Technical Note: Investigation of Service Station Sites
Note
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Comments are welcome via email to upssreg@epa.nsw.gov.au

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Abbreviations/acronyms

ANZECC  Australian and New Zealand Environment and Conservation Council
ARMCANZ  Agricultural and Resource Management Council of Australia and New Zealand
AS  Australian Standard
ASC NEPM  National Environment Protection (Assessment of Site Contamination) Measure 1999 (amended 2013)
BTEX  Benzene, toluene, ethylbenzene and xylene
BTEXN  Benzene, toluene, ethylbenzene, xylene and naphthalene
CoPC  Contaminant of potential concern
CLM Act  Contaminated Land Management Act 1997
COAG  Council of Australian Governments
CRC CARE  Cooperative Research Centre for Contamination Assessment and Remediation of the Environment
CSM  Conceptual site model
DECCW  [NSW] Department of Environment, Climate Change and Water
DQO  Data quality objective
DSI  Detailed site investigation
EPA  Environment Protection Authority
LNAPL  Light non-aqueous phase liquid
MNA  Monitored natural attenuation
OEH  [NSW] Office of Environment and Heritage
PAH  Polycyclic aromatic hydrocarbon
PSI  Preliminary site investigation
QA/QC  Quality assurance/quality control
RAP  Remedial action plan
SAQP  Sampling and analysis quality plan
TPH  Total petroleum hydrocarbon
TRH  Total recoverable hydrocarbon
UST  Underground storage tank
UPSS  Underground petroleum storage system
VOC  Volatile organic compound
1. Introduction

1.1 Scope

This technical note describes industry best practice in the assessment of service station sites in line with relevant legislation and policies and replaces the *Guidelines for Assessing Service Station Sites* (EPA 1994).

Service station sites may be investigated for a variety of reasons including redevelopment, modification, following environmental incidents and as a result of apparent fuel losses. This technical note may also be applicable to the assessment of other sites with petroleum storage systems.

The *National Environmental Protection (Assessment of Site Contamination) Measure 1999* (NEPC 2013) (‘ASC NEPM’) referenced throughout this document relates to the amendment which took effect on 16 May 2013.

**Investigation levels**

The threshold values quoted in the previous guidelines (EPA 1994) have been superseded by the investigation levels (and screening levels) contained in Schedule B1 of the ASC NEPM as follows:

> Investigation levels and screening levels are applicable to the first stage of site assessment. The selection and use of investigation and screening levels should be considered in the context of the iterative development of a conceptual site model (CSM) (refer to Schedule B2, Section 4) to ensure appropriate evaluation of human health and ecosystem risks.

Relevant Australian Standards, including those listed in the further reading section of this technical note, should also be followed during any assessment or remediation.

**Application**

Approximately 2200 service stations operate in NSW, together with a large number of underground fuel storage systems used by other industries, such as maintenance and logistics depots, manufacturing facilities, marinas and golf courses, and for standby generators, heating and waste oil. Thirty per cent of notified leaking underground petroleum storage systems (UPSS) sites in NSW are regulated under the *Contaminated Land Management Act 1997* (CLM Act).

Assessment of service station sites presents many challenges including:

- the location of many sites in areas with residential neighbours
- the volatile and soluble nature of many fuel constituents that can lead to off-site migration in the soil and groundwater and the intrusion of soil vapour
- lack of information about the presence, location and size of tanks, the history of their use and modifications to the site that may have occurred
- potential local disruption due to the intrusive nature of sub-surface assessment and the generation of noise, odour and dust
- complex ownership of the site and therefore difficulty assigning responsibility for contamination – for example, the landowner, site operator/tenant, fuel supplier and owner of the tanks or UPSS may all be different organisations or individuals.
Section 15 in Schedule B2 of the ASC NEPM outlines the issues that must be considered to protect the environment and local amenity during the assessment process. Schedule B8 of the NEPM provides guidance on the importance of community involvement throughout the assessment process. Community engagement should be carried out by suitably qualified, experienced and competent persons.

**Workplace health and safety**

This technical note does not discuss applicable safety requirements for investigations at service station sites or other obligations under the *Work Health and Safety Act 2011* (WHS Act) and *Work Health and Safety Regulation 2011*. All site assessors should ensure that their investigations are undertaken in accordance with the WHS Act as well as industry occupational health and safety procedures. It is also essential that all works comply with relevant local and state requirements for environmental management.

