecting the environment with focus on 'how' things are done:

Best practice can simply be explained as "the best way of doing things". Best practice environmental management in mining demands a continuing, integrated process through all phases of a resource project from the initial exploration to construction, operation and closure. It is based on a comprehensive and integrated approach to recognising, and avoiding or minimising, environmental impacts....

... best practice is not fixed in space or time. A best practice technique at one mine may not be suitable at a similar mine elsewhere.....Continual improvement may be driven by changes in legislative requirements, public expectations, corporate thinking, or by development of new and improved technology

Best practice in this guide is more comprehensive than this definition.

3.2 Best practice regulation of mining in Australia

In terms of regulation in Australia, which is largely the responsibility of State/Northern Territory authorities, best practice focuses on the outcomes to be achieved – it is based on underpinning principles, rather than a fixed set of practices or particular technologies. It is consistent with *Best Practice Regulation – A guide for ministerial councils and national standard setting bodies* agreed by the Council of Australian Governments (COAG) in October 2007. COAG endorsed a move to performance based regulation, focusing on 'outcomes, rather than inputs'. COAG noted that the prescriptive approach may be unavoidable in regulations that deal with public health and safety (which include radiation protection).

The general principles considered best practice for regulation applying to mining generally in Australia are summarised in **Box 1**.

Box 1: Best practice regulatory principles applying to mining generally in Australia

- The basis for planning and approval of a mining project should be a comprehensive characterisation of the geological, environmental and social setting at and around the proposed site, involving the proponent, the regulatory authorities and local communities, including any indigenous communities. Approval and licensing should depend on the proponent satisfying government authorities that all of the potential environmental, social and economic risks have been identified and that plans for mining, environmental management, monitoring, closure, rehabilitation and completion will result in acceptable best practice environmental outcomes and constitute best practice for mitigating these risks for the life of the operation and thereafter.
- Mining regulation in Australia should be, wherever possible, more outcome-based than prescriptive (focus on 'what' should be achieved, not 'how' it should be achieved).
- Operators should take responsibility for meeting best practice performance standards set by government regulators and are expected to pursue continual improvement where practicable. If operators do not achieve the approved outcomes, they should be held liable.

- All decision making, mining lease conditions and performance assessments should be informed, science-based, ethical, transparent and publicly available.
- The environmental outcomes should be set by the regulators through an iterative process involving the proponent and relevant stakeholders, which identifies all of the appropriate environmental values that should be protected and considers what best practice is for that particular set of circumstances. Negative environmental impacts on land, water, air and biota should be avoided where feasible, and any impacts on environmental values should meet approved outcomes.
- Where the owner of land is not the mining company, any compensation for demonstrated economic loss caused by mining should be agreed in principle at the time of project approval.
- Mine planning should be holistic, providing for progressive rehabilitation and agreed future land uses.
- Rigorous monitoring and public reporting programs should be used to demonstrate both progress towards, and achievement of, agreed environmental outcomes, such that it will be possible to take corrective or enforcement action if the environmental outcomes may not be, or are not being, achieved. Monitoring data should be publicly available.
- Public health and safety should not be compromised.
- The mine operator should demonstrate capability through implementation of suitable management systems (including contingency plans) with adequate training and resources to ensure best practice is implemented on the site.
- A rehabilitation security bond or other form of financial assurance should be lodged and reviewed regularly to reflect the full third party costs of clean up of the site at any stage this may become necessary. At mine completion, the site should be fit for agreed post-closure land uses and governments should not be left with any liabilities.

The principles and approaches above are inherent in the contributions of the mining industry in Australia to the *Leading Practice* booklets, and the Minerals Council of Australia's policy on responsible access to and management of land. They have proven effective and have helped achieve increased trust by stakeholders through a clear demonstration that the environmental, social and economic aspects of the mining operation are being managed appropriately and ensuring that the miner takes responsibility for the mining operation. They involve a lot of constructive discussion between the proponent and the regulators before the setting and approval of environmental outcomes to be achieved, taking into account the views of other stakeholders. Flexibility is retained to allow approval documents to be revised during mining if circumstances warrant this.

Continual improvement is espoused in these principles and incentives for this include: increased chance of approval of expansions/additional mines; reduced regulatory, monitoring and reporting costs; improved safety; corporate image, industry leadership, and market-linked 'green' or International Organisation for Standardisation (ISO) accreditation.

In contrast, mining regulators in the US and some other countries have used more prescriptive approaches for regulation of mining activities, focusing on 'Best Available Control Technology' (BACT) and other prescribed control measures. These are not considered best practice for Australia (other than for specific health and safety issues) as more prescriptive approaches result in the regulatory agencies assuming liability for non-compliance. Highly prescriptive approaches have not always proven to be effective in achieving good environmental outcomes as they can lead to an avoidance of responsibility by the mine operator.

3.3 Best practice radiation protection

The framework for radiation safety in Australia is outlined in the National Directory of Radiation Protection (NDRP), which has been developed to achieve uniformity of radiation protection practices between jurisdictions.

With regard to radiation protection in mining, States and Territories adopt the regulatory approach outlined in the *Code of Practice and Safety Guide on Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005)* produced by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

This so-called 'Mining Code' (www.arpansa.gov.au/pubs/rps/rps9.pdf) provides a regulatory framework to manage the protection of people and the environment from harmful effects of radiation exposures arising from mining or mineral processing and from the resulting wastes both now and in the future. The Mining Code defines best practicable technology and has the aim of ensuring that the magnitude of the individual radiation doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received, are all kept As Low As Reasonably Achievable, taking account of economic and social factors (ALARA principle).

4. Best Practice Environmental Protection and Regulation for ISR Uranium Mining in Australia

4.1 Principles for best practice

Box 2 presents the specific principles which should be used as the basis for setting best practice for environmental protection and regulation for ISR uranium mining, which are discussed below.

Box 2: Principles for best practice ISR uranium mining in Australia

The following principles supplement the general principles in Box 1.

