Containment Assessment for Cambridge Sludge Treatment Centre

June 2022

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Executive summary

This study includes an assessment of the existing capacity available for accidental spills from Cambridge Sludge Treatment Centre (STC) and to identify potential high-level tertiary containment mitigation that could be implemented for the STC to comply, as far as is reasonably practicable, in terms of the requirement for the provision of tertiary containment.

The study is based on CIRIA C736 Containment Systems for the Prevention of Pollution (London, 2014), which provides guidance on identifying the hazards, assessing the risks, and mitigating the potential consequences of a failure of the primary sludge storage facility/source. The sources are referred from the Cambridge Sludge Treatment Centre Environmental Permit Application (Main Supporting Document) prepared by Mott MacDonald (2021).

This report discusses the site condition, potential sources, modelling of surface water flows and sludge pathways to identify the spill containment requirement, and the performance of the proposed tertiary containment assessment in case of failure of the assets/ tanks in Cambridge STC.

Based on the spill modelling and assessment, high-level tertiary containment options are proposed within this study. The high-level tertiary containment options are also discussed with the site operators to assess feasibility. The high-level tertiary containment options would be further detailed and optimized during subsequent stages of design.

The hydraulic modelling shows that the proposed mitigation options are successful in retaining sludge on the site even in the event of a recent rainfall event that has resulted in ponding on the site.

1 Introduction

1.1 Background

Sewage sludge is the residue produced by wastewater treatment processes. It is a residual semi-solid material, produced as a by-product when industrial or municipal wastewater is treated. As it is a by-product of treated wastewater, it has to be treated so that it is managed and disposed of safely. The sludge contains both organic and inorganic materials, as well as a large concentration of plant nutrients and pathogens. Treating the sludge reduces its weight and volume, at the same time reducing its disposal costs and potential health risks on land, plants, humans, and animals. Hence the Sludge Treatment Centre (STC) is important for the safe disposal of sludge.

Mott MacDonald has been appointed by Anglian Water to carry out a containment assessment of Cambridge Sludge Treatment Centre (STC). The purpose of the project is to assess the existing capacity available for accidental spills from Cambridge STC and identify potential high-level tertiary containment mitigation that could be implemented. The study is based on *CIRIA C736 Containment Systems for the Prevention of Pollution (London, 2014)*, which provides guidance on identifying the hazards, assessing the risks, and mitigating the potential consequences of a failure of the primary storage facility, as well as the design of new containment systems. Different levels of containment are described in Section 1.2.

1.2 Levels of Containment

Primary containment or storage is the most important means of preventing major incidents involving the loss of sludge. It comprises the equipment used to store or transfer sludge such as storage tanks, intermediate bulk containers (IBCs), drums, pipework, valves, pumps and associated management and control systems. It also includes equipment that prevents the loss of primary containment under abnormal conditions, such as high-level alarms linked to shut-down systems.

Secondary containment minimises the consequences of a failure of the primary storage. It comprises equipment that is external to and structurally independent of the primary storage, for example, localised concrete or earth bunds around storage tanks, or the walls of a warehouse storing drums. Secondary containment may also provide storage capacity for firefighting and cooling water.

Tertiary containment minimises the consequences of a failure in the primary and secondary containment systems by providing an additional level of protection preventing the uncontrolled spread of the sludge. These include purpose-built structures such as diversion tanks and lagoons but can also use other measures such as containment kerbing to roadways and parking areas and impervious liners and/or flexible booms. Tertiary containment will be used when there is an event that causes the escape of liquids from the secondary containment through failure or overflow (e.g., bund joint failure, or firewater overflowing from a bund or escaping from a building/warehouse during a prolonged fire).

1.3 Site location

Cambridge STC is located approximately 3.5km north of Cambridge city centre. The address for the site is Cowley Road, Cambridge, Cambridgeshire, CB4 0AP (NGR TL 47440 61636).

This report discusses the site condition, potential sources of pollution, modelling of surface water flows and sludge pathways to identify the spill containment requirement, and the performance of the proposed containment assessment in case of catastrophic failure of assets/tanks in Cambridge STC.

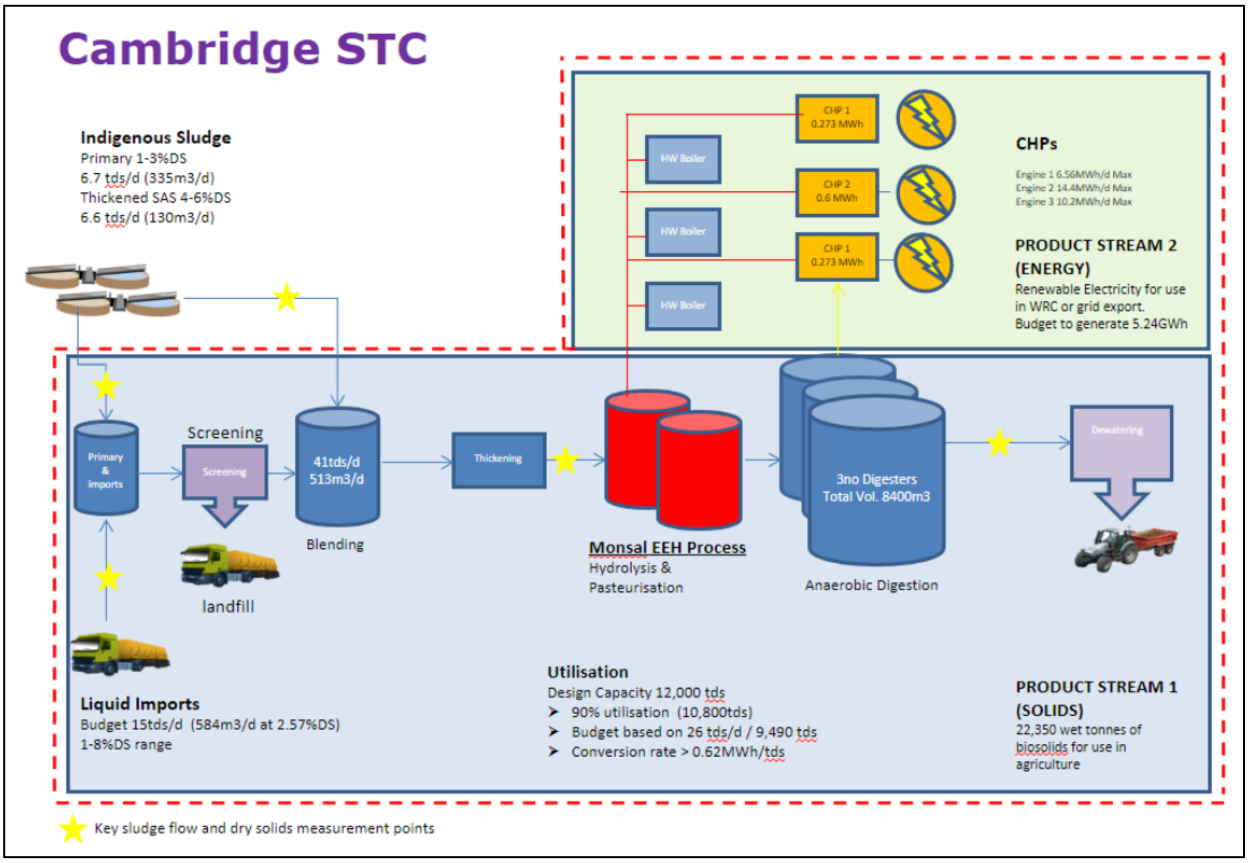
2 Site Assessment

2.1 Site Operation and Flows

Cambridge Sludge Treatment Centre (STC) is situated within the boundary of Cambridge Water Recycling Centre (WRC). STC treats the waste derived from the wastewater treatment process indigenously produced on-site and the imported liquid sludge.

STC process is explained in the flow diagram (Refer to Figure 2.1) where the assets involved in the STC process and sludge flow direction are marked.

Figure 2.1: Flow Diagram of Cambridge STC



Source: Cambridge Sludge Treatment Centre Environmental Permit Application (Main Supporting Document 101265_MSD_Main_CAM) – Mott MacDonald, 2021

The list of assets in STC (Refer Environmental Permit Application[1]) is tabulated in Table 2.1 and the location of these assets is marked in Figure 2.2.

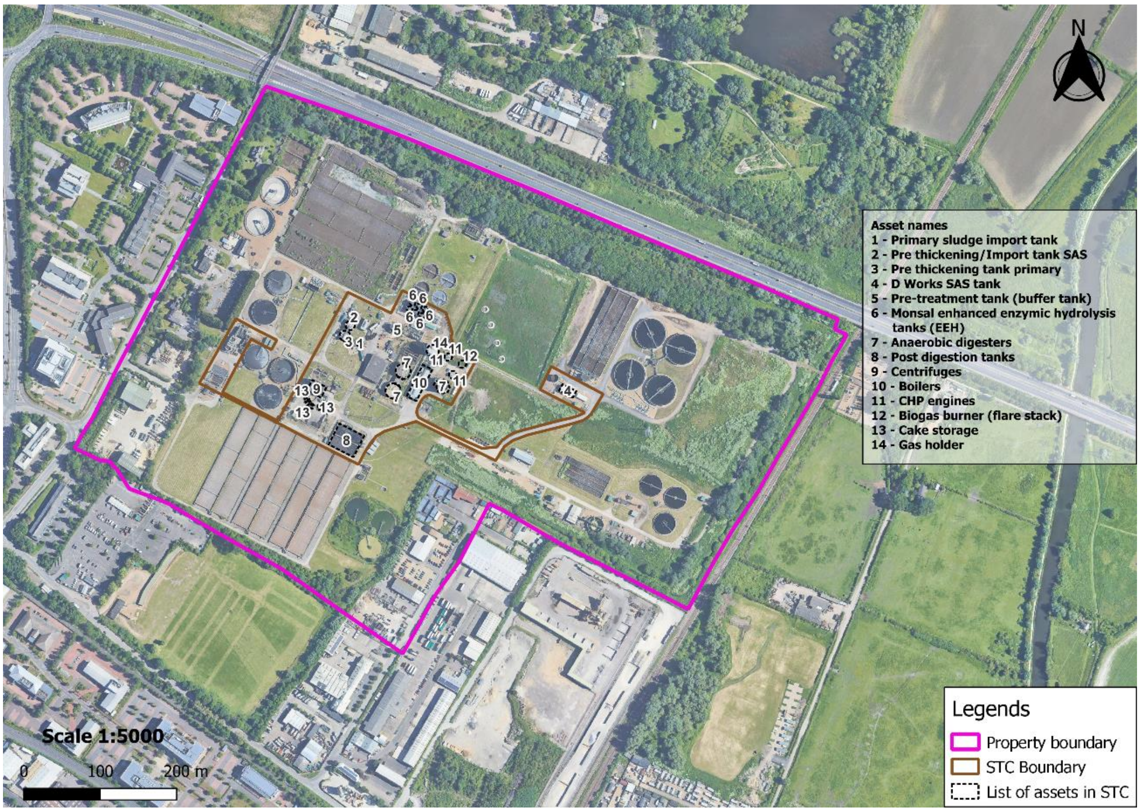
Table 2.1: List of Assets in STC

S. No.	Asset Name	Description	Volume	Considered as a "source"	Justification to consider as a source
1	Primary sludge import tank	1 No.	140 m^3	Yes	Raw Sludge
2	Pre thickening/Import tank SAS	1 No.	462 m^3	Yes	Raw Sludge
3	Pre thickening tank primary	1 No.	580 m^3	Yes	Raw Sludge
4	D Works SAS tank	1 No.	250 m^3	Yes	Activated Sludge
5	Pre-treatment tank (buffer tank)	1 No.	800 m^3	Yes	Raw Sludge
6	Monsal enhanced enzymic hydrolysis tanks (EEH)	6 Nos. (5 are in operation)	230 m^3 each	Yes	Raw Sludge
7	Anaerobic digesters	3 Nos.	2700 m^3 each	Yes	Digested Sludge
8	Post digestion tanks	2 Nos.	1596 m^3 each	Yes	Treated Sludge
9	Centrifuges	2 Nos.		No	No storage of Sludge
10	Boilers	3 Nos.		No	No storage of Sludge
11	CHP engines	3 Nos.		No	No storage of Sludge
12	Biogas burner (flare stack)	1 No.		No	No storage of Sludge
13	Cake storage	5 No. ro-ro skips		No	Treated sludge is stored as cakes and the volume of skips/ bays is not available
14	Gas holder	1 No.	2250 m^3	No	No storage of Sludge

Source: Cambridge Sludge Treatment Centre Environmental Permit Application (Main Supporting Document 101265_MSD_Main_CAM) – Mott MacDonald, 2021

[1] Source: Cambridge Sludge Treatment Centre Environmental Permit Application (Main Supporting Document 101265_MSD_Main_CAM) – Mott MacDonald, 2021

Figure 2.2: List of Assets in STC Process



Source: Cambridge STC Site Layout Plan (101265_MSD_SiteLayoutPlan_CAM) – Mott MacDonald, 2021

The STC receives sludge for treatment in two forms, liquid sludge produced from the host WRC (indigenous sludge and thickened Surplus Activated Sludge (SAS)), and liquid sludge imported by road tanker (liquid import). Indigenous sludge from the primary settlement tanks (PSTs) is screened and then pumped to the Primary Sludge Pre-thickening Tank. Liquid imports of primary sludge are received in the Primary Sludge Import Tank, they are then screened and blended with the indigenous sludge in the Primary Sludge Pre-thickening Tank. The treated sludge is dewatered, and sludge cakes are stored in five skips before being transported off-site for application to agricultural land as a soil conditioner. The biogas collected from the anaerobic digestion process is used to fuel CHP engines.

The operation at this site has been discussed with the site operator. The site operators are on site 7 days a week and carry out daily inspections to identify any maintenance issues. The site is also extensively monitored using a telemetry system which monitors tank levels and flows between process stages among many other items. Alarms are set against these monitored data points and the data points are updated every 15 minutes. Where trigger points are hit an alarm is raised with the alarms assigned a priority code. The alarms which are classified as representing an immediate threat to life are given the highest priority and immediate response. On the STC the highest priority codes are typically alarms around the biogas systems, fire alarms and the steam raising boilers. Alarms that protect against loss of containment (high levels/ overflows etc.) will have a 1-hour response time.

