

EPA Guidelines

Assessment of Underground Storage Systems

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Introduction

Underground storage systems (USS) are one of the major sources of soil and groundwater contamination and have been the subject of environmental assessment and remediation projects for the past 15 years or so. The US EPA acknowledged USS in 1988 as one of five major threats to groundwater quality (Bedient, 1994). USS are generally located at fuel outlets – service stations, motor vehicle dealerships, general stores, produce stores and transport yards. USS may also be found at industrial and commercial chemical and fuel storage facilities. Determining how many USS there are, and where they are, is difficult as they are used for many applications, including storing fuel for backup equipment such as generators.

In some Australian states, storage of combustible liquids does not require a licence, and disused or abandoned USS are often overlooked. The Australian Institute of Petroleum (AIP, 2002) states that as of the end of 2000 there were 8370 service stations in Australia. Practical experience suggests that there are probably more than twice this number of USS on sites other than service stations and perhaps up to five times more disused or abandoned USS.

In many cases investigation of USS may have focused on soil condition assessment as part of an environmental or due diligence process to assess liability, or to set baseline conditions, at commencement of lease agreements or the sale or purchase of a property. Such an assessment may not have been completed for the whole site and may not have adequately addressed the possibility of groundwater contamination.

Worldwide, there is growing awareness of the environmental impact of USS. The Leaking Underground Storage Tank (LUST) program in the US has been operational since 1987. It attempts to identify and rectify environmental impacts caused by USS. Groundwater contamination can be a serious problem, as groundwater interacts with sensitive surface water and other ecosystems, and is used for drinking and irrigation. Detecting contamination and evaluating groundwater quality is difficult due to poor access to USS and groundwater. As contaminants in groundwater move slowly



when compared to surface water flow, it may take a long time before contamination of soil, and ultimately contamination of groundwater, caused by a leaking USS becomes apparent, making early detection critical. For this reason, understanding the behaviour of contaminants in the environment and the structure of the subsurface environment is critical when investigating sites containing USS.

Underground storage tank systems

Underground storage tanks are defined by Australian Standard AS1940-1993 as systems where the storage vessel (tank) is installed either totally or partially below ground. Underground storage systems (USS) are likely to comprise some or all of the following:

- tanks or vessels of various size that may be compartmentalised
- delivery systems (dispensing pumps, suction lines, pressure lines, pipe work, joints, filters, valves, etc.)
- access tube for measuring liquid volume within the tank (dip point)
- direct or indirect tank filling point (indirect filling points can be quite a distance from the tank)
- vapour recovery systems
- vent line and vent point
- spill containment systems (dip, fill, under-pump containment and drainage pipe work)
- backfill sand or gravel
- tank anchoring system
- electrical cabling
- tank-pit monitoring wells
- corrosion prevention systems
- groundwater monitoring wells
- leak detection systems
- automatic tank gauging systems
- ullage space (headspace above the liquid in the tank, including fill and vent lines)
- interstitial monitoring systems
- overfill protection systems.

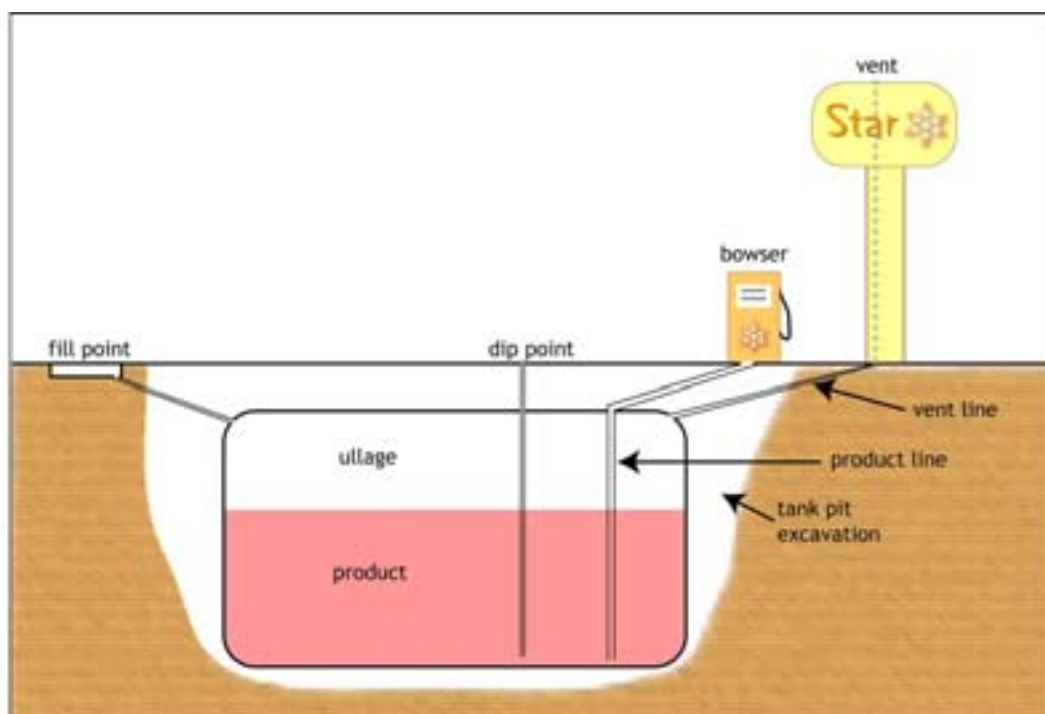
The diagram on the following page provides a schematic overview of a USS typical of fuel retailing sites. USS can contain multiple tanks connected to multiple dispensing points. USS may also contain one tank with multiple dispensing points, such as may be found at a manufacturing plant.