- An ISR mining proposal should be based on a full understanding of the hydrological/hydrogeological/hydrogeochemical features – including features indicating favourability for ISR mining, the current and potential uses and values of groundwaters and natural radioactivity in the project area and environs.
- The nature of the uranium mining solution and well field design should be matched to the site characteristics, particularly the minerals and groundwaters in the uranium mineralised aquifer.
- Mining should not compromise groundwater in the mineralised aquifer to the extent that it cannot be remediated to meet the agreed post-mining use at mine completion. At no stage should mining compromise groundwater use in the mineralised aquifer outside an agreed distance (not exceeding a few kilometres) or groundwater travel time from a mined area. Other aquifers present in or around the mine lease should not be affected by ISR mining.
- Radiation protection should be integrated into all facets of the mining, rehabilitation, and mine completion planning. Best practice radiation protection is covered by the *Code of Practice and Safety Guide on Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005)*.
- The impact assessment process should lead to the best option for dealing with liquid residues: (i) injection into deep aquifers containing poor quality groundwaters that have no foreseeable use; (ii) injection into former mining well fields for dispersion, attenuation and/or containment; or (iii) evaporation to solid residues and disposal on site (or at a low level radioactive waste repository).

- Monitoring wells should be located so as to demonstrate effective containment of mining solutions and liquid residues (where present) within the mining aquifer and provide early warning of any excursions. Monitoring of groundwater pressures and quality should be conducted for all other aquifers in the area to verify they have not been affected by the ISR mining.
- Solid radioactive residues generated on an operational ISR mine site should be managed as low level radioactive waste and disposed of in an approved disposal facility.
- For lease relinquishment, regulators should be confident that the rehabilitated site does not present any significant radiation exposure risks; impacts on groundwater quality are within agreed parameters which reflect future land uses; there have not been and, will not be, impacts on any other aquifers at the mining lease or beyond; and the lease and surrounding area is left in a state fit for agreed future land uses. Best practice entails being able to demonstrate that completion criteria will be achieved within an agreed reasonable period (typically less than 10 years after cessation of mining).

4.2 Aspects of the existing environment to be considered

An ISR mining proposal should contain sufficient information on the geological, environmental and social features of the project site and its regional setting to enable a full assessment of the potential impact events and potential risks of the proposed mining operation.

A best practice mining proposal would include sufficient detailed information to enable understanding of the baseline groundwater characteristics and flow dynamics, and the likely response of the groundwater system to the proposed operation at both local (mining operation) and regional scales. This includes:

- Potentiometric surfaces – with sufficient data points – showing locations of all wells used and their individual water elevations and natural groundwater flow direction;
- Baseline groundwater hydrochemistry, radiological and proposed monitoring parameters;
- Aquifer properties for each aquifer that may be affected by mining operations (e.g. proposed mining aquifer, disposal aquifer, water supply aquifer);
 - o Hydraulic conductivity, transmissivity, storage coefficient, total porosity, effective porosity, aquifer thickness, piezometric pressures;
 - o Mineralogy of the mining aquifer and the chemical composition range for natural groundwaters in it;
- Hydrogeological characteristics of confining strata (hydraulic conductivity, thickness);
- Connectivity between the mining and disposal aquifers and lateral, overlying or underlying aquifers and surface water;
- Conceptualisation and, if considered warranted by regulators, numerical modelling of groundwater flow dynamics including recharge and discharge areas and processes; and
- Identification of aquifer usage category and of values associated with groundwater systems, as defined in national water quality management guidelines, including domestic/stock and irrigation/environmental/surface water recharge uses.

There will generally be naturally elevated concentrations of radionuclides in a mineralised zone, where most observations are made. The quality of groundwater down flow cannot be assumed to be of similarly poor quality, as natural processes will modify its composition as it flows in the aquifer.

4.3 Aspects of the proposed mining techniques to be considered

Given the main risks relating to ISR uranium mining are groundwater impacts, comprehensive information is required on the:

- ISR mining method;
- Management of mining solutions;
- Disposal of residual mining solutions and residues; and
- Surface storage facilities and trunklines.

A best practice mining proposal should also include information on the proposed area to be mined, the estimated ore reserves/mineral resources, the market and economic significance.

4.3.1 ISR mining method and management of mining solutions

The nature of the host sediments and ores should determine whether acid or alkaline solutions are used for leaching of uranium ores. Best practice is a function of the composition of the host sediments and ores. Acid solutions normally represent best practice where carbonate contents are low, as it results in lower volumes of reactant, faster rates of leaching, higher uranium recovery rates and minimisation of the amounts of oxidants required in the mining solution. The amounts of acid required increase with the amounts of carbonate minerals in the mining aquifer. Ores containing more than a few percent calcite or dolomite generally require alkaline leaching, although grain size (surface area) and the nature of the neutralising minerals are also factors. The well field technology and design is determined by the leaching solution used and the need to keep this solution within the mineralised zones.

Well field technology and design is determined by the leaching solution used and the grade and disposition of the mineralisation. The proponent should describe how they will ensure that mining solutions and groundwater will not move between aquifers – for example, by casing and grouting all of the injection, recovery and monitoring wells with materials that are inert to the leaching solution and strong enough to withstand injection pressures as demonstrated by hydraulic pressure tests.

Aquifer pressure and/or water balance modelling should be used to determine the range of operational parameters required to maintain the integrity of the mining aquifer and related aquifers. The level of connectivity between monitoring wells and the mining zone should be demonstrated and used to determine the spacing of monitoring wells.

Mining operations should be designed to minimise the risk of breaching impermeable strata and excursions of mining solutions. This risk can be minimised by controlling the water balance during mining operations. During ISR operations a small bleed stream can be used to ensure the volume of the solutions extracted from a wellfield is slightly higher than the volume injected which results in a net inflow of surrounding groundwaters.

Relative hydrostatic pressures for each of the main aquifers should be maintained (on average) during mining where there are multiple related aquifers. This can be achieved by maintaining an overall neutral water balance in the mining and/or disposal aquifers. Mining and disposal in a stagnant aquifer should involve maintaining a neutral water balance.

4.3.2 Management of residual mining solutions and liquid wastes in aquifers

When a well field is mined out the area will contain residual mining fluid, which will be more acidic, or alkaline (depending on the lixiviant), and more saline than the natural groundwaters. As well as mining solutions left in aquifers, liquid residues are produced in ISR processing operations. These excess liquids typically consist of bleed solutions, wash down water and spilt process liquids. They contain low levels of radionuclides from the mineralised aquifer, and are more acid or alkaline (depending on the lixiviant) and more saline than the natural groundwaters. Accordingly, mining solutions and waste liquids should be managed during operation under the approved radioactive waste management plan to ensure final closure conditions can be achieved.