2.2 Site Condition

2.2.1 Groundwater

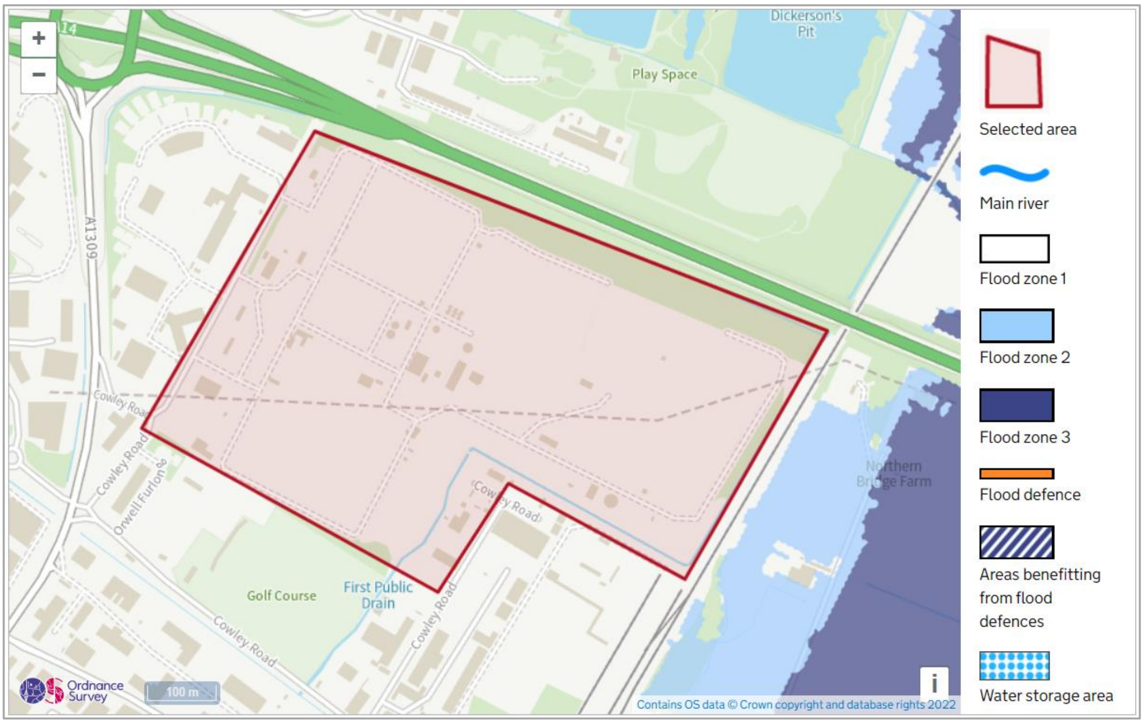
The site is underlain by superficial River Terrace Deposits (RTD) described by the Environmental Risk Assessment (2021) (ERA) as sand and gravel, locally with lenses of silt, clay or peat. An area of Alluvium is present adjacent to the east of the Site associated with the River Cam. The bedrock deposits beneath the site comprise the Gault Formation, this is described in the ERA as pale to dark grey or blue-grey clay or mudstone, glauconitic in part with a sandy base. The Gault Formation is typically 20m thick. Below this lies the Lower Greensand Formation. No faults or other linear features are found within 250m of the site. The ERA states that according to the British Geological Society's (BGS) GeoIndex (2020), there is no artificial made ground underneath the Sewage Treatment Centre (STC).

The ERA states that the online DEFRA interactive map service 'Magic Map' (2020) indicates the superficial RTD, and nearby Alluvium are designated as a Secondary A aquifer. Secondary A aquifers comprise permeable layers capable of supporting water supplies at a local rather than strategic scale, these aquifers are generally classified as minor aquifers. The bedrock aquifer is designated as Unproductive Strata. The site does not lie within a groundwater source protection zone (SPZ), or a Drinking Water Protection Zone.

2.2.2 Fluvial Water Flood Risk

The River Cam is located approximately 300m east of the site. A drainage ditch ("First Public Drain") runs directly adjacent to the east of the site boundary and south of the site. There are two ponds located approximately 250m northeast of the site (Todd's Pit and Dickenson's Pit). According to the Environment Agency Flood maps the site is located within Flood Zone 1 and is classified as having a low probability (less than 0.1% Annual Exceedance Probability (AEP)) of fluvial flooding (see Figure 2.3).

Figure 2.3: Fluvial Flood Risk – Zones

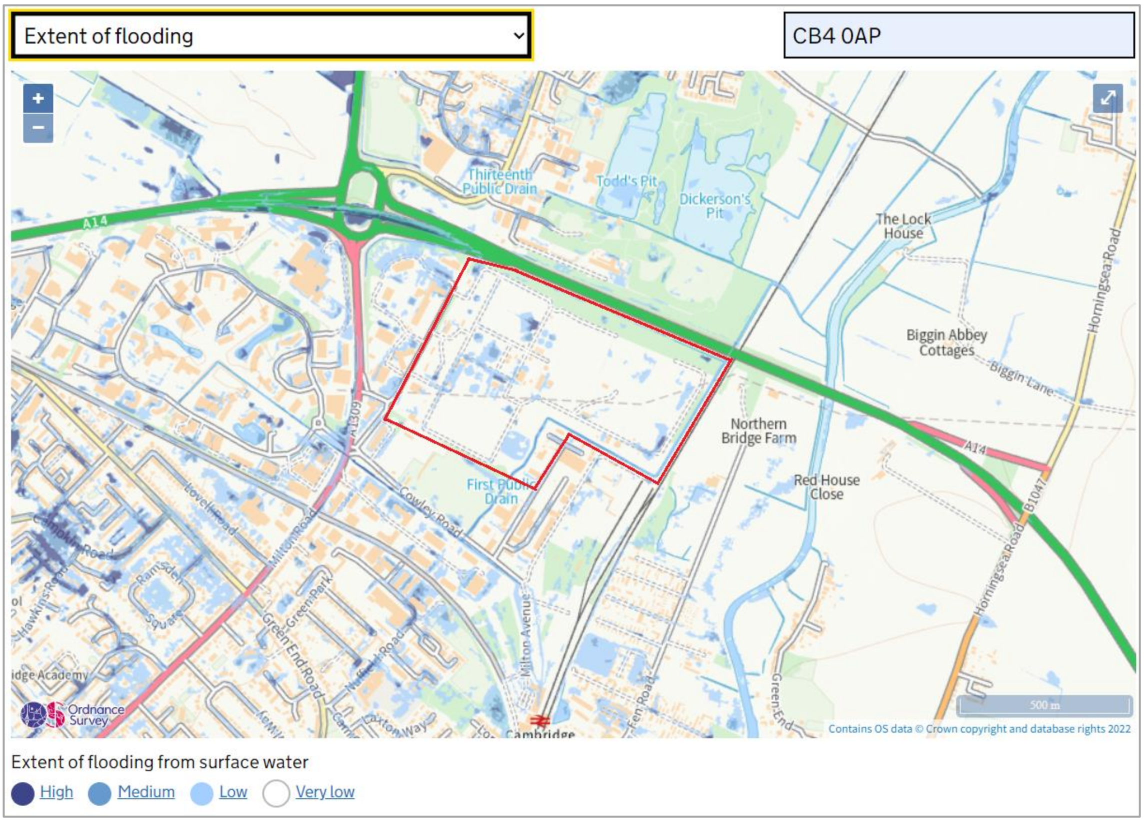


Source: https://flood-map-for-planning.service.gov.uk/

2.2.3 Surface Water Flood Risk

There are small, localised areas across the site which are at medium to high risk of flooding from surface waters (see Figure 2.4).

Figure 2.4: Extent of Flooding – Surface Water



Source: https://check-long-term-flood-risk.service.gov.uk/map

There are several discharge consents for the River Cam, most of which are related to the discharge of treated effluent, and storm tank discharged from the Water Recycling Centre (WRC)[2].

2.3 Groundwater

As ERA states, the BGS groundwater flooding susceptibility maps indicate that site has the potential for groundwater flooding to occur at the surface.

2.4 Site Hazard

Site Hazard is estimated using the Anaerobic Digestion Bioresources Association (ADBA) classification tool. In this tool, hazard rating is provided for sources, pathways, and receptors separately to identify the overall site hazard rating. Based on the likelihood of different risks and site hazard rating, site risk is evaluated, and the corresponding containment design class required is identified to be Class 3.

The ADBA tool with all the details discussed above is attached in Appendix A.

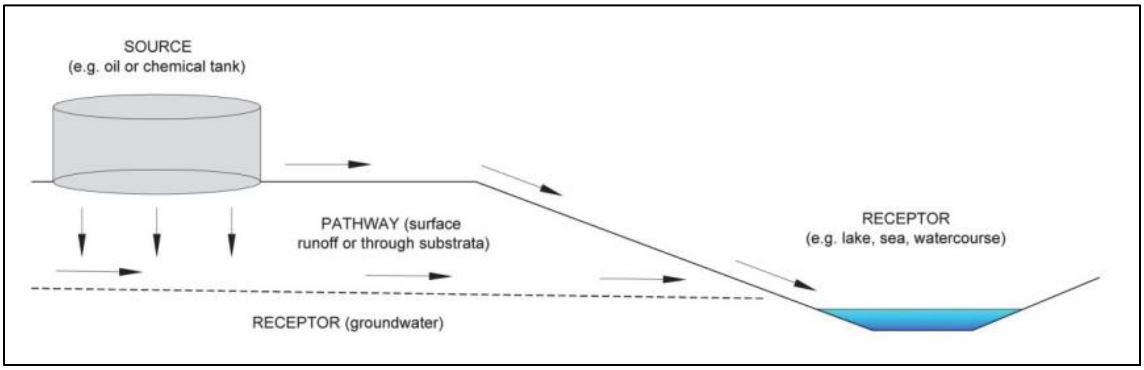
[2] Source: Cambridge Sludge Treatment Centre Environmental Permit Application (Environmental Risk Assessment 101265_ERA_CHEL) – Mott MacDonald, 2021

3 Source - Pathway - Receptor Analysis

The purpose of a risk assessment is to ensure that the measures put in place to manage or mitigate risk are proportionate. Primary, Secondary and Tertiary containments are discussed in Section 1.2. The risk assessment framework underpins the three-tiered classification system (Refer to Appendix A.5) for secondary and tertiary containment facilities. Class 1 containment systems are provided where the risk of pollution arising from the storage of the inventory is relatively low, whereas Class 3 containment systems are provided where this risk is relatively high.

Source – Pathway – Receptor analysis is important for determining the Site Hazard Rating which helps to identify the level of containment requirement. Figure 3.1 shows the schematics diagram of the Source, Pathways and Receptors.

Figure 3.1: Schematic diagram of Source – Pathway – Receptor



Source: CIRIA C736

The following sections discuss how the critical source is identified, and how the sludge would travel/ spread along the pathways and reach the receptors.

3.1 Source

3.1.1 Tanks

A list of tanks considered to be potential sources is tabulated in Table 3.1. The location of these tanks can be referred from Figure 2.2.

Table 3.1: List of sources within STC

S. No.	Asset Name	Volume
1	Primary sludge import tank	140 m^3
2	Pre thickening/Import tank SAS	462 m^3
3	Pre thickening tank primary	580 m^3
4	D Works SAS tank	250 m^3
5	Pre-treatment tank (buffer tank)	800 m^3
6	Monsal enhanced enzymic hydrolysis tanks (EEH) – 5 nos.	1150 m^3 (5 x 230 m^3 each)
7	Anaerobic digesters – 3 nos.	2700 m^3 each
8	Post digestion tanks – 2 nos.	1596 m^3 each

Source: Cambridge Sludge Treatment Centre Environmental Permit Application (Main Supporting Document 101265_MSD_Main_CAM) – Mott MacDonald, 2021

Based on the volume of tanks within STC, the Anaerobic Digesters, EEH Tanks and Post Digestion Tanks are identified to be the critical sources.

3.1.2 Firefighting Water

A gas holder is located near the boiler house within STC (Refer to Figure 2.2). In the event of a fire at the site, the volumes of firefighting water put onto the site to quell a fire are important to consider as a potential source. The capacity of the gasholder is 2250 m^3 (approx. 2475 kg) and based on this quantity, the severity of a potential fire is categorised as medium by CIRIA C736 (see Table 3.2). The volume of firefighting demand is around 4000 m^3 however, as per CIRIA C736 this is specifically for chemical plants. The volume of water required would be less for a STC site compared to chemical plants. It is considered that the fire-fighting water demand would be less than 4000 m^3 and less than the volume of critical sources considered in this study.

Hence the critical sources are identified to be Digesters, EEH tanks and Post digestion tanks.

Table 3.2: Firefighting water demand

Table 4.4 Forecast of firefighting water needed to tackle major chemical plant fires (courtesy ICI)

Plant hazard rating[1]	Firefighting water demand
High severity	Total demand 1620–3240 m^3/hr for four hours
Medium severity	Total demand 1080–1620 m^3/hr for four hours
Low severity	Total demand 540–1080 m^3/hr for four hours

Notes[1]

High severity includes plants with:

- over 500 tonnes of flammable liquid above its flashpoint
- over 50 tones LPG above its boiling point and over 50 bars
- over 100 tonnes combustible solid with ready flame propagation
- other factors what increase severity

Medium severity covers plants that fall between high and low severity ratings.

Low severity includes plants with:

- less than 5 tonnes flammable liquids above or below flashpoint
- less than 100 kg flammable gas under 1 bar or a flash liquid
- less than 5 tonnes readily combustible solid
- other factors that decrease severity

Source: CIRIA C736

3.2 Pathway

Pathways are how a hazardous substance would reach a receptor. As per CIRIA C736, the area of search for potential receptors is governed by the potential pathways and these might include:

1. Simple overland flow following the local topography
2. Existing pipes, sewers, drains or other underground features that could lead to a receptor such as a watercourse
3. Permeable sub-soils and strata underlying a site that could provide a pathway to groundwater or a watercourse.

Multiple combinations of pathways may exist and should be considered. In considering the hazard rating of potential pathways the following should be considered (Source: CIRIA C736):

1. The distance between the source and the various potential receptors.
2. Site layout (including topography), and the position and effectiveness of drains and other internal and external pathways.
3. Geographical, geological, and hydrogeological features that could either impede or facilitate the escape of inventory from the site. In addition, building foundations may impede or alter sub-surface drainage paths.
4. Climatic conditions and expected variability.
5. The direct effects of fire and the introduction of firefighting water, or foam.
6. The presence of treatment plants (on or off-site).
7. Modification of the inventory during passage through the pathway such as the cooling of a liquid.

