Wessex Water Services Limited

Avonmouth Bioresources Centre

CIRIA 736 IED Report - Secondary Containment Assessment

Environmental Permit Application (Ref: EPR/PP3734LK)

	Author	Checked	Approved
Name	JBC	Richard Margrett	Nick Lowe
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Contents

1. Report Context and Scope

This report has been prepared to support the Application for Environmental Permit Variation at Avonmouth Bioresources Centre (BC), issued in June 2021, Permit Ref EPR/PP3734LK.

The Environmental Permitting (England and Wales) Regulations 2016 (EPR) application was submitted due to changes to the Environment Agency (EA) interpretation of the environmental permitting exclusion for Urban Wastewater Activities (under (EPR) Schedule 1, Part 2, Chapter 5, Section 5.4). The EA interpretation now requires that anaerobic digestion (AD) plants treating over 100 tonnes/day (t/d) are classified as installations for the purposes of EPR.

The primary purpose of the addendum is to secure stakeholder agreement of the method, logic, assumptions and outputs in the risk assessment and the general level of intervention deemed necessary to achieve BAT 19c compliance at Avonmouth BC and, specifically, emissions to soil and water due to overflows and failures from tanks, vessels, and associated pipework. Upon acceptance, detailed solutions will then be developed to satisfy the EPR.

This report includes:

- A full environmental risk assessment (ERA) of all existing primary and secondary containment measures at Avonmouth BC to safeguard against the impacts of catastrophic containment failure scenarios.
- Consideration of credible modes of failure to emphasise the actual level of risk associated with each primary containment asset.
- Spill modelling of the complete loss of the above ground level inventory from each primary containment tank, to demonstrate the potential to reach key receptors.
- The nature and extent of improvements deemed necessary to contain inventory spills following catastrophic failure of primary containment to satisfy BAT 19c of the Waste Treatment BREF.

The ERA has been developed in line with CIRIA 736 'Containment Systems for the Prevention of Pollution' guidelines (CIRIA 736) and the 'ADBA Secondary Containment at AD plants: An Industry Guide' document (ADBA Guidance). Solutions align with the guidance outlined in CIRIA 736 where it is practicable (not grossly disproportionate) to do so on an existing operational site. Where it is not practicable, alternative best available techniques are proposed for acceptance. The 110% and 25% rule outlined in the CIRIA 736 guidance is adhered to as a minimum requirement.

2. General Approach

The Source-Pathway-Receptor model as prescribed by CIRIA 736, and in accordance with sector guidance, has been used to establish the level of risk of failure of BC assets containing large volumes of sludge and sludge liquors, and the subsequent impact on local receptors. The class of containment required is based on this risk assessment.

2.1 Source

One of the key elements for determining the site hazard rating is as described in CIRIA 736 Section 2.3.1 – defining the Source of the pollution. It is the inventory of waste, surface water runoff that is contaminated by the inventory, firefighting agents that are harmful to the environment, and firefighting and cooling water is contaminated by the inventory.

The potential pollutants present on site are assessed by the physical properties such as density and viscosity (percentage dry solids of the inventory) and the flammability that can indicate the potential impact of the inventory and severity to the receptor.

Loss of containment scenarios and the subsequent total volume of inventory released are based on catastrophic failure of BC assets, regardless of whether the mode of failure is credible or not. The minimum volume assumed for a catastrophic failure is based on the 110% and 25% rule outlined in Chapter 4 of CIRIA 736.

2.1.1 Credible Failure Modes

Credible modes of failure are considered to emphasise the actual level of risk associated with each primary containment asset. This approach is important when assessing the probability of a failure mode occurring within the risk assessment to determine the required class of containment. It also helps to emphasise the design and inspection and maintenance safeguards needed to minimise the risk of smaller spills associated with higher probability events.

Credible failure modes of a tank or vessel have been established by considering the following factors:

- Containment material
- Height to width Aspect ratio
- Working volume
- Current Structural Condition
- Dry Solids content of the inventory
- Vulnerability to vehicle collision
- Site security risk with respect to an intruder causing irreputable damage
- Operating requirements of a given BC asset

For example:

A worst-case scenario:

A rapid and complete loss of containment would be a reasonably expected for a glass coated steel digester (pressurised) tank which has exceeded its design life and is showing clear signs of severe corrosion and fatigue.

