EPA
South Australia

Guidelines for assessment of underground storage systems

ENVIRONMENT PROTECTION AUTHORITY

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Guidelines for assessment of underground storage systems
Cover Subtitle

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Disclaimer This publication is a guide only and does not necessarily provide adequate information in relation to every situation. This publication seeks to explain your possible obligations in a helpful and accessible way. In doing so, however, some detail may not be captured. It is important, therefore, that you seek information advice regarding your obligations, including legal advice.

EPA FOR RECONCILIATION

The EPA acknowledges and respects the Aboriginal peoples of South Australia as the first peoples and nations of this State. We recognise them as the traditional custodians of land and waters in South Australia and that their spiritual, social, cultural and economic beliefs are of ongoing importance today. We recognise that they have made, and continue to make, a unique and irreplaceable contribution to the State.

Artwork: 'Caring for Country', courtesy of Arrernte man Scott Rathman, for the EPA.

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Abbreviations

ASC NEPM	*National Environment Protection (Assessment of Site Contamination) Measure 1999* (as amended 2013)
AST	above ground storage tank
COI	chemicals (substance) of interest
CRC CARE	Cooperative Research Centre for Contamination Assessment and Remediation of the Environment
CSM	conceptual site model
DNAPL	dense non-aqueous phase liquid
DQO(s)	data quality objective(s)
DSI	detailed site investigation
EPA	South Australian Environment Protection Authority
EP Act	*Environment Protection Act 1993*
EPP	environment protection policy
EP Regulations	*Environment Protection Regulations 2023*
LNAPL	light non-aqueous phase liquid
NAPL	non-aqueous phase liquid
PAH	polycyclic aromatic hydrocarbon
PCA	potentially contaminating activity
PID	photo-ionisation detector
PSI	preliminary site investigation
QA/QC	quality assurance/quality control
ROA	remediation options assessment
RVR	remediation validation reporting
SAQP	sampling and analysis quality plans
SRP	site remediation plan
SSRA	site-specific risk assessment

USS	underground storage systems
UST	underground storage tank
VI	vapour intrusion
VOC(s)	volatile organic compound(s)

1 Introduction

The South Australian Environment Protection Authority (EPA) has prepared this guideline to describe the expected approach to risk–based assessment of site contamination in relation to underground storage systems (USS).

This guideline is primarily to provide information to site contamination consultants and site contamination auditors undertaking the assessment of site contamination in relation to USS. It also informs owners and operators of any site containing USS.

This guideline will ensure the assessment of site contamination associated with USS and related infrastructure is conducted to an appropriate standard in South Australia.

This document should be read in conjunction with the following EPA publications:

- Guidelines for the assessment and remediation of site contamination
- Guideline for the assessment of background concentrations
- Site contamination regulatory framework

Site contamination publications are available on the EPA website[1].

1.1 Purpose

The assessment of site contamination associated with USS may be undertaken for a number of reasons including due diligence, redevelopment, system upgrades, environmental assessment following loss of containment and release of stored liquid to the environment, condition of licence or as may be required under the *Environment Protection Act (1993)* (the EP Act).

This guideline has been prepared to align and promote the policy framework and guidance in the *National Environment Protection (Assessment of Site Contamination) Measure 1999 as amended in 2013* (ASC NEPM) and relevant EPA guidelines. The ASC NEPM (including any amendments and errata) is available for download from the ComLaw website[2]. The website for the former Standing Council on Environment and Water (SCEW) provides supporting information about the ASC NEPM, including frequently asked questions, errata and the ASC NEPM Toolbox[3].

1.2 Application of the guideline

USS are most often associated with the storage of petroleum products, commonly referred to as underground petroleum storage systems or UPSS. Other hazardous substances, including waste products, may also be stored in underground tanks. For the purpose of this guideline USS includes, but is not limited to, any tank, vessel, pipework, delivery system and any other infrastructure associated with the storage, transfer and/or dispensing of liquids or hazardous substances that are installed either totally or partially below the ground, with the exception of the storage of water or septic tanks. USS are generally located at

1 https://www.epa.sa.gov.au

2 http://www.comlaw.gov.au/

3 https://www.nepc.gov.au/nepms/assessment-site-contamination/toolbox

retail fuel outlets such as service stations, and are also used by other industries such as maintenance and logistics depots, commercial/industrial facilities, marinas, and for standby generators, heating and waste oil.