Best practice is to use the remediation technique that will achieve closure outcomes in an agreed timeframe with the minimum environmental impact. The appropriate least intensive remediation technique should be progressively validated by using real data collected during mining to demonstrate that the remediation model will achieve agreed outcomes. A staged remediation approach may be considered best practice for small operations (e.g. field leach trial), such that a less intensive remediation method (e.g. groundwater flushing to accelerate natural attenuation) could be used initially. More active remediation methods (e.g. groundwater sweep and reverse osmosis) should only be adopted if the initial remediation technique is not proving adequate to achieve closure outcomes in an agreed reasonable timeframe – these methods require more energy and surface infrastructure, they produce waste streams and they incur additional costs.

4.3.3 Management of solid radioactive wastes

Solid radioactive residues generated on an operational ISR mine site are classified as low level radioactive waste (LLRW) and can include used pipes, pumps, filters, contaminated soil and radioactive sludge from ponds, including from evaporation of waste liquids. These may be disposed of in a purpose built on-site LLRW disposal facility, or disposed off-site if approved by the regulatory authority. LLRW disposal facilities should be constructed in accordance with the approved radioactive waste management plan at a site that will not compromise future land use. Closure reports should be provided for each LLRW facility detailing the location and contents, confirmation of construction and monitoring.

4.3.4 Management of surface storage facilities and trunklines

The location and protective measures for storage of reagents, temporary storage of process fluids and liquid residues, and wellfield trunklines should be based on consideration of extreme weather events, bushfires, earthquakes and the underlying geology and location of environmental receptors.

Well field and mining infrastructure should be maintained in a way that minimises the occurrence of spills. The route of trunklines and well field pipelines, should be planned to minimise interaction with water courses. Bunding should be put in place for all trunklines and wellfields whenever possible. Remote pressure monitoring, with alarms, in trunklines, wellhouses, pipes and wells can be used for the early detection of leaks and spills. Well drip trays with contained moisture sensors should be used to allow for the early detection and containment of minor leaks.

4.4 Best practice environmental standards

4.4.1 Protection of aquifers during mining operations

If the aquifers meet the criteria for potable, irrigation, ecosystem support or stock water use in the current national water quality management strategy guidelines, all groundwaters beyond the restricted zones immediately down flow from mining wellfields should be maintained at their original use category, unless otherwise agreed with stakeholders and endorsed by regulators. The mining solutions should be controlled and monitored to limit the extent of mining affected groundwaters to within an agreed distance down flow, not exceeding a few kilometres.

4.4.2 Remediation of aquifers after mining operations

The impact assessment process should take all risks, benefits and costs into account – particularly the quality of the groundwaters down flow, flow rates, aquifer mineralogy, attenuation modelling and water and energy requirements – in deciding whether the residual mining solutions should be remediated (e.g. by groundwater flushing or reverse osmosis). In summary, some degree of active remediation of the residual fluids in the mining aquifer should be required to supplement natural attenuation, where:

- Groundwaters down flow from the mine meet use criteria in the national water quality guidelines;
- The quality of the aquifer water downstream is not adequately known (because of insufficient sampling sites); or
- Natural attenuation is not progressing at a pace that will ensure the sequential land uses can be achieved in an agreed timeframe.

4.4.3 Disposal of liquid residues

In deciding the best practice for the disposal of liquid residues, the risk of human or environmental impacts due to the build up of radioactive solids in surface evaporation ponds needs to be balanced against the risks associated with disposal in an aquifer. Three general options are available:

Option 1: Disposal of liquid residues in deep aquifers unrelated to the mining activity, where the groundwater is of poor quality ('no foreseeable use') and there is sufficient volume available to store the residues. This may be judged best practice where suitable aquifers are available in the region and there has been adequate characterisation of the disposal aquifers and adjoining hydrostratigraphic units to ensure waste will be contained.

Option 2: Injection of ISR liquid residues into mined-out areas may be accepted as best practice where deep injection is not practicable. In this case, injected liquid residues should be treated similarly to mining solutions left behind in the mined out areas of the aquifer, as follows:

- Where **natural groundwaters in the mineralised zones have a current or potential use other than industrial** (no examples documented in Australia to date), disposal into the mined-out parts of the aquifer should only be permitted if there is appropriate pre-injection treatment of the liquid residues, so as to ensure that groundwater impacts are constrained within the shortest reasonably achievable times and distances from injection sites.
- Where the **natural groundwaters in the mineralised zones are not suitable for uses other than industrial, but are of better (or unknown) quality down flow**, liquid residues to be injected into former production areas should be treated as required, to ensure that attenuation occurs in a reasonable timeframe and within the zone known to have naturally poor quality water.
- Where the **natural groundwaters throughout the mineralised aquifer are established to be of poor quality, such that they have no pre-mining or potential use other than industrial**, liquid residues should not require treatment, provided it can be demonstrated that the affected aquifer waters are confined and will stabilise, such that the site will be fit for agreed future land uses.

For both options 1 and 2, the residual liquids may need to be partly evaporated to minimise their volume before injection. Regulatory authorities will consider the proponent's predictions of natural attenuation (based on laboratory tests and modelling relevant to the particular site) in considering whether and to what extent the liquid residues should be treated before or after injection. Further, to ensure the integrity of the aquifers, there should be, as appropriate:

- Predictions of sustainable disposal volumes of liquid residues through review of hydrogeological data and modelling of the aquifer;
- Regular determination of the liquid residue plume extent through groundwater monitoring and chemical analysis; and
- Predictions of future disposal plume extent, based on hydrodynamic and hydrogeochemical modelling.

Option 3: Surface evaporation of liquid residues is an option in cases where there is no deep, poor quality aquifer available, and disposal in the mining aquifer is not permitted by the regulatory authorities. It results in significant quantities of residual radioactive precipitates requiring near surface disposal on site (or at a registered radioactive waste facility off site), and associated radiological handling issues. This method generally will be very dependent on site specific factors and will involve significant regulatory input as well as strict controls and monitoring to ensure it does not contaminate shallow aquifers.

Other options such as precipitation of radium salts followed by land application of the clean water may be best practice in some specific cases, but would need to be justified by documented management and closure strategies.

4.4.4 Natural attenuation

Where natural attenuation is to be relied on for the remediation of aquifers post mine closure, or for the disposal of liquid waste residues, the nature and rates of the site-specific attenuation processes should be described – predictions of the rate and full extent of attenuation should be supported by laboratory tests and modelling. Where the predicted rate is not acceptable to the regulators, or there is a lack of confidence in the attenuation process, the affected waters should be actively remediated to an acceptable degree.

