CRC for Contamination Assessment and Remediation of the Environment

National Remediation Framework

Technology guide: Excavation

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National Remediation Framework

The following guideline is one component of the National Remediation Framework (NRF). The NRF was developed by the Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE) to enable a nationally consistent approach to the remediation and management of contaminated sites. The NRF is compatible with the *National Environment Protection (Assessment of Site Contamination) Measure* (ASC NEPM).

The NRF has been designed to assist the contaminated land practitioner undertaking a remediation project, and assumes the reader has a basic understanding of site contamination assessment and remediation principles. The NRF provides the underlying context, philosophy and principles for the remediation and management of contaminated sites in Australia. Importantly it provides general guidance based on best practice, as well as links to further information to assist with remediation planning, implementation, review, and long-term management.

This guidance is intended to be utilised by stakeholders within the contaminated sites industry, including site owners, proponents of works, contaminated land professionals, local councils, regulators, and the community.

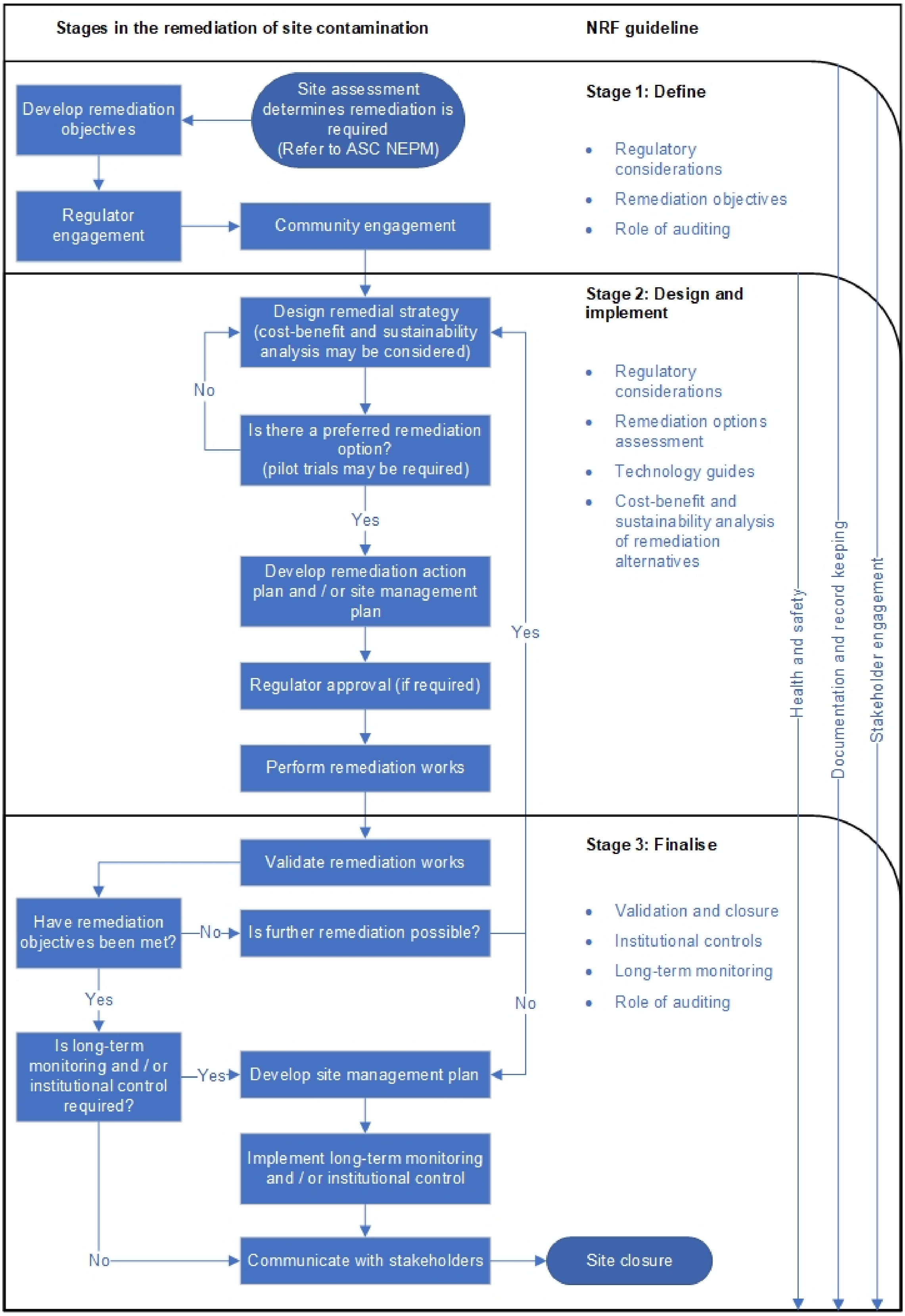
The NRF is intended to be consistent with local jurisdictional requirements, including State, Territory and Commonwealth legislation and existing guidance. To this end, the NRF is not prescriptive. It is important that practitioners are familiar with local legislation and regulations and note that **the NRF does not supersede regulatory requirements**.