Loss or leakage of USS contents may result from:

- incompatible USS materials for the product being stored
- unsuitable geotechnical conditions, such as reactive or collapsing soils
- corrosion of USS
- human error (delivery losses, inadequate system management, poor installation, damage)
- small incremental losses, undetected by monitoring

- catastrophic loss through line or tank failure
- leaks from pumps, loose fittings, tank filling activities, maintenance activities (pressurised systems will exacerbate losses)
- vapour loss to the subsurface or atmosphere
- pilfering
- over-dispensing pumps
- bent, damaged or unsuitable tank dipping or gauging equipment.

Losses from USS can be disguised through over- or under-dispensing pumps, fuel temperature, inappropriate triggers for further investigation, or failure to complete system checks. There is no system that will control or prevent all leaks – human error can lead to accidents and USS will age and may fail.



Schematic plan of an underground storage system

Prevention

The Victorian EPA (2002) states that 'improved practice and performance of UPSS is necessary to ensure protection of people, property and the environment'. Correct operating procedures and preventive maintenance programs are critical for preventing leaks. Management of USS involves:

- using suitable construction materials for the USS
- correctly installing the system
- adequate operation and maintenance, including inventory reconciliation

- understanding the limitations of stock reconciliation – for example, dip sticks only being marked in 100-litre or greater increments
- systematically investigating discrepancies in volumes, such as the statistical inventory reconciliation fail or inconclusive result (USEPA, 1995); this approach includes checking pump calibration and testing equipment integrity
- taking prompt action if a leak is suspected or detected.

Investigation

Investigation of sites containing USS can be initiated as a result of loss, or suspected loss, of USS contents, lease or ownership transfer, redevelopment of the site for a more sensitive land use or for due diligence purposes.

Schedule A of the *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPM) includes a flow chart describing the process for assessing site contamination. The NEPM states 'adequate data collection is the foundation for acceptable assessment of health and environmental risks associated with site contamination'. The investigation should consider the entire site, not just the USS.

Preliminary investigation

Step 1 of the assessment is a preliminary investigation, defined in the NEPM as a data collection phase 'to the point where analysis is undertaken when the site history indicated that contamination may be present'.

For USS sites, the data collection phase is particularly important. This phase is often overlooked due to the USS itself being a trigger to proceed to a detailed site investigation. The potential for contamination is used to define the scope of sampling, the sampling techniques and analysis to investigate the presence and distribution of chemical or waste.

Traditionally, assessments of USS sites have assumed that contaminants are petroleum hydrocarbons and lead associated with fuel additives. This approach does not consider other contaminants such as:

- products that may have previously been stored in the USS or former USS
- drum cleaning and filling, e.g. pesticides, oil, grease, fuel, herbicides, solvents
- mechanical repairs, including parts cleaning and brake machining
- waste oil and coolant
- importation of contaminated fill
- operation of oil-water separation systems
- surrounding land uses, including underground pipelines
- fuel sources for previous boilers, etc. – may include coal or fuel oil
- waste disposal practices.

The information requirements of the preliminary investigation are listed in the NEPM and Australian Standard AS4482.1-1997 (AS4482.1). In addition to the information requirements listed in these documents, the following information should also be obtained for USS:

- copies of reports or completion certificates for maintenance, repairs or replacements, equipment integrity testing and stock inventory control records

- construction details of the USS, including backfill materials
- the condition of all pipe work and tanks removed from the site.