4.4.5 Mine completion

For lease relinquishment, regulators should be confident that the rehabilitated site does not present any significant radiation exposure risks, impacts on groundwater quality are as limited as is practicable, and the site will be fit for agreed future land uses. Best practice entails being able to demonstrate within an agreed reasonable period (typically less than 10 years after cessation of mining), that completion criteria will be achieved.

This should involve the operator demonstrating to the satisfaction of the regulators that the agreed future uses of the groundwater will not be compromised beyond agreed distances from mining well fields and that water quality is improving at acceptable rates within the limited zones affected by mining. In naturally confined aquifers, the primary consideration should be that there is no likelihood of breaching the confining beds.

4.5 Best practice monitoring of environmental and radiation standards

All significant risks should have an acceptable environmental outcome and measurable criteria set by the regulator, and achievement of the outcome should be monitored appropriately by the mine operator, and independently verified by the regulator. All monitoring results, including an interpretation of the compliance status of the mine, should be made publicly available at least annually.

4.5.1 Reporting of incidents

An approved process will be required for immediate reporting to regulatory authorities of serious environmental incidents, including significant spills and accidental releases of radioactive (or other) process materials, liquids or solid residues. Radiation incidents should be incorporated within the approved radiation management plan and be based on risk to workers or members of the public, and the potential for impacts on the receiving environment.

4.5.2 Monitoring of mining zone groundwaters

Networks of monitor wells should be installed in connected parts of the aquifer and located so as to provide effective early warning of unexpected excursions of residual mining solutions or injected liquid residues. Monitoring should continue for a period agreed with the regulatory authorities to confirm the attenuation rate and containment of the mining-affected groundwaters.

4.5.3 Monitoring of other aquifers

Monitoring of groundwater pressures and chemical compositions should be conducted for all aquifers in the lease area to ensure the integrity of the well field. The location, spacing and number of monitoring wells should be based on a good understanding of the hydrogeological setting, the values being protected and their location, modelling and operational experience.

A dedicated monitoring network should be installed in cases where liquid residues are disposed of in deep poor quality aquifers.

4.5.4 Surface storages and trunklines

Where necessary, monitor wells or alternative sub-membrane detection systems should be installed to detect seepages from all surface storages and near surface residue disposal cells.

4.5.5 Radiation

Monitoring should be adequate to establish that radionuclides in the environment and the associated potential for radiation exposures do not exceed authorised constraints or limits. The Radiation Waste Management Plan (RWMP) and associated groundwater and surface environment monitoring program should be aligned with the broader Environmental Management Plan for the mine.

4.6 Best practice management of ISR uranium operations

Mine operators should be able to demonstrate that they are able to manage the mine in a manner that ensures public safety and protection of the environment, and that it is likely that they will meet the approved best practice environmental standards. This will involve an assessment by the regulator of the management systems the operator has in place, and best practice should be demonstrated by compliance with recognised quality management standards such as AS/NZS ISO 9000 and in particular the environmental management standard (AS/NZS ISO 14001) and the compliance programs standard (AS 3806). The focus of all of these systems is on continuous improvement in performance. Assessment of capability may include consideration of the past performance of the mine operator, and contingency planning for key environmental indicators moving outside agreed parameters.

4.7 Best practice mine closure, rehabilitation and completion

There should be a long term decommissioning/rehabilitation process following ISR mine closure, which should not lead to regulators having to take on any operator responsibilities for environmental management or monitoring.

Mine closure planning should commence in the early stages of an ISR uranium mining project. Mine closure, decommissioning and rehabilitation plans should come into effect as soon as practicable after operations are completed in an area of the mine, so there is a seamless transition from mining into rehabilitation. The underlying methodology should be a 'risk-based closure planning process'.

The completion plan should summarise what progressive groundwater remediation or other measures will be involved in final rehabilitation, such as removing all pumps and tubing from the wells, and plugging the wells to protect aquifers. The surface should be rehabilitated by returning all lands disturbed by the mining project to a state suitable for the future land use(s) as agreed in the impact assessment and approval process. This should include decommissioning, decontaminating and removing mine infrastructures, unless otherwise agreed with regulatory authorities.

A permanent record should be made of details of the mined aquifer to minimise future disturbance via water or mineral exploration. Any future water allocation licence should be subject to the groundwater being demonstrated to be safe for the projected use.

From the start of the project, a continually updated contingency plan should be maintained, which describes how the mining and other aquifers in the area will be protected in the event that mining operations cease unexpectedly. The regulator should hold and review regularly rehabilitation security bond or other form of financial assurance (that reflects the maximum full third party costs of rehabilitation) to ensure that this contingency plan can be implemented should the mine close prematurely.

5. Concluding Remarks

This guide has outlined the general principles and guidelines for best practice mining in Australia and considered the issues of main concern for ISR uranium mining in the light of these. The onus is on the operator to determine what technologies and approaches should be used at a mining operation to ensure that the environmental outcomes agreed with government authorities are met and radiation protection standards are adhered to.

Attachment 1 provides more detailed information on what a proponent should take into account in preparing integrated plans for best practice mining. It develops the links between best practice principles and best practice regulation.

ATTACHMENT 1: Linking best practice mining to best practice regulation

This attachment provides detailed guidance on what the proponent should take into account in best practice planning, operating and closing of a mine. It links the principles and approaches in this guide to best practice regulation of ISR mines, drawing in particular on *Minerals Regulatory Guidelines MG2*, prepared by Primary Industries and Resources, South Australia (www.minerals.pir.sa.gov.au) and ARPANSA's *Code of Practice and Safety Guide on Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005)* (www.arpansa.gov.au/pubs/rps/rps9.pdf).