The NRF has three main components that represent the general stages of a remediation project, noting that the remediation steps may often require an iterative approach. The stages are:

- Define;
- Design and implement; and
- Finalise.

The flowchart overleaf provides an indication of how the various NRF guidelines fit within the stages outlined above, and also indicates that some guidelines are relevant throughout the remediation and management process.

It is assumed that the reader is familiar with the ASC NEPM and will consult other CRC CARE guidelines included within the NRF. This guideline is not intended to provide the sole or primary source of information.


Stages in the remediation of site contamination
NRF guideline
Site assessment determines remediation is required (Refer to ASC NEPM)
Develop remediation objectives
Regulator engagement
Community engagement
Stage 1: Define
Regulatory considerations
Remediation objectives
Role of auditing
Design remedial strategy (cost-benefit and sustainability analysis may be considered)
No
Is there a preferred remediation option? (pilot trials may be required)
Yes
Develop remediation action plan and / or site management plan
Yes
Regulator approval (if required)
Perform remediation works
Stage 2: Design and implement
Regulatory considerations
Remediation options assessment
Technology guides
Cost-benefit and sustainability analysis of remediation alternatives
Health and safety
Documentation and record keeping
Stakeholder engagement
Validate remediation works
Have remediation objectives been met?
No
Is further remediation possible?
Yes
No
Is long-term monitoring and / or institutional control required?
Yes
Develop site management plan
Implement long-term monitoring and / or institutional control
No
Communicate with stakeholders
Site closure
Stage 3: Finalise
Validation and closure
Institutional controls
Long-term monitoring
Role of auditing

Executive summary

Excavation methods comprise characterisation followed by removal of identified contaminated soil. Excavation may be followed by ex-situ treatment (on-site or off-site) and reuse on-site or off-site, or disposal at an approved facility (e.g. landfill).

Key design parameters for an excavation program include:

- Nature of soils (fill, natural) and 'other' contents (e.g. pavements, foundations, waste, oversize, degradable material, rubbish, metal), contamination status including presence of asbestos and definition of excavation requirements / plans;
- Requirements for geotechnical stabilisation;
- Requirements for management of emissions;
- Requirements for classification, segregation (stockpiling) and use or disposal;
- Defining procedures for tracking fate of contaminated soils; and
- Defining requirements for validation, backfilling and demonstrating final site conditions.
- Excavation is an effective measure for most soil contaminants and can be applied in most geological conditions. The difficulty and complexity of the excavation method and site management process will depend on the contaminants present, together with the soil, geology and groundwater conditions and site constraints such as space available, presence of services and surrounding land uses.
- Data collected in the site contamination assessment should inform the initial and detailed remediation screening stages to assess the feasibility of excavation to remove contaminated soil from the site. It is essential to have a sufficient understanding of the soil properties, such as permeability and plasticity, as well as the contaminant mass and distribution to inform the decision as to whether excavation will be appropriate and how excavation should be undertaken.

Stages involved in undertaking an excavation program include:

- Characterisation of soils and contaminant distribution;
- Design of an excavation plan;
- Shoring or stabilisation of excavation;
- Management of emissions (soils, dust, water, odour, vapour) during excavation;
- Survey excavation and stockpile volumes and weighing the mass of material treated or disposed of;
- Tracking the fate of soil (treatment, transport and/or disposal);
- Validating excavations and final site conditions; and
- Backfilling excavations and final site contours.

Abbreviations

CRC CARE	Cooperative Research Centre for Contamination Assessment and Remediation of the Environment
NRF	National Remediation Framework
PPE	Personal Protective Equipment
RAP	Remediation Action Plan
WHS	Work Health and Safety

Glossary

Concentration	The amount of material or agent dissolved or contained in unit quantity in a given medium or system.
Conceptual site model	A representation of site-related information including the environmental setting, geological, hydrogeological and soil characteristics together with the nature and distribution of contaminants. Contamination sources, exposure pathways and potentially affected receptors are identified. Presentation is usually graphical or tabular with accompanying explanatory text.
Contaminant	Any chemical existing in the environment above background levels and representing, or potentially representing, an adverse health or environment risk.
Contaminated site	A site that is affected by substances that occur at concentrations above background or local levels and which are likely to pose an immediate or long-term risk to human health and/or the environment. It is not necessary for the boundaries of the contaminated site to correspond to the legal ownership boundaries.
Contamination	The presence of a substance at a concentration above background or local levels that represents, or potentially represents, a risk to human health and/or the environment.
Environment(al) protection authority / agency	The government agency in each state or territory that has responsibility for the enforcement of various jurisdictional environmental legislation, including some regulation of contaminated land.
Ex-situ	A Latin phrase that translates literally to "off site" or "out of position". It refers to remediation that is performed on the contamination following removal, usually the excavation of soil.
Hotspot	A portion of soil which features non-random elevated concentrations of the contaminant
In-situ	A Latin phrase that translates literally to "on site" or "in position". It refers to remediation that is performed on the contamination while it is in place, without excavating soil.
Practitioner	Those in the private sector professionally engaged in the assessment, remediation or management of site contamination.
Proponent	A person who is legally authorised to make decisions about a site. The proponent may be a site owner or occupier or their representative.