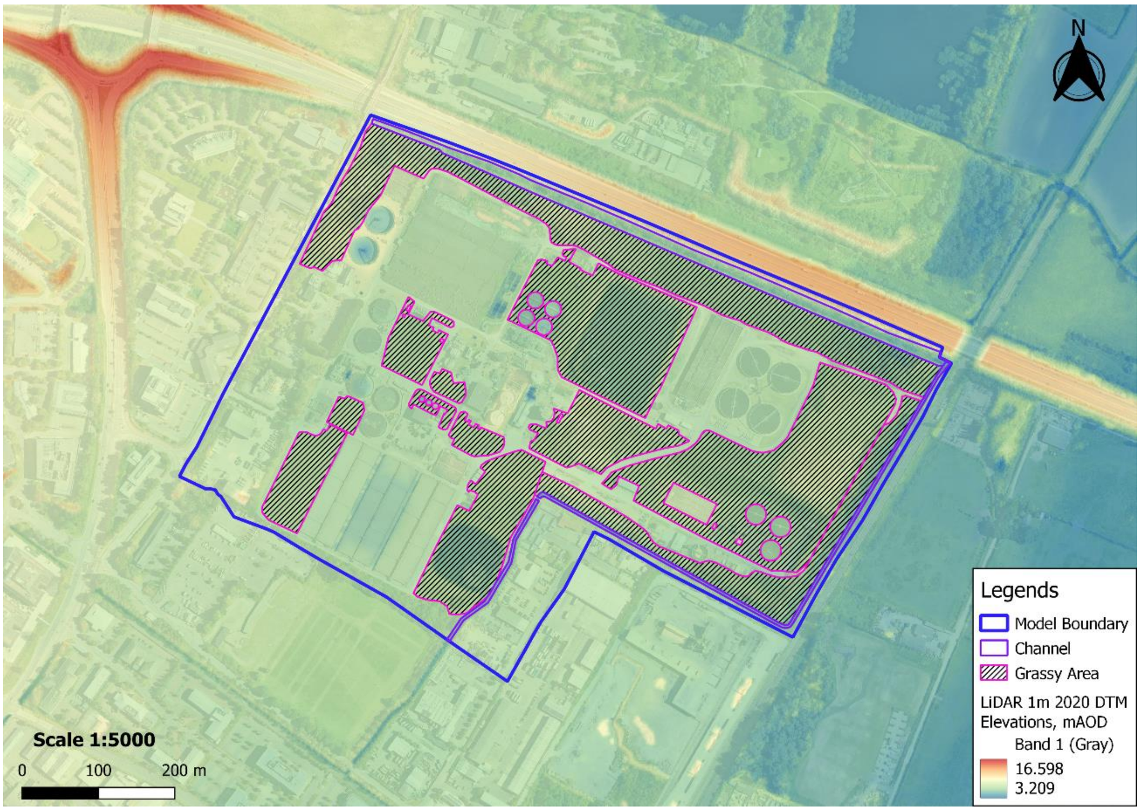
8. Inventory that is not particularly mobile in ambient conditions may be soluble in water.
9. The scale of potential incidents (larger incidents and firewater generally have greater potential for mobilisation in the environment than smaller spills).

Three potential pathways are identified in Cambridge STC. They are overland flow, flow through the channel and subsurface flow.

3.2.1 Overland Flow Pathway

Overland flow paths within the site are as per the existing topography. Ground levels on the site generally decrease from west to east and north to south. The rainfall-runoff water flows based on the topography and towards the area that has a relatively low elevation (Refer to Figure 3.2).

Figure 3.2: Topography – LiDAR 1m 2020 Digital Terrain Model (DTM)



3.2.2 Channel Flow Pathway

A drainage ditch runs directly adjacent to the east and south of the site boundary that flows north into the River Cam. There is another channel running west to east draining to the River Cam (Refer to Figure 3.2). These channels carry rainfall runoff water from the site along with flows from upstream of the site.

3.2.3 Groundwater/Subsurface Flow Pathway

There are four grassy, permeable areas on the site. These are in the north, southeast, east and west of the site which may serve as a pathway to enter the groundwater (Refer to Figure 3.2).

3.3 Receptor

3.3.1 Off-Site Receptors

3.3.1.1 River Cam

The River Cam is located approximately 300m east of the Site. The channels within the site drain into the River Cam to the north-east of the site as discussed in Section 3.2.2.

3.3.1.2 Designated Sites

There are several designated sites in the vicinity of Cambridge STC, and these are tabulated in the below tables.

Table 3.3: List of Statutory designated national sites within 2km

Site name	Designation	Distance from the site	Comments
Bramblefields	Local Nature Reserve (LNR)	400m	Located south of the site
Milton Country Park	Country Park	350m	Located north-east of the site

Source: Cambridge Sludge Treatment Centre Environmental Permit Application (Environmental Risk Assessment 101265_ERA_CHEL) – Mott MacDonald, 2021

Table 3.4: List of Statutory designated habitat sites within 10km of the site

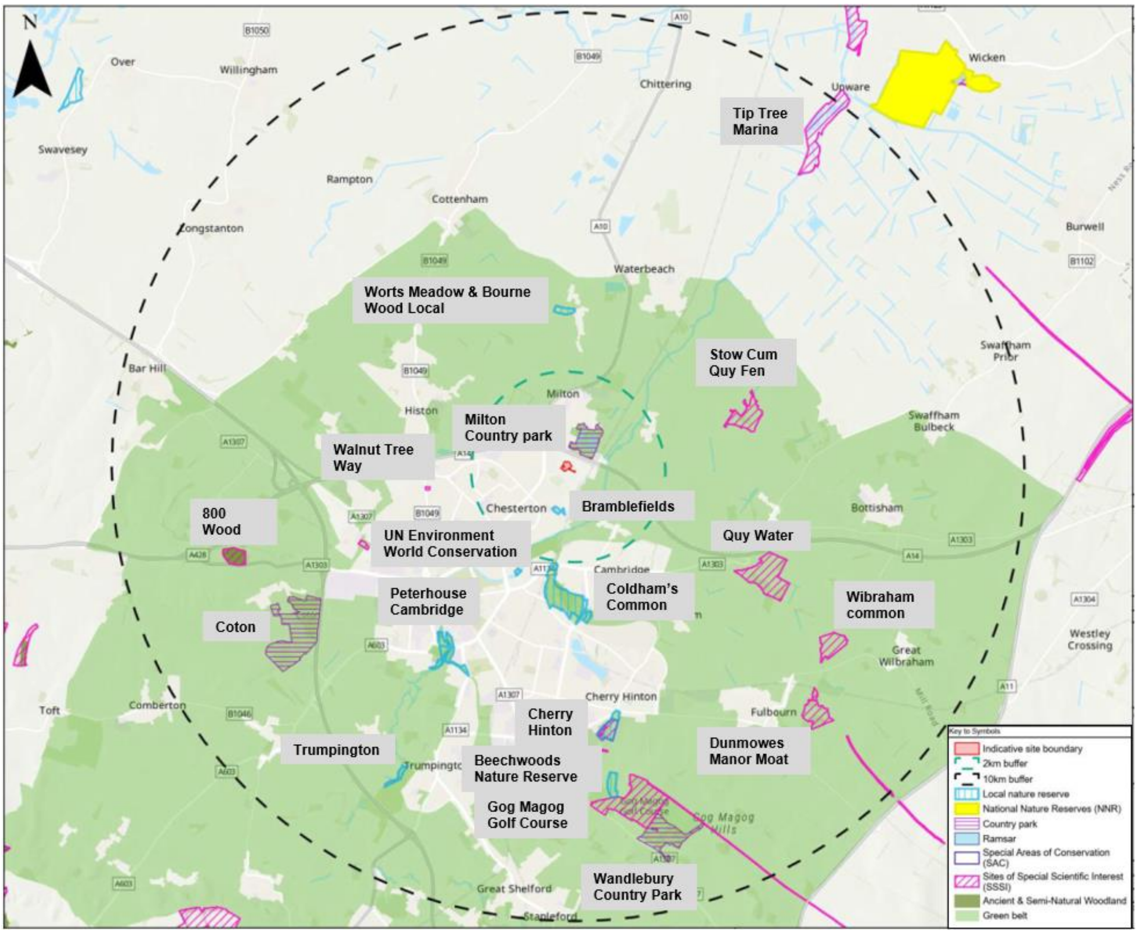
Site name	Designation	Distance from the site	Comments
Tip Tree Marina	SSSI	8.2 km	Located in North-East
Stow Cum Quy Fen	SSSI	3 km	Located in North-East
Quy Water	SSSI	3.8 km	Located in South-East
Wibraham common	SSSI	6 km	Located in South-East
Dunmowes Manor Moat	SSSI	6.7 km	Located in South-East
Gog Magog Golf Course	SSSI	6.4 km	Located in South-East
800 Wood	SSSI	7 km	Located in South-West
UN Environment World Conservation	SSSI	4.3 km	Located in South-West
Walnut Tree Way	SSSI	2.6 km	Located in South-West
Wandlebury Country Park	Country Park	7.5 km	Located in South-East
Coton	Country Park	5.8 km	Located in South-West

Site name	Designation	Distance from the site	Comments
Worts Meadow & Bourne Wood Local	Local nature reserve	3 km	Located in North-West
Coldhams Common	Local nature reserve	1.7 km	Located in South
Cherry Hinton	Local nature reserve	5 km	Located in South
Beechwoods Nature Reserve	Local nature reserve	6.25 km	Located in South
Trumpington	Local nature reserve	6.8 km	Located in South-West
Peterhouse Cambridge	Local nature reserve	4.1 km	Located in South-West

Source: Cambridge Sludge Treatment Centre Environmental Permit Application (Environmental Risk Assessment 101265_ERA_CHEL) – Mott MacDonald, 2021

Sites listed in the above tables (within 2km and 10km) are marked in Figure 3.3 below.

Figure 3.3: Statutory designated habitat sites within 10km of the site

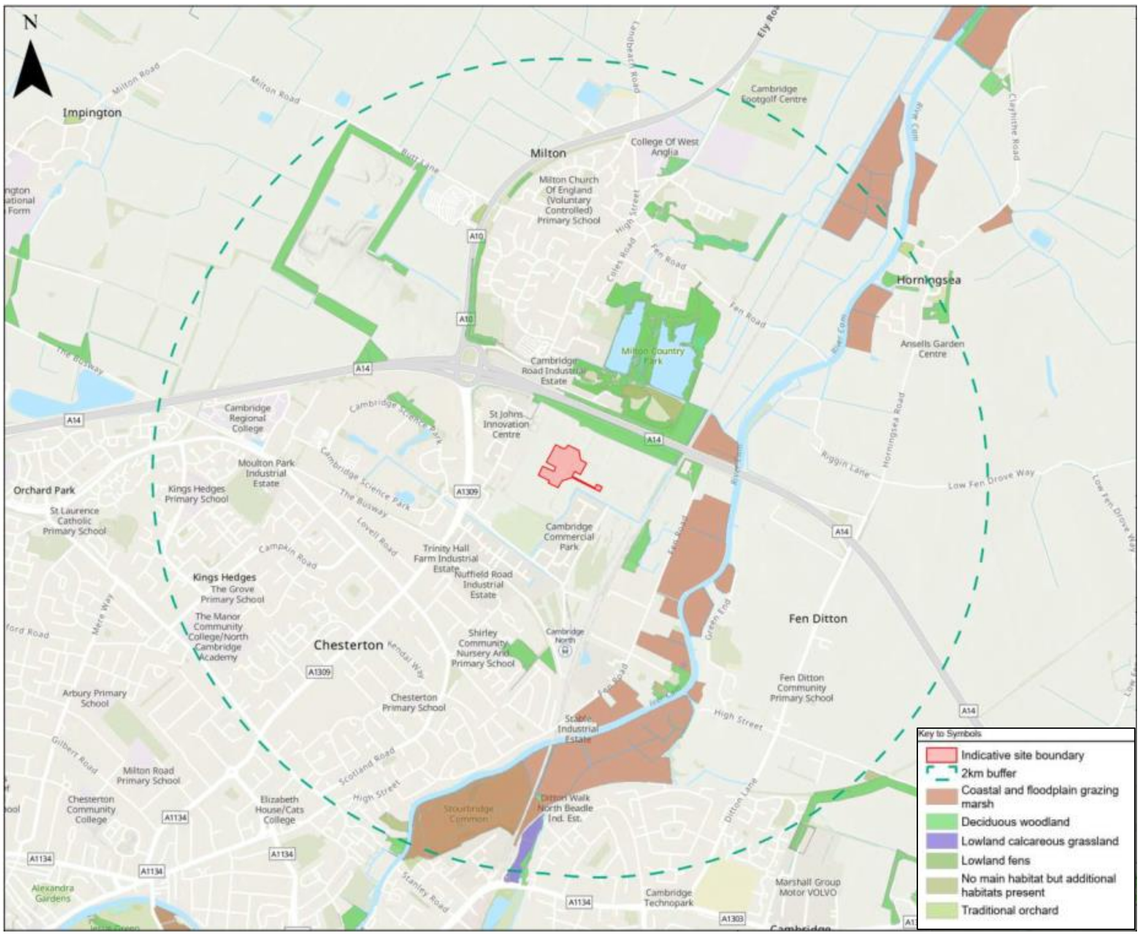


Source: Cambridge Sludge Treatment Centre Environmental Permit Application (Environmental Risk Assessment 101265_ERA_CHEL) – Mott MacDonald, 2021

The priority habitats within 2km of the site are listed below (see Figure 3.4)

1. Coastal and floodplain grazing
2. Deciduous woodland
3. Lowland calcareous grassland
4. Lowland fens
5. Traditional orchard

Figure 3.4: Non-statutory designated habitat sites within 2km of the site



Source: Cambridge Sludge Treatment Centre Environmental Permit Application (Environmental Risk Assessment 101265_ERA_CHEL) – Mott MacDonald, 2021

3.3.1.3 Built Environment

The River Cam is located approximately 300m east of the site and there is a public footpath which is routed along the length of the riverbank. Therefore, the site is within 500m of a Public Right of Way. There are no public rights of way through the site boundary or directly adjacent to the facility[3].

[3] Source: Cambridge Sludge Treatment Centre Environmental Permit Application (Environmental Risk Assessment 101265_ERA_CHEL) – Mott MacDonald, 2021

3.3.2 On-Site Receptors

3.3.2.1 WRC Assets

There are channels and assets within WRC which could potentially receive sludge from the failure of various sources (see Figure 3.5). These receptors are listed in Table 3.5.