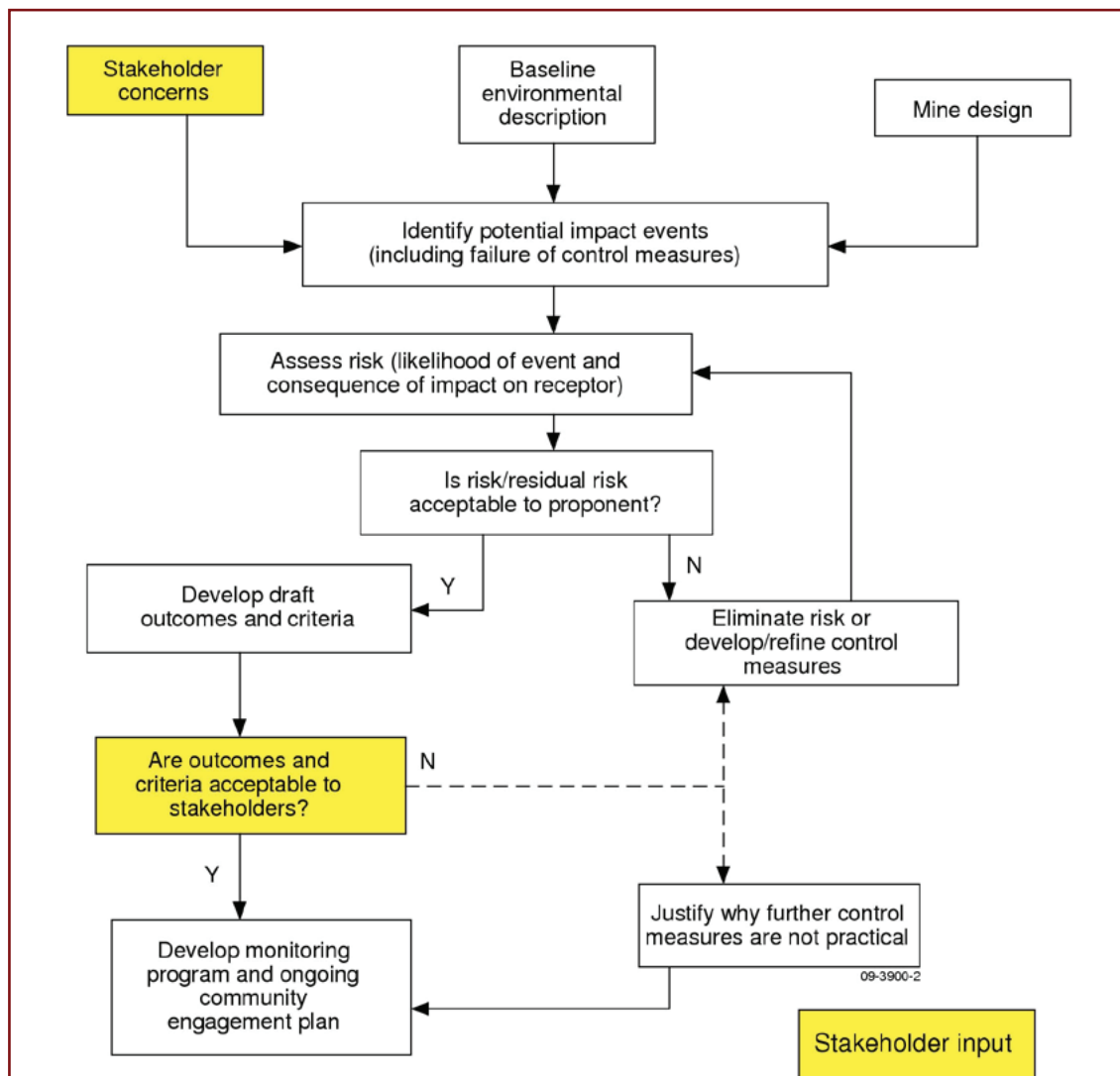
ENVIRONMENTAL IMPACT ASSESSMENT

The ISR mining proposal should identify all of the environmental values, any environmental 'standards' to be met and, potential impacts or events that are likely to be created by the ISR mining operation. For each environmental value identified, a management program should be developed setting out how each of the identified impacts will be managed.

The general process leading up to approval is summarised in the flowchart below. It shows that stakeholder inputs, which are essential in determining environmental values and outcomes, and future land and aquifer uses.

Important assessment issues include:

- Potential impact events affecting environmental values;



- Control and management strategies;
- Acceptance of residual risk;
- Environmental outcomes and criteria, leading to monitoring program;
- Mine closure plan; and
- Management systems and operator capability.

The documentation should include:

- Mining proposal documentation, including all relevant baseline environmental data;
- Company responses to public consultation on proposals; and
- Regulator assessment of reports including reasons for the decisions, and approval conditions.

Potential impact/events

The proponent needs to identify and describe the actual or credible potential impact events associated with proposed mining activities that could pose a threat to the natural environment (including air quality, surface and underground water supplies, flora, fauna). For ISR mining, the key impact will be on potential changes to the use category of the land and the mining and disposal aquifers.

The environmental values potentially affected by the project must be clearly identified through a comprehensive characterisation of the geological, environmental and social setting at and around the proposed site, involving the proponent, the regulatory authorities and local communities, including any indigenous communities. A precautionary approach should be used where there is uncertainty over whether or not a value is likely to be affected.

Events associated with construction should be considered as well as events associated with operation of the mine. Risk assessment should take into account:

- Sufficiency of data, for realistically estimating risk factors, and consequent issues of perceptions of risk by stakeholders;
- The potential long timeframes associated with environmental events;
- The inherent resilience of the natural environment to cope with impacts; and
- Potential for some impacts to be irreversible.

The impact event analysis should identify the source, pathway, barrier, receptor (human, fauna, flora etc.) and consequences (scope, ability to remediate, duration, cumulative effects etc.). The basis for the determination of these issues should be described in some detail.

The effect of impacts on the aquifer may be usefully demonstrated by the use of numerical modelling. If a model is constructed, this may also be used to demonstrate the effect of proposed control measures. The description of the model should clearly state the assumptions used to build the model, and evaluate the effects these assumptions (or alternative valid assumptions) may have on the conclusions reached.

Control and management strategies

A description of any proposed control and management strategies to reduce environmental impacts should be included. The strategies should be technically and economically achievable, and they should reflect progressive rehabilitation wherever possible.

The risk should be addressed using an accepted hierarchy of controls approach, applied in the following order:

- *Elimination*. Redesign so as to eliminate the risk.
- *Substitution*. Replace the material process with a less hazardous one.
- *Design engineering (physical) controls*. Install barriers to control the risk.
- *Management system (procedure) controls*. Manage the risk through procedures and the way the activity is conducted by personnel.

The description of the control strategies should clearly state if it is a design (physical) based measure or if it is a management system (procedure) based measure and how it avoids or reduces the likelihood of the event occurring or the consequences of an event, should it happen.

The effect of control strategies may often be usefully demonstrated through numerical modelling, showing the effect of the impact after the control strategy has been implemented.