USS are one of the major sources of soil and groundwater contamination in South Australia. Due to the potential for leakage of product to the environment, approximately 45% of all site contamination records held by the EPA are associated with sites containing USS. The resulting environmental harm[4] or site contamination[5] that may result from USS, may present a risk to human health and/or the environment and impact on the acceptability of the site, or nearby sites, for their current or proposed use.

The assessment of sites containing USS present the following challenges:

- location of sites adjacent to sensitive receptors such as residential land use and receiving environments (ie surface water bodies, creeks and streams)
- the characteristics of the substance stored within the USS can lead to the off–site migration of chemicals in soil, vapour and groundwater
- limited information in relation to the size, location and age of USS infrastructure, including any changes in configuration, repairs or failures of the system that may have occurred historically
- access and disruption issues while undertaking intrusive assessment works to characterise the site contamination status of the site.

1.3 Currency of this guideline

This guideline describes industry best practice in the assessment of site contamination associated with USS in line with relevant legislation, policies and standards. It replaces EPA guideline, Assessment of underground storage systems (2005).

1.4 Protection of the environment during assessment

There should be appropriate protection of the environment during site assessment and remediation of site contamination. Section 1.7 of the EPA publication *Guidelines for the assessment and remediation of site contamination* and Schedule B2, section 15 of the ASC NEPM provides minimum measures that should be adopted to ensure the protection of the environment during site assessment.

Causing environmental harm (including serious or material environmental harm or environmental nuisance) is an offence under the EP Act and further regulatory action may be taken by the EPA. For information relating to the regulation of general environmental duty and the environmental harm provisions of the EP Act, refer to *Compliance and enforcement regulatory options and tools*.

1.5 Community engagement and risk communication

Community engagement and risk communication in relation to site contamination should be carried out by a suitably qualified and experienced person and in accordance with the principles and approach provided in Schedule B8 of the ASC NEPM and *Site contamination guideline for communication and engagement*.

The EPA expects an odour management plan to form part of any community engagement program.

4 As defined in section 5 of the EP Act

5 As defined in section 5B of the EP Act

1.6 Work health and safety

USS can contain hazardous and explosive substances. Working near or with USS can present significant risks which must be assessed and managed. This guideline does not detail the work health and safety requirements for the assessment of sites containing USS. There should be appropriate work health and safety measures in place for any person involved in the assessment of USS in accordance with the *Work Health and Safety Act 2012* and *Work Health and Safety Regulations 2012*, and guidance issued by *SafeWork SA* and other relevant organisations.

1.7 Acknowledgements

The EPA acknowledges the assistance of the New South Wales EPA and its publications in the development of this guideline.

2 Assessment

2.1 Introduction

Part 3 of the *Guidelines for the assessment and remediation of site contamination* details the recommended process for the assessment of site contamination in South Australia. In addition, Schedules A and B2 of the ASC NEPM outline and provide direction on the tiered–risk approach for the assessment of site contamination. The ASC NEPM states 'adequate site characterisation is the foundation for appropriate assessment of health and environmental risks associated with site contamination'. The assessment process should consider the entire site, not just the USS.

The assessment of USS should only be undertaken by suitability qualified and experienced site contamination consultants or certified site contamination practitioners, as defined in the EP Act, and EPA guidelines and policies.

Many site assessments proceed in multiple stages due to the complexity of site conditions and contaminant properties, and/or the discovery of unexpected contamination. Poorly planned and executed site assessments are likely to result in time delays and additional costs (both during the assessment and any subsequent remediation) and inadequate or misleading data which may result in risks to human health and/or the environment not being addressed (ASC NEPM, Schedule B2).

The ASC NEPM recommends the use of a systematic planning process to define the objectives of the site assessment and developing a plan for the collection and evaluation of representative data to achieve the defined objectives.

Without systematic planning, the site assessment may be ambiguous or inconclusive, which may lead to additional sampling requirements, resulting in increased costs and project delays (ASC NEPM, Schedule B2).

The following sections provide details on the information and minimum standard of assessment that the EPA expects to be undertaken for sites containing, or potentially containing, USS.