2. Assessing service station sites

All assessments of service station sites should be conducted in accordance with guidelines that have been made or approved by the EPA under section 105 of the CLM Act. Assessments should only be carried out by suitably qualified, experienced and competent persons as described in Schedule B9 of the ASC NEPM. Assessors should also take into consideration other EPA guidelines and technical practice notes where relevant.

*Many site investigations proceed in multiple stages due to the complexity of site conditions and of contaminant properties and/or the discovery of unexpected contamination. Poorly planned and executed site investigations are likely to result in time delays and additional costs (both during the investigation 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 a site assessment and develop a sampling plan for the collection and evaluation of representative data to achieve 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).

Typical stages of an investigation at a service station site range from the trigger for the initial assessment through to remediation/validation (where required). These stages are outlined in the flow chart in Figure 1. The following sections provide details on the information and reporting requirements relevant to the assessment, remediation and management stages of service station sites.

To assist with implementation of the amended ASC NEPM, the COAG Standing Council on Environment and Water provides an online Toolbox with additional guidance documents and calculators, including a field checklist of parameters for consideration when collecting data.
Figure 1: Decision chart for the assessment of service station sites

Possible triggers
- UPSS programs
- spills and suspected or recorded fuel losses
- upgrade of site facilities
- change in land use and zoning
- due diligence
- observation of hydrocarbon sheens, odours in neighbouring or nearby down-gradient properties
- ageing infrastructure

Preliminary site investigation
Key info Schedule B2 (NEPM)
- identification and location of fuel infrastructure
- tank and pipeline history
- drainage diagram
- 'as built' diagram of site
- tank and line integrity testing
- UPSS gauging of site and stock reconciliation
- nearby sensitive receptors

Detailed site investigation
Intrusive investigations
- soil
- groundwater
- soil vapour

Refined conceptual site model

Adopted criteria exceeded?

YES

Additional assessment
Where required may include:
- further investigation/monitoring
- site-specific human and/or environmental risk assessment
- LNAPL assessment
- indoor air/flux

NO

Consider duty to report under Contaminated Land Management Act 1997

Updated conceptual site model

Site management plan/environmental management plan required?

YES

Remediation required?

NO

Remedial works
Some options include:
- MPVE
- pull tank and excavate
- in-situ chemical oxidation
- air sparge
- pump and treat
- monitored natural attenuation

Validation
Including monitoring (can be post-validation of specified period)

NOTE: Stakeholder engagement – applicable to every stage throughout the assessment process

Develop and implement management plan
2.1 Preliminary site investigation

Preliminary site investigation (PSI) usually involves a desktop study and site inspection to collect information on site characteristics such as location, current and historic land uses and activities, site layout, building construction, and geological and hydrogeological setting, as well as identifying potential sources and pathways of contamination.

The information collected during a PSI should be used to assess information gaps and prepare an initial conceptual site model (CSM) which will help plan a targeted site investigation.

PSIs do not necessarily need to be standalone reports and, under some circumstances, may be included in detailed site investigation (DSI) reports. Although not always carried out, PSIs may also include limited sampling. For further information on sampling, refer to Sections 2.5 and 2.6 of this technical note.

Section 2.1 of Schedule B2 of the ASC NEPM describes information recommended for inclusion in a PSI. Reference should also be made to the Guidelines for Consultants Reporting on Contaminated Sites (OEH 2011). Information particularly relevant to service stations includes:

- identification and location of all present and former tanks, lines, dispensers and filling points, workshops and waste disposal locations
- tank and pipeline history, such as their method of construction, the age of tanks, details of cathodic protection and maintenance, and records of any product or waste spills and leaks
- a review of the data held in the site’s management and maintenance plans
- site and forecourt drainage and pollution control system diagrams which can include triple interceptor traps or above-ground coalescing plate interceptors (wired steel or plastic boxes); blind sumps (underground concrete ring tanks); and oil/water separators (including full retention oil/water separators which have 5000–20,000 litre underground holding tanks)
- 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
- as-built diagrams of the site
- historical aerial photographs to indicate changes and modifications
- records of previous incidents and equipment modifications
- details of any previous tank and line integrity testing
- details of any UPSS gauging at the site and review of stock reconciliation records, if available
- dangerous goods records.

It is important to assess whether the layout of the service station site has changed during its years of operation and if this masks historical areas of potential contamination that require targeted investigation to find ‘lost’ underground infrastructure.

During walkovers at the PSI stage, it is also important to note any observations of concrete scarring. This can assist in identifying locations of UPSS infrastructure and identify potential discrepancies in UPSS locations between site plans and observed features.
A PSI is rarely sufficient as a robust and comprehensive assessment of contamination at a service station.