Figure 3.5: Receptors - WRC and STC assets within the site boundary

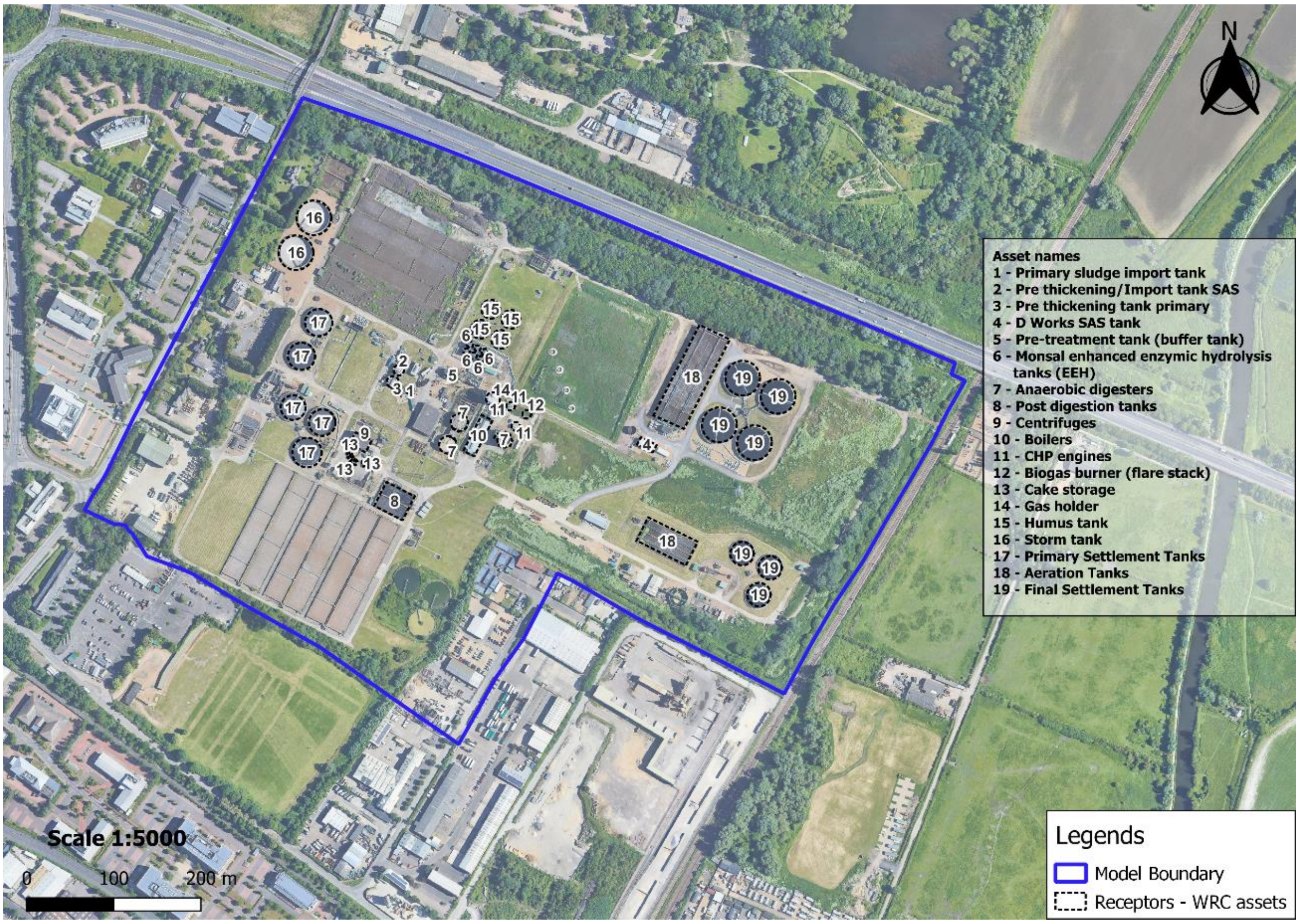


Table 3.5: List of Receptors within WRC and STC

S. No	List of Receptors	Assets within
1	Primary sludge import tank	
2	Pre thickening/Import tank SAS	
3	Pre thickening tank primary	
4	D Works SAS tank	
5	Pre-treatment tank (buffer tank)	Sludge Treatment Centre (STC)
6	Monsal enhanced enzymic hydrolysis tanks (EEH)	
7	Anaerobic digesters	
8	Post digestion tanks	
9	Centrifuges	
10	Boilers	

S. No	List of Receptors	Assets within
11	CHP engines	
12	Biogas burner (flare stack)	
13	Cake storage	
14	Gas holder	
15	Humus tank	Water Recycling Centre (WRC)
16	Storm tank	
17	Primary Settlement Tanks	
18	Aeration Tanks	
19	Final Settlement Tanks	

4 Failure Assessment

This section discusses the modelling of the site carried out to identify the potential impact due to the failure of critical sources. Hydraulic modelling (spill modelling) has been carried out to understand the extent of sludge because of a catastrophic failure that occurred after a 24-hour antecedent 10-year design storm.

4.1 Factors influencing sludge movement

When there is a sudden failure, the sludge from different sources follows the topography of the site (topography shown in Figure 3.2). The movement of sludge is influenced by various factors as below.

(a) Topography
(b) Surface Roughness
(c) Initial storage/ water levels

4.1.1 Topography

Ground levels on the site generally fall from west to east toward the River Cam. Two anaerobic digesters (out of the three on the site) are installed on a bund that is elevated above the ground and are approximately half-buried within the bund. The third anaerobic digester is installed wholly above the ground. Humus tanks (redundant) in the south are approximately 1.5m below ground and the channel running from south to north is approximately 1m to 2m deep and drains water towards the north (see Figure 3.2).

4.1.2 Surface Roughness

Different surface types are represented within the model as shown in Figure 4.1 to replicate the on-site condition in the model. The roughness values are assigned based on the surface types as listed in Table 4.1.

Figure 4.1: Different Surface types within STC

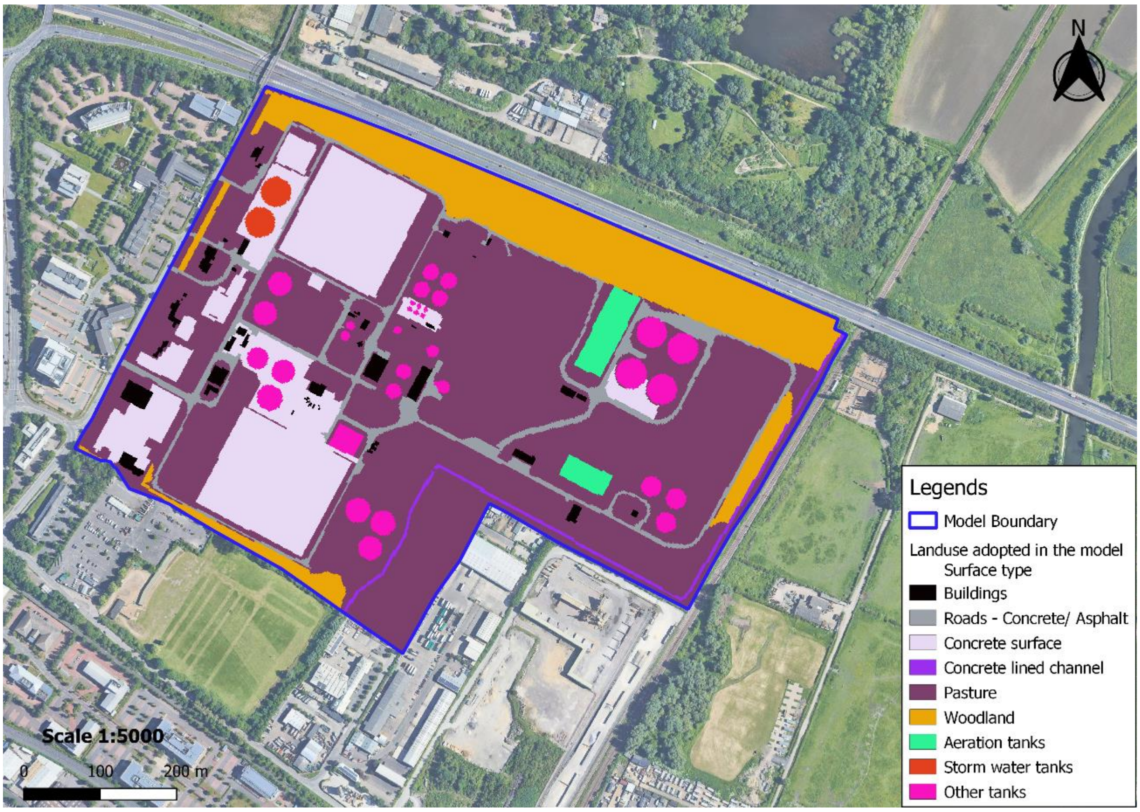


Table 4.1: Manning's n value adopted in the model

Material ID	Manning's n	Description
1	0.100	Buildings
2	0.013	Roads - Concrete/ Asphalt
3	0.013	Concrete surface
4	0.020	Concrete lined channel
5	0.035	Pasture
6	0.060	Woodland
7	0.100	Aeration tanks
8	0.015	Stormwater tanks
9	0.100	Other tanks

Source: Open Channel Hydraulics, Ven Te Chow

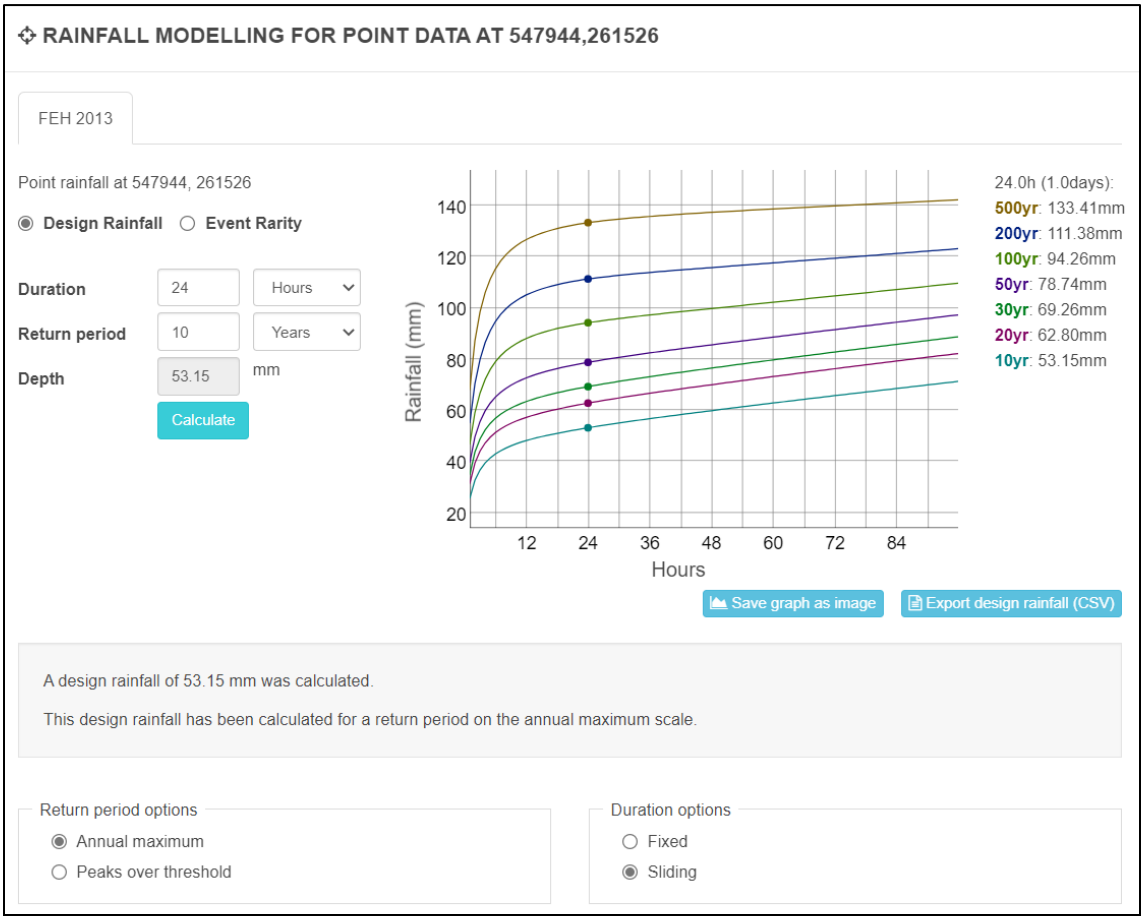
4.1.3 Initial Conditions/Initial Water Level

Sludge movement and storage depend on the available storage on the site. An initial model run was therefore carried out which simulated the impact of a 24-hour duration, 1 in 10-year (10% AEP) rainfall event. This provided initial conditions on the site where ponding had occurred in low-lying areas of the site. The details of the rainfall data used are described in Section 4.1.4.

4.1.4 Rainfall

Figure 4.2 shows the annual maximum rainfall depth of 53.15 mm for a 10-year return period of 24-hour duration. Two rainfall profiles (Winter and Summer) were derived from FEH13 and analysed for further assessment.

Figure 4.2: Rainfall data - Cambridge



Source: https://fehweb.ceh.ac.uk

The available storage on the site was assessed by the Direct Rainfall approach. This approach applied the 1 in 10-year (10% AEP) design rainfall over the entire site boundary (model extent) and capture the water levels at the end of a 24-hour model simulation. The final water levels on the site are subsequently used in defining the storage capacity in the site after the design storm event. Hence, this scenario named 'Pre-Failure' helps in capturing the existing storage capacity at the site before failure. The 'Post-Failure' scenario represents the failure of the source with the initial condition representing the available storage capacity after the rainfall event. In this scenario, the initial condition is included in the model as initial water levels (IWL) from the 'Pre-Failure' case.

4.2 Pre-Failure assessment

In this scenario, the model is updated with the inputs discussed in Sections 4.1.1, 4.1.2 and 4.1.4 (viz. Topography, surface roughness and the rainfall). Two scenarios of the model were run for a duration of 24-hour representing Summer and Winter rainfall. Based on the model results, the higher water levels from the summer and winter profiles are adopted for further assessment.

4.3 Post-Failure assessment

4.3.1 Breach inputs

4.3.1.1 Location

The list of potential sources tabulated in Table 3.1 is considered in the failure assessment. Out of all the sources, the volume of Anaerobic Digesters, EEH tanks and Post digestion tanks are significantly higher than other assets and are considered the critical sources (Refer to Section 3.1) in the breach analysis. All three Anaerobic Digesters are located close together with two buried partially and one wholly above the ground. Out of six EEH tanks, five are active. The two Post digestion tanks are situated together on the southern side of the site.

4.3.1.2 Volume

A breach is represented by applying a hydrograph (a rectangular shape) discharging the volume of the asset being modelled over a one-minute duration[4]. This represents the sudden failure of the source when a catastrophic failure occurs, and the entire contents of each source are released in one minute.

Two anaerobic digesters (out of three) are partially buried and are considered to breach with half of their total volume. Whereas the other anaerobic digester which is wholly above the ground is breached with its total volume (2700 m^3). EEH tanks which are hydraulically connected are considered to fail together and hence the volume of the five EEH currently active tanks (1150m^3) is considered in this breach analysis. The post digestion tanks are likely to fail individually hence these are considered as two different scenarios and the volume of tank considered for breach is 1596m^3.

The peak of the hydrograph is derived from the total volume in cubic meters (Example: Anaerobic Digester 3 - 2700m^3) divided by the number of seconds in a minute (60 seconds) to obtain a constant inflow for one minute ($2700 \div 60 = 45 m^3/s$). The details of each scenario and results are discussed in Section 4.2.

