TECHNICAL NOTE

Reading STW – IED Containment

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Secondary Containment	[project no]	8th January 2024

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Document history

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Client signoff

Client	Thames Water Utilities Ltd		
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1. Introduction

AtkinsRéalis were tasked to undertake a high level BAT assessment for secondary containment at Reading STC and the provisions within Best Available Techniques' (BAT) for waste treatment under the Industrial Emissions Directive (IED) [1] with specific regard to BAT 19 and CIRIA C736 [2]. This could be used to inform whether the provisions for secondary containment within the existing permit for Reading STC could be re-visited as part of the updated BAT assessment.

The EU's Industrial Emissions Directive (IED) [1] takes an integrated approach to controlling pollution to air, water and land, and sets challenging industry standards for the most polluting industries. The IED aims to prevent and reduce harmful industrial emissions, while promoting the use of techniques that reduce pollutant emissions and that are energy and resource efficient.

Applicable facilities are required to use 'Best Available Techniques' (BAT) to prevent or minimise emissions and impacts on the environment. 'Techniques' include both the technology used and the way the installation is designed, built, maintained, operated and decommissioned. BAT reference documents (BREFs) [3], informed by BAT Conclusions, contain emission limits associated with BAT, which must not be exceeded unless agreed.

This Technical Note seeks to identify the relevant provisions within the BAT conclusions, BAT reference document for waste treatment, other guiding documents and CIRIA, and therefore identify what the storage volumes of secondary containment need to be and how this applies to Reading STW to assess / inform whether the provisions for secondary containment within the existing permit for Reading Sludge Treatment Centre could be re-visited.

2. Applicable provisions for secondary containment

2.1 Waste Treatment BREF document

The published Waste Treatment documents [4] cover:

- common waste treatments such as the temporary storage of waste, blending and mixing, repackaging, waste reception, sampling, checking and analysis, waste transfer and handling installations, and waste transfer stations.
- biological treatments of waste such as aerobic/anaerobic treatments and mechanical and biological treatments.
- physio-chemical treatments of waste such as dewatering, filtration, oil/water separation, precipitation, solidification and stabilisation.

Specifically, the sections of BREF that detail how secondary containment should be managed:

- Section 2.3.11 Techniques for the prevention and reduction of soil and water contamination
    - Having in place **containment measures to prevent wastes from escaping**. All bunds, humps, vessels, tanks, pipes, containers are sound, and maintained and checked as required.
    - Providing and then maintaining the **surfaces of operational areas**, including applying **measures to prevent or quickly clear away leaks and spillages**, and ensuring maintenance of drainage systems and other subsurface structures.
    - **Depending on the risks** posed by the waste in terms of soil and/or water contamination, making the **surface of the whole waste treatment areas** (e.g., waste reception, handling, storage, treatment and dispatch areas) **impermeable** to the liquids concerned.
    - **Depending on the risks** posed by the liquids in terms of soil and/or water contamination, ensuring that the areas where **liquids are transferred are bunded** and that the bund is resistant to stored materials. The bund is designed so that in the event of an accident the liquid can be contained until security measures are in place. The **bund has sufficient capacity** to cope with any spillage and firefighting water (it is **normally sized to accommodate the loss of containment of the largest tank** within the secondary containment) and is used to ensure containment of wastes and raw materials.
- Section 6.1.5 Emissions to Water (BAT19)
    - Technique D - Techniques to reduce the likelihood and impact of overflows and failures from tanks and vessels - **Depending on the risks posed** by the liquids contained in tanks and vessels in terms of soil and/or water contamination, this includes **techniques such as**:
        - overflow detectors.
        - overflow pipes that are directed to a contained drainage system (i.e., the relevant secondary containment or another vessel).
        - tanks for liquids that are located in a suitable secondary containment; the volume is normally sized to accommodate the loss of containment of the largest tank within the secondary containment.
        - isolation of tanks, vessels and secondary containment (e.g., closing of valves).

  - Technique H - Design and maintenance provisions to allow detection and repair of leaks - Regular monitoring for potential leakages is risk-based, and, when necessary, equipment is repaired. The installation of **secondary containment for underground piping may be limited in the case of existing plants**.
- Emissions from Storage (guidance for BAT implementation) [5] specifies that secondary containment must be coated with an impermeable material and have the same height as the maximum liquid level, **a total capacity 25% greater than the capacity of the associated tank or sufficient capacity to accommodate the loss of containment of the largest tank** within the area covered as applicable.

2.2 Control of Major Accident Hazards Regulations (COMAH)

The main aim of the Control of Major Accident Hazards Regulations [6] is to prevent and mitigate the effects of those major accidents involving dangerous substances that can cause serious damage/harm to people and/or the environment. COMAH ensure that businesses and duty holders:

- take **all measures necessary** (AMN) to prevent major accidents involving dangerous substances,
- limit the consequences to people and the environment of any major accidents that do occur.

AMN must be in place '**so far as is reasonably practicable**' (SFAIRP) to prevent environmental harm and in particular a 'major accident to the environment' (MATTE). AMN are interpreted to require use of good practice for pollution prevention, and these are deemed to be in place when the risks are demonstrated to be either 'broadly acceptable' or ALARP. The HSE definition states:

*"ALARP, 'as low as reasonably practicable', [enables the regulator] to set **goals** for duty-holders, **rather than being prescriptive**. This flexibility is a great advantage, but it has its drawbacks too. Deciding whether a **risk is ALARP can be challenging because it requires operators and regulators to exercise judgement**. In essence, making sure a risk has been reduced **ALARP is about weighing the risk against the sacrifice needed to further reduce it**."* [7]

2.3 Environmental Permitting Regulations

The Environmental Permitting Regulations (England and Wales) [8] recognises the potential harm that can be caused by accidental releases from primary containment vessels and a condition of the permit will be the **provision of secondary containment or other appropriate measures** to prevent or minimise leakage from the primary container.

No specific recommendation is made on containment capacities, however, where there is potential for significant pollution to occur an emissions management plan is required informed by an environmental risk assessment. The outcome of the risk assessment determines the containment or other measures that may be required.

2.4 Biological waste treatment: appropriate measures for permitted facilities.

This guidance [9] explains the standards (appropriate measures) that are relevant to permitted waste management facilities that handle organic waste, also known as biowaste. The guidance explains that there is overlap between best available techniques (BAT) for waste installations and necessary measures for waste operations. The Environment Agency uses the term 'appropriate measures' to cover both sets of requirements. The guidance sets out what you **must** consider when assessing the appropriate measures for a facility, it also allows alternative measure to be proposed but they must achieve the same level of environmental protection and provide the evidence to support this.