2.2 Conceptual site model

The development of a conceptual site model (CSM) is an essential part of all site assessments and provides the framework for identifying how the site became contaminated and how potential receptors may be exposed to contamination, either in the present or the future (ASC NEPM, Schedule B2).

A CSM identifies site-related information about contamination sources and receptors and exposure pathways between those sources and receptors. A preliminary CSM constructed from the findings of a PSI will also identify data gaps and continue to be developed and refined throughout the investigation process as new information becomes available.

The key elements of a CSM include:

- known and potential sources of contamination and contaminants of concern, including the mechanisms of contamination (such as ‘top down’ spills or subsurface releases from corroded tanks or pipes)
- potentially affected media (such as soil, sediment, groundwater, surface water, indoor and ambient air)
- human and ecological receptors
- potential and complete exposure pathways.

A comprehensive assessment of the presence of contamination and likely pathways should be undertaken whether the locations of the UPSS and utilities at a site are known or not. Utilities can potentially cause the migration of contaminants of potential concern (CoPCs) in directions other than along a groundwater hydraulic gradient. These preferential pathways need to be considered when designing a sampling program and included in the CSM.

Figure 2 provides an example of a schematic CSM. For more details on CSMs, see Schedule B2 of the ASC NEPM.

2.3 Contaminants of potential concern

The main CoPCs which are typically associated with the handling and storage of fuels at service stations include:

- petroleum hydrocarbon fractions which range from C6 to C40 (analysed as total recoverable hydrocarbons – TRHs)
- BTEX – benzene, toluene, ethylbenzene and xylenes
- naphthalene
- fuel additives, such as ethanol, methyl tert-butyl ether (MTBE) and lead for sites with older infrastructure – leaded fuel was phased out in Australia in 2002
- other volatile organic compounds (VOCs) such as hexane, heptane, cyclohexane and trimethylbenzene.
Secondary contaminants that may be associated with other activities carried out on service station sites include:

- polycyclic aromatic hydrocarbons (PAHs), phenols (such as from waste oil kerosene or diesel tanks)
- acids (such as from storage of spent batteries)
- asbestos, heavy metals and chlorinated solvents (such as from workshops)
- phosphates, oil and grease (such as from carwashes).

Site assessors should also be aware of the potential for fill materials of unknown origin to be found on sites, such as where fill has been used to level or elevate the site or backfill old tank pits. Contaminants which may be present in fill include metals (lead, cadmium, chromium, zinc, copper, mercury, arsenic and asbestos), TRH, BTEX, organochlorine pesticides and polychlorinated biphenyls.

The contaminants discussed are not exhaustive and analytical testing suites should always be based on the CSM and sampling and analysis quality plan (SAQP) for the site.

### 2.4 Detailed site investigations

A detailed site investigation (DSI) typically refines the preliminary CSM developed in the preliminary investigation. Intrusive investigations are generally conducted at this stage to establish potential source-pathway-receptor linkages. As noted above, in some cases the DSI and PSI stages may be combined into a single investigation.

*The detailed investigation stage should identify the nature of the 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 drilling of boreholes and the installation of groundwater and soil vapour monitoring wells and test pits. This stage may require statutory approvals, including licences for monitoring well installation and permission from the local council for investigations on public land.

The CSM should be refined during and at the conclusion of the DSI process by assessing and testing data gaps and uncertainties identified in the preliminary CSM.

The term ‘TRH’ (total recoverable hydrocarbons) has replaced the previously used term ‘TPH’ (total petroleum hydrocarbons) and represents biogenic and petrogenic (petroleum) hydrocarbons extracted by selected solvents.

Common laboratory methods detect both petroleum and naturally occurring hydrocarbons. Where significant levels of non-petroleum hydrocarbon interferences are suspected, a silica gel clean-up is recommended, in which case the result should be clearly identified as ‘TRH-silica’. For further information, refer to Section 13 of Schedule B3 of the ASC NEPM.

As outlined in *Guidelines for Consultants Reporting on Contaminated Sites* (OEH 2011), data quality objectives (DQOs) and a sampling and analysis quality plan should be adopted for all assessment programs. The DQO process is outlined in Appendix B of Schedule B2 of the ASC NEPM.
2.5 Sampling and analysis quality plan

A robust sampling and analysis quality plan (SAQP) is necessary to ensure that the data collected is representative and able to be used to make reliable site assessment decisions. To meet the objectives of an SAQP, refer to Section 5.3 of Schedule B2 of the ASC NEPM. The sampling plan should be prepared ahead of site assessment in consultation with relevant stakeholders, field staff and laboratory personnel.

