UK Landfill Industry Code of Practice

The Establishment of Appropriate Containment Standards for

Leachate Storage Infrastructure

January 2017

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EXECUTIVE SUMMARY

In 2014, CIRIA published Guidance Document C736 "Containment systems for the prevention of pollution (C736) - Secondary, tertiary and other measures for industrial and commercial premises". This guidance was subsequently promoted by the Environment Agency (EA) as best practice for storage of all potentially polluting liquids for industrial operators in England.

When applying this guidance to the UK Landfill Industry from 2014 onwards, initial experiences highlighted a number of areas where landfill operators felt that clarifications, additional information, or further information would be beneficial to provide guidance specific to the landfill industry and to promote more consistent interpretation of the CIRIA C736 guide by both operators and regulators.

In response to this need, this Industry Code of Practice (ICoP) has been produced by the major landfill operators sponsoring this report. It is intended to provide industry specific and focussed guidance on the provision of suitable primary and secondary containment for the following types of leachate storage systems:

- Leachate treatment plants (LTP's);
- Stand-alone leachate storage tanks (for leachate removal by tankering etc);
- On-waste leachate storage facilitates; and
- Working areas associated with the above facilities (road tanker loading bays, LTP compounds etc).

This Landfill Industry Code of Practice (ICoP) entitled 'The Establishment of Appropriate Containment Standards for Leachate Storage and Treatment Plant' has been written on behalf of the following waste management companies that have funded the production of the document: Biffa Waste Services Limited, Cory Environmental Limited, FCC Environment Limited, Veolia and Viridor. While the need for this industry guidance was identified by the companies listed above in late 2014, evolution of this document has been completed through to the end of 2016 by all parties. The Environment Agency was consulted and commented on a pre-consultation draft of the document in Summer 2016.

It is recognised that this document expresses the practical aspects of leachate storage and management in structures at landfills across the UK and reflects a contemporary Industry Code of Practice within the current and future regulatory environment for such activities in the UK. In publishing this document into the wider waste management community in the UK, feedback on the contents and its application for the storage and management of leachate at landfills is welcome. It is recognised that a future update of this document may occur in response to evolution with time on the understanding of risk and the emergence of new / innovative solutions associated with leachate management.

From design and operation experience over 30 years at UK landfills, it is recognised that leachate storage tanks installed in accordance with established design principles tend not to catastrophically fail through the design life of the structure(s). Instead, the principal causes of risk to the receiving water environment are most likely to be associated with leaks and spills associated with loading and unloading of storage tanks, human error in site management and issues surrounding longer term infrastructure repair and maintenance. Key risks posed to the environment are (a) the storage of raw, untreated leachate in large (> 100m^3) engineered storage tanks, principally located at leachate treatment plants and (b) the storage of raw untreated leachate in smaller (~ 50m^3) engineered storage tanks used mainly for off-site tankered disposal of landfill leachate.

It is recognised and accepted that the storage of treated leachate in designed structures presents a lower risk to any receiving water environment when compared to raw or partially treated leachate.

The Authors accept that CIRIA C736 guidance class 2 secondary containment is the default minimum position unless specific risk assessment can show otherwise. A risk based design approach is integral to both the BREF and CIRIA documents and so this is extended to the ICoP and, as detailed within the CIRIA C736 Guidance itself, derogation from CIRIA C736 Guidance is acceptable, as long as it is backed up by suitable risk assessment to demonstrate why derogation from the guidance is required and how risks associated with loss of containment are otherwise accommodated / mitigated. Containment risk assessment design should however be based on credible failure scenarios.

It is also recognised that retrospective application of this ICoP and the CIRIA C736 Guidance is not appropriate at existing facilities as long as operators can demonstrate that they actively assess the risks posed by their existing portfolio of leachate infrastructure and are actively making improvements where necessary. However, it is recognised as good practice to assess how a storage or treatment facility performs against both the CIRIA C736 Guidance and this ICOP as this should be the basis upon which any decision to improve a facility is made.

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1.0 INTRODUCTION

The requirement to adequately contain potentially polluting liquids along with framework details of how this is best achieved is contained within the European Commission Waste Treatment Industries BREF note (2006)[1]. Based on the BREF document, updated guidance on containment systems for the prevention of pollution was published in 2014 by CIRIA (Guidance Document C736[2]) and has been promoted by the Environment Agency (EA) as best practice for storage of all potentially polluting liquids for industrial operators in England.

Initial experiences of applying the CIRIA C736 guidance to landfill leachate storage facilities has highlighted a number of areas where landfill operators felt that clarifications, additional information, or further information is required to provide guidance specific to the landfill industry to promote more consistent interpretation of the CIRIA C736 guide by both operators and regulators.

This Industry Code of Practice (ICoP) has been produced for and on behalf the major landfill operators sponsoring this report. It is intended to provide industry specific and focussed guidance on the provision of suitable primary and secondary containment for the following types of leachate storage systems:

- Leachate treatment plants (LTP's);
- Stand-alone leachate storage tanks (for leachate removal by tankering etc);
- On-waste leachate storage facilitates; and
- Working areas associated with the above facilities (road tanker loading bays, LTP compounds etc).

This ICoP covers issues relating to containment standards for the majority of proposed and existing landfill leachate treatment plants, leachate storage tanks and their closely associated ancillary infrastructure such as loading bays and so covers the majority of areas where there is a potential risk of leachate escape from containment once leachate has been removed from the landfill.

The ICoP has been produced by five of the major UK landfill operators and has included discussion and input from the EA facilitated by the Environmental Services Association (ESA). It is intended that by making the document available to all operators and regulators in the sector further comments and suggestions can be collated and, if necessary, further iterations of the ICoP produced to address new issues that may be identified in the future.

The ICoP intends to provide guidance for use by the landfill industry and regulators to promote a consistent approach to issues such as;

- The status of legal obligations and associated guidance up to 2015;
- Quantification of the risks of leachate treatment and storage;
- The risks and mechanisms of accidental leachate release;
- A proposed framework for the phased approach to projects involving leachate storage;
- Selection of appropriate risk based designs for primary containment at new facilities;
- Selection of appropriate risk based designs for secondary containment at new facilities;
- Practicalities of retro-fitting secondary containment to existing plants; and
- Operational guidance for routine and foreseeable exceptional management planning

The CIRIA C736 guide provides extensive details of the assessment methodologies and engineering considerations for provision of secondary containment systems. Fundamentally the BREF and CIRIA documents encourage a risk based review and justification of the design of secondary containment systems and only provides guidance on best practice. Where specific

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[1] 'Integrated Pollution Prevention and Control. Reference Document n the Best Available Techniques for the Waste Treatment Industries'. European Commission. 2006

[2] 'Containment systems for the prevention of pollution: Secondary, tertiary and other measures for industrial and commercial premises'. CIRIA C736. 2014.

circumstances exist, designs other than those described within CIRIA C736 can be acceptable as long as operators demonstrate that designs take into account issues highlighted within CIRIA C736 and have accommodated them in a robust and acceptable manner, usually in the form of a design risk assessment for the facility.

In most instances it is accepted that CIRIA C736 Class 2 standard secondary containment should be provided as a minimum for all <u>new</u> installations that store raw leachate, with some minor clarifications and amendments to detailed designs to accommodate specific risks appropriate to storage of landfill leachate.

Secondary containment for vessels that contain part or fully treated leachate may be of a lesser standard or in some instances may not be required at all if operators can demonstrate, through suitably robust risk assessment, that site specific circumstances exist that result in a much lower risk being posed from these vessels. Instances where secondary containment may not be required are likely to be restricted to structures where high quality, poured in-situ reinforced concrete tanks are installed employing an agreed CQA methodology and are located in a relatively low sensitivity setting.

There are limitations to the CIRIA C736 guidance when applied to leachate storage; for example elements relating to fire and the need for secondary containment to store polluting effluent for long periods are not always relevant to the landfill industry. A number of specific issues of particular note for the landfill industry were highlighted in relation to the CIRIA C736 guidance as follows;

1. Situations where there is no credible source-pathway-receptor model or where simple engineering solutions can be used to disrupt the source-pathway-receptor model need to be recognised;
2. When manufactured out of suitably designed, high quality, poured in situ reinforced concrete and employing agreed CQA methodologies there is almost no chance of jetting except through wall penetrations for pipe fittings etc. therefore it is acceptable for a concrete tank of this nature to be installed within the jetting distance of the bund wall so long as any such engineered tank wall penetrations point ‘inwards’ away from bunds;
3. Secondary containment does not necessarily need to be to the standard outlined in CIRIA C736 (i.e. 1m of clay at $1x10^{-9}m/s$) on the basis that the bund does not need to be capable of storing spilt inventory for an indefinite period of time. As long as the operator can demonstrate that they have in place the means to dispose of inventory within a defined (short) period of time then the bunds containment properties can be designed to suite this time period;
4. Clarify that when assessing an earth (clay) bund with geomembrane (composite liner) the performance of the geomembrane is included in the permeability assessment, not just the underlying earthen (clay) layer;
5. When manufactured out of high quality poured in situ reinforced concrete using suitably designs and employing agreed CQA methodologies, concrete tank bases do not need to have a structurally independent secondary containment layer underneath them as long as they incorporate some form of underdrainage or leak detection instead; and
6. Recognition of the wider environmental risks posed by landfills to the environment, with regard to the potential of leakage of leachate to the receiving water environment from the main body of landfilled waste.

The landfill industry acknowledges that operators have a legal requirement not to cause pollution and to take all reasonable measures to prevent harm. It is now recognised that this requirement will remain for decades into the future, with the required longevity for infrastructure to last through both the operational and then aftercare periods of a sites life.

However, it also notes that it is the role of the regulator is to ensure that designs for any proposed leachate storage tanks represent Best Available Techniques as outlined within the BREF note and any specific sector guidance that may be provided.

1.1 Regulator Review

Environment Agency review of this document has been provided by members of the National Landfill and Deposit for Recovery Team and members of the Agency's Landfill Engineering Working Group.

The Environment Agency has reviewed this document and provided advice and recommendations on its technical and regulatory content. However, it reflects the UK landfill industry's opinion of best practice, which may not satisfy English or European law. To ensure you are compliant with the law you should refer to separate regulatory advice available from gov.uk and the European Commission (e.g. Best Available Techniques Reference documents (BREF)).

1.2 Abbreviations Used

The following abbreviations have been used in this report;

Abbreviation	Definition
AA-EQS	Annual Average Environmental Quality Standard
BAT	Best Available Techniques
BOD	Biochemical Oxygen Demand
BREF	BAT Reference
CIRIA	Construction Industry Research and Information Association
COD	Chemical Oxygen Demand
COSHH	Care Of Substances Hazardous to Health
CQA	Construction Quality Assurance
EA	Environment Agency
EC	European Commission
EQS	Environmental Quality Standard
GRP	Glass Reinforced Plastic
HAZID	Hazard Identification
HAZOP	Hazards and Operability
HDPE	High Density Polyethylene
HRAR	Hydrogeological Risk Assessment Review
ICoP	Industry Code of Practice
IPPC	Integrated Pollution Prevention and Control
ISO	International Organisation for Standardisation
LC50	Lethal Concentration 50
LTP	Leachate Treatment Plant
m^3	Cubic Metre
mAOD	Metres Above Ordnance Datum
mg/L	Milligrams per Litre
NRW	Natural Resource Wales
PA	Planning Authority
P&ID	Piping and Instrumentation Diagram
PPM	Planned Preventative Maintenance
QA	Quality Assurance
SAC	Special Area of Conservation
SEPA	Scottish Environmental Protection Agency
SGN	Sector Guidance Note
SPA	Special Protected Areas

SPZ	Source Protection Zone
SSSI	Site of Special Scientific Interest
WFD	Water Framework Directive

2.0 LEGAL OBLIGATIONS

Landfill operators are obliged to prevent pollution by leachate, particularly of ground and surface waters (controlled waters), these obligations being delivered by the Environmental Permitting regime. There is a legal requirement for Industry not to cause pollution that includes all reasonable measures to prevent harm. This requirement will remain for an extended period of decades into the future until the permit is surrendered.

‘Taking all reasonable measures’ would normally involve 'appropriate measures' as defined by the sites permit that include demonstrating that the principal of ‘Best Available Technology’ (BAT) have been applied to plant design and operation. This will be site specific but based on common principals for all leachate storage tank facilities. In all cases, the decision making process should be supported by a documented risk assessment to underpin the outcomes to reasonability. Even if BAT designs have been approved and implemented, should an operator cause pollution they will still be liable to prosecution. However, if the operator can satisfy the regulator that they have used 'appropriate measures' and that pollution resulted from an unforeseen accident, this will influence the regulators regulatory response which may be to use other regulatory tools than prosecution.

As such, the principle behind facility design assessment where there is the potential to cause environmental harm should be that the operator (usually ‘Industry’) designs the plant and accepts the risks implied by its operation and that the regulator approves designs with regard to ‘Good Practice’, it does not re-design.

‘Good Practice’ in general is accepted to be contained within CIRIA C736 (and from a regulatory perspective from the BREF 08/06 documents) but for the landfill industry (and only the landfill industry) ‘Good Practice’ is also contained within this ICoP. Deviation from the guidance contained within CIRIA C736 is potentially acceptable at UK landfill sites and can be acceptable to the regulator by a suitably robust risk assessment.

It should also be noted that there is a defined (small) number of landfill sites in the UK which have LTPs installed and a larger number of sites that have storage tanks for offsite removal of leachate. In all cases going forward, the number of major new facilities will be limited with the long term focus instead being the maintenance and periodic upgrade of existing assets in the UK.

3.0 UNDERSTANDING THE CIRIA C736 GUIDANCE

The CIRIA C736 guidance was written largely in response to the Buncefield oil depot incident in 2005 where large scale fires led to the eventual failure of secondary containment due to structural damage from heat and the intensity of firefighting activities. As a result of this the guidance provided in CIRIA C736 was written to accommodate the effects of fire and firefighting on secondary containment design.

Containment system designs for landfill leachate need not accommodate all the resultant failure mechanisms anticipated in the CIRIA C736 guidance. Instead CIRIA C736 allows, via risk assessment, for non-credible scenarios to be discounted and so, as a result, bund designs can deviate from those presented in the guidance as long as they can be demonstrated to be suitably robust for the anticipated scenarios that they will be likely to encounter and comply with BAT.

3.1 CIRIA C736 Guidance ‘Myth Busting’

Since publication of the CIRIA C736 guide in February 2014, operators have experienced a number of different interpretations of the guidance when applied to leachate containment system projects around the UK.

These issues have been collated and are presented below as a series of ‘myth busting’ statements intended to detail issues relating to the design of leachate containment systems that should be acceptable to both operators and regulators;

1. The landfill industry accepts that the basic minimum standard is a CIRIA C736 Class 2 containment bund;
2. Design of any containment system should be based on *credible* failure scenarios for the specific project under consideration. Scenarios considered and those that have been rejected as not credible (along with reasoning for the rejection) should be recorded and presented alongside any risk assessment and / or design statements for containment systems to be employed;
3. Leachate is not flammable or explosive and therefore provided that primary containment is designed, installed and maintained to appropriate standards the risk of catastrophic failure can generally be discounted. The effects of both fire and heat damage along with any surge from catastrophic failure would not therefore normally have to be considered in secondary containment designs for use in the storage of landfill leachate;
4. Secondary containment may be achieved by means other than concrete or composite (clay with geomembrane) bunds. Alternative methods of providing secondary containment will need to be risk assessed to demonstrate that suitable and similar levels of containment (both in terms of bund volume, shape, robustness etc.) are provided. This may include the concept of ‘natural containment’ (secondary containment supplied by in-situ geology etc.). Where this is proposed evidence of the containment properties of the natural in-situ geology will need to be provided to the regulator. Such evidence will be provided via an appropriate site investigation.
5. The main risk posed by a landfill facility (including any leachate storage) is potential instantaneous release of a controlled volume of raw or partially treated leachate to surface waters, not pervasive release through ground (attenuation zone) to groundwater. This latter method of release is generally accepted as an inevitable eventuality from landfills and its acceptability is assessed via the hydrogeological risk assessment process, linked to the sites Permit. The main function of secondary containment is therefore to prevent immediate surface flow to controlled waters of escaped raw or partially treated leachate. Design and good quality construction of primary containment should address the issue of pervasive leaks to ground;
6. The purpose of secondary containment is *temporary* storage of liquid that has escaped from primary containment, to be used infrequently as a back-up to other controls designed into the storage facility, therefore it has to be sufficiently robust and impervious to retain spills for long enough to control and clean up. It does not necessarily have to be suitably robust to retain liquid for an indefinite period of time; noting that it is not desirable to operators or regulators to have liquid within the secondary containment for any extended period of time after an event.

7. In commissioning new infrastructure, the design life of the principle components should be clearly stated, recognising that different failure modes may occur over different timescales against the design life of the infrastructure.
8. Correctly designed, manufactured and installed tanks, whether concrete, plastic or steel, rarely fail catastrophically when installed and maintained in accordance with the design life of the infrastructure. Where operators can demonstrate through design and subsequent QA procedures that tanks are purchased from reputable sources, are of high quality and have been correctly installed (including venting to mitigate explosive risk), failure scenarios that need to be considered in designs for secondary containment should be limited to leaks and spills from fittings and associated pipework rather than the tanks themselves;
9. Where containment failures occur this is normally due to poor operating practice (including maintenance). Robust operating procedures and PPM are more likely to control these issues than installation of secondary containment bunds designed to store leachate for long periods of time;
10. Significant spillages (i.e. full tanker loads) from the collection and delivery of leachate are rare, smaller volume leaks and spills are more common and are generally able to be stopped within a short space of time (by actions of the tanker driver, LTP operator etc.). Facilities to contain full tanker loads are not usually necessary, instead the ability to contain and pump away to storage adequate volume of spilt material is sufficient in most instances;
11. Leakages from pipework, valves and similar fittings may occur but are usually small and readily contained or controlled. Systems to collect any spills to sumps where their presence can be detected and notified by probes to alarm and activate remedial systems can be successfully used to prevent escape of contaminants;
12. Landfill leachate presents a low risk of harm to public health in all but exceptional cases and does not pose a fire risk. Leachate does not burn and therefore there is no need to consider the consequences of fire or firefighting, consideration of explosive atmosphere is however required (particularly in raw leachates that can contain entrained methane);
13. Some landfill operators have many years of experience disposing of leachate and similar quality liquids and are likely to have continuous access to tanker fleets and disposal outlets, Secondary containment designs can be adjusted to reflect this (reduced containment volume requirement to accommodate rainfall after an incident; containment bund construction materials, permeability and robustness appropriate for the length of time spilt liquid is likely to require storage etc.) as long as tankering and disposal arrangements can be demonstrated to be reliably in place at all times;
14. Penetration of the primary containment is allowable and necessary in most instances (for example installation of overflows) as long as consideration of jetting from penetrations is considered (for example, penetrations located so as to point away from high risk locations such as sensitive receptors, fragile equipment or containment walls) and suitable controls are in place (lock-off procedures, site security, leak detection etc.). This includes allowing 'man-ways'[3] where necessary (for example where health and safety issues exist for installation and on-going operation of tanks). However, such penetrations should be minimised and avoided where possible;
15. Penetrations of secondary containment should be avoided where possible. Penetrations in secondary containment walls to allow for access are allowable only if no other workable solutions can be found. In such circumstances associated risks will have to be assessed and suitably managed. For example, proprietary 'flood gate' or 'bund gate' type systems are widely available and used in various industrial sectors (for example the brewing and petro-chemical industries) where bunding is required but vehicular and pedestrian access to the bunds is still routinely required. Gates of this nature, if accompanied by suitable operational procedures, periodic testing and maintenance regimes, can be used to accommodate the need to gain vehicular access inside of secondary containment where other options are not practical;

[3] A 'man-way' is a water tight access door, typically circular but sometimes rectangular in shape that is large enough to provides safe access for workers through a tank wall for maintenance and inspection purposes. They employ either 'swing in' or 'swing out' designs, are typically sealed shut and can be opened only after tank contents have been emptied.