2.2 Preliminary site investigation

Preliminary site investigations (PSIs) usually include a desktop and field study to collect basic site information and identify the site characteristics (site location, land use, site layout, building construction, geological and hydrogeological setting, historical land uses and activities at the site), as well as identifying potential sources and pathways of contamination.

The PSI report should include an initial conceptual site model or CSM (see section 2.3), which should clearly identify any significant data gaps. This will assist in developing the required targeted site assessment works to address these data gaps.

Assessments of USS sites typically assume that the main chemicals of concern are those associated with petroleum hydrocarbon products. This approach does not consider other contaminants associated with:

- products that may have previously been stored in the USS or former USS
- drum cleaning and filling, eg pesticides, oil, grease, fuel, herbicides and solvents
- mechanical repairs, including parts cleaning, spray booths, body shop, tyre shop and brake machining
- waste oil and coolant usage and storage

- importation of contaminated fill
- operation of oil/water separation systems and car wash
- surrounding land uses, including underground pipelines
- fuel sources for previous boilers, etc – may include coal or fuel oil
- waste disposal practices.

Schedule B2 of the ASC NEPM describes the recommended information to be included in a PSI. Information particularly relevant to USS sites are:

- identification and location of all present and former tanks (site layout changes), lines, dispensers and filling points, workshops and waste disposal locations
- identification of systems on adjacent land, and kerbside tanks and pumps
- tank and pipeline history, such as method of construction, size, age of tanks, orientation, details of cathodic protection and maintenance, and records of any product or waste spills and leaks
- drainage and pollution control system diagrams which can include triple interceptor traps, blind sumps and oil/water separators
- information on service trenches and infrastructure on and adjacent to the site such as stormwater, sewer, gas, telecommunications and electrical easements which could represent pathways for contaminant migration
- current and historical as–built diagrams of the site
- concrete patchwork or newly filled areas that may indicate previous tanks and/or equipment having been removed or replaced, or new tank locations
- historical aerial photographs and/or council searches to indicate changes and modifications
- records of previous incidents and equipment modifications
- details of any tank and line integrity testing results
- details of any USS gauging at the site including current liquid volumes, stock reconciliation records (manual or statistical inventory reconciliation analysis if available), maintenance schedules and previous investigations
- dangerous goods records (refer to SafeWork SA)
- location of all above and underground structures and services to assist in planning detailed site investigation (DSI) sampling locations
- potential areas subject to filling with imported fill of unknown origin.

It is noted that this is not an exhaustive list, with all relevant information to be considered, investigated and presented, where available, as part of the PSI. Where information is not readily available this should be considered and discussed in the development of the CSM. In most instances a PSI is not a sufficient assessment of contamination at sites containing USS, with DSIs required to characterise the nature and extent of site contamination.

During site inspections it is important to verify the site layout, including the location of USS infrastructure, to determine any differences between historical and current site plans, and identify any potential changes between plans and observed site conditions. The current site layout may be different to the original layout, and there may be additional areas of potential contamination that require further investigation in the DSI stage.

2.3 Conceptual site model

Part 3 of the *Guidelines for the assessment and remediation of site contamination* and Schedule B2 of the ASC NEPM describes the fundamentals of developing a conceptual site model (CSM) and required information.

2.4 Chemicals (substances) of interest

The main chemicals (substances) of interest (COI) should be determined in the PSI and will vary depending on the potentially contaminating activity (PCA) undertaken at the site and the use of the USS. The main COI that may be associated with USS include, but are not limited to:

- petroleum fuels, lubricating oil and additives such as organometallic compounds, surfactants, biocides, molybdenum compounds and corrosion inhibitors, eg ethanol, lead, methyl tertiary butyl ether (MTBE), methyl ethyl ketone (MEK), di–isopropyl ether (DIPE), ethanol, trimethylbenzene (TMB), polycyclic aromatic hydrocarbons (PAHs) and phenols
- chemicals associated with chemical or fuel manufacturing
- metals naturally occurring in the product being refined including nickel, vanadium, copper, zinc and mercury
- catalysts and solvents that may have been used in the manufacturing process such as vanadium, cobalt, molybdenum and platinum
- degreaser and solvents such as chlorinated hydrocarbons
- waste oil (highly variable composition)
- other chemicals including ammonia, copper chrome arsenate (CCA), acids, caustics, coal tar distillates, paint, poison and chrome
- Per– and poly–fluoroalkyl substances (PFAS) associated with firefighting equipment (including training) or fire suppression systems.