Remediation	An action designed to deliberately break the source-pathway-receptor linkage in order to reduce the risk to human health and/or the environment to an acceptable level.
Risk	The probability that in a certain timeframe an adverse outcome will occur in a person, a group of people, plants, animals and/or the ecology of a specified area that is exposed to a particular dose or concentration of a specified substance, i.e. it depends on both the level of toxicity of the substance and the level of exposure. 'Risk' differs from 'hazard' primarily because risk considers probability.
Site	A parcel of land (including ground and surface water) being assessed for contamination, as identified on a map by parameters including Lot and Plan number(s) and street address. It is not necessary for the site boundary to correspond to the Lot and Plan boundary, however it commonly does.

Measurements

Unit or symbol	Expansion
m	Metres

Table of contents

1. Introduction

The purpose of this guideline is to provide information on excavation as a treatment technology for the remediation of contaminated sites to assist with selection of remediation options. The document contains information to inform remediation planning and aid compilation of a remediation action plan (RAP).

This guidance is primarily intended to be utilised by remediation practitioners and those reviewing practitioner's work, however it can be utilised by other stakeholders within the contaminated sites industry, including site owners, proponents of works, and the community.

Excavation is one of many technologies available for contamination remediation, and other technologies may be more appropriate. It is assumed that the information presented within will be used in a remediation options assessment to identify and select the preferred technologies for more detailed evaluation. This guideline provides information for both initial options screening and more detailed technology evaluation. This guideline does not provide detailed information on the design of excavations as this is a complex undertaking and should be carried out by appropriately qualified and experienced practitioners. Readers are directed to the NRF *Guideline on performing remediation options assessment* for detailed advice on assessing remediation options. In addition, the remediation objectives, particularly the required quality of the soil after treatment, are a critical matter and it is assumed that these have been determined and considered in the remediation options assessment and selection process.

Whilst excavation and off- site disposal, also known as 'dig and dump', may be the least sustainable remedial option, it remains the most commonly used method of remediation in Australia due to its simplicity and applicability to a wide range of sites. Readers are directed to the NRF *Guideline on performing cost-benefit and sustainability analysis of remediation options* for further information on incorporating sustainability into remediation options decisions. Readers are also directed to the NRF *Guideline on establishing remediation objectives* for further discussion on considering the remediation hierarchy of options when assessing remediation options.

References to case studies are provided in **Appendix A**.

A number of sources of information were reviewed during the formulation of this document to compile information on potential technologies. These are listed in references, and provide an important resource to readers.

2. Technology description and application

Excavation methods comprise characterisation followed by removal of selected soils. The term ‘soil’ within this guideline refers to solid spadeable material, either of fill or natural origin. Excavated soils may be of varying water content and consistency including sand and clay. Excavation may be followed by ex-situ treatment (on-site or off-site) and/or on-site or off-site use, reuse or disposal at an approved facility (e.g. landfill).

Any combination of the above components may be needed for successful implementation of excavation, depending on the contamination present, physical and chemical conditions along with the potential receptors at the specific site.

Excavation is an effective measure for most soil contaminants and can be applied in most geological conditions, though the difficulty and complexity of the excavation method and site management process will depend on the contaminants present, together with the geology and groundwater conditions.

Data collected in the site contamination assessment should inform the initial and detailed remediation screening stages to assess the feasibility of excavation to remove contaminated soil from the site. It is essential to have a sufficient understanding of the soil properties, such as permeability and plasticity, as well as the contaminant mass and distribution to inform the decision as to whether excavation will be appropriate and how excavation should be undertaken. This data will also inform potential reuse options.

3. Feasibility assessment

The viability of excavation as a potential remediation option will often depend on the following site-specific factors:

- Whether excavation is the only feasible alternative of meeting the requirements for remediation (particularly considering time, outcome and regulatory requirements);
- Whether the cost and requirements for disposal of excavated material compares favourably with other remediation options;
- Whether the depth required for excavation, nature of the geology (eg rock or sand) and proximity to sensitive infrastructure and services makes the cost or risk unacceptable; and
- Whether the contamination extends below the water table and whether dewatering is required.