SAQPs should also outline:

- the quality assurance and quality control (QA/QC) processes that will be used during site investigations
- the data quality indicators (DQIs)
- the investigation levels to be adopted for the assessments
- the QA/QC program for laboratory data.

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

When designing an SAQP, potential safety and environmental hazards at the sampling site must be considered and mitigated. For instance, installing groundwater wells in roadways or adjacent to buried infrastructure may present health, safety, security and environmental risks that must be addressed. The plan should also include contingencies for encountering unexpected finds.

2.6 Soil assessment

Known locations of UPSS infrastructure and site utilities (such as fill points, tanks, feed lines, dispensers, pits and utility trenches) should be early targets for assessment.

The site assessor should also 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 and waste oil tanks are identified, additional targeted sampling may be required once their locations have been established.

**General sampling strategy**

Selection of sampling locations should be based on information collected during the PSI with the site assessor fully documenting the reasons for selecting each sampling domain and the methodology undertaken. Although statistically biased, a judgement-based approach to sampling may be appropriate when there is sufficient knowledge of site history and the location of infrastructure. It is important to obtain soil samples from below the base depth of any known or suspected UPSS.

Where the PSI is unable to reliably identify the locations of the service station infrastructure, grid-based soil sampling should be carried out in accordance with protocols set out in Section 6.2.3 of Schedule B2 of the ASC NEPM.
The site's preliminary CSM should guide identification of any areas of concern, the number of samples, the CoPCs and the sampling protocols to be used (see Section 2.5 of this technical note). Based on this information, sampling and quality assurance and quality control procedures should also be documented in the SAQP. See Section 5.4 of Schedule B2 of the ASC NEPM for appropriate soil investigation and sampling techniques and Section 3 of Schedule B3 for appropriate QA/QC lab procedures.

As there is always a degree of uncertainty about the precise locations of underground infrastructure, a 'dial before you dig' check is mandatory in NSW to provide information on underground services. A survey by a professional service locator may also be required to confirm the location of infrastructure. Data obtained during these activities may assist to further refine the CSM.

Targeted sampling protocols

Where identified, potentially contaminated areas, including contaminant source locations, should be sampled and analysed for all relevant CoPCs listed in Section 2.3 of this technical note, using the methods outlined in Section 4 of Schedule B3 of the ASC NEPM. QA/QC procedures and sampling also need to be carried out in accordance with Section 5.4 of Schedule B2 of the ASC NEPM.

As a minimum, field screening during soil sampling should use an organic vapour analyser, such as a photo-ionisation detector (PID) to gather information on selecting samples for laboratory analyses. This should be supplemented by observations during fieldwork, including the visual appearance of samples (such as colour or staining) and the presence of odours. Data from the organic vapour analyser provides only qualitative information and must be supported by laboratory data. Different methods and technologies are available and site characteristics will dictate which is suitable.

Field screening of soil samples by organic vapour analysers should follow the headspace method in a way that minimises the loss of volatiles (Section 7.4.3 in Schedule B2 of the ASC NEPM).

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. Schedule B2 of the ASC NEPM and CRC CARE Technical Report 11 (Clements et al. 2009) have more details.

Field-screening equipment should only be operated by trained personnel. The site assessor should keep training records, calibration gas certificates (where applicable), instrument maintenance records and calibration records for all screening equipment used in an assessment.
Table 1 summarises the minimum recommended protocols for soil sampling at potential locations of concern at service station 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 or validation and access and safety constraints. The protocols should be considered a minimum requirement for sites being decommissioned or validated. Reference should be made to the UPSS Technical Note: Site validation reporting (DECCW 2010a) for additional guidance on the validation of sites where in situ abandonment occurs.

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 (e.g. visual or olfactory observations of contamination in the field) may lead to a changed sampling strategy. Samples must be collected in accordance with the Australian Standards and Schedule B2 of the ASC NEPM.