16. Secondary containment need not be to the standard implied in CIRIA C736 for class 2 or 3 bunds in terms of permeability if it can be demonstrated that design and operation of installations means that spilled or escaped leachate will not be stored in secondary containment for prolonged periods of times (e.g. clean up in weeks, not months). Whilst surfaces need to be suitably robust to prevent damage that could compromise short term containment and may also need to be regularly inspected (particularly after use in storing leachate), concrete, tarmac, lined blockwork etc. can be used where appropriately justified. Clay and membrane bunds don't necessarily need to conform to the guidance of hydraulic performance equivalent to a 1m depth of clay at $1x10^{-9}$m/s plus flexible membrane liner for protection. For example, hydraulic performance equivalent to $1x10^{-9}$m/s with transmission rates through the clay of more than 3 times the justified 'clean-up period' should be acceptable as long as the minimum clay depth can be demonstrated to be sufficiently thick to ensure its robustness. Where containment is to be provided by soils (either through 'natural containment' or in engineered containment systems) consideration should be given to long term soil quality. Once operations cease and the plant removed, soil quality will need to be assessed for any surrender application. The more substantial the containment design is, the lower the risk of impact on soil;
17. Jetting[4] needs considering for all tanks constructed primarily from metal or plastics. For tanks constructed from reinforced concrete (with suitable CQA procedures) jetting is only likely to occur at penetrations which can be controlled by positioning these features to point to bund centres. As the only credible failure scenario from such concrete tanks are weeps through the walls concrete tanks can be positioned next to bund walls, as long as they are well designed, their installation is subjected to suitable CQA and tank wall penetrations face away from the facility perimeter and in towards the centre of contained areas;
18. Double skinned / integrally bunded tanks are acceptable as long as the outer skin or bund provides sufficient storage volume (usually 110% of the largest tank brim-full capacity or 25% of the total brim-full tankage volume) and the base has structurally independent containment. The bund / second skin also needs to be robust enough to withstand 'surge' from inner tank failure and is well protected from external impact damage (vehicles). Other design considerations that would make double skinned / integrally bunded tanks acceptable for use are presented in Section 9.0;
19. Reinforced concrete floors of tanks do *not* need a structurally secondary containment layer underneath as long as they are installed with some form of under-base leak detection system, likely to be a drainage layer from which a sample of any liquid emanating from beneath the tank base can be gained. Well designed, reinforced concrete installed under suitable CQA is sufficiently robust to negate the need for structurally independent secondary containment under the tank base. However, such concrete bases will need be subject to proper design, testing, QA, installation and monitoring / inspection;
20. Fixings to bunds (concrete or membrane / clay) are allowable if undertaken to suitable standards as long as bunds (or any other walls etc. in the facility to be used in this way) can be shown to have been designed to accommodate the anticipated loading from liquids (and any other loads) and the fixing or bolting does not compromise the structural integrity or water retaining features of the surface,. For example, when securing cable trays or pipework to membrane / clay bunds concrete plinths or blocks can be placed onto which supports can be secured. For concrete or blockwork, suitable drilled holes that do not fully penetrate the concrete or blockwork used for bolting of other structures are also acceptable. When bolting to concrete, resin anchored systems should be used in preference to friction anchored systems as friction anchored systems do not always fully back-fill the hole in the concrete and so water ingress to the core of the concrete wall is possible;
21. Pipework can be buried without the need for double skinning or inspection channels where it is not possible to install above ground, as long as the installation has been subject to risk assessment at design stage with particular attention to where buried pipework may need protection from damage or additional support due to its location (under roadways, crossing

[4] Escape of liquid under pressure through a hole or penetration in containment that can project horizontally from its source (see 'Containment systems for the prevention of pollution: Secondary, tertiary and other measures for industrial and commercial premises'. CIRIA C736. 2014. Section 3.3.1, page 86)

ditches etc.), QA is in place for installation and testing and leakage inspection is provided by some other means (periodic pressure assessment for example);

22. The greater the physical plan area of secondary containment around a leachate storage facility, the greater the volume of (rain) water that will accumulate within the secondary containment. On-going management of all water accumulating inside the secondary containment will be required in order to retain the effective storage capacity of the bunding;
23. Often secondary containment can incidentally provide primary containment structures with protection against accidental impact damage (e.g. vehicle impacts). Where secondary containment does not provide this protection, other suitable means of preventing damage from impact must be provided (bollards, Armco barrier etc.);
24. It must also be recognised that leachate is a waste (until it is discharged to the public sewerage network or surface water by consent). Thus an uncontrolled emission of leachate is potentially an unauthorised deposit of waste on land and a breach of the Duty of Care. While there is a risk assessment element to leachate storage vessel design and construction, operators also have a duty not to allow waste to escape their control; and
25. Treated leachate still presents a residual risk to the local water environment, but the severity of the risk is accepted to be far lower than that posed by the storage of raw or partially treated leachate. An assessment of the risks of stored treated leachate is recommended but as a starting point, secondary containment is unlikely to be required for treated leachate infrastructure.

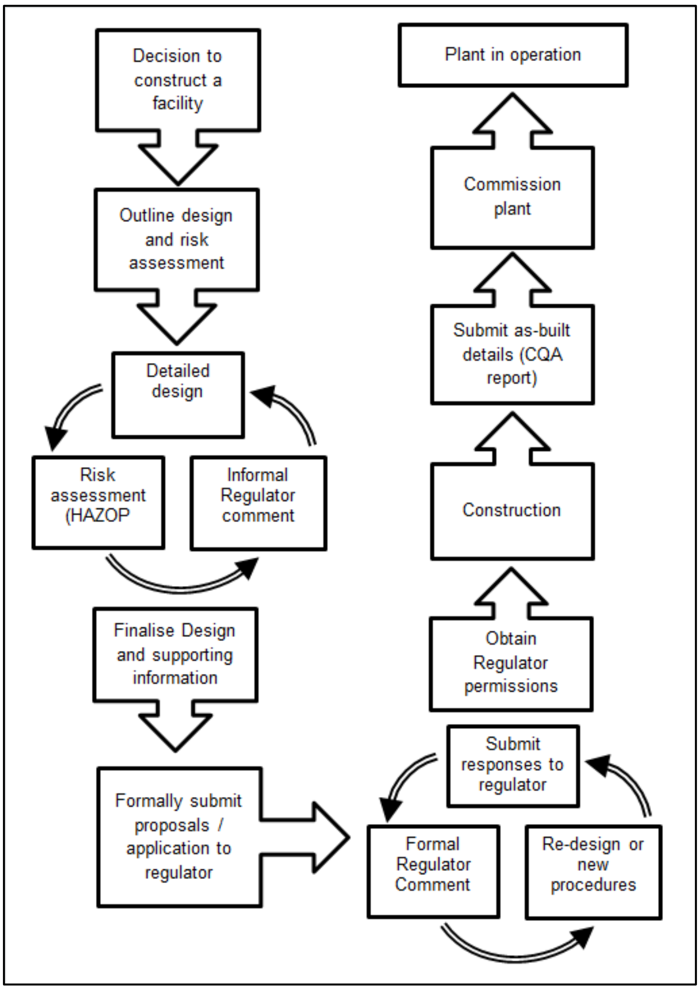
4.0 IDEALISED APPROVALS PROCESS

So that a project can progress quickly and smoothly from inception to delivery it is important to engage with the regulator as early as possible with a meaningful design and CQA plan. This should also include any details of proposed operating techniques so that the regulator can be assured that good practice will be followed. This is even more important if it is intended to employ secondary containment measures at a facility that are not in accordance with the guidance in CIRIA C736 for class 2 bunding (or above).

To assist operators in ensuring that the process of designing, permitting and then constructing a facility that is intended to store leachate (or to significantly up-grade existing infrastructure that is involved in storing leachate) takes place as quickly and easily as possible, presented below as Figure 1 is flow chart indicating the tasks involved in an 'idealised' project.

It is noted that each operator wishing to follow this Project Flow Diagram will be subjected to their own internal company procedures and policies with regards to (for example) the timings of engagement with the regulator and the release of capital and associated approvals within the process.

Figure 1
Simplified Project Steps Flow Diagram



5.0 FACILITY DESIGN AND INSTALLATION PROCESS

Design of plant for the storage of landfill leachate should be via a suitably robust documented risk assessment based method. In this way it can be demonstrated to regulators that all reasonable steps have been taken to identify and control risks associated with the proposed plant, including the potential for loss of containment.

Regulatory approval processes are not limited to an assessment of the physical design of any proposed works but also include a review of the nature and extent of the quality assurance procedures employed at both the design and construction phases and prior to the operation of any new plant. If justifying away from the basic concept of provision of CIRIA C736 class 2 type bunding for the whole plant risk assessments must be detailed and robust and a low residual risk must be adequately justified. Designs that deliver high quality primary containment may be used to justify secondary containment systems that deviate from the standard CIRIA C736 guidance designs as long as the deviation is suitably justified and still allows operators to discharge their legal responsibilities including BAT. “Good quality / Holistic” design does not need to focus solely on secondary containment design and the risk of catastrophic tank failure (as it is so rare) but should also consider control of accidents and mistakes that lead to escape of liquid as these are a much more common causes of loss of containment.

Construction Quality Assurance (CQA) plans coupled with suitable operational monitoring and reporting regimes are encouraged to demonstrate that the storage facility is constructed as agreed with the regulator and that plant is subsequently operated correctly to avoid accidental losses of containment. Almost all instances of tank leakage, failure or other loss of containment are due to CQA plans not being adhered to during construction or improper or careless operation of plant after construction has been completed, as such Planned Preventative Maintained (PPM) is critical in maintaining containment over the lifetime of storage facilities.

Early engagement with regulators, providing details of proposed plant designs, risk assessments and quality assurance procedures, is encouraged so that projects can proceed as quickly and smoothly as possible.

5.1 Design Risk Assessment

Suitable existing risk assessment templates have been in common usage within the Landfill industry, such at the H1 modelling available on the ‘gov.uk’ website, and these should be considered as a reasonable starting point for any assessment produced to support a design for the provision of secondary containment at a leachate storage facility.

This ICoP does not attempt to provide a template for a suitable risk assessment (set layout, agreement on what constitutes low, medium and high risks etc.) because a standard approach is not possible given the site specific considerations needed. Instead it highlights the need for operators to produce suitably robust environmental risk assessments to support plant designs. It will however include a list of aspects that need to be considered as a minimum (see Section 5.2).

Where significant disagreement is found to exist between the operator and regulator for individual design proposals, for example at high risk sites or where considerable deviation from the CIRIA C736 guidance is proposed, a quantitative risk assessment may be needed. This should be discussed with EA’s National Landfill and Deposit for Recovery Team and members of the Landfill Engineering Working Group on a case-by-case basis.

For most new build or major refurbishment of existing leachate treatment plant Hazard Identification (HAZID) and / or Hazard and Operability (HAZOP) studies are encouraged to be employed although it is noted that they are <u>not</u> mandatory. These studies are structured and systematic examinations of processes or operations used to identify and evaluate problems that may represent risks to personnel or equipment, the operability of the process (or operation) and the environment.

A suitably detailed and robust HAZID or HAZOP assessment or other similar assessment (for example a ‘Designer Risk Assessment’) can be used to inform credible failure scenarios and so justify details of both primary and secondary containment design, process controls and operating techniques to prevent pollution in relation to BAT. Note that such studies need to consider plant failure scenarios including events such as loss of power to ensure that all valves and pump fail to a ‘safe’ position so that any potential for loss of containment is avoided. This is typically achieved through the use of Uninterruptable Power Source (UPS) devices that provide enough back-up power to enable plants to shut down safely in the event of a power failure or the use of sprung valves that require power to keep them in an ‘open’ (or ‘at risk’) position. This is particularly important for gravity controlled systems where flows may not stop if there is a power failure and switches / control valves do not work.

Whilst not mandatory, documented qualitative risk assessment procedures are more likely to be beneficial for more complex and large scale projects. Where deviation from the guidance provided in CIRIA C736 is proposed it is anticipated that a suitably robust and detailed design risk assessment will be viewed more favourably by the regulator than where no explanations for alternative designs or procedures are supplied.

5.2 Design Risk Assessment Content

Any risk assessment undertaken by the operator should include a conceptual model of the facility, indicating the source, pathways and receptors involved and must result in a risk rating for each element considered. In general, risk assessments should take the form of a table defining risks in qualitative terms such as ‘Low’, ‘Medium’ or ‘High’.

5.3 Source, Pathway, Receptor Model

Any methodology for assessing the risk posed by a leachate storage installation should begin with an assessment of the nature and magnitude of the hazard posed by the liquid being stored (the source), the presence and nature of a pathway and sensitivity of the receptor.

<u>Source</u>

This is a combination of the volume of material stored and its contaminating potential. For landfill leachate and part or fully treated effluents this classification is driven mainly by ammonia, BOD, COD and Suspended Solids and the duty of care to prevent the escape of waste materials.

For designs that intend to provide CIRIA class 2 type secondary containment to the whole plant characterization of leachate quality is not required, except for the presence of hazardous substances that may influence the level of risk. Where other designs are being proposed, more robust justification will be required via suitable risk assessment and characterization of the liquid to be stored will be required. Typically this will be no more detailed than the need to assess loadings of ammonia, BOD, COD and chloride or hazardous substances in raw leachate, solids and chloride in mixed liquors (in a biological LTP) and in the treated effluent only chloride may need to be considered.

Most landfill leachate storage facilities are likely to result in an assessment of ‘Medium’ magnitude for the source risk.

<u>Pathway</u>

This is site dependent and needs to be assessed mainly in terms of overland travel of escaped inventory to soil and surface water receptors (or drainage systems that ultimately connect to surface water) but also needs to be aware of movement through underlying geology to groundwater receptors.

Pathways need to be considered in terms of distance to the receptor, for example a long distance to nearest receptor may be more than 100m, a near-by receptor may be within 50m – 100m and a short distance to receptor could be within 50m of the proposed development. However, time taken for escaped inventory to reach the receptor must also be taken into account particularly when travel times are so short as to make any kind of emergency response intervention impractical. The nature of the material that makes up the Pathway also needs to be considered, for example impervious geology (e.g. clays) will affect the assessment of the Pathway in comparison to permeable geology such as sands, gravels or porous rock.

<u>Receptor</u>

This is also site dependent and needs to be assessed mainly in terms of the quality of local surface water receptors (or drainage systems that ultimately connect to surface water) but also needs to be aware of underlying groundwater receptors, soils and sites of ecological importance etc. In addition, other local site specific issues such as the nearby presence of unlicensed water abstractions, protected ecological areas or other highly sensitive sites need to be considered. The presence of such features near to the proposed leachate storage location is likely to inflate the rating that would otherwise be attributed to the receptor sensitivity assessment.

For most leachate storage facilities controlled waters are the primary receptor of concern and so the categorisation of surface and / or groundwater is often the main driver in the assessment:

Classification of surface and groundwaters into poor, moderate and high (for surface waters) and non, secondary and primary (SPZ 1, 2 or 3) (for groundwaters) is provided by the appropriate regulator (EA, SEPA, NRW, NIEA). These classifications are time dependent and the regulator usually targets an improvement over time. Therefore plant designs need to be suitably robust over the proposed lifetime of the installation and the potential for changes to water quality objectives for the receptor in question. For example, short term installation of a storage tank that will be removed within 5 years may base its receptor sensitivity assessment on current water quality assessment, but for a full scale LTP with a 60+ year lifetime the assessment will need to be based on the regulators long term quality objectives.

Assessment of the sensitivity of the receptor should result in a detailed ‘site setting’ being established for the location which needs to take into account the wider setting of the installation as well as its immediate surroundings.

<u>‘Natural Containment’</u>

Where assessment demonstrates that the source/pathway/receptor model cannot be established at a particular location so that the only ‘receptor’ is the ground (soil) immediately surrounding the proposed facility, it may be possible to justify that only very minimal engineered containment is required, mainly to minimize areas susceptible to contact with spilled liquid. Such a proposal would need to be based on a detailed site investigation and include appropriate surface water management procedures (to control accumulations of rainfall) and would also need to address the implications of contamination of the ground beneath the facility. In such circumstances local geology, topography and hydrology provides ‘natural containment’.

Key for natural containment is the recognition that secondary containment would provide some degree of reduced leakage to the external world beyond the bund/natural containment and that any spill would be probably of low impact in terms of actual release to the subsurface environment compared to leakage through the base of the landfill. The biggest practical issue for ‘natural containment’ sites would be management of surface water within the natural containment bund/floor and this would need to be detailed in any risk assessment and provisions made for suitably designed sumps and pumps for example to prevent systems for dealing with this surface water becoming a pathway in themselves.

Use of ‘Natural Containment’ may need more detailed justification to the Regulator. Appendix A presents a typical contents list for such a detailed assessment as a guide to the type of information that may need to be presented.

5.4 Hazards to Consider

Storage facilities designs need to reflect the assumption that leachate storage sites are the areas of highest risk for leachate contamination at a site. This then is mitigated by they used of the highest degree of CQA. Mitigation includes; appropriate design, high quality construction, CQA, inspection and maintenance all of which should be detailed in the overarching design risk assessment for the facility.

As a minimum, the following potential hazards should be considered in any risk assessment to support containment design proposals for a facility.

Loss of containment (tanks): Use of high quality construction materials, selected as being appropriate and robust for the liquid being stored, provided and installed by reputable suitably trained suppliers employing agreed CQA and QA procedures will reduce the likelihood of loss of primary containment. This is particularly true if an on-going means of detecting potential loss of containment is included through either automated monitoring systems or regular site inspections.

In principal if tank contents are not raw leachate, the site is not in a high risk location and it is constructed from the highest standard of primary containment materials, considered to be poured in-situ reinforced concrete tanks installed employing an agreed CQA methodology (see Section 6.1), secondary containment may not be necessary;

- Under most normal circumstances raw leachate storage should be provided with secondary containment;
- Treatment vessels are likely to need secondary containment unless through appropriate design (likely to mean that as a minimum the tank is from high quality poured in situ reinforced concrete) and robust risk assessment it can be demonstrated that secondary containment is not necessary; and
- Effluent storage vessels may not necessarily require secondary containment. However, the risk assessment will need to justify this to the satisfaction of the regulator.

Loss of containment (interconnecting pipework): On the basis of risk, containment of field leachate pipework may not be necessary. For example, where pipework is directly adjacent to surface water bodies the need for secondary containment is more likely than where pipework is distant from such receptors. Similarly, mitigation would exist on the basis that landfills have a monitoring network in place along with engineered surface water control systems so that they have the ability to detect and mange any risk posed by pipework leaks, this being in contrast to most other industries.

In relation to leachate storage facilities, wherever possible and practical within the fence line of any facility, above ground pipework is preferred. If pipework has to be below ground then it should be contained. If below ground pipework cannot be contained then the accompanying risk assessment will need to detail the acceptability of such a design and provide for other control mechanisms such as increased inspection and monitoring for pipeline integrity.

Materials Selection: Materials need to be selected that are suitably robust and can withstand chemical and physical attack from both the liquids being stored within them and the external environment in which they are located. Integrity of containment will need to be maintained over extended periods of time (30 to 60 years is a typical lifetime for major leachate storage infrastructure) and over a wide range of ambient conditions (for example, temperatures that may range from -10^{o}C to 35^{o}C over an annual cycle).

Structural Design: All tanks and vessels must be designed so that they are capable of accommodating the static and dynamic loads associated with their intended use. This needs to include assessment of loads developed as a result of failure scenarios.

Impact Damage: Leachate storage vessels, and other vessels storing liquid associated with the storage and treatment of leachate (for example process chemical stores) will need to be adequacy protected against accidental damage and puncture. Some provision for this can be achieved through choice of storage vessel materials (i.e. a poured in situ concrete tank is more robust than an HDPE tank). Other, credible, impact scenarios will need to be considered and control measures included in designs. Often secondary containment can provide primary containment structures with protection against accidental impact damage (e.g. vehicle impacts). Where secondary containment does not provide this protection, other suitable means of preventing damage from impact must be provided (bollards, Armco barrier).

Chemical Spills: Storage of process chemicals may be associated with the storage of leachate, particularly at leachate treatment plants. Consideration should be given to the potential for these chemicals to contaminate receptors such as controlled waters and the ground. The risks posed by such chemicals can be very different to those posed by leachate and this may affect issues such as the choice of construction materials and the decree of containment required. Additional health and safety considerations may be required including the need to keep incompatible chemicals separate from one another and from other co-located plant and equipment, even under spill conditions.

Unauthorised Intervention: System designs to prevent loss of containment need to consider the possibility of accidental or malicious unauthorised intervention. Level control systems can be interfered with and in so doing can become ineffective; valves can be opened to allow storage vessels to drain when not intended. Infrastructure designs should minimise the consequence of such event where possible and should also consider the installation of suitable security measures to prevent unauthorised access. Automated monitoring equipment that can alarm operators to incorrect conditions may also be required along with suitably robust operating procedures to inspect and maintain critical equipment and to manage access to critical areas of sites.

Failure scenarios: The effects of failure need to be considered and mitigated against. Inclusion of robust monitoring and inspection regimes in site procedures can reduce the risk of failure as can commitment to maintain plant as per manufacturer’s instructions. Instrumentation and automated monitoring systems (PLC and SCADA for example) can provide continuous monitoring and early warning and alarm systems that protect against failure of containment. Periodic inspection in terms of both water retain properties of vessels and their structural stability can also reduce risks associated with loss of containment.

5.5 Quality Assurance

Design and quality assurance (QA) good practice is required by the regulatory approval process.

QA procedures ensure that competent designers are used and that designs are assessed and checked as part of the design process by suitably qualified and experienced personnel. QA procedures also ensure that high quality materials are used, that installation works proceed according to best practice and that record keeping during both the construction and operational phases of any project is suitable, adequate and issues or deficiencies in plant design or operation can be highlighted and actioned appropriately at the earliest opportunity.

Along with the design risk assessment process (see Section 3.1), suitable QA procedures are in most cases mandatory and should in any case be seen as ‘best practice’ for operators to aspire to.

5.6 Output of Assessments

Through the submission of suitable risk assessments, the use of detailed CQA, the use of suitably competent suppliers and high quality construction materials it is possible to justify installation designs that move away from the provision of CIRIA C736 class 2 containment for all leachate storage vessels in all circumstances.

6.0 PRIMARY AND SECONDARY CONTAINMENT

Primary containment is provided for leachate by the materials that make up the leachate storage, treatment and effluent tanks along with interconnecting pipework systems and its associated mechanical equipment.

Primary containment should be designed to be resistant to the materials being contained and should take into account effects such as mechanical abrasion and scouring, longevity and general robustness. Primary containment systems should be designed to prevent the likelihood of accidental damage and, wherever possible, the number of wall penetrations should be limited. Pipework should preferably be above ground wherever this is practical.

Bunding (or secondary containment) is a facility built around an area where potentially polluting materials are handled, processed or stored, for the purposes of containing any unintended escape of liquid until such time as remedial action can be taken. Bund walls and bases, with the exception of reinforced concrete bases (see Section 4.1), should be structurally independent from the primary containment system.

Plant designs also need to balance health and safety considerations versus environmental protection when considering issues such as the need for penetrations of containment.

6.1 Primary Containment Materials

Suitable construction materials typically used for primary containment systems are as follows:

- Reinforced cast concrete;
- Precast reinforced concrete;
- Glass-coated, epoxy-coated, stainless or mild steel;
- Various plastics (HDPE, GRP etc);
- Flexible membrane liners; and
- Soils (clay)

Concrete tanks are typically vertical cylinders or rectangular in shape and can either be constructed above ground or part buried[5]. They are typically fixed to a reinforced concrete base with a basal jointing detail that includes some form of ‘water stop’ arrangement or similar.

Metal tanks (best practice would be to use steel) can either be coated or uncoated. In either case they are usually cylindrical, often panel sectioned, with tank walls bolted to a reinforced concrete tank floor <u>or</u> cylindrical tanks supported by cradles lying lengthways with sealed ends (either flat or domed). Typically, when applied to storage of leachate, glass coated tanks are seen as providing a greater degree of containment, followed by epoxy coated, stainless and finally mild steel. Mild steel tanks are often used as stand-alone storage tanks typically for leachate tankering operations. Metal tanks need to be inspected internally on a regular basis for signs of corrosion, most manufacturers recommending inspection by a suitably trained specialist contractor between every 5 and 10 years.