A low-risk scenario:

Any catastrophic loss of containment from a reinforced concrete digester would be considered highly unlikely where the structure has been designed to the relevant water retaining codes, constructed under supervision, built with industry standard safeguards in place, and is routinely inspected and maintained in accordance with a robust inspection and maintenance regime.

The risk assessment will normally only include BC assets containing large working volumes as these are likely to define the containment solution for the site. Small BC tanks / vessels, mechanical plant, and interconnecting pipework is not normally included within the assessment unless their position or alignment, in relation to the containment solution, results in a significant residual risk to receptors.

Although credible failure modes are considered in the ERA, the proposed secondary containment solution volumes align with the 110% and 25% rule outlined in Chapter 4 of CIRIA 736.

2.1.2 Inventory

For the purposes of the spill modelling, the inventory will either be raw sludge and sludge liquors or digested sludge. Section 3.5 of the ADBA Guidance notes that CIRIA 736 suggests raw sludge should be classed as a hazardous substance given its influence on the oxygen balance (of aquatic environments) and microbial contamination.

- Raw sludge is therefore classed as high risk in the risk assessment.

The ADBA guidance does acknowledge that the hazard rating for fully digested sludge may be reduced given that it may be safely spread on fields under controlled conditions.

- Fully digested sludge is therefore classed as medium risk if considered in the risk assessments.

Section 4.3.4 of CIRIA 736 focusses on recommendations for quantifying firefighting water and agents and emphasises the need to adequately provide for a resultant volume for a secondary containment solution. However, Section 3.21 of ADBA Guidance acknowledges that:

- Sludge inventory at a BC is not flammable.
- Biogas will be produced through the digestion process at relatively low volumes and pressures and accidental ignition will lead to short lived fire/explosion.
- Fire-fighting foam and water is therefore not anticipated to be used in significant volumes for fighting a fire or cooling a tank in this scenario.

Firefighting foam or water is therefore not normally considered for the purposes of the spill modelling. The exception is if there is potential for a fire caused by the ignition of WRC asset near the BC assets. In this case the fire itself may credibly cause failure of the BC asset. In this scenario, firefighting agents, and loss of inventory would be considered.

2.2 Pathways

Following a catastrophic failure of above ground primary containment, the escaped inventory will follow the natural topography of the ground before it reaches access points to underground drainage, duct services, surface water bodies, or permeable areas of ground.

Once a spill reaches permeable ground it will continue to migrate according to the ground topography. However, a proportion of the inventory now in contact with the ground will also start to infiltrate into the ground. The rate of infiltration will vary depending on the properties of the inventory and the permeability of the ground. From here, the escaped inventory has the potential to migrate towards receptors such as groundwater or surface water bodies.

Buried tanks or above ground tanks with features that partially extend below ground also need to be considered. These tanks will typically be of reinforced concrete construction. The credible modes of failure are limited to gradual degradation caused by potentially aggressive ground conditions or the slightly corrosive nature of the inventory. This is likely to lead to leaks rather than large scale spill events.

Spill simulations are therefore focussed on the routes of the spill migration overland to identify the proportion of volume (if any) reaching surface water bodies or permeable ground. The spill simulations are then used to confirm the suitability of proposed bund solutions.

Note: The inventory volume held below ground in an asset is not included in the overland spill simulations.

Vertical and horizontal migration potential of lost inventory in the ground has been considered in the ERA. This is based on the local geology and hydrogeology described in Section 4 of this document.

2.2.1 Spill Simulation Method

Overland spill simulations from the BC assets of interest are generated using a Geographical Information Systems (GIS) “rolling ball” tool. For each BC asset, an Esri ASCII grid file is created from 1m Lidar Digital Terrain Model data (point density of 1 point per square metre) with a 1km radius from the selected spill position.

The potential spillage route is determined by following the path of least resistance from the selected spill position. From this spill position, the tool will look up the eight adjacent 1m square cells and spill into the cell with the lowest ground elevation. In the next iteration the tool will look at all cells adjacent to the two cells currently containing the spill and spill into the adjacent cell with the lowest elevation and so on.