Section 4.2 provides guidance on primary and secondary containment and states:

Existing sites

16. Operators of existing sites **must use a chartered engineer** to carry out a detailed **assessment of primary and secondary containment** where it has not previously been validated to industry recognised standards.
17. You **must assess containment structures against CIRIA 736**. This is a risk-based assessment. Where you have not used CIRIA 736, the assessment must be an equivalent approved standard. Where improvements are identified, you must propose an improvement programme or process monitoring to make sure there are no uncontrolled process releases.
18. You **should monitor underground pipe work** or ducting and drainage to make sure there is no leakage.
19. **Underground tanks <u>should</u> have secondary containment**. You **<u>must</u> implement a method of inspection and leakage detection** as a minimum.

2.5 CIRIA C736 Guidance Document

CIRIA C736 [2] was published in 2014 to provide practical guidance on containment systems around best practices on spill prevention, mitigation, and response following several incidents including the Buncefield Fire. The guidance advocates a risk-based approach to managing the storage of inventory appropriate to the regulatory regime within which a site or facility is operating.

Secondary containment minimises the consequences of a failure of the primary storage by preventing the uncontrolled spread of the inventory. Secondary containment is achieved by equipment that is external to and structurally independent of the primary storage, for example concrete or earth bunds around storage tanks, or the walls of a warehouse storing drums.

Clause 1.3.3 states that "*The application of this guidance to existing facilities should be **based on risk**, and any upgrades completed to reduce risk sufficiently to satisfy the law and to be in accordance with guidance under the relevant legislative regime. Upgrades may be subject to as **low as reasonably practicable (ALARP) and/ or best available techniques (BAT)** 'tests' and **supporting cost-benefit analyses (CBA)** depending on the legislative regime (COMAH, EPR etc). It is, however, recognised that **the costs of upgrading existing facilities might outweigh the environmental benefits**, and therefore not be viable, or that other equally effective risk reduction measures to those suggested in this guidance may be implemented*".

Details on estimating containment capacity for local systems can be found in 7.Appendix A.

2.6 WINEP – Options Development Guidance

Introduction of the Industrial Emissions Directive [1], as transposed into the Environmental Permitting Regulations [8], is not seen by the Environment Agency as a new obligation arising from environmental legislation. As such this is not included within the Water Industry National Environment Programme (WINEP) [10].

However, if IED provision had been included in the WINEP for PR24 the industry would have had to follow the WINEP Methodology. The WINEP options development guidance [10] sets out the 6 principles water companies should follow when developing the WINEP options:

- Environmental net gain – **quantifiable benefits** to the environment and society.
- Natural capital approach.

- Catchment and nature-based solutions – where feasible.
- Proportionality - **options** to address the environmental risks and issues ensuring the full range of benefits and opportunities are identified.
- Evidence - **evidence based** and transparent.
- Collaboration - collaborative approach with regulators to understand the environmental risks.

It also sets out the evidence required to support the options development and sets out how to evaluate **costs and benefits** of WINEP options to support consistency across water companies.

A **best value plan** is one that considers factors alongside **economic cost** and seeks to achieve an outcome that increases the overall **benefit to customers, the wider environment and overall society**. A best value plan should be efficient and affordable to deliver, legally compliant and account for the range of legislation that applies to it.

In developing the best value plan the methodology requires development of a fully unconstrained list of options, which are then screened against:

- Expected to meet statutory obligation(s) or meet non-statutory requirements.
- Contribute to the WINEP wider environmental outcomes.
- Be technically feasible.
- Be deliverability.

This short-list is then further assessed to leave a list of feasible options. Importantly this stage requires a whole life calculation of costs and benefits (including environmental benefits and dis-benefits using natural capital metrics) calculated over 30 years considering opex and capex to be completed.

From the feasible options a preferred, lowest cost and up to 2 alternative options are submitted for review and consideration by the EA.

3. CIRIA C736 - Risk Assessment and Containment Classification Approach

3.1 Risk Assessment

Risk is a combination of **consequence** and the **likelihood** (or probability of occurrence) of that consequence. Consequence can be further defined in terms of the extent of harm and the severity of harm.

CIRIA C736 [2] recognises the fact that there is always a finite risk of a loss of primary containment, for example error in design, structure behaviours differently that expected, construction error etc as well as changes over the asset life due to O&M issues.

The general framework for the risk assessment is a three-step approach:

- Step 1 applies the source– pathway–receptor model to the site to assess the hazard presented by the inventory to the surrounding environment.
- Step 2 considers the likelihood of a loss of containment. This will depend on several factors such as the reliability of the operations and inspections undertaken on site, the conditions of the primary storage vessels and the degree they are protected from impact damage etc.
- Step 3 uses the likelihood of a loss of containment and combined with the site hazard rating which leads to a recommendation for an appropriate class of containment.

The **Source** considers such things as:

- The inventory being contained and its potential impact as a pollutant if released,
- Environmental Harm Index (EHI) – a function of the sensitivity of the receptor, severity of the impact, extent of the impact and duration it could last for.
- Toxicity Hazard Assessment

Pathway considers the means by which a substance would reach the receptor and looks at het topography, geology and hydrogeology of a site and the proximity of receptors. In addition, climatic conditions are considered as these can impact the way and speed that substances can reach receptors.

Receptors includes humans, animals, fish, plants and biota, watercourse or body, groundwater or soils. that would be affected (directly or indirectly) by the escape of the inventory. A receptor could also be a downstream process such as a WwTW, which could be impacted if the substance overloads that process.

The three factors are now combined to obtain an overall **site hazard rating** designated as high, moderate or low.

To assess the risk, it is necessary to consider the events that may lead to the release of inventory from the primary containment and the likelihood that this would occur.

The potential failures and the reasons for failure are stated to include:

- operational failures, such as failure of plant, or human failure by operators
- shortfalls in design – lack of alarms and fail-safe devices
- structural failure – materials, components, detailing, corrosion or when exposed to heat and flame.

- abuse – inappropriate change of use or other misuse
- impact, e.g., from a vehicle
- vandalism, terrorism, force majeure etc
- flood, fire or explosion
- geological factors -subsidence etc
- ageing or deteriorating assets/sub-components.