Whether the extent of contamination required to be excavated to satisfy remediation requirements has been sufficiently well delineated and uncertainties in the volume and cost are acceptable

The level of characterisation required prior to implementation of excavation as a soil remediation option will vary depending on a number of factors, including:

- Presence or absence or services, hardstand, building foundations, odour control enclosures;
- Soil lithology and heterogeneity;
- Regulatory requirements;
- Fate of soils and corresponding requirements (e.g. on-site reuse criteria, requirements from landfills for accepting soils, specific data requirements if soil is to be treated by a technology);
- Level of certainty required for characterisation/classification prior to excavation;
- Whether space and time permits stockpiling and ex-situ classification after excavation; and
- Whether volatile and odorous compounds are present at concentrations that would require an odour control enclosure and emission control system to safely and effectively manage volatile emissions and odour.

The depth of the soils requiring excavation will influence the feasibility of this method. Contamination at shallow depths may be readily excavated, whereas material at significant depth below ground level, particularly where rock is involved, can involve major works and may not be feasible.

The volume of material to be treated is also a key consideration, as this will determine the cost and could also determine the feasibility of the method and how it might relate to other methods. Quantifying the volume will require careful delineation of the material that needs to be excavated for treatment. Delineation of the volume and location of material can be expected to require additional sampling and analysis (over that undertaken in the DSI which concluded that there is material present requiring treatment). Typically, the location and extent of material should be indicated on a map; ideally this should be prepared using software where the available sampling and analytical information can be input as the source data for the plan. The uncertainty in the volume and location of material to be treated should be understood and related to the requirements for decision making.

It will be important to balance the detail of the sampling program with the project objectives and the cost of treatment or disposal. For example, if the site is characterised by small pockets of highly contaminated material surrounded by lower contamination levels, or if potentially clean oversize material is present, then additional characterisation may be warranted to allow segregation of the highly contaminated material which will be costlier to treat or dispose of.

3.1 Data requirements

Successful implementation and design of an excavation remediation program is dependent upon the following key technical considerations

- Are the site soils amenable to bulk excavation?
- What is the local water table level, and would this impact the ability to excavate the required contamination?
- Is an appropriate treatment facility or landfill available to receive the excavated soils?
- Is pre-treatment on-site required to render soils suitable for acceptance at an off-site facility?
- Is suitable access available for excavation equipment, soil storage, transport vehicles and associated infrastructure?
- Are there time constraints that would bring excavation into consideration over other options?
- Are there sensitive receptors close to the site that might not be compatible with impacts arising from a soil excavation program?
- Are there geotechnical reasons that excavation may not be feasible (e.g. stability of adjacent buildings)?
- Is the expected order of cost to implement the excavation program suitable (this may be heavily influenced by cost of ex situ treatment or disposal)?

During the earlier stages of the remediation screening, it may be sufficient to generate broad estimates of soil volumes to obtain preliminary costs for transport and further treatment or disposal to allow comparison with other remediation options. However, prior to formulation of an RAP, it will be necessary to obtain more accurate estimates of the total volume of soil to be treated – this will also be required to enable firm costs to be supplied by remediation providers or landfill operators.

In general volume and mass should be estimated on an in-situ basis, requiring in situ density to also be characterised. Both volume and mass characterisation are used for commercial transactions, including quantities such as excavation volume and mass disposed. Moisture content is also an important consideration, because moisture can be lost (e.g. by free draining or air drying wet material) or added (e.g. rewetting dry soil after thermal treatment, or for dust suppression). Care should be taken to avoid adding excessive or unnecessary moisture (i.e. for other than dust or odour control) to soil destined for landfill disposal.

Direct reading instruments such as laser-induced fluorescence and membrane interface probes attached to various down-hole tools can be used to provide detailed logs of the subsurface and help delineate impacts. Results from these field screening tools can assist with decision-making in the field, such as:

- The location and extent of excavations to delineate contamination and whether the removal of additional soil is likely to be required; and/or
- A more focused sample collection (number and location) and the determination of which samples should be selected for laboratory analysis.

3.2 Categorisation of soil for disposal

If excavated soils are to be disposed of off-site to a landfill, it will be necessary to categorise the soils in accordance with the relevant jurisdiction legislation. At the time of publication, the relevant waste regulations for the classification and disposal of contaminated soils are contained in the following resources, as shown in Table 1.

Table 1: Waste regulations by jurisdiction.