Plastic tanks tend to be used in situations where smaller volumes of liquid are to be stored. Whilst it is possible to construct plastic tanks to store volumes in excess of 100m^3 it is more common to see them being used to store volumes of 50m^3 or below per tank. They are very commonly used as process chemical storage tanks at treatment plants where they are often supplied with integral secondary containment bunds of various designs. Where plastic tanks are used for primary

[5] Note that if part or fully buried, the British Standard for Water Retaining Structures (BSEN1992-3) requires that a 7 day inspection and test of concrete tanks is completed to prove water tightness, this includes a visual inspection for signs of leakage. Such a test would need to be successfully completed before backfilling around a buried tank could take place.

containment the duty that they will be expected to perform and the environmental conditions that they will encounter need to be clearly stated and understood at design stage. The specific gravity, temperature, rate and frequency of filling and emptying, exposure to sunlight and chemical composition of the material stored all need to be considered in the tank design when using plastics.

In all instances it is possible to include membrane lining systems (or other similar impermeable coatings) to provide water retention if the structural element of a tank is provided by a permeable material. Historically tanks constructed from substances such as corrugated steel panelling (part buried) have been installed with 'tank liners' to contain the liquids. Currently membrane lining systems would more commonly be associated with lagoon based storage systems where they may replace or enhance a clay lining system.

In most instances it is accepted by the Industry that reinforced concrete structures are likely to provide the best containment properties over the extended period required for leachate treatment at operational and closed landfills. Use of lined steel tanks is also appropriate accepting that it is likely that such tanks will require periodic inspection and are more likely to require replacement over a 20+ year period when compared to a concrete tank.

Other similar materials may also be acceptable for use and should be capable of being approved by the regulator as long as proposals are accompanied by sufficiently robust design information that demonstrates how the proposed material has been assessed and structures designed to accommodate the use to which they will be put.

6.2 Secondary Containment Materials

Secondary containment of raw leachate storage infrastructure is always required; however it may be supplied by both engineered materials or 'natural' topography and geology. Secondary containment (bunding) is defined as;

> *A facility (including walls and a base) built around an area where potentially polluting materials are handled, processed or stored, for the purposes of containing any unintended escape of material from that area until such time as remedial action can be taken. Bunds must be structurally independent from the primary containment tank.*

Exception to the above definition is allowed where high quality concrete bases have been installed under an agreed CQA regime. In such cases concrete bases may not need independent secondary containment as long as they incorporate underlying leak detection. This could include underlying geocomposite or gravel drains to detect any potential leaks. For existing plant it may be possible to justify the use of suitable groundwater monitoring borehole installations to retrospectively supply leak monitoring. New concrete base designs would need to incorporate good design features such as no joints in the base, water stops etc.

The main purpose of secondary containment is to collect and contain incidental spills and escapes from pipework, fittings and other interconnecting infrastructure and to contain spills and escapes as a consequence of operator error. Very rarely will secondary containment be used to contain major or catastrophic failures of primary containment tanks. Secondary containment should be designed to be able to contain more frequent but lower volume incidental spills and escapes as well as the consequences of tank failure.

If operators are able to demonstrate that contaminated material collected within bunds can be quickly, easily and reliably removed and disposed of and that such arrangements are written into site operating procedures for agreement with the regulator, secondary containment need not be designed to have the same long term water retaining and structural capabilities as primary containment as its use is intended to be intermittent and for short time durations.

As such, suitable construction materials typically used for secondary containment systems include those used for primary containment;

- Reinforced cast concrete;
- Precast reinforced concrete;
- Glass-coated, epoxy-coated, stainless or mild steel;
- Various plastics (HDPE, GRP etc);
- Flexible membrane liners; and
- Soils (clay)

They also include other materials that have sufficiently low permeability so as to retard and contain liquid for long enough to allow for clean-up, bearing in mind that they must also have sufficient structural stability to be able to accommodate any loading imposed when in use, such as;

- Blockwork;
- Masonry;
- Tarmac;
- Grout impregnated macadam;
- Bentonite matting;
- Bentonite enhances soils; and
- Use of membrane liners or other low permeability surface applications may also be used if suitably justified.

Other similar materials may also be acceptable for use as long as designs are accompanied by sufficiently robust design information that demonstrates how the use of the material has been assessed and structures designed to accommodate the use to which they will be put. Early dialogue with the Environment Agency is recommended on the proposed secondary containment properties/materials where alternative secondary containment standards are being considered to those listed above.

In all cases both the primary and secondary elements of containment should be accompanied by a maintenance plan to ensure the integrity of the containment is maintained throughout the life of the structure as detailed in Section 12.0 of this report.

6.3 Primary and Secondary Containment Standards

CQA procedures are required to be used in the construction of new plant or the significant upgrading of existing plant associated with the storage of landfill leachate. As part of these procedures standards that may be applied to different construction materials are presented below in Table 1. These references are provided only as example guidance on the type of information that may be provided to accompany CQA plans for storage tank design.

Leachate storage construction is a specialist area of work and CQA plans and procedures will be significantly different from landfill cell or cap construction projects. Permanent CQA supervision is not necessarily appropriate and best practice would be to include in a leachate tank construction CQA plan justification for elements of the work that needed supervision and which require the sign off by a suitably experienced and qualified engineer. The main aim of CQA for this type of work should be to demonstrate that construction standards have been met and this cannot be achieved simply by having the works observed. The scope of the CQA therefore needs to be agreed with the regulator at design stage including what information is required by the regulator to enable them to sign off the CQA report in a timely manner on completion of construction.

Table 1 Typical Containment Materials Design and Test Standard Guidance

Material	Design Standard	Test Standard
Concrete	• In situ concrete BS EN 206-1, BS 8500-1 & 2 and the latest edition of the National Structural Concrete Specification. • In situ reinforced concrete designed to BS 8110 (latest revision plus relevant codes referred to therein) and / or Eurocode 2. This should include, but not be limited to: o Minimum cover to reinforcement to meet durability requirements; ▪ Concrete either buried or in contact with the ground to meet ACEC Class AC-3 of BRE Special Digest 1 (subject to the results of a full site investigation). o Minimum cover to reinforcement to meet all the requirements of BS 8110 or Eurocode 2; and o Deflection limits in accordance with BS 8110 or Eurocode 2. • Concrete mix developed to comply with the requirements of latest edition of BRE Special Digest 1 in respect of resistance of concrete in aggressive ground. • The use of recycled materials, including aggregates and cement replacements is permitted and should be actively encouraged. • Concrete Grades to Specific Elements o Retaining walls generally = C32/40; and o External concrete slabs (generally) = C28/35 with air entrainment. • Water Resisting Structures designed in accordance with BS 8007 or BS EN 1992-3: o Maximum crack width of 0.2mm; o Maximum w/c ratio of 0.5; o The use of GGBS is recommended to assist in reducing the heat of hydration and to assist in meeting BREEAM requirements; o For water bars (at all junctions) bentonite may be considered in lieu of other (e.g. PVC) water bar materials; o For deep lifts or large volume pours, appropriate measures should be adopted to minimise the risk of early age thermal cracking; and o The type of shutter ties utilised should facilitate sealing of the structure to maintain integrity and ensure longevity of the structure. o Visible seeps may occur during the construction of poured concrete tanks. This should not give rise to undue alarm until any remedial works have been completed and a water tightness test has ended. • Reinforcement bar should comply with BS 4449 or BS 4483 or BS EN 10080 and cut and bent to BS 8666; o Standard reinforcement to be to Deformed Type 2 bars - Grade 460 to BS 4449 or Grade 500 to BS EN 100080. o Stainless steel reinforcement to BS 6744: 2001. o Steel fibre reinforcement to replace or supplement bar reinforcement may be used. o Products should be Agrèment certified or compliant with ASTM A820. o Reinforcement should be placed within the tolerances set out in the NSCS. • Ready Mix Concrete should be sourced from a production plant currently certified by a body accredited by UKAS to BS EN	BSEN 1992-3

Material	Design Standard	Test Standard
	45011 with plant identity testing carried out to BS EN 206-1 and BS 8500-1 annexe B, by a UKAS accredited laboratory (or other national equivalent).	
Precast Concrete	• Precast concrete products should be; o Agrément certified; and o Detailed to comply with the fire and durability requirements of BS 8110-2 or by testing to BS 476-21	
Low permeability soils / clay	• Soil Bunds: Class 1 = Permeability of $1x10^{-9}$m/s with a transmission rate of more than x3 the time period that a bund would contain spilled material; • Soil Bunds: Class 2 = Permeability of $1x10^{-9}$m/s (achieved as a combination of soil and membrane) with a transmission rate of more than x3 the time period that a bund would contain spilled material; • Soil Bunds: Class 3 = Permeability of $1x10^{-9}$m/s (achieved as a combination of soil and membrane) with a transmission rate of more than x3 the time period that a bund would contain spilled material. Leakage detection defined as drainage layer, permanent resistivity or borehole array with periodic (not continuous) testing and assessment; • Taking account of relevant elements of Guidance Notes; o LFE1*: Assessment of engineering designs for landfill sites o LFE2: Cylinder testing geomembranes and their protective materials o LFE3: Using geosynthetic clay liners in landfill engineering o LFE4: Earthworks on landfill sites o LFE5: Using geomembranes in landfill engineering o LFE7: Using nonwoven protector geotextiles in landfill engineering o LFE8: Geophysical testing of geomembranes used in landfills o LFE9: Compliance testing earthworks on landfill sites using nuclear density gauges o LFE10: Using bentonite enriched soils in landfill engineering	As per EA, Guidance Notes LFE1, 2, 3, 4, 5, 7, 8, 9 and 10
Other	• Specific to materials selected, to be justified as part of design risk assessment	Hydrostatic head testing** Pressure testing***

Notes:

* This document will be included within the amended landfill sector guidance and will therefore no longer be available.

** Unless otherwise specified hydrostatic head test to be at brim-full tank capacity, duration of 24hrs with an acceptable change in level being based on 1/7th of the requirements of BS EN 1992-3 (as BS EN 1992-3 is a 7-day test) resulting in 1.57mm or 1/,500th of the tank volume, whichever is the greater. Noting that in practice it is unlikely that such accuracy in measurement is possible, it is often more practical to assume 'no measurable loss of level' for a 24hr tank test.

*** Integrally bunded independent/stand-alone tanks may also be pressure tested to test welds

7.0 PRIMARY CONTAINMENT DESIGN

Tank designs should be justified via risk assessment as is the case for all elements of leachate storage infrastructure. In particular the following points should be considered in any design risk assessment;

- The nature of the liquid being stored may result in the use of different primary containment materials and construction standards, for example at a treatment plant designs for raw leachate storage and treated effluent storage may differ;
- Vessels and associated equipment such as pipes, hoses and connections should be resistant to the substances (and mix of substances) being stored;
- Penetrations to storage tank walls should be avoided where possible; however it is almost inevitable that some tank wall penetrations will be required. Where penetrations are unavoidable a water tight and tamper proof design should be used and consideration should be given to issues such as location of penetrations and the consequence of any jetting from them;
- Vessels should not be used beyond the specified design life or used in a manner or for substances for which they were not designed;
- Where roofed or sealed, venting of tanks should be considered along with release of odours and other point source emissions to air;
- Storage and treatment vessels should be capable of being de-sludged;
- Connections between vessels must be capable of being closed via suitable valves;
- Overflow pipes should be directed to a contained drainage system (such as a bunded or secondary contained area) where liquid can be retained and prevented from discharging to the outside environment;
- Pipework should preferably be routed above ground; if below ground BAT requires where possible containment within suitable inspection channels and suitable periodic inspection. Where this cannot be achieved testing for water-tightness may be appropriate; and
- Tanks should be designed with safe access to enable long-term inspection, monitoring and maintenance of the tank. This may result in the need for features such as 'manways'[3], particularly in the instance of metal tanks where periodic internal access may be required for cleaning and maintenance. If such access is as the designer intended and the supplier is a reputable commercial supplier this should be acceptable if suitably designed and accompanied by agreed operational procedures to manage the risk of leakage through such features.

Where there is a conflict between health and safety considerations and good practice in terms of environmental risk reduction (for example, in the instance of the need for manways in a tank wall) health and safety considerations should be paramount. However, when justifying the need for such features in a tanks design the frequency and duration of the need to use these features needs to be borne in mind. The need for such features during construction (when it may be convenient but not impossible to build without them) is less likely to justify their inclusion in a tank design than an on-going operational requirement (where, if required, their presence will be more acceptable).

7.1 Primary Containment Example Instrumentation

Best practice to prevent overfilling is to fit leachate stores with 'fail to shut' actuated inlet valves connected to level control devices. Typically a primary control device is installed to control the filling of the tank from delivery systems.

Where the risk assessment indicates it is necessary, further secondary or even 'fail safe' level controls should also be installed. Level control devices may also be connected to alarm systems so that operators can be notified of high levels. Typically the following types of level control device can be used;

- Float switches;
- Conductivity probes;
- Ultrasonic sensors; and
- Pressure transducers.

Similar level control devices can be installed to bunded areas, particularly if they are covered tanks or ‘double skinned’, so that leakage into the bund can be detected and an operator informed even where visual inspection is difficult.

Where highly sophisticated multi-layer level controls[5] to primary containment tanks are employed it may be possible to justify using the ‘operational full’ volume of the tank (i.e. the upper level at which level control systems are set) to calculate required secondary containment bund volumes (see Section 8.3.)

7.2 ‘On Waste’ Tanks

Installation of new tanks is unlikely to be on waste and this would not represent best practice for cells with permanent capping installed.

There may however be a need for leachate tanks on sites to support leachate transfer around the site towards the ultimate storage location (holding tank) which may be installed or already exist on waste.

Where ’on-waste’ tanks are required best practice is to justify their need by a suitable risk assessment. Risk assessments will need to adequately address the following issues;

- Waste settlement will not lead to structural distress causing loss of containment;
- When installed on waste above the cap, ‘self-bunded’ or double skinned tanks are acceptable, as long as the issues in Section 9.0 below are addressed;
- When installed within the waste mass, in a lined cell, with no capping under the tank the following issues are considered;
    - Tanks are in continuity with underlying waste so that any spilt or escaped leachate can drain freely into the waste mass;
    - Tanks are adequately monitored or inspected to detect if leakage of leachate is occurring;
    - Tanks do not represent a point of emission for landfill gas;
    - Landform topography is such that surface run-off beyond the waste mass of any leachate release is not possible, only locations where run-off from leaks and spills remain contained by the underlying cell liner will be acceptable, surface run-off must not be allowed to occur towards unlined areas or areas that could contaminate controlled waters;
    - Leakage from tanks or the transfer of leachate into or out of the tanks must be controlled so as to prevent issues such as the potential for local ground saturation;
    - The use of storage tanks in this scenario must not result in leachate heads breaching compliance levels within the cell in which the tank is located; and
    - Tanks are covered to prevent rainfall overfilling them and to prevent odours.

  If the answer is ‘yes’ to these questions then a tank without secondary containment can be installed into the waste mass, if the answer is ‘no’ then it is likely that a tank with secondary containment will be required.

8.0 SECONDARY CONTAINMENT DESIGN

Under most circumstances leachate containment structures, where secondary containment is required, will need to conform to CIRIA C736 class 2 containment, with amendments to detailed design to accommodate specific risks appropriate to storage of landfill leachate.

Unless ‘natural containment’ could be justified (see Section 5.3) raw leachate storage vessels would always require secondary containment. However, as the risk posed by the inventory being stored reduces (for example where leachate is part or fully treated) the degree or need for secondary containment can be reduced.

At leachate treatment facilities mixed liquor (treatment tank) and treated leachate storage vessels may not require secondary containment as default if manufactured out of high quality poured in situ reinforced concrete unless, in a specific site setting that was sensitive to, for example, high suspended solids, chloride, hazardous substances pollution or a risk that structural failure could damage the base of tank or floor of the compound in which they are located.

In each instance if justifying something other than CIRIA C736 class 2 containment, key considerations in the design risk assessment will be primary containment construction details and contaminants of concern; in raw leachate principal contaminants of concern will be ammonia, BOD, COD and chloride or hazardous substances, in mixed liquors solids and chloride and in the treated effluent only chloride.

Stored part or fully treated leachate is also likely to require class 2 bunding if it cannot be ‘guaranteed’ that these storage tanks will always only contain treated leachate. To guarantee that only treated leachate is in storage it may be necessary to include continuous monitoring of the quality of leachate in the tanks with interlocks to prevent the transfer of non-compliant liquid. Where such systems are installed it may be possible to remove the need for secondary containment of the treated leachate tanks.

Whilst it is accepted that in most instances, for off-waste facilities (see Section 7.0) storing landfill leachate, class 2 containment bunding will be required it is also highlighted that;

- Where no ‘source-pathway-receptor model’ can be established secondary containment may be naturally supplied by the site setting (subject to maintaining good soil quality around the installation and complying with the Waste Duty of Care);
- Where engineering solutions can break the ‘source-pathway-receptor’ model (considering both groundwater and surface waters) secondary containment may not be needed, for example where placement of additional material (as bunds) or cutting drainage ditches could divert spilt material to an area from which it is not free to drain and can be subsequently removed and disposed of;
- It may be possible in some scenarios where a ‘source-pathway-receptor’ model does exist to demonstrate through established hydrogeological risk assessment methods that secondary containment does not provide sufficiently significant additional protection to the environment and so their installation may not be justifiable;
- That where effluent has been treated to a sufficiently high standard that its composition is suitable for release to the environment then it no longer poses a significant risk to the environment in relation to the relatively low likelihood of accidental release from storage and so these elements of a LTP may not be required to be installed with secondary containment.
- Penetrations to secondary containment should be avoided where possible; Where penetrations are unavoidable a water tight and tamper proof design should be used and consideration

should be given to issues such as location of penetrations and the ability of liquid to escape from them;

- Pipework should preferably be routed above ground; if below ground BAT requires where possible containment within suitable inspection channels and suitable periodic inspection. Where this cannot be achieved testing for water-tightness may be appropriate; and
- Containment areas should be designed with safe access to enable long-term inspection, monitoring and maintenance. This may result in the need for features such as 'manways'3, particularly in the instance of collar bunds where periodic internal access may be required for cleaning and maintenance. Alternatively, features such as 'flood gates' may be needed in bund walls to allow for suitable access to be gained. If such access is as the designer intended and the equipment is purchased from a reputable commercial supplier this should be acceptable if suitably designed and accompanied by agreed operational procedures to manage the risk of leakage through such features.

As for primary containment design, where there is a conflict between health and safety considerations and good practice in terms of environmental risk reduction (for example, in the instance of the need for manways or flood gates) health and safety considerations should be paramount. However, when justifying the need for such features the frequency and duration of the need to use these features needs to be borne in mind. The need for such features during construction (when it may be convenient but not impossible to build without them) is less likely to justify their inclusion in containment design than an on-going operational requirement (where, if required, their presence will be more acceptable).

8.1 Secondary Containment Classification by Risk Assessment

The type of bunding required at any site proposed for the storage of landfill leachate or treated effluents should be assessed using an appropriate risk assessment methodology.

The CIRIA C736 guidance describes a methodology for assessing the 'Class' of secondary containment required and then describes appropriate bund designs for each class of containment dependent upon the materials to be used. Note that this applies to engineered bunding only, where 'natural' containment is proposed a risk assessment should be presented that describes and justifies the appropriateness of the containment provided by the in-situ geology, topography, hydrogeology and hydrology (see Section 5.3). A summary of the CIRIA C736 guidance method is presented in Appendix B

A more simplified assessment process is summarised below that may be more appropriate for use in the case of landfill leachate storage facilities where characterisation of landfill leachate is understood, the site setting and conceptual model has been established (for example in the landfills HRA process) and so the risks posed and sensitivity of receptors is already well understood.

8.1.1 Step 1 – Source/Pathway/Receptor Model

Assess the Source/Pathway/Receptor for the proposed location as detailed in Section 5.3. If it is established that a Source/Pathway/Receptor system exists, go on to Steps 2 to 4.

If a Source/Pathway/Receptor system cannot be established it may be possible to justify the existence of 'Natural Containment' without the need for an engineered bund bearing in mind issues such as the need to consider the in-situ soil around the plant as a likely first receptor and consider engineering designs to minimises any impact on soil to immediately adjacent to any tanks, making subsequent clean-up simpler. See Appendix A for an indication of the content of an assessment that can be used to investigate the source/pathway/receptor model.

8.1.2 Step 2 – Likelihood of Loss of Containment

Assess the likelihood of loss of containment from primary containment systems. This will be driven by the materials used to construct storage tanks, interconnecting pipework and associated mechanical infrastructure. High quality concrete tanks with CQA at installation will result in the lowest likelihood of loss of containment. However, there will always be some risk of loss of containment due to human error during operational and maintenance procedures. Whilst such losses are often (but not always) of low volume and easily rectified they nonetheless need to be recognised and managed.

Use of high quality primary containment materials and designs may lead to a reduced need for containment of, particularly, partly or fully treated leachates.

8.1.3 Step 3 – Site Risk Rating

Assess the overall site risk, this being a combination of the sensitivity of the Source/Pathway/Receptor model and the risk of loss of containment. The overall site risk will then drive the justification for different secondary containment designs.

8.1.4 Step 4 – Bund Classification

Where the 'Site Risk Rating' indicates a 'Low' risk it may be that simple 'Class 1' bunding may be required or indeed no bunding may be needed where tanks store low hazard material such as part or fully treated effluent rather than for tanks storing raw or part treated leachate.

Where the 'Site Risk Rating' indicated a 'Medium' risk, this being the most likely outcome for most raw leachate storage locations, 'class 2' bunding will be required. Such bunding is likely to be a well-engineered bund capable of retaining liquids long enough for suitable clean up to take place.

Where the risk increases such that a 'Site Risk Rating' of 'High' is obtained a bund of 'class 2' type design or better is likely to be required with the addition of leak detection systems to enable monitoring of the performance of the containment systems to be provided.

8.2 CIRIA C736 Guidance on Secondary Containment Designs for New Plant

Class 1 is the lowest class of bunding for the lowest risk sites where volumes of material stored and/or the composition of materials has a low potential to harm the environment.

Class 2 is the middle class of bunding, most landfill leachate storage facilities are likely to fall within this classification. Volumes of leachate stored and it's potential to pollute the environment are likely to be sufficiently high to require some additional considerations when designing secondary containment infrastructure.

Class 3 is the highest class of bunding. In the context of storage of landfill leachate this is only likely to be required in exceptional circumstances where, for example, a highly sensitive receptor is near-by that escaped leachate could rapidly reach.

