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TECHNICAL REPORT NO. 45

Societal perceptions on remediation technologies: guidance for engagement with residents

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April 2019

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Enquiries and additional copies:
CRC CARE, C/- Newcastle University LPO, PO Box 18, Callaghan NSW, Australia 2308
Tel: +61 (0) 2 4985 4941
Fax: +61 (0) 8 8302 3124
admin@crccare.com
www.crccare.com

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CRC for Contamination Assessment and Remediation of the Environment

Technical Report no. 45

Societal perceptions on remediation technologies:

Guidance for engagement with residents

April 2019

CRCCARE

A safer, cleaner environmental future

Executive summary

Significance: Remediation policies and guidelines are increasingly recognising the value of drawing on the knowledge and experiences of diverse stakeholders, including affected residents, to support technology selection, and to inform other related areas of remediation policy such as risk management and sustainability assessment. Despite policy support for these approaches, there is little understanding within the remediation industry of residents' perceptions or acceptance of the growing diversity of technologies that are being used to remediate contaminated sites. This document addresess this lack of understanding by providing a unique evidence-based understanding of residents' perceptions and acceptance of remediation technologies that can be used by those within the remediation industry to guide the development of plans for the remediation of specific contaminated sites.

Purpose: The purpose of this document is to assist the responsible party, remediation service providers, auditors, local governments, health professionals and environmental regulators to develop and implement plans for remediation using an evidence-based understanding of residents' perceptions and acceptance of remediation technologies. The document does this through guidance, in the form of evidence-based insights and questions, focused on how residents living near contaminated sites:

- **worry** about the application of remediation technologies in their local environments
- **perceive risks and benefits** from the application of remediation technologies in their local environments, and
- **accept** the application of remediation technology in their local environments. Residents' acceptance is understood as the residents' level of **support** for the application of the remediation technology in their local area, and the **choices** they make when deciding between different technologies that may be applied in their local area.

The guidance is relevant to both remediation planning and community engagement planning.

Evidence-base: The unique evidence-base used to construct this guidance document has been internationally peer reviewed, and is drawn from a detailed study of the perceptions and acceptance of different remediation technologies by 2953 Australian residents, 2009 of whom lived near 13 contaminated sites across Australia (Huynh *et al* 2017; Prior *et al* 2014; Prior 2016; Prior & Rai 2017; Prior *et al* 2017; Prior 2018). The sites were located in New South Wales, South Australia, the Australian Capital Territory, Tasmania, Queensland and Victoria. The 13 sites had a range of recognised environmental contaminants present, including solvents, hydrocarbons, heavy metals, asbestos and putrescible waste.

The guidance within this document, and evidence-base, were developed with support from the SA Environment Protection Authority, NSW Environment Protection Authority, Orica, Thiess Services, GHD Australia, LandCorp West Australia, NSW Health, and Queensland Health. The guidance within this document should be considered in conjunction with guidance in the National Remediation Framework, and any relevant state specific remediation policies and guidelines.

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- By a team including Jason Prior, with support from Dena Fam, Tapan Rai, Emma Partridge, Peter Rickwood, Ceridwen Dovey, Roel Plant, Aleta Lederwasch, Dustin Moore and Ben Madden from the Institute for Sustainable Futures at the University of Technology Sydney; Elisabeth Huynh and Jorge Arana from the Institute for Choice at the University of South Australia; and Phil Hubbard from the King's College London.
- Through the contributions made by 2953 Australian residents, 2009 of whom lived near 13 contaminated sites across Australia. The sites were located in New South Wales, South Australia, the Australian Capital Territory, Tasmania, Queensland and Victoria. These residents participated in telephone surveys, interviews and focus groups.
- With the ongoing support and guidance of a project reference group which comprised Andrew Pruszinski and Rebecca Hughes (SA Environment Protection Authority), James Stening (Orica), John Hunt (Thiess Services), Peter Nadebaum (GHD Australia), Niall Johnston (NSW Environment Protection Authority), Uma Rajappa (Queensland Health) Sharon Clark (Landcorp) and Adam Capon (NSW Health).
- With the aid of a series of workshops with the SA Environment Protection Authority and the NSW Environment Protection Authority that provided information and advice about the content and form of the Guidelines.

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1. Introduction

1.1 Background

Australia has an estimated 160,000 sites that are potentially contaminated, and experts suggest that only a tiny fraction of them are currently being remediated to remove risks to human health and the environment. The range of technologies that can be used to remediate these sites has increased significantly over the past few decades. Today, the breadth of possible technologies that can be used for remediation is far-reaching and includes thermal, biological, physical and chemical technologies.

Whilst expert views on what technologies should be used to remediate contaminated sites are important, in recent decades more inclusive and participatory approaches have been used to choose technologies based on the views of a multitude of stakeholders including affected residents (Pollard *et al* 2004; Bardos *et al* 2011; Benn *et al* 2009; Brown & Benn 2009; Couch & Coles 2011; CRC CARE 2019n; Hillier *et al* 2009; Sustainable Remediation Forum United Kingdom 2009; United States Sustainable Remediation Forum 2009). This approach is not based on a view that residents' views of remediation technologies are more important than those of experts, but on the understanding that residents provide alternative knowledge that may be useful to the evaluation of remedial technologies. There is a growing recognition that it is impossible for any single perspective, discipline, or knowledge to monopolise the answers and solutions to complex environmental challenges like contamination, and that the identification of solutions to these environmental challenges, like the selection of remedial technologies, requires insights from multiple stakeholders (Berkes *et al* 2013; Evans & Plows 2007; Huntington 2000; Raymond *et al* 2010; Ribeiro & Lima 2016).

Remediation policies and guidelines are increasingly recognising the value of drawing on the knowledge and experiences of diverse stakeholders, including affected residents, to support technology selection, and to inform other related areas of remediation policy such as risk management and sustainability assessment that can be enhanced through more holistic understanding (CRC CARE 2019l; EnHealth 2012; Sustainable Remediaton Forum Australia, CRC CARE & Australiasian Land and Groundwater Association 2011b). For example, remediation policies and guidelines increasingly acknowledge the value of residents' perceptions of risk, and more recently, their perceptions of the benefits associated with the remediation of contaminated environments (EnHealth 2012; CRC CARE 2019n). Despite policy support for these approaches, and a growing diversity of decision support tools, there is little understanding within the remediation industry of residents' perceptions or acceptance of the growing diversity of technologies that are being used to remediate contaminated sites.

This document seeks to address this lack of understanding by providing an evidence-based understanding of residents' perceptions and acceptance of remediation technologies that can be used by those within the remediation industry to guide the development of plans for the remediation of specific contaminated sites.

1.2 Evidence-base

This document builds on an evidence-base of how residents living near contaminated sites:

- **worry** about the application of remediation technologies in their local environments
- **perceive risks and benefits** from the application of remediation technologies in their local environments, and
- **accept** the application of remediation technology in their local environments. Residents' acceptance is made up of two parts. Firstly, residents' acceptance within the context of these guidelines is understood as the residents' level of **support** for the application of the remediation technology in their local area. Secondly, residents' acceptance within these guidelines is also understood to be defined by the **choices** they make when deciding between different technologies that may be applied in their local area to remediate an environment that has been polluted by contaminants.

The evidence-base used to construct this document has been internationally peer reviewed, and is drawn from a detailed study of the perceptions and acceptance of different remediation technologies by 2953 Australian residents, 2009 of whom lived near 13 contaminated sites across Australia (Huynh *et al* 2017; Prior *et al* 2014; Prior 2016; Prior & Rai 2017; Prior *et al* 2017; Prior 2018). The sites were located in New South Wales, South Australia, the Australian Capital Territory, Tasmania, Queensland and Victoria. The 13 sites had a range of recognised environmental contaminants present, including solvents, hydrocarbons, heavy metals, asbestos and putrescible waste. A detailed discussion of the conceptual frameworks and methodology used, and the evidence obtained, is presented in a series of peer-reviewed publications (Huynh *et al* 2017; Prior *et al* 2014; Prior 2016; Prior & Rai 2017; Prior *et al* 2017; Prior 2018). Figure 1 presents a conceptual overview of the study.

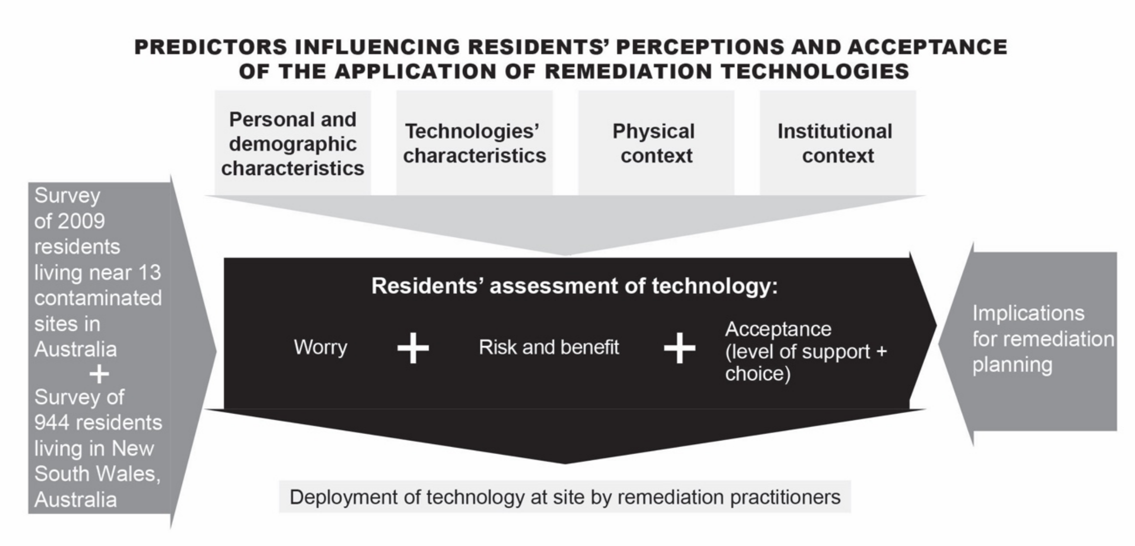


Figure 1. Overview of the study that informed this document.

1.3 Purpose

The purpose of this document is to assist the responsible party, remediation service providers, auditors, local governments, health professionals and environmental regulators to develop and implement plans for remediation using an evidence-based understanding of residents' perceptions and acceptance of remediation technologies.

The document does this through guidance, in the form of evidence-based insights and questions, that are provided in matrices in sections 3, 4, and 5 of this document. These evidence-based insights are drawn from the evidence-base outlined in section 1.2. For each evidence-base insight that is presented, we pose a question(s) for consideration when developing and reviewing plans for the remediation of a contaminated site. For each question, we provide an indication of whether the question is relevant to remediation planning, to community engagement planning, or possibly both.

The guidance within this document should be considered in conjunction with guidance in the National Remediation Framework, including the *Guideline on Stakeholder Engagement*, and the technology assessment and implementation guidelines (CRC CARE 2019c, d, e, g, h, I, m, n). We also recommend that the guidance in this document be considered in conjunction with any relevant state specific remediation policies and guidelines.

1.4 Structure

This document is organised into the following sections (also see figure 2):

- **Section 1** provides the background and purpose for the document.
- **Section 2** provides the key steps for using the document, including questions and issues to consider before using it.
- **Sections 3, 4 and 5** are the guidance portions within the document. Building on the evidence-base outlined in section 1.2, each of these parts pose a series of evidence-based insights and questions that may be considered when developing plans for the remediation of specific contaminated sites. Each section is based on key characteristics of residents' perceptions and acceptance of remediation technologies including worry (section 3), risk (section 4) and benefit perceptions and acceptance (support and choice, section 5).
- A **glossary of key terms** is provided in section 6.

Figure 2. Overview of the structure of the document.

2. Preparing to use the guidance sections: three steps

This section provides an overview of the three steps that need to be considered when preparing to use the guidance, in the form of evidence-based insights and questions, in sections 3, 4 and 5 of this document. Those who have read this section can use the quick checklist in section 2.4.

2.1 Step 1: where and when to use the guidance sections

The evidence-based insights and questions presented provide a means of bringing residents, and their perceptions and preferences regarding remediation technologies, into dialogue with the practitioners who draft and implement plans for the remediation of specific contaminated sites.

The evidence-based insights and questions can be used to inform:

- remediation planning for specific sites, and
- community engagement planning for specific sites.

The evidence-based insights and questions can inform these plans in two key ways:

- to provide guidance during the developmental phase of the plans, and
- to assist with providing comment on drafted plans (e.g. by environmental regulators or local government to responsible parties).

Knowledge about residents' perceptions and preferences about remediation technologies is not necessarily more important than expert knowledge. Rather, residents provide different forms of knowledge that may be of value in developing plans for the remediation of specific contaminated sites (Delgado *et al* 2011; Irwin 2006). To value this knowledge requires a degree of openness on the part of the experts involved in remediation, and an emergent understanding that the remediation process must be open to being influenced by the perspectives and experiences of those who stand to be affected by a course of action, including residents, if experts are to avoid making self-serving or narrowly-focused decisions about remediation technologies (CRC CARE 2013n; O'Riordan & Cameron 1994; Sustainable Remediation Forum Australia, CRC CARE & Australasian Land and Groundwater Association 2011a; United States Sustainable Remediation Forum 2009).

2.1.1 Remediation planning

Remediation planning normally relates to a specific site or area. Remediation plans and proposals involve many stages, some of which may occur in sequence and/or in parallel.

Figure 3 provides a generic conceptualisation of the remediation process. This is not intended to be a realistic depiction of remediation – these processes are rarely simple or linear, and variations occur from site to site. This generic conceptualisation is intended to provide an understanding of the general components of remediation processes.

Remediation planning, as depicted in figure 3, can be broken into three key stages:

1. identifying remedial options

2. selection of remedial technologies/treatability studies, and
3. application of remedial technologies.

The first stage involves a detailed appraisal of the remediation options available. Following the detailed options appraisal, one or more technologies or management solutions are selected as appropriate to treat contaminants at the site, taking into consideration site-specific conditions. Treatability studies may be required at this stage to further assess the applicability of the technologies.

The evidence-based insights and questions regarding residents' perceptions and acceptance of technologies presented in sections 3, 4 and 5 has application across the three key stages of remediation planning.

Case study 1 discusses one of many ways in which the evidence-based insights and questions detailed in sections 3, 4 and 5 might be used during the development of a remediation plan for a specific site or series of sites.

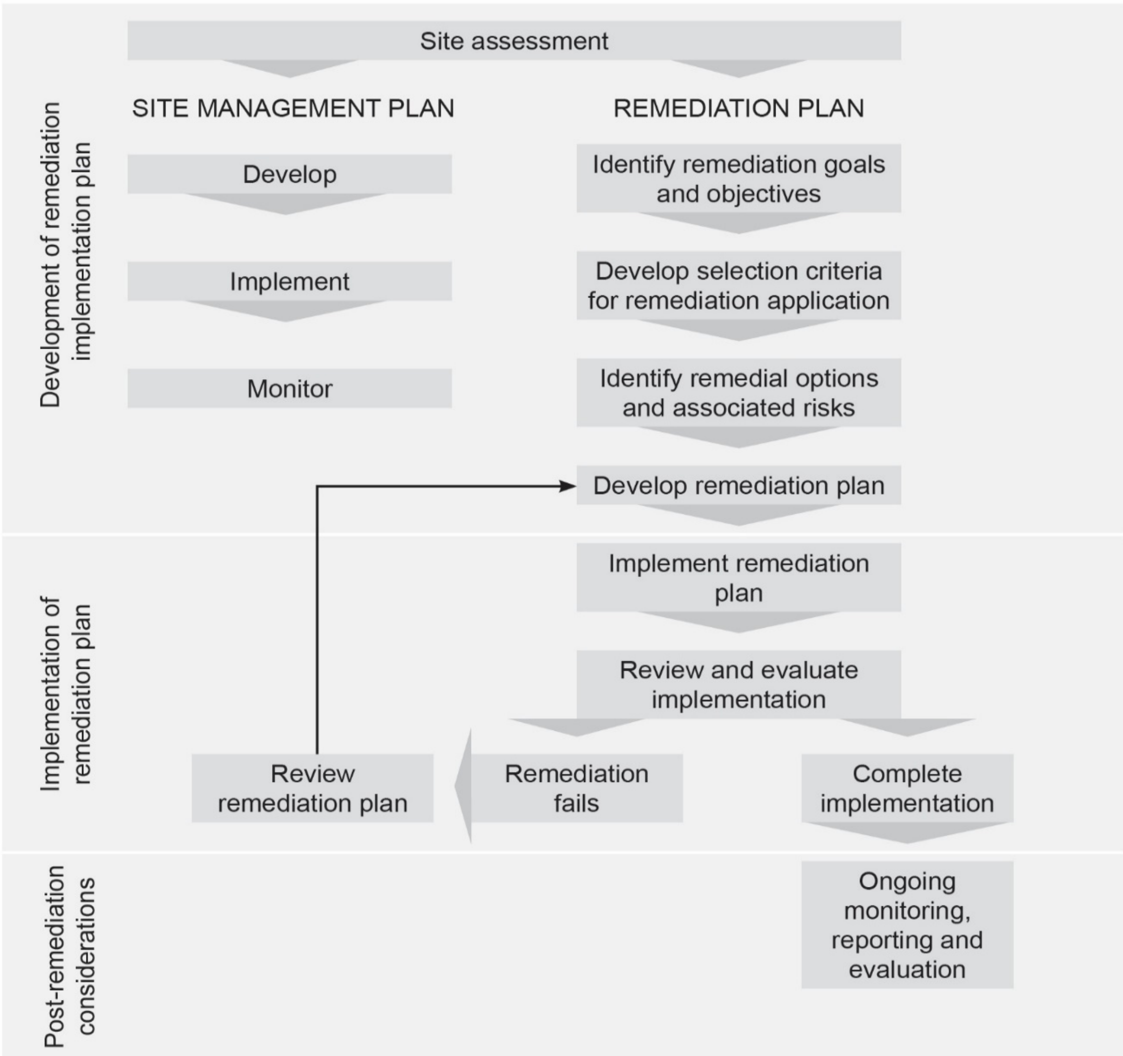


Figure 3. Overview of the remediation process. Groupings on the left indicate how this process relates to the stages identified in the overview provided in the National Remediation Framework.

Case study 1: An example of how to incorporate the guidance in this document into a remediation plan

This hypothetical case study provides a brief overview of how the evidence-based insights and questions outlined in this document might be considered when developing a remediation plan. It is worth noting that there is no single way in which the evidence-based insights and questions presented may be used in remediation plans. The hypothetical scenario presented here involves a remediation expert who regularly develops remediation plans for petrol stations.