Jurisdiction	Website
Australian Capital Territory	environment.act.gov.au/environment/ environment_protection_authority/business_and_industry/ wastemanagementandhazardousmaterials
New South Wales	epa.nsw.gov.au/waste/classification.htm
Northern Territory	ntepa.nt.gov.au/waste-pollution/guidelines/guidelines
Queensland	qld.gov.au/environment/pollution/management/contaminated-land/permits
South Australia	epa.sa.gov.au/xstd_files/Waste/ Information%20sheet/current_waste_criteria.pdf
Tasmania	epa.tas.gov.au/documents/ ib105_classification_and_management_of_contaminated_soil_2012.pdf
Victoria	epa.vic.gov.au/business-and-industry/guidelines/waste-guidance/industrial-waste-resource-guidelines
Western Australia	der.wa.gov.au/images/documents/our-services/approvals-and-licences/landfillwasteclassificationandwastedefinitions1996.pdf

Deciding on how soil is to be disposed of can be a complex matter, and very significant in terms of cost. In Australia, landfill levies have made the cost of landfill for more highly contaminated soil very costly in some jurisdictions (in the order of $1,000 per tonne), and this can be the single greatest cost for remediation involving excavation and disposal. Where the soil is highly contaminated, landfill disposal can be prohibited, and treatment is the only option.

Use and reuse of contaminated soil can also be a complicated matter depending on the jurisdiction, and reference should be made to the relevant regulations. Distinctions can be made with respect to whether soil is to be used on-site (which may allow contaminated soil to be used in locations where it will be safe to do so), or off-site (which may only allow soil that complies with certain requirements to be used and soil which does not comply with these requirements prohibited from off-site use). In some jurisdictions "use", "reuse" and "beneficial reuse" can have regulatory meaning and require that a benefit be demonstrated from the reuse (i.e. it does not merely constitute disposal).

Soils can be classified in situ (prior to excavation) or following placement of the excavated soil into stockpiles. There may be the requirement for segregation of soil into separate stockpiles based on different classifications, with some soil destined for reuse on-site, some for secure landfill, some for municipal landfill, and some appropriate for off-site use.

Although the in-situ classification avoids delays in waiting for sample results to categorise the soil for transport and disposal, it can lead to more conservative classifications given the inherent bias of investigation data to the more contaminated areas. In jurisdictions where disposal costs are significant, reclassification of excavated soil may provide the lowest cost approach.

Once the soils have been classified and the volumes to be disposed of are known, a suitable landfill (licensed to accept the relevant category of waste) can be selected and accurate costs sought.

3.3 Regulatory requirements

Regulatory approvals may not be required to undertake a simple small soil excavation program; however, some jurisdictions will have a quantity threshold which, if exceeded, will require regulatory approval. The requirement for an environmental impact statement may also be triggered for large remediation programs, depending on the jurisdictional requirements. Most jurisdictions will also require documented consideration of the hierarchy of remediation options before approving excavation as a remediation technology. Readers are directed to the NRF *Guideline on establishing remediation objectives* for further discussion on considering the remediation hierarchy of options when assessing remediation options.

In any event, "pollution" should not occur, in which contaminated material is allowed to leave the site and pollute adjacent land or pose a risk to persons or the environment. It is quite possible that this could occur unless appropriate measures are in place: this may be in the form of windblown dust arising during excavation, handling or from stockpiles; volatile emissions from excavated material; rainfall runoff containing contaminated material that flows onto adjacent land or into drainage lines or streams; inadequate provisions for containment of stockpiles and stockpile failure; and disposal of groundwater and rainwater that has collected in excavations.

It is essential to determine what approvals are required, and to ensure that these are complied with. The regulatory agencies (particularly the agencies responsible for protection of the environment, town planning and licensing of facilities) should be consulted to determine the specific requirements relating to obtaining the necessary approvals and licences, and controls that can be expected. The application of remediation works is often a matter of concern for the community and it can be expected that the regulatory agencies will be careful in applying their processes for permitting and approval.

3.4 Treatable contaminants and matrices

Excavation is applicable to most contaminants with no particular target group. Excavation may be followed by ex situ treatment (on-site or off-site), use or reuse or disposal to an approved other location (e.g. landfill).

Excavation is not limited to a particular matrix though different geology and lithology characteristics will affect the practicality and cost of excavation. Excavation can be applied to unconsolidated soils and wet material, though this will often require pre-treatment to improve consistency and stabilise material.

4. Treatability studies

Excavation of contaminated soil does not involve active treatment stages; it simply removes the contaminated material from the site for ex situ treatment or disposal.

However, treatability or pre-remediation studies may be relevant to determine:

- The extent and acceptability of odour and volatile emissions; this may require a health risk assessment to determine the risks posed and whether measures to limit odour or volatile emissions are required (such as limiting the active excavation area, limiting stockpiles, or providing enclosures).
- Potential asbestos fines/fibres and necessary management measures (such as air monitoring or providing enclosures).
- Occupational health and hygiene requirements for workers, particularly in enclosed spaces or operating excavation equipment.
- The practicability of excavation below the water table and the excavation characteristics of weathered rock and softer rock types.
- How material is to be classified for use or disposal, with testing to confirm that it will be able to be demonstrated that material complies with classification requirements (this may include leachability studies and statistical assessments).
- How residual material will be assessed to confirm that it complies with the remediation criteria, and how exceedances will be dealt with if exceedances occur.
- More detailed site investigation with the objective of delineating areas that do or do not require excavation and obtaining more certainty on the design of the excavation program and the requirements for segregation and use/disposal of material. Note that such investigations differ from investigations that are carried out to determine if remediation is required.