Site inspection

A site inspection is important to verify available data, and to determine the:

- location of all USS, pipe work and dispensing pumps, including former USS and pumps and systems on adjacent land, and kerbside tanks and pumps
- workshops previously used for, among other things, bulk oil storage, interceptors and in-ground hydraulic hoists, which may now be used for other purposes
- the number of tank vents compared with the number of known tanks (note that some installations may have a single vent for multiple tanks and that vents may be used for more than one purpose)
- current USS layout, including location of pipe work, by checking concrete patchwork, dip points, fill points, etc.
- site fill area
- areas of pre-1960s bitumen
- size and depth of all tanks
- concrete patchwork or newly filled areas that may indicate previous tanks and/or equipment having been removed or replaced, or new tank locations
- data with site operators, including stock control records, age and size of tanks, maintenance, abandoned or disused tanks, and previous investigations.
- location of all above- and underground structures and services to assist in planning soil and groundwater sampling locations
- receptors that may be at risk should there be soil or groundwater contamination:
 - on-site: site workers, customers, maintenance workers
 - off-site: underground utilities, preferential pathways, maintenance workers, land uses, surface water bodies
- presence of concrete cores or monitoring well covers that would indicate previous soil and/or groundwater investigations
- waste disposal practices and stormwater management measures – for example, does stormwater from the forecourt run through separators, stormwater disposal to groundwater aquifers, air compressor drainage waste
- underground services – some services may form confined spaces to which entry is not recommended.

Chemical substances

Chemical substances that may be associated with USS include:

- petroleum fuels, lubricating oil and additives such as organometallic compounds, surfactants, biocides, molybdenum compounds and corrosion inhibitors
- 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 solvent
- waste oil (highly variable composition)
- other chemicals including ammonia, copper chrome arsenate, acids, caustics, coal tar distillates, paint, poison and chrome.

Detailed site investigation

The completed preliminary investigation should provide sufficient information to design a detailed soil and groundwater sampling and analysis program specific for the site and the chemicals and wastes which are believed to be present.

The timing of the detailed site investigation can be critical. If improvements such as buildings and structures, including the USS, are on the site at the time of the detailed investigation, then a full assessment cannot be completed due to difficulties accessing soil and groundwater sampling locations beneath the USS, buildings and structures.

Therefore, the detailed site investigation can be completed at the following stages, with increasing degrees of reliability:

- with the site in its current configuration – the USS and all site improvements remain in place
- following the removal of all above-ground improvements – leaving underground improvements including USS and foundations in place
- following the removal of all improvements, including USS.

Completion of the detailed site investigation would ideally occur once all site improvements have been removed to allow access to the entire site. However, such an approach may not be feasible as, for example, the site may be up for sale with existing improvements.

If the assessor needs to compromise sampling locations due to the position of structures, the resulting uncertainty should be explained and accounted for in the report.

Soil assessment

Soil sampling programs for sites containing USS should identify and delineate the lateral and vertical extent of soil contamination and arrive at a scientifically defensible and statistically valid data set that characterises chemical concentrations in the soil. Traditionally, two samples per tankpit floor and one sample per wall of excavation have been used to examine the condition of soils within a USS excavation. Such an approach may be adequate for smaller excavations, but for the removal of larger storage systems, additional samples are needed to detect hotspots.

There are three statistical methods provided in AS4482.1 for determining the number of soil samples required to be taken to:

- determine the degree of contamination
- determine the average concentration of an analyte
- detect a hotspot.

Determining the average concentration of an analyte requires background information on chemical concentrations and a detailed understanding of imported fill and natural soil properties.

Hotspot size calculations do not require such site-specific contaminant information; rather they rely upon average size of breaches in the USS. Leakage from USS is unlikely to occur over the entire area of the storage portion of the USS. Based on previous experience, leakage is most likely to occur at a tank opening, such as a fill line, or at a corrosion point that may range from pinhole to fingernail size. Older USS were usually built from steel, which corrodes when left in the ground for a long time. Corrosion typically results in pitting of the steel and minute holes in the tank or lines.

Such point sources would result in plumes of contaminated soil with a small cross section, significantly smaller than the tank. Therefore, a significant number of sampling locations are required to provide a 95% confidence level that the investigation or validation program can detect these small hotspots.

Sampling the condition of soils surrounding a USS is complicated by many factors, including soil porosity and permeability, presence of lenses of varying soil type, heterogeneity, extent of weathering, presence of fill and state of the leaking material, e.g. vapour or liquid.