2.5 Detailed site investigation

The PSI should provide sufficient information to design a detailed site investigation (DSI) that considers the preliminary CSM developed at the PSI stage, with intrusive site assessment works to support the refinement of the CSM to establish the potential source–pathway–receptor linkages using a multiple–lines–of–evidence approach. In some instances, it may be appropriate to complete the PSI and DSI stages as a single phase of assessment work.

The DSI stage should identify the nature of the site contamination and delineate its lateral and vertical extent to a sufficient degree that an appropriate level of risk assessment may be undertaken and, if necessary, provide the basis for the development of an appropriate remediation or management strategy (section 2.2 of Schedule B2 of the ASC NEPM).

Methods used at the DSI stage can include intrusive soil, groundwater, surface water and vapour assessments on and off the site, as determined by the data quality objectives (DQOs), and a sampling and analysis quality plan (SAQP) developed for the assessment. The development of the DQOs and SAQP should be guided by the identification of critical data gaps in the CSM. The DQO and SAQP process is outlined in section 5 and Appendix B of Schedule B2 of the ASC NEPM should be prepared for all DSI programs prior to the commencement of sampling activities.

Appropriate approvals should be sought prior to undertaking any intrusive assessment on public or private land. This may include permits for monitoring well installation, permission from the local council and informed consent from private land-owners[6].

The DSI process may be completed in a staged process, including a number of field events, to support the continual refinement of the CSM by assessing and testing data gaps and uncertainties identified in the CSM at the completion of each DSI stage.

Consultants, auditors, land-owners and occupiers should have regard to the mandatory reporting requirements to the EPA pursuant to the EP Act, EPPs and relevant EPA guidelines when undertaking any assessment. Further details in regards to mandatory notification requirements can be found in the Guidelines for the assessment and remediation of site contamination (EPA 2018).

Due to the uncertainty about the precise locations of underground infrastructure, an accurate site layout plan should be obtained (where available) and a 'dial before you dig' check must be completed to provide information on underground services. A survey by a professional service locator, which may include the use of ground penetrating radar, must be completed to confirm the location of all underground infrastructure prior to the commencement of any intrusive assessment works. Potential safety and environmental hazards must be considered and mitigated. For instance, installing groundwater wells in roadways or adjacent to buried infrastructure may have health, safety, security and environmental risks which must be addressed.

2.6 Data quality objectives and sampling and analysis quality plan

The establishment of DQOs and SAQP is necessary to ensure that the data collected is representative and reliable riskbased decisions can be reached as part of site assessment. The DQO process has seven steps to define the objectives, type, quantity and quality of information required for site assessment to inform the development of the SAQP.

To meet the objectives of a SAQP, refer to section 5.3 of Schedule B2 of the ASC NEPM. A SAQP should be prepared ahead of site assessment in consultation with relevant stakeholders, field staff and laboratory personnel.

SAQPs should also outline establishment of DQOs including:

- objectives/purpose of site assessment
- summary of the CSM (visual representation) including critical gaps
- a data gap analysis of existing data for inclusion/exclusion
- the appropriate environmental values and investigation levels and criteria to be adopted for the assessments including justification and limitations of criteria[7]
- media to be sampled and analysed ('where, how, what and when' approach)

6 Refer to section 12.3, *Guidelines for the assessment and remediation of site contamination*

7 Refer to section 3.5, *Guidelines for the assessment and remediation of site contamination*

- adequate quality assurance and quality control (QA/QC) processes to ensure that data collected will be reliable (field and laboratory data quality assessment)
- occupational health and safety requirements
- contingencies
- reporting and interpreting outcomes including any limitations or remaining data gaps.

Information on sampling design and QA/QC in the field and laboratory are described in the ASC NEPM schedules B2 and B3, respectively.

2.7 Soil assessment

Soil investigation programs for sites containing USS should delineate the nature and extent (lateral and vertical) of contamination of soil, and arrive at a scientifically defensible and statistically valid data set that characterises chemical concentrations in the soil. Investigation should target the locations of USS infrastructure (tanks, lines, fill points, dispensers and pits), site utilities and other potential contaminating activities undertaken at the site as identified in the PSI.