By analysing the events and circumstances that may affect a site it is possible to arrive at an assessment of the probability of a loss of containment and release of inventory expressed as low, medium or high. It is unlikely to be possible to precisely estimate the probability of a failure of the primary containment due to the inherent uncertainties involved, and as such the guidance gives the following probabilities outlined in Table 3-1:

Table 3-1: CIRIA C736 Containment risk probabilities

Loss of containment risk	Annual Probability
High	Greater than 1% (1 in 100)
Medium	Between 1% (1 in 100) and 0.001% (1 in 1 million)
Low	Less than 0.001% (1 in 1 million)

The loss of containment risk is combined with the source– pathway–receptor risk to give an overall site hazard risk outlined in Table 3-2:

Table 3-2: CIRIA C736 Site Hazard Risk Categorisation

Site Hazard Risk	Combined risk (containment loss/S-P-R)
High	HH, HM, MH
Medium	MM, HL, LH
Low	LL, ML, LM

An alternative method that CIRIA C736 refers to combines EHI with likelihood of occurrence (frequency) and has three zones showing where mitigation would be required:

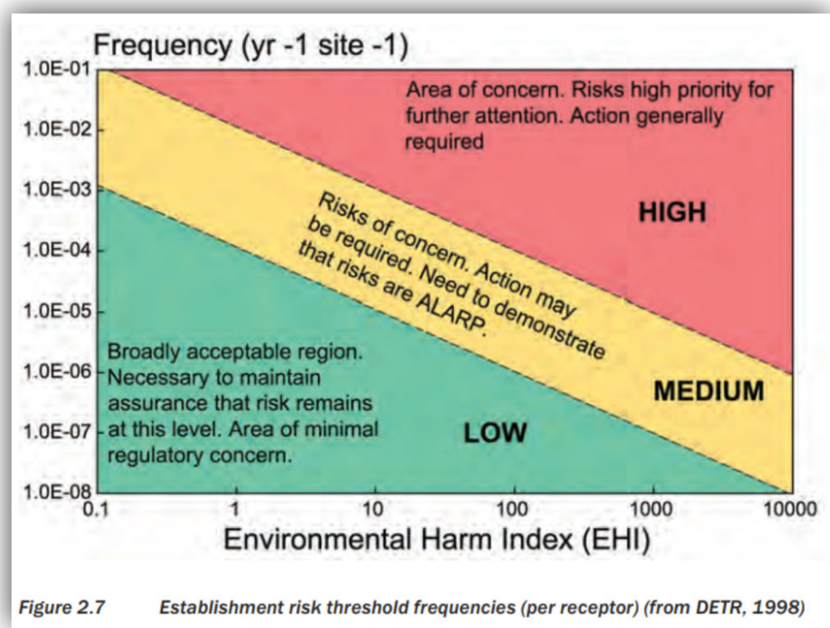


Figure 2.7 ***Establishment risk threshold frequencies (per receptor) (from DETR, 1998)***

Figure 1: Risk / frequency model from CIRIA C736

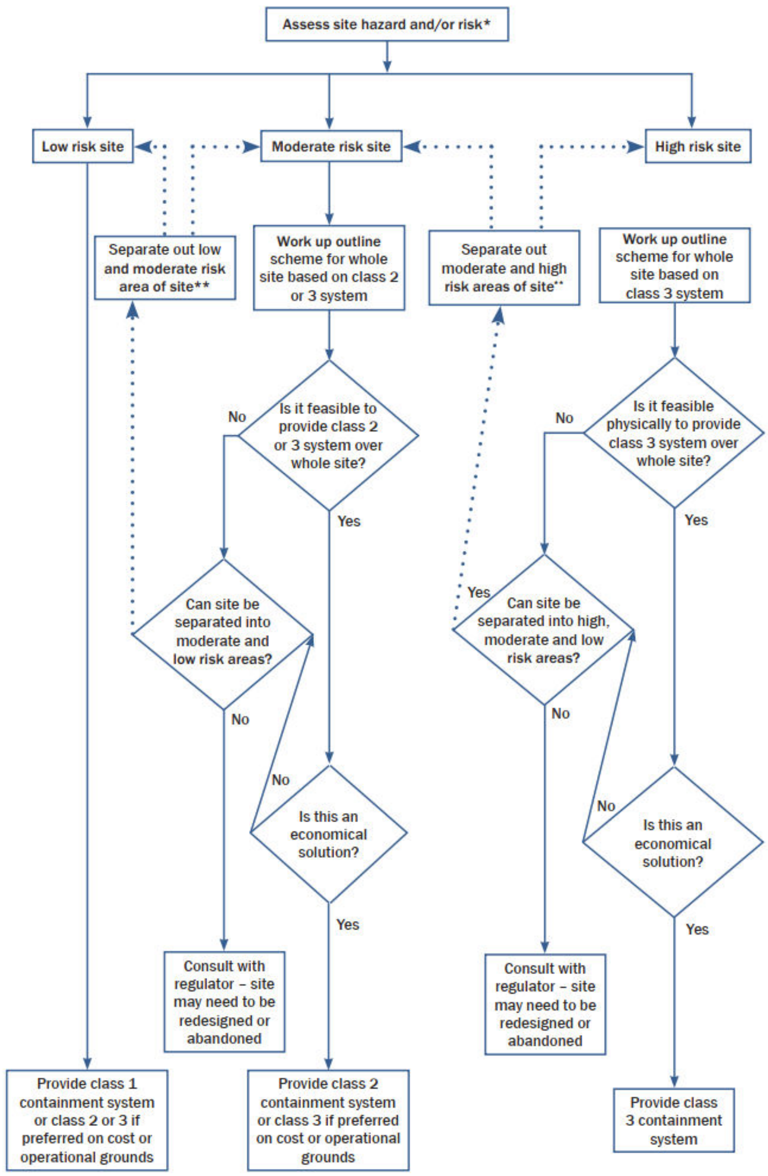
3.2 Containment Classification System

Based on the results of the risk-based assessment, the guide then provides specific recommendations for managing the assessed level of risk appropriate to the class of containment. Recommendations cover design, construction and performance considerations with increasing requirements corresponding to the three classes in terms of design and construction integrity:

- low overall site risk containment type class 1, i.e., base level of integrity,
- moderate overall site risk containment type class 2, i.e., intermediate degree of integrity,
- high overall site risk containment type class 3, i.e., highest degree of integrity.

The site classification uses a flowsheet (Figure 2) to identify the containment class that should be provided at a site.

Figure 2: CIRIA C736 Containment System Classification



Notes

* The expression 'hazard and/or risk' is abbreviated to 'risk' in the flowchart.