Each iteration adds a 1 metre x 1 metre x 0.1m spill volume and iterations will continue until:

- The simulation reaches the end of the number of iterations, defined by the total credible spill volume determined by the risk assessment or.
- The spill reaches a surface water body such as a lagoon, lake, watercourse, or sea.

For any given iteration, if adjacent cells do not have a ground elevation lower than the cells containing the spillage, then the simulation adds 0.1m to the cells featuring the spillage and adjusts the remaining number of iterations based on the residual spill volume.

2.2.2 Simplifications

The model simulation is simplified in the following ways, to generate a conservative but reasonably accurate overland spill route for the loss of containment from a given source.

- All surfaces behave as impermeable surfaces, so flows are not lost to ground in the simulation.
- Small chambers such as drainage features and cabling drawpits are not included for the purposes of the rolling ball simulation.

- Buildings and structures have 100 metres added to their lidar value so the spill cannot travel through them.
- Water in the Lidar model is given a negative elevation value and once the spill reaches water, 100% of the residual inventory volume is assumed to also spill into the water.
- If a bund is proposed for a solution, then 0.3 metres is added to the relevant Lidar cells along the suggested perimeter of the bund to represent a notional height in the first instance.

2.2.3 Limitations

The failure mode of an asset can significantly influence how the spill volume migrates from the primary containment. For example, overtopping of a tank will normally cause flows to spill around the complete perimeter whereas tank corrosion leading to a localised rupture will result in flows discharging from a single position. The rolling ball method always assumes a point source discharge regardless of the established failure mode. A worst-case spill position is selected based on surrounding topography and proximity to nearby receptors. In certain instances, more than one spill position is required to prove that a containment solution is effective; for example, when the ground levels fall in more than one direction away from the asset.

The model simulation does not account for percentage dry solids of the spill. However, the rolling ball method described above closely represents the behaviour of water, or sludge with a very low dry solids content. The model is therefore likely to overpredict the extent of a spill where the percentage dry solids of the source’s contents is higher.

2.2.4 **Other Pathway Considerations**

The GIS “rolling ball” tool will generally overpredict the extent of the overland spill and therefore the risk to local receptors. However, below ground services such as surface water drainage routes or duct routes do have the potential to rapidly carry a spill to local receptors, or to bypass containment solutions. Site services are therefore acknowledged as part of the risk assessments to highlight any potential short circuiting, and this will be considered further when developing a detailed solution.

The GIS “rolling ball” tool cannot model dynamic effects caused by a relatively rapid loss of containment. It also does not account for pressurised ejections or “jetting” from a source. This could be crucial when considering containment solutions if:

- The asset is close to a defined bund perimeter,
- The asset is close to a receptor and,
- An established credible failure mode could cause surge or jetting effects.

Table 6.5 in CIRIA 736 recommends that the requirement to assess the implications of these events depends on the overall site hazard rating and hence the class of containment required. The key recommendations are summarised below.

Recommendation	Class1	Class2	Class3
c. No structure within the bund to be closer than its own height to the bund wall	Not necessary	Desirable	Recommended
g. Take account of possible jetting failure	Desirable	Recommended	Recommended
h. Take account of surge effects	Desirable	Recommended	Recommended

Figure 2.1: Extract from the ADBA Guidance Summarising Examples of Key Performance Recommendations by Class from Table 6.5 CIRIA 736.

Given that the volumes of inventory stored are significant at most BC, the impact of dynamic and jetting effects are always considered in addition to the spill modelling, regardless of the containment class. The potential for dynamic and jet effects are based only on the established credible failure modes of assets and subsequent movement of the escaped inventory. In certain cases, this may mean that the intended bund position does not need to align with recommendation c in Figure 2.1 for class 2 and class 3 containment. For this assessment, the requirements are assessed by inspection. However, at detailed design, assertions will be demonstrated by calculation for jetting where appropriate.

BC are often situated in low lying areas close to water bodies and can therefore be at risk of fluvial flooding, which may introduce an additional and more direct pathway to a receptor. Avonmouth BC is not at risk of fluvial flooding as indicated in Figure 2.2 unless the flood defences that serves the site and surrounding area is breached. In this scenario, the site largely resides within flood zone 3. The ERA does therefore acknowledge the extremely remote possibility of flooding and approaches to containment will be developed to mitigate the risk of floodwater ingress.