Hypothetical scenario

Underground storage systems from former petrol stations are a common source of contaminants in Australia. These former petrol stations are often found near residential areas. The contaminant types often found at these sites include petroleum hydrocarbons and lead with remediation often involving air monitoring and capping or removal of contaminated soil.

A remediation expert who had developed remediation plans to address contaminants at several former petrol stations became aware that the proximity of these former petrol station sites to residential areas often resulted in nearby residents expressing concern about the potential risks the contamination from these sites posed to their health, and that the contaminant may be migrating through the groundwater and soil to nearby residential properties. The remediation expert was also aware that residents had expressed concern about whether the types of remediation approaches being used at the sites, and their by-products, might pose a risk to residents' health.

Given the perceived health risks that nearby residents had expressed at previous sites, and instances where these concerns often emerged in local media, the remediation expert decided that it would be prudent to incorporate a section on resident risk perceptions into the remediation plans developed for future sites. The remediation expert saw this as a means of developing a more holistic assessment of the types of risks that might arise from technologies during the remediation process. One source of information that the remediation expert decided to use to inform their understanding of residents' risk perception for technologies within the remediation plans developed were the evidence-based insights and questions detailed in section 4.4 of this document. The remediation expert found the evidence-based insights and questions on how technology characteristics affect residents' risk perceptions as particularly useful (see RB4.1 through RB4.7 in section 4.4). This section of the document explains the types of technology characteristics most likely to affect a residents' risk perception. The remediation expert understood the importance of using the evidence-based insights and questions within this document in conjunction with reviewing the context of the actual site (see section 2.2.2).

2.1.2 Community engagement planning

Community engagement planning, like remediation planning, normally relates to a particular site or area. Community engagement planning provides a key vehicle for framing how those responsible for the remediation process and their remediation service providers, engage with stakeholders, including residents, who might be affected by the remediation processes associated with a nearby contaminated site. Community engagement planning aims to address the affected stakeholders' representation and participation in processes, such as remediation, that may affect or impact them and their environment.

The purpose of community engagement planning is:

- to help identify crucial stages or criteria in a process like remediation that might prompt engagement, and
- to help prepare for those upcoming engagement activities.

Community engagement plans are often initiated during the early stages of the remediation process, at the site assessment stage, and they are often implemented right through to the ongoing monitoring, reporting and evaluation stage (see figure 3). Given the inherent complexity and challenges of remediation processes, the need for community engagement planning may change over time, so there is an ongoing need to frequently re-evaluate community engagement plans through the life of a remediation process.

There are several broad levels of engagement that can be used within community engagement plans (Arnstein 1969; Beierle & Konisky 2000; Freudenberg 2004; Gallagher & Jackson 2008; Murdock *et al* 2005; Reed 2008; Wakefield *et al* 2001). Each of these requires different commitments from those implementing the plan and the stakeholders. The levels reflect a spectrum of degrees of engagement that range from providing information through to collaboration and empowerment. In the context of remediation technology selection, these levels include:

- **informing** stakeholders, including residents, about technologies that have been selected to clean-up or manage contaminants associated with a site.
- **Consulting** with stakeholders, including residents, about remediation technologies that have been selected to remediate a site to obtain feedback while providing them with a clear explanation of how their feedback will be used to inform the selection of a remedial option for the site.
- **Involving** stakeholders, including residents, in the technology selection process by working directly with them in mechanisms such as community committees, to ensure that there is a common understanding of the issue(s), and that residents' perceptions, concerns and aspirations are reflected in the technology approaches that will be used in the remediation. This is a two-way exchange of information that encourages discussion and provides residents with an opportunity to influence the outcome.
- **Collaborating**, that is, building a working partnership between the responsible party and the stakeholders which enables the incorporation of stakeholders' input and advice into technology selection, and the joint formulation of technology solutions and/or options.
- **Empowerment**, where the remediation service providers and responsible party give the stakeholders, including residents, some degree of power in making the final decision about technology options that may be used at a given site.

The evidence-based insights and questions regarding residents' perceptions and acceptance of technologies presented in sections 3, 4 and 5 can be used to support the development and implementation of community engagement planning through a deeper understanding of how residents' worries, their perceptions of risks and benefits, and their acceptance of remediation technologies are affected by diverse aspects of their lives.

Case study 2: An example of how to incorporate the guidance in this document into a community engagement plan

This hypothetical case study provides a brief overview of how evidence-based insights and questions outlined in this document might be considered when developing a community engagement plan. It is worth noting that there is no single way in which the evidence-based insights and questions presented may be used in community engagement plans. The hypothetical scenario below involves an old gas works site in an Australian city.

Hypothetical scenario

The hypothetical gas works site operated between the 1800s and 1960s. The site is approximately 1 hectare. Significant contamination exists at the site, predominantly related to its former use as a gas works as well as other industrial uses. Contaminants include polyaromatic hydrocarbons, petroleum hydrocarbons, phenols, monoaromatic hydrocarbons, heavy metals, ammonia, total cyanides and soluble sulfates. Offsite migration of contamination through groundwater was likely. Hazardous materials at the site included asbestos. Remediating the site may last many years and the cost is expected to be significant. As part of the remediation process the responsible party employed a community liaison consultant to engage with residents near the site.

To develop the community engagement plan for the site, the community liaison consultant drew on a range of remediation and policy guidance resources (see section 2.2.3 for suggestions), including a draft version of this document. The community liaison consultant was particularly interested in using the evidence-based insights and questions in section 5 of this document to provide evidence for residents' acceptance (support and choice) of different remediation technologies that might be used at the site (see section 5.4). The community liaison consultant understood the importance of using evidence-based insights and questions in conjunction with a review of the context of the actual site (see section 2.2.2). The details within this document provide an evidence-based understanding of why the community engagement plan might need to address particular issues.

The evidence-based insights and questions in section 5 provided the community liaison consultant with several points they could use as guidance during the development of the community engagement plan (see section 5.4), including the need for understanding:

- demographic characteristics of the residents in the local area likely to be affected and their level of support for remedial technologies at the site (e.g. household tenure and income level, see A1.1 and A1.2 in section 5.4).
- Transportation of the contaminant through the local streets as part of a remedial solution (e.g. dig and dump) is likely to affect residents' level of support the remedial option (see A2.1 in section 5.4).
- Trust, including trust between the responsible party and the residents which will play a key role in residents' level of support for remediation technologies that are applied in the local area (see A3.1 in section 5.4).
- The characteristic of a remediation technology is likely to affect residents' levels of support for remediation technology (e.g. effectiveness, safety, containment, location, naturalness amongst others, see A4.1 through A4.10 in section 5.4).

The community liaison officer's attention was drawn to the fact that different types of remediation technologies have reputational effects (stigma) which influence the level of support received from residents (see A4.1 in section 5.4).

The community engagement plan being developed by the community liaison consultant sought to engage with the community through a variety of channels e.g. a bi-monthly newsletter, 1800 community contact line, project website, updates in local newspapers, site tours, community liaison committee, planning open days, information sessions, and a six-week public exhibition of the draft remediation options plan. The points mentioned above proved useful to the community liaison consultant as they were investigating how they would engage with residents through the above channels about various remediation options that may be used at the site.

For example:

- The evidence-base provides insight on the possible effect of transporting the contaminant through local streets and how this might influence residents level of support for remedial options. The community liaison consultant therefore needs to provide information about possible remedial solutions for the site to clearly indicate if they include transportation through local streets, as well as talking with the remediation engineers to determine if other transport solutions might be possible (e.g. removal by barge down a river).
- Whilst trust cannot be manufactured, the evidence-based insight that trust plays a key role in residents' levels of support for the application of remediation technologies. The community engagement plan needs to set in place procedures that ensured that all communications about the selection of remedial technologies for the site be as transparent and well documented as possible.
- The community liaison consultant could tailor information to reflect the characteristics of the technologies of most importance to residents. Furthermore, the evidence-based insights from this document outlines statements commonly used by residents to negotiate support for different.
- Remediation technologies and a series of questions that residents are likely to use when discussing the selection of remediation technologies (see A5.3 in section 5.4).

2.2 Step 2: using the guidance sections in context

The use of the evidence-based insights and questions presented in this document to inform the development of plans for the remediation of a contaminated site needs to be considered in conjunction with an understanding of the:

- technology types that could be used to remediate contaminants associated with that site
- actual context of the residents who are living near that site, and
- policy context of that site.

2.2.1 Consider the technology types

The technology types envisaged in the evidence-based insights and questions in this document have different targets, mechanisms, and capabilities. Each technology can be used to target specific contaminants in particular settings. We worked with industry experts to develop a high-level typology that could be used within this document: **biotechnologies, thermal technologies, chemical technologies, and physical technologies**. These remediation types are explained further in table 1.

This broad typology enables the evidence-based insights and questions in this document to remain relevant in light of the growing diversity of remediation technologies that are being used for the remediation of contaminated sites. In this document, residents' worries, and their perceptions of the risks and benefits associated with particular technologies, and their acceptance of particular technologies, are discussed in relation to the following four types of remediation technologies.

Table 1. Remediation types with examples

Bioremediation	Thermal remediation	Chemical remediation	Physical remediation
The use of biological technologies in the form of microbes, fungi or enzymes to clean up contaminated land and ground water. Bioremediation technologies include: • **Microbial bioremediation** (in-situ) utilises microbial activity to remove contaminants in groundwater, waste or soil, and involves delivering something that can stimulate native microorganisms that can degrade contaminants, or a microbial culture to the contaminated medium that is capable of degrading contaminants. • **Phytoremediation** (in-situ) uses plants to clean up contaminated soils and groundwater. This process takes advantage of the ability of plants to take up, accumulate, stabilise and/or degrade contaminants in soil and groundwater.	The use of heat to de-contaminate an area. This is done onsite (in-situ) (e.g. steam injection, resistance heating and conductive heating) or by carrying out the treatment of excavated soil onsite (ex-situ) or offsite (ex-situ). In particular, thermal treatment is used to treat recalcitrant compounds such as persistent organic pollutants. Thermal technologies include: • **Thermal desorption** (ex-situ onsite) involves excavating and heating soils so that contaminants are vaporised and then collected and treated by other means. • **Incineration** (ex-situ offsite) involves excavating and heating soils so that the contaminants are destroyed. Thermal desorption differs from incineration in that it does not aim to destroy the organic matter but rather to change the form to a more treatable one. • **Thermal vapour extraction** (in-situ) involves injecting heat into the soil or waste so that contaminants are vaporised and extracting the vapour.	**T**he use of chemical reagents to oxidise or reduce contaminants, particularly in groundwater, although the method can extend to soils. There are a number of chemical oxidants that can be used to treat chlorinated solvents, and certain mobile heavy metals. Chemical technologies include: • **Chemical treatment** (in-situ) generally involves the injection of chemical oxidants or reductants into groundwater or soil, which leads to the destruction of the contaminant or its transformation into something safer. • **Nanoremediation** (in-situ) involves introducing chemical substances containing microscopic particles called nanoparticles to destroy or degrade the contaminant in the soil or groundwater to reduce contamination to an acceptable level. • **Permeable reactive barrier** (in-situ): This approach involves introducing a chemical treatment wall into the groundwater flow. As contaminated groundwater passes through the treatment wall, the contaminants are either trapped by the treatment wall or transformed into harmless substances that flow out of the wall.	The use of a range of physical techniques such as vacuum extraction (to remove contaminants in vapour form), soil washing, and separation. Excavation and removal of contaminated soil and disposal in landfill is a very common method of physical remediation, although the increasing costs of landfill disposal are making this technique less widely used. Physical technologies include: • **Encapsulation** (in-situ): This technique involves the physical isolation and containment of the contaminated material. The impacted soils are isolated by low-permeability caps, slurry walls, grout curtains, or cut-off walls. • **Immobilising/stabilisation** (in-situ, ex-situ) generally refers to a process that reduces the risk posed by a waste or soil by converting the contaminant into a less soluble, immobile, and less toxic form. • **Mining** (ex-situ onsite, ex-situ offsite) involves excavation, screening and separation and recycling of all old landfill material. Unusable or contaminant-producing materials are then stored. • **Dig and dump** (ex-situ offsite) involves the excavation and removal of the contaminated soil from the site and its transportation to a landfill site where it is stored and monitored.

Table 2. Suggestions and questions to consider when developing an understanding of the context of the plan

Consider the following in relation to residents:	**Consider the area surrounding the contaminated site:**	**Consider the impacts of the contaminants and remediation technologies:**
• key characteristics of the existing resident population and the future (projected) resident population including size, age, household composition, socio-economic status and ethnicity • identification of vulnerable, disadvantaged or at-risk groups in the local population, and • whether the residents have already been consulted.	• Where is the site? • What is there at present? • What is in the areas around it?	Impact is about how the contaminant, or the remediation technology might impact on community members' access to opportunities and resources and how it might affect their daily lives (health, safety, open space, transport, housing etc.). • Who will most likely be affected by the contaminant and the remediation technology? • What is known or understood about the sections of the community most likely to be affected? • What will the nature of the effects be? • How do you know this is likely to happen (what is the evidence)? • How likely is it that this will occur?

2.2.2 Consider the residents' actual context

When developing or reviewing plans for the remediation of a contaminated site it is important that the evidence-based insights and questions presented in this document be considered in conjunction with a review of the affected residents' actual context. This review should consider:

- the profile of affected residents
- the area surrounding the contaminated site, and
- the impacts of the contaminants and remediation technologies.

For greenfield and brownfield sites, it can sometimes be difficult to identify who these residents are. They could be the existing residents near the contaminated site, future residents, or both, depending on the lifespan of a remediation project. It is important to understand the physical and social contexts of the residents and to identify who in existing or future resident populations may be affected. Whilst this information can be obtained through engagement with existing residents, it can also be obtained through discussions with others, such as council planners, who may be able to clarify issues about the changing residential population. Information can also be sourced on residents through such sources as the Australian Bureau of Statistics.

Table 2 presents several suggestions and questions that can be used to develop a better understanding of the residents' actual context. The scale of the project will determine the level of detail at which these questions need to be answered.

2.2.3 Consider the remediation policy and guidance context

The evidence-based insights and questions this document should be considered in parallel with existing remediation policies and guidelines that provide guidance for the development of plans for the remediation of specific contaminated sites. As discussed, remediation policies and guidelines increasingly highlight the importance of considering residents' perceptions and experience when developing plans for management and remediation of contaminated sites (CRC CARE 2019n). Despite these developments, there has been little to no evidence available on residents' perceptions and acceptance of technologies to support this emerging policy approach. This document seeks to address this current knowledge gap. Building on the evidence-base discussed in section 1.2 of this document, the evidence-based insights and questions presented here provide a means of bringing residents perceptions and preferences regarding remediation technologies into dialogue with the practitioners who draft and implement plans for the remediation of specific contaminated sites (Huynh *et al* 2017; Prior *et al* 2014; Prior 2016; Prior & Rai 2017; Prior *et al* 2017; Prior 2018). When developing these plans, we recommend that the guidance in this document be considered in conjunction with the National Remediation Framework and other relevant national guidance (CRC CARE 2019n; National Environment Protection Council (NEPC) 2013). We also recommend that the guidance in this document be considered in conjunction with any relevant state specific remediation policies and guidelines.

2.3 Step 3: how to use the guidance sections

Once the type of plan to be developed or evaluated has been identified, and broader context specific information has been collected, the consultant will be ready to consider the guidance in the form of evidence-based insights and questions.

2.3.1 Consider residents' perceptions and acceptance

The evidence-based insights and questions in sections 3, 4 and 5 are focused on residents' perceptions and acceptance of remediation technologies, and do not focus on residents' perceptions of contamination:

- Section 3 explores how residents **worry** about different remediation technologies that are being applied within their local area.
- Section 4 explores how residents **perceive the risks and benefits** of different remediation technologies that are applied in their local area.
- Section 5 explores the extent to which residents **accept (support + choose)** different remediation technology approaches that are applied in their local area.

In sections 3 and 4, we treat worry and perceived risk as distinct concepts. Whilst worry and perceived risk are sometimes discussed together, given both refer to potential negative consequences, there is strong evidence to suggest they are best treated separately (Baron *et al* 2000; Loewenstein *et al* 2001; Schmiege *et al* 2009; Sjöberg 1998; Sjöberg 2004; Sjöberg 2006). Understanding that some may feel uncomfortable developing plans that include the word worry, the word concern/concerns may be a useful substitute.

Risk and benefit perceptions are considered together in section 4. We consider risks and benefit perceptions together because one of the evidence-based insights (RB5.1) presented indicates that residents' risk and benefit perceptions are interconnected, and that an inverse relationship exists between them. Thus technologies that are judged high in risk tend to be judged low in benefit, and vice versa. Arguably, this inverse relationship is indicative of an interconnection of risk and benefit in people's minds, an interconnection linked to a person's overall evaluation of a technology (Alhakami & Slovic 1994).

2.3.2 Consider the evidence-based insights and questions

Sections 3, 4 and 5 each contain a series of matrices containing evidence-based insights on residents' perceptions about remediation technologies that are applied in their local area, and their acceptance of these remediation technologies (see sections 3.4, 4.4 and 5.4). These evidence-based insights are drawn from the evidence-base discussed in section 1.2 of this document.

These matrices present evidence-based insights on how residents' levels of worry, risk and benefit perception, or acceptance for the application of a remediation technology in their local area might be affected by the:

- **residents' personal and demographic characteristics** (e.g. gender, income, education, children living in the home).[1]
- **Residents' physical context** (e.g. transportation of contaminants through local streets, sense of place, proximity, impact of contamination on daily life, amenity impacts).[2]
- **Institutional context**, that is, the ways in which institutions engage with residents about contaminated sites and their remediation affect residents' perceptions and acceptance of remediation technologies (e.g. trust, regulation, confidence in experts, language used by organisations to communicate with residents).[3]
- **Technology characteristics**, which refers to the attributes of the remediation technologies that affect residents' perceptions and acceptance of those technologies (e.g. type, containment, controllability, location, naturalness, plausibility, and safety).[4]

In addition to evidence-based insights into factors that affect residents' levels of worry, perceived risk and benefit, and acceptance for the application of remediation technology in their local area, these matrices also provide other evidence-based insights, such as: the object of residents' worries, and risk and benefit perceptions (e.g. human health, safe ecosystem services) and how residents negotiate acceptance (e.g. the norms and rules they might use to negotiate their support for the application of technology in their local area).

For each evidence-based insight that is presented within the matrices we pose a question(s) for consideration when developing and reviewing plans for the remediation of a contaminated site. For each question, a dot in the relevant column provides an indication of whether the question is relevant to remediation planning, to community engagement planning, or possibly both.