**Table 1: Minimum recommended soil sampling**

<table>
<thead>
<tr>
<th>Area of concern (location)</th>
<th>Indicative no. of samples/locations</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Underground storage tank (UST)</td>
<td>Minimum two samples per tank with samples taken from each tank wall and floor</td>
<td>Collect samples if tank is to remain in place or during excavation and tank removal. Samples to be taken at or below the base of the tanks.</td>
</tr>
<tr>
<td>2. UST pit natural soils and backfill sands</td>
<td>Two samples (though may not be necessary if backfill sands are found to be unaffected)</td>
<td>Samples between 0–200 mm into surrounding soil. Recommended to be at or below the base of the tank.</td>
</tr>
<tr>
<td>3. UST pit water</td>
<td>One sample</td>
<td>Sample if there is water present and backfill sands or natural soils appear contaminated.</td>
</tr>
<tr>
<td>4. Dispensers</td>
<td>One sample per dispenser backfill and one per natural soil (if needed)</td>
<td>Sample area adjacent to line and dispenser junction, taking representative sample of backfill during excavation and removal of the dispenser. If contamination apparent, sample 0–200 mm into natural soils.</td>
</tr>
<tr>
<td>5. Fuel feed lines to dispensers</td>
<td>One sample every 5 m of line</td>
<td>Take representative sample of backfill sands and, if it appears contaminated, sample 0–200 mm into natural soils. Additional attention should be given to changes of line direction and the depth of burial of the line.</td>
</tr>
<tr>
<td>6. Remote fill points</td>
<td>One sample per fill point</td>
<td>Representative sample from backfill sands and, if it appears contaminated, sample 0–200 mm into natural soils.</td>
</tr>
<tr>
<td>7. Above-ground fuel storage (drum/tank)</td>
<td>One sample per 25 m²</td>
<td>Collect samples in areas of spills, otherwise collect samples below storage area at depth intervals of 0–200 mm and 200–500 mm.</td>
</tr>
</tbody>
</table>

Wherever possible, collect more samples than may be thought to be required for analysis. These may be useful to further verify field observations or delineate contamination. However, it should be noted that there are limited holding times for CoPCs and samples cannot be held for long periods without analysis.
### Area of concern (location) | Indicative no. of samples/locations | Action
--- | --- | ---
8. Below-ground waste oil/wastewater tank | Two samples per tank | Collect samples if tank is to remain in place or collect samples during excavation and tank removal.
9. Spent battery storage | One sample per 25 m$^2$ | Take representative auger samples in the 0–200 mm layer.
10. Waste disposal areas (including wastewater disposal on site) | One sample per 25 m$^2$ | Collect samples at the site of contamination or within the disposal area in the 0–200 mm layer.
11. Fill materials of unknown origin | Adopt sampling density in accordance with Section 6 and 7 of Schedule B2 of the ASC NEPM | Collect representative auger/borehole samples from surface to natural ground level.
12. Workshop (current or historical – may include smash repair activities, i.e. blasting grits) | Dependent on CSM and site observations | Collect samples at the site of contamination at depth intervals of 0–200 mm and 200–500 mm. Where pits or hoists are present, sampling should extend below the base of the structure.
13. Carwash | Dependent on CSM and site observations | Take representative samples in the 0–200 mm layer.

### Notes
1. As it is always possible to take samples from areas that are uncontaminated, sampling locations should be identified using appropriate screening (such as via visual inspection and photos, PID screening, reference to CSM) and the decision rules used justified in the sampling methodology.
2. Consideration should be given to lithology changes and the distribution of the tank pits and fuel lines which may require additional samples. For example, an adequate number of samples should be collected from the following areas: each wall of tank pit excavation, in the lower half of the excavation and targeted at any permeable soil layers.
3. Where a UST is removed, as a guide sampling should be: one sample from beneath the centre of the UST if tank length is less than 4 m and at least one sample from each of the four walls. If the tank is 4–10 m long, at least two samples from each of the four walls and under each end. If the tank is longer than 10 m, at least three samples from each of the four walls and under each end are taken. This applies to each tank in the same tank pit.

### 2.7 Groundwater monitoring and assessment

The Protection of the Environment Operations (Underground Petroleum Storage Systems) Regulation 2008 (‘UPSS Regulation’) requires all sites with operating UPSS to install groundwater monitoring wells positioned to detect leaks from underground infrastructure. These must be monitored at six monthly intervals. Some sites may be exempted or use alternative systems to monitor for leaks. The Guidelines for the Assessment and Management of Groundwater Contamination (DEC 2007) outlines the framework for assessing and managing contaminated groundwater in NSW. Schedule B2 of the ASC NEPM also has guidance on groundwater assessment.

On their own, groundwater monitoring wells installed on a site as required by the UPSS Regulation may not be adequate to characterise the nature and extent of contamination from a leaking UPSS. Comprehensive groundwater assessment therefore requires a staged approach. The initial investigation should be targeted around known or suspected source areas while subsequent investigations may be...
required to delineate the extent of the impact. Off-site wells may be required where it is suspected that the impact on groundwater has extended beyond site boundaries. Installing wells off-site may be subject to landowner and other approvals.