The consultant should be aware that unidentified infrastructure (such as old tanks and lines or unmarked drainage and service trenches) may exist at the site and ensure this is covered by a more generalised sampling strategy so that the nature and extent of site contamination is fully characterised. Where other potential sources of contamination, such as fill of unknown origin, workshop areas, above–ground storage tanks (AST) and waste oil tanks are identified, additional targeted sampling may be required once their locations have been established.

The selection of the investigation strategy and sample locations should be based on the information collected in the PSI stage and the preliminary CSM. The adopted sampling design and methodologies used should be fully documented and justified by the consultant, consistent with the section 6 of Schedule B2 of the ASC NEPM. Where sufficient information has been collected for the site in the PSI and the location of all current or former USS or associated infrastructure are known, a judgemental sampling design may be appropriate. Where the PSI is unable to reliably identify the locations of the USS infrastructure, systematic and grid–based sampling should be undertaken. The site's preliminary CSM should guide identification of any areas of concern, number of samples, COIs and sampling protocols to be used.

Based on the selected investigation strategy, design and methodology, appropriate sampling and QA/QC procedures should be clearly documented in the SAQP. Sections 5.4 and 7 of Schedule B2 of the ASC NEPM provides further details in relation to QA/QC procedures and investigation techniques respectively.

It is important to obtain soil samples from below the base depth of any known or suspected USS or associated infrastructure. Where identified, potentially contaminated areas, including contaminant source locations, should be sampled and analysed for all relevant COIs (see section 2.4 of this guideline).

As a minimum, field screening of all soil samples for volatile organic compounds (VOCs) should be undertaken using a photo–ionisation detector (PID) to gather information on the presence of contamination to inform further investigations and aid selection of samples for laboratory analyses. This should be supplemented by observations during fieldwork, including the visual appearance of samples (such as colour or staining) and olfactory indicators of contamination (odour).

Data from the field screening techniques are only qualitative indicators of contaminant concentrations and must be supported by laboratory data. Different methods and technologies are available and site characteristics will dictate which will be suitable. A number of more advanced field screening tools are available to identify areas or strata of interest. These include membrane interface probes (MIPs), laser–

induced fluorescence (LIF) and soil vapour surveys. Further details can be found in Schedule B2 of the ASC NEPM and *CRC CARE Technical Report 11 – Characterisation of sites impacted by petroleum hydrocarbons* (2009).

The consultant should ensure that accurate and detailed lithological logs are developed for each soil sampling location, which include the field screening and observation results. Further details with regard to the information to be included in soil assessment logs can be found in section 7 of Schedule B2 of the ASC NEPM.

The consultant should keep calibration gas certificates (where applicable), instrument maintenance records and calibration records for all field screening equipment used in an investigation. As a minimum calibration records on each day of the soil investigation should be recorded and presented within the DSI report.

Table 1 summarises the minimum recommended protocols for soil sampling at potential locations of concern at USS sites. The list is not exhaustive and the applicability of these protocols should be based on the CSM for each site, the stage of investigation (including field screening) or validation and access and safety constraints. The protocols should be considered a minimum requirement for sites being decommissioned or validated.

Table 1 Minimum recommended soil sampling (excluding QA\QC)

Potential locations of concern	Assessment (infrastructure remaining)	Validation (infrastructure removal)	Comment
USS	Minimum of one sample per each side and end of the USS (a minimum of four samples) down to a minimum depth of 3 m. Borehole locations and depths should be guided by olfactory/visual/field indicators (PID).	Minimum of five samples per UST at or below the base of the tank or where UST corrosion is observed and each wall of the UST pit (ie one base and four wall samples). Samples should be collected at the approximate depth of the base of the tank. Collect and analyse any ingress water and or residual emulsion.	If assessing a tank farm then it is acceptable to have boundary assessment bores rather than four sample locations per UST. If resulting UST excavation is large (>25 m^2 per wall or base) then collect one extra wall and base sample per 25 m^2 increase.
AST including triple interceptor or grease traps (parts washing) and chemical storage	Minimum of two sample locations up to 1 m depth beneath the AST guided by olfactory/visual/field indicators (PID). If concrete bund is present then sample where overflow/crack evident or nearest down gradient position.	Two samples analysed from beneath each AST at depths of 0.1–0.2 m and 1 m guided by olfactory/visual/field indicators (PID).	Sample any spill or stain areas. Observe any bund cracks or piping (migration pathways) and sample beneath infrastructure.