For simplicity, questions are phrased in a way that might initially suggest that a yes/no

[1] The current focus within remediation guidelines is upon the effect of demographic characteristics on residents' levels of perceived risk regarding the contaminant, not upon their effect on perceptions and acceptance of remediation technologies. These guidelines recommend that demographic characteristics be considered in community engagement planning (CRC CARE 2019n). Demographic characteristics considered include age, gender, education, income (CRC CARE 2019n).

[2] The current focus within remediation guidelines is upon the effect of physical context on residents' levels of perceived risk for the contaminant, not upon their effect on perceptions and acceptance of remediation technologies. The guidelines foreground the importance of physical context for community engagement planning and remediation planning associated with contaminated sites. Physical context issues considered in the current policy include amenity impacts, proximity, extent and impact of the environment contamination on a resident's daily life (CRC CARE 2019n).

[3] Institutional context is a focus of remediation guidelines. They highlight the importance of considering the institutional context in development of community engagement planning and remediation planning. Trust amongst stakeholders is understood as paramount to remediation processes, as is confidence in the experts carrying out the remediation and the way in which communication occurs during the remediation process. Issues considered include trust, residents' confidence in experts, language used to communicate with residents (CRC CARE 2019n).

[4] Some existing remediation guidelines briefly note that technology characteristics will affect residents' risk perceptions (CRC CARE 2019n). In more recent guidance, there is an increased recognition of the importance of considering stakeholder perceptions and acceptance of remediation technologies. For example, each of the National Remediation Guidelines for performing remediation options assessments asks 'is it likely that other stakeholders (such as local government or members of the public) will accept the use of the technology, particularly those stakeholders that have a significant bearing on whether the technology is applied at the site?' (e.g. CRC CARE 2019a). Technology characteristics considered in current guidance include the technologies' effectiveness, safety, economy, containment, controllability, location, un\proven, naturalness, duration (CRC CARE 2019a, I, j, k, l, o).

answer is expected, however, this is not the intention. Mostly there will not be a categorical yes/no response and often the context, complications and uncertainties will necessitate contingent answers. The extent to which sections 3, 4 and 5 are used will depend on the experience of the individual user and the nature of the plan being developed or reviewed.

The nature of the evidence-based insights and questions presented in this document means that there may be overlapping and interrelated issues across the sections. This has led to some repetition of questions across sections. For example, issues to do with trust are relevant to residents' worry, risk and benefit perceptions, and their acceptance of remediation technologies. This is considered to be a positive feature as it serves to reinforce key issues and emphasise the interrelated nature of the diverse factors that affect residents' perceptions and acceptance of remediation technologies.

2.3.3 Consider how you will use the evidence and questions

The evidence-based insights and questions presented in sections 3, 4 and 5 are primarily intended to assist the responsible party, remediation service providers, auditors, local government, health professionals and environmental regulators to develop and review plans for remediation using an evidence-based understanding of residents' perceptions and acceptance of remediation technologies. While there is an emphasis on using these sections for the development and review of plans, it is important to recognise that there may also be circumstances where the evidence-based insights and questions are used to inform participation in meetings, discussions and workshops where the focus is on verbal advice and dialogue.

There is no single way in which the evidence-based insights and questions presented here may be used in plans. The development of plans derived from the evidence-based insights and questions in these sections requires careful consideration. If providing advice on a plan, it is advisable to speak with the person who will be the recipient of the advice when you have a reasonable idea about what your advice will include. It is important to ensure that the advice will be useful and relevant, especially if it is not entirely supportive of the plan in question. Using evidence to support recommendations is important.

2.4 Quick guide to this document

Table 3 is a quick guide, developed for users of this document to simultaneously obtain an overview of the key steps for preparing to use sections 3, 4, and 5 and an overview of the content of these sections. Table 3 includes references to sections and matrices (and questions within the matrices) referred to in figure 2. Purple coding refers to considerations explained in section 3 (worry), orange refers to section 4 (risk and benefit perceptions), and green refers to section 5 (acceptance).

Table 3. Quick guide

Step 1: when and where to use the guidance sections						
• Remediation planning for specific sites	☐	Sect 2				
• Community engagement planning for specific sites	☐					
Are you seeking to use the guidance to inform the plan in one of the following ways:						
• to provide advice or input during the developmental phase of the plan	☐					
• to assist with providing comment on a drafted plan (e.g. by EPA representatives or local councils to responsible parties)	☐					
Step 2: using the guidance sections in context						
Which types of technologies are being considered in the plan:						
• bioremediation	☐					
• thermal remediation	☐					
• chemical remediation	☐					
• physical remediation.	☐					
Have you considered the residents' actual context:						
• profile of residents living near site	☐					
• profile of the site and area surrounding the site	☐					
• profile of the impacts of the contamination and remediation on the residents.	☐					
Have you considered the policy context:						
• National and state policy and guidance	☐					
• National Remediation Framework	☐					
Step 3: using the guidance sections						
• worry about technologies	☐	Sect 3				
• perceived risks and benefits of technologies			☐	Sect 4		
• technology acceptance (choice + support)					☐	Sect 5
Consider the evidence-based insights and questions within the guideline sections						
Does the plan consider resident's personal and demographic characteristics:	☐	W1		RB1	☐	A1
• gender effects on residents' perceptions	☐	W1.1				
• age effects on resident's perceptions	☐	W1.2				
• income effects on resident's perceptions and acceptance	☐	W1.3			☐	A1.1
• household tenure (rent or own) affects resident's acceptance					☐	A1.2
• the effects of having children living in a household on a resident's perceptions	☐	W1.4				
• the effects of personal motivational values on resident's acceptance					☐	A1.3
Does the plan consider the residents physical context:	☐	W2	☐	RB2	☐	A2
• impact of the contaminant on the daily life of residents affects their perceptions	☐	W2.1	☐	RB2.1		
• extent to which the transportation of the contaminant medium impacts on residents' perceptions and acceptance	☐	W2.2	☐	RB2.2	☐	A2.1
• how a resident's sense of place affects their perceptions	☐	W2.3				

Does the plan consider the institutional context:	☐	W3	☐	RB3	☐	A3
• the effect of residents' general trust in others on their perceptions and acceptance			☐	RB3.1	☐	A3.1
• the effect of resident's collective trust in companies, research institutions and government on their perceptions	☐	W3.1	☐	RB3.2		
• the extent to which a resident's confidence in experts impacts their perceptions	☐	W3.2	☐	RB3.3		
• the language used to engage with residents affects their perceptions	☐	W3.3	☐	RB3.4		
Does the plan consider the technology characteristics:	☐	W4	☐	RB4	☐	A4
• different types of technologies and reputational effects	☐	W4.1	☐	RB4.1	☐	A4.1
• technologies based on their effectiveness	☐	W4.2	☐	RB4.2	☐	A4.2
• technologies based on their safety			☐	RB4.3		A4.3
• technologies based on their economy	☐	W4.3			☐	A4.4
• technologies based on their containment	☐	W4.4	☐	RB4.4	☐	A4.5
• technologies based on their controllability	☐	W4.5	☐	RB4.5		
• technologies based on their location	☐	W4.6	☐	RB4.6	☐	A4.6
• technologies based on whether or not they are understood as proven to work	☐	W4.7			☐	A4.7
• technologies based on their duration	☐	W4.8			☐	A4.8
• technologies based on their naturalness	☐	W4.9	☐	RB4.7	☐	A4.9
• technologies based on their plausibility	☐	W4.10			☐	A4.10
Does the plan consider how residents' worry about technologies generally impact them:	☐	W5				
• worry as a community impact	☐	W5.1				
• supporting problem solving in the community	☐	W5.2				
• worry about technology's impact on human health and wellbeing	☐	W5.3				
• technology's impact on the environment (local ecosystem and ecosystem services)	☐	W5.4				
• technology's social and economic side effects	☐	W5.5				
Does the plan consider how residents assess the risks and benefits from technologies, and how they balance those risks and benefits:			☐	RB5		
• inverse relationship between residents' perceived benefits and risks for technologies			☐	RB5.1		
• human health and wellbeing as a beneficiary and/or risk receptor of remediation technologies			☐	RB5.2		
• the environment as a beneficiary and/or risk receptor of remediation technologies			☐	RB5.3		
• trade-offs between risk and benefit types			☐	RB5.4		
Does the plan consider the way in which residents weigh up their support for technologies, and the statements they use to provide or withhold their support:					☐	A5
• weighing up risks and benefits					☐	A5.1
• assessing environmental improvements and human health improvements					☐	A5.2
• statements residents use for negotiating support					☐	A5.3
• statements residents use for not negotiating support					☐	A5.4
• possible social sanctions imposed by residents that generate socio-political risks for the remediation process					☐	A5.5

3. Residents' worry about remediation technologies

Introduction

The matrices set out in section 3.4 of this section present evidence-based insights that are drawn from a study of residents living near thirteen contaminated sites in Australia, which explored residents' worries about the application of remediation technologies in their local area (Prior *et al* 2017). Within the matrices, the evidence-based insights are linked to a series of questions that can be considered when developing plans for the remediation of specific contaminated sites.

Before presenting the matrices, section 3.2 discusses why consideration might be given to residents' worries about technologies when developing plans, and section 3.3 provides a brief overview of the evidence-based insights and questions that are laid out in the matrices.

3.2 Why consider residents' worries?

Whilst worry is not currently explicitly mentioned in remediation policies and guidelines, these policies and guidelines talk about stress and other psychological states such as anxiety that are often associated with worry (Heath *et al* 2010). The EnHealth *Environmental Health Risk Assessment* guidelines state that 'high levels of stress … [or] concern … are bound to make the already complex task of risk communication [within such contexts as contaminated site management and remediation] more difficult' (EnHealth 2012, p.89). Furthermore, the CRC CARE *Engaging the Community* handbook notes that 'heightened stress and anxiety to the point of "dread" may be observed in [groups affected by contaminated sites]' (Heath *et al* 2010, p. 7).

Residents' worry has been included in this document for several reasons:

- Firstly, to encourage the consideration of residents' worry about technologies when planning for the remediation of specific contaminated sites, because it is important to 'recognis[e] that the psychological needs of the community are as important as the scientific and technical risks' when dealing with contaminated sites (Heath *et al* 2010, p. 9).
- Secondly, engagement with residents' worry about technologies through planning can be used to support residents in their attempts to address their concerns about the application of those technologies given that a function of worry like other forms of anticipatory cognition is to propel people to seek out information that will help them address their concerns (Bechara *et al* 1997; Borkovec *et al* 1983; Peters *et al* 2006; Tallis *et al* 1994; Waters 2008). As MacGregor has suggested: 'we [can] master or make controllable [risks] because we invest a great deal of worry in them' (Macgregor 1991, p. 321).

We understand that some may feel uncomfortable developing plans that use the word worry. If this is the case, we suggest that concern/concerns may be useful substitutes.

3.3 Overview of evidence-based insights and questions

Matrices W1, W2, W3, W4, and W5 in section 3.4 present evidence-based insights on how residents' worry about the application of remediation technologies in their local area. The evidence-based insights are drawn from a detailed study of 2009 residents living near thirteen contaminated sites in Australia (Prior *et al* 2017). Within this study, worry and perceived risk were understood as distinct concepts. Whilst worry and perceived risk are sometimes discussed together, given both refer to potential negative consequences, there is a strong argument for treating them differently (Baron *et al* 2000; Loewenstein *et al* 2001; Schmiege *et al* 2009; Sjöberg 1998; Sjöberg 2004; Sjöberg 2006). Within this study, worry was understood as a cognitive as well as emotional process that can be shaped by a residents socio-demographic background, their physical context, the way in which they engage with institutions, and the characteristics of the remediation technology that may be applied in their local area (Borkovec *et al* 1983; Macgregor 1991). For example, the degree to which a resident might worry about the upcoming application of a remediation technology in their local area is likely to vary based on the residents socio-demographic background, that is, their gender, age and income.

Matrices W1, W2, W3, and W4 present evidence-based insights on how residents' levels of worry for the application of a remediation technology in their local area might be affected by the:

- residents' personal and demographic characteristics (see matrix W1)
- residents' physical context (see matrix W2)
- institutional context in which the resident engages during the remediation (see matrix W3), and
- characteristics of the remediation technologies that might be used in their local area (see matrix W4).

Finally, matrix W5 presents evidence-based insights on how resident's worries about remediation technology affects them (avoidance, problem solving, health impacts) and what they worry about.

For each evidence-based insight that is presented within the tables we pose a question(s) for consideration when developing and reviewing plans for the remediation of a contaminated site. For each question, we provide an indication, with a dot in the relevant column, of whether the question is relevant to remediation planning, to community engagement planning, or possibly both.

Figure 4 presents an overview of the topics addressed in the evidence-based insights and questions presented within each of the matrices within this section and their relationship to the resident's process of worry about the application of remediation technologies in their local area.

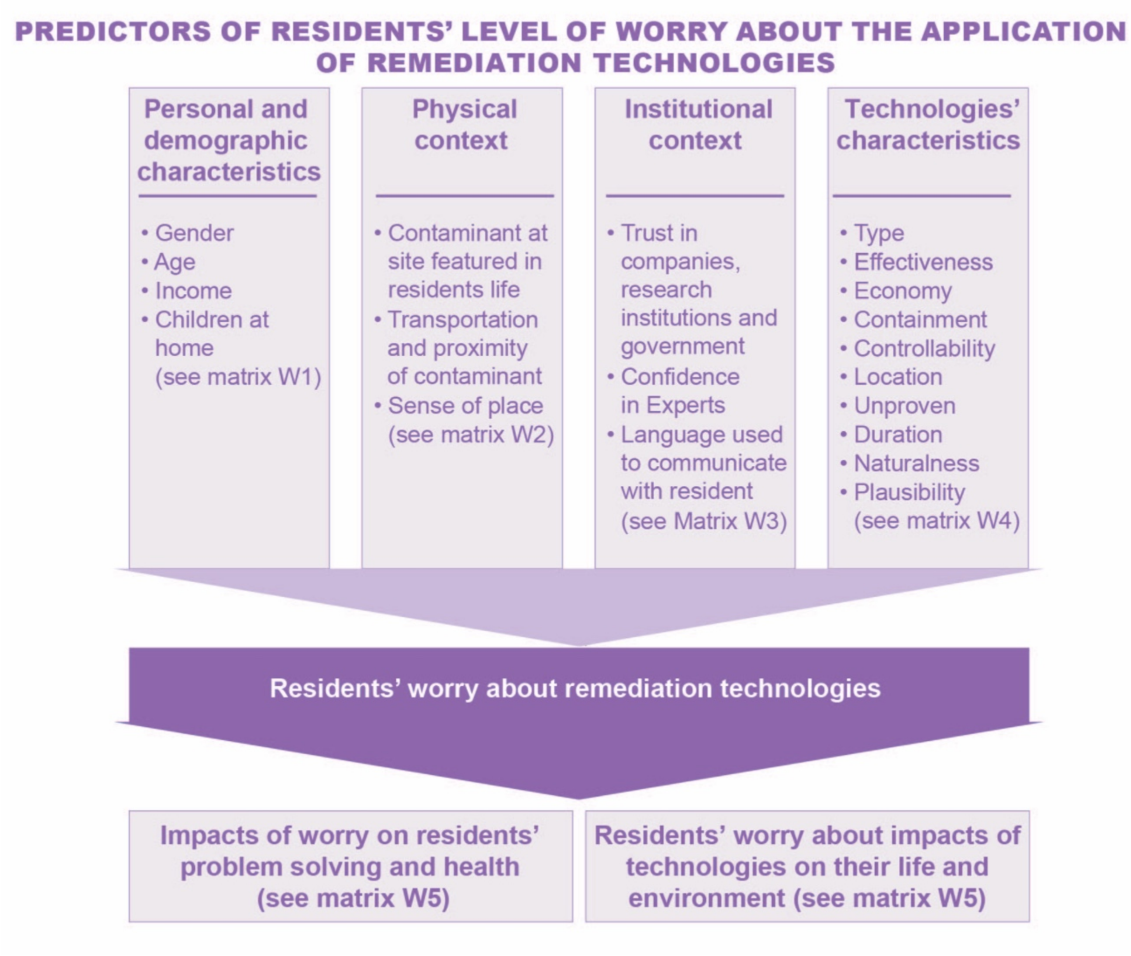


Figure 4. Overview of the topics discussed in the five matrices within this section and their relationship to the resident's process of worry about the application of remediation technologies in their local area.