5. Design

The key stages of planning and executing an excavation program are:

- Investigation and analysis of the site.
- Definition of in situ volumes using the footprint and measured thickness.
- Definition of batter volumes using physical survey, AutoCAD® / geographical information systems software and measurement of footprint and thickness.
- Definition of layers of soil/ rock/ material types including an analysis of contaminant associations with the different materials.
- Identification of groundwater depth and excavation and soil quality below the water table.
- Assessment of dust, odour and volatile emissions and associated health and aesthetic risks. If odour control enclosures and / or emission control systems are required, these may need odour and volatile emission and assessment trials to inform the design.
- Characterisation and volume calculations for the types of contaminated soils (fill materials may include asbestos containing materials and other deleterious materials such as brick/concrete/glass fragments). In order to access the soils requiring excavation, it may be necessary to remove pavements, foundations and solid waste - an estimation of the mass of oversize materials will be useful in the remediation planning stages. Such material may require separate disposal to the impacted soils.
- Decommissioning of services such as gas, electricity, water, sewer and communications.
- Measure density and moisture content (or estimate) to calculate mass.
- Survey all site features including stockpiles and excavation voids.

When sampling and testing soils for designing an excavation plan, it should be remembered that the objective is not to characterise the condition of the overall site (although the sampling conducted may inform multiple characterisation objectives), but rather to obtain enough information to enable design of an appropriate excavation program. Depending on-site conditions, this may prompt a more detailed sampling program, for example if there are multiple lithologies with different characteristics, if the soils or contamination are particularly heterogeneous or if a significant fraction of oversize material is present which may be clean or have special treatment requirements (such as screening and crushing).

5.1 Excavation plan

All excavation programs should be undertaken in accordance with a site-specific excavation plan. The level of detail and complexity will vary according to site conditions and objectives but in general, excavation plans should contain the following information as a minimum:

- Define the extent (lateral and vertical) of soils present at the site that require removal (due to exceeding adopted criteria for site suitability). This should include detailed plans showing the lateral and vertical extent of excavations required;

- Identify which soils require removal from site and which are suitable for reuse on-site and that require treatment for reuse or disposal. The criteria that determine the requirements for reuse or disposal (such as landfill acceptance criteria) need to be established;
- Shoring or stabilisation required for excavation works (where relevant);
- Management of emissions (soil, dust, water, odour and vapour) during excavation works, including (if required) the design of an odour control enclosure and foundations and associated emission control system;
- Survey and tracking the fate of excavated materials (treatment, transport, reuse, recycling and/or disposal);
- Validation plan for excavations and final site conditions;
- Validation plan for materials to be used for backfilling;
- Backfilling excavations and compaction of fill to final site contours;

The excavation plan can be developed using an appropriate method, such as:

- Defining which layers of soil should be excavated (applicable if contamination levels are consistent across a specific geological layer, such as imported fill across a site);
- Defining excavation ‘cells’ (e.g. 5 x 5 m area, 0.5 m thickness) across a site and allocating a classification to each cell based on available data; or
- Use of statistical and spatial methods to assign classifications to calculated excavation cells with a defined extent and depth.
- For more complicated excavation programs it is generally helpful to produce a series of excavation plans that can be easily referred to and interpreted by the contractor, such as a series of 0.5 m ‘slices’ across the site showing the defined cells and their classification.

Any of these methods (or others not listed) may be appropriate depending on the characteristics of site soils, contamination and considering project specific objectives and needs.

In determining the material that requires excavation and removal, understanding the distribution of contamination and the basis for setting remediation criteria are important factors. In particular:

- On many sites the contamination can be “spotty” and highly variable in concentration. This is particularly the case with contamination present in particulate form, such as polycyclic aromatic hydrocarbons or heavy metals. Defining the area that is relevant in assessing exposure and health risk and over which the concentration can be averaged can greatly affect the quantity of soil that requires excavation and removal, and the use of statistical methods to support this is a key matter.
- Similarly, there can be systematic variations in contaminant concentration that are able to be distinguished, and therefore where excavation may or may not

be required. High densities of sampling may be necessary to resolve such situations and, although involving relatively high investigation costs, this may be cost effective in reducing the off-site disposal costs. Sampling and analysis methods that facilitate the obtaining large numbers of measurements may be helpful.