Table 2, below, presents a summary of the guidance on construction materials and basic design considerations of the three bund classifications from CIRIA C736.

Table 2 New Plant Bund Class Design Summary Look-up Table

Containment Class	Acceptable Materials *	Additional Membrane Protection	Bund Base Independence From Tank Base	Under-bund Leak Detection
1	• Reinforced cast concrete	No	No	No**
	• Reinforced pre-cast concrete • Blockwork • Masonry • Glass or Epoxy coated steel • Plastics • Flexible membrane liners • Tarmac • Grout impregnated tarmac • Bentonite matting • Low permeability soils / clay	No	Yes	No
2	• Reinforced cast concrete	No	No	No**
	• Reinforced pre-cast concrete • Blockwork • Masonry • Glass or Epoxy coated steel • Plastics • Flexible membrane liners • Tarmac • Grout impregnated tarmac • Bentonite matting	No	Yes	No
	• Low permeability soils / clay	Yes	Yes	No
3	• Reinforced cast concrete	No	No	Yes**
	• Reinforced pre-cast concrete • Blockwork • Masonry • Glass or Epoxy coated steel • Plastics • Flexible membrane liners • Tarmac • Grout impregnated tarmac • Bentonite matting	No	Yes	Yes
	• Low permeability soils / clay	Yes	Yes	Yes

Notes: * Or similar if justified by suitable risk assessment

** Under tank base leak detection would be required in this case

8.3 Secondary Containment Design Considerations

Once the Class of bunding required has been established, detailed bund design needs to be completed. Issues that should to be considered are summarised as follows;

<u>Structural design:</u> Containment designed to withstand anticipated static and dynamic loads;

Containment volume: Secondary containment should be provided to at least 110% of the brim-full capacity of the main storage tank or 25% of the total brim-full tankage, whichever is the greater unless an overflow or suitably robust level control systems have been installed. The EA's preferred tank level from which to calculate secondary containment volumes would be an overflow pipe level but this can obviously only be done if an overflow has been installed (and the overflow drains to a contained area or back to the raw leachate tank). If a suitably robust level control system has been installed the use of 'operational full' level from which to calculate required containment volumes can be justified.

Suitably robust level control systems will need to employ a 'primary, 'secondary' and third 'fail safe' level detection system with each being fully independent of the other. Level detection systems will need to measure level by at least two different physical properties (for example a float switch and a pressure transducer or a pressure transducer and an ultrasonic sensor). Automated controls will need to 'fail safe' (i.e. close or stop pumping etc.) on loss of power and loss of signal. Procedures for testing level control systems should also be included as part of any justification for the use of 'operational full' levels as the means of calculation secondary containment requirements. Testing should take place on a minimum of an annual basis.

The use of '110% or 25% rule' for calculating bund volumes should be the basis of containment volume calculations unless designers want to use more detailed methods to demonstrate that they have accommodated issues such as rainfall, surge, wave action etc. with a secondary containment volume that is less than that calculated by the '110% or 25% rule'. It is understood by industry that this approach has been welcomed/encouraged by the Environment Agency, in part due to the auditability of the design approach.

Containment volume management: Secondary containment volumes should be maintained by automated pump out of accumulated water into the main storage tank. The bund liquid level should be monitored and alarmed by level detection devices.

Retention: Containment designed to accommodate incident rainfall for the duration of time that any 'clean-up' may take as well as the maximum volume of spilt material. In practice a volume of 110% of the largest tank capacity is used, however alternative methods of calculating the retention volume do exist and can be justified.

Proximity of storage: 'Jetting'[4] of liquid over containment walls is possible, selection of primary storage materials can reduce this risk as can locating pipework connections etc. into low risk areas. Where high quality poured in-situ concrete is used for primary containment vessels, bund or secondary containment walls can be located within the 'jetting' distance.

Durability: The purpose of a bund (secondary containment) is to limit the effect of a leak for the duration of time required to clean it up, not to contain a leak indefinitely Containment should be designed to contain the materials that are stored within the primary vessels without corroding or otherwise being weakened after coming into contact with the material for the duration of time that they would be required to store spilt material. Any spillage that would generate the need for secondary containment would be addressed by any operator in a timely manner (and the commitment and ability to do so written into site procedures for agreement with the regulator).

If an operator can include in a risk assessment that suitable accident and emergency response procedures exist at a site, it may be that containment engineering design to retain spilt liquid for a shorter period of time than the many tens of years implicit in the CIRIA designs may be appropriate.

Permeability: Secondary containment walls and floors should be sufficiently impermeable to contain spilt liquids for the length of time necessary to remove and remediate any spills.

CIRIA C736 class 2 containment bunds employing ‘earth’ bunding states that clay should be placed equivalent to a 1m depth of clay at $1x10^{-9}$m/s permeability. It may be possible to provide suitable ‘equivalent’ containment with a thinner layer of material of a lower permeability. Alternatively, for class 2 bunding where a geomembrane is required, the hydraulic performance of the geomembrane can be included in the permeability assessment.

Structural independence: For new plant, containment bases and walls should be structurally independent of the primary storage vessels. The only exception to this is where cast reinforced concrete bases, installed to high CQA standards, are used. Here the concrete tank base does not need structurally independent secondary containment as long as basal leak detection is included. For existing plant, whilst this is ideal, practical considerations may result in a need to apply different standards on a case by case basis, such as monitoring of groundwaters via boreholes (see Section 10.0).

Pipework containment: Ideally pipework associated with primary storage vessels should be routed above ground within the secondary containment. If pipework is below ground it should be secondary contained and capable of being inspected. In low risk settings where above ground installation or secondary containment is not possible testing for leaks on a regular basis maybe appropriate.

Penetrations: These should be avoided in secondary containment. If necessary they should be as few as possible and be of suitably robust design to prevent leakage. Where vehicles or pedestrian access is required proprietary systems exist that can be employed (for example ‘flood gates’) and can be acceptable if provided by a reputable commercial supplier, suitably designed and accompanied by agreed operational procedures to manage the risk of leakage through such features (for example, flood gate installed at the high point of bund floor slope and subject to annual inspection to prove water-tightness). Bund penetrations of this nature may also be required to enable safe and unimpeded access to items such as safety showers.

Surge: This only needs to be considered if catastrophic tank failure is a credible scenario. For some leachate storage facilities this need not be considered.

Firefighting: Considered only if flammable liquids are stored. For most leachate storage facilities this need not be considered.

Leak detection: Initial testing at construction is likely to be required as part of good CQA procedures; installed continuous leak detection is only needed for class 3 bunds, which are unlikely to be common for leachate storage facilities or if structurally independent secondary containment is not proposed to be installed beneath a tank floor. This latter case can only be acceptable where the tank floor is of high quality poured in-situ concrete installed subject to an approved CQA plan.

<u>Bund shape:</u> Bund floors should fall to low points from where collected liquids can be detected and pumped; any required containment penetrations or entrances should be at the 'up-slope' end of bunds

8.4 Secondary Containment General Considerations

Some general principles to consider when designing secondary containment bunds are as follows;

- Combinations of materials; Secondary containment is often provided by concrete or blockwork bunds[6], earthwork bunds or a combination of concrete secondary containment bases with containment tank walls of a different material (for example, an epoxy coated steel tank wall on a concrete base enclosing a primary tank is acceptable). It is important that the bund floor is appropriately surfaced as well as the bund walls;
- Preparedness of containment: Secondary containment does need to be maintained 'in preparation' for unexpected use at any time. Therefore suitable inspection regimes are needed to ensure that secondary containment is in good condition and that any repairs are made to any defects. This is particularly important where concrete or blockwork bunding is employed as joints and seals can, over time, part or degrade and become ineffective;
- Maintenance of bund volumes: To ensure that the designed bund volume is always available for storage of escaped liquids, bunds should either be covered to prevent rainfall or other 'run-on' of water filling the bund and/or otherwise provided with drainage features (for example sloped floors falling to pump sumps) where water can be removed and bund volumes maintained. Similarly this is likely to be a practical issue for 'natural containment' where management of surface water within the natural containment bund/floor will still be required but can be designed for (provision of suitable sumps and pumps for example to prevent systems for dealing with this surface water becoming a pathway);
- Bund wall crests: The crest of bund walls should be designed to have a constant elevation. If this is not possible the available bund volume should only account for that which is below the lowest point (in mAOD) on the bund wall;
- Bund wall access: If secondary containment bund walls are to be installed with 'flood gate' or 'bund gate' type access features (see Section 4.1) this feature should be installed at the up-gradient (lower risk) end of the sloping bund floor;
- Equipment inside of the bund: Consideration should be given to the equipment that is contained within the bunded area and the consequences to that equipment should the bund ever fill with liquid. For example it may be appropriate to install critical equipment that would be damaged by submersion above the height of bund walls or external to the bund; and
- Construction Quality Assurance procedures, supervision during construction and validation post construction will be required under an Environmental Permit and must be undertaken.

8.5 Tanker Bay Design

The location of the storage facilities within the site should be made on a risk based approach whilst taking the following in consideration;

- Tanker access;
- Traffic management;
- Site development;

[6] CIRIA C736 suggests that blockwork bunds should not be used for Class 2 and 3 type bunds. However, the reason is their poor fire resistance and therefore if no fire hazard is anticipated, as is the case at most LTP's, arguably they may be appropriate subject to agreement with the regulator. This point has been raised with CIRIA and a response awaited at time of writing.

- Supervision / inspection; and
- Spillage risk.

A delivery bay should be constructed to house tankers and associated tanker loading equipment and loading bay / turning areas. 110% containment of the largest conceivable tank or vehicle capacity proposed to use the loading bay is not required, a smaller volume can be accommodated by kerbing to a pumped sump or similar solution, providing there is infrastructure in place capable of managing the whole content of the tanker. Risk assessed designs should consider;

- Impervious surfacing: Areas associated with storage tanks and tanker loading should be considered for impervious surfacing to prevent any drips and spills contaminating the ground and controlled waters. Typically this will include (but not necessarily be limited to) a suitable drip tray / spills sump below the loading point and rear end of the tanker when at the loading point. The EA will normally refer to highway standards for surfacing in loading areas, typically concrete or tarmac, draining to a blind sump or contained drainage. Note: spillages and drips are usually short-term incidents or low frequency events compared to the hours of non-tankering at any facility, however the consequences of relatively small volumes of leachate escaping can be significant, so the overall risk is often still high;
- Storage volume: Loading bays should be designed to contain a known volume of spilt or leaked liquid. The volume required should be based on risk assessments and control mechanisms such the ability to pump out spills to appropriate containment;
- Drainage systems: Tanker bays should be kept free from standing water so that storage volumes are maintained. Consideration should be given to where water is pumped and how to define if it is clean or contaminated. Systems that detect clean versus contaminated liquids that are capable of directing them to different outlets are acceptable. Pumping or drainage back into the primary or secondary containment of the associated tank/treatment plant is a simpler solution as this solution results in the most rapid return of any liquid into a larger containment system designed for the purpose of storage of the liquid;
- Protection from impact damage: The tanker loading bay and tank compound should incorporate tank protection such as bollards or bump banks etc. so that the tank and its bund are fully protected from physical damage; and
- Security: The compound / delivery bay should be located within site security fencing or, within its own fenced area to prevent unauthorised access.

9.0 INDEPENDENT STORAGE TANKS

Independent storage tanks are tanks that are typically supplied 'off the shelf' complete with an integral bunding / containment system. They are typically deployed on landfills to store leachate in relatively low volume (<100m^3 per tank) for bulking up prior to off-site tankering or passing onto other treatment and storage facilities and are often not within the curtilage of an LTP.

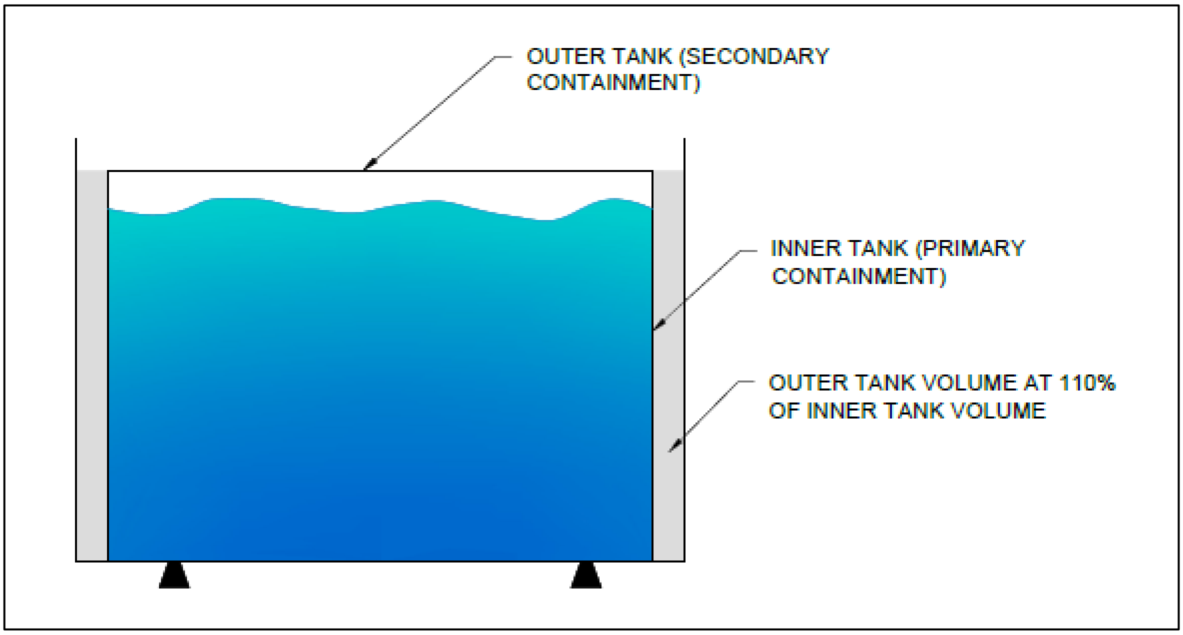
Tanks of this nature are sometimes described as being 'double skinned' and are not considered to provide secondary containment by the BREF or CIRIA C736 documents. However, there is no clear definition of a 'double skinned' tank beyond the following; tanks where the primary and secondary containment wall are 'close' to one another and are made of material that could be easily penetrated by impact damage, also tanks with a 'common base'.

Use of independent, 'self-bunded' storage tanks, is allowable as long as they are properly designed, providing 110% capacity of the primary tank (or 25% of the total tanked storage contained with the bund or skin) and can be shown to be suitably protected from credible impact damage scenarios and they do not have a 'common' base used by both the tank and the bund.

Presented below are 3 examples of typical independent storage tanks (examples of cylindrical and rectangular tanks are provided).

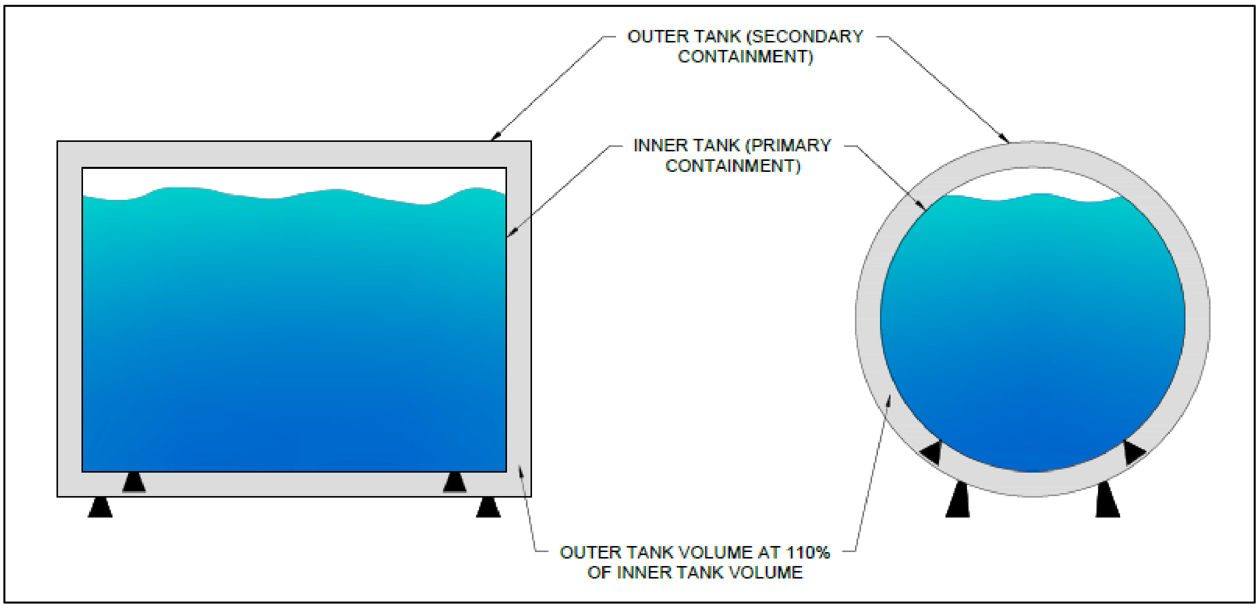
Tanks that share a common base, unless the common base is of high quality, poured in situ concrete (see Section 6.0), are considered to be 'double skinned' are not considered to provide adequate secondary containment (see Figure 2).

Figure 2
'Double Skinned' Tank



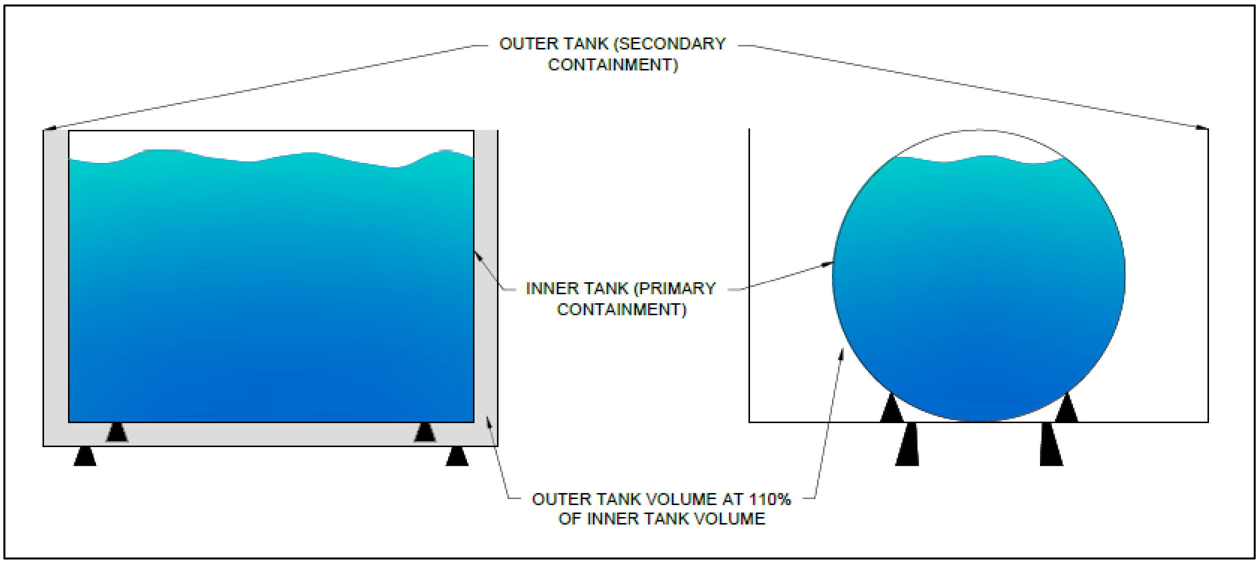
Other similar tank options are presented as Figure 3 for enclosed and Figure 4 for open independent storage tanks.

Figure 3
Enclosed Independent Storage Tank



These are both acceptable as long as they are supplied from reputable suppliers and conform to the design elements laid out in Section 6.0, 7.0 and 8.0). The need to protect such tanks from credible impact scenarios is highlighted as they are more susceptible to complete failure from such damage than other engineered tank and bund designs.

Figure 4
Open Independent Storage Tank



It is reiterated that the purpose of secondary containment is to manage an outward failure risk from the inner tank failing, not an inward tank risk from external objects puncturing both secondary containment and inner tank. Protection from impact damage can be achieve via means that do not include the outer secondary containment. Reasonable protection from such potential damage can be achieved by Armco barriers or similar, but this is only required where this is a credible risk (for example, barriers not required where it is not possible to gain vehicle access). Further details of issues surrounding the design and use of independent storage tanks are presented in Appendix C.

9.1 Chemical Storage Tanks

Within the landfill industry the acceptability of ‘off the shelf’ chemical storage tanks has been challenged at some sites since the issue of CIRIA C736. The basis of the concern is that some tanks can be considered as being ‘double skinned’ but with no clear definition of what this means (see Section 9.0 above) or on the basis that ‘collar bunds’ do not extend to the top of the primary tank and so the collar bund has had to be retrospectively extended to the full height of the primary tank.

Discussions with chemical tank suppliers indicated that these issues are only being raised by the landfill leachate industry, not from other industries within the UK to whom they supply identical tanks

Best practice is to purchase “off the shelf” specialist storage tanks from a recognised supplier that includes integral secondary containment. Where this is the case it can usually be assumed that no further secondary containment arrangements would be needed as long as the installation details conformed with the general requirements for all tanks and bunds (designed from suitable materials, adequate protection from impact etc.) as detailed in Sections 6.0, 7.0, 8.0, 8.3 and 9.0.

Whilst “off the shelf” chemical storage tanks purchased from a recognised specialist supplier are considered BAT for the purpose for which they have been designed (i.e. they are storing the chemical at the specified grade for which the tank has been designed) if a bespoke solution is proposed for an individual project then a more detailed justification for the design would be required and a design risk assessment would need to be submitted.

10.0 EXISTING INSTALLATIONS

For 'new' landfill related installations it is appropriate to consider CIRIA C736 guidance for secondary containment systems subject to the approach and departures set out within this Industry Code of Practice document and compliance with BAT. However, for existing plant the retrospective installation of CIRIA C736 standard containment is not mandatory (noting that compliance with BAT is required). Indeed, in many cases, retrospective installation of containment as described in CIRIA C736 will not be possible.