Matrices of evidence-based insights and questions to support plan development

Matrix W1. Does the plan consider how residents' worries about technologies are impacted by their **personal and demographics characteristics?**

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
W1.1	**Gender**: Gender influences the degree to which people worry about the application of remediation technology. Males are less likely to be worried than females about remediation technologies (Prior *et al* 2017).	Does the plan consider that worry about remediation technology is affected by gender?	●	
W1.2	**Age**: The maturity of people influences the degree to which they worry about the application of remediation technology, with those aged over 75 likely to be less worried about the application remediation technologies than younger residents (Prior *et al* 2017).	Does the plan consider that a resident's age affects their level of worry about remediation technologies?	●	
W1.3	**Income**: Income level influences the degree to which people worry about the application of remediation technology. People earning incomes in the lowest bracket ($0–$40K annual household income) are likely to be more worried about the application of remediation technologies than those in the highest income cohort ($120K+ annual household income) (Prior *et al* 2017).	Does the plan consider that communities earning lower incomes are more likely to worry about the application of remediation technologies than those on higher incomes?	●	
W1.4	**Children in the home**: Having children living at home was found to influence the degree to which people worry about the application of remediation technology. People with children at home are more likely to be worried about the application of remediation technologies than those without (Prior *et al* 2017).	Does the plan consider how household composition may affect resident's worries about the application of remediation technologies, in particular the presence of children?	●	

Matrix W2. Does the plan consider how residents' worries about technologies are impacted by their **physical context?**

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
W2.1	**Extent to which the contaminant has impacted the daily life of the resident**: The extent to which the contaminant impacts on the daily life of the resident at home and in the local community influences the degree to which they worry about the application of remediation technology. Where contamination at the local site features in the daily life of a resident, they are more likely to be worried about the application of remediation technologies (Prior *et al* 2017).	Does the plan consider the extent to which the contaminant impacts on the daily lives of residents? How does this impact affect a resident's level of worry about technologies?	●	●
W2.2	**Transportation through local streets**: Transportation of contaminant materials influenced the degree to which residents worried about the application of remediation technology. While some respondents opposed transporting contaminated material largely because transportation can put these materials in relatively close contact with their homes, families and community, others supported transportation of the contaminated medium as a means of removing it from their local area (Erkut & Verter 1995; Greenberg *et al* 2002, 2011; Macgregor *et al* 1994; Prior *et al* 2017).	Will transportation of the contaminant be required? Will it be transported past the resident's home? Or past sensitive sites? Does the plan consider how this impact may affect a resident's level of worry about technologies?	●	●
W2.3	**Resident's sense of place**: A resident's level of worry concerning the application of remediation technologies in their local area was influenced by their sense of place – 'the affective relation or emotional bonds that … [they] have with places that they live' (Bonaiuto et al 2002, p. 636; Wester-Herber 2004). Research indicates that residents' sense of connection to the local community and environs have an effect on the degree to which they worry about the application of remediation technology. Those who felt a connection to their local community and environs are more likely to be worried about the application of remediation technologies than those who did not (Prior *et al* 2017).	How attached are residents to the local area (is it a well-established community or a greenfield site)? Do they feel that they have a strong attachment to place? Have you considered in your plan how this may affect their level of worry about the application of technologies?	●	

Matrix W3. Does the plan consider how residents' worries about technologies are impacted by the **institutional context?**

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
W3.1	**Combined trust in companies, research institutions, and governments:** Peoples' collective trust in companies, research institutions, and government influences the degree to which they worry about the application of remediation technology. People who are less trusting of companies and industry organisations, scientific organisations such as universities and the CSIRO, government agencies and regulators, are more likely to be worried about the application of remediation technologies. Those who have greater trust in these types of organisations are less likely to worry about remediation technology.[5]	Does the plan consider that a resident's worry about technology applications is closely linked to their level of trust in the organisations that are responsible for the regulation and implementation of remediation technologies at a site?	●	
W3.2	**Confidence in experts:** Residents who believe that experts know how best to manage technologies – that is, those who have confidence in experts – are less likely to worry about the application of those technologies than those who have diminished confidence in experts (Prior *et al* 2017).	Does the plan consider that a resident's worry about technology application is closely linked to their confidence in the experts carrying out the remediation?	●	
W3.3	**Language used in communication with residents:** The evidence suggests that the sole use of English as a tool for communicating about technology applications may lead to increased worry about remediation technology applications among those residents who speak English as a second language (Prior *et al* 2017).	Does the plan consider that the language used to communicate with residents will affect their level of worry about remediation technologies? What are the prominent languages spoken	●	

[5] Study respondents provided insights into why their combined trust in businesses, scientific institutions or government played a key role in alleviating or generating worry. Government was seen as the **ultimate regulator** of technologies, companies as the **implementers,** and scientific institutions as key **knowledge holders**. Together, these three organisational types were thought to support the three key services that are needed for the effective application of remediation technologies to a local context: **regulation, implementation and knowledge**. Distrust in any of these organisations (although to a lesser extent scientific institutions) brought into play uncertainties about one or more of the key services that were required to implement remediation technologies effectively, the result being that residents were unable to use their trust of these organisations as a means to shut down or ameliorate their worry over the remediation technologies (Prior *et al* 2017).

		by affected residents? Have you considered using these languages in key communications with residents?		

Matrix W4. Does the plan consider how residents' worries about a technology are impacted by the **technology's characteristics?**

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
W4.1	**Type:** Residents are more worried about the application of chemical remediation technologies than the application of physical and thermal remediation technologies, which in turn causes more worry than the application of biotechnology (Prior *et al* 2017).	Does the plan consider how residents might worry about different technology types?	●	●
W4.2	**Effectiveness:** Residents worry about the effectiveness of a remediation technology, in particular the application's ability to either mitigate the risk of the contaminant or remove 100% of the contaminant (Prior *et al* 2017).	Does the plan consider how residents might worry about the effectiveness of the selected technology option?	●	●
W4.3	**Economy:** The economy of the remediation technology is a source of worry for some residents. Residents' perceptions of a technology's economy are not concentrated solely on the monetary cost of the technology; they are also concerned with the environmental costs and benefits of a technology stemming from waste production, energy usage resource usage, and greenhouse gas emissions (Prior *et al* 2017).	Does the plan consider how residents might worry about the economy of the selected technology options?	●	●
W4.4	**Containment:** Residents worry about the containment of the contaminant during the application of the remediation technologies, and the side effects and by-products of the remediation technology and its potential to become a 'future contaminant too'. Containment was one of the most frequently stated sources of respondents' worries concerning thermal and physical technology types. For physical technology applications, worries were focused on the ability of technologies such as encapsulation or immobilisation to conceal, contain and hold the contaminated material. For thermal technology applications respondents' worries focused on the containment of vapours (Prior *et al* 2017).	Does the plan consider how residents might worry about a technology's ability to contain the contaminant or its possible side effects?	●	●

W4.5	**Controllability:** The degree to which a resident agreed with the proposition technologies are out of control affected their worry about the application of remediation technology. Those residents who agreed that technology is out of control are significantly more likely to be worried about the application of remediation technologies. Reflecting the findings within this study, people's worry about technology has been found to be characterised by the level of control that people believe society or science has over those technologies (Prior *et al* 2017).	Does the plan consider how residents might worry about the controllability of the technology options?	●	●
W4.6	**Location:** The location (onsite in-ground, onsite out-of-ground, offsite) of remediation technology applications has a highly significant effect on the degree to which residents worry about the application of remediation technology. Residents' stated preferences for remediation location (onsite in-ground, onsite out-of-ground, offsite) are consistent with their responses to specific remediation technology applications, in the sense that respondents who are more supportive of offsite treatment are significantly less likely to be worried about offsite remediation technology applications. Location is more frequently stated as a source of worry when residents are asked to consider technologies that involve ex-situ offsite treatment or storage (see incineration and dig and dump in table 4). Conversely fewer residents stated that location is a source of worry about in-situ and ex-situ onsite technologies (e.g. permeable reactive barrier, stabilisation, nanoremediation in table 4) (Prior *et al* 2017).	Does the plan consider how residents might worry about the location of technology options?	●	●
W4.7	**Proven/unproven:** Residents worry about whether remediation technologies have been proven, whether they have been tested first, trialled or researched and whether there is evidence of success (Prior *et al* 2017).	Does the plan consider how residents might worry about emergent technologies because they are perceived to be unproven?	●	●

W4.8	**Duration:** The duration of a remediation technology application is a source of worry for residents. Worry about the duration of the application has two notable emphases: the time that it takes to complete the remediation, and whether the remediation technology is potentially transferring the problem to future generations (Prior *et al* 2017).	Does the plan consider how residents might worry about the duration of the application of the technology types?	●	●
W4.9	**Naturalness:** Residents who agree that natural methods should be used in remediation are more likely to be worried about the application of remediation technologies. This finding reflects broader technology research that has identified naturalness as an important factor that influences people's perception of technologies. The importance of naturalness is not only a significant predictor for worry about all remediation technologies, with worry most acutely associated with chemical technologies and least for bioremediation technologies (Prior *et al* 2017).	Does the plan consider how residents might worry about the perceived naturalness of the technology type?	●	●
W4.10	**Plausibility:** The perceived plausibility of a remediation technology application is a source of worry for residents. Plausibility is a more frequently stated source of worry for residents who are asked to consider what they perceived as emergent technologies (see phytoremediation and nanotechnology in table 4) (Prior *et al* 2017).	Does the plan consider how residents might worry about the plausibility of different technology types?	●	●

Table 4. Characteristics of the technology applications most commonly identified as worrying residents.

Remediation technology type	Remediation technology application	Type of contaminant medium	Location of technology application		Characteristics of the remediation technology most commonly identified as worrying to residents							
				Effectiveness	Economy	Containment	Controllability	Location	Unproven	Duration	Unnaturalness	Plausible
Thermal	Thermal vapour extraction	Soil, waste	In-situ	●		●	●		●			
	Thermal desorption	Soil	Ex-situ onsite	●		●	●	●				
	Incineration	Soil	Ex-situ offsite	●	●	●	●	●				
Chemical	Chemical treatment general	Groundwater, soil	In-situ/ex-situ onsite	●		●	●				●	
	Nanoremediation	Groundwater, soil	In-situ	●			●		●		●	
	Permeable reactive barrier	Groundwater	In-situ	●	●	●					●	
Physical	Encapsulation	Soil	In-situ/ex-situ onsite	●		●		●		●		
	Dig and dump	Soil	Ex-situ offsite	●		●		●		●		
	Stabilisation	Soil, waste	In-situ	●	●	●				●		
	Mining	Soil, waste	Ex-situ onsite, ex-situ offsite	●	●	●		●				
Bio	Microbial bioremediation	Groundwater, soil, waste	In-situ	●			●		●	●		
	Phytoremediation	Groundwater, soil	In-situ	●	●					●		●

Matrix W5. Does the plan consider how residents' worries about technologies **impact them?** And what perceived **impacts from technologies worry them?**

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
W5.1	**Worry as a community impact:** Whilst the negative effects of worry may not be as immediately obvious or tangible as other effects stemming from remediation technology applications such as traffic generation, noise and nuisance, they fit within a broader definition of impact and arguably trigger the right for affected local communities to be engaged in decisions about remediation processes in their local environs (Prior *et al* 2017).	Is the plan sensitive to the broader effects that the application of remediation technologies might have on residents?	●	●
W5.2	**Supporting problem solving in the community:** A key reason for engaging with residents' worry is for remediation practitioners to provide knowledge or help to facilitate the problem solving, helping prepare the residents for stressful situations by arousing/strengthening coping strategies (Prior *et al* 2017).	Does the plan consider the worries of residents about remediation technologies, and does it seek to provide guidance that can help them cope with and resolve their worries about remediation technologies?	●	●
W5.3	**Worries about technology's impact on human health and wellbeing:** residents worry about the adverse impacts that remediation technologies could have on human health, with concern for vulnerable populations (e.g. children, elderly, pregnant women). This is particularly true for chemical (especially nanotechnologies) and thermal remediation technologies, which people worry might exacerbate the adverse effects of the contaminant. Biotechnological remediation, particularly phytoremediation, is more likely to be seen as safe to residents' health than any other technology (Prior *et al* 2017).	Does the plan consider the worries for human health and wellbeing held by residents about remediation technologies and seek to provide guidance that can help them cope with and resolve those worries? Does the plan consider how these worries related to key human health impacts that the community may face because of remediation technologies?	●	●

W5.4	**Technology's impact on the environment:** Residents worry about the effect of remediation technologies on the environment (though this is less of a worry for most residents than human health). Particular worries include adverse impacts to the: • soil and water (e.g. bore water, bays, rivers, plumes, groundwater, or drinking water) by chemical and thermal technologies • atmosphere (e.g. vapours, fire, odour, gas, fumes) by thermal technologies • flora and fauna (e.g. marine life, fungi, bacteria) by biotechnologies, chemical technologies and thermal technologies, and • built environment (e.g. bridge, home, house, earthworks, manmade structure) by physical technologies (Prior *et al* 2017).	Does the plan consider the worries for human health and wellbeing held by residents about remediation technologies and seek to provide guidance that can help them cope with and resolve those worries? Does the plan consider how these worries related to key environmental impacts that the community may face because of remediation technologies?	●	●
W5.5	**Technology's social and economic side effects:** While residents were aware that remediation may be economically beneficial for communities, for example by generating local employment, and in the longer term by increasing the use options and value of land, they were also worried about the negative effects that remediation technologies might have on social and economic opportunities both now and in the future. Echoing other studies, residents were concerned about the immediate side effects remediation technology might have on local economic and social opportunities. For example, odour, increased traffic, dust, and closure of local amenities. Residents were also concerned about whether or not the selection of different technologies would have longer-term economic impacts on residents and the community. For example, residents were worried about the social and economic effects that physical remediation technologies might have on the public's use of their local amenities (e.g. restricted access to a park or limited use rights to land) (Vodouhe & Khasa 2015; Prior *et al* 2017).	Does the plan consider the worries for social and economic side effects held by residents about remediation technologies and seek to provide guidance that can help them cope with and resolve those worries? Does the plan consider the most likely social and economic side effects that the community may face because of a remediation technology?	●	●

4. Residents’ perceptions regarding the risks and benefits associated with remediation technologies

Introduction

The matrices set out in section 4.4 of this section present evidence-based insights that are drawn from a study of residents living near thirteen contaminated sites in Australia, which explored residents’ risk and benefit perceptions about the application of remediation technologies in their local area (Prior & Rai 2017). Within the matrices the evidence-based insights are linked to a series of questions that can be considered when developing plans for the remediation of specific contaminated sites.

Before presenting the matrices, section 4.2 discusses why consideration might be given to residents’ risk and benefit perceptions about remediation technologies when developing plans, and section 4.3 provides a brief overview of the evidence-based insights and questions that are laid out in the tables.

4.2 Why consider residents’ risk and benefit perceptions?

Risk perception is a key focus of remediation policies. These policies advocate for its consideration in both community engagement planning and remediation planning. Remediation policies recognise that all stakeholders, both expert and non-expert, will have perceptions of risks, and that these perceptions need to be considered during the development of remediation approaches (Heath *et al* 2010). These risk perceptions are ‘influenced by emotion, beliefs and their views of the world’ (EnHealth 2012, p. 89). Residents tend to perceive risk based on magnitude rather than probability (Heath *et al* 2010). The National Environment Protection Council’s *Guideline on Community Engagement and Risk Communication* and the National Remediation Framework *Guideline on Stakeholder Engagement* are both primarily concerned with risk perception and communication (CRC CARE 2019l; NEPC 2013). While these documents tend to focus on risk perceptions associated with the contaminant, recently some remediation guides, such as the National Remediation Framework guideline for *Performing Remediation Options Assessments* and the Sustainable Remediation Forum of Australia and New Zealand *A Framework for Assessing the Sustainability of Soil and Groundwater Remediation*, have begun to focus more explicitly on the perceived risks associated with the remediation technology and their application, the remedial solution will have a level of risk associated with it and that risk must be acceptable to various stakeholders critical to the decision making process for the project (CRC CARE 2019l; Sustainable Remediation Forum Australia, CRC CARE & Australasian Land and Groundwater Association 2011a; Sustainable Remediation Forum Australian And New Zealand 2012d)

Benefit perception is an emergent focus within remediation policy, which advocates its consideration within both community engagement planning and remediation planning (Sustainable Remediation Forum Australian And New Zealand 2012a, 2012d). Based on broader risk and benefit research, these policies assert that benefit perceptions affect risk perceptions and the acceptance of remediation approaches. The CRC CARE *Engaging the Community* handbook very briefly refers to the importance of benefit perceptions, noting that ‘groups with positive attitudes … will commit to change if they see the benefits of a planned project' (Heath *et al* 2010, p. 61). The National Remediation Framework *Guideline on Stakeholder Engagement*, while focused primarily on risk perception, notes that perception of risk is likely to be lessened when there are clear benefits (CRC CARE 2019n). More recently, the National Remediation Framework *Guideline on performing remediation options assessments* highlights the importance of considering 'benefits beyond reducing or controlling the unacceptable risks on site as an objective when developing remediation plans' (CRC CARE 2019l, p. 5). Similarly, sustainable remediation guidelines suggest that consideration should be given to a planning horizon over which benefits are considered – whether it is ten years, one generation or 100 years (Sustainable Remediation Forum Australia, CRC CARE & Australasian Land and Groundwater Association 2011a).

These existing policies do not, however, provide any guidance on what might influence risk and benefit perceptions or guidance on how to determine what residents' risk and benefit perceptions of these technologies are.

4.3 Overview of evidence-based insights and questions

Matrices RB1, RB2, RB3, RB4 and RB5 in section 4.4 of this section present evidence-based insights into residents' risk and benefit perceptions about the application of remediation technologies in their local area. The evidence-based insights are drawn from a detailed study of 2009 residents living near thirteen contaminated sites in Australia (Prior & Rai 2017).

Within this section residents' perceptions of the risks associated with a remediation technology are understood as being subjectively defined by individuals (Beck 1992; Finucane *et al* 2000; Slovic *et al* 1980, 1991; Slovic 2001). Furthermore, residents' perceptions of benefits are understood as their perceptions of the positive consequences of applying a remediation technology. The scope of these benefits extends beyond reducing or controlling the immediate unacceptable risks of an environmental contaminant to broader benefits such as land use opportunities that not only benefit current but also future generations (Leung 2013).

One evidence-based insight (RB5.1) presented within matrix RB5 indicates that residents' risk and benefit perceptions are interconnected, and that an inverse relationship exists between them, such that technologies that are judged high in risk tend to be judged low in benefit, and vice versa. Based on this evidence it could be argued that this inverse relationship is indicative of a connection between risk and benefit in people's minds, and that this connection is linked to their overall evaluations of a technology (Alhakami & Slovic 1994). In other words, people fail to distinguish between the dimensions of risks and benefits. This inverse relationship is the reason why risk and benefit perceptions are included in the same section.

The evidence-based insights presented in the matrices provide an awareness of how residents' risk and benefit perceptions about remediation technologies are influenced by a residents socio-demographic background, their physical context, the way in which they engage with institutions, and the characteristics of the remediation technology that may be applied in their local area (Prior & Rai 2017). For example, a resident might perceive a greater risk about the upcoming application of a remediation technology in their local area than other residents because the contaminant has had a greater impact on their daily life than it has had on the lives of other residents (see evidence-based insight RB2.1).

Matrices RB1, RB2, RB3, and RB4 present evidence-based insights on how residents' levels of perceived risks and benefits for the application of remediation technologies in their local area might be affected by the:

- residents' personal and demographic characteristics (matrix RB1)
- residents' physical context (matrix RB2)
- institutional context in which the resident engages during the remediation (matrix RB3), and
- characteristics of the remediation technologies that might be used in their local area (matrix RB4).

Finally, matrix RB5 presents evidence-based insights on the types of risks and benefits that residents associate with remediation technologies, how residents' perceived risks and benefits related to each other, and how residents balance those perceived risks and benefits.

For each evidence-based insight presented within the matrices we pose a question(s) for consideration when developing or reviewing a plan for the remediation of a contaminated site. For each question we provide an indication, with a dot in the relevant column, of whether the question is relevant to remediation planning, to community engagement planning, or possibly both.

Figure 5 presents an overview of the topics addressed in the evidence-based insights and questions presented within each of the matrices within this section and their relationship to how resident's perceive risks and benefits about the application of remediation technologies in their local area.

Tables 5, 6, 7, 8 referred to in the following matrices present useful information on:

- characteristics of different technology applications that residents most commonly identify as influencing perceived risks and/or benefits for human health (table 5)
- characteristics of different technology applications that residents most commonly identify as influencing perceived risks and/or benefits for the local environment (table 6)
- commonly reported types of perceived risk and benefit balances mentioned by residents (table 7), and
- risks and benefits that residents associate with remediation technologies (table 8).