** Beyond these points in the iteration, for 'site' and 'whole site' read 'area' and 'whole area' respectively.

Figure 2.8 Containment system classification

Class 2 and Class 3 containment systems, located on sites classified as relatively medium and high overall risk, respectively, include more detailed recommendations compared to Class 1 containment systems which are located on sites classified as low overall risk. The guide further provides increased requirements for classes 2 and 3 in terms of testing, inspection, and maintenance of the containment system to ensure ongoing integrity.

The guide recommends that the risk assessment and capacity requirements of secondary containment should be routinely reviewed in accordance with the specific methodology set out in the report, but as minimum this should be undertaken every five years or where *'there are any modifications made to the primary or secondary containment; the volume of material in the primary containment is increased; the nature of the material in the primary containment is change/reclassified; or the potential pathways and/or receptors have changed.'*

Once the class secondary containment system has been validated, it is recommended that a gap analysis exercise be conducted to identify any deficiencies in the system's design or operation against criteria that are specific to its containment class. This exercise also includes determining the necessary improvements to ensure that the identified risks have been managed sufficiently to comply with the law. Where the class of a secondary containment facility has not been determined (e.g., for pre-1994 and small sites) the guidance stipulates that a baseline asset survey should be completed by competent personnel to identify and evaluate the effectiveness of existing control measures, irrespective of class, to then allow classification by the CIRIA C736 risk-based methodology.

3.3 Containment system capacity

Where the site hazard assessment shows that there is a risk to receptors from loss of containment, secondary containment systems are required. The size of the containment system has to be sized on a most likely credible failure scenario so that it is efficient (i.e., economic in terms of resources) and adequate (i.e., has the required capacity to store the spill).

3.3.1 The ‘110%’ and ‘25%’ rules

Within CIRIA there is reference to a simplified sizing method has been used as an industry ‘rule of thumb’ historically, however this **does not follow the CIRIA recommended risk-based approach** (see CIRIA C736 section 4.2.1 paragraph 1). This method employs:

- Where a single bulk liquid tank is bunded, the recommended minimum bund capacity is 110% of the capacity of the tank.
- Where two or more tanks are installed within the same bund, the recommended capacity of the bund is the greater of:
    - 110% of the capacity of the largest tank within the bund.
    - 25% of the total capacity of all of the tanks within the bund, except where tanks are hydraulically linked in which case they should be treated as if they were a single tank.

3.3.2 CIRIA C736 Recommended Approach

The CIRIA C736 recommendations on estimating capacity for local systems (designated areas surrounding primary storage vessel to contain spills) can be summarised as follows:

- Allowance based on risk assessment of a credible spill scenario while accounting for tertiary containment (measures for additional level of spill protection such as diversion tanks and lagoons) and where applicable fire-fighting waters.
    - For single-tank installations minimum capacity of 100% of the primary containment volume.
    - For multi-tank installation capacity based on risk assessment around credible scenario
- Allowance for total volume of accumulated rainfall with annual exceedance probability (AEP) of 10% (if uncovered) with a minimum retention period of eight days.
- Minimum freeboard (increased height to account for uncertainty factors) of 100 mm for firefighting agents (e.g., foams).
- Freeboard allowance for dynamic effects which varies depending on the type of containment structure e.g., 250 mm for secondary containment tanks.

Additional allowances, such as the provision of sufficient capacity to manage firefighting and cooling water, are also included in containment capacity estimates for remote systems (designated areas located away from spilling or leaking equipment) and combined systems, which contain elements of both local and remote systems along with the means of collecting and transferring spills.

The CIRIA C736 further states:

> "*The designer of the containment system should take into account the probability of a number of events occurring simultaneously. The worst-case scenario for containment is represented by the design return period rainfall (e.g., the rainfall that is likely to occur, e.g., once in 10 years) coinciding with the sudden and total loss of primary containment and a fire involving applied firefighting water. At low-risk sites or sites where it can be demonstrated that the probability of a simultaneous occurrence of events is sufficiently low, it may be possible to apply less stringent capacity requirements. Such relaxations should be subject to the designer's and site operator's discretion and the agreement of the various regulatory bodies in the light of the particular circumstances.*"

Which implies that if the designer can demonstrate that the risk of worse-case scenario is low then a lower level of containment could be proposed.

4. Discussion point

The EA have stated that they expect relevant guidance (e.g., CIRIA C736) be adhered to for new and existing facilities and have advised that adherence to the more conservative 110%/25% rule is expected rather than a risk-based approach.

BREF states that secondary containment should be able to accommodate the total volume from the largest tank within the containment area, and a risk-based approach should be followed to assess the impacts of containment failure.

Whilst CIRIA C736 discusses the 110%/25% rule it doesn't recommend this as a blanket approach and suggests a site-specific risk assessment is more appropriate to ensure that secondary containment is efficient and adequate.

The CIRIA C736 approach (e.g., 110%/25% rule) may result in costs greater than those if only BREF requirements (largest tank volume) were met. However, it should be noted that CIRIA C736 was developed prior to BREF being released and was based on UK containment experiences and as such does go further than the later recommendations of BREF. The EA have used CIRIA C736 in their interpretation of BREF requirements at a national level for all new permit applications, as they have done historically.

Whilst CIRIA C736 has wide applicability, Section 1.2 of the guidance describes issues that are not covered in the guide. This specifically states that "sewage and sewage effluents, farm waste and related materials" are excluded as "Stored inventory".

The guidance also notes in Section 1.1.3 that the "costs of upgrading existing facilities might outweigh the environmental benefits, and therefore not be viable, or that other equally effective risk reduction measures to those suggested in this guidance may be implemented".

As such there is precedence within BREF and CIRIA C736 that suggests site specific risk assessment should be carried out to ascertain the most cost beneficial secondary containment solution, while providing an acceptable level of environmental protection. Neither document state that the solution must provide total environmental protection, rather as low as reasonably practical.

5. Findings

The review of the relevant documents detailed in Section 2 and following the Risk Assessment and Containment Classification approach in Section 3, the impacts at Reading on the most credible primary containment failure are detailed in Table 5-1 below. This shows that it is unlikely that there will be a catastrophic failure of the largest storage vessels due to their construction, age and condition. However, there is a medium risk that a lower level of containment loss (leak) or a slower release (failure of a pipe penetration) could occur. In addition, the arrangement of these tanks would unlikely cause a cascade failure of other tanks. As such the ‘rule of thumb’ consideration of 25% of total tank volume is not a credible solution and worse case would be 100% loss of the largest tank.