Blanket retrospective application of both this Landfill Industry Code of Practice and CIRIA C736 guidance on provision of suitable containment is not appropriate as long as operators can demonstrate that they have assessed their existing portfolio of leachate storage facilities, are aware of the risks that they pose and, where necessary, have addressed those risks to show that they comply with BAT. Retro-fitting CIRIA compliant secondary containment to an existing well managed plant that has no history of loss of containment and is in a low risk setting is not considered a good use of resources. Exact replication of CIRIA C736 standards would not always be possible but that 'improvements towards CIRIA standards' is what should be aimed at.

'Good practice' is for operators to maintain a risk register or series of assessments of existing installations and to review these as part of routine monitoring, inspection and maintenance programmes. Risk registers or assessments should be formally documented and operators should retain their own risk assessment and statement of alignment or deviation (risk register) from this ICoP and CIRIA C736. Upgrade plans should then be developed and incorporated into capital life models of the asset.

It is the operators risk to continue operating leachate storage facilities that are not contained to current standards, which if giving rise to an environmental incident, would result in a higher degree of regulatory action or intervention where (a) no risk assessment had been completed or (b) the risk assessment identified works or actions that had not been completed.

10.1 Risk Registers or Site Level Assessments

A 'Risk Register' or site level assessment should set out the operator's portfolio of leachate storage infrastructure, including (but not necessarily limited to) the following;

- What installations they have;
  - Locations
  - Number of tanks
  - Volume of tanks
  - Age of tanks
  - Expected design life of infrastructure
- What materials are stored;
  - Compositional analysis
  - COSHH sheets
- Details of potential pathways for leachate escape;
  - Assessed as per Section 5.0
- Details of receptors;
  - Assessed as per Section 5.0
- Complete a basic Source/Pathway/Receptor Risk assessment, for example as per Section 5.0, to establish what is at risk from the existing installation; Detail existing controls;
  - Details of any secondary containment in place

  - o Details of any level control and/or alarm devices
  - o Details of inspection regimes
- Gap analysis for each installation compared to the recommendations in this Code of Practice, the CIRIA Guide2 and the BREF1 (for installations) to address risk mitigation by control measures (see Sections 6.0, 7.0, 8.0, 8.3 and 9.0); and
- Where installations are assessed to be acceptable (there is a low risk posed by potential escape of leachate from the installation) and this is agreed with the regulator, no further action would be required, other than routine maintenance and inspection (see Section 12.0).

Registers will usually be pro-forma driven and where high risk installations are identified a programme of work should be established as per Section 10.2 and 12.0.

10.2 Assessment and Future Management of Existing Installations

If Operators identify installations that are failing, good practice is to take action to survey sites in detail so that remedial action plans can be established. Actions should include the following:
1. Introduce inspection and maintenance plans;
2. Undertake a ‘base-line’ survey of the installation;
3. Note any defects in primary or secondary containment and locate them on site plans.
4. Where secondary containment does not exist or only partially exists produce site plans indicating location and volume of primary storage, location and volume of effective existing containment and potentially available locations for additional containment;
5. Assess and describe other relevant infrastructure;
6. Complete a risk assessment for the plant (for example as detailed in Section 5.0) to establish ‘ideal’ nature of containment to be provided;
7. Assess and rank required works to improve standards of containment; and
8. Produce a programme of works to undertake improvements

Further details of the possible actions that may be considered are presented in Appendix D.

11.0 LAGOONS

Lagoon based leachate storage facilities are commonly used and can be an effective means of providing large volume leachate storage. Lagoons are acceptable as a means of leachate storage but they are not covered by the CIRIA C736 guidance. It is not intended to cover their design in detail within this Industry Code of Practice but the following commentary is supplied in understanding and assessing the risks associated with the storage of raw leachate in such structures:

Whilst lagoon design is not directly comparable to landfill cell design it is nonetheless more akin to landfill cell design than to tank construction and so should instead be covered by landfill infrastructure guidance. The landfill engineering guidance notes provide useful material on which to base the design of a lagoon including assessment of engineering designs, suitable testing protocols for geomembranes and their protective materials, use of geosynthetic clay liners, earthworks on landfill sites, use of geomembranes and associated nonwoven protector geotextiles, geophysical testing of geomembranes used in landfills, compliance testing earthworks and use of bentonite enriched soils.

For new lagoons, the risks posed by loss of containment from lagoon based storage systems should, as for tanks, be assessed and mitigated at lagoon design stage. Lagoons have a lower probability of catastrophic failure (dependent upon the design) than tank based storage, for lagoons this would be restricted to stability issues and leaks through holes and tears in a geomembrane. The risks posed by the potential for puncture or perforation of the lining system would need to be considered in any risk assessment.

Another significant mechanism by which loss of containment from a lagoon may occur is from overtopping due to overfilling from pumping systems. Proven risk control measures to date have focussed on prevention of overtopping and provision of sufficient freeboard in lagoon bank designs.

For both new and existing lagoons, operational procedures should also be considered to prevent damage to geomembranes and regular inspection; maintenance and repair of lining systems and stability bunding should also be prepared to periodically assess the condition of the lagoon.

12.0 APPROPRIATE MAINTENANCE AND INSPECTIONS

In addition to good design and installation, appropriate on-going management and maintenance of leachate storage infrastructure is critical in ensuring that contaminating liquids are prevented from harming the environment.

Bunds need to be managed to ensure that the designed storage volume is maintained and that any spills or leaks of liquids from primary containment are detected and acted upon.

On-going inspection and maintenance of the bunded area is also required to ensure that designed water retaining features continue to operate as expected.

12.1 Management of Water in Secondary Containment

Any water that collects in secondary containment bunds should be removed so as to maintain the designed storage volume of the secondary containment. However, it is noted that unless an incident / leakage or spillage has occurred at an installation (which should be classified as a low frequency event), the dominant water contribution being impounded within the secondary containment will be rainwater.

It is possible to cover containment bunds to prevent rainwater collecting, but this is only practical for very small contained areas.

Water removed from bunded areas should be treated as if it is contaminated and discharged to leachate storage and/or treatment systems to be handled as if it was leachate. Storage and treatment systems should be designed to accommodate volumes of water predicted to be dealt with in this way by either having suitable disposal rates or suitable spare capacity (or ‘ullage’) left in tanks to accommodate the anticipated rainfall volumes.

Alternatively, drainage systems from bunded areas can be fitted with sensors to detect if collected water is ‘clean’ or contaminated. Typically use of electrical conductivity, ammonia and pH meters, either alone or in combination, can be used to determine if collected water is contaminated or not. If waters are found to be clean they can be discharged to existing on-site surface water discharge systems. If found to be contaminated they should, as described above, be treated as leachate. A specific monitoring and maintenance plan would be required for this task.

Level sensors may also be employed to activate pumps or valves to manage water collected in bunds. In any case it is good practice to install level sensor systems that not only manage pumps and valves but also detect if bunds are becoming overfilled with water or if unexpectedly rapidly increases in water volume is experienced. These systems should have the capability of alarming operators to these potentially abnormal situations so that physical inspections can be made.

12.2 Management of Spills into Secondary Containment

Detection of spills will usually be as a result of visual inspections of bunded areas by operators and are most likely to be associated with manual activity within the bunded area at the time. Spills should be cleaned up as quickly as possible using spills procedures included in the environmental management system and agreed in advance with Regulators.

Bunds will be installed with sumps or falls on their bases so that spilt material can be collected as a liquid and pumped back to storage for later disposal. Where this is not possible spills kits may be used to absorb spilt liquids so that they can be collected and disposed of as a solid material. Disposal of such materials should be to a suitably licensed facility, this is likely to be a non-hazardous landfill site as few options exist for the recovery of such materials.

Good practice is to use installed instrumentation and computerised control systems (where they are installed) to detect unexpected changes in the physical status of tank or pipeline contents as a means of detecting leaks or spills from primary containment. Rapid and unexpected changes in tank levels, loss of pressure in pipelines, lack of flow when expected can all be used to alert operators to potential losses of containment.

Where possible such features should be employed to provide added levels of protection against loss of containment at leachate storage facilities.

12.3 Secondary Containment Inspections

Bunded areas should be regularly inspected and records kept of the inspections and any remedial actions taken. At operational sites inspections may be daily but at closed sites with little activity inspection intervals could be monthly.

Typically visual inspections will be sufficient to highlight any areas where further specialist investigations may be required before determining if remediation work needs to be carried out.

Inspections / formal maintenance schedules should include the following:

- Visual signs of leaks (from primary and secondary containment;
- Spalling of concrete or brickwork;
- Signs of corrosion;
- Failure of seals or joints;
- Aging of sealants (parting of sealants from joints etc.);
- Misalignment of tank or bund walls;
- Slumping (or soil bunds);
- Damage from flora / fauna;
- Torn or damaged liners; and
- Deterioration of coatings / de-bonding of surfaces

The results of the above inspection and maintenance schedule should be recorded within the operator’s management systems. Best practice would be to supplement operator inspections with assessment by a qualified engineer. Such additional inspections may be as infrequent as every 5 to 10 years depending on construction materials and supplier recommendations.

Installed devices to detect liquid levels and / or liquid quality should be regularly tested and calibrated. Testing of level detectors such as float switches can be achieved by manually triggering the switch and recording that the anticipated action is triggered (i.e. sump pump starts, alarm raised etc.). Similarly, water quality sensors (such as electrical conductivity probes or ammonia sensors) can be triggered by immersing them in a container of leachate or treated effluent as required. Again, it should be recorded that the anticipated action is triggered. It is important to check that level control devices are not installed in series and that high alarms are fully independent from primary level control system to ensure that a single failed component of the system does not affect all devices. Best practice is to ensure that instrumentation such a liquid level and quality detectors should be replaced at a frequency recommended by the manufacturer.

In addition, it may be necessary to periodically test buried pipework to determine if it continues to be watertight. If secondary containment of buried pipework has been installed this will simply be a visual inspection at the out-flow point of the secondary containment. If secondary containment of buried pipework has not been installed it is likely to take the form of a pressure test of section of pipework that cannot be visually inspected.

It is noted that inspections are only possible for areas of primary and secondary bunding that are not underneath other infrastructure. For example, where access ramps enter bunded areas or tanks are located above bund bases it is not always possible to inspect the containment under these structures.

Inspections should also take place on an ad-hoc basis after any loss of containment incident. This is particularly true where secondary containment materials have been used that could, over time, degrade under prolonged contact with leachate (for example, tarmac). Suitable repairs should be arranged if visual inspection suggests that damage may have occurred.

Any repairs should be subjected to similar CQA planning and reporting as per the original installation method.

12.4 Maintenance of Secondary Containment

The CIRIA guide C736 includes, in Section 12, details on the maintenance of concrete and earth bunds. This guidance is briefly summarised here;

12.4.1 Concrete Bunds

Defects are generally categorised as cracks, surface deterioration or deterioration of joints. Cracks can not only be a source of loss of containment but can also let liquids come into contact with reinforcement bars that then leads to further structural weakening of concrete structures.

Before undertaking repairs the cause of the damage should be defined. Guidance on the causes of deterioration of concrete and appropriate repair techniques is detailed in BS EN 1504-9:2008.

Cracks or surface defects can be repaired using surface mortar applications. Where cracks appear to be the full thickness of concrete walls or are seen to be leaking a variety of liquid sealants can be injected into the concrete under pressure that form a water tight seal on contact with water.

Where cracks in concrete are ‘active’ (i.e. moving) sealants used must be ductile as well as leak-resistant.

In all cases it is important to understand the cause of the defect as, if the cause is on-going, any repair will only be temporary until the underlying active cause is addressed.

Where defects appear to be the result of structural inadequacy, injectable products exist that can improve the strength of the concrete wall and / or supports or props to walls can be considered.

Consideration should also be given (at least in the short term) to reducing the loading being applied (i.e. reduce the water level in tanks).

Holes and penetrations can be filled with a variety of proprietary materials but in all cases the hole should first be cleaned, any lining materials removed and any loose concrete chased out.

Surface protections can also be retrospectively applied to concrete surfaces. Different products exist for different purposes ranging from simple improvements to permeability to resistance to particular chemical attack. In all cases detailing of how joints and existing cracks in concrete surface are to be accommodated is critical.

Finally, concrete slab joints are often joined using a variety of sealants. Over time these can degrade and part from the edges of slabs. Such joints should be subject to regular inspection and, where necessary, sealant removed, the joint cleaned and new sealant installed.

12.4.2 Earth Bunds

Earthwork defects include slumping, slope failure, settlement, subsidence, heave, desiccation, erosion and damage from animals and plants. These are mostly due to flaws in initial geotechnical designs.

Slumped earthworks should have any protection materials (membranes, textiles, aggregates etc) carefully removed and the slumped sections exposed. Banks should then be reconstructed having due regard to updated geotechnical designs that are needed to rectify any previous deficiencies in design.

Subsidence and heave issues are more fundamental and would require specialist engineering advice to rectify.

Desiccation can be controlled by covering of soils with liners or suitable soil thicknesses to prevent moisture loss.

Erosion can be controlled by suitable planting with vegetation, or if necessary surfacing with resistant materials. If caused by vehicles or pedestrians alternative access arrangement should be arranged.

Fencing can help control damage from animals.

12.5 Notifications and Record Keeping

All inspections should be recorded on proforma type inspection forms and stored as hard-copy or as part of electronic records storage systems.

Wherever possible records should positively note that inspections have been carried out and whether issues were found or not. Where remediation action is required this should be clearly stated along with details of when and how actions were completed and issues closed out.

Typically, where significant loss of containment has been observed that required abnormal action to remediate it, the Regulator (EA, SEPA, NRW, NIEA etc.) should be notified within a reasonable time frame, usually 1 working day.

Appendix A – Natural Containment Assessment Typical Contents Page

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TABLES

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Appendix B – Summary of CIRIA C736 Secondary Containment Assessment Methodology

This methodology is presented for reference should an operator decide to make more detailed justifications using the CIRIA C736 guidance.

A methodology for defining appropriate containment standards for new leachate treatment plant is proposed that is based on the CIRIA C736 guide but that also acknowledges more explicitly the following points:

- Where no source-pathway-receptor model can be established secondary containment may be naturally supplied by site setting;
- Where engineering solutions can break the source-pathway-receptor model secondary containment may not be needed;
- It may be possible in some scenarios where a source-pathway-receptor model does exist to demonstrate through established hydrogeological risk assessment methods that secondary containment does not provide sufficiently significant additional protection to the environment to be worth the additional expense of providing it; and
- That where effluent has been treated to a sufficiently high standard that its composition is suitable for release to the environment then it no longer poses a significant risk to the environment in relation to the relatively low risk of accidental release from storage and so these elements of a LTP may not be required to be installed with secondary containment.

Thereafter a brief outline of the design issues that may need to be considered in providing secondary containment (where required) at a LTP will be summarised along with provision of references to the relevant sections of the CIRIA C736 guide where more detail can be found.

Methodology for Assessing Secondary Containment Requirement

For new or major new development or refurbishment of existing facilities that store landfill leachate, the following preliminary Risk Assessment Framework can be used to establish if secondary containment is likely to be required to be incorporated into the facility design.

Initial Secondary Containment need assessments should ideally be completed prior to engagement with the regulator or obtaining detailed designs so that the need for suitable containment measures can be included or excluded at an early stage.

The conclusion of the Secondary Containment Assessment should be communicated to and discussed with the relevant regulator at the earliest opportunity (EA in England, SEPA in Scotland, NRW in Wales and NIEA in Northern Ireland).

Ideally, after completion of initial facility design, a HAZOP assessment should be carried out to ensure that all environment, health and safety, process and operational risks have been designed out or reduced to acceptable levels.

As a result of the HAZOP study, the detailed designs should be finalised and submitted to the Regulator for comment and approval. These designs should highlight information and plant design details that are relied upon to justify the level of secondary containment proposed. This may include the provision of basic risk assessments on topography, hydrology, geology and hydrogeology (site settings), more detailed site specific (to the location of the facility) HRA's, designer risk assessments and details such as any proposed installation of continuous monitoring and alarm systems.

Assess the Source – Pathway – Receptor model

Where it has been shown that a 'Pathway' and 'Receptor' exists, an assessment of each element of the model should be undertaken.

<u>Source</u>

This is a combination of the volume of material stored and the 'polluting potential' of that material. Volumes stored will be related to the tank volumes (including process chemicals) and their contents. The source that is being considered as part of this risk assessment relates to the uncontrolled discharge of potentially untreated and treated leachate effluent from the proposed LTP. The source term relates to a breach of the primary containment. The CIRIA C736 guide includes a source Classification in relation to the likely risk posed by the toxicity of the inventory' (in this case leachate). This is based around the LD50 (concentration that kills 50% of exposed relevant organisms) for each chemical determinant in question.

Whilst many contaminants exist within raw leachate, they are present in concentrations orders of magnitude below those of the main bulk contaminants, ammonia, COD and chloride. In addition, within the treatment process of a typical LTP biological nitrification of ammonia takes place, generating a significant BOD within the mixed liquors, this elevated BOD also presents a significant risk to the environment. Of these three main bulk contaminants the most toxic to aquatic organisms is ammonia, this being both the only one of the three main bulk contaminants classified as a 'Priority' substance and also having the lowest EQS limit for surface waters at 0.3mg/L with BOD at 0.4mg/L and chloride at 250mg/L[7] . COD does not have an EQS limit but a comparable limit of 30mg/L is often applied[8]. As such it is appropriate to use ammonia to assess the hazard of the 'Source'. However, other chemical constituents of leachate could also be considered.

Fish are the most sensitive taxon to acute exposure to ammonia with the lowest valid acute LC50 value being 0.068 mg NH_3-N l^{-1} for *Oncorhynchus gorbuscha* (pink salmon) alevins exposed to ammonia for a 96-hour period[9].

Unfortunately LD50's are not readily available for all substances. Therefore a conversion factor has been applied to produce a version of the CIRIA C736 guide Figure 2.6 – Relationship between material quantities, toxicity and hazard (Section 2.3.1, page 17) based upon EQS levels for chemical constituents of leachate that are more commonly available to landfill operators. This conversion is based around the assumption that the LD50 and the EQS are related to one another and that for ammonia the AA-EQS (mg/l) - ($CaCO_3$ >250mg/l) is 0.3mg/L whilst the LD50 is 0.068mg/L. Therefore a conversion factor of 4.4 is applied to the EQS for each substance to approximate its LD50 equivalence. The table below provides example EQS levels and approximate LD50 conversions that may be used to assess the source term.

EQS and Approximate LD50 Conversions for Common Substances in Leachate

Substance	AA-EQS (mg/l) - ($CaCO_3$ >250mg/l)	TOXICITY - LD50 Approximation
Ammonia	0.3	0.068
Cadmium	0.00025	5.667E-05
Chromium	0.0034	0.0008
Copper	0.028	0.0063
Lead	0.0072	0.0016
Mercury	0.00005	1.133E-05

[7] 'H1 Annex D - Discharges to Surface Waters', Environment Agency January 2015

[8] EU Standard - Protection of Surface Waters Intended for the Abstraction of Drinking Water - EA Chemical Database

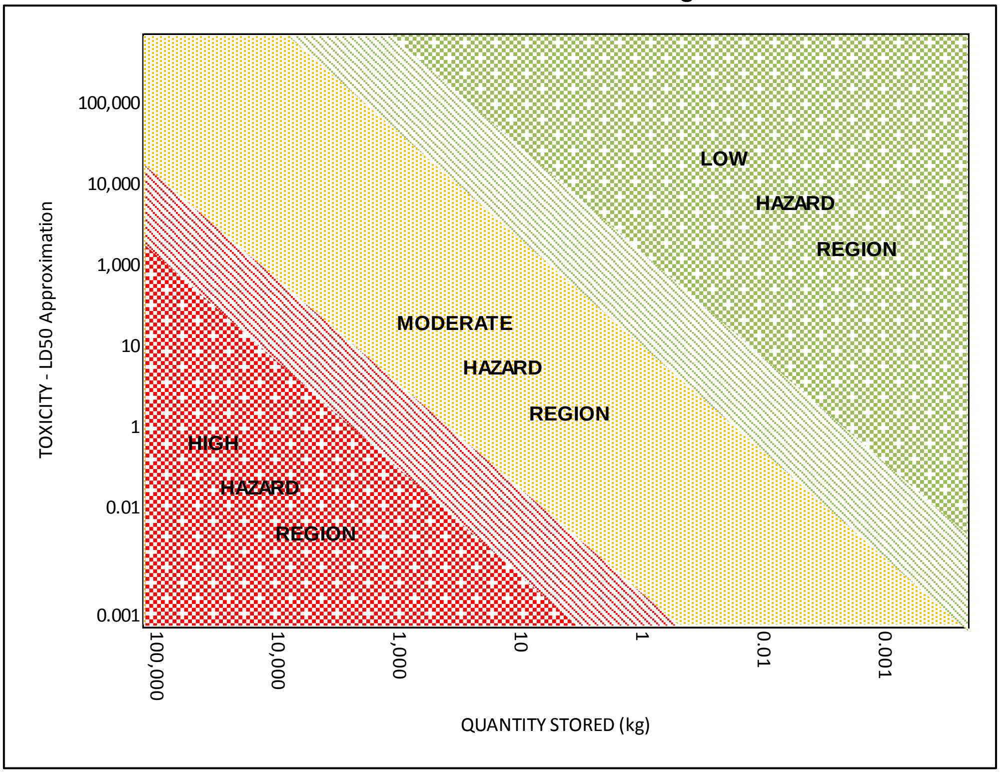
[9] 'Proposed EQS for Water Framework Directive Annex VIII substance: ammonia (unionised). Science Report SC040038/SR2'. Environment Agency 2007.

Nickel	0.02	0.0045
Sulphate	400	91
Zinc	0.125	0.028
Chloride	250	57
Iron	1	0.2
BOD	0.4	0.1
COD	30	7

Whilst it is recognised that wide range of contaminants may be present in landfill leachate and that each presents a different level of risk to different receiving environments, in attempting to provide a relatively easy to follow approach ammonia and chloride have been considered assess the polluting potential of landfill leachate in terms of the need to provide differing secondary containment designs.

After calculating the total amount of material stored within the LTP at full capacity this value, in kilogrammes, along with the approximation of toxicity, should be plotted on the diagram below to determine whether the LTP contents fall into the low, moderate or high hazard region.