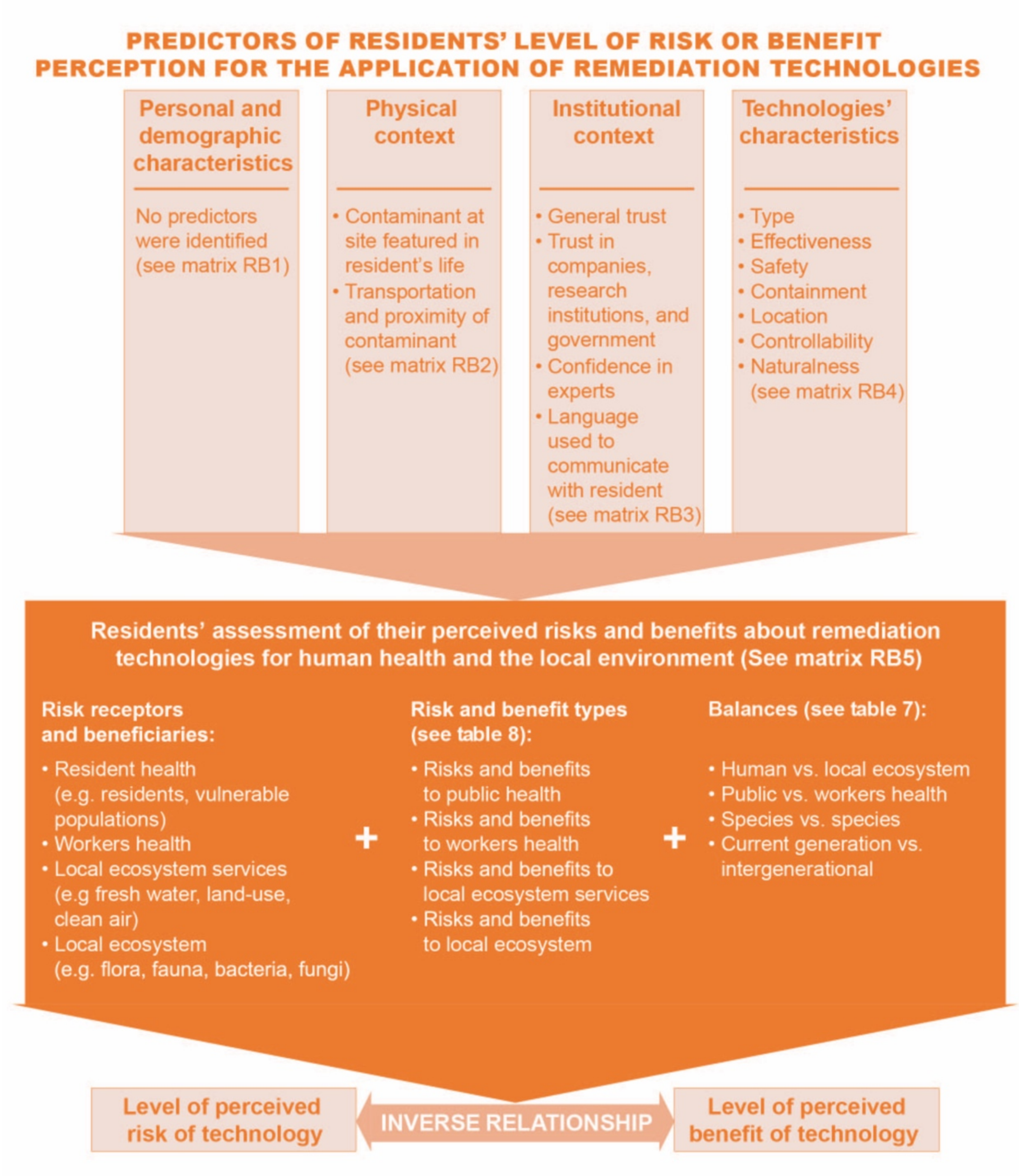


Figure 5. Overview of the topics discussed in the five matrices within this section and their relationship to how residents perceive risks and benefits about the application of remediation technologies in their local areas

4.4 Matrices of evidence-based insights and questions to support plan development

Matrix RB1. Does the plan consider how residents' risk and benefit perceptions about technologies are impacted by their **demographics and personal characteristics?**

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
	No demographic predictors were identified: The findings suggest that residents living near contaminated sites do not perceive risks or benefits for remediation technology application differently because of a range of demographic factors: resident's gender, income, age, home ownership, having children and education (Prior & Rai 2017). This aligns with a lot of broader technology research which has found that few personal or demographic characteristics show a systematic pattern in risk or benefit perception (Brody 1984; Ho *et al* 2011, 2013; Lee *et al* 2005; Miller & Kimmel 2001; Siegrist 1998, 2000). The fact that no significant relationship was found between a resident's gender and risk or benefit perception is more unusual, although not all technology research has shown a significant relationship between gender and risk and benefit perceptions (Satterfield *et al* 2009).	No question is provided because demographic characteristics did not influence residents' perceptions in the study on which the guidelines are based.		

Matrix RB2: Does the plan consider how residents' risk and benefit perceptions about technologies are impacted by their **physical contexts?**

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
RB2.1	Extent to which the contaminant has impacted the daily life of the resident: The extent to which the contamination at the local site impacted a resident's daily life influenced the level of risk that they believed remediation technologies posed to human health and to their local environment. Those who believed that contamination at the local site featured in their daily lives, perceived greater risk from the use of remediation technologies to human health and to the local environment. However, the belief that contamination at the local site features in one's daily life did not influence residents' perceptions regarding the benefit to human health or the environment from the technology (Prior & Rai 2017).	Does the plan consider the extent to which the contaminant impacts on the daily lives of residents? How does this impact affect a resident's level of risk for technologies?	●	●
RB2.2	Transportation through local streets: Concern for the transport of contaminated material through local streets influenced the level of perceived risk and benefit residents thought remediation technologies posed to human health and to their local environment. Those who expressed concern over contaminants being transported through local streets were likely to perceive higher risk in the use of remediation technologies, to both human health and the local environment. Conversely, these individuals were less likely to perceive benefits of remediation technologies to either residents or to the environment (Prior & Rai 2017).	Will transportation of contaminated material be required? Will the material be transported past a resident's home or past sensitive sites (e.g. schools, childcare centres)? Does the plan consider how the transportation of the material may affect a resident's perceptions of the levels of risk and benefit associated with particular technologies?	●	●

Matrix RB3: Does the plan consider how residents' risk and benefit perceptions about technologies are impacted by their **institutional context?**

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
RB3.1	**General trust in others:** a resident's general level of trust for others (companies, government, scientific organisations, NGOs, as well as other residents) influences their perceptions regarding levels of risk and levels of benefit for remediation technologies. Individuals who are generally more trusting perceived lower levels of risk, both for public health and for their local environment. Conversely, individuals who were generally more trusting perceived greater benefits from remediation technologies both for public health and for the local environment (Prior & Rai 2017).	Does the plan consider how a resident's general level of trust in others influences their perceptions regarding levels of risk and levels of benefit for remediation technologies?	●	
RB3.2	**Combined trust in companies, research institutions, and governments:** a resident's combined trust in companies, research institutions and governments was found to influence their perceptions of the levels of risk and benefit that respondents believed the application of the remediation technologies posed to residents' health and their local environment. This combined trust reflects the central role these organisations play in the regulation, implementation and knowledge development of remediation technology applications. Individuals who were more trusting of companies, research institutions and governments perceived lower levels of risk, both for human health and for their local environment. Conversely, these individuals who were more trusting of companies, research institutions and governments perceived greater benefit from remediation technology both to the resident's health and to the local environment (Prior & Rai 2017).	Does the plan consider that a resident's perception regarding the risks and benefits associated with the application of a technology is closely linked to their level of trust in those organisations that are responsible for the regulation and implementation of remediation technologies at a site?	●	

RB3.3	**Confidence in experts:** residents who believe that experts will know how best to manage technologies – that is, those who have confidence in experts – are more likely to believe that remediation technology would benefit the health of the residents and the local environment than those with less positive views. Conversely, individuals who believed experts know best perceived lower levels of risk to the local environment from remediation technologies (Prior & Rai 2017).	Does the plan consider that a resident's perceptions regarding the risks and benefits associated with the application of a technology are closely linked to their level of confidence in the experts carrying out the remediation?	●	
RB3.4	**Language used in communication with residents:** the evidence suggests that the sole use of English as a tool for communicating about technology applications may increase perceived human health risks from remediation technology applications among those residents who speak English as a second language (Prior & Rai 2017).	Does the plan consider that the language used to communicate with residents will affect their level of perceived risk for human health from remediation technologies? What are the prominent languages spoken by affected residents? Have you considered using these languages in key communications with residents?	●	

Matrix RB4: Does the plan consider how residents' risk and benefit perceptions about technologies are impacted by the **technologies' characteristics?**

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
RB4.1	**Type:** the type of technology used for remediation influenced residents' perceptions of the levels of risks and benefits for both human health and the local environment. Residents perceived greater risk to the health and wellbeing of residents and to the local environment from thermal, physical and chemical technologies than from bioremediation. Conversely, respondents perceived these technologies (chemical, physical, thermal) as being less beneficial (to both resident health and the environment) than bioremediation. Remediation technologies judged by residents as having higher risk, like chemical technologies, were judged to be low in benefit, and those judged higher in benefit such a biotechnology were judged to be low in risk (Prior & Rai 2017).	Does the plan consider that residents might perceive the risks and benefits of technology types differently?	●	●
RB4.2	**Effectiveness:** residents who agree that technologies are effective at solving our problems were significantly more likely to believe that the application of remediation technologies will be beneficial to human health and the local environment. A frequently reported benefit of the application of remediation technologies by residents is their ability to successfully eliminate an environmental contaminant or restrain or block its exposure pathway to receptors. Conversely, residents also perceived risks in the failure of a technology application to effectively remediate a site, with respondents speaking about the risks that may result to the environment and human health if the technology is unable to effectively block or eliminate an exposure pathway to receptors from existing environmental contaminants, or to amplify exposure to existing environmental contaminant (e.g. metalloids) (tables 5 and 6) (Prior & Rai 2017).	Does the plan consider how residents' perceptions of the effectiveness of a technology affect the level of risk or benefit that they attribute to that technology?	●	●

RB4.3	**Safety:** residents use their perceptions of a remediation technology's safety level as a means of assessing the level of risk or benefit of that technology to human health or their local environment (tables 5 and 6) (Prior & Rai 2017).	Does the plan consider how residents' perceptions of the safety of a technology affect the level of risk or benefit that they attribute to that technology?	●	●
RB4.4	**Containment:** residents use their perceptions of a technology's ability to contain the contaminant during application, or of the risk of it generating side effects, as a means of assessing the level of risk or benefit of that technology to human health or their local environment. Failure to contain a contaminant is more frequently reported as a perceived risk by residents for thermal and physical technology types. For physical technology, the risk focused on is the possible failure of technologies such as encapsulation or immobilisation to conceal, contain and hold the contaminated material over time (table 5 and 6) (Prior & Rai 2017).	Does the plan consider how residents' perceptions of a technology's ability to contain the contaminant, or its possible side effects, affects the level of risk or benefit that they attribute to that technology?	●	●
RB4.5	**Controllability:** residents agreeing with the proposition that technologies are out of control are more likely to perceive a remediation technology as a risk to human health and local environment. Conversely those who believe that technologies are out of control are significantly less likely to believe that remediation would benefit human health. Residents are particularly concerned about the controllability of emergent remediation technologies such as nanoremediation (Prior & Rai 2017).	Does the plan consider how residents' perceptions of a technology's controllability affect the level of risk or benefit that they attribute to that technology?	●	●
RB4.6	**Location:** the location (onsite in-ground, onsite out-of-ground, offsite) of a remediation technology application influences a resident's perceptions of the technology's level of risk and benefit. Residents' preferences for remediation location are consistent with their responses to specific remediation technology applications, in the sense that residents who are more supportive of offsite treatment are significantly less likely to perceive risks to human health and their local environments from offsite remediation technology applications and more likely to perceive benefits	Does the plan consider how residents' preferences for remediation location affect the level of risk or benefit that they attribute to technologies?	●	●

	to human health and local environment (table 5 and 6) (Prior & Rai 2017).			
RB4.7	**Naturalness:** those who believe that natural methods should be used in remediation are more likely to perceive remediation technologies as a risk to the local environment. For these respondents, the term natural is generally associated with: non-human, non-artificial and unspoilt environments (table 5 and 6) (Prior & Rai 2017).	Does the plan consider how residents' preferences for natural methods, affect the level of risk that they attribute to technologies?	●	●

Table 5. Characteristics of different technology applications that residents most commonly identify as influencing perceived risks and/or benefits for human health.

				Characteristics of remediation technology most commonly identified as influencing perceived risk and benefit perceptions about human health					
Remediation technology type	**Remediation technology application**	**Type of contaminant medium**	**Location of technology application**	Effectiveness	Safety	Containment	Location	Controllability	Naturalness
Thermal	Thermal vapour extraction	Soil, waste	In-situ	●		●		●	
	Thermal desorption	Soil	Ex-situ onsite	●	●	●			
	Incineration	Soil	Ex-situ offsite	●		●	●		
Chemical	Chemical treatment general	Groundwater, soil	In-situ/ex-situ onsite	●	●			●	
	Nanoremediation	Groudnwater, soil	In-situ	●		●			●
	Permeable reactive barrier	Groundwater	In-situ	●	●	●			
Physical	Encapsulation	Soil	In-situ/ex-situ Onsite	●		●	●		
	Dig and dump	Soil	Ex-situ offsite	●	●		●		
	Stabilisation	Soil, waste	In-situ	●	●	●			
	Mining	Soil, waste	Ex-situ onsite, ex-situ offsite	●	●		●		
Bio	Microbial bioremediation	Groundwater, soil, waste	In-situ	●	●				●
	Phytoremediation	Groundwater, soil	In-situ	●	●				●

Table 6. Characteristics of different technology applications that residents most commonly identify as influencing perceived risks and/or benefits for the local environment.

				Characteristics of remediation technology most commonly identified as influencing perceived risk and benefit perceptions for the local environment					
Remediation technology type	**Remediation technology application**	**Type of contaminant medium**	**Location of technology application**	Effectiveness	Safety	Containment	Location	Controllability	Naturalness
Thermal	Thermal vapour extraction	Soil, waste	In-situ	●	●	●			
	Thermal desorption	Soil	Ex-situ onsite	●	●	●			
	Incineration	Soil	Ex-situ offsite	●	●		●		
Chemical	Chemical treatment general	Groundwater, soil	In-situ/ex-situ onsite	●	●			●	
	Nanoremediation	Groundwater, soil	In-situ	●		●		●	
	Permeable reactive barrier	Groundwater	In-situ	●			●	●	
Physical	Encapsulation	Soil	In-situ/ex-situ onsite	●	●		●		
	Dig and dump	Soil	Ex-situ offsite	●		●	●		
	Stabilisation	Soil, waste	In-situ	●		●	●		
	Mining	Soil, waste	Ex-situ onsite, ex-situ offsite	●				●	●
Bio	Microbial bioremediation	Groundwater, soil, waste	In situ	●	●				●
	Phytoremediation	Groundwater, soil	In situ	●	●				●

Matrix RB5: Does the plan consider the types of risks and benefits that residents associate with technologies, and how they balance those risks and benefits?

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
RB5.1	**Inverse relationship between resident's perceived benefits and risks for technologies:** residents' perceptions of the level of risk and level of benefit are inversely related for remediation technologies. For example, remediation technologies judged by residents as having higher risk like chemical technologies are judged to be low in benefit, and those judged higher in benefit such a biotechnology are judged low in risk (Prior & Rai 2017).	Is the plan sensitive to the inverse relationship that exists between the perceived level of risk and the perceived level of benefit that residents hold for remediation technologies?	●	●
RB5.2	**Human health and wellbeing as a beneficiary and/or risk receptor of remediation technologies:** most residents refer to the public's health, particularly that of residents and vulnerable populations (e.g. children, elderly, pregnant women, people living with a disability, and those with long term illness e.g. arthritis, asthma, diabetes) as a beneficiary and/or risk receptor of remediation technologies. Residents also refer to the health of workers at the contaminated site as a risk receptor of remediation technologies. See table 8 for types of risks and benefits that residents associate with human health and wellbeing (Prior & Rai 2017).	Is the plan sensitive to the perceived risks and benefits to human health and wellbeing that residents associate with remediation technologies?	●	●
RB5.3	**The environment as a beneficiary and/or risk receptor of remediation technologies:** residents identify various aspects of the local environment as beneficiaries and/or risk receptors of remediation technologies. These beneficiaries and/or risk receptors in the environment could be separated into two broad categories: the local ecosystem (e.g. flora, fauna, fungi, bacteria) or the services that the local ecosystem provides to humans (e.g. clean air and water, fresh food, species diversity). See table 8 for types of risks and benefits that residents associate with the local environment (ecosystem and ecosystem services (Prior & Rai 2017).	Is the plan sensitive to the perceived risks and benefits to the environment that residents associate with remediation technologies?	●	●

RB5.4	**Trade-offs between risk and benefit types:** given the diverse beneficiaries and risk receptors of remediation technologies, when assessing the overall risks and benefits of a technology, residents make trade-offs between risks and benefits for the different receptors (worker, resident, flora, fauna, bacteria, fungi, clean air) that result from the application of different remediation technologies (table 7). The most commonly used risk and benefit trade-off by residents focuses on the ways in which risks to ecosystems and human health are addressed differently by some remediation technologies. For example, whilst physical remediation technologies, (e.g. capping, dig and dump, or the placement of an impermeable covering over the contamination), are beneficial in that they eliminate risk to humans by physical blocks to the exposure pathway, they were not perceived as doing the same for plants, animals, and microorganisms that reside permanently in a contaminated area or at the landfill site. Similarly, thermal and chemical technologies were seen as beneficial to human health, but as having the potential to devastate other biological components of a local ecosystem and precluding natural recovery (Prior & Rai 2017). Table 7 is a compilation of key trade-offs made by residents. They included balancing: ecological and human health risks; worker and resident/public health risks, risks to current and future generations; and risk among species (plants versus animal, one animal versus another) (Prior & Rai 2017).	Does the plan consider how resident's trade-off the risks and benefits for different beneficiaries and risk receptors resulting from remediation technologies?	●	●

Table 7. Most commonly reported types of perceived risk and benefit balances mentioned by residents.