Furthermore, this risk is low and could be manged via more local secondary containment around the higher risk pipe penetration areas. The remaining area around the tanks could be laid to hardstanding fed to a drainage system back to the adjacent WwTW should minor leakage occur from the entire tank. A full risk assessment based on CIRIA C736 methodology can be seen in Section 7.Appendix A Reading Site Specific Risk Assessment.

The failure mode analysis using the CIRIA C736 recommended risk-based approach suggests that the site is MEDIUM risk and therefore a lower level of containment might be acceptable to offer the same level of environmental protection. Furthermore, a review of the credible failure modes shows that the failure of multiple assets simultaneously is unlikely and therefore a secondary containment system of 110% of the largest single tank, in line with BREF, is more appropriate.

Table 5-1 - Risk Assessment and Containment Classification

	Failure at a penetration (pipe or mixer)	Fire and/or explosion	Overflow/spill	Adverse pressure build-up (burst or negative pressure collapse/inwards buckling)	Corrosion	Leak	Mechanical (physical) failure	Equipment failure	Tank impact (e.g., vehicle)	Operator / human error
Impact at Reading	There are low level penetrations into the tanks for the feed pipe and the mixing system. These were cast during the construction of the insitu reinforced concrete tank with correctly designed thrust and water stops. On the glass fused to steel tanks, these were all installed during manufacture/construction and have the correct level of strengthening around the opening. The stub pipes have bolted flanges attached to isolation valves. The orientation of the pipes is away from the bank of tanks, thus reducing risk of jetting adversely impacting/damaging other tanks. The tanks have been in service for 20-years and have not shown any sign of failure of these penetrations. Visual inspection is carried out during site walk-arounds to look for sign of damage, missing bolts, leakage and none have been identified.	Biogas is contained in separate gas holders protected by catenary lightening conductors to reduce risk of explosion/fire from lightening strikes. Robust procedures in place to avoid risk of biogas release and working in zoned areas is controlled by Permit to Work system	Overflow from tanks is monitored by level protection inside tank and for the primary digesters there are pressure release valves on roof. Both are monitored and alarmed to the site control room and remote operations centre. Other tanks on site are fitted with high level overflows to drains that return to the WwTW, these are also monitored with high level alarms and process inhibits to upstream pumping.	Pressure monitoring on pumps and tanks to mitigate risks.	Concrete tanks - so unlikely within life of assets. Glass fused to steel tanks are potentially prone to corrosion if the glass gel coat is damaged (such as through impact damage or scour due to process fluids) Regular inspections are carried out to look for surface pitting that if left unchecked could lead to panel failures. Damaged panels are replaced when identified.	Potential risk around joint failures, especially of construction mastic. Periodic replacement and resealing and monitoring for visual indication	Insitu reinforced Concrete tanks - so unlikely within life of assets Glass fused to steel tanks are potentially prone to corrosion if the glass gel coat is damaged (such as through impact damage or scour due to process fluids) Regular inspections are carried out to look for surface pitting that if left unchecked could lead to panel failures. Damaged panels are replaced when identified. Impact of failure of tank on adjacent tanks is negligible due to construction (e.g., RC, low pressure, slow release and orientation of most likely damage locations)	Potential risk around mechanical plant (pumps and valves) but generally low volume release	Very Low probability and protective barriers (armaco, kerbs etc) in place where there is a perceived risk	Potential for operator error, but online instrument and monitoring should identify process parameters before failure occurs
Likelihood	MEDIUM	LOW	LOW	LOW	LOW	MEDIUM	LOW	LOW	LOW	MEDIUM
Mitigation	- Frequent inspection of penetrations - Online instruments to protect against vibration/load - Design undertook full HAZOP study to understand failure modes	Fire alarms and containment in place already; Lightening protection to current standards	Not a risk due to arrangement of tanks	Not a risk due to arrangement of tanks	Not a risk due to arrangement of tanks	- Periodic inspection of tanks - Proactive repair of surface cracks and replacement of sealant	Not a risk due to arrangement of tanks - impact on adjacent tanks is negligible due to construction and orientation.	Proactive maintenance of ancillary equipment	Impact protection already installed	Proactive maintenance of ancillary and monitoring equipment Operator training
Potential containment solution(s)	Local hardstanding to road drainage; temporary spill containment systems; gulley sucker to clean up spills	No additional works	NONE	NONE	NONE	hardstanding around tank	Challenge to 125% of total volume as negligible likelihood of multiple tank failures. Single tank failure possible due to failure of ancillary equipment but this would only lose containment of single vessel. Therefore, recommend that 110% of single tank for overall secondary containment	NONE	NONE	NONE

6. Secondary Containment Solutions

Containment solution	CIRIA C736 Class	Strength	Weakness	Reading consideration
Full concrete bund wall around tank area	Class 3	▪ Local to tanks. ▪ Fully engineered containment system.	▪ Will need to be emptied to remove rainwater. ▪ Access into bund area will need stairs and lifting facility to move plant/machinery into area. ▪ Hinders easy operation of site as vehicle access not possible. ▪ Construction will interfere with ongoing operation. ▪	No, adverse impact on existing operation
Accessible concrete bund wall around tank area	Class 2/3	▪ Local to tanks. ▪ Fully engineered containment system. ▪ Access into bund area provided by vehicle gates.	▪ Will need to be emptied to remove rainwater. ▪ Access gates will need to be automated to avoid operator error in leaving them open.	Yes, mitigates permanent issues with access/egress
Earth bund around lagoon (impermeable surfaces)	Class 2	▪ Remote from tank area so construction may not impact operation. ▪ Fully engineered containment system.	▪ Will need to be emptied to remove rainwater. ▪ Transfer system required from tank area, thereby needed small local bund to tanks or around penetrations to capture initial spill.	No, topography difficult to provide this option
Earth bund around diffuse spill area (impermeable surface or sacrificial land)	Class 1/2	▪ Remote from tank area so construction may not impact operation. ▪ Engineered solution.	▪ Initial spill allowed to flow across natural surface area and contained within topography of site. ▪ Extended clean up following spill.	Yes, earth bunding to reduce risk of spill leaving site, with containment utilising topography of site, sites roads,

			▪ Some of spill will enter local drainage system	car parks and/or sacrificial grassed area.
Temporary bunding system (CIRIA C736 section 11.4)	Class 1	▪ Remote from tank area so construction may not impact operation. ▪ No permanent installation to hinder operation	▪ Initial spill allowed to flow across natural surface area and topography of site. ▪ Relies on operator intervention to install barriers after initial spill occurs	No, not a permanent engineering solution

7. Conclusion

The review demonstrates that a risk-based approach at Reading would still need secondary containment but smaller than the current permit requirements and further consideration of local containment and/or with operational intervention.