Potential locations of concern	Assessment (infrastructure remaining)	Validation (infrastructure removal)	Comment
Fuel lines	Minimum of one sample location for each fuel line leading to canopy dispensers and from refill locations to USTs. Sample depth of up to 1 m depth guided by olfactory/visual/ field indicators (PID).	Collection of one sample per 5–m fuel lineage. Validated via test pits rather than boreholes.	
Dispensers	One sample location per dispenser at up to 1 m depth guided by olfactory/visual/field indicators (PID). Sample location should be as close as possible to dispenser or down gradient to assess impacts noting depth of bore should be increased to compensate for potential contamination migration.	Two samples analysed from beneath each dispenser at depths of 0.1–0.2 m and 1 m.	
Remote fill points	Minimum of one sample per refill point area down to 1 m depth. Position as close as possible in a downgradient position (where known).	Minimum of one sample per refill point or as otherwise dictated by olfactory/ visual/field indicators (PID).	
Workshop (hoists, compressors, etc)	Inspect the surface area for cracking and detail the migration pathways of potential waste disposal. Depending on the outcome, target the locations of the hoists, compressors, sumps or other workshop activities. Minimum of four targeted sample locations for a workshop should be undertaken.	As per assessment, with a minimum of four targeted locations undertaken in the workshop area.	

Potential locations of concern	Assessment (infrastructure remaining)	Validation (infrastructure removal)	Comment
Stockpiles	In accordance with the ASC NEPM (Schedule B2, section 7.5).	In accordance with the ASC NEPM (Schedule B2, section 7.5).	Applying statistical analysis to lower sampling rates can only be used for similar material types (cannot use fill and natural to reduce sampling rates).

Whether this or an alternative protocol is adopted, the protocol used must be justified in the SAQP. For instance, alternatives based on site history or other evidence (eg visual or olfactory observations of contamination in the field) may lead to a changed sampling strategy. Samples must be collected in accordance with the EPA guidelines, Australian Standards and Schedule B2 of the ASC NEPM.

2.8 Groundwater monitoring and assessment

The assessment of site contamination in groundwater at sites containing USS can be complex. Generally comprehensive groundwater assessments are completed in a staged approach to fully characterise the nature and extent (laterally and vertically) of site contamination. The groundwater assessment program should be based on the findings of the PSI, soil assessment and robust CSM. Details in regards to the minimum requirements for the design and application of detailed groundwater assessments can be found in the *Guideline for the assessment of background concentrations* (EPA 2018), and Schedules B2 and B6 of the ASC NEPM.

For sites containing USS the EPA recommends that initial groundwater investigations should target known or suspected source areas (ie USS), with subsequent investigations undertaken to delineate the lateral and vertical extent of the site contamination (if identified). Groundwater investigations may need to extend off site to fully characterise the nature and extent of the plume and to establish background groundwater quality values. Any off-site investigations should not be undertaken until approval from the relevant authority and/or property owner(s) has been granted. Where consultants deviate from this approach, the alternate approach must be justified in the SAQP.

When developing the DQOs and SAQP for the groundwater assessment, the potential for off-site sources of contamination should be considered in the CSM, depending on the surrounding PCAs identified in the PSI. Sites containing USS may be situated in areas surrounded by other commercial or industrial land uses that may also be sources of groundwater contamination

2.8.1 Groundwater monitoring well installation

The location and design of the groundwater monitoring wells should be based on the CSM and designed to assess the nature and extent of any contamination and determine the direction of groundwater flow and velocity. The CSM should guide the required location and number of wells, screen intervals and depths. Consideration should be given to the hydrogeological conditions beneath the site including the presence of more than one water bearing unit. To minimise the potential for vertical flow between aquifers via the well, the monitoring well screen should not be installed across different geological units, water–bearing zones or aquitards and aquicludes.

Guidance on the appropriate methods for the installation of groundwater monitoring wells, including screen depth and length selection, can found in the *Guideline for regulatory monitoring and testing – Groundwater sampling* and in section 8 of Schedule B2 of the ASC NEPM.