Types	Examples using physical technologies
Human versus local ecological	e.g. Dig and dump was seen reducing risks to residents living near the source site, but destructive to soil ecology and vegetation at the landfill site and source site.
Resident health versus worker health and safety	e.g. Mining was perceived as beneficial to human residents' health, but several respondents also perceived mining as increasing risks to workers' health and safety.
One group of species versus another	e.g. Whilst dig and dump is perceived as destructive to ecosystems and all the organisms within it at the landfill site and source site, leaving the contaminant in place is less disruptive where levels are not causing adverse ecological effects.
Current generational versus intergenerational	e.g. Dig and dump and stabilisation were often perceived as solutions that addressed health risks to current residents whilst passing the risk on to future generations.

Table 8. Risk (R) and benefit (B) types that residents associate with remediation technologies.

Benefit types	Risk types
B1. Improved resident's health and wellbeing:	**R1. Impaired resident's health and wellbeing:**
B1.1. Improved physical health.	R1.1. Impaired physical health.
B1.2. Other types of improved health, e.g. reduced anxiety.	R1.2. Other types of impaired health, e.g. increased anxiety.
B1.3. Improved economic viability, e.g. by contracting local venders.	R1.3. Impaired economic viability, e.g. business disruptions.
B1.4. Increased sense of security, e.g. of services, health, property and access.	R1.4. Reduced sense of security, e.g. of services, health, property and access.
B1.5. Improved social relations, e.g. community and social relations.	R1.5. Impaired social relations, e.g. stigmatisation and conflict.
B1.6. Increased freedom of choice, e.g. increased social and economic freedom.	R1.6. Decreased freedom of choice, e.g. decreased social and economic freedom.
B1.7. Enhanced quality of everyday life, e.g. through increased recreational opportunities.	R1.7. Reduced quality of everyday life, e.g. decreased recreational opportunities.
B1.8. Reduced undesirable environmental impacts, e.g. removing odour.	R1.8. Increased undesirable environmental impacts, e.g. increased odor or by bypoducts.
B1.9 Improved wellbeing and health of vulnerable populations.	R1.9 Impaired wellbeing and health of vulnerable populations.
	R2. Impaired worker's health:
	R2.1. Impaired physical health.
B3. Increased provision of local ecosystem services:	**R3. Decreased provision of local ecosystem services:**
B3.1. Improved value of real estate.	R3.1. Decreased value of real estate.
B3.2. Increased ability of land to support food production.	R3.2. Decreased ability of land to support food production.
B3.3. Increased ability of land to support recreational use.	R3.3. Decreased ability of land to support recreational use.
B3.4. Increased ability of land to support human uses, e.g. residential use, commercial use, industrial use.	R3.4. Decreased ability of land to support human uses, e.g. residential use, commercial use, industrial use.
B3.5. Improved air quality.	R3.5. Decreased air quality.
B3.6. Improved quality of groundwater and surface water.	R3.6. Decreased quality of marine habitats, groundwater and surface water.
B3.7. Improved aesthetic value of local landscape.	R3.7. Decreased aesthetic value of local landscape.

B3.8. Sustainable use of natural resources through technology selection, e.g. reduced carbon emissions, reduced use of non-renewable resources.	
B4. Improved local ecosystem:	**R4. Impaired local ecosystem:**
B4.1. Maintain, recover or enhance plant diversity.	R4.1. Decreased plant diversity and de-vegetation, e.g. destruction of aboveground vegetation and below ground seeds and root material.
B4.2. Maintain, recover or enhance soil habitats, micro-organisms and invertebrates.	R4.2. Impairment or destruction of soil habitats, micro-organisms and outmigration by vertebrates, e.g. failure of soil habitats to recover if nonindigenous fill soil is used.
B4.3. Maintain, recover or enhance marine, groundwater, surface water habitats.	R4.3. Impairment or destruction of marine, groundwater, surface water habitats.
B4.4. Maintain, recover or enhance air quality.	R4.4. Decrease in air quality and associated health effects to wildlife or plants.
B4.5. Improved health of wildlife, e.g. fungus, bacteria.	R4.5. Impaired health of wildlife.
B4.6. Maintain, recover or enhance and supporting habitats.	R4.6. Impairment or destruction of wildlife habitats.

5. Residents' acceptance (support and choice) of remediation technologies

Introduction

The matrices set out in section 5.4 of this section present evidence-based insights that are drawn from two studies – a study of residents living near thirteen contaminated sites in Australia and a study of residents in New South Wales, Australia. Both these studies explored residents' level of acceptance of the application of remediation technologies in their local area (Prior 2018). Within the matrices the evidence-base insights are linked to a series of questions that can be considered when developing plans for the remediation of specific contaminated sites.

Before presenting the matrices, section 5.2 discusses why consideration might be given to residents' acceptance of remediation technologies when developing plans, and section 5.3 provides a brief overview of the evidence-based insights and questions that are laid out in the matrices.

5.2 Why consider residents' acceptance?

Acceptance is discussed within remediation policies and guidelines in reference to risk perception and benefit perception; they advocate its consideration within both community engagement planning and remediation planning. These policies and guidelines focus on what constitutes acceptable risk at a given site and what constitutes an acceptable remedial solution at that site for its various stakeholders (CRC CARE 2019m; International Organisation of Standardisation 2015; Sustainable Remediation Forum Australia, CRC CARE & Australiasian Land and Groundwater Association 2011b; Sustainable Remediation Forum Australian and New Zealand 2012c, d). The National Remediation Framework guidelines for the application of remediation technologies guides users to consider whether the technology will be acceptable to stakeholders, and call for acceptance to be considered as a key objective in remediation planning (CRC CARE 2019f). These existing policies do not, however, provide any guidance on what might influence technology acceptance nor on how to determine what is acceptable to residents.

5.3 Overview of evidence-based insights and questions

Matrices A1, A2, A3, A4 and A5 in section 5.4 of this section provide evidence-based insights into residents' acceptance of the application of remediation technologies in their local area. These evidence-based insights are drawn from two studies:

- a study of 2009 residents living near 13 contaminated sites in Australia, which explored residents' support for the application of remediation technologies in their local areas (figure 6) (Prior 2018), and
- a choice experiment involving 944 residents living in New South Wales, Australia, which focused on residents' preferences for remediation technology applications (Huynh *et al* 2017).

Within this section residents' acceptance of remediation technology is not equated with the formal approval, direct-use or deployment of remediation technologies; these are the responsibility of remediation regulators, the responsible party and the remediation service providers (Venkatesh & Davis 2000). Residents' acceptance within this section is understood as the residents' level of support for the application of the remediation technology in their local area, where level of support is understood as being influenced by the residents' physical context (e.g. proximity to contaminant source site) institutional context (e.g. trust for organisations communicating with residents), as well as technology characteristics (e.g. proven technology), and their personal and demographic characteristics (e.g. values). Furthermore, residents' levels of support for a technology is understood as being pliable, where this pliability is dependent on a series of statements and sanctions (rules) which they utilised in dialogue with others involved in the remediation process (table10) (Wong 2015).

Residents' acceptance within this section is also understood to be defined by the choices residents make when deciding between different technologies that may be applied in their local area to remediate an environment that has been polluted by contaminants. Matrices A1, A2, A3 and A4 present evidence-based insights on how residents' levels of support for the application of remediation technologies in their local area are affected by the:

- residents' personal and demographic characteristics (matrix A1)
- residents' physical context (matrix A2)
- institutional context in which the resident engages during the remediation (matrix A3), and
- characteristics of the remediation technologies that might be used on their local area (matrix A4).

Finally, matrix A5 presents evidence-based insights into the way in which residents weigh up their support for different remediation technologies, and the statements and sanctions that residents use with others involved in remediation processes to negotiate their support for technologies.

For each evidence-based insight that is presented within the matrices we pose a question(s) for consideration when developing and reviewing plans for the remediation of a contaminated site. For each question, we provide an indication, with a dot in the relevant column, of whether the question is relevant to remediation planning, to community engagement planning, or possibly both.

Figure 6 presents an overview of the topics addressed in the evidence-based insights and questions presented within each of the matrices within this section and their relationship to how resident's support and choose the application of remediation technologies in their local area.Tables 9 and 10 referred to in the following matrices present useful information on:

- Characteristics of different technology applications that most associate with remediation technologies (table 9), and
- Statements commonly used by residents to provide or withhold their support for the application of technologies (table 10).

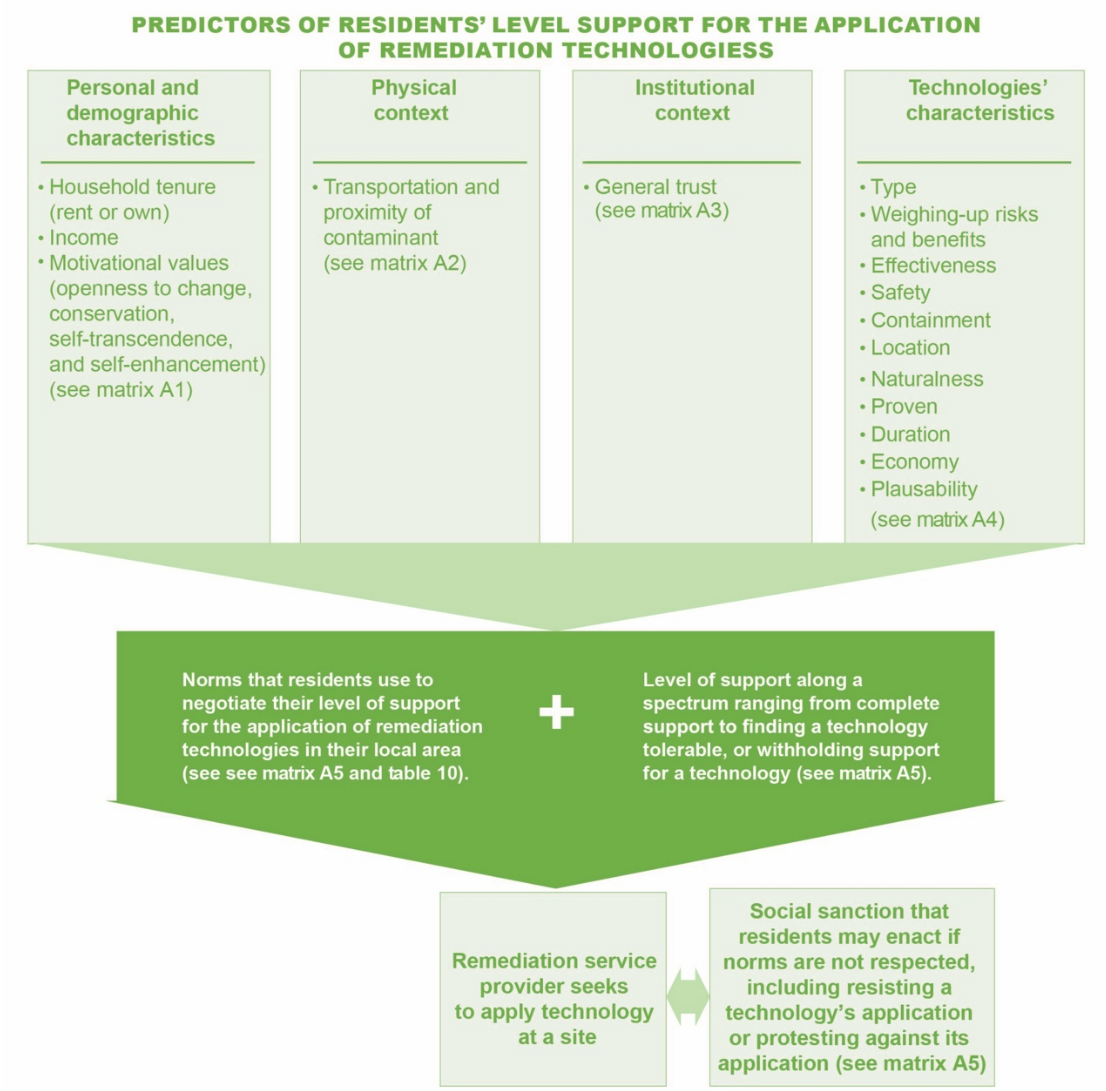


Figure 6: Overview of the topics discussed in the five matrices within this section and their relationship to how residents' support and choose the application of remediation technologies in their local area

5.4 Matrices of evidence-based insights and questions to support plan development

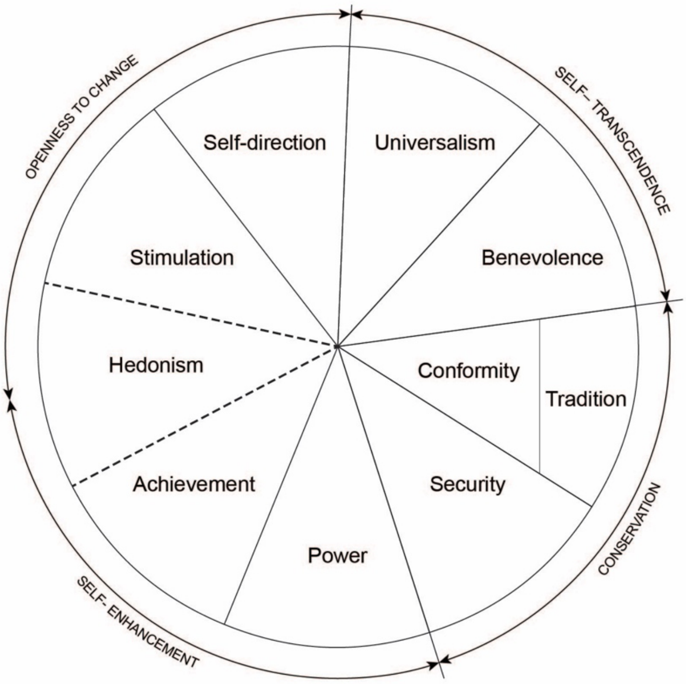
Matrix A1: Does the plan consider how residents' support of technologies is impacted by their **demographics and personal characteristics?**

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
A1.1	Income: income level influences residents' levels of support for the application of remediation technologies in their local area. Residents on medium incomes ($80K to $120K) are less likely to support the application of technologies than those on higher incomes (over $120K) (Prior 2018).	Does the plan consider that residents earning lower incomes are less likely to support the application of remediation technologies than those on higher incomes?	●	
A1.2	Household tenure (rent or own): type of household tenure influences residents' levels of support for the application of remediation technology in their local area. Residents who own or are purchasing their own home in neighbourhoods surrounding the site are less likely to support the application of remediation technologies than those who rent a home (Prior 2018).	Does the plan consider the household tenure (rent or own), and how this influences a resident's support for the application of remediation technologies?	●	
A1.3	Personal motivational values: the range of values found to motivate residents' decisions to withhold or grant support for the application of technologies spanned the four domains of the Schwartz value system (see figure 7 for more detail): • openness to change (self-direction and stimulation) • conservation (conformity, tradition) • self-transcendence (universalism, benevolence), and • self-enhancement (power, achievement). These values crossed the two key dimensions of the Schwartz value	Does the plan consider that residents' acceptance of remediation technologies is strongly influenced by their motivational values? In situations where residents have strong positive and negative views on the application of technology types, it can be helpful to engage with those residents to understand the motivational values that guide their positions. The Schwartz framework provides one tool that can be used to assess those	●	

	system: across the contrasting domains of self-transcendence (e.g. universalism) and self-enhancement (e.g. power, achievement), and across the contrasting domains of openness to change (e.g. stimulation) and conservation (e.g. tradition, conformity). Threats to these motivational values have a key impact on a resident's level of support for remediation technologies, and furthermore if residents hold contrasting motivational values this may generate conflict. For example, a potential conflict may exist between residents who support a technology application based on an openness to the change brought about by that technology and those who seek to withhold support based on beliefs that such technologies are unnatural (risky) interventions (Prior 2018).	values (figure 7)		

Self-transcendence (universalism, benevolence): For some residents level of support for a technology is dependent on the belief that it enhances the welfare of their local community, neighours, or family. This benevolence is often made apparent when respondents openly assess their support for a remediation technology, using pronouns like we, residents, community, us. Some residents assessed their support for a technology based on it's perceived ability to protect the welfare of all people (the public) and the environment. This contrasts with the in-group focus of benevolence. In some instances a residents universalism values can extend to the welfare of distant communities and future generations.

Openness to change (self-direction and stimulation): For some residents willingness to withhold or grant support for the application of remediation technologies was motivated by a belief in the beneficial, positive, rather than threatening change that could be brought about by remediation technologies. These motivational values are reflected in those residents who agreed that technologies are effective at solving problems faced by human beings.



Self-enhancement (power, achievement): Some residents level of support for a technology is dependent on the belief that the technology is in their own interests, that is, the technology enhances their own welfare (e.g. health, amenity). This is apparent in the frequent use of first person language and the pronouns my and I.

Conservation (conformity, tradition): Some residents' willingness to withhold or grant support is motivated by their conformity and commitment to specific customs and ideas that their culture belief or religion provided. Traditional values residents use as reason for withholding support for technologies, often focus on beliefs that nature knows best and that human interference does not improve the situation at the contaminated site.