The breach of the source in the model without any rainfall data helps to understand the extent of pollutant spread. Failure of each source and its sludge extents is discussed in the following sections.

[4] Source: CFRAM Guidance Note 24 – Breach Analysis, 2013

4.3.2 Breach – Failure of critical sources

The spread of sludge varies depending on the source of the breach. Sludge spreads predominantly towards the north and north-east from Anaerobic Digester 1 and the EEH tanks, spreads towards the south and south-east from Anaerobic Digester 2, spreads in all directions (except towards north-east) from Anaerobic Digester 3, and spreads towards south-west from each of the Post digestion tanks. Failure of each critical sources is discussed in the following sections.

4.3.2.1 Failure of Anaerobic Digesters

All the Anaerobic Digesters are located close together at the centre of the site and have the same capacity (2700 m^3). Anaerobic Digester 1 and 2 are partially buried whereas Digester 3 is wholly above the ground. Sludge extent varies extensively for each Anaerobic Digester location in the event of catastrophic failure (Refer to Figure 4.3, Figure 4.4 and Figure 4.5).

Figure 4.3: Sludge extent – Failure of Anaerobic Digester 1

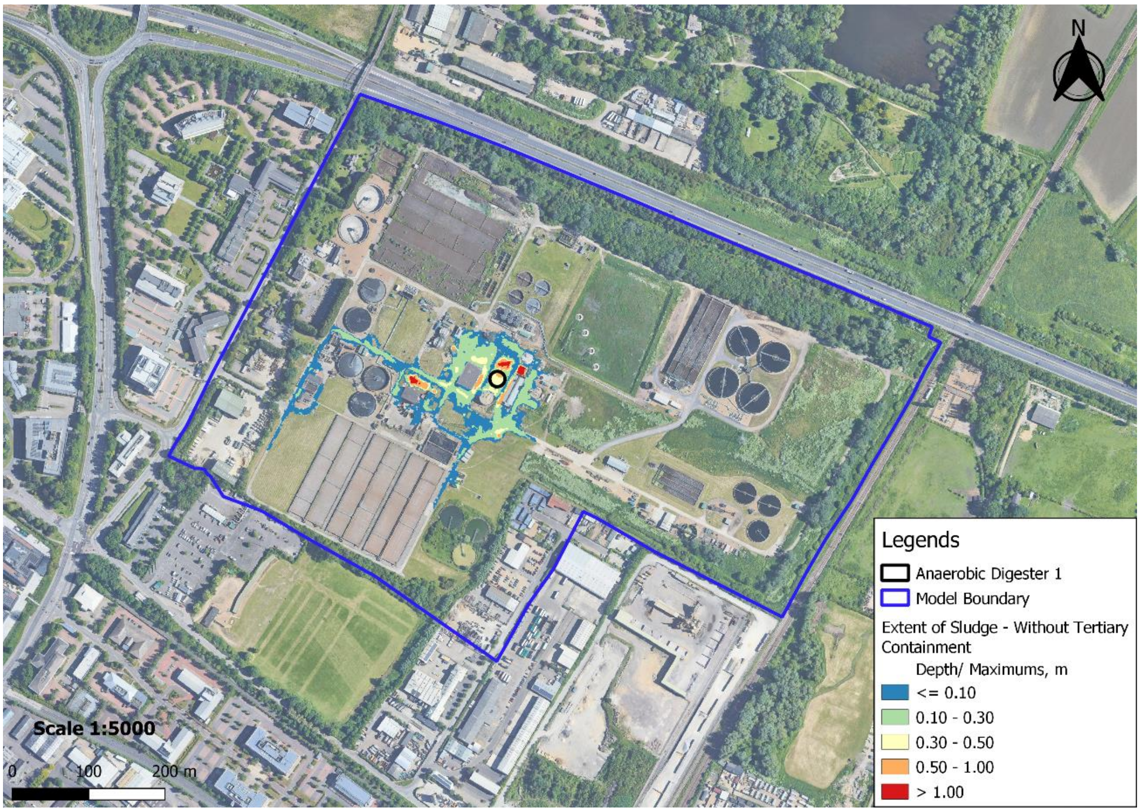


Figure 4.4: Sludge extent – Failure of Anaerobic Digester 2

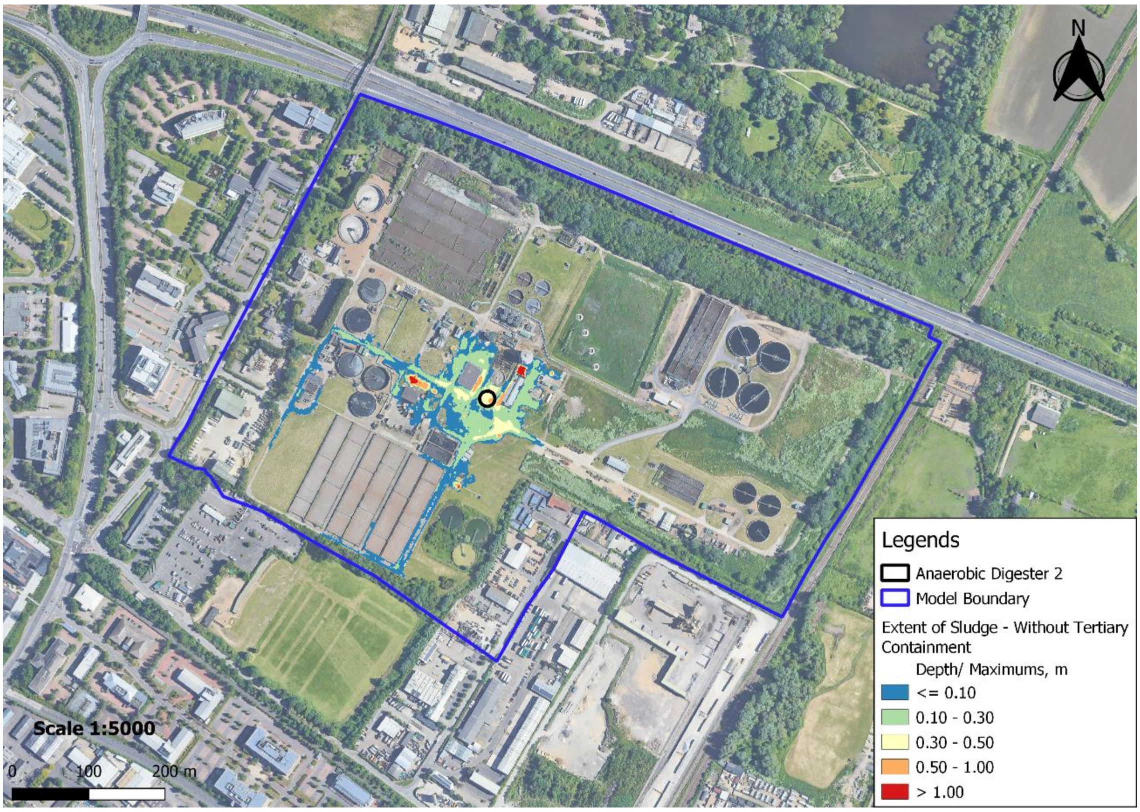
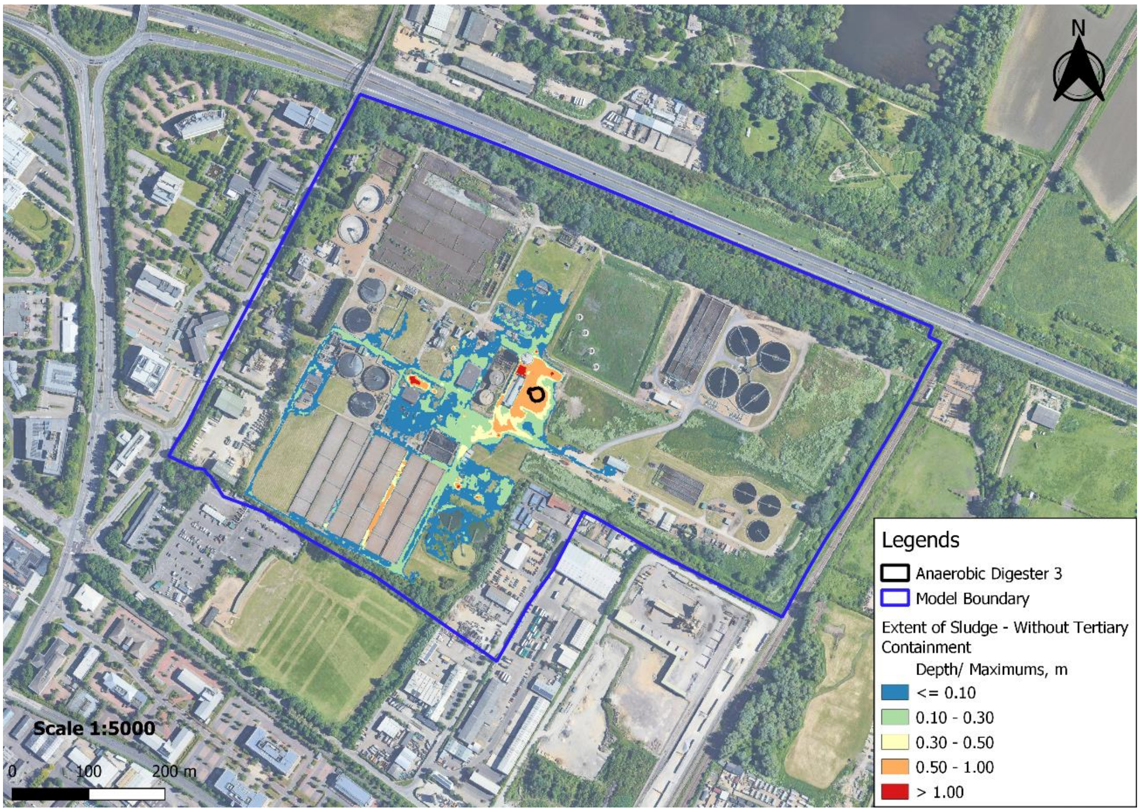


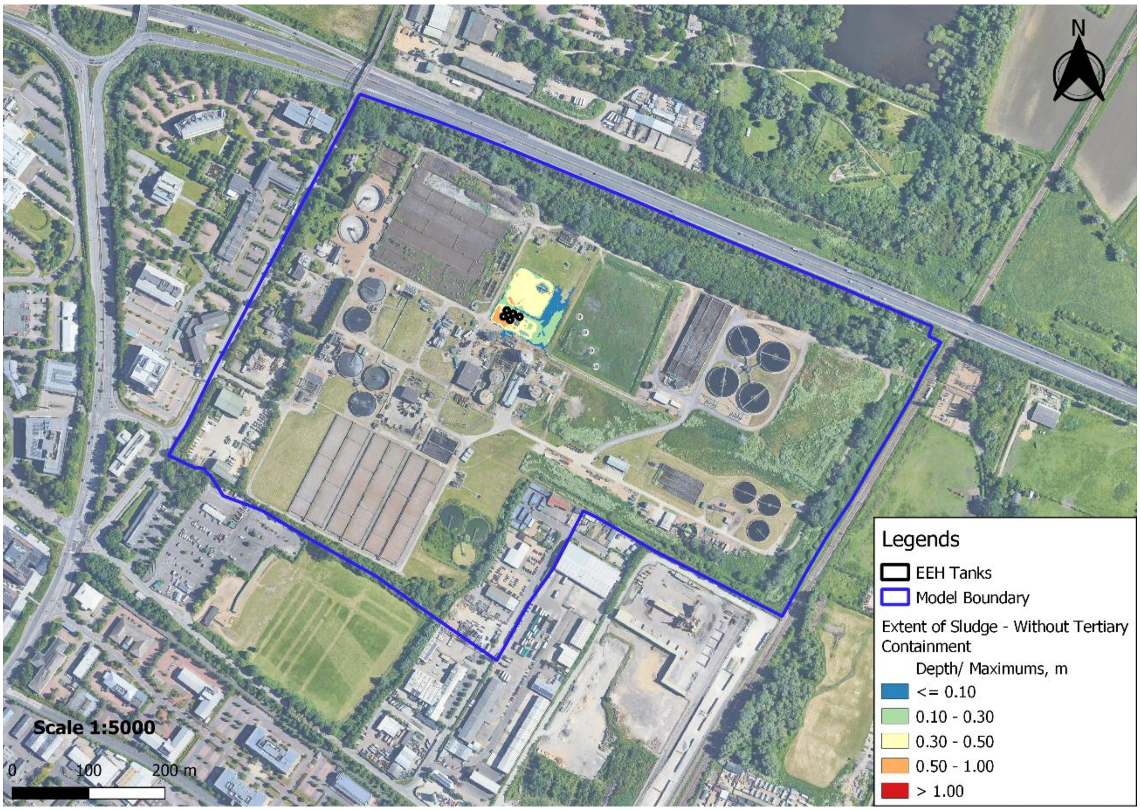
Figure 4.5: Sludge extent – Failure of Anaerobic Digester 3



4.3.2.2 Failure of EEH tanks

The extent of sludge in the event of failure of EEH tanks is modelled by breaching all the five active tanks together. Sludge spread is of limited extent in this scenario and predominantly enters humus tanks to the north of EEH tanks and has extents to the west and east of EEH tanks (Refer to Figure 4.6).

Figure 4.6: Sludge extent – Failure of EEH Tanks



4.3.2.3 Failure of Post digestion tanks

To understand the extent of sludge in the event of failure of the post digestion tanks, scenarios are created by breaching each tank separately. Sludge spreads predominantly towards the north and west and enters the space between the Primary sludge import tank, Anaerobic Digesters and Boiler house. Also, sludge reaches towards the south-west boundary of the site (Refer to Figure 4.7 and Figure 4.8).