- Where highly variable concentrations occur, it is not uncommon to erroneously interpret individual high concentrations of contamination as being indicative of a "hotspot" where excavation is required; the use of step-out sampling (e.g. taking several samples within a metre of two of the high concentration location) can be revealing in demonstrating that the contamination is random and individual high concentrations are not associated with hotspots.
- The requirements relating to determining the soil that is not acceptable to remain on-site may vary from the requirements for acceptance of the excavated soil for reuse or disposal, and the sampling program should meet these various requirements. Where contaminant concentrations are variable, these issues may not be trivial. Note that leachate testing may be necessary for landfill disposal, and should be considered.
- Quantifying the uncertainty and reaching reliable conclusions regarding what excavation should take place and how compliance can be demonstrated are matters that require careful consideration and advice from persons with appropriate skills and experience.

5.2 Shoring or stabilisation

Depending on the depth of excavation, soil properties and site surroundings (e.g. proximity to existing buildings), it may be necessary to consult a geotechnical specialist to determine appropriate methods for shoring or stabilisation of the excavation. This may be required under safety legislation in some Australian jurisdictions and Safe Work Australia should be consulted. Shoring or stabilisation methods may include:

- Battering of excavation walls;
- Shoring of excavation walls;
- Dewatering to prevent groundwater ingress and destabilisation and collapse of the excavation;
- Planning of stockpile and plant placement to minimise load on excavation walls; and
- Use of sheet piles, secant piles or cutter soil mixing, which may also be helpful in preventing groundwater ingress to the open excavation.

Readers are directed to the NRF *Guideline on health and safety*, as well as the SafeWork Australia website (www.safeworkaustralia.gov.au) and publications, for more information.

5.3 Emissions management

Emissions management is an important aspect of any excavation program and can significantly add to the cost of a remediation program if environmental controls such as monitoring and control of emissions are required.

Every excavation program will require a system to be in place to minimise spreading of contaminated soil via machinery and vehicle traffic, as well as for containing stockpiled soils to prevent spreading of contamination via runoff, collapse or wind (dust).

Depending on the site conditions, contaminants and surrounding receptors, excavation programs may need to consider:

- Dewatering of excavations and management of waste water produced (e.g. storage and testing of water for disposal);
- Odour management for exposed soils on walls of excavations or in stockpiles (e.g. odour suppression sprays, plastic sheeting, or odour control enclosure with an emission control system); and
- Vapour emissions control for volatile contaminants (e.g. odour control enclosure with an emission control system).

5.4 Material tracking

For all excavation projects it will be important to collect information and documentation sufficient to track the fate of all soils excavated from the site. This may include:

- Keeping records of the volume and fate of each excavation cell or stockpile (e.g. Cell 1, excavated volume XX, transferred to stockpile A, transported off-site to Facility B for disposal);
- Keeping records of material imported to site for backfilling excavations (including validation information);
- Retaining records of truck movements and weighbridge receipts from transport companies and destination (landfill or treatment facility); and
- Tracking reuse of soils on-site (e.g. cell, excavated volume XX, transferred to stockpile B, reused on-site as backfill in north east corner).

In most jurisdictions, transport of contaminated soils will be regulated and it will be a legal requirement to maintain records of source, transport and destination of contaminated soils, as a minimum. Soil volumes and locations are commonly surveyed as part of the tracking process.

Where off-site landfill disposal is involved, documentation that adequately characterises the contaminant concentrations and demonstrates compliance with the landfill acceptance criteria will need to be maintained. In addition to contaminant concentrations, other factors such as odour and water content may affect acceptance.

For complex excavation programs it may be helpful to maintain a register of soil movements together with a photographic record so that a ‘soil balance’ can be produced at the completion of remediation to satisfy stakeholders (e.g. regulators, auditors) that the works have been adequately tracked and all contaminated soil can be accounted for. The complexity of this process should not be underestimated, particularly where soil may be moved from one stockpile location to another before final placement or removal, as the program progresses.

6. Validation

The following information describes the specific validation appropriate for excavation, to assist validation planning within the RAP. Readers are directed to the NRF *Guideline on validation and closure*.

As with all remediation programs it will be necessary to demonstrate that the final site conditions following completion of the excavation program are compliant with the defined acceptability criteria. For excavation programs this will generally consist of a validation sampling program (of sufficient sampling density) from the base and walls of the completed excavations to demonstrate that the required contamination has been removed. If some site soils were segregated for reuse on-site, then it will also be necessary to demonstrate that these soils are appropriate for such use. Likewise, any imported soils (e.g. to fill excavation voids) will need to be proven suitable for use.

Whilst not a contamination issue, it should also be confirmed that soils proposed for use on-site or importation to site for backfill are suitable from a geotechnical perspective and required compaction has been achieved where soil is placed.

The validation approach should verify that the impacted material has been removed by sampling the base and walls of the excavation and comparing analytical results against validation criteria. Validation should be tailored to specific site conditions and any relevant regulatory requirements, with appropriate sampling densities based on DQOs and the heterogeneity of the soil, sensitivity of proposed land use and type of contamination. The sampling frequency adopted should be supported by a statistically relevant assessment of the data.