The current permit application process has been issued based on a single feasible solution, which is based on the worst case failure scenario. A cost benefit analysis of alternative options, which might provide the same degree of environmental protection but at a lower cost has not been accepted at this time as they were not submitted with the initial permit application. This is contrary to the WINEP methodology, and the risk-based approach recommended in CIRIA C736.

Analysis of the site using the ‘110%/25%’ Rule has demonstrated that an engineering solution can be provided but it is not cost effective and potentially provides more storage than the site requires. As such, using the CIRIA recommended approach shows that the site is medium risk and could provide the required environmental protection by only containing the largest tank volume.

In addition, the most credible failure mode is not a catastrophic tank failure, but rather a slower escape of material over time, due to leakage or a failure of pipe penetration. This could facilitate an operational solution whereby the spill is managed by temporary bunding directed to tertiary containment or controlled return to the adjacent WwTWs – whilst it is appreciated this is not in line with BAT/CIRIA, spill modelling over time could provide evidence that a spill at Reading could be managed without the need for permanent concrete bunding.

Provision of capacity for firefighting water is not required as the contained material is not flammable and therefore only consideration of the stored capacity and management of rainwater needs to be considered.

Appendices

Appendix A. Reading Site Specific Risk Assessment

A.1 Site Hazard Rating

	1	2	3	4	5	6	7	8	9	10
Type of failure modes	**Failure at a penetration (pipe or mixer)**	**Fire and/or explosion**	**Overflow/spill**	**Adverse pressure build-up (burst or negative pressure collapse/inwards buckling)**	**Corrosion**	**Leak**	**Mechanical (physical) failure**	**Equipment failure**	**Tank impact (e.g., vehicle)**	**Operator / human error**
Typical factors to facilitate the failure mode	Pipe stub at the penetration breaks/shears as a result of excess vertical loading: - Design deficiency results in differential settlement results in pipe/ancillaries all hanging off the stub rather than being supported elsewhere - Mechanical plant affixed to the stub generates fatigue due to significant vibration (failing bearings or the like) - Valve on outlet fails to operate to provide isolation. - incorrect detailing in original design	Ignition source - examples include - electrical issues with failure of component or fire in adjacent facility. - Gas and air mixture to ignite - unauthorised hot work in the vicinity of the zoned area - lightning strike	Overflow operation and discharge requires inflow to continue, and other exit routes being blocked	- Pressure relief valves blocked - Foaming is a typical element contributing to PRV failure - Failure of level instrument leading to overfilling and lifting of roof structure - Blockage of inlet but outlet pump continues to draw down volume	- Corrosion on internal surfaces (such as through scour from grit) results in water path to external surface. Corrosion exacerbates a weakness in the surface - external mechanical damage to glass coating on steel tank (such as through stone chips from grass cutting) can create corrosion path	- Pipework joint - relaxation of fittings or gasket position or gasket age - incorrect re-assembly of joint after maintenance - failure of joint sealant in construction joints - thermal cracking of concrete	-Corrosion of structural elements (e.g., post tension steel cables, carbonation/sulphite attack of concrete and rebar, loss of gas coating on steel tanks, unwinding of plastic tanks) - Gas holder (raising bell on guide) failure when guide mechanism failed, resulting in misalignment and gas escape. - Gas membrane brittleness leading to fabric cracking	- Failure of control system (monitoring and control instruments) - Valve failure on pipeline linked to tank - Pipe rupture (pressure impacts, erosion, corrosion, UV attack)	- Proximity to road - Driver error/failure to have vehicle leaving road at speed - Incorrectly designed protection barriers	- Incorrect operation of plant - driver failing to detach pipe from tanker discharge - shift handover failing to pass on communication of issues - Lack of training / inexperience
What type of tank / asset is this likely to occur on? (e.g., RC or glass coated steel?)	All tanks. - Glass coated steel more susceptible as has both the connection to the tank as well as the flange, and the tank shell is thinner. - Note that failures, occur when attached equipment not properly supported or a tank is modified, and the design not correctly assessed	Gas holders (membrane or steel bell type)		Glass coated steel tanks as excess pressure gives seeping at panel joints Negative pressures induce buckling. Concrete tanks have sufficient strength that walls not impacted	More likely on Glass Coated Steel tanks	All tanks	All tanks	All tanks	All tanks but glass coated steel tanks more susceptible due to thinner structural elements	All tanks
Age of tank? (any, over a certain age or asset condition?)	Risk will increase with age	Risk will increase with age - electrical assets over 20-yrs old likely to have higher probability of fire due to break down of electrical insulation	Risk will increase with age	Risk will increase with age	Risk increases with age - concrete tanks designed for a 60-year asset life whereas glass coated steel tanks have a nominal life of 20-years	Risk increases with age	Risk will increase with age - membrane gas holders have a nominal life of 15-yrs before deterioration of fabric	Risk increases with age		
Where on the tank / asset is it likely to fail?	- Failure location indicated by the penetration position. Tanks frequently fed at low level and drawn-off at high level - Failure due to the applied loading on the pipe rather than location on the tank	Explosion will lead to loss of containment of biogas, but tank containment not lost Fire examples are where external items caught fire and the fire spread - this is likely to lead to a stoppage of the process (especially if control panels are involved) but not a loss of containment within tanks	Tank does not catastrophically fail as overflow protects from excess loadings, but material will spill until overflow condition is stopped.	Any location where the pressure exceeds the safe working pressure in the system.	Both at the lower margin where potential construction impacts more likely and at the upper margins where fluid levels may vary allowing combined gas/fluid interaction	Any location	Any location	Any location	Generally, towards base of structure	Any location
What would size of failure likely be that would allow spilling? (circular aperture and diameter, crack and crack width-length, etc)	Typical 300-400 mm dia opening is common. May get an initial crack around two thirds of the pipe but failure could be rapid after crack formation	As above - does not impact the tank walls	Not a loss of primary containment	Opening of panel joints	Pin hole escapes in Glass Coated Steel tanks and weeping at fine cracks in concrete	Pin hole escapes in Glass Coated Steel tanks and weeping at fine cracks in concrete	Escape of gas rather than liquid containment		Generally, a catastrophic failure would incur if damage significant enough to impact structural integrity.	
What loss of liquid waste would we get spilling from the tank? How would it be lost? Volume, rate and risk to adjacent tanks?	- Potential for release of 90%+ of tank contents is real from lower penetrations. - Rate of discharge depends upon depth of liquid in the tank. Rate could be in range 500-700 l/s for the likely orifice size. - Risk is low due to rate of flow, time for tank to empty and directional nature of flow. - Risk to adjacent structures depend on pressure behind the flow and the direction of impact on adjacent structures - unlikely to have any impact on concrete structures only glass coated tanks	Volume of loss of biogas is dependent on the scale of the damage to the system, range from a minor emission to full catastrophic loss	Discharge of flow commensurate with the rate of inflow Does not threaten adjacent tanks	Leakage at joints - low rate of escape	Low rates of escape flow and low volumes escaping	Low rates of escape flow and low volumes escaping	Volume of loss is dependent on the scale of the damage to the system, range from a minor emission to full catastrophic loss	Low rates of escape flow and low volumes escaping	Generally deemed a catastrophic failure and loss of content of entire tank. Unlikely to have impact on adjacent structures as energy dissipated around vehicle	Low rates of escape flow and low volumes escaping
Impact on adjacent process tanks - would the failed tank be connected to other tanks? - How are they	Site specific - but generally tanks are not hydraulically linked as process fluid often pumped between them or set as	Fire may result in loss of process capacity but not loss of containment	Discharge of flow commensurate with the rate of inflow Does not threaten adjacent tanks	Site specific - but generally tanks are not hydraulically linked as process fluid often pumped between them or set	Site specific - but generally tanks are not hydraulically linked as process fluid often pumped between them or set	Site specific - but generally tanks are not hydraulically linked as process fluid often pumped between them or set as spill/fill, so largest loss would be 1 tank volume	Site specific - but generally tanks are not hydraulically linked as process fluid often pumped		Unlikely to have impact on adjacent structures	