All monitoring wells should be installed by an appropriately licenced driller to ensure monitoring wells are in accordance with the *Landscape South Australia Act 2019, Minimum construction requirements for water bores in Australia* (National Water Commission 2012) and any other relevant specifications or guidelines.

A staged comprehensive groundwater investigation should ensure sufficient monitoring wells have been installed to assess up hydraulic gradient groundwater conditions, assess concentrations within and immediately down hydraulic gradient of the source area(s), and define the lateral and vertical extent of the contaminant plume arising from each confirmed source zone in each aquifer on and off site. A minimum of three monitoring wells per aquifer should be installed to assess groundwater flow direction, velocity and background chemical concentrations.

The initial groundwater assessments should be:

- close to each potential source of contamination
- similar in installation and construction methodologies to minimise potential variation and uncertainty in collected data
- screened across the upper aquifer to assess for the presence of any light non–aqueous phase liquids (LNAPLs) and/or screen across the relevant hydrogeological unit to assess for presence of any dense non–aqueous phase liquids (DNAPLs). At sites where groundwater levels may fluctuate over time (ie seasonal or tidal influences), screen lengths should be designed to take this into consideration.

Table 2 details recommended protocol for the initial groundwater assessment at a site containing USS. The number and location of monitoring wells should be guided by the CSM and detailed in the SAQP. Whether this or an alternative protocol is adopted, the protocol used must be justified in the SAQP. For instance, alternatives based on site history or other evidence (eg soil or vapour assessment results) may lead to a change in assessment strategy.

Table 2 Recommended groundwater monitoring well locations

Well location	Indicative number of groundwater well locations	Comment
Within and immediately down hydraulic gradient of known or suspected source area(s)	Minimum of one well per contamination source area and immediately down hydraulic gradient, subject to size and proximity of areas (ie additional monitoring wells may be required).	Focus of monitoring wells to assess source zone(s). Monitoring wells need to target the part, or parts, of the aquifer most likely to be affected by contamination. Depending on COI and underlying hydrogeological conditions, deeper wells may need to be installed to assess for DNAPL.
Down hydraulic gradient of known or suspected contamination	A number of monitoring wells may be required to determine lateral extent of plume on–site. The	Focus of monitoring wells is to determine the lateral extent of the contamination and determine

Well location	Indicative number of groundwater well locations	Comment
source(s), site perimeter and off site	number of on–site, perimeter and off–site down hydraulic gradient wells will be dependent on the lateral extent of contamination and sensitive receptors requiring protection.	potential pathways to sensitive receptors. Sufficient monitoring wells should be installed to allow an accurate assessment of groundwater flow direction and velocity.
Up hydraulic gradient monitoring well to establish background groundwater quality	Minimum of one groundwater monitoring well should be installed at a suitable location to assess background groundwater quality.	See the EPA publication, *Guideline for the assessment of background concentrations* (2018) for further information.

2.8.2 Groundwater sampling

Groundwater sampling methodology and analytical schedule should be defined by the CSM, and designed to meet the developed DQOs. The selection and application of appropriate groundwater sampling methodologies are detailed in Guideline for *regulatory monitoring and testing – Groundwater sampling* and section 8.2.4 of Schedule B2 of the ASC NEPM.

The selection of groundwater sampling techniques should be based on a number of considerations including, but not limited to, the hydrogeological conditions, COI to be sampled and monitoring well design. To reduce uncertainty within the groundwater analytical data set, groundwater monitoring wells should be sampled using consistent methodologies. Generally, the same methods should be used each time the wells are sampled to avoid introducing sampling methodrelated uncertainties to the analytical data. Where an improved technique becomes available, it is recommended that it is trialled in combination with the existing sampling method to establish the nature and magnitude of any changes in analytical results as a result of the new sampling method.

All monitoring wells should be gauged for the presence of NAPL prior to sampling. All gauging data utilised for developing relative levels to determine the direction of groundwater flow should be corrected to account for the presence of NAPL and salinity of the groundwater.

Prior to sampling the consultant should ensure that a representative sample of groundwater is collected. Where the sample is being collected to assess the dissolved phase concentration of a COI, the EPA does not consider it appropriate that wells containing NAPL (measurable thickness or a sheen) be sampled for this purpose. The sampling of NAPL can be undertaken to assess the composition of the NAPL and/or to complete specialised analysis (such as fingerprinting).