In order to determine the level of risk associated with various impact events, both the likelihood and severity of the consequences of impact events have to be separately considered. Risk should be evaluated and documented both before and after proposed control strategies have been taken into consideration, as follows:

- **Qualitative measure of likelihood.** The likelihood of each event occurring should be determined based on information such as past experience, known environmental data, and modelling data. The likelihood can be classified using a system such as AS4360, or another recognised risk assessment methodology.
- **Qualitative measure of consequences.** The consequences of each event occurring should be determined based on information such as the potential scale of the event, the range of stakeholders who may be affected, the duration of the event, and the difficulty in remediating the impact.

There should be an evaluation of the uncertainty of the final risk determination due to factors such as:

- Lack of data/knowledge of the environment, the event or the consequences on the receptor;
- Use of novel or innovative control measures; and
- Natural climate variations.

Where appropriate, the potential for the risk to be greater than that stated should be documented.

Justification for acceptance of residual risk

There should be discussion of how the residual risks (i.e. after control measures have been implemented) associated with credible events will be managed to as low as reasonably achievable (ALARA). As development proceeds, adaptive management, auditing, review and refinement should be used to achieve an enhanced understanding of risks and a better targeting of mitigation measures.

Where the risk has not been eliminated, the proponent will need to provide justification that the risk is such that:

- There are no practical control measures available, and the risk is considered acceptable given the benefits that will arise from the mining operation will outweigh the risk; or
- The cost of implementing further control measures is grossly excessive compared with the benefit obtained. In this case there should be included in this section a description and evaluation of these alternate control measures.

Environmental outcomes

A set of outcomes (with associated measurable assessment criteria) are to be developed for each of the identified environmental values and potential impacts. These will be based on the residual risk and will indicate the expected impact on the environment caused by the proposed or current mining activities subsequent to control strategies being implemented.

The outcomes should be a commitment on the extent to which the ISR operation will limit impact on the environment. These outcomes should be reasonable and realistically achievable, acceptable to affected parties and meet other applicable legislative requirements, to maintain an amiable co-existence between interested parties.

The regulator will consider the extent to which the outcomes are acceptable to affected parties and balance these with the practicality of the alternative mining options when deciding to approve the outcomes. There may be no need to document an outcome if the risk can be demonstrated to be very low probability, or trivial in consequence, without the use of control measures. However, where

the risk is such that specific control measures are required to eliminate it, there are strong public perceptions, or there is uncertainty in the risk level, outcomes are required.

Clear and measurable criteria should be set to demonstrate the achievement of outcomes. The criteria should be described in specific terms that clearly define the achievement of the outcomes. They may be expressed in quantitative or qualitative terms, but the former are preferred (where practical).

The criteria should demonstrate clear and unambiguous achievement of the environmental outcomes by:

- Including the specific parameters to be measured and monitored;
- Specifying the locations where the parameters will be measured, or how these locations will be determined;
- Specifying the frequency of monitoring;
- Identifying what background or control data are to be used, or specifying how these will be acquired if necessary; and
- Clearly stating the acceptable values for demonstrating achievement of the outcome, with consideration of any inherent errors of measurement.

For example, a water quality criterion should mention the parameters to be measured, and state the acceptable levels. If the outcome is to be measured against background levels, these should be already acquired, or if in relation to control points, provide a clear process about how this data will be acquired during operations.

Where appropriate, recognised industry standards, codes of practice or legislative provisions from other Acts can be used as criteria. The measurement criteria for all significant areas of risk should drive development of the monitoring plan. All point-related criteria, such as water bores, sampling points and visual amenity photo points, should be included on a map and in a table of locations of the points.

Leading indicator criteria

Where there is a high consequence event that relies significantly on a control strategy to reduce the risk, leading indicator criteria should be developed. This will be determined through the risk assessment process, but international experience indicates that this usually includes excursion monitoring for ISR mining fluids. These should give early warning if a control measure is failing and the outcome is potentially at risk of not being achieved. These may relate to the proposed control measures (e.g. audits of the management system), near misses, or trends in environmental data. Detection of unexpected results should lead to immediate action being taken.

The leading indicator criteria should be included in the monitoring plan.

Compliance monitoring plan

A company-driven monitoring program to measure the achievement of each outcome and the effectiveness of each strategy should be developed and implemented. This should not be reliant on the regulator's inspections.

The monitoring program should be built from the outcome measurement criteria and leading indicator criteria as discussed above. The monitoring program should describe in some detail:

- What will be measured, the accuracy of measurements if applicable and who will be responsible for them;
- Where will it be measured (including controls and baseline) and how;
- Frequency of measurement, interpretation and review;
- Record keeping; and
- Frequency of reporting to management and external stakeholders.

Company, regulator or independent third party reports on compliance, should include all raw monitoring data used to support demonstration of compliance, incident reports (e.g. spills); and compliance actions taken by the regulator.

MINE CLOSURE AND SITE REHABILITATION

The elements covered in the Mine Closure and Rehabilitation Plan should be as follows:

Potential impacts of mine closure

The focus should be on issues that may remain after mine closure (e.g. contaminated land, contaminated aquifers) and should include a risk assessment. Socio-economic impacts and cultural heritage aspects should be included.

Outcomes and completion criteria

For closure of an ISR mining site, the key issue will be demonstrating that the mining and disposal aquifers will ultimately revert to a stable condition consistent with the sequential land use environmental values. The extent and location of monitoring required to demonstrate this will be determined on a case by case basis and dependent on the predictions of groundwater model of the aquifer after mining.

Outcomes and completion criteria for the site post mine closure should be stated and clearly related to the relinquishment process before endorsement by stakeholders and agreement with regulators. As a guide the following outcomes would normally be expected to be included as a minimum and it should be demonstrated that they are likely to be achieved indefinitely after closure:

- The external visual amenity of the site is in accordance with the reasonable expectations of relevant stakeholders, including removal of mine-related infrastructure as agreed with the landowners and regulators;
- The risks to the health and safety of the public and fauna are as low as reasonably achievable (ALARA);
- Ecosystem and landscape function is resilient, self-sustaining and indicating that the agreed post-mining ecosystem and landscape function will ultimately be achieved;
- The site is physically stable;
- The quality and quantity of ground- and or surface-water available to existing and future users and water dependent ecosystems meet agreed criteria;
- All waste materials left on site are chemically and physically stable; and
- All other legislative requirements have been met.