Source Hazard Determination Diagram



A theoretical leachate storage facility calculation is presented below. The likely total stored mass of ammonia and chloride has been calculated for the theoretical facility at anticipated typical influent ammonia and chloride content.

It is assumed that three tanks are present in a 'standard' LTP and these will be full to their design net capacity as follows;

- Raw leachate balance tank: 150m^3
- Treatment tank (SBR): 1,500m^3

- Effluent balance tank: $150m^3$

The ammonia concentrations will be at un-treated levels in the raw leachate tank (1,500mg/L) but will be limited to a conservative maximum of 20mg/L in the treatment and effluent balancing tank. Chloride is assumed to be at 1,800mg/L throughout the system.

On this theoretical basis presented below are calculations determining the likely total kilograms of ammonia to be stored at a typical LTP site.

Estimate of Ammonia and Chloride Stored in Leachate Storage Tanks

Substance	Concentration mg/L			RLBT kg	SBR kg	EBT kg	Total Stored at LTP kg
	RLBT	SBR	EBT				
Ammonia	1,500	20	20	225	30	3	258
Chloride	1,800	1,800	1,800	270	2,700	270	3,240

This indicates that 258kg of ammonia and 3,240kg of chloride are likely to be in storage at a typical LTP.

With reference to the 'Source hazard determination diagram' above, the Source Hazard Rating for the example LTP would therefore assessed as being 'Moderate' under normal circumstances. This also indicates that due to the chloride in storage in the EBT alone it would not be possible to justify a lower Source Hazard Rating for the EBT.

Pathway

It is assumed that a leachate storage facility will be provided with suitable primary containment in compliance with best practice[10] and relevant standards[11].

Establish if a means exists by which any potential escaped inventory can travel to a potential receptor. Reference could be made to the existing landfill HRAR (bearing in mind that this is for leakage at a predicted rate through the landfill base and not designed to account for a point source discharge as may occur if a storage tank leaks or spills) for this information and reviewed for the specific location of the proposed facility (for example, in the case of surface waters, would topography in the vicinity of the proposed facility mean flows towards the surface water could be established). Consideration of the following pathways at a site may include:

- Overland flow following topography;
- Pipework, sewers, drains or other underground features that lead to a receptor (watercourses etc); and
- Permeable geology underlying the site providing a pathway to groundwaters or watercourses.

The following items need considering when assigning a hazard rating to these potential pathways;

- Distance between the source and receptor(s);
- Site layout (topography) and position and effectiveness of drainage features;
- Geographical, hydrological, geological and hydrogeological features;
- Climate conditions;
- Effects of fires and firefighting liquors;
- Presence of off-site treatment plants (eg; sewage works attached to sewers);
- Modification of inventory by passage through pathways;
- Mobility of inventory; and

[10] For example, 'Integrated Pollution Prevention and Control Reference Document on Best Available Techniques for the Waste Treatments Industries'. European Commission, August 2006.

[11] For example, BS EN 1992 – Part 3 Eurocode 2. Design of concrete structures. Liquid retaining and containing structures.

- Scale of potential loss of inventory.

Should contaminant escape a leachate storage facility the pathways that exist at the location should be considered along with the speed of transit through them and a rating then applied. The following Classification system is suggested;

- High Classification. There is a direct pathway to a receptor that is close to the source;
- Moderate Classification. There is an indirect pathway to a receptor which is not immediately adjacent to the site boundary but still possible for a source pathway to exists; and
- Low Classification. There is no or limited pathway identified and the receptor is not adjacent to the site source.

An example of a simple pathway Classification is presented in the table below. Note that 'Firefighting Water' has not been included in the assessment as leachate storage facilities are unlikely to contain flammable materials

Example Site Pathway Classification

Pathway Description	Critical Receptor Proximity	Site layout and drainage	Topography, geology, hydrogeology	Climatic Conditions	Hazard Rating
Overland flow from the site following the topography.	River located on the southern boundary. Surface water features in west and south-west of site.	There are or may be shallow drains across parts of the site for surface water management.	Ground is generally flat lying and does not slope steeply towards the River. If Lower Greensand is present this is more permeable.	Area not in flood plain. Surface ponding likely in relation to impermeable surface soils.	Moderate - High depending on final location of LTP
Infiltration through the superficial and bedrock geology.	Principal aquifer underlying the site. (Lower Greensand) Kimmeridge Clay is Unproductive aquifer	If site constructed on clay, minimal infiltration and surface drainage will dominate.	Underlain by permeable Lower Greensand and low permeability Kimmeridge clay. Vertical permeability considered very low for the clay and high for the Lower Greensand. If surface water lagoons present they may be in hydraulic continuity with aquifer.	Ponding of rain water indicates slow permeability of soils in some areas	Low - High depending on location of LTP

In this example the preliminary overall pathway hazard Classification is considered to be 'Moderate - High' based on the potential for overland flow from the facility, and infiltration into a Principal aquifer, if this can be shown to be present beneath the site at the location of the LTP.

Receptor

Establish if a viable and credible receptor exists. This is likely to be surface water or groundwater but could include a wide range of other receptors, eg soils, housing. A receptor hazard Classification as presented in the table below:

Receptor Hazard (from CIRIA C736, 2014)

Receptor Description	Classification
Nationally designated sites (SSSIs/SPAs/SACs) and drinking water sources (source protection zones)	High
Locally designated sites, surface or groundwater bodies defined as such by the WFD	Moderate
Non-designated sites and other water and groundwater	Low

If the source-pathway-receptor model could not be established then full secondary containment would not be necessary, as long as other H&S issues and land contamination from discharges to ground could be precluded.

It is likely that this situation would be the case for leachate storage facilities sited on non-aquifers or impermeable geology where topography prevented run-off to surface water systems and suitable proposed operating techniques existed to deal with land contamination (for example dig-out and disposal followed by replacement with new material should spills go to ground).

Establish the Site Design and Risk Rating

This is an elaboration of the process of establishing a Site Risk Rating included within the CIRIA C736 guide. It attempts to acknowledge the different circumstances and risks that may be presented at a landfill LTP compared to that of other industries that also store potentially polluting liquids.

Site Hazard Rating

If the source-pathway-receptor model can be established, then a Site Hazard Rating should be established. This involves assessment of the nature and magnitude of the hazard posed by the liquid being stored (the source). A rating of 'High', 'Medium' or 'Low' would be assigned and in most instances the rating will be 'High' or 'Medium' due to the likely composition of landfill leachate and volumes stored. For the Pathway and Receptor a rating of 'H', 'M' or 'L' could be assigned. These ratings are multiplied together to produce a Site Hazard rating as per the table below:

Overall Site Hazard Classification

Source (hazard rating)	Pathway (transport potential)	Receptor (damage potential)	Overall Hazard Classification
H, M, L or non	H, M, L or non	H, M, L or non	H, M, L or non
Possible Combination of ratings		**Suggested Consequent overall site hazard rating:**	
HHH or HHM or HMM		High	
HHL or MMM or HML		Moderate	
MML or HLL or MLL or LLL		Low	
Any containing 'non'		Non	

If a rating of 'None' is produced it is most likely to be due to either the receptor or pathway being absent. This would suggest that there is no need for secondary containment and a justification for this should be submitted to the regulator as early as possible in the design process ideally supported by provision of a HAZOP report to demonstrate that other health and safety issues have been considered as a consequence. Where a rating of ‘Low’, ‘Moderate’ or ‘High’ is obtained further consideration of containment needed.

Site Risk Rating

If the Site Hazard Rating is ‘Low’, ‘Moderate’ or ‘High’ assign a Site Risk Rating by multiplying the Site Hazard Rating by the Risk of Loss of Containment that is dependent on the tank construction materials.

The Site Risk Rating is a combination of the Site Hazard Rating and the risk of loss of primary containment (frequency of loss of containment). Frequency of loss of containment risks are assigned as in the table below and are summarised as follows:

- High: Greater than 1% (1 in 100 or >0.0.1)
- Medium: Between 1% (1 in 100) and 0.001% (1 in 1 million or 0.01 - $1x10^{-6}$)
- Low: Less than 0.001% (1 in 1 million or < $1x10^{-6}$)

These frequencies of loss of containment and subsequent ratings have been compared to guidance produced by the HSE so that different primary containment construction materials can be assigned to each rating summarised as follows:

Primary Containment Construction	**Annual probability of loss of containment per site**	**Risk of loss of containment**
Poured in-situ monolithic concrete With CQA to appropriate standards	Less than 0.001% (1 in 1 million or < $1x10^{-6}$)	Low
Pre-cast Concrete Glass or Epoxy Coated Steel (5mm thick steel) With CQA to appropriate standards	Between 1% (1 in 100) and 0.001% (1 in 1 million or 0.01 - $1x10^{-6}$)	Medium
Stainless Steel Carbon Steel Alloys Plastics (GRP, PP, HDPE, uPVC, PVDF, FEP etc)	Greater than 1% (1 in 100 or >0.0.1)	High

The combination of the site hazard rating with the frequency of loss of containment for the storage tank with the highest potential frequency at the proposed LTP provides the overall site risk rating.

As an example, assuming a typical leachate storage facility Site Hazard Rating of ‘Moderate’, a facility with primary containment tanks constructed from different materials would have the following Site Risk Rating:

Material	Site Hazard Rating		Risk of Loss of Containment		Site Hazard Rating
Poured in-situ monolithic concrete	‘M’	x	‘L’	=	Low
Pre-cast Concrete Glass or Epoxy Coated Steel	‘M’	x	‘M’	=	Moderate
Stainless Steel Carbon Steel Alloys Plastics	‘M’	x	‘H’	=	High

Site Design Rating

CIRIA C736 does not consider the quality of primary containment provided apart from in terms of the frequency of loss of containment assessment set in establishing the Site Risk Rating. Other plant design elements can be considered to determine if loss of primary containment is more or less likely. Where sufficiently high quality plant designs are proposed that limit the possibility of loss of containment due to issues such as leaks and incidental spills or losses due to human error a lower risk can be assigned. A Classification on a qualitative basis is as follows:

- Low: High quality pipework (for example butt welded HDE with an SDR of 11 or above, stainless steel etc.), no wall penetrations, all pipework joints, pumps, valves etc. located over or within tanks, plant protected from vehicles, tanks fitted with continuous level monitoring and inter-locked auto shutoffs (at least 3 independent systems per tank), detection of loss of containment within liquid storage and transfer systems (for example, SCADA systems that detect and alarm for unexpected loss of level from tanks, loss of pressure in pipework, detection of ‘no-flow’ when pumps running etc.)
- Moderate: Minimal wall penetrations, all pipework joints, pumps, valves etc. located over impervious surfaces, plant protected from vehicles, tanks fitted with continuous level monitoring and inter-locked auto shutoffs (at least 2 system per tank), detection of loss of containment within liquid storage and transfer systems by manual inspection and operator review to detect unexpected loss of level from tanks, loss of pressure in pipework, observation of ‘no-flow’ when pumps running etc.
- High: Many wall penetrations, pipework joints, pumps, valves etc. located outside of impervious surfaces, plant not protected from vehicles, tanks not fitted with continuous level monitoring and inter-locked auto shutoffs (1 system per tank), no systems or procedures to detect loss of containment within liquid storage and transfer systems.

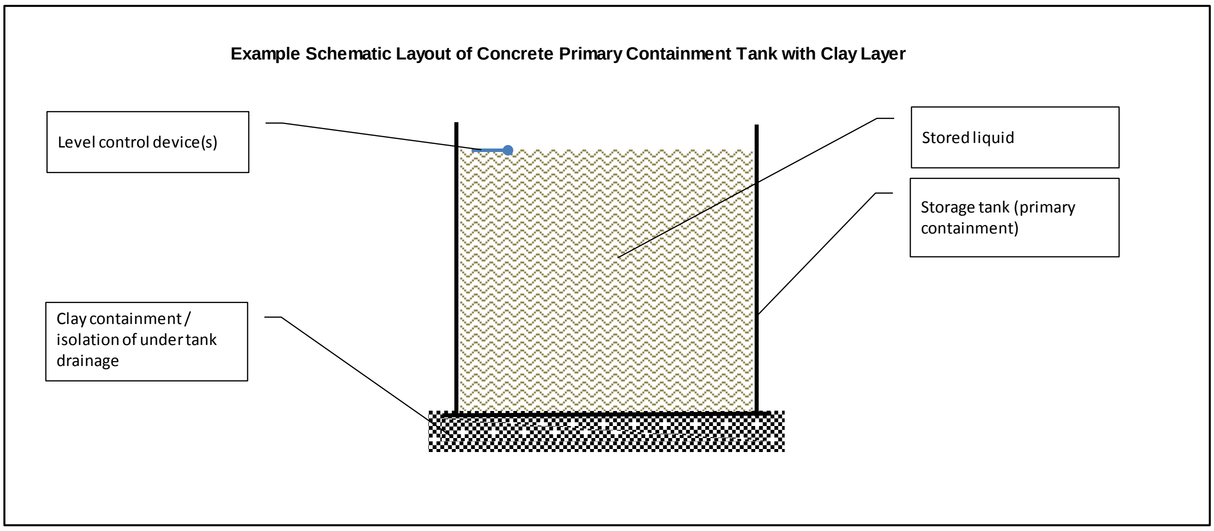
Site and Design Risk Rating

Evidence suggests that post construction failure of well-constructed poured in situ concrete tanks does not occur, failures associated with these tanks are limited to wall penetrations, pipework joints etc. If these points of weakness can be 'designed out' it may be possible to justify not installing full secondary containment if evidence can be presented to the Regulator that suitable continuous leak detection is proposed or credible maximum leakage rates are acceptable by way of a quantitative HRA for the installation.

Examples of continuous leak detection system are presented in Section 8.12 and Appendix A3 of the CIRIA C736 guidance. In practice this amounts to groundwater monitoring boreholes external to the containment area, monitoring of installed underdrainage below the containment area (for example fin drains isolated from the external environment) or in some cases permanent electrical resistivity arrays that can be installed below geomembrane lining systems.

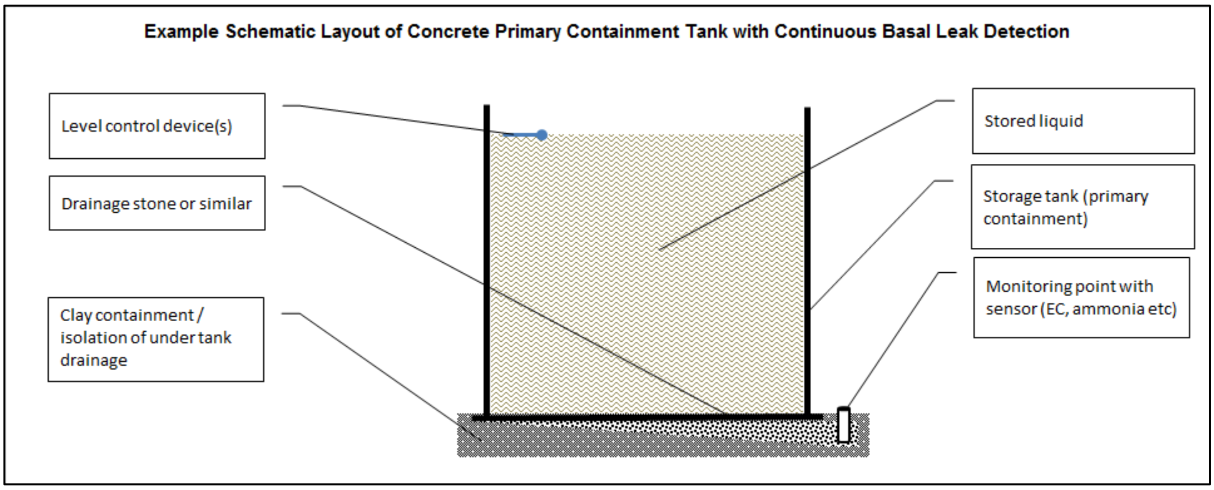
A full quantitative HRA would need to consider if the concrete tanks (as this could only apply to poured in-situ monolithic concrete tanks) could be considered as a source for leachate escape similarly to a landfill cell. This would only be possible if the tank base were to be underlain by a clay layer (see diagram below) to comply with the requirements of the Landfill Directive. Potential maximum leakage rates could then be calculated for each tank based on the leakage tests contained within BS EN 1992 – 3 (assuming all leakage through the base). If a suitable HRA for the leachate storage facility were able to be constructed and demonstrates an acceptable emission from such a plant then full secondary containment may not be required.

Example Tank Schematic ~ Concrete Tank with Clay Under-layer



Alternatively, continuous leak detection could be provided to tanks assessed as having a 'Low' risk of loss of containment and, if this were to be fitted with continuous monitoring and alarm systems to detect potential leakage from the underside of the tank base then secondary containment under the tank base may not be required. The diagram below presents a conceptual schematic of how such a system may be installed.

Example Tank Schematic ~ Concrete Tank with Engineered Clay Isolation Layer and Leak Detection



Suggested combinations of hazard and risk ratings to give an overall Site and Design Risk Rating are presented in the table below.

Overall Site and Design Risk Rating

Site Risk Rating	Frequency of Loss of Containment
H, M or L	H, M or L
Possible Combination of ratings	**Suggested Consequent overall site risk:**
HH or HM or MH	High
MM or HL or LH or ML or LM	Moderate
LL or	Low

It may also be possible to divide the site into separate areas, each of which could be assessed differently from one another due to;

- The Classification of the Source (hazard): For example, the effluent tank and associated systems hold a liquid of significantly lower pollution potential than the raw leachate or treatment tanks and systems;
- The Classification of the tank in terms of its risk of loss of containment: For example, the effluent tank may be constructed from poured in-situ monolithic concrete whilst the other tanks may be glass coated steel;
- The Classification of the plant design: For example, pumping and pipework infrastructure may be more easily accommodated within the effluent balance tank without the need for tank wall penetrations than for other tanks on the plant; or
- The provision of proprietary storage tanks: This being most likely to be in relation to bulk chemical storage tanks for alkali and acids. These are typically supplied with integral independent bunding systems and so could be considered separately from the remainder of the plant, providing that the proprietary tank bund and interconnecting pipework complies with the requirements described elsewhere in this guide for bunding (i.e. no penetrations of the secondary bund, pipework secondarily contained etc).

Bund Classification

Should assessment indicate that bunding is required for all or part of the leachate storage facility, the Classification system proposed in CIRIA C736 should be followed.

Section 2.6.1 of CIRIA C736 details the containment Classification system for high, moderate or low site risk rates plants. This information is summarised in the table below.

Outline Containment Classification and Construction Method

Site Risk Rating	Containment Classification	Containment Integrity	Outline Acceptable Bund Construction Method
Low	Class 1	Base level	Appropriately designed impervious in-situ reinforced concrete or masonry bund, concrete base and tank wall system, or Appropriately designed earth bund with properties equivalent♠ to a 1m depth of soil
Moderate	Class 2	Intermediate level	Appropriately designed impervious in-situ reinforced concrete or masonry bund, concrete base and tank wall system, or Appropriately designed earth bund with properties equivalent♠ to a 1m depth of soil with a permeability coefficient of 10^{-9} m/sec with an impermeable membrane liner♣.

Site Risk Rating	Containment Classification	Containment Integrity	Outline Acceptable Bund Construction Method
High	Class 3	Highest level	Appropriately designed impervious in-situ reinforced concrete or masonry bund, concrete base and tank wall system, or Appropriately designed earth bund with properties equivalent♠ to a 1m depth of soil with a permeability coefficient of 10^{-9} m/sec with an impermeable membrane liner♣ incorporating a sub-base leakage detection system
Notes:	♠	‘Equivalence’ is not simply determined by the soils permeability coefficient but needs to account for structural robustness and reliability so typically means a depth of less than 0.75m of any material would not be acceptable	
	♣	Note that the permeability performance of the soil bund must be assessed without reference to the performance of membrane liner. The soil bund must, independently of the membrane liner, have a performance equivalent to a 1m depth of material at $1x10^{-9}$m/s	

Summary of bund assessment process

Presented below is a flow chart summarising the bund assessment process described above.