Where a measurable thickness of LNAPL has been identified, bail down testing should be undertaken to provide information on the potential mobility and recoverability of the LNAPL in the immediate surroundings of the monitoring well. Further information in regards to the assessment of LNAPL fluid properties and mobility/recovering testing can be obtained from the following documents:

- *CRC CARE Technical Report 11 – Characterisation of sites impacted by petroleum hydrocarbons*
- *CRC CARE Technical Report 34 – A practitioner's guide for the analysis, management and remediation of LNAPL*

- *ASTM Standard Guide for Estimation of LNAPL Transmissivity*
- *API LNAPL Transmissivity Workbook – A tool for baildown test analysis*

Where natural attenuation of a COI may be occurring, appropriate field hydro–geochemical parameters (pH, redox, electrical conductivity, dissolved oxygen and temperature) should be collected, with key samples analysed for biodegradation parameters (nitrate, ferrous iron, manganese, sulphate, dissolved methane and alkalinity) and relevant breakdown products (these will depend on the COI).

Further details in regards to the minimum requirements of a natural attenuation assessment for petroleum hydrocarbons can be found in *CRC CARE Technical Report 15 – A technical guide for demonstrating monitored natural attenuation of petroleum hydrocarbons in groundwater*.

2.9 Vapour assessment

The need for a vapour assessment should be informed by a well–developed and robust CSM. For a vapour intrusion (VI) pathway to be complete there must be a source of subsurface vapours (soil and/or groundwater), a receptor such as occupied buildings or the potential for occupied buildings, and a migration route to the receptor (ie subsurface or utilities). Where the CSM considers an unlikely VI pathway, the DSI report should provide multiple lines of evidence to demonstrate the absence of this pathway and why no vapour assessment is required.

A framework and relevant considerations for vapour assessment are detailed in section 9 of Schedule B2 of the ASC NEPM. In addition, the EPA recommends the following documents to provide further details for the vapour assessment process:

- *CRC CARE Technical Report 23 – Petroleum hydrocarbon vapour intrusion assessment: Australian guidance*
- *OSWER Technical Guide for Assessing and Mitigating the Vapour Intrusion Pathway from Subsurface Vapour Sources to Indoor Air*

The CSM should inform the consultant of the current or potential VI pathways and what vapour assessment is required to assess the vapour risk. The developed DQOs and subsequent SAQP should detail the specifics of the vapour assessment including the COI, sampling methods, locations, depth (soil vapour), number and frequency of sampling events.

2.10 Risk assessment

Based on the findings of the DSI an assessment of the risk posed to human health and the environment may be required. The need or value of a risk assessment will be informed by the outcome of the DSI process and resulting CSM. Details relating to when a site–specific human and/or ecological risk assessment is required, the tiered risk assessment approach and a framework on how to undertake a risk assessment are provided in the Guidelines for the assessment and remediation of site contamination and the ASC NEPM.

3 Remediation

Remediation of sites containing USS should be undertaken in accordance with Part 4 of the Guidelines for the assessment and remediation of site contamination (EPA 2019). In circumstances where the USS or associated infrastructure are being upgraded (ie re–tanking) as part of maintenance and development works, the EPA expects that an appropriate assessment to be completed, and if necessary, a site remediation plan (SRP) and remediation validation report (RVP).

4 Reporting

The EPA recommends that the following reporting process be completed during the standard assessment and remediation process:

- preliminary site investigation (PSI)
- sampling analysis and quality plan (SAQP)
- detailed site investigation (DSI) • site-specific risk assessment (SSRA)
- remediation options assessment (ROA) • site remediation plan (SRP)
- remediation validation report (RVP)
- site management plans (SMP), if required. Depending on the findings of the assessment, selected reporting stages may not be required.

All reporting provided to the EPA must be undertaken in accordance with the *Guidelines for the assessment and remediation of site contamination* (EPA 2018), ASC NEPM (2013), this guideline and prepared or reviewed and approved by a certified site contamination practitioner. Refer to *Site contamination policy: certification of practitioners*.

A BETTER ENVIRONMENT *FOR THE* HEALTH, WELLBEING *AND* PROSPERITY *OF* ALL SOUTH AUSTRALIANS

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