Figure 4.7: Sludge extent – Failure of Post Digestion tank 1

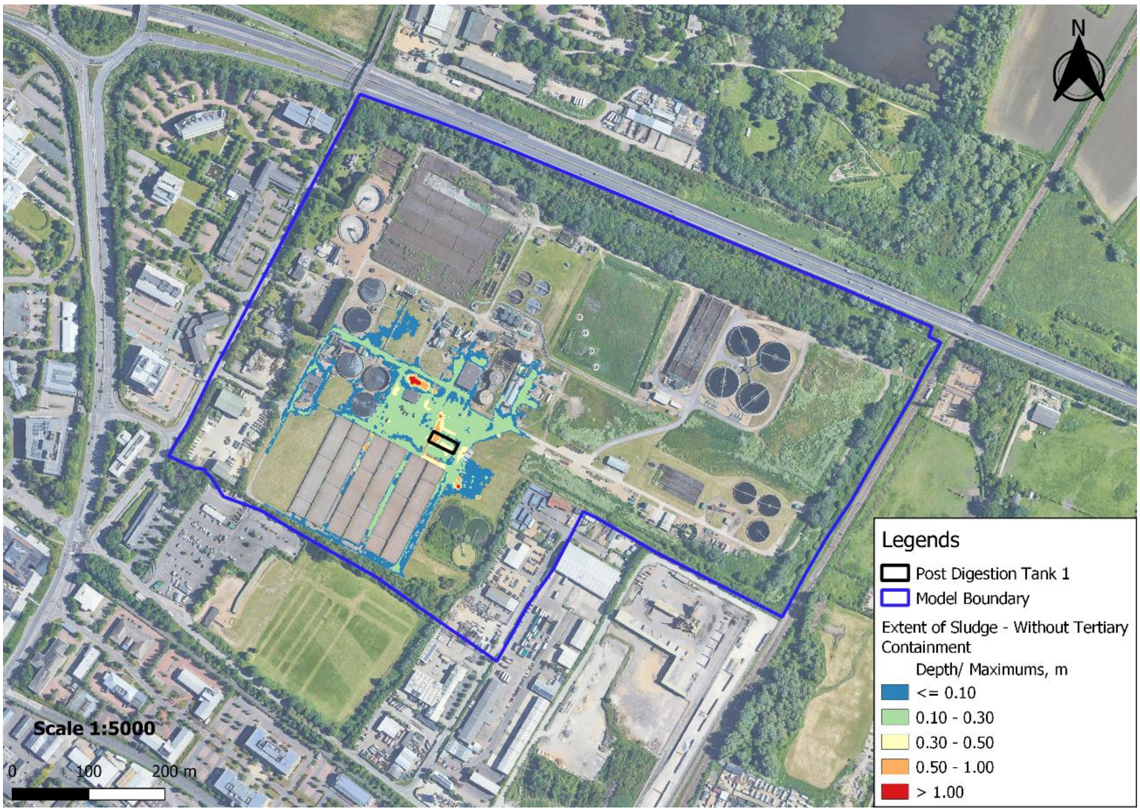
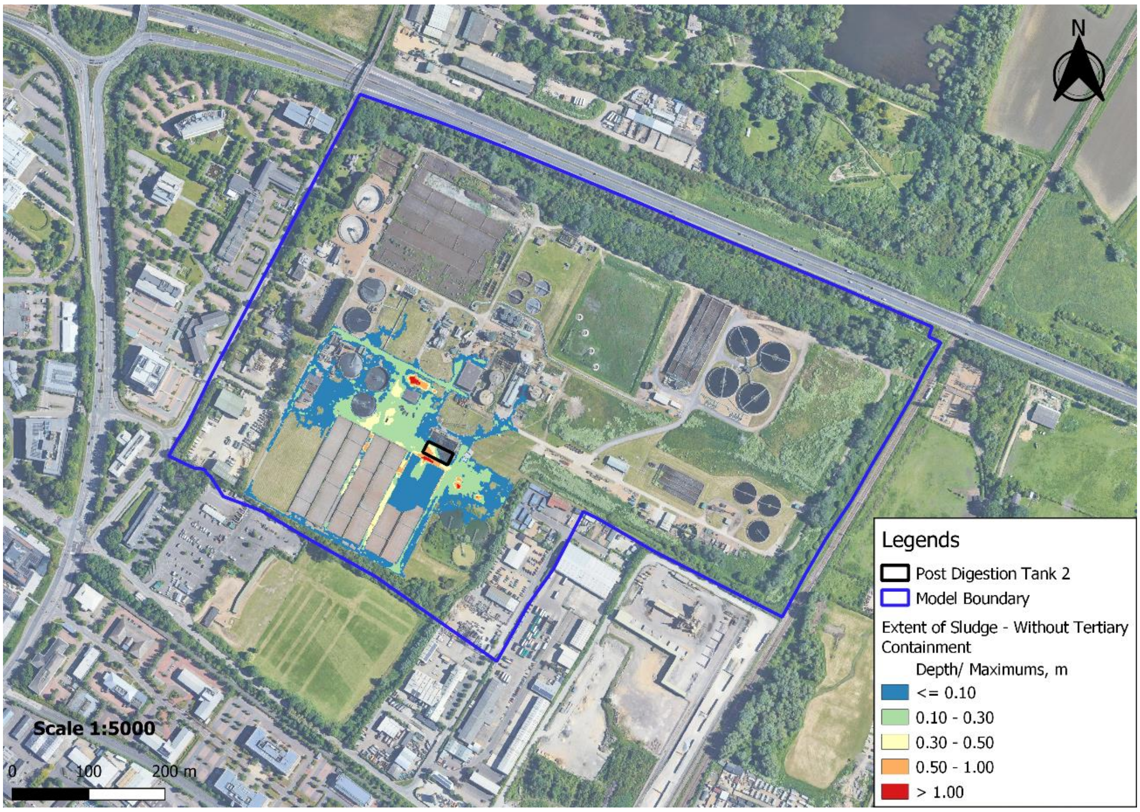


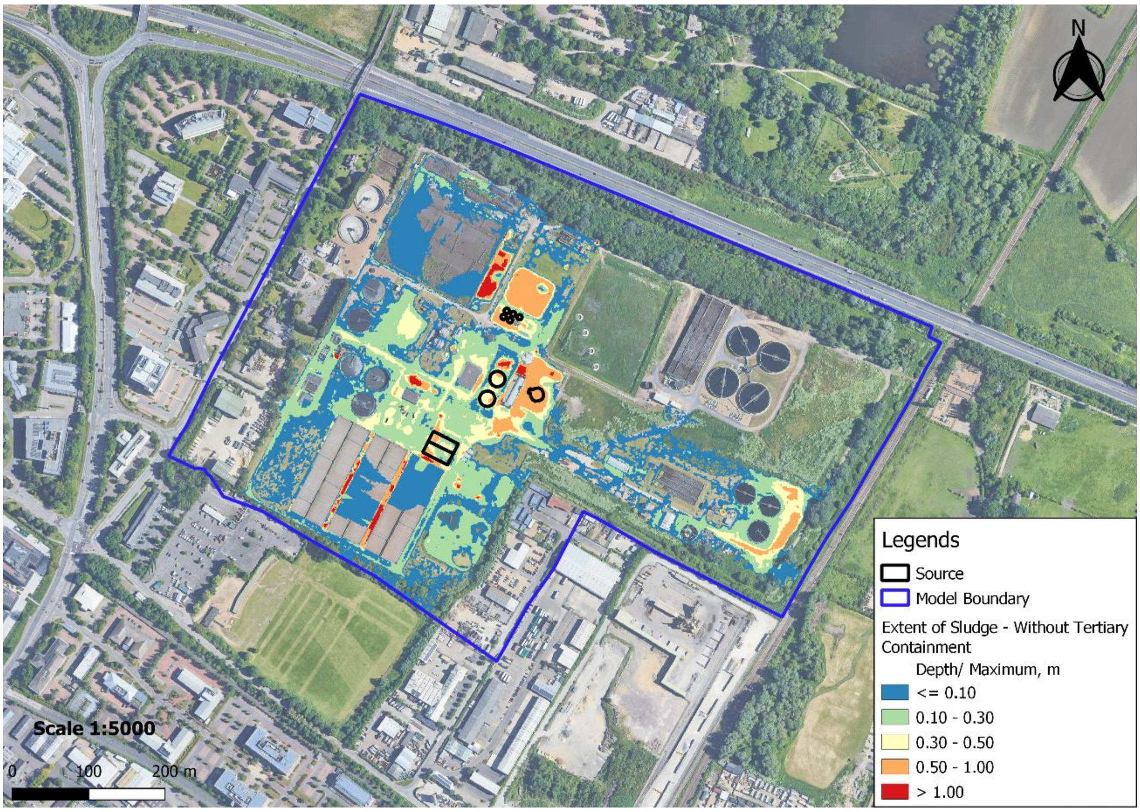
Figure 4.8: Sludge extent – Failure of Post Digestion tank 2



4.3.3 Breach with Initial Water Levels

The post-failure scenario includes the initial water level followed by breaching of different sources (Anaerobic Digester 1, Anaerobic Digester 2, Anaerobic Digester 3, EEH Tanks, Post digestion tank 1 and Post digestion tank 2). The combined sludge extent from the failure of all sources with initial water levels is shown in Figure 4.9. The sludge extends towards final settlement tanks in the east, humus tanks in the north, primary settlement tanks in the west and exits the site boundary in the south-west at a few locations from the failure of all critical sources. Also, the sludge spreads towards the east and enters the channel running from south to north at a few locations (Refer to Figure 4.9).

Figure 4.9: Combined Extent of Sludge from all the post-failure scenarios (Without Tertiary Containment)



As per CIRIA C736, containment capacity is estimated based on 110% and 25% rules to compare with the volume considered in the model including storage due to rainfall-runoff (Refer Table 4.2). The volume of storage in the site due to a 1 in 10yr return period storm is relatively high compared to the sludge volume and hence the containment capacity considered in this study for identifying the tertiary containment options is safe.

Table 4.2: Containment system capacity comparison - ‘110 per cent’ and ’25 per cent’ rules

110% of the capacity of the largest tank within the bund (in m^3)	25% of the total capacity of all the tanks within the bund (in m^3)	Total volume including antecedent 24-hr rainfall (in m^3)
2970	3668.5	13020 = [2700 (Sludge volume) + 10320 (Volume of storage due to antecedent rainfall)]

In summary, the following scenarios were used in the failure assessment of STC.

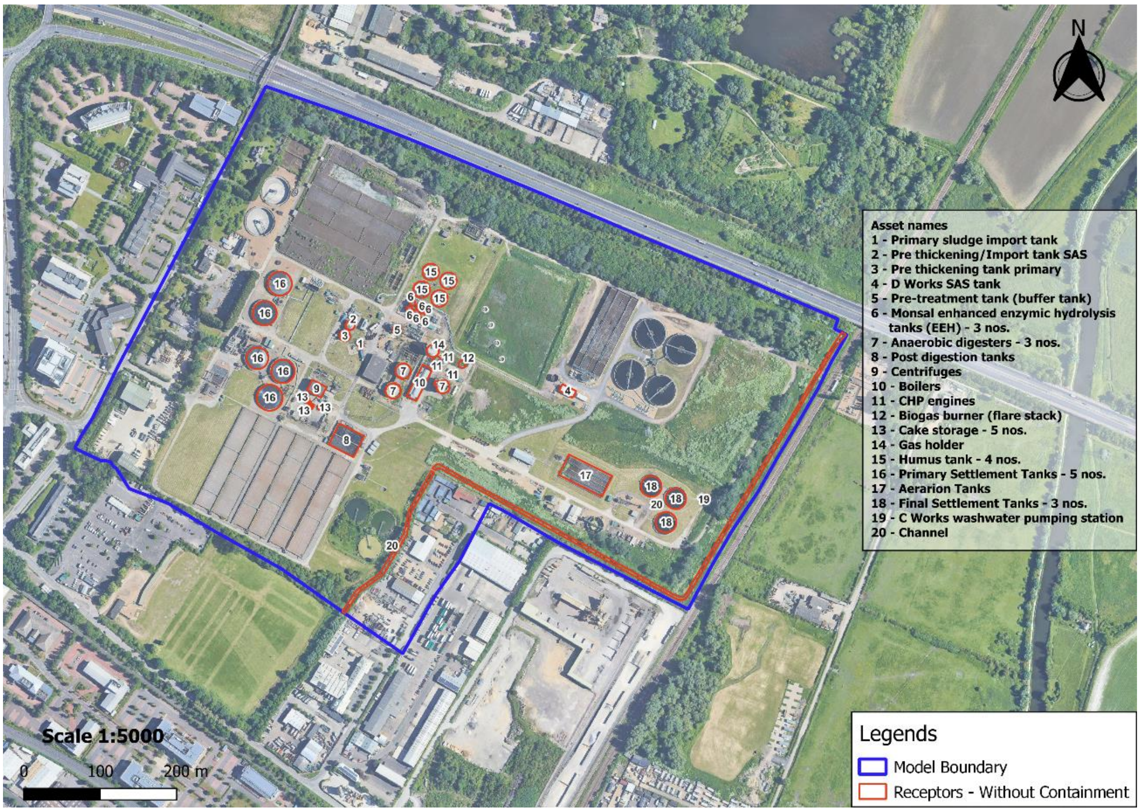
(a) Pre-Failure – Rainfall is applied over the site to extract the initial water levels (IWL) at the end of a 24-hour simulation,

(b) Post-Failure without containment options – Breaching of the source is applied with IWL defined and no containment options included

(c) Post Failure with containment options - Breaching of the source is applied with IWL defined along with the containment options (Proposed containment options are discussed in chapter 5)

The assets within STC and WRC (on-site receptors) that are affected by the footprint of sludge around/ within them from the above failure scenarios are marked in Figure 4.10.

Figure 4.10: Combined Receptors from all the post-failure scenarios - Without Tertiary Containment options



5 Proposed Improvements

This section provides a detailed assessment of the mitigation measures which are being proposed and the potential impact of these improvements.

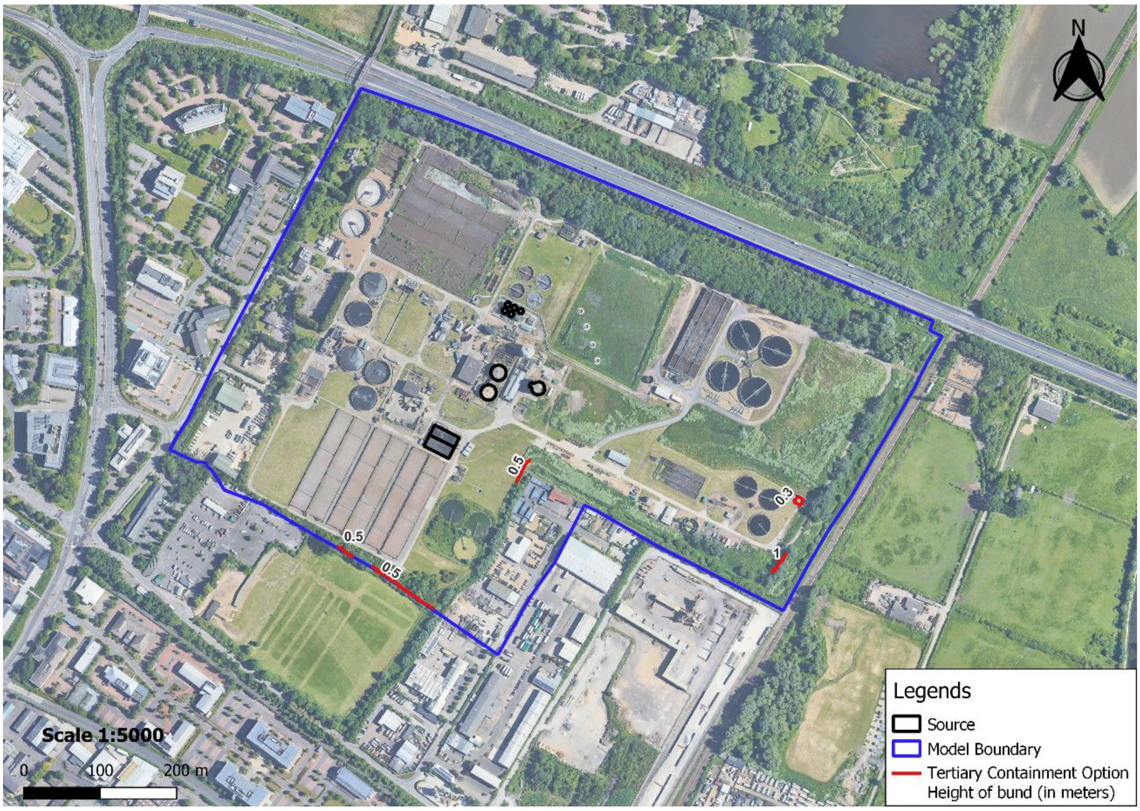
This study assesses the requirement of tertiary containment which is explained in Section 5.1.