SECONDARY CONTAINMENT ASSESSMENT FLOW DIAGRAM

STEP	ASSESSMENT	OUTPUT	NOTES
1	Can the presence of a **SOURCE** at the proposed LTP be established? High, Moderate or Low NO → Secondary Containment may not be required YES ↓	If a source, pathway or receptor is not likely to be present, or if suitable engineering means can be found to remove the pathway, a 'Mini' qualitative HRA of the area of the proposed LTP development shold be carried out to confirm the actaul site setting. This is likely to include: •A review of any geotechnical report (for the site, together with conceptual hydrogeological models for the landfill site, in order to understand potential pathways and receptors. • A site visit to visually 'ground truth' the LTP location. • A tabulated risk assessment, identifying site specific receptors and pathways at potential risk from loss of primary containment at the LTP. • Outline identification of appropriate additional site investigation works and secondary containment measures that may be necessary to mitigate identified risks at the LTP site Findings report to regulator with proposal for how 'natural' containment of site will be achieved and intention to omit secondary containment as a result.	At a 'typical' LTP (150m^3 RLBT, 1,500m^3 SBR, 150m^3 EBT, Raw leachate ammonia c. 1,500mg/L) it is likely that the RLBT and SBR at least represent a sourced classified as 'Moderate' by CIRIA C736 for ammonia, COD, BOD and chloride. It is unlikely that any other substances found in landfill leachates at 'normal' concentrations would increase this classification to 'High'. It may also be possible in some circumstances to classify the EBT alone as 'Low'.
2	Can the presence of a **RECEPTOR** within close proximity of the proposed LTP location be established? High, Moderate or Low NO → Secondary Containment may not be required YES ↓		Receptor hazards as defined by CIRIA C736 are defined as follows: • Low = Non-designated sites and other water and groundwater • Moderate = Locally designated sites, surface or groundwater bodies defined as such by the WFD • High = Nationally designated sites (SSSIs/SPAs/SACs) and drinking water sources (source protection zones)
3	Can the presence of a credible **PATHWAY** between the source and receptor be established? High, Moderate or Low NO → Secondary Containment may not be required YES ↓		CIRIA C736 does not present explicit guidance on pathway classification. A classification on a qualitative basis is as follows: • Low = No or limited pathway identified and the receptor is not adjacent to the site source • Moderate = Indirect pathway to a receptor which is not immediately adjacent to the site boundary but still possible for a source pathway to exists • High = There is a direct pathway to a receptor that is close to the source
4	Can reliable engineering design be used to remove the pathway? YES → Secondary Containment may not be required NO ↓		For example, if site survey indicates that natural topography, hydrology, geology, and hydrogeology indicate that the only credible pathway is overland flow, is it possible to re-engineer topography to interrupt the flow path and so contain the proposed LTP site?
5	Establish the **SITE HAZARD RATING** High, Moderate or Low	Possible combination Site of ratings: / Consequent overall Hazard Rating HHH or HHM or HMM – High HHL or MMM or HML – Moderate MML or HLL or MLL or LLL – Low	CIRIA C736 presents suggested combinations of Site hazard Ratings from a combination of the Source, Pathway and Receptor classification to give an overall Site Hazard Rating where H = High, M = Moderate and L = Low. Possible combination of ratings: / Consequent overall site hazard rating: HHH or HHM or HMM – High HHL or MMM or HML – Moderate MML or HLL or MLL or LLL – Low
6	Establish the **SITE RISK RATING** High, Moderate or Low	Possible combination Site of ratings: / Consequent overall Risk Rating HH or HM or MH – High MM or HL or LH – Moderate LL or ML or LM – Low	CIRIA C736 presents suggested risks due to frequency of loss of containment as follows: • Low = < 0.001% (1 in 1 million) per site • Moderate = Between 1% (1 in 100) and 0.001% (1 in 1 million) per site • High = Greater than 1% (1 in 100) per site
7	Establish **SITE DESIGN RATING** High, Moderate or Low	Possible combination Site of ratings: / Consequent overall Risk Rating HH or HM or MH – High MM or HL or LH or ML or LM – Moderate LL – Low	CIRIA C736 does not consider the quality of Primary Containment provided. A classification on a qualitative basis is as follows: • Low = High quality pipework, no wall penetrations, all pipework joints, pumps, valves etc located over or within tanks, plant protected from vehicles • Moderate = Minimal wall penetrations, all pipework joints, pumps, valves etc located over impervious surfaces, plant protected from vehicles • High = Many wall penetrations, pipework joints, pumps, valves etc located outside of impervious surfaces, plant not protected from vehicles
8	Establish the **SITE and DESIGN RISK RATING** High, Moderate or Low Low → Full Secondary Containment may not be required Moderate or High ↓	If the LTP tank bases are provided with continuous leak detection and alarms, and/or they are provided with a secondary geological liner (clay under base), full secondary containment may not be required by agreement with the Regulator. • Details of continuous leak detection need to be agreed with Regulator along with emergency response and management plans • Full quantitative HRA to be undertaken on LTP and agreed with Regulator that risks are acceptable for installation in relation to the Landfill Directive.	CIRIA C736 does not include this step. However, evidence suggests that post construction failure of well constructed poured in situ concrete tanks does not occur, failures associated with these tanks are limited to wall penetrations, pipework joints etc. If these points of weakness can be 'designed out' it may be possible to justify not installing full secondary containment if evidence can be presented to the Regulator that suitable continuous leak detection is proposed or credible maximum leakage rates are acceptable by way of a quantitative HRA for the installation
9	Can the site be subdivided into Low and Moderate/High areas? Yes → Full Secondary Containment may not be required for Low SITE and DESIGN RISK RATING Effluent tanks NO ↓	Designer Risk Assessment demonstrating that the contents of the EBT are at a low risk of escape due to primary containment design and that contents are suitable for persistent release to the environment. Therefore low frequency accidental release risk acceptable without secondary containment.	CIRIA C736 does allow for a site to be subdivided into high, moderate and low risk areas. LTP's, unlike sites such as fuel, chemical or other product stores are designed to render a previously highly contaminating liquid suitable for discharge to the environment. Therefore it is reasonable to allow that fully treated effluent, if stored in a low Site Risk and Design Rating setting, may not be required to have full secondary containment
10	Classify the bunding requirement as; Class 1, Class 2 or Class 3		Follow CIRIA C736 Section 2.6 Containment Classification System process once options to reduce or remove secondary containment requirements outlined in steps 1 - 9 above have been exhausted
11	→ **Class 1 Bund** Low overall Site Risk Rating Omission of secondary containment cannot be justified by Steps 1, 2, 3, 4, 8 or 9 → **Class 2 Bund** Moderate overall Site Risk Rating → **Class 3 Bund** High overall Site Risk Rating	In situ reinforced concrete or mason bund in accordance with CIRIA C736 Section 7 or Class 1 earth bund in accordance with CIRIA C736 Section 8 - equivalence to 1.0m thick (vertical measurement) layer at permeability of 1 x 10^{-9}m/s. In situ reinforced concrete or mason bund in accordance with CIRIA C736 Section 7 or Class 2 earth bund in accordance with CIRIA C736 Section 8 - equivalence to 1.0m thick (vertical measurement) layer at permeability of 1 x 10^{-9}m/s plus impermeable membrane liner. In situ reinforced concrete or mason bund in accordance with CIRIA C736 Section 7 or Class 2 earth bund in accordance with CIRIA C736 Section 8 - equivalence to 1.0m thick (vertical measurement) layer at permeability of 1 x 10^{-9}m/s plus impermeable membrane liner and under base leakage detection system.	Secondary containment required for all tanks, pipework, ancillary equipment and loading facilities (including tanker bays etc) to 110% of brim-full largest tank capacity or 100% plus 10% AEP rainfall allowance, whichever is the larger. Secondary containment to be fully structurally independent of primary containment (including tank bases). No penetrations through secondary containment allowed, all pipework, cabling and other services (including man-access) to be 'up and over' secondary containment walls. Detection of events that fill the secondary containment bund required as well as control of rainwater within the contained area to preserve the required volume. This is likely to mean covered bund with suitable visual or level detection devices and for open secondary containment designs automated rainwater pumping and disposal (to the LTP if a continuous system is provided) Note that most process chemical bulk storage (caustic soda, acids etc) will need to be supplied with secondary containment that conforms to the above description and so may not need to be included within the general site bunded area, however connecting pipework would also need to be secondarily contained.

Bund Design

CIRIA guide C736 provides details of design considerations once the Class of containment required has been established. These details can be followed when producing engineering designs for secondary containment bunds. The relevant sections of the CIRIA guide C736 for design details relating to the structure of containment bunds are as follows;

- In-situ reinforced concrete and masonry bunds: CIRIA C736 Section 7
- Earth banked containment basis (lagoons), earth bunds and earth floors: CIRIA C736 Section 8

Further details on considerations for provision of remote secondary containment and associated transfer systems as contained in the following sections of the CIRIA guide C736;

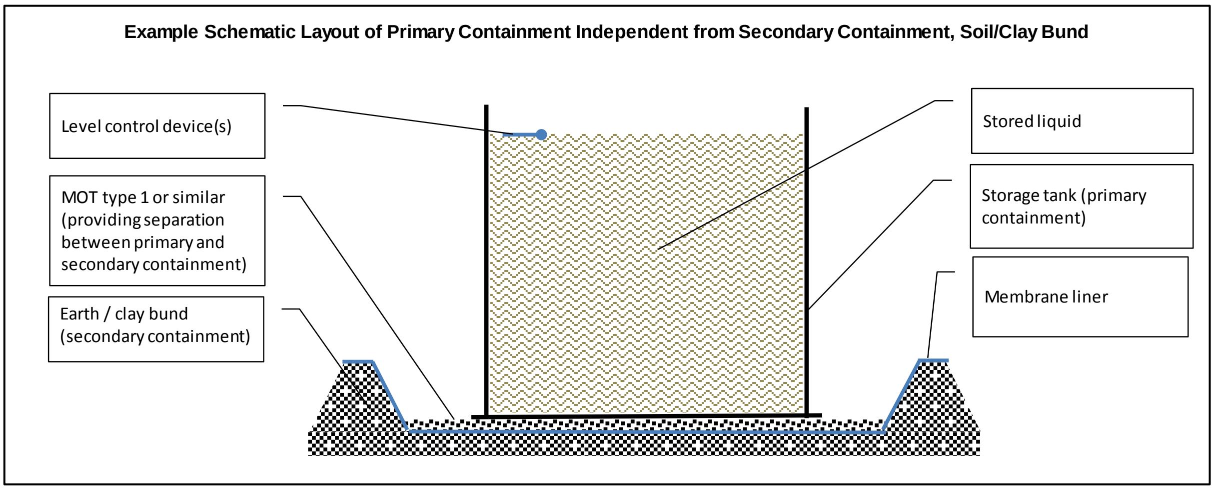
- Secondary and tertiary containment options: CIRIA C736 Section 3
- Transfer systems: CIRIA C736 Section 10

<u>General</u>

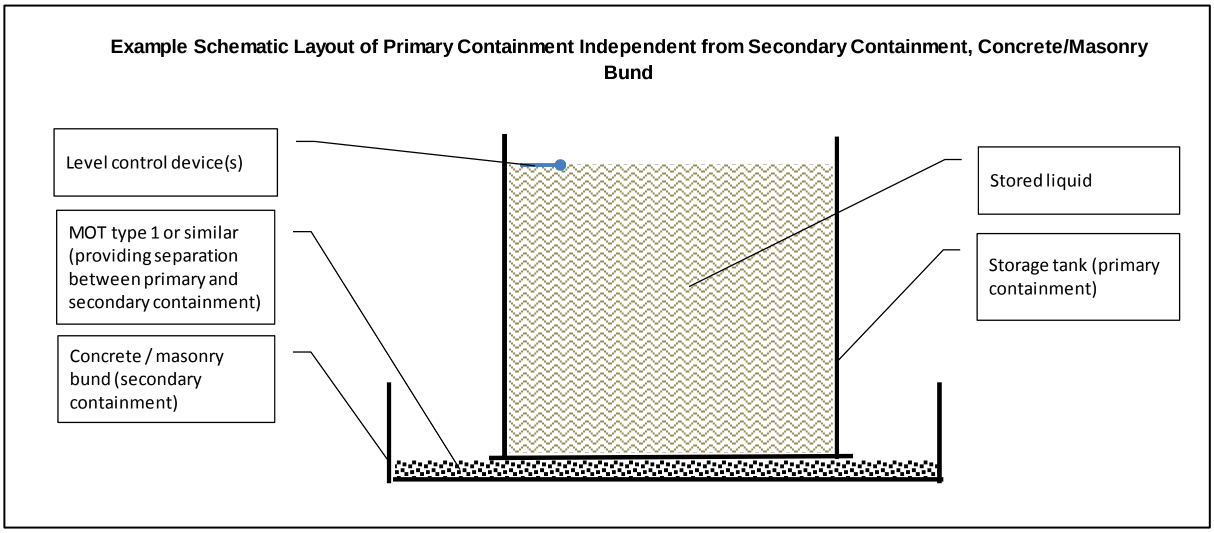
General considerations for bund design are as follows. Simplified example schematics for plant layout are presented where appropriate using the example of bunds provided in concrete or masonry as well as for a Class 2 soil bund:

1. Secondary containment should have impermeable base and walls to surround the primary containment tanks or vessel and should be resistant to the stored materials; and
2. Secondary containment should be structurally independent from the primary containment tanks with the exception of where poured reinforced concrete tank bases are used. In these cases primary containment tanks and bund walls can share the same base.
3. Lagoon storage can also be supplied by systems that employ concrete / masonry or composite lined primary containment respectively.

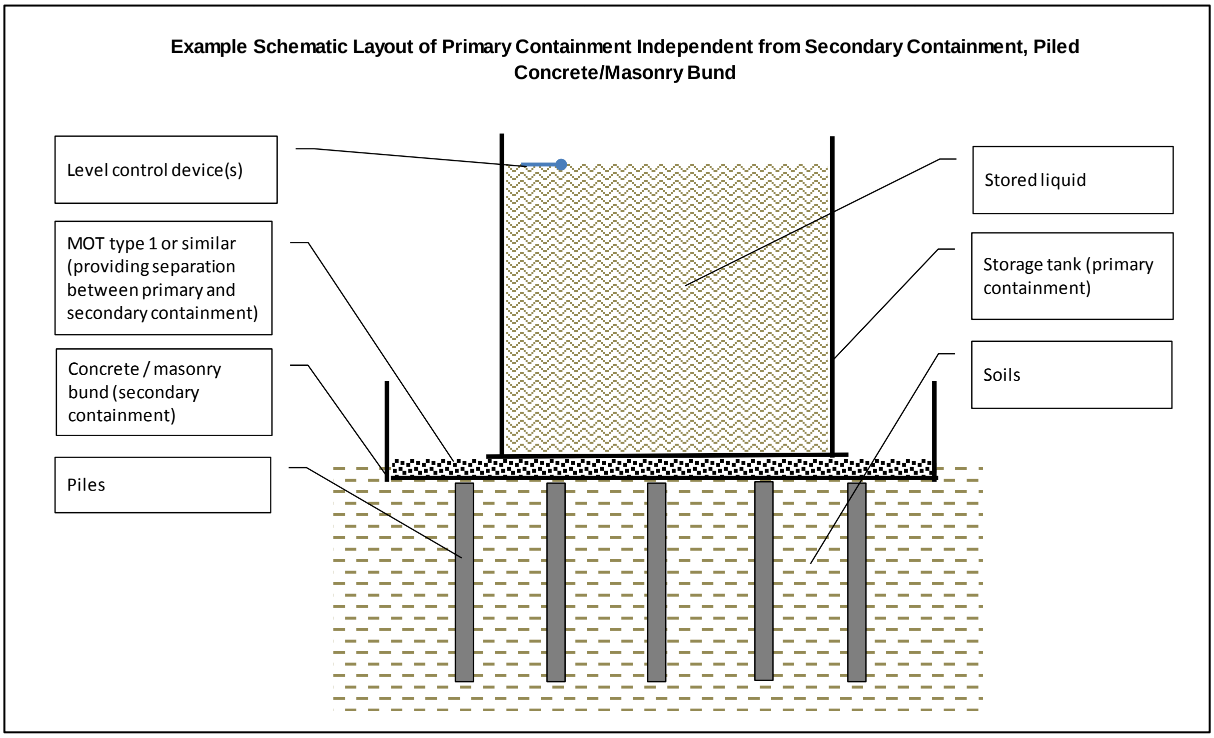
Example Tank Schematic ~ Class 2 Soil Bund Independent from Primary Tank



Example Tank Schematic ~ Concrete/Masonry Bund Independent from Primary Tank

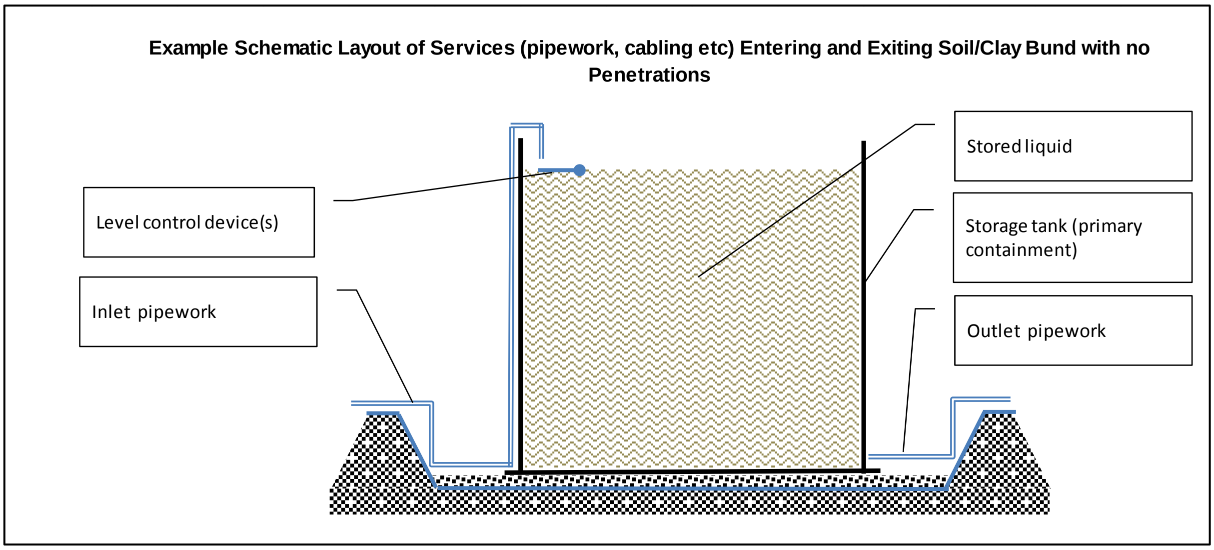


Example Tank Schematic ~ Concrete/Masonry Bund Independent from Primary Tank Incorporating Piling



4. Secondary containment should avoid having outlets or penetrations (that is, no drains or taps), but should drain to a collection point for treatment. Where bund waters are intended to be pumped away as clean surface water when not contaminated robust procedures to ensure that bund water is clean prior to discharge need to be agreed with the regulator. Penetrations to the secondary containment bund can be permitted if no other method of gaining required access is possible. Use of systems such a ‘flood gates’ or ‘bund gates’ should be employed in these circumstances;

Example Tank Schematic ~ Class 2 Soil Bund Without Penetrations



5. Pipework along with associated valves and pumps etc. should wherever possible be routed within bunded areas with the minimum number of penetration into contained surfaces. Pipework and associated infrastructure should wherever possible be routed above ground so that it can be inspected, if installation below ground is necessary then pipework should have secondary containment and/or be installed in channels where any leaks can be detected or, alternatively in low risk settings, the buried pipework periodically monitored or inspected for leaks by some other means (for example, periodic pressure testing);
6. Secondary containment should be designed to catch leaks from tanks or fittings and have a sufficient bund capacity to accommodate a minimum of 100% of the content of the largest tank contained within the bunded area. In practice, a pragmatic design approach is to design secondary containment at 110% of the largest tank contained within the bunded area. Calculations on the additional volume to accommodate rainfall etc can then be presented to justify the provision (or not) of additional storage volume;
7. Calculations on required bund storage capacity should be based on the brim-full capacity of the primary storage vessels that they contain. Use of 'operational fill' levels can be justified if it can be demonstrated that suitably robust level control systems are to be installed. This is likely to mean that a 'primary, 'secondary' and third 'fail safe' level detection system is in place and that each is fully independent of the other;
8. Secondary containment should be subject to regular visual inspections and any contents pumped out or otherwise removed under manual control should be checked first for contamination. Where not frequently inspected, the bunds should be fitted with a high level probe and an alarm as appropriate. There needs to be a routine programmed inspection of bunds;
9. Fill points for delivery and removal of leachate, sludges, other effluents and process chemicals should be within the bunded area and facility should be included to capture any spills from delivery vehicles.

<u>Containment System Options</u>

It is acceptable to provide secondary containment by employing either local or remote storage for any escaped liquid. The following types of system or combination of systems can be considered:

- Local – i.e. bund floor and walls immediately adjacent and surrounding the primary storage tanks and associated facility
- Remote – i.e. a tank, lagoon or storage area that does not immediately surround the primary storage tank and associated facilities but that is connected to the primary facility by a transmission system (pumps and pipework or channels) so that any escaped liquid is transferred to the remote storage. Note

however that for this type of system to operate the primary tank and associated facility need to be located on an impervious surface.

Bund Volume

CIRIA guide C736 has moved away from prescriptive bund capacities based simply on the volume of storage contained within the bunded area. Instead it allows for bunding to be provided at less than the previously required 110% of the largest tank (or 25% of the total stored volume) capacity by considering issues such as credible tank failure modes along with issues that include the volume of inventory, rainfall, fire-fighting agents (foam), fire-fighting and cooling waters. If a bund volume of less than 110% capacity is to be provided the design should allow for accommodation of rainfall into the bund immediately preceding an incident where the largest tank has failed and during operations to subsequently empty the bund. It is suggested that an Annual Exceedance Probability (AEP) of 10% should be allowed for rainfall for a period of at least 10 days (1 day preceding the event, 1 day for the event and 8 days after the event) unless the operator can demonstrate that the secondary containment can be emptied following an incident in less than 8 days (for example, if the operator has access to a fleet of tankers and off-site disposal outlets as short notice) then you can argue this could be reduced. Section 4.3.3 of the CIRIA C736 guide provides information on the rainfall depth associated with the 10-year return period AEP for different regions of the county. These range from a 24hr allowance of 29mm in the driest regions of the UK (typically the south east) through to 106mm in the wettest (typically the highlands of the north and west).

When calculating bund storage capacities allowances should be made for the volume of the bund taken up by infrastructure and materials installed within the bunded area. For example the area occupied by tank bases, equipment plinths, access roadways and construction materials (such as drainage stone etc) needs to be accounted for when calculating bund volumes.

It should be noted that, except in exceptional circumstances, the tank volume around which the bund volume should be calculated in the 'brim-full' capacity, not the operational fill level or the overflow level capacity.

Proximity of Storage

Careful consideration should be given to the siting of the primary containment to ensure that inventory is not lost via a jetting failure; a hole in the tank wall from which inventory would escape under hydrostatic pressure as a jet. The height and distance of containment bund walls from tanks should be considered to prevent jetting of material beyond the contained area. CIRIA guide C736 provides guidance on how to calculate the distance required between the primary and secondary containment of a tank to prevent liquid loss by jetting failure. The formula $I_{MAX} = H - h$, where 'I_{MAX}' is the required distance between the primary and secondary tank walls, 'H' is the maximum fill level of the primary tank and 'h' is the height of the secondary containment bund wall can be used to calculate the required bund wall height and separation distances. Jetting failure is highly unlikely to occur through the walls of the in-situ concrete tank walls and is therefore not considered a credible scenario.

Bund Shape & Compartmentalisation

This is not likely to be a significant consideration at an leachate storage facility where the shape of the bund is usually dictated by the site constraints and compartmentalisation is not considered necessary as the most of the materials stored are compatible with each other. The only exceptions to this may be the storage of alkalis (such as caustic soda) and acids (such as phosphoric acid) which, should be considered for storage in separate bunded areas, either in a compartmentalised bund or to have their own independent containment provided.

Retention: Bunds should retain at least 100% of the brim-full capacity of the largest tank plus the rainfall from an appropriate and justified duration 10% AEP storm event. In practice, a pragmatic design approach is to design secondary containment at 110% of the largest tank contained within the bunded area to achieve this. There is a requirement to make any allowance for firefighting water or agents (C736, Paragraph 4.3.1.) but as most leachate storage tanks will not contain any significant flammable materials this is not usually relevant.