Material imported to a site must be validated, with appropriate sampling frequencies and consideration of heterogeneity. Local regulatory guidance around validation of virgin excavated natural material and excavated natural material should additionally be sought.

Due to the simplicity of this method, multiple lines of evidence may not be required to validate that remediation has been successful. Validation should focus upon confirming that soils in the walls and base of the excavation, as well as the soils imported to the site to fill the excavation, meet the requirements of “clean” fill / validation criteria. This would be considered a primary line of evidence documenting reduction of contaminant concentration. It is noted that other lines of evidence may be required at a site where this remedial method is employed, should contamination be known or suspected to impact media other than soil.

7. Health and safety

Excavation poses a risk of exposure to site workers during the remediation work, via dust or vapour inhalation, or dermal contact with contaminated soils and associated emissions (soil, dust, water, odour, vapour, asbestos).

Excavation can also pose a risk of exposure to surrounding receptors, be they human (e.g. run off from soils or dust from the site, as well as offensive odours or health effects from vapours) or environmental (e.g. run off from soils or dust from the site to sensitive environments) or.

Some of the hazards associated with excavation and control mechanisms are outlined in Table 2. The list is intended to provide an indication of the hazards potentially associated with soil washing application. They will vary significantly from site to site and the list is not intended as a substitute for a detailed hazard assessment of the operation, which should be provided in the RAP.

Readers are directed to the NRF *Guideline on health and safety* for further information on health and safety on remediation sites, including risk assessment, the hierarchy of controls and suggested documentation.

Hazard	**Source of hazard**	**Suggested controls**
Site Contaminants	Releasing or encountering contaminants during excavation, storage or transport, via dust or vapour inhalation, or dermal contact.	Site workers: • Work 'up-wind' of disturbed soil, when possible. • Use enclosed excavators to minimise potential exposure to dust or vapour (where relevant). • Consider use of enclosures and emissions control if contaminant risks warrant this level of protection. • Ensure medical monitoring requirements as stipulated in the WHS Regulations are completed. • Use gloves and chemical protective clothing that are suitable for the task e.g. ensure they provide chemical resistance to the hazardous chemicals. • Use respiratory protection that is suitable for the task • Perform personal exposure monitoring for hazardous substances as identified in an occupational exposure risk assessment as per the Off-site receptors: • Implement good practice environmental management processes for construction sites including preventing run off from contaminated soils, preventing stormwater run off, dust suppression, odour suppression, protection of stockpiles, consider use of enclosures and emissions control if contaminant risks warrant this level of protection. • Ambient air monitoring where required.
Deep excavations	Falling into or being within an excavation when collapse of the excavation occurs.	• Security and control on access to excavations in accordance with regulations. • Minimising open deep excavations. • Proper shoring of excavations. • Use of high visibility barricades around the excavation. • Control on use of machinery within excavations and the excavation procedures.

Hazard	**Source of hazard**	**Suggested controls**
Stockpiles	Stability of stockpiles and danger associated with falling from them, or operating machinery	Procedures and controls relating to the construction of stockpiles and security associated with access to them.
Underground services	Danger arising from underground electrical services, high voltage or gas lines.	Dial before you dig, clearance programs, procedures.
Ergonomic Risks	Lifting or performing any other movement with too much force and/or in an awkward position, or repeating the lift/movement too often.	Site workers: • Provide conveniently located equipment for the job, like carts, adjustable work stations (operators), and correctly sized tools. • Train workers on ergonomic risks and prevention.
Thermal Heat Stress	Wearing chemical protective clothing.	• Perform a thermal stress risk assessment to identify necessary control measures in accordance with the, “Heat Stress Guide Developed for use in the Australian Environment” (AIOH).
Noise	Working in and around heavy plant	• Follow requirements in the Safe Work Australia Code of Practice, “Managing Noise and Preventing Hearing Loss at Work” and AS/NZS 1269. • Locate noisy operations away from other workers. • Isolate or insulate noisy equipment components. • Identify and mark areas requiring hearing protection. • Implement a Hearing Conservation Program. • Perform an occupational noise assessment to identify the need for additional control measures including identification of an appropriate class of hearing protection.

Hazard	Source of hazard	Suggested controls
Slips, Trips and Falls	• Storing construction materials or other unnecessary items on walkways and in work areas. • Creating and/or using wet, muddy, sloping, or otherwise irregular walkways and work surfaces. • Creating and/or using uneven terrain in and around work areas.	Site workers: • Keep walking and working areas free of debris, tools, electrical cords, etc. • Keep walking and working areas as clean and dry as possible. • Ensure use of PPE.
Moving Vehicles	Moving contaminated soil from excavation location to temporary stockpile storage or off-site transport vehicles.	• Train affected employees on limitations of equipment and drivers. • Set acceptable speed limits and traffic patterns around the site. Ensure that equipment has, and workers use, back-up alarms, mirrors, and seat-belts. • Conduct routine maintenance.

Appendix A – References

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