Locations to be sampled at USS sites include:

- immediately above any current or former groundwater level within the excavation
- the intersection of backfill with natural soil
- the base of the tank pit excavation where the more permeable tank pit backfill meets soil – sampling will need to extend into natural soil
- beneath the USS to determine potential for accumulation of chemicals at depth, e.g. groundwater or non-aqueous phase liquid (NAPL).

Hotspot detection is the preferred method for assessing and validating USS locations to provide a statistically defensible methodology on which to determine with confidence that there are no residual areas of soil contamination.

Groundwater assessment

Groundwater assessment is critical for appraising the environmental effects of USS and can be very complex. Leakage of USS contents to soil can often lead to low, or non-detectable, levels in the soil, although concentration of USS contents within groundwater may often exceed drinking water standards. Assessment of groundwater often reveals the true impacts of the USS.

Substances that have leaked from USS have been reported to migrate up to 450 metres from the source (Barber, 1996). Groundwater plumes have been found to extend as far as 120 metres (Rice, 1995) and 1600 metres (Bedient, 1994) from the source USS.

Seasonal variations, and variations across saturated zones, also add to the complexity of groundwater assessment. The Victorian EPA (EPA Victoria, 2002) provided case studies that indicate that the cost of decommissioning (and/or replacing), assessing and remediating a USS may reach, and even exceed, one million dollars.

Before assessing groundwater for contamination, the following should be investigated:

- the products stored at the site and their breakdown products
- mobility
- site hydrogeology
- potential for preferential flow

- potential for groundwater mounding and resulting radial flow
- bedrock type, such as fractured rock
- potential infiltration to deeper aquifers
- plunging groundwater plumes
- potential for the presence of either light or dense NAPL.

Groundwater monitoring wells should define the vertical and lateral extent of contamination, taking into account contaminants present at or surrounding the site. Wells should be sited and constructed to allow for future monitoring – that is, they should allow for seasonal groundwater level fluctuations. For any groundwater assessment, at least one well should be located directly beneath the former location of the USS. The presence of NAPLs should be investigated. However, the presence or absence of NAPL is difficult to confirm, as residual NAPL trapped in soil pores is difficult to detect and may not readily flow into monitoring wells.

Quality assurance and quality control

The generally liquid, highly mobile and volatile nature of substances associated with USS is such that volatilisation, degradation and transformation may affect soil or groundwater sample integrity from the time the sample is recovered. This can also affect soil that is to be sampled if it is exposed during remediation work. Therefore, care must be taken to preserve the integrity of the sample.

AS4482.1 provides guidance on sample methodology, health and safety, sample preservation, decontamination of sampling equipment and quality assurance. Consideration should be given to:

- providing a chilled environment to store the recovered samples
- taking duplicate samples for field testing
- taking care when selecting sampling locations to ensure that the samples are representative of the site
- sampling immediately after excavation
- using a non-reactive liner for sealing the sample container
- managing field work to reduce the potential for loss of volatile chemicals
- sampling from discrete locations or soils and not sampling at depth intervals greater than 100 mm.

Sampling programs should provide a high quality data set that is scientifically defensible. Sample integrity should be maintained by using correct techniques and preservation. Analysis of samples should be completed in accordance with standard laboratory analysis methodology by laboratories accredited to national standards such as National Association of Testing Authorities (NATA), and in accordance with Schedule B(3) of the NEPM. Sufficient sampling must be undertaken to adequately characterise the site and to provide enough data points to provide a statistically valid assessment of the site.

Summary

Underground storage systems are considered worldwide to be a major source of soil and groundwater contamination. In addition to the standard site assessment process outlined in the National Environment Protection (Assessment of Site Contamination) Measure and Australian Standard AS4482.1, other measures need to be taken with sites containing underground storage systems.

People assessing sites containing underground storage systems need to understand the general site history and use, as well as the complexities of assessing soil and groundwater conditions to provide a scientifically defensible and statistically significant data set. Data should provide for the assessment of human health and ecological risks. Hotspot detection is the preferred method for assessment and validation of USS locations to determine with confidence that there is little or no residual soil contamination. Direct groundwater assessment at USS location is also recommended to fully understand the potential environmental effects of the site.

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FURTHER INFORMATION

Legislation

Legislation may be viewed on the Internet at: www.parliament.sa.gov.au/dbsearch/legsearch.htm

Copies of legislation are available for purchase from:

Government Information Centre
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