connected? - Are there valves and/or bypasses?	spill/fill, so largest loss would be 1 tank volume			as spill/fill, so largest loss would be 1 tank volume	as spill/fill, so largest loss would be 1 tank volume		between them or set as spill/fill, so largest loss would be 1 tank volume			
Early warning indication what signs would we get of the failure? Visual, sensors? How long in advance? How could we monitor for these? And how regularly?	- Visual site tours looking for movement around penetrations or damage to pipe/valves, settlement around tanks - clear markers could help operatives notice changes - online instrumentation of flows and vibration monitors Weekly recorded inspection and more thorough annual external inspections	- Fire alarms in relevant locations (e.g., within CHP unit housing) - Condition checks on fuel lines and firebreaks - level indication in fuel sumps - Lightning protection systems in working order (site wide) - catenary wire system over gas holders -	Level sensor in tank giving overflow level and alarm	- Feed/draw off pumps fitted with pressure protection that will be set below safe working pressure in tanks - Pressure sensor would give ability to respond to issue and arrange isolation of flow. - Pressure relief valves fitted to digesters - Pressure test (water test) included as part of 5/10 year inspection for tanks	Visual inspection and NDT testing undertaken during 10-yr inspections	Visual inspection	Visual inspection - check on alignments	Visual inspection	Catastrophic event - no prior warning	Catastrophic event - no prior warning
Likelihood of this failure mode - HSE Ref. Failure Rate and Event Data for use within Land Use Planning Risk Assessments Is there a Reference/source of data? COMAH, CDOIF	Potential weak point of the system 6 failures recorded across (what would be the total number of tanks???? Say 100,000 in the UK) over a 8-9 year period (2010-2018)- so a likelihood of 6/ (800,000)	Electrical equipment installed into these areas is suitably rated (Ex). Low likelihood for this equipment failing. Tank contents at STW are not flammable. Risk of gas gives explosion, but materials do not burn.	Low - particularly when level controls in place as needing instrument failure and control failure	Newer tanks have multiple PRVs - increasing small probability	Tanks designed for appropriate asset life and inspected both internally and externally at prescribed intervals to identify issues.	Low volumes escape and are generally fixable before progressive failure occurs. Normally seen as seepage in joints or failed sealants both of which are patch repairable	Not typical for the sludge tank mechanisms - floating digester roofs are being replaced.	Routine maintenance and condition-based monitoring	Very Low probability and protective barriers (armaco, kerbs etc) in place where there is a perceived risk	Correct training and periodic refresher courses. Rotation of staff to know issues at other sites to cover shift rota's
Impact at Reading	There are low level penetrations into the tanks for the feed pipe and the mixing system. These were cast during the construction of the insitu reinforced concrete tank with correctly designed thrust and water stops. On the glass fused to steel tanks, these were all installed during manufacture/construction and have the correct level of strengthening around the opening. The stub pipes have bolted flanges attached to isolation valves. The orientation of the pipes is away from the bank of tanks, thus reducing risk of jetting adversely impacting/damaging other tanks. The tanks have been in service for 20-years and have not shown any sign of failure of these penetrations. Visual inspection is carried out during site walk-arounds to look for sign of damage, missing bolts, leakage and none have been identified.	Biogas is contained in separate gas holders protected by catenary lightening conductors to reduce risk of explosion/fire from lightening strikes. Robust procedures in place to avoid risk of biogas release and working in zoned areas is controlled by Permit to Work system	Overflow from tanks is monitored by level protection inside tank and for the primary digesters there are pressure release valves on roof. Both are monitored and alarmed to the site control room and remote operations centre. Other tanks on site are fitted with high level overflows to drains that return to the WwTW, these are also monitored with high level alarms and process inhibits to upstream pumping.	Pressure monitoring on pumps and tanks to mitigate risks.	Concrete tanks - so unlikely within life of assets. Glass fused to steel tanks are potentially prone to corrosion if the glass gel coat is damaged (such as through impact damage or scour due to process fluids) Regular inspections are carried out to look for surface pitting that if left unchecked could lead to panel failures. Damaged panels are replaced when identified.	Potential risk around joint failures, especially of construction mastic. Periodic replacement and resealing and monitoring for visual indication	Insitu reinforced Concrete tanks - so unlikely within life of assets Glass fused to steel tanks are potentially prone to corrosion if the glass gel coat is damaged (such as through impact damage or scour due to process fluids) Regular inspections are carried out to look for surface pitting that if left unchecked could lead to panel failures. Damaged panels are replaced when identified. Impact of failure of tank on adjacent tanks is negligible due to construction (e.g., RC, low pressure, slow release and orientation of most likely damage locations)	Potential risk around mechanical plant (pumps and valves) but generally low volume release	Very Low probability and protective barriers (armaco, kerbs etc) in place where there is a perceived risk	Potential for operator error, but online instrument and monitoring should identify process parameters before failure occurs
Likelihood	Medium	LOW	LOW	LOW	LOW	Medium	LOW	LOW	LOW	Medium
Mitigation	- Frequent inspection of penetrations - Online instruments to protect against vibration/load - Design undertook full HAZOP study to understand failure modes	Fire alarms and containment in place already; Lightening protection to current standards	Not a risk due to arranging of tanks	Not a risk due to arranging of tanks	Not a risk due to arrangement of tanks	- Periodic inspection of tanks - Proactive repair of surface cracks and replacement of sealant	Not a risk due to arrangement of tanks - impact on adjacent tanks is negligible due to construction and orientation.	Proactive maintenance of ancillary equipment	Impact protection already installed	Proactive maintenance of ancillary and monitoring equipment Operator training
Potential containment solution(s)	Local hardstanding to road drainage; temporary spill containment systems; gulley sucker to clean up spills	No additional works	NONE	NONE	NONE	hardstanding around tank	Challenge to 125% of total volume as negligible likelihood of multiple tank failures. Single tank failure possible due to failure of ancillary equipment but this would only lose containment of single vessel. Therefore recommend that 110% of single tank for overall secondary containment	NONE	NONE	NONE