Contamination may be confined to the tank pit where site-specific geology limits the impact of leaks on groundwater. In these situations, monitoring wells additional to those installed under the UPSS Regulation may not be required. This should be justified by a robust CSM which supports a low likelihood of hydraulic connection between the base of the tank pit and the groundwater surface. However where this appears likely, the EPA recommends validation of this conclusion by installation of at least one down-gradient well to intersect the upper aquifer.

When designing a groundwater investigation, the potential for off-site sources of contamination should be considered in the CSM. Service station sites can often be located in clusters or adjacent to other light industrial/commercial operations with their own potential sources of groundwater contamination.

**Groundwater well installation**

The location of groundwater wells should be designed to assess the nature and extent of any contamination of groundwater and determine the direction and speed of groundwater flow.

Consideration should be given to the depth of wells and whether more than one water-bearing formation needs to be investigated. 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.

The CSM should be used to guide details of the groundwater investigation, including the number of wells, their location and depth, and screen intervals. Groundwater assessments should generally include monitoring wells up-gradient, lateral to and down-gradient of contamination sources, with at least three wells per aquifer to assess the groundwater flow direction.

Table 2 outlines groundwater investigation protocols to assist site assessors in selecting sampling locations, depth and density. Site assessors who deviate from these protocols should record and justify why using the CSM where applicable.

Initial investigation bores should be:

- close to each potential contamination source
- installed with similar construction techniques to minimise sources of variation and uncertainty in the data
- where appropriate, screened across the upper aquifer to locate any light non-aqueous phase liquids (LNAPLs) and identify contamination derived primarily from surface spills and leaching.

While the size of a plume strongly depends on source characteristics and local hydrogeology, for those estimated to be over 200 m long, wells should generally be spaced 20–50 m apart in the direction of groundwater flow and 10–20 m apart perpendicular to flow. Well spacing should generally be less than 10 m for the delineation of source zones (Sundaram et al. 2009).

Any groundwater bores and monitoring wells which are not exempt must be licensed by the NSW Office of Water under Part V of the *Water Act 1912* or the *Water Management Act 2000* (and associated NSW Aquifer Interference Policy).
Table 2: Indicative groundwater investigation protocols

<table>
<thead>
<tr>
<th>Well location</th>
<th>Indicative no. of wells</th>
<th>Action</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjacent to and down-gradient of any contamination sources on-site</td>
<td>One well per contaminated area on site, subject to size and proximity of areas</td>
<td>Collect samples from monitoring wells. Sampling depth will be dictated by local hydrogeological conditions.</td>
<td>CoPCs as per Section 2.3. Additional parameters to be considered may include: Physico-chemical – • redox • pH • electrical conductivity • dissolved oxygen • temperature</td>
</tr>
<tr>
<td>Adjacent to site perimeter, down-gradient or off-site where possible (consent and approvals may be required)</td>
<td>One well per site to check for off-site migration if on-site groundwater is contaminated</td>
<td>Monitored natural attenuation – • nitrate • ferrous iron • dissolved methane • manganese • sulfate</td>
<td></td>
</tr>
<tr>
<td>Adjacent to site perimeter, up-gradient or off-site where possible (consent and approvals may be required)</td>
<td>One well per site as a control if on-site groundwater is contaminated</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Groundwater flow direction may not be confirmed prior to the installation of monitoring wells. In these instances, information from the PSI should be used to infer likely flow directions, taking into account geology, local topography and local surface water features.

The construction of groundwater monitoring wells must not cause contamination of underlying aquifers and aquicludes separated by low permeability strata from contaminated surface material. In the case of confined systems, screens across the water table are not likely to be appropriate: instead use small screen sections across the water-bearing zone only to safeguard against potential cross-contamination.

Licensed drillers are required to ensure that monitoring wells are installed in accordance with the Minimum Construction Requirements for Water Bores in Australia (NUDLC 2012), which is endorsed by the NSW Department of Primary Industries and NSW Office of Water. A report detailing monitoring well installation must be prepared for each well in accordance with industry standards. This may be needed to supplement licence applications to the NSW Office of Water.

To assist in determining which legislation may apply to the site under consideration, refer to the NSW Office of Water’s which Act applies webpage.