5.1 Tertiary Containment options

The tertiary containment options are proposed after discussion with site operators on the feasibility. As per the discussion, it is ensured that there is no spillage to the storm lagoon and channels running from west to east and south to north. There are critical assets which need to be protected from sludge entering them and the protection work is recommended. Protection work is recommended to avoid the sludge leaving the site in the south-west.

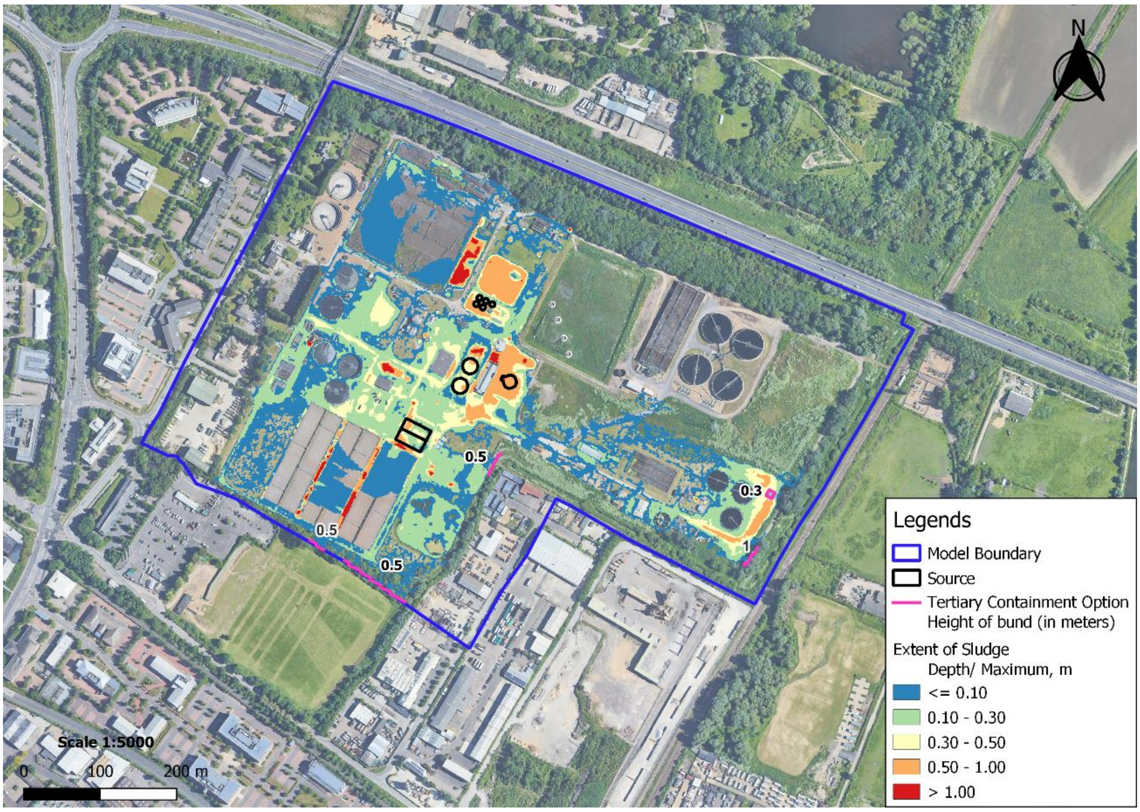
Figure 5.1 shows the tertiary containment options with the approximate height of the bunds.

Figure 5.1: Tertiary Containment Options



The height of the bunds is estimated by checking the maximum depth of the sludge adjacent to the bunds as shown in Figure 5.2.

Figure 5.2: Combined Extent of Sludge from all the post-failure scenarios with tertiary containment option



The height of the bund would vary based on the topography and hence the detailed design of these tertiary containment options should be carried out in order to optimize the height of bunds.

Near the channel in the south, the bunds are recommended to a limited extent where overtopping is observed. There are embankments along the top of the channel which retains the sludge on one side of the channel preventing it from entering the channel. There is a freeboard of approximately 200mm between the modelled level of the sludge and the crest level of the embankment.

Tertiary Containment options proposed are

(a) Bunds near the humus tanks to avoid sludge entering the channel and leaving the site in the south-west

(b) Bunds in the east near Final settlement tanks to avoid any spilling into the channel

(c) Bund around the critical asset (C works wash water pumping station) in the east – Additional height of 0.3m is recommended as existing height informed by client is approximately 0.7m

Various containment options like Fixed Bund, Toggle Blok, and Drain Cover (refer to Appendix B for details) were initially assessed. Following consultation with Anglian Water, the bund was chosen to be the most feasible option.

In addition to these tertiary containment options, an impervious liner is recommended to ensure that no pollutants reach the groundwater through areas of permeable ground. As the liner is near the surface, a capping layer of 1mm LLDPE[5] with a sand layer above or an HP4 geofabric with the LLDPE liner in the middle is recommended.

The process to lay the impervious liner is summarised below

a. Strip off grass gently as this can be reused
b. Excavate down about 300mm and make them smooth
c. Lay the geofabric (if using), lay the LLDPE liner, then another layer of geofabric (if using) otherwise place a capping sand layer over the top (need to be durable enough to drive on if remediation is necessary)
d. Replace 200-300mm of the excavated soil and reinstate the turf (or reseed if necessary).

Any additional surface water runoff which may need to be attenuated within the site due to the implementation of the impervious liner is to be assessed during the detailed design stage.

Any potential inlets to the drainage system which are located within the modelled extent of the sludge which could discharge sludge to the watercourse are recommended to be covered with drain covers (Refer to Appendix B) in the event of catastrophic failure of the sludge source.

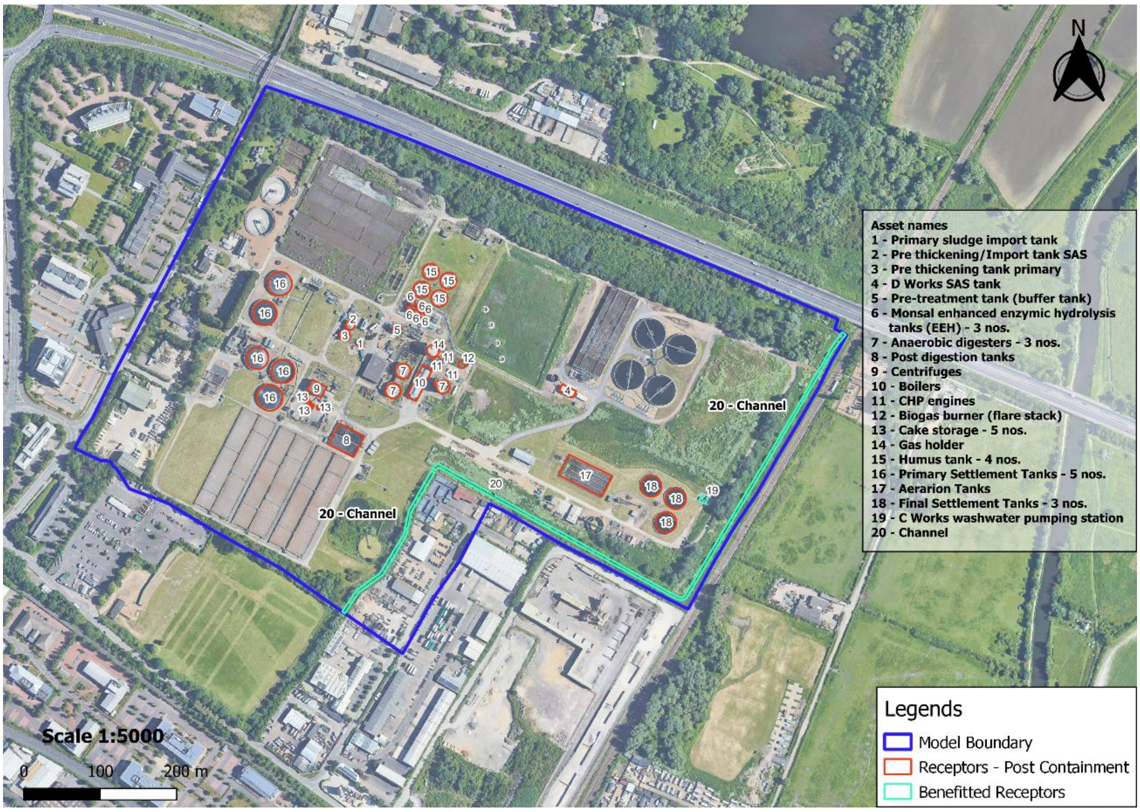
5.2 Impact of Tertiary Containment Options

Figure 5.2 shows the combined extent of sludge following the inclusion of containment measures within WRC. The modelling shows that no flow is allowed either off-site or into the channels on the site.

When proposed improvements are included, the sludge does not enter the channel and this benefitted receptor is marked in Figure 5.3.

[5] Refer Technical Datasheet (1.0 mm LLDPE) for more details

Figure 5.3: Receptors after inclusion of Tertiary Containment Options



After the inclusion of tertiary containment options, the list of receptors which remain affected is tabulated in Table 5.1 together with the depth of sludge. Assets near the Anaerobic Digester tanks generally experience a depth of sludge of greater than 0.5m (viz. Boiler house and Gas holder). The highest depth of sludge (3.44m) is noted near the Boiler house.

Table 5.1: Receptors with sludge depth – Post failure with containment options

S. No.	List of receptors	Maximum depth of sludge, m (Without containment option)	Maximum depth of sludge, m (With containment option)	Receptor's location
1	Primary sludge import tank - 3 nos.	0.95	0.95	Sludge Treatment Centre
2	Pre thickening/Import tank SAS	0.07	0.07	
3	Pre thickening tank primary	0.11	0.11	
4	D Works SAS tank	0.04	0.04	
5	Pre-treatment tank (buffer tank)	0.20	0.20	
6	Monsal enhanced enzymic hydrolysis tanks (EEH) - 6 nos.	0.84	0.84	
7	Anaerobic digesters - 3 nos.	1.52	1.52	
8	Post digestion tanks - 2 nos.	1.76	1.76	
9	Centrifuges	0.53	0.53	
10	Boilers	3.44	3.44	
11	CHP engines	0.95	0.95	
12	Biogas burner (flare stack)	1.15	1.15	

S. No.	List of receptors	Maximum depth of sludge, m (Without containment option)	Maximum depth of sludge, m (With containment option)	Receptor's location
13	Cake storage - 5 nos.	0.39	0.39	
14	Gas holder	2.70	2.70	
15	Humus Tank - 4 nos.	1.19	1.19	Water Recycling Centre
16	Primary Settlement Tanks - 5 nos.	0.86	0.86	
17	Aeration Tanks - 2 nos.	0.06	0.06	
18	Final Settlement Tanks - 3 nos.	0.67	0.67	

From Table 5.1, it is clear that the depth of sludge around the receptors remains same in the presence of tertiary containment option and does not cause any adverse impact with increased depth of sludge. The tertiary containment options were recommended in this section whereas if required any secondary containment can be proposed in the subsequent stages of design based on the storage volumes.

6 Conclusion

The hydraulic modelling shows that the proposed mitigation options are successful in retaining sludge on the site even in the event of a recent rainfall event that has resulted in ponding on the site.

The site is located within Flood Zone 1 and has a low probability (less than 0.1% AEP) of flooding from rivers or surface water according to Environment Agency flood maps.

There is a channel within the WRC which is a prominent pathway which could carry pollutants from the site to third-party receptors in the event of a catastrophic failure of critical sources. The high-level tertiary containment options are proposed in a way that the pollutants (sludge) are prevented from entering the channels by proposing bunds in key, at risk locations.

The escape of pollutants from the site along the property boundary is prevented by proposing bunds along the low points on the south-west side of the site. These mitigation measures have not been tested in the event of an extreme fluvial event which results in flooding to the site.

Impervious liners are proposed to ensure that no pollutants reach the groundwater through the permeable ground and the drain covers are recommended for the drainage inlets where they are located within the modelled extents of the sludge.

The spread of pollutants is shown to be contained within WRC. However, the assets within STC and WRC will be surrounded by sludge. Continuing operation of the site will require that these assets are provided with protection.

7 Assumptions

The model is built and assessed with various assumptions as listed below. The complex drainage and spill containment requirements are identified by developing a 2D model using TUFLOW software. The model helps to visualize the performance of any proposed containment design.