The site hazard rating, looking at credible failure modes of the primary containment system has shown that there is unlike to be a catastrophic failure of a tank, and consequential impact on other tanks due to the most likely failure will have negligible impact – therefore this scenario would be deemed a LOW risk. However, operator error and gradual deterioration of assets over time resulting in leaks could happen which would raise the site hazard to **MEDIUM** risk.

A.2 C736 Containment risk probabilities

Table 7-1: CIRIA C736 Containment risk probabilities

Loss of containment risk	Annual Probability
High	Greater than 1% (1 in 100)
Medium	Between 1% (1 in 100) and 0.001% (1 in 1 million)
Low	Less than 0.001% (1 in 1 million)

Based on the credible failure modes above and an understanding of historic performance of the site where there have been negligible spills in the 20-years that the site has been in operation, the loss of containment risk is deemed as **MEDIUM**.

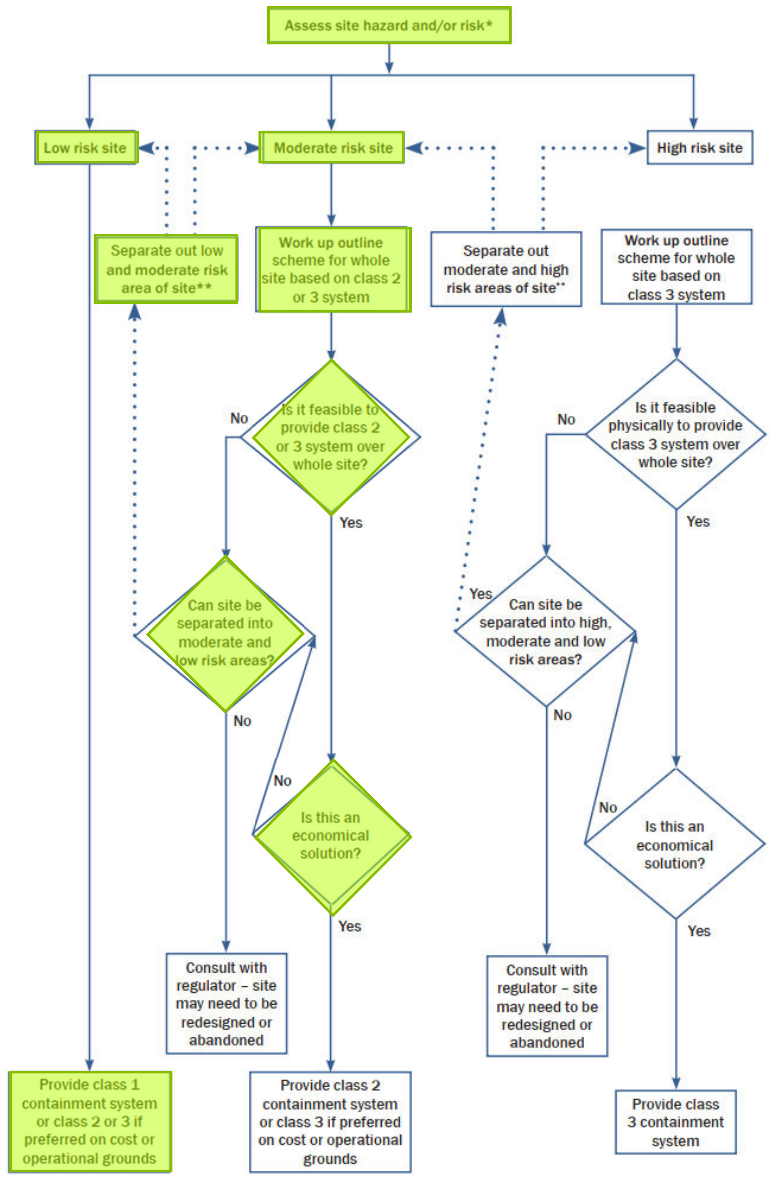
A.3 CIRIA C736 Site Hazard Risk Categorisation

Table 7-2: CIRIA C736 Site Hazard Risk Categorisation

Site Hazard Risk	Combined risk (containment loss/S-P-R)
High	HH, HM, MH
Medium	MM, HL, LH
Low	LL, ML, LM

Taking the Containment loss risk (medium) and Site Hazard Rating (medium), the overall Site Hazard Risk based on CIRIA C736 is **MEDIUM.**

Using the flowsheet from CIRIA C736 to assess the type of containment system required and the flood risk assessment modelling previously carried out for a catastrophic tank failure (using the 110%/25% Rule) the secondary containment system for the site is uneconomic to provide that for the entire permitted area. Therefore, the methodology recommends separating the area into medium and low risk areas and considering these separately.



Notes

* The expression 'hazard and/or risk' is abbreviated to 'risk' in the flowchart.

** Beyond these points in the iteration, for 'site' and 'whole site' read 'area' and 'whole area' respectively.

Figure 2.8 Containment system classification