Groundwater sampling

Groundwater sampling procedures are discussed in detail in Section 8.2.4 of Schedule B2 of the ASC NEPM. Consistent methods should be used each time the wells are purged and sampled to avoid introducing sampling method-related uncertainties to the analytical data (DEC 2007). Where an improved sampling technique becomes available, this should be 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 method.
Prior to groundwater sampling, the water level in the wells should be gauged. During purging of groundwater wells, physico-chemical parameters, including pH, electrical conductivity, temperature, dissolved oxygen and redox potential, should be measured and recorded.

The presence of LNAPLs (free phase) can affect the groundwater elevation measured at a monitoring well. Due to the uncertainties involved, corrected groundwater elevations from wells affected by LNAPLs should not be used to determine the direction of groundwater flow. However, sampling and characterising LNAPLs may be useful in determining the composition, age, weathering and potential source of the contamination.

Natural degradation of petroleum hydrocarbons in the environment may mitigate the impacts of contamination and play a part in the remedial approach to groundwater contamination. To demonstrate whether natural attenuation is occurring, recording and analysis of physico-chemical parameters is required. Table 2 lists key parameters although this is not exhaustive. For further information on monitored natural attenuation (MNA), refer to Beck & Mann (2010) and Clements et al. (2009).

### Other useful groundwater assessment tools

<table>
<thead>
<tr>
<th>Tool</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fingerprint analysis of LNAPLs</td>
<td>May provide information on type of product (unleaded, E10, premium) and age of the product.</td>
</tr>
<tr>
<td>Bail-down testing of LNAPLs</td>
<td>Provides information on the potential mobility and recoverability of the LNAPL in the immediate surroundings of the monitoring well.</td>
</tr>
</tbody>
</table>

More information can be obtained from Clements et al. (2009) and ASTM (2013).

### 2.8 Soil vapour assessment

*A well-developed CSM incorporating vapour risk is essential for understanding current site conditions, determining potential vapour behaviour (including possible variation in soil vapour concentration) and, as part of the DQO process, identifying data gaps and uncertainties and priorities for investigation (ASC NEPM, Schedule B2).*

The CSM should assist in identifying vapour intrusion pathways to potential receptors and whether vapour assessment needs to be conducted at a site.

If vapour assessment is considered necessary, details on the location and number of sampling points, depth (soil vapour) and frequency of sampling events should be included in the SAQP. Where a soil vapour risk is not considered to be significant, the DSI should demonstrate why pathways and vapour intrusion are unlikely to be present.

Vapour assessment considerations are discussed in Section 9 of Schedule B2 of the ASC NEPM. Additional information on the planning, installation, sampling, reporting and interpretation of petroleum hydrocarbon vapours in soil is provided in the *Vapour Intrusion Practice Note* (DECCW 2010b) and Wright (2013).

### 3. Remediating service station sites

Removal and repair of fuel infrastructure, tanks and lines must be undertaken by duly qualified contractors in accordance with NSW legislation and guidance, relevant Australian Standards, and applicable work health and safety legislation: see *Storage and Handling of Dangerous Goods Code of Practice* (WorkCover NSW 2005).
The *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites* (ANZECC & NHMRC 1992) state that the goals of contaminated site assessment and clean-up should be to:

- render a site acceptable and safe for the long-term continuation of its existing use
- minimise environmental and health risks both on- and off-site
- maximise, to the extent practicable, the potential future uses of a site.

Remediation strategies should take into account the technical feasibility of the options selected, nominated remedial target concentrations and the environmental impact of the remediation operations. The impact on air and water quality, noise levels, waste management and effects on the community should also be primary considerations.

A remedial action plan (RAP) should be prepared in accordance with the requirements of the *Guidelines for Consultants Reporting on Contaminated Sites* (OEH 2011).

Remediation options that could typically be considered for service station sites following appropriate removal of redundant infrastructure include:

- on-site in-situ remediation of soil and groundwater, such as multi-phase vacuum extraction, air sparging with or without soil vapour extraction, and injections to enhance site-specific naturally occurring degradation processes
- on-site ex-situ treatment and remediation of soil and groundwater, such as enclosed bioremediation cells and pump and treat systems with emission controls
- on-site treatment, using enhanced bioremediation (with appropriate odour and stormwater controls), where high concentrations of VOCs are present, or passive bioremediation without the addition of organic matter at sites where the soils are contaminated with low concentrations of volatiles – note, however, that the EPA does not consider treatment by removing volatile fractions through exposure of the mass to atmosphere to be a legitimate form of bioremediation: refer to *Landfarming: Best practice note* (EPA 2014) and *Soil Bioremediation Guidelines* (SA EPA 2005)
- off-site controlled soil treatment
- off-site controlled remediation of soil at a licensed waste facility and subsequent use as cover material
- off-site disposal to a licensed waste facility as contaminated soil as per the NSW *Waste Classification Guidelines: Part 1 – Classifying waste* (DECC 2009)
- 'cap and contain’ strategy with human health/ecological risk assessment to confirm remediation is appropriate: refer to *Guidelines for the Assessment of On-site Containment of Contaminated Soil* (ANZECC 1999)
- monitored natural attenuation.