Figure 7: Personal motivational values guiding residents' support for remediation technology applications

Matrix A2: Does the plan consider how residents' support of technologies is impacted by their **physical context?**

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
A2.2	**Transportation through local streets**: transportation of contaminant-related materials influenced residents' support for the application of remediation technology. Those residents who are concerned about contaminant-related materials being transported through local streets to be treated at an offsite location were less likely to support the application of remediation technologies. For example, residents frequently explained that they withheld support for the much-applied dig and dump alternative of removing contamination from the site, because of concern about the risks associated with transporting the contaminated medium through streets in proximity to local homes (Prior 2018).	Will transportation of the contaminant be required? Will this travel be past people's home? Or past sensitive sites? Does the plan consider how this impact may affect a resident's acceptance of a technology?	●	●

Matrix A3: Does the plan consider how residents' support of technologies is impacted by their **institutional context?**

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
A3.1	**General trust in others**: A resident's general level of trust for others (companies, government, scientific organisations, NGOs, as well as other residents) influences their levels of support for the application of remediation technologies. Those who were generally more trusting were more supportive of the application of technologies, and conversely those who were less trusting were generally less supportive of the application of technologies (Prior 2018).	Does the plan consider how a resident's general level of trust in others influences their support of remediation technologies?	●	

Matrix A4: Does the policy or plan consider how residents' support of technologies is impacted by the **technologies' characteristics?**

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
A4.1	**Type and reputational effect (stigma)**: the type of technology proposed for remediation has an influence on residents' levels of support for that technology's application at a nearby site. Respondents are more supportive of the application of biotechnologies than they are of chemical technologies, thermal technologies, and physical technologies (Prior 2018). Residents' support for remediation technology types can be explained in part by the reputation effect associated with each technology type. In other words, the level of residents' support for a remediation technology type seems to be affected by an intrinsic value associated with it. For instance, the probability that a resident favours biotechnologies over chemical technologies with the same impact on objective environmental quality levels (e.g. air and water quality) is much larger. In fact, residents prefer biotechnologies over any other types of remediation technologies when the level of environmental quality improvement is similar. Physical and thermal technologies have a similar effect on residents' acceptance, whilst chemical technologies have the lowest level of acceptability. It can be concluded that chemical technologies have the highest stigma effect and they need better levels of environmental quality improvement in order to be accepted by the residents over other technology types (Huynh *et al* 2017).	Does the plan consider how resident's support for a technology's application is affected by the technology type? Is the plan sensitive to the reputational effect (stigma) that is attributed to a remediation technology type by residents, and the effect this has on a resident's choice of a technology? Furthermore, is the plan sensitive to the way in which reputational effect (stigma) impacts residents' perceptions of environmental quality improvement?	●	●
A4.2	**Effectiveness**: residents support of a technology is guided by its perceived effectiveness, in particular the application's perceived ability to eliminate an environmental contaminant, or restrain or block its exposure pathway to receptors (table 9) (Prior 2018).	Does the plan consider how residents' acceptance of a technology's application is affected by the technology's perceived effectiveness?	●	●

A4.3	**Safety**: residents often use a technology's perceived safety to assess support for its application. Safety considerations influence residents' acceptance of technologies in two main ways: firstly, residents often declare their support for a technology in preference to another based on their perceptions of safety for the technologies, and secondly, they will not support a technology unless it can be shown that the technology is safe (table 9) (Prior 2018).	Does the plan consider how residents' acceptance of a technology's application is affected by the technology's perceived safety?	●	●
A4.4	**Economy**: the economy of the remediation technology was a reason that may residents choose to withhold or grant their support for the application of a technology. Residents' perceptions of a technology's economy was not concentrated on the monetary risks of the technology alone, but also extended to its economic use of resources and energy (table 9) (Prior 2018).	Does the plan consider how resident's support of a technology's application is affected by the technology's perceived economy?	●	●
A4.5	**Containment**: residents frequently highlighted how their support for the application of a technology was contingent on its perceived ability to contain the contaminant during application, or the side effects of the application. Containment was more frequently reported as a motivation for withholding support for the application of thermal and physical technology types (table 9) (Prior 2018).	Does the plan consider how residents' acceptance of a technology's application is affected by the technology's perceived ability to contain the contaminant and the side effects from the remediation technology?	●	●
A4.6	**Location**: residents' stated preferences for remediation location (on-site in-ground, on-site out-of-ground, offsite) are consistent with their responses to specific remediation technologies, in the sense that residents who are more supportive of offsite treatment are more likely to support the application of offsite remediation technology (table 9) (Prior 2018).	Does the plan consider how residents' acceptance of a technology's application is affected by the technology's location?	●	●

A4.7	**Un/proven**: residents often withheld support for technologies that they perceived as unproven, in particular emergent technologies like nanotechnologies and phytoremediation, and often only supported technologies that had been successfully trialled (table 9) (Prior 2018).	Does the plan consider how resident's support of a technology's application is affected by whether residents perceive them to be proven or not?	●	●
A4.8	**Duration**: the perceived duration of a remediation technology application affects residents' levels of support for that technology. Two dimensions of a technology's duration influence residents' levels of support for it: the perceived long period of time that it takes some technologies to complete the remediation, and the perception that some technologies are only short-term solutions that transfer the problem to future generations. Perceived duration is a more frequently stated reason for residents to withhold support for physical and biotechnology applications (table 9) (Prior 2018).	Does the plan consider how residents support of a technology's application is affected by whether residents perceive duration of the technology?	●	●
A4.9	**Naturalness**: residents frequently use a technology's perceived naturalness as a motivation for withholding or granting support for its application (table 9) (Prior 2018).	Does the plan consider how residents' acceptance of a technology's application is affected by the degree to which residents perceive the technology as natural?	●	●
A4.10	**Plausibility**: the perceived plausibility of a remediation technology application affects whether residents support or withhold support for its application. Plausibility was a more frequently stated concern for emergent technologies (table 9) (Prior 2018).	Does the plan consider how residents' support of a technology's application is affected by whether they perceive them as plausible?	●	●

Table 9. Characteristics of different technology applications that most commonly identified as affecting residents' support for different technologies.

				Characteristics of a remediation technology most commonly identified as affecting residents' support for different technologies								
Remediation technology type	**Remediation technology application**	**Type of contaminant medium**	**Location of technology application**	Effectiveness	Safety	Containment	Location	Naturalness	Proven	Duration	Economy	Plausibility
Thermal	Thermal vapour extraction	Soil, waste	In-situ	●	●	●		●				
	Thermal desorption	Soil	Ex-situ onsite	●	●	●						●
	Incineration	Soil	Ex-situ offsite	●	●	●					●	
Chemical	Chemical treatment general	Groundwater, soil	In-situ/ex-situ onsite	●	●		●	●				
	Nanoremediation	Groundwater, soil	In-situ	●		●		●	●			
	Permeable reactive barrier	GW	In-situ	●	●	●		●				
Physical	Encapsulation	Soil	In-situ/ex-situ onsite	●		●	●			●		
	Dig and dump	Soil	Ex-situ offsite	●			●			●	●	
	Stabilisation	Soil, waste	In-situ	●	●	●				●		
	Mining	Soil, waste	Ex-situ onsite, ex-situ offsite	●	●		●				●	
Bio	Microbial bioremediation	Groundwater, soil, waste	In-situ	●					●	●	●	
	Phytoremediation	Groundwater, soil	In-situ	●	●					●		●

Matrix A5: Does the plan consider the way in which residents weigh up their support for technologies, and the statements and sanctions that residents use to provide or withhold their support for technologies?

Code	Evidence-based insights	Questions	Community engagement planning	Remediation planning
A5.1	**Weighing up risks and benefits**: how residents weigh up the risks and benefits of a technology application influences their levels of support for the application of that technology. Those who believed the risks outweighed the benefits of a technology were less supportive of the technologies' application at the site, than those who believed the risks and benefits of a technology application where equal, who in turn were less supportive than those who believed the benefits outweighed the risks of the technology's application at the site (Prior 2018).	Is the policy or plan sensitive to how residents' assessments of the risks and benefits of a technology application influence their levels of support for a technology application?	●	●
A5.2	**Assessing environmental improvements and human health improvements:** residents' acceptance of remediation technologies can be influenced by the extent to which they expect it to improve environmental quality (e.g. improvement in air quality, ground water quality, or the ability to grow vegetables in a garden) and the importance of that environmental improvement to human health levels. For example, a resident's acceptance of a remediation technology increases significantly when it involves an improvement in air quality levels: In assessing the level of environmental or health improvement preferred by residents, detailed consideration needs to be given to the design of environmental quality ladders and health scales (Huynh *et al* 2017).	Is the plan sensitive to the ways in which residents' acceptance of a remediation technology is affected by the technology's ability to improve local environmental quality levels (e.g. improvement in air quality, ground water quality, or ability to grow vegetables in a garden) and the utility of that environmental improvement to human health levels?	●	●

<table>
<tr>
<td>A5.3</td>
<td>Statements[6] residents use to negotiate support: residents use a common set of statements to indicate their willingness to shift from withholding to granting support for the application of technologies. Whilst residents identified the responsible party, the regulatory authority, the remediation service provider, the local government, independent experts and an auditor as the appropriate entity to address these statements, there was a preference for them to be answered by an independent expert. These statements could be separated into 3 key types:

1. The first type of statement (see statement 1, table 10) disclosed a resident’s willingness to shift from withholding to granting support upon the provision of evidence (i.e. information or demonstration) that a technology has certain desired characteristics e.g. the containment of gases, treatment will be onsite.

2. The second type of statement (see statements 2 to 4, table 10) reveals a resident’s willingness to shift from withholding to granting support for a technology based on the provision of evidence (i.e. information or demonstration) to the resident about the range of technologies that can be used at the site.

3. The third type of statement (see statements 5 to 11, table 10) highlights how a resident’s shift from withholding to granting support for a technology may be enabled through certain roles and responsibilities being carried out by the responsible party, regulatory authority, remediation service provider, local government, independent expert and auditor (Prior 2018).</td>
<td>Is the plan sensitive to the types of questions that residents ask in an effort to shift from withholding to granting support for the application of technologies?</td>
<td>●</td>
<td>●</td>
</tr>
</table>

[6] Within the context of these guidelines we have used the word statements here, in the study these statements are understood as a series of norms. See the full study for an explanation of why we use the term norms (Prior 2018).

A5.4	**Statements residents use for not negotiating support**: respondents used two types of statements to explain why they refused to grant support for the application of remediation technologies: 1. Residents indicated that they would not provide their support for a selected technology due to perceived characteristics that amplified its risks (see statement 12, table 10). 2. Residents indicated that they were not willing to support any technology applications at the site due to risks that they perceived were innate to all technologies (see statement 13, table 10) (Prior 2018).	Is the plan sensitive to the types of statements that residents make when they do not wish to support the application of technologies?	●	●
A5.5	**Possible social sanctions imposed by residents that generate socio-political risks for the remediation process**: where residents do not support the application of remediation technologies in their local area, and a responsible party proceeds with its application at a site, some residents may respond by imposing social sanctions. Tangible forms of these social sanctions include: • inhibiting the movement of those carrying out the remediation, through e.g. restrictions on access to neighbouring properties and communities near the site • lodging objections through formal regulatory processes • instigating economic sanctions or restrictions on specific actors carrying out the remediation process • protesting against the application of the technology • generating political sanctions e.g. through engaging with political figures, and • drawing attention to the actions of those carrying out the remediation with support of the media as a deterrent, with the aim of adversely impacting their reputation, profits or stability. The implementation of these social sanctions may pose significant socio-political risks to remediation practice at a given site (Prior 2018).	Does the plan consider the socio-political risks that may stem from implementing technologies that are not supported by residents?	●	●

Table 10. Statements commonly used by residents to provide or withhold their support for the application of technologies.

Part 1: Norms 1 through 11 – for negotiating level of support
Norm 1: [All[a], but with preference for an independent expert] [must] [provide evidence[b] that technology A[c] … … can *contain* the contaminant and/or by-products of the remediation process] … is *safe*] … is *effective*] … is *proven*] … is at a preferred *location* e.g. on-site inground, on-site out-of-ground, offsite] … is *natural*] … is *economical*] … is of a preferred *duration* e.g. long-term or short-term] … does not include *transporting* contaminated materials through local streets] … will generally work] … accords with their values] … is beneficial to humans, ecosystem services, and the environment] … is not a risk to humans, ecosystem services, and the environment] [before technology A is applied in the local area]
Norm 2: [All[a], but with preference for an independent expert] [must] [provide evidence[b] that technology A[c] when compared to other technologies B, C, D[d] that can be applied at the site is … … as or more able to contain the contaminant and/or by-products of the remediation process] … as safe or safer] … as or more effective] … as or more proven] … at a preferred location, e.g. on-site inground, on-site out-of-ground, offsite] … as or more natural] … as or more economical] … of a preferred duration, e.g. long-term or short-term] [before technology A[c] is applied in the local area]
Norm 3: [All[a]] [may] [apply technology A[c] in the local area, but would prefer technology B, C, D[d] because it is … more able to contain the contaminant and/or by-products of the remediation process] … safer] … more effective] … more proven] … at a preferred location, e.g. on-site inground, on-site out-of-ground, offsite] … more natural] … more economical] … of a preferred duration, e.g. long-term or short-term]

Norm 4: [All[a]] [must] [use technology A[c] in conjunction with technologies B, C, D[d] because of concerns about technology A's …

… ability to contain the contaminant and/or by-products of the remediation process]
… safety]
… effectiveness]
… proven use]
… location e.g. on-site inground, on-site out-of-ground, offsite]
… naturalness]
… economy]
… duration e.g. long-term or short-term]

[before technology A[c] is applied in the local area]

Norm 5: [Remediation service provider, regulatory authority or problem holder] [must] [address the resident's uncertainty about technology A[c] by providing *guarantees* about its …

… ability to contain the contaminant and/or by-products of the remediation process]
… safety]
… effectiveness]
… proven use]
… location e.g. on-site inground, on-site out-of-ground, offsite]
… naturalness]
… economy]
… duration e.g. long-term or short-term]

[before technology A[c] is applied in the local area]

Norm 6: [All[a]] [must not] [apply technology A[c] in the local area without first providing residents with evidence[b] of other possible technologies B, C, D[d]] [that can be used in the local area]

Norm 7: [All[a]] [must] [provide a truthful and transparent step-by-step explanation of technology A[c]'s application e.g. what is being remediated, who is doing it, how it will be done, and where it will be done] [before technology A[c] is applied in the local area]

Norm 8: [Remediation service provider] [must] [agree to …

… keep residents informed about the selection and application of technology A[c]]
… provide ample community engagement about technology A[c]]

[before technology A[c] is applied in the local area]

Norm 9: [The regulatory authority and local government] [must] [regulate the application of technology A[c]] [before the technology is applied in the local area]

Norm 10: [Independent expert] [must] [validate evidence about technology A proposed by the problem holder] [before technology A[c] is applied in the local area]

Norm 11: [The problem holder] [must not] [provide evidence about technology A[c] without verification from an independent expert] [before technology A[c] is applied in the local area]

Part 2: Norms 12 through 13 – for not negotiating level of support
Norm 12: [All[a]] [must not] [apply technology A[c] in the local area because it … … is unable to contain the contaminant and/or by-products of the remediation process] … is unsafe] … is ineffective] … is unproven] … occurs at a certain location e.g. on-site inground, on-site out-of-ground, offsite] … is unnatural] … is uneconomical] … is of a duration e.g. long-term or short-term] … includes transporting materials through local streets] … is a type of technology e.g. chemical, physical, thermal, bio]
Norm 13: [All[a]] [must not] [apply any technology A[c] or B, C, D[d] in the local area because its application does not accord with a resident's motivational values e.g. nature knows best, and all human intervention in nature is wrong]

[a] All includes problem holder, regulatory authority, remediation service provider, local government, auditor, and independent expert; [b] evidence includes explanation, information, demonstration; [c] technology A is the technology under consideration; [d] technology B, C, D' are other technologies that might be considered.

6. Glossary of terms

Bioremediation refers to the use of biological technologies in the form of microbes, fungi and enzymes to clean up contaminated land and groundwater.

Chemical remediation involves the use of chemical reagents to oxidise or reduce contaminants, particularly in groundwater, although the method can extend to soils. There are several chemical oxidants that can be used to treat chlorinated solvents, and some mobile heavy metals.

Chemical treatment general (in-situ) involves the injection of chemical oxidants or reductants into groundwater or soil, which subsequently leads to the destruction of contaminants of concern or their transformation into something safer.

Contamination means the condition of land or water where any chemical substance or waste has been added as a direct or indirect result of human activity at above background level and represents, or potentially represents, an adverse health or environmental impact (CRC CARE 2019n; NEPC 2013).

Contaminated land is land (including buildings and structures on land and surface and underground water) on and/or in which a substance is present at a concentration which exceeds that normally present (i.e. commonly referred to as the background level) and the presence of which presents, or would be likely to present, a risk of harm to human health and/or a risk of environmental harm (Barnes *et al* 2013).

Contaminated site means the area impacted by the contaminant. The parcel(s) of land where remediation activity is occurring.

Dig and dump (ex-situ offsite) involves the excavation and removal of the contaminated soil from the site and its transportation to a landfill site where it is stored and monitored.

Encapsulation (in-situ) comprises the physical isolation and containment of the contaminated material. In this technique, the impacted soils are isolated by low-permeability caps, slurry walls, grout curtains, or cut-off walls.

Environmental regulator refers to the government agency in each state or territory that has responsibility for matters relating to contaminated sites.

Ex-situ offsite remediation involves remediation options where the affected medium (soil, water) is removed from its original location and either stored or cleaned offsite.

Ex-situ onsite remediation involves remediation options where the affected medium (soil, water) is removed from its original location and cleaned or stored onsite.

Immobilising/stabilisation (in-situ, ex-situ) refers to a process that reduces the risk posed by a waste or soil by converting the contaminant into a less soluble, immobile, and less toxic form.

Incineration (ex-situ offsite) involves excavating and heating soils so that the contaminants are destroyed.

In-situ remediation involves treatment of contaminants in place using technologies such as microbial bioremediation.

Microbial bioremediation (in-situ) utilises microbial activity to remove or degrade contaminants in groundwater, waste or soil.

Mining (ex-situ onsite, ex-situ offsite) involves excavation, screening and separation and recycling of all old landfill material. Unusable or contaminant-producing materials are then stored.

Monitored natural attenuation (MNA) may be used after remediation has been carried out to the extent practicable through other technology types. It may be acceptable to allow the residual contamination to degrade naturally (i.e. monitored natural attenuation). This particularly applies in the case of residual groundwater contamination, where the residual matter poses a low risk.

Nanoremediation (in-situ) involves introducing chemical substances containing microscopic particles called nanoparticles to destroy or degrade the contaminant in the soil or groundwater to an acceptable level.

Phytoremediation (in-situ) uses plants to clean up contaminated soils and groundwater. This process takes advantage of the ability of plants to take up, accumulate, stabilise and/or degrade contaminants in soil and groundwater.

Proximity (distance to site) is considered in remediation guidelines (CRC CARE 2019n). The proximity of residential areas or sensitive receptors – childcare centres, hospitals, schools or nursing homes – to the contaminated site will have a bearing on the degree of engagement required (Heath *et al* 2010).

Permeable reactive barrier (in-situ) involves introducing a chemical treatment wall into the groundwater flow – as contaminated groundwater passes through the treatment wall, the contaminants are either trapped by the treatment wall or transformed into harmless substances that flow out of the wall.

Physical remediation generally involves a range of physical techniques such as vacuum extraction (to remove contaminants in vapour form), soil washing, and separation. Excavation and removal of contaminated soil and disposal in a landfill is a common method of remediation.

Remediation means the clean-up or mitigation of pollution or of contamination of soil or water by various methods (CRC CARE 2019l).

Remediation service provider means any entity in the private sector professionally engaged in the assessment, remediation or management of contaminated sites.

Residents are the affected individuals and/or groups residing in a locality near a contaminated site who may be affected by contamination from the site or the remediation process associated with the site (Heath *et al* 2010).

Responsible party is the party who is responsible for remediation at a contaminated site. Each state and territory legislates for the regulation of activity related to contaminated sites. In Australia the ‘polluter pays principle’ is generally adopted to determine liability and responsibility for the remediation and management of a contaminated site. If it is not possible or practicable to impose liability on the polluter, each jurisdiction has legislative powers to issue notices to appropriate persons.