Clear and measurable completion criteria should also be set to demonstrate the achievement of outcomes so the ultimate goal of relinquishment and promotion of alternative land uses can be achieved. These should be explicit and, as far as practical, quantifiable. The criteria will form the basis for relinquishment of the lease and the proponent should be careful in developing these so as to be confident of being able to meet the criterion stated. Where appropriate, recognised industry standards, codes of practice or legislative provisions from other Acts can be used as criteria. The measurement criteria should drive development of the completion monitoring plan.

Sustainable closure strategies

In summary, the mine closure and rehabilitation plan should:

- Provide a description of the legal and regulatory requirements and demonstrate how these are met through the body of the plan;
- Include a description of the proposed closure strategies to achieve stated closure outcomes, which should implement best practice in mining and environmental management, be technically and economically achievable and sustainable with minimal ongoing maintenance, and reflect progressive rehabilitation wherever possible;
- Enable all stakeholders to have their interests considered;
- Ensure that mine closure occurs in an orderly, cost-effective and timely manner;

- Ensure the cost of rehabilitation is adequately represented in company accounts and that the community and government is not left with any liability;
- Ensure there is clear accountability, and adequate resources for rehabilitation;
- Establish a set of indicators, accepted by regulators, which will demonstrate the successful completion of rehabilitation; and
- Reach a point where the company has achieved agreed completion criteria so as to meet the expectations of stakeholders and satisfy the regulating authority.

Closure strategies should avoid a reliance on ongoing maintenance or monitoring, and should be focused on stable physical measures. This is due to the difficulty in ensuring ongoing responsibility and adequate resources for the site in the long term once the operator has relinquished the mining lease. The effect of control strategies may often be usefully demonstrated through numerical modelling showing the effect of the impact after the control strategy has been implemented.

Completion/emergency risk assessment

The risk analysis should follow the process outlined above. The risk analysis needs to consider that the timeframes are much longer than for the operating phase. For instance, 1 in 100 year rainfall events may be considered appropriate for assessing risks during the operational phase, but 1 in 1000 year events may be more appropriate for assessing the risk post mine closure. This should consider the risks of the proposed closure strategy failing, and be completed by both regulatory authorities ultimately responsible for relinquishment and the proponents.

Closure risks may include:

- Financial;
- Sudden closure due to market changes;
- Poor management of rehabilitation activities;
- Experimental or novel rehabilitation techniques;
- Ongoing maintenance requirements for protective structures;
- Changes in legislative requirements, community or regulator expectations (if the mine has a long life);
- Changes to surrounding land use;
- Inadequate understanding of the existing environment and the impacts of the operations;
- Unexpected or unusual climatic conditions; and
- Other emergencies including earthquakes, terrorism.

This section should also describe how significant risks will be controlled (e.g. by contingency provisions in cost estimates, or by additional monitoring) and demonstrate that these risks have been managed to as low as reasonably practical.

In some cases, where there is significant reliance on engineered protective structures to reduce post-closure risks, an independent third party audit of the closure design and modelling may be required to demonstrate that the structure is likely to meet agreed outcomes.

Closure cost estimate

An estimate should be included of maximum third party rehabilitation and decommissioning costs at any time during the mine life in the mining and rehabilitation plan. Note the maximum liability may not be at mine closure, but may be very early in the mine life. The estimate should include, where applicable:

- The decommissioning domain or component;
- An estimate of the area, volume, machinery type, personnel, material or time (as appropriate) as a measure of the rehabilitation effort required, and how these estimates were derived;

- The rehabilitation costs per unit of rehabilitation effort, and how these costs were derived (including a breakdown of all unit costs);
- Any costs for ongoing maintenance and management;
- Survey and design;
- Project management, administration (normally 10–25% of total costs);
- Provision for normal project variation (10–20%);
- Provision for contingency costs; and
- Allowance for inflation.

The cost should be calculated on the basis that a third party contractor would undertake the rehabilitation work. Unprocessed material and salvage costs should not be deducted due to the likelihood that, as an unsecured creditor, the government would not be able to access these assets.

A staged bond schedule should be proposed that reflects the increasing liability as mining progresses, and gradually reduces the bond as rehabilitation progresses. If this option is chosen, the staging frequency should be no more than annual, and the stages should reflect the maximum liability at any time during the forward year.

There will always be some financial risk associated with uncertainty in estimating rehabilitation and closure costs, and contingency costs are a critical element of the closure cost estimate.

Key risks are:

- Residual risk;
- The potential to underestimate the costs or effort required to rehabilitate;
- Planned rehabilitation may fail (and hence will require further effort or redesign to achieve the agreed outcomes);
- Sudden (unplanned) closure; and
- Temporary closure (care and maintenance).

The closure plan should document closure cost uncertainty. The cost estimates determined may be used to calculate and set an appropriate bond for the operation. The proponent should also describe in the mining and rehabilitation plan how provision will be made in the company's accounts for the rehabilitation liability, how this liability will be reviewed during the life of the project, and how the liability will be provided for as the mine progresses to ensure that sufficient funds are left at mine close to fully fund rehabilitation.

The closure plan and bond should be revisited at a set frequency to ensure that closure plans and bonds are reflecting current requirements.

Radiation protection

Regulation of radioactive materials and radioactive wastes to protect people and the environment from the harmful effects of radiation, is based on fundamental internationally agreed principles supported by International Atomic Energy Agency (IAEA) Safety Standards, Safety Fundamentals, Safety Requirements and Safety Guides.

In Australia, the National Directory of Radiation Protection (NDRP) has been developed to achieve uniformity of radiation protection regulations between jurisdictions. All Australian jurisdictions have agreed to adopt the NDRP. The *Code of Practice on Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing 2005* (the Mining Code) will be included in the NDRP in order to move towards uniform standards of radiation protection and radioactive waste management in mining and mineral processing in Australia.

The Mining Code, based on IAEA guidance, applies to a wide range of operations with varying radionuclide concentrations and with associated variations in the risk arising from the operation. In order to allow for a graded approach to the regulation of these operations the Mining Code allows the granting for exemptions from the provisions of the code either for a whole operation or for parts of an operation.

The Mining Code sets out a system of approvals and authorisations across all stages of mining and mineral processing operations. These stages include construction, commissioning, operation, decommissioning and rehabilitation. Each stage of an operation requires an approved Radiation Management Plan (RMP) and Radioactive Waste Management Plan (RWMP) based on best practicable technology and the identified risks associated with potential radiation dose delivery pathways.