Remediation technologies should incorporate best practice emission and odour control systems. Careful consideration and planning, combined with active stakeholder engagement, must be carried out prior to potential odour-generating works, especially where there are sensitive receptors nearby (such as residential areas, childcare centres and schools). Non-aqueous phase liquids must be managed in accordance with the *Guidelines for the Assessment and Management of Groundwater Contamination* (DEC 2007) and NSW waste guidelines.
Proponents must check with the local council whether development consent is required for the removal of the storage system or other remediation works. Approvals may also be required from other agencies under state and federal legislation before remedial works are able to commence. Where development consent is not required (such as for Category 2 remediation work), the relevant planning authority must be notified of the proposed site activities at least 30 days before the commencement of work in accordance with *State Environmental Planning Policy 55*.

### 4. Validating service station sites

Where a UPSS is decommissioned, abandoned or removed, a report validating that the site is suitable for continued use must be prepared. This report must be submitted to the relevant local authority (usually the council) within 60 days of completion of the validation or any necessary remediation works.

A validation report provides independent verification using objective and measurable criteria that a UPSS site is free of unacceptable levels of contamination, all necessary remediation works have been successfully carried out, and the site is suitable for an ongoing or future use.

Guidance on the requirements for site validation is presented in *UPSS Technical Note: Site validation reporting* (DECCW 2010a) and *Guidelines for Consultants Reporting on Contaminated Sites* (OEH 2011).

Where validation of a site to the standards required under NSW contaminated land or planning legislation is not feasible, it should be clearly stated in the report summarising remediation outcomes. The report should not be termed a ‘validation report’ as it will generally be insufficient to support a planning consent.

A systematic and/or stratified sampling pattern can be used for the soil validation sampling plan and this will be dictated by the refined CSM (post-remediation). The data obtained from the soil validation program should be statistically analysed and compared with the adopted validation criteria in accordance with Schedule B1 of the ASC NEPM and, where applicable, the *Guidelines for the NSW Site Auditor Scheme* (DEC 2006). Note that investigation levels are not designed to be remediation criteria.

The validation aims to confirm that remedial objectives and remedial endpoints or targets in the RAP have been met.

For groundwater validation, sampling may need to demonstrate, where applicable, that:

- LNAPLs (if initially recorded during the DSI) are no longer present or have been cleaned up to the extent practicable
- LNAPLs are no longer expanding, that is, the plume or the LNAPL mass is decreasing
- concentrations of the CoPCs are below the nominated clean-up criteria
- the concentrations of the nominated CoPCs do not pose an unacceptable risk to human health or the environment
- the mass of dissolved phase contaminants is degrading through monitored natural attenuation – refer to Beck & Mann (2010).
For soil vapour validation, sampling may need to demonstrate, where applicable, that:

- concentrations of the CoPCs are below the nominated validation criteria
- concentrations of the nominated CoPCs do not pose an unacceptable risk to human health or the environment.

5. Reporting

The reporting process may be separated into the following stages:

- preliminary site investigation
- sampling and analysis quality plan
- detailed site investigation
- remedial action plan/options assessment
- site management plan
- validation report.

Reports must be prepared to a standard described in Section 14 of Schedule B2 of the ASC NEPM and Guidelines for Consultants Reporting on Contaminated Sites (OEH 2011). For validation reporting, the requirements of UPSS Technical Note: Site validation reporting (DECCW 2010a) should also be considered.

References and further reading

Links were current at the time of publication.

References


Technical Note: Investigation of Service Station Sites


EPA 1994, *Guidelines for Assessing Service Station Sites*, Environment Protection Authority, Sydney [replaced by this technical note]


Further reading

Inclusion of these additional reading sources is designed to assist stakeholders meet EPA requirements but does not imply EPA endorsement of them.

Technical Note: Investigation of Service Station Sites


EPA 1995, *Contaminated Sites: Sampling design guidelines*, Environment Protection Authority, Sydney