1. The sludge spillage was modelled as a typical water flow in terms of viscosity
2. ADBA classification tool was updated with the available limited information received from the client
3. The extent of the model is adopted based on the property boundary of WRC and along the ridges
4. Buildings, tanks, and other assets within WRC which are elevated above the ground are raised in the model (post-failure scenario) based on information received from the client and a high roughness value is assigned. However, at a few locations (where information from the client) is missing, the height of the buildings/ assets is assumed from 3D buildings in Google Earth.
5. In the pre-failure scenario, the buildings/ assets are raised by only 0.3m as there are instabilities caused where rainfall is added to the areas of the assets and then immediately flows off of the elevated area and falls to ground level.
6. The terrain is defined using the latest 2020 LiDAR data of 1m resolution. Survey data elevations received from the client are compared with LiDAR DTM and the difference observed is predominantly around the buildings and assets which are already elevated to appropriate heights in the model. Also, the survey data points are not regular, and they are inconsistent. Hence this is not considered in the model.
7. The channels running from south to north and from west to east are assumed to be concrete channels.
8. Land use is represented by downloading the OS Vector Map. Additionally, buildings and roads were digitized and included in the model based on Google Satellite Aerial Imagery.
9. FEH13 design rainfall is generated using the catchment descriptors of the site location downloaded from https://fehweb.ceh.ac.uk/GB/map. Rainfall is derived for a 10-year return period 24-hour duration using the InfoWorks ICM tool.
10. The breach/failure analysis was undertaken by applying the point inflow in the model. The location of the point inflow is the same as that of the storage facility. The breach was represented by a rectangular hydrograph with the volume of the asset discharged over a one-minute duration[6] representing the sudden failure of the source.
11. In the breach analysis, the tanks are raised by 0.5m only in their respective failure scenario to avoid the instabilities and represent the real-time situation at the time of failure

[6] Source: CFRAM Guidance Note 24 – Breach Analysis, 2013

12. Anaerobic Digesters 1 and 2 are assumed to be almost half-buried and hence considered to breach half of their total volume. Whereas the other Anaerobic Digester which is wholly above the ground is breached and discharges its total volume.
13. The density of Biogas from AD is assumed to be 1.1 kg/m^3 for calculating the volume of firefighting water required at the site
14. The mitigation measures have not been tested in the event of an extreme fluvial event (in excess of the 0.1% AEP event).
15. The tertiary containment options were included in the pre-failure scenario with the provision for cross drainage (openings in the bund) to simulate the initial water levels for the post failure scenarios and the cross drainage must be assessed in the detailed design stage to minimise any loss of flood storage.

Appendices

A. Site Risk Assessment from the ADBA tool

A.1 Hazard Posed

A.1.1 Source

Material	Physical properties	Quantity	units	Storage	Flammability	Corrosive	Ecotoxicity (based on LD and quantity)	Environmental hazard rating	Justification
Process									
Raw sludge	Liquid	5 x 230	m3	Covered clamp	Not flammable	No		H	EEH tanks
Raw sludge	Liquid	140	m3	Covered clamp	Not flammable	No		H	Primary sludge import tank
Raw sludge	Liquid	462	m3	Covered clamp	Not flammable	No		H	S A S holding tank
Raw sludge	Liquid	800	m3	Covered clamp	Not flammable	No		H	Sludge storage tank
Raw sludge	Liquid	580	m3	Covered clamp	Not flammable	No		H	Thickened sludge holding tank
Digested sludge	Liquid	3 x 2700	m3	Covered clamp	Not flammable	No		H	Digester tanks
Treated sludge	Liquid	2 x 1596	m3		Not flammable	No		M	Post digestion tank
Biogas	Gas	2250	m3	Covered clamp	Flammable	No		H	Gas holder
							Process Overall Rating	H	Any material with a "High" rating means the overall rating is High
Additives and site chemicals									
Ferric Sulphate	Solid			Stored in stainless steel or mild steel rubber lined tanks or plastic tanks	Not flammable			M	Reacts with most metals producing hydrogen- explosive Could emit highly toxic oxides of sulphur if heated to decomposition
Polyelectrolyte	Liquid/Solid			Avoid extremes, especially frost / freezing	Not flammable			M	Mild skin and eye irritant, may cause irritation of mucous membranes, Slippery underfoot when spilt
							Chemicals Overall Rating	M	
Fire fighting agents and cooling water spillages									
Foam, dry chemical powder or carbon dioxide types					Not flammable			M	Used as firefighting agent for Diesel and Gas Oil
							Spillages Overall Rating	M	
							Sources Overall Hazard Rating	H	

A.1.2 Pathway

Pathway – the route from primary containment to receptor		Environmental hazard	Notes
Site layout and drainage			
Channel - Concrete (Running from West to East)		H	Channel that carries flow to the river Cam
Channel - Concrete (Running from South to North)		H	Channel that carries flow to the river Cam
Overland surface runoff		H	Overland runoff to the river Chem through channels
Topography, geology and hydrology			
Secondary Aquifer		M	Refer Environmental Risk Assessment/ Permit application
Groundwater protection zone		L	Refer Environmental Risk Assessment/ Permit application (The site does not lie within a groundwater source protection zone)
Drinking water protection zone		L	Refer Environmental Risk Assessment/ Permit application (The site does not lie within a Drinking Water Protection zone)
Mitigation – do these apply?			
If a secondary containment system is present…		H	No secondary containment exists at present
If the rain water drainage system in the secondary containment fails safe…			NA
	Path & Mitigation Overall Rating	H	
Climatic conditions			
Annual rainfall < 1000 mm		L	Average annual rainfall is around 563mm
Annual rainfall > 1000 mm			NA
Snow accumulation is possible			NA
Fire Fighting Water			
Inflammable materials normally present on site in large quantities?		L	Gas holder is within STC but however sludge is not flammable
Location			
Site is in a flood plain		L	Site is not within the EA flood zones 2 & 3
Site is at bottom of a hill			NA
Site is connected to a sewage treatment works		H	STC is within WRC itself
	Site Considerations Overall Rating	H	
	Pathway Overall Hazard	**H**	

A.1.3 Receptor

Receptors	Within	units		Environmental hazard rating	Notes
Watercourses and bodies					
River Cam	300	m		H	
			Water Overall Rating	H	
Habitation					
Dwelling				M	Residential property is located in the north west of the site
Workplace	250	m		M	Refer Environmental Risk Assessment/ Permit application (101265_ERA_BioRA_CAM-Table 3.1) it contains Receptors within 250m of potential emisson sources.
			Habitation Overall Rating	M	Justification: As per ERA, ratings are updated
Other					
WRC and STC assets	9	m		H	
Bramblefields (LNR)	400	m		M	
Milton Country Park (Country Park)	350	m		M	
Tip Tree Marina (SSSI)	8.2	km		M	
Stow Cum Quy Fen (SSSI)	3	km		M	
Quy Water (SSSI)	3.8	km		M	
Wibraham common (SSSI)	6	km		M	
Dunmowes Manor Moat (SSSI)	6.7	km		M	
Gog Magog Golf Course (SSSI)	6.4	km		M	
800 Wood (SSSI)	7	km		M	
UN Environment World Conservation (SSSI)	4.3	km		M	
Near Walnut Tree Way (SSSI)	2.6	km		M	
Wandlebury Country Park (Country Park)	7.5	km		M	
Coton (Country Park)	5.8	km		M	
Worts Meadow & Bourne Wood Local (LNR)	3	km		M	
Coldhams Common (LNR)	1.7	km		M	
			Other Overall Rating	M	
			Receptors Overall Hazard Rating	H	

A.2 Site Hazard Rating

Calculated hazard ratings:			
Source	Pathway	Receptor	Site Hazard Rating
H	H	H	High
Possible Combination			Site Hazard
L	L	L	Low
M	M	L	Low
H	L	L	Low
M	M	M	Medium
H	M	L	Medium
H	H	L	Medium
H	M	M	High
H	H	M	High
H	H	H	High

A.3 Likelihood of loss of containment

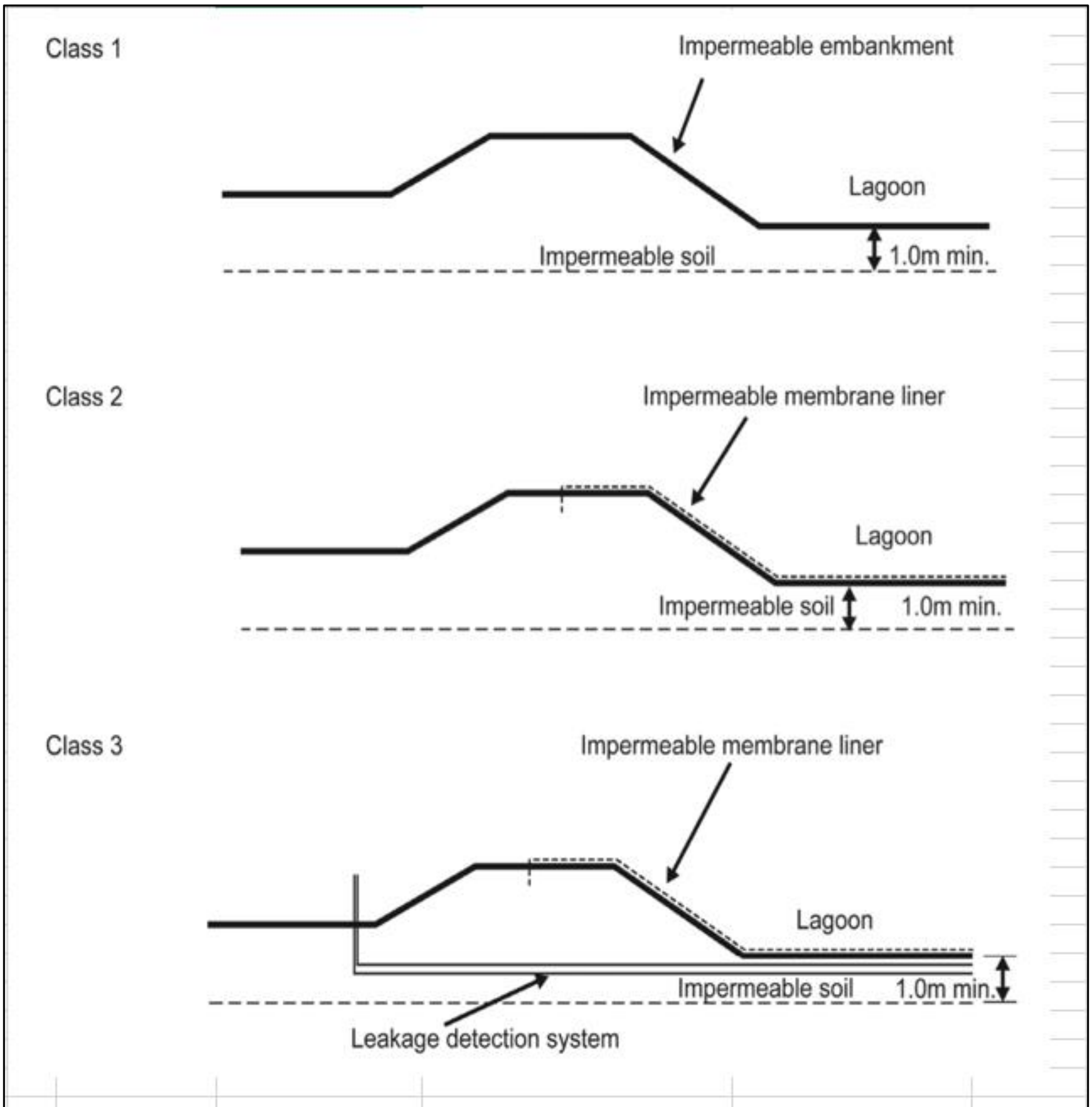
Risk of loss of containment	Annual probability of loss of containment
High	Greater than 1% (1 in 100)
Medium	Between 1% (1 in 100) an 0.0001% (1 in 1 million)
Low	Less than 0.0001% (1 in a million)

Risk #	Description of Risk	UNMITIGATED LIKELIHOOD	Mitigation applied	MITIGATED LIKELIHOOD	High	Site Overall Likelihood
1	Operational failures, such as failure of plant, or human failure by operators	H	Tertiary containment option is proposed	L		
2	Shortfalls in design – lack of alarms and fail-safe devices	L		L		
3	Structural failure – materials, components, detailing, corrosion or when exposed to heat and flame	H	Tertiary containment option is proposed	L		
4	Abuse – inappropriate change of use or other misuse	L		L		
5	Impact, eg from a vehicle	L		L		
6	Vandalism, terrorism, force majeure etc	L		L		
7	Fire or explosion	H	Tertiary containment option is proposed	L		
8	Geological factors -subsidence etc	H	Tertiary containment option is proposed	L		
9	Ageing or deteriorating assets/sub-components.	M	Tertiary containment option is proposed	L		
10	Lightning strike	L		L		
11	Pollutant reaching the River Cam	H	Tertiary containment option is proposed	L		

A.4 Site Risk and Classification

Site Hazard Rating	Likelihood	Overall Site Risk Rating	Indicated Class of Secondary Containment Required
High	High	High	Class 3

A.5 Standard containment designs



It should be stressed that in all cases the ground and soil conditions should comply with the impermeability, stability and durability criteria set out previously. Where impermeable linings and leakage detection systems are required these are as an **additional** level of protection and **not** to compensate for inadequate ground and soil conditions.

B. Spill Containment Equipment

Equipment	Reactive	Proactive	Ease of Remote Activation	Retrofittable	Manual Handling	Solar Powered	Testable	Sustainability & Recycling. L=LOW	Suitable for Firewater Containment	Comments
Spill Kit	Yes	No	N/A	Yes	Yes	N/A	No	L	No	Mainly used for maintenance and small volume spills, should be used by trained staff. Generates contaminated waste which requires disposal.
Fixed Bund	Yes	Yes	N/A	Yes	N/A	N/A	Yes	H	Yes	Refer to CIRIA736. Expensive and generally requires capital investment. Essential for high risk storage. Normally only protects the primary vessel.
Portable Bund	Yes	No	N/A	Yes	Yes	N/A	Yes	H	No	Designed for storage of IBC's mainly used in production areas.
Chemical Store	Yes	Yes	N/A	Yes	N/A	N/A	Yes	H	Yes	Primarily used for Chemical and IBC storage. Normally fitted with bunded base.
Drain Cover	Yes	No	N/A	Yes	Yes	N/A	Yes	L	Yes	Drain covers are part of the spill kit and require correct fitting. Clay mats are single use only. When used for spills it is important to use correct PPE. Can expose operator to the spillage. No containment capacity so tertiary area must be good to prevent ground contamination.
DrainBlok	Yes	Yes	N/A	Yes	Yes	N/A	Yes	L	No	DrainBlok can be used multiple times to seal off drainage. These are used by the fire service when the site has no control of drainage run off. Requires trained operators.
Fixed Bladder System	Yes	Yes	Yes	Yes	No	Yes	Yes	H	No	Uses a fixed bladder (stopper). Originally developed in 1998 as a single use emergency containment valve. Air leaks and rodent damage can make them unreliable. Any air leaks will result in containment loss. Easy to retrofit to most drains. Large stoppers are slow to inflate. Not suitable for long term fire water containment due to air leakage.
Penstock Valves / Sluice Gates	Yes	Yes	Yes	Yes	Yes/No	No	Yes	L	Yes/No	Penstocks require correct installation and are most suited to the water and process industry. Have been used as the preferred containment valve by the Environmental Regulators. The word Penstock is generic and fails to consider the leak rate of valves. Any site using a valve for containment should consider the need for the valve to stop all flow. Expensive and difficult to retrofit to drains.
ToggleBlok	Yes	Yes	Yes	Yes	Yes/No	Yes	Yes	H	Yes	Specifically designed as a drop seal valve for spill and fire water containment. Developed to use low power radio and solar power.

Source: Making Water Pollution Prevention Pay (Prepared by David Cole from Sandfield Penstock Solutions, 2018) mottmac.com