Risk means the probability in a certain timeframe that an adverse outcome will occur to a person, group, or ecological system that is exposed to a particular dose or concentration of a hazardous agent; the level of risk depends on both the toxicity of the hazardous agent and the level of exposure (Heath *et al* 2010).

Risk communication is an interactive process involving the exchange among individuals, groups and institutions of information and expert opinion about the nature, severity and acceptability of risks and the decisions to be taken to combat them. Risk communication is delivered most efficiently in the context of a well-structured stakeholder engagement process.

Risk management is a coordinated set of activities and methods that are used to direct and to control risks (CRC CARE 2013a).

Risk perceptions are the subjective judgements that people make about the characteristics and severity of a risk. Perception of risk can be influenced by numerous factors beyond just the scientific data (CRC CARE 2019l; NEPC 2013).

Stakeholder is often used interchangeably with the term community. For the purposes of this guideline, stakeholder means an individual, group, organisation or other entity that may be interested in, or affected by, the remediation and management of a contaminated site. Depending on specific site circumstances, stakeholders may include residents, site owners, public health officials, government regulatory authorities, media outlets, businesses working on site, and environmental or other action/interest groups, as well as site owners and people working on the project (CRC CARE 2019n).

Stakeholder engagement is the process of engaging and communicating with people (individuals and groups) who have an interest, or stake, in the remediation and management of a contaminated site. It can include a variety of approaches:

- to inform – one-way communication or delivery of information
- to consult – providing for ongoing stakeholder feedback
- to involve – a two-way process to ensure stakeholder concerns are considered as part of the decision-making process
- to collaborate – developing partnerships with stakeholders to make recommendations, and
- to empower – allowing stakeholders to make decisions and to implement and manage change (CRC CARE 2019l).

Sustainability means an integrated assessment of the environmental, economic, and social impacts of remedial activities which meets the needs of the present without compromising the ability of future generations to meet their own needs (CRC CARE 2013a).

Sustainable remediation is a remediation solution selected through the use of a balanced decision-making process that demonstrates, in terms of environmental, economic and social indicators, that the benefit of undertaking remediation is greater than any adverse effects.

Thermal desorption (ex-situ onsite) involves excavating and heating soils so that contaminants are vaporised and the vaporised contaminants are then collected and treated by other means.

Thermal vapour extraction (in-situ) involves injecting heat into the soil or waste so that contaminants are vaporised and extracting the vapour that is formed by the heat.

Thermal remediation generally refers to the use of heat to de-contaminate an area. Thermal remediation can be done onsite (in-situ) (e.g. steam injection, resistance heating and conductive heating); or by carrying out a treatment of excavated soil offsite (ex-situ). In particular, thermal treatment is used to treat recalcitrant compounds such as persistent organic pollutants.

Worker means any person who carries out work for a person conducting a business or undertaking, including work as an employee, contractor, subcontractor, self-employed person, outworker, apprentice, trainee, work experience student, employee of a labour hire company placed with a host employer, or volunteer.

7. References

Alhakami, AS & Slovic, P 1994, 'A psychological study of the inverse relationship between perceived risk and perceived benefit', *Risk Analysis* vol. 14, pp. 1085–1096.

Arnstein, S 1969, 'A ladder of citizen participation', *Journal of the American Planning Association* vol. 35, pp. 216–224.

Bardos, P, Harries, ND & Smith, JWN 2011, *Applying sustainable development principles to contaminated land management using the SuRF-UK framework*, Spring, pp. 77–100.

Barnes, S, Clements, L & Hill, CM 2013, *Identification of existing guidance for a National Remediation Framework*, Technical Report no. 28, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide, Australia.

Baron, J, Hershey, JC & Kunreuther, H 2000, 'Determinants of priority for risk reduction: the role of worry', *Risk Analysis* vol. 20, pp. 413–428.

Bechara, A, Damasio, H, Tranel, D & Damasio, AR 1997, 'Deciding advantageously before knowing the advantageous strategy', *Science* vol. 275, pp. 1293–1295.

Beck, U 1992, 'From industrial society to risk society: questions of survival, social structure and ecological environment', *Theory, Culture & Society* vol. 9, pp. 97–123.

Beierle, TC & Konisky, D 2000, 'Values, conflict, and trust in participatory environmental planning', *Journal of Policy Analysis and Management* vol. 19, pp. 587–602.

Benn, S, Brown, P & North-Samardzic, A 2009, 'A commentary on decision-making and organisational legitimacy in the risk society', *Journal of Environmental Management* vol. 90, pp. 1655–1662.

Berkes, F, Reid, W, Wilbanks, T & Capistrano, D 2013, 'Conclusions: bridging scales and knowledge systems', in Reid, W, Wilbanks, T, Capistrano, D & Berkes, F (eds.) *Bridging Scales and Knowledge Systems*, Washington: Island Press.

Bonaiuto, M, Carrus, G, Martorella, H & Bonnes, M 2002, 'Local identity processes and environmental attitudes in land use changes: the case of natural protected areas', *Journal of Economic Psychology* vol. 23, pp. 631–653.

Borkovec, T, Robinson, E, Pruzinsky, T & Depree, JA 1983, 'Preliminary exploration of worry: some characteristics and processes', *Behaviour Research and Therapy* vol. 21, pp. 9–16.

Brody, C 1984, 'Differences by sex in support for nuclear power', *Social Forces* vol. 63, pp. 209–228.

Brown, P & Benn, S 2009, 'Toxic risk and governance: the case of hexachlorobenzene', *Journal of Environmental Management* vol. 90, pp. 1557–1558.

Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE) 2013a, *Defining the philoshopy, context and principles of the National Remediation Framework for remediation and management of* *contaminated sites in Australia Adelaide*, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2013b, *National Framework for Remediation and Management of Contaminated Sites in Australia*, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2019a [in prep], *Application guide for barrier systems*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2019b [in prep], *Application guide for bioremediation*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2019c [in prep], *Application guide for chemical immobilisation and solidification*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2019d [in prep], *Application guide for containment*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2019e [in prep], *Application guide for excavation*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2019f [in prep], *Application guide for in situ air sparging*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2019g [in prep], *Application guide for monitored natural attenuation*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2019h [in prep], *Application guide for pump and treat remediation*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2019i [in prep], *Application guide for skimming*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2019j [in prep], *Application guide for soil vapour remediation technologies*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and

Remediation of the Environment, Adelaide Australia.

CRC CARE 2019k [in prep], *Application guide for thermal desorption*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2019l [in prep], *Performing remediation options assessments*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2019m [in prep], *Guideline on documentation, record-keeping and reporting*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2019n [in prep], *Guideline on stakeholder engagement*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

CRC CARE 2019o [in prep], *Soil washing (physical separation and chemical extraction)*, National Framework for Remediation and Management of Contaminated Sites in Australia, Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Adelaide Australia.

Couch, SR & Coles, CJ 2011, 'Community stress, psychosocial hazards and EPA decision-making in communities impacted by chronic technological disasters', *American Journal of Public Health* vol. 101, pp. 140–149.

Delgado, A, Lein Kjølberg, K & Wickson, F 2011, 'Public engagement coming of age: from theory to practice in STS encounters with nanotechnology', *Public Understanding of Science* vol. 20, pp. 826–845.

EnHealth 2012, *Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards*, Commonwealth of Australia, Canberra, ACT.

Erkut, E & Verter, V 1995, 'A framework for hazardous materials transport risk assessment', *Risk Analysis* vol. 15, pp. 589–601.

Evans, R & Plows, A 2007, 'Listening without prejudice?: Re-discovering the value of the disinterested citizen', *Social Studies of Science* vol. 37, pp. 827–853.

Finucane, M, Alhakami, A, Slovic, P & Johnson, S 2000, 'The affect heuristic in judgments of risks and benefits', *Journal of Behavioral Decision Making* vol. 13, pp. 1–17.

Freudenberg, N 2004, 'Community capacity for environmental health promotion: determinants and implications for practice', health education and behaviour', *Health Education and Behaviour* vol. 31, pp. 472–490.

Gallagher, DR & Jackson, S 2008 'Promoting community involvement at brownfields sites in socio-economically disadvantaged neighbourhoods', *Journal of Environmental Planning and Management* vol. 51, pp. 615–630.

Greenberg, M, Burger, J, Powers, C, Leschine, T, Lowrie, K, Friedlander, B, Faustman, E, Griffith, W & Kosson, D 2002, ‘Choosing remediation and waste management options at hazardous and radioactive waste sites’, *Remediation Journal* vol. 13, pp. 39–58.

Greenberg, M, Mayer, H & Powers, C 2011, ‘Public preferences for environmental management practices at DOE's nuclear waste sites’, *Remediation Journal* vol. 21, pp. 117–131.

Heath, L, Pollard, S, Hrudey, S & Smith, G 2010, *Engaging the Community: a handbook for professionals managing contaminated land*, CRC Contamination Assessment and Remediation of the Environment, Adelaide, Australia.

Hillier, N, Gennissen, J, Pickering, B & Smolenski, R 2009, ‘Our battle with hexachlorobenzene: citizen perspectives on toxic waste in botany’, *Journal of Environmental Management* vol. 90, pp. 1605–1612.

Ho, S, Scheufele, DA & Corley, EA 2011, ‘Value predispositions, mass media, and attitudes toward nanotechnology: the interplay of public and experts’, *Science Communication* vol. 33, pp. 167–200.

Ho, S, Scheufele, DA & Corley, EA 2013, ‘Factors influencing public risk–benefit considerations of nanotechnology: assessing the effects of mass media, interpersonal communication, and elaborative processing’, *Public Understanding of Science* vol. 22, pp. 606–623.

Huntington, HP 2000, ‘Using traditional ecological knowledge in science: methods and applications’, *Ecological Applications* vol. 10, pp. 1270–1274.

Huynh, E, Araña, J & Prior, J 2017, ‘Evaluating residents' preferences for remediation technologies: a choice experiment approach’, *Science of the Total Environment* vol. 621, pp. 1012–1022.

International Organisation of Standardisation 2015, *Soil quality: guidelines on sustianable remediation*, committee draft ISO/CD 18504.

Irwin, A 2006, ‘The politics of talk: coming to terms with the ‘new’ scientific governance’, *Social Studies of Science* vol. 36, pp. 299 –320.

Lee, CJ, Scheufele, DA & Lewenstein, BV 2005, ‘Public attitudes toward emerging technologies: examining the interactive effects of cognitions and affect on public attitudes toward nanotechnology’, *Science Communication* vol. 27, pp. 240–267.

Leung, Y 2013, ‘Perceived benefit’, in Gellman, M & Turner, J (eds.) *Encyclopedia of Behavioral Medicine*, New York: Springer Science+Business Media.

Loewenstein, G, Hesee, C, Weber, E & Welch, N 2001, ‘Risk as feeling’, *Pscyhological Bulletin* vol. 127, pp. 267–286.

Macgregor, D 1991, ‘Worry of technological activities and life concerns’, *Risk Analysis* vol. 11, pp. 315–324.

Macgregor, D, Slovic, P, Mason, RG, Detweiler, J, Binney, SE & Dodd, B 1994, ‘Perceived risks of radioactive waste transport through Oregon: results of a statewide survey’, *Risk Analysis* vol. 14, pp. 5–14.

Miller, J & Kimmel, L 2001, *Biomedical Communication: Purposes, Audience, and Strategies,* Academic Press: London.

Murdock, B, Wiessner, C & Sexton, K 2005, ‘Stakeholder participation in voluntary environmental agreements: analysis of 10 project XL case studies’, *Science, Technology, & Human Values* vol. 30, pp. 223–250.

National Environment Protection Council (NEPC) 2013, *Schedule B(8) – Guideline on Community Engagement and Risk Communication*, National Environment Protection Council Service Corporation, Canberra.

O'Riordan, T & Cameron, J 1994, *Interpreting the Precautionary Principle,* Earthscan: London.

Peters E, Slovic P, Hibbard JH, Tusler M 2006. ‘Why worry? Worry, risk perceptions, and willingness to act to reduce medical errors’, *Health Psychology* vol. 25,pp. 144-152.

Pollard, S, Brookes, A, Earl, N, Lowe, J, Kearney, T & Nathanail, CP 2004, ‘Integrating decision tools for the sustainable management of land contamination’, *Science of the Total Environment* vol. 325, pp. 15–28.

Prior, J 2016, ‘The norms, rules and motivational values driving sustainable remediation of contaminated environments: a study of implementation’, *Science of the Total Environment* vol. 544, pp. 824–836.

Prior, J 2018, ‘Factors influencing residents’ acceptance (support) of remediation technologies’, *Science of the Total Environment* vol. 624, pp. 1369–1386.

Prior, J, Hubbard, P & Rai, T 2017, ‘Using residents' worries about technology as a way of resolving environmental remediation dilemmas’, *Science of the Total Environment,* vol. 580, pp. 882–899.

Prior, J, Partridge, E & Plant, R 2014, ‘We get the most information from the sources we trust least: residents' perceptions of risk communication on industrial contamination’, *Australasian Journal of Environmental Management* vol. 21, pp. 346–358.

Prior, J & Rai, T 2017, ‘Engaging with residents' perceived risks and benefits about technologies as a way of resolving remediation dilemmas’, *Science of the Total Environment* vol. 601–602**,** pp. 1649–1669.

Raymond, C, Fazey, I, Reed, M, Stringer, L, Robinson, G & Evely, A 2010, ‘Integrating local and scientific knowledge for environmental management’, *Journal of Environmental Management* vol. 91, pp. 1766–77.

Reed, M 2008, ‘Stakeholder participation for environmental management: a literature review’, *Biological Conservation* vol. 141, pp. 2417–2431.

Ribeiro, R & Lima, F 2016, ‘The value of practice: a critique of interactional expertise’, *Social Studies of Science* vol. 46, pp. 282–311.

Satterfield, T, Kandlikar, M, Beaudrie, CEH, Conti, J & Harthorn, BH 2009, ‘Anticipating the perceived risk of nanotechnologies’, *Nature Nanotechnology* vol. 4, pp. 752–758.

Schmiege, SJ, Bryan, A & Klein, WMP 2009, ‘Distinctions between worry and perceived risk in the context of the theory of planned behavior’, *Journal of Applied*

Social Psychology vol. 39, pp. 95–119.

Siegrist, M 1998, 'Belief in gene technology: the influence of environmental attitudes and gender', *Personality and Individual Differences* vol. 24, pp. 861–866.

Siegrist, M 2000, 'The influence of trust and perceptions of risks and benefits on the acceptance of gene technology', *Risk Analysis* vol. 20, pp. 195–203.

Sjöberg, L 1998, 'Worry and risk perception', *Risk Analysis* vol. 18, pp. 85–93.

Sjöberg, L 2004, 'Editorial: Asking questions about risk and worry: dilemmas of the pollsters', *Journal of Risk Research* vol. 7, pp. 671–674.

Sjöberg, L 2006, 'Will the real meaning of affect please stand up?', *Journal of Risk Research* vol. 9, pp. 101–108.

Slovic, P 2001, *The Perception of Risk,* London, Earthscan Publications.

Slovic, P, Fischhoff, B & Lichtenstein, S 1980. 'Facts and fears: understanding perceived risk, *in:* Schwing, R & Albers, W (eds.), *Societal Risk Assessment: How Safe is Safe Enough?* New York: Springer Science.

Slovic, P, Layman, M, Kraus, N, Flynn, J, Chalmers, J & Gesell, G 1991, 'Perceived risk, stigma, and potential economic impacts of a high-level nuclear waste repository in Nevada', *Risk Analysis* vol. 11, pp. 683–696.

Sustainable Remediation Forum Australia, CRC CAREnvironment & Australiasian Land and Groundwater Association 2011a, *A framework for assessing the sustainability of soil and groundwater remediation*, Sustainable Remediation Forum Australia.

Sustainable Remediation Forum Australia, CRC CAREnvironment & Australiasian Land and Groundwater Association 2011b, *Draft: a framework for assessing the sustainability of soil and groundwater remediation*, Sustainable Remediation Forum Australia.

Sustainable Remediation Forum Australian and New Zealand 2012a, *Case study examples: working group report*, accessed 9 January 2013, available from <www.surfanz.com.au/pdfs/Case Example WG DRAFT Report Dec 2012.pdf>.

Sustainable Remediation Forum Australian and New Zealand 2012c, *Metrics and tools: working group report*, available from <www.surfanz.com.au/pdfs/Metrics and Tools DRAFT WG Report Dec 2012.pdf>.

Sustainable Remediation Forum Australian and New Zealand 2012d, *Planning: working group report*, accessed 9 January 2013, available from <www.surfanz.com.au/pdfs/Planning WG DRAFT Report Dec 2012.pdf>.

Sustainable Remediation Forum United Kingdom 2009, *A framework for assessing the sustainability of soil and groundwater remediation*, draft copy subject to public consultation May 2009, Sustainable Remediation Forum, United Kingdom.

Tallis, F, Davey, G & Capuzzo, N 1994, 'The phenomenology of non-pathological worry: a preliminary investigation', In*:* Davey, G & Tallis, F (eds.), *Worrying: Perspectives on Theory, Assessment, and Treatment,* Oxford: John Wiley.

United States Sustainable Remediation Forum 2009, 'Sustainable remediation white paper—Integrating sustainable principles, practices, and metrics into remediation projects', *Remediation Journal* vol. 19, pp. 5–114.

Venkatesh, V & Davis, FD 2000, 'A theoretical extension of the technology acceptance model: four longitudinal field studies', *Management Science* vol. 46, p. 186.

Vodouhe, FG & Khasa, DP 2015, 'Local community perceptions of mine site restoration using phytoremediation in Abitibi-Temiscamingue (Quebec)', *International Journal of Phytoremediation* vol. 17, pp. 962–972.

Wakefield, SEL, Elliott, SJ, Cole, DC & Eyles, JD 2001, 'Environmental risk and (re)action: air quality, health, and civic involvement in an urban industrial neighbourhood', *Health & Place* vol. 7, pp. 163–177.

Waters, EA 2008, 'Feeling good, feeling bad, and feeling at-risk: a review of incidental affect's influence on likelihood estimates of health hazards and life events', *Journal of Risk Research,* vol. 11, pp. 569–595.

Wester-Herber, M 2004, 'Underlying concerns in land-use conflicts—the role of place-identity in risk perception', *Environmental Science & Policy* vol. 7, pp. 109–116.

Wong, CML 2015, 'The mutable nature of risk and acceptability: a hybrid risk governance framework', *Risk Analysis* vol. 35**,** pp. 1969–1982.

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CRC CARE
ATC Building
University of Newcastle
Callaghan NSW 2308
Australia

Postal
C/- Newcastle University LPO
PO Box 18
Callaghan NSW 2308
Australia

Contact us
P: +61 2 4985 4941
E: admin@crccare.com

www.crccare.com

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