The RWMP applies to the management of radioactive waste generated at all stages of mining or processing, including mining solutions and liquid wastes, solid wastes and airborne releases. To ensure the RWMP aligns with the broader environmental management plan, the RWMP (and RMP) should be based as much as possible, on the same iterative risk based impact assessment process as described above in Attachment 1.

Under a risk based and graded approach, the RMP and RWMP will require detailed descriptions of the systems used at an operation to control exposures to radiation and manage radioactive waste. This level of detail may be greater than that normally required by an outcome based regulatory approach.

ATTACHMENT 2: Definitions and abbreviations

Acid leach — in situ mining solution or lixiviant containing acids used to leach uranium from the ore zone.

Affected community — members of the community affected by a company's activities. The effects are most commonly social (resettlement, changed services such as education and health), economic (compensation, job prospects, creation of local wealth), environmental and political. Whilst the economic and associated social impacts of a company may be extensive and operate at provincial, state or national levels, these broader impacts would not typically be used to define the affected community.

Affected party — an individual or group of people who will be directly or indirectly affected by the mining operation. These may include landowners, Native Title holders, neighbours, the local council or the wider community.

Alkaline leach — in situ mining solution or lixiviant containing alkalies used to leach uranium from the ore zone.

Aquifer — a permeable rock formation (usually sand or sandstone) capable of storing and permitting the transmission of water.

Attenuation — natural attenuation processes result in gradual changes in the pH and chemical compositions of mining-affected groundwaters towards natural background values. Natural attenuation is caused by hydrodynamic dispersion, mixing with other groundwaters and physical-chemical reactions between the fluids and aquifer minerals.

Baseline environmental data — data acquired to identify the state of the environment prior to any disturbance from mining. It should give a pre-mining inventory of factors such as the diversity of flora and fauna and quality of air or water. The values acquired can be used as a benchmark for final mine rehabilitation.

Closure — a whole of mine life process which typically culminates in tenement relinquishment. It includes decommissioning and rehabilitation.

Community (including local and affected community) — a community is a group of people living in a particular area or region. In mining industry terms, 'community' is generally applied to the inhabitants of immediate and surrounding areas who are affected by a company's activities.

The term 'local' or 'host community' is usually applied to those living in the immediate vicinity of an operation, being indigenous or non-indigenous people, who may have cultural affinity or claim, or direct ownership of an area in which a company has an interest.

Completion — the goal of mine closure. A completed mine has reached a state where mining lease ownership can be relinquished and responsibility accepted by the next land user.

Completion criteria — an agreed standard or level of performance which demonstrates successful closure of a site.

Conservation status — as defined in the *National Parks and Wildlife Act 1972*.

Consultation — the act of providing information or advice on, and seeking responses to, an actual or proposed event, activity or process.

Criterion/criteria — agreed clear and specific measurable targets or standards that demonstrate achievement of an agreed outcome. They state what is to be measured, where it is to be measured, when (or how often) it will be measured, the measurement technique or standard and the acceptable result.

Decay products — the product of the spontaneous radioactive decay of a nuclide. A nuclide such as uranium-238 decays through a sequence of steps and has associated with it a number of successive decay products in a decay series.

Engagement — at its simplest, 'engagement' is communicating effectively with the people who affect and are affected by a company's activities. A good engagement process typically involves identifying and prioritising potentially affected parties, conducting a two-way dialogue with them to understand their particular interest in an issue and any concerns they may have, exploring with them ways to address these issues, and providing feedback to potentially affected parties on actions taken. At a more complex level, 'engagement' is a means of negotiating agreed outcomes over issues of concern or mutual interest.

Environment — includes:

- land (including soil, geology and landforms), air, water (including both surface and underground water), organisms and ecosystems;
- residences, buildings, public or private infrastructure, and cultural artefacts;
- existing or potential land use and productive capacity;
- public health, safety and amenity; and
- the aesthetic and cultural values of an area.

It extends to all areas potentially affected by mining operations.

Environmental component — an element of the environment that may be affected by mining activities.

Environmental values — physical characteristics and qualities of the environment that contribute to biodiversity conservation, and the social, spiritual and economic health of individuals and society.

Extraction well — a screened water bore used for removing fluids from an aquifer.

Flushing — a process where contaminated residual mining solutions from a well field where ISR mining is completed are pumped to a new well field; and simultaneously the 'clean' water from the new well field is pumped back into the completed well field. This exchange of solutions between the well fields is undertaken to rehabilitate the completed well field.

Impact — any change to the environment wholly or partially, directly or indirectly caused by mining operations.

Impact event — a specific event that may result in an impact (may be natural, e.g. rainfall, earthquake, wind) by third party activities or caused by normal or abnormal operations.

Injection well — a cased well used to deliver fluids (leaching solution, waste liquids or water) into underground strata.

Ion exchange — the transfer of uranium from uranium-bearing lixiviant to resin beads in an ion exchange column. The process is similar to that applied in domestic water softeners.

ISL — in situ leach (same as ISR, see below).

ISR — in situ recovery. Chemical leaching of ore conducted by introducing lixiviant to sub-surface aquifer containing uranium mineralisation and subsequent recovery of uranium in a hydrometallurgical processing plant at the surface.

Liquid residues — excess liquids produced in ISR mining operations from bleeding off portion of the leaching solutions after uranium recovery (at the processing plant) to maintain a hydraulic pressure gradient into the mining well field. Also includes washings from the processing plant.

Lixiviant — water, usually groundwater from the ore zone aquifer, to which chemicals including complexing agents and oxidants have been added to leach minerals from the ore.

LLRW — low level radioactive waste

Natural groundwaters — underground water contained within an aquifer.

Outcome — a statement of the expected level of protection of an environmental value that must be achieved despite impact on the environment caused by the proposed or current mining activities. Outcome statements are accompanied by measurable assessment criteria designed to demonstrate that the outcome has been achieved.

Permeability — the capacity of a porous rock for transmitting a fluid.

Radionuclide — any nuclide (isotope of an element) which is unstable and undergoes radioactive decay.

Reverse osmosis — purification of water by forcing it under pressure through a membrane that is not permeable to the impurities that are to be removed.

Risk — the combination of the likelihood of an event occurring that negatively affects on the environment and the consequences should it occur.

Residual risk — risk remaining following implementation of controls.

RMP — radiation management plan

RWMP — radiation waste management plan

Solvent extraction — a separation process in which two water-based and organic-based solvents are brought into contact for the transfer or recovery of a component, in the present case uranium.

Stakeholders — all parties having a direct interest, including the project proponents (mine operators), government regulators and affected communities.