Permeability: Secondary containment provided in concrete or masonry should be proven to be constructed as water retaining structures as per the requirements of the relevant British Standards[12]. For soil bunds the permeability suggested is equivalent to 1.0m of materials at a permeability of $1x10^{-9}$ m/s. However, the requirement at each individual facility should be assessed with reference to the period of time that any escaped liquid will be stored within the bunded area. This calculation needs to achieve both the equivalent leakage rate and transmission rate. For soil bunds incorporating a membrane liner (Class 2 and 3) suitable integrity testing should be performed (e.g. resistivity leak detection).

Strength: Containment should be designed to withstand static loads (and dynamic loads only if catastrophic failure is a credible scenario) associated with potential release of materials from primary containment. Bund floors need to be capable of withstanding loads from the structures contained within them and activities that are likely to be taking place.

Durability: Construction materials should be selected to resist the effects of;
- Weather
- Aggressive ground conditions
- Abrasion; and
- Effects from the inventory being stored (i.e. chemically resistance).

Effects of fire should be considered (although in practice this is not a credible scenario at LTP's. These issues should be considered over the likely lifespan of the plant, suggested as a minimum of 50 years.

Structural Independence: Bund walls and bases should be structurally independent from primary containment. However, use of properly CQA'd poured reinforced concrete bases are considered sufficiently robust to be a suitable common base slab for both primary and secondary containment tank walls.

Pipework Containment: Pipework associated with the plant should be routed above ground and within the secondary containment provided. Where this is not possible pipework may need to be secondary contained or periodically checked for leaks. Suitable integrity testing would include periodic pressure testing.

Penetrations: Penetrations to primary and secondary containment are allowed where they cannot be avoided, however they should be reduced to the bare minimum. Wherever possible the location of penetrations should be chosen so that any jetting as a result of failure of the primary containment points towards the centre of the contained or surfaced area. Any valves or other equipment that could enable liquid to be manually released from the primary containment should be capable of being locked in the closed position and suitably robust security measures undertaken to prevent unauthorised access and use. Penetrations of secondary containment should be avoided wherever possible but are 'more' acceptable for Class 1 bunds than for Class 3 (see CIRIA C736 Table 6.2 for more details). Ideally all services (pipework, cabling etc) will enter and leave the containment system over the top of the bund. The use of man-ways, flood or bund gates in secondary containment is allowable but best practice is to avoided them wherever possible in primary containment (but are more acceptable for Class 1 bunds than for Class 3), except where above brim-full liquid levels (i.e. allowable in roof structures) or where the need is for unavoidable and frequent (i.e. more than annual) site operation reasons. If man-ways are desired as part of the plant design a designer risk assessment justification should be produced to support the proposed inclusion making clear that the LTP or tank /storage vessel cannot reasonably be constructed or operated without them.

Surge: This needs to be considered if catastrophic tank failure is a credible scenario. If not, secondary containment designs need not accommodate surge issues.

[12] BS EN 1992 – 3

If surge effects have need to be considered (i.e. that is a ‘Moderate’ or ‘High’ risk of loss of containment) then additional freeboard needs to be provided. This can be calculated or justified on a site specific basis or standard surge allowance depths can be added to bund wall designs as follows:

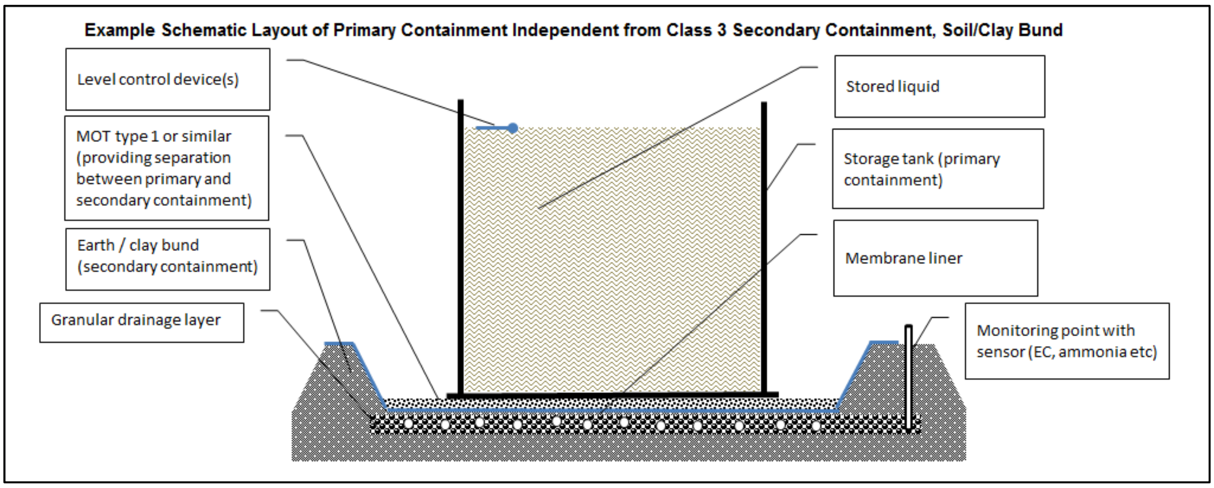
- Concrete or blockwork bunds: Allow additional 250mm freeboard
- Secondary containment tanks: Allow additional 250mm freeboard
- Earthwork bunds: Allow additional 750mm freeboard

Firefighting Liquids: As leachate storage facilities do not containable flammable inventory and due to the nature of their construction little flammable or combustible material is used it is unlikely that an allowance needs to be made in secondary containment design for firefighting liquids.

Leak Detection: Leak detection is only required for Class 3 bunds or subsurface storage systems. In addition, they may be proposed for sites where a Site Design and Risk Rating of ‘Low’ have been assigned and it is hoped to justify not constructing secondary containment.

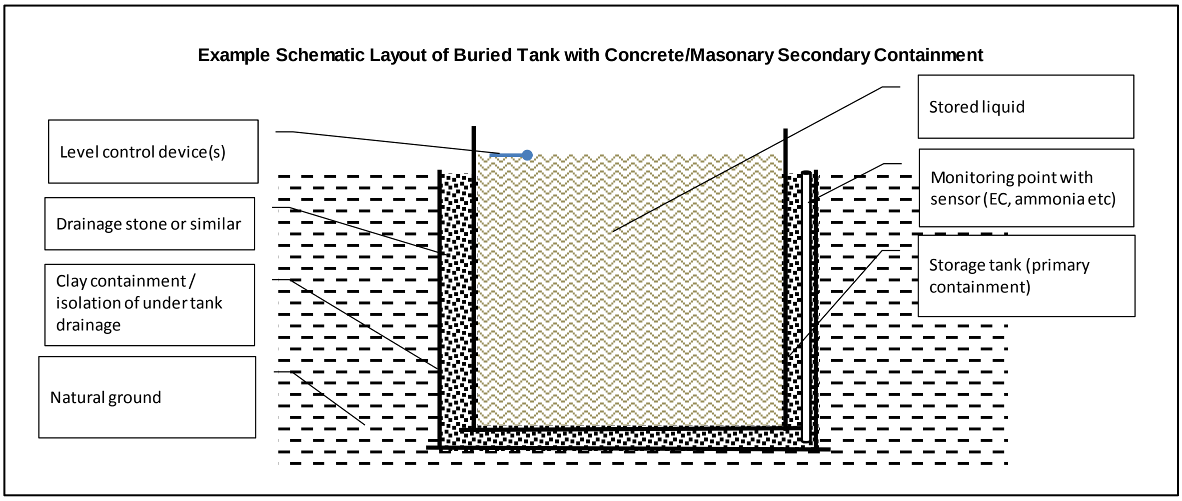
Examples of how continuous leak detection may be achieved is presented in the diagrams below. Alternatively, in appropriate geological settings, use of monitoring boreholes surrounding the LTP could instead be employed.

Example Tank Schematic ~ Class 3 Secondary Containment Soil/Clay Bund with Leakage Detection



Similar leakage detection systems would need to be employed where buried or part buried tanks were required.

Example Tank Schematic ~ Below Ground Tank Employing Concrete / Masonry Bund



Appendix C – Independent Storage Tank Details

Independent storage tanks are tanks that are typically supplied 'off the shelf' complete with an integral bunding / containment system. They are typically deployed on landfills to store leachate in relatively low volume (<100m^3 per tank) for bulking up prior to off-site tankering or passing onto other treatment and storage facilities. In many cases they are installed outside of the curtilage of an LTP.

If properly designed so the inner tank is structurally independent of the containment bund, and the containment bund is sufficiently structurally robust to contain the primary tank contents without failing and the tank is installed with a suitable means of protection against credible impact damage scenarios, then standalone leachate storage tanks are acceptable. This includes the use of 'double skinned' tanks as long as they are shown to be suitable protected from credible impact damage scenarios.

It is noted however that horizontal cylindrical tanks with dome-ends are better but are typically placed in open rectangular box type bunds. A number of failures of the bunding due to the accumulation of rainwater have been reported.

Designs should consider how to prevent the bund filling with rainwater and propose suitable maintenance and inspection regimes that enable bund content to be emptied and bunds to be assessed for leaks.

This can typically be achieved by either having an open bund installed with level sensors and alarms to trigger bund pumping to the storage tank and to alarm when bund levels reach a critical depth that indicates failure of the primary tank. Alternatively, bunds can be covered with rain cowls but in this case the jetting of liquid from levels in the primary tank above the cowl need to be considered as does the need for detection equipment in the bund to alert operators to leakage from the primary tank.

Standalone storage tank example instrumentation

To prevent overfilling of the storage tank standalone storage tanks may be fitted with a 'fail to shut actuated inlet valve' (this means that the valve requires power to keep it open, any loss of power or signal that something is wrong within the system causes the valve to automatically close). The valve must be set to close when the tank is full. This feature is particularly important where there is a likelihood of the field pumping system siphoning into the tank.

A primary level control device, fitted in the storage tank, may be set to close the actuated inlet valve and shut off power to the field pumping systems (either electrical power to individual pumps or shutting down the compressor to a pneumatic system) when the tank is full. Similarly it should re-open the actuated valve and restart the field system when the tank is no longer full. There are a number of types of level control device that are used to achieve this, each with its own pros and cons:

- Float Switches: Cheap and easy to install but prone to failure from problems such as cables becoming tangled and freezing. Suffer from corrosive attack due to prolonged physical contact with leachate;
- Conductivity Probes: More expensive and difficult to fit. Can be confused by the presence of foam;
- Ultrasonic Sensors: Uses ultrasonic sound reflections to read the level of the liquid surface. Benefits from never coming into contact with the leachate but can be confused by ripples in the liquid if fitted close to the filling point and also by vapour phases; and
- Pressure Transducers: Relatively expensive, monitor the pressure of the liquid above them and convert this into a depth of liquid. Have been known to occasionally fail due to corrosion as they are usually submerged in leachate. May need occasional removal and cleaning/de-scaling.

Tanks may also be fitted with a secondary independent fail safe high level control device. Typically such devices will completely shut down the pumping system and isolate the tank should the leachate level exceed the primary high level control level and in a high risk setting may also raise an alarm to operators.

Further level control devices may be fitted to secondary containment bunds. Level control devices fitted within bunds should be fail safe, shutting down the entire field pumping system if they are triggered and, if telemetry is fitted, dialling out a warning. Such tanks should be fitted with a beacon and/or other visual device and/or an automatic call out system so that it is known when the tank is full. Such automated control systems must ‘fail to safe’ on loss of power or loss of signal shutting valves to prevent overtopping or siphoning from gravity fed system effects.

It is also good practice for level management systems to have the capability of alarming or alerting operators not only when full but also when unexpected events occur. Such event may include;

- Loss of signal
- Unexpected change in level – particularly where no decline in leachate level in a tank is expected (remote storage tanks should only show a decline in levels in response to tankering from the site – so it is unlikely that a decline in level should occur between 18:00hrs and 07:00 hrs)
- Too long or too short event duration

Standalone storage tank design

Leachate storage tanks should be of sufficient capacity to fulfil their design function. For instance, if the tank is intended to provide a bulking up facility prior to removal by road tanker then the storage tank volume should be at least the same as that of the road tanker, ideally several times the volume.

Off waste leachate storage tanks should be bunded to a volume 110% of the capacity of the primary storage tank or as otherwise justified. Ideally the bund should be designed in such a way as to enable acceptance of spilt/leaking leachate whilst shedding rainfall away from the bunded containment.

Penetrations to storage tank bunds should be avoided where possible. Pipework should enter and exit the bund by passing up and over the top of bund walls. Where penetrations through the bund are unavoidable a water tight and tamper proof design should be used.

Tank construction materials should be justified by suitable risk assessment and should be designed to accommodate the structural loading required during operation.

Bunds can be fitted with sumps so that they can be kept free of accumulated liquid by use of permanently installed bund pumps or by regular manual bund emptying. In this way the required bund capacity can be maintained.

Tanks should be fitted permanent access gantries, ladders, crawl boards or similar so that the top of the tank and loading points within the bunded area can be easily and safely accessed.

Inlets and outlets to the tank should be through the primary tank roof. Attachment points for transferring leachate (such as Bauer Points) and features such as sight glasses should be located either within the bunded area or within separately bunded / spill protected areas external to the tank. Locations for equipment such as Bauer points, valves etc. should also be easily accessible but protected from accidental damage.

Tanks should be fitted with breather pipes that enable air flow in and out of the tank as it is filled and emptied to prevent pressurisation or vacuuming of the tank. Breather pipe should be constructed so that it can be easily connected to a suitable flammable gas or odour control system such as carbon filters (if ever required).

Sampling points may be fitted to tanks to enable safe sampling of their content. Consideration should be given to their design to prevent them from becoming potential points by which stored liquid can escape containment.

All manual valves associated with the tank should be capable of being securely locked to prevent unauthorised tampering.

Tankering points should be designed to enable the loading of the leachate to a road tanker. These loading / unloading points should be supported by a robust stand so that the pipework connecting the loading /

unloading point to the storage tank supports its own weight as this has the potential to cause failure of the pipework due to mechanical stress. Loading points should be fitted with breather valves so that loading pipework can be purged before disconnection. A sampling point must be fitted so that a representative sample of the stored leachate being loaded can be obtained. All of this equipment should be installed so as to be located within or over the secondary containment bund. This often leads to issues relating to the operability of tanks and may encourage temporary connection hoses to be left in place so as to avoid the need by tanker drivers to carry heavy pipework up tank access steps at every delivery or collection.

Further details of issues that need to be considered in the design of storage vessels are detailed in the document Sector Guidance Note IPPC S5.06 'Guidance for the Recovery and Disposal of Hazardous and Non Hazardous Waste'. Amongst other issues it specifically lists the following items for consideration in relation to bulk liquid storage vessels;

- Bulk storage vessels should be located on an impervious surface that is resistant to material being stored, with sealed construction joints within a bunded area with a capacity at least 110% of the largest vessel or 25% of the total tankage volume, whichever is the greater.
- Vessels supporting structures, pipes, hoses and connections should be resistant to the substances (and mix of substances) being stored. There should be a routine programmed inspection of tanks, mixing and reaction vessels including periodic thickness testing. In the event of damage or significant deterioration being detected, the contents should be transferred to appropriate storage. These inspections should preferably be carried out by independent expert staff, and written records should be maintained of the inspection and any remedial action taken.
- Vessels should not be used beyond the specified design life or used in a manner or for substances that they were not designed, Vessels should be inspected at regular intervals, with written records kept to prove that they remain fit for purpose. See HSE Guidance Note PM75.
- As a general rule, no open-topped tanks, vessels or pits should be used for storage or treatment of hazardous or liquid wastes. Exceptions would require justification in the permit application.
- Tank and vessel optimum design should be considered in each case, taking into account waste type, storage time, overall tank design and mixing system to prevent sludge accumulation and to ease desludging. Storage and treatment vessels should be regularly desludged.
- Tanks and vessels should be equipped with suitable abatement systems and level meters to alert the management staff either at the facility and/or remotely from the installation. Industry operators recognise that in moving to a portfolio of closed, largely unmanned landfills during the site's aftercare phase, reliance on traditional audible and visual high-level alarms may have limited value in promoting early intervention by the site's management team when alarm events occur. All systems should be sufficiently robust and regularly tested and maintained to ensure the reliability of the gauges/systems selected along with clear documented management plans to respond to alarm events.
- All connections between vessels must be capable of being closed via suitable valves. Overflow pipes should be directed to a contained drainage system, which may be the relevant bunded area, or to another vessel provided suitable control measures are in place.
- Underground or partially underground vessels without secondary containment should be scheduled for replacement with above-ground structures.
- Pipework should preferably be routed above ground; if below ground it should be contained within suitable inspection channels and be secondary contained or if this is not possible regularly tested for leaks.

Standalone storage tanker bay design

The location of the storage tank within the site should be made on a risk based approach whilst taking the following in consideration;

- Tanker Access: Storage tanks will need to be accessed by tankers so the turning circle of such a vehicle should be taken into account. Ideally the tank location will accommodate a sufficiently large turning area so that an articulated tanker can arrive, load and then exit without the need for 'shunting' in a restricted area.
- Traffic: If located adjacent to other site roads the possibility of traffic disruption during tanker loading and turning should be considered.

- Site Development: A location for the tank should be chosen with consideration to the development of the landfill. Locations should be avoided that will mean the tank is likely to be in the way of future development or that will leave the tank in an isolated or difficult area to access in future.
- Supervision / Inspection: Locations close to permanently/frequently manned locations should be considered.
- Spillage Risk: Storage tanks should be located as far as possible from sensitive receptors such as water courses, drains, unprepared surfaces etc. When selecting a suitable location consideration should be given to where the leachate would run to if it were to escape from the engineered containment e.g. if a tank is located at the top of a slope, what is at the bottom?

A delivery bay should be constructed to house the tank and its associated tanker loading equipment and loading bay / turning area. This compound should be;

- Clearly Defined: Distinct from the surrounding area to ensure that its extent is obvious in order to discourage other uses of the area that may interfere with tanker access etc or the tankering operation encroaching on other areas. The compound should also be clearly and suitably signed to make clear its function, the risks involved and any site specific instructions (loading procedures, emergency contact numbers, traffic management and location of spill kits) should be prominently displayed.
- Impervious Surfaces: The ground should be level, free from extreme cambers and capable of providing a firm and stable base for the tanks proposed for the location. Wherever possible the tank compound should be located on an impervious or on low permeability materials such as concrete etc. Ideally the whole area associated with the storage tank and loading bay should be impervious and contained with appropriate bunding or kerbing. Where this is not possible a risk assessment should be carried out to define alternative solutions to minimise the consequence of an un-controlled release / spill of leachate. Typically this will include (but not be limited to) a suitable drip tray / spills sump below the loading point and rear end of the tanker when at the loading point.
- Storage Volume: Loading and unloading is probably the greatest failure risk. Containment should be provided to the tanker bay equivalent to the volume of the tanker plus an appropriate allowance for rainfall;
- Drainage: The location should be kept free from standing water / mud etc. This is so that there are no H&S implications (submerged hazards, slips and falls, splashes of potentially contaminated liquids etc.) for tanker drivers and other personnel who will be working in the area. It also reduces the impact of any accidental spills into pre-existing water bodies, which would increase the volume of contaminated materials to manage. Finally, a water logged loading area encourages poor practices such as temporary steps / pontoons, use of temporary pipework to access locations and other such accommodations that may lead to an increased risk of accidents.
- Protected from Impact Damage: The tanker loading bay and tank compound should incorporate tank protection such as bollards or bump banks etc. so that the tank and its bund are fully protected from physical damage or uncontrolled entry by other vehicles.
- Secure: The compound / delivery bay should be located within site security fencing or, within its own fenced area to prevent unauthorised access.
- Housekeeping: Temporary hoses (such as the flexible armoured pipes with Bauer fittings used to load tankers, ‘lay-flat’ hoses etc.) must be used only during the loading/un-loading of the tank. Once the active loading or un-loading has ceased all temporarily connected pipework must be removed and stored in a suitable location where any residual liquids within them will remain contained.

Appendix D – Assessment & Future Management of Existing Installations

Further details that could be undertaken by operators who identify installations that are failing include the following;

1. Introduce inspection and maintenance plans for the installation;
2. Undertake a 'base-line' survey of the installation to retrospectively define 'as-built' details;
3. Note any defects in primary or secondary containment and locate them on site plans. Typical issues to include are as follows:
   Where both primary and secondary containment exist, evidence of;
   - Primary and secondary storage volumes
   - Visual leaks
   - Spalling of concrete or brickwork
   - Signs of corrosion
   - Failure of seals or joints
   - Aging of sealants
   - Misalignment of tank or bund walls
   - Slumping (or soil bunds)
   - Damage from flora / fauna
   - Torn or damaged liners
   - Deterioration of coatings / de-bonding of surfaces
   - Location and routing of pipework
   - Loading facilities and their containment
4. Where secondary containment does not exist or only partially exists;
   - Where no secondary containment is present, note primary containment volumes that may need to be contained
   - Where only partial or inadequate containment is present, note the extent of existing containment and the primary tank volumes that would be contained by it and those that would not
   - Note available space for installation of bunding and physical restrictions that may limit or prevent retrospective installation
5. Assess other relevant infrastructure;
   - Presence of drainage infrastructure
   - Means of emptying rainwater
   - Leakage detection systems
6. Complete a risk assessment for the plant (for example as detailed in Appendix D) to establish 'ideal' nature of containment to be provided;
7. Assess and rank required works to improve standards of containment;
   Where secondary containment is present consider the following
   - Improve structural stability of bund walls by adding internal or external supports;
   - Improve impermeability by adding liners or low permeability surfacing;
   - Remediate any failed seals and joints;
   - If possible remove and seal bund penetrations, reduce number if not possible to remove;
   - Introduce bund sensors and pumps;

   Where secondary containment is present but inadequate;
   - Increase bund volumes by removing unnecessary infrastructure from within the bunded area
   - Consider the acceptability of increasing bund wall heights
   - Consider installation of tertiary bunded areas with suitable transfer system

   Where secondary containment is absent
   - Consider practicalities of installation of a low permeability surface between and around existing primary storage tanks;
   - Consider installation of bund walls to low permeability surfaces;
8. Produce a programme of works to undertake improvements.

END OF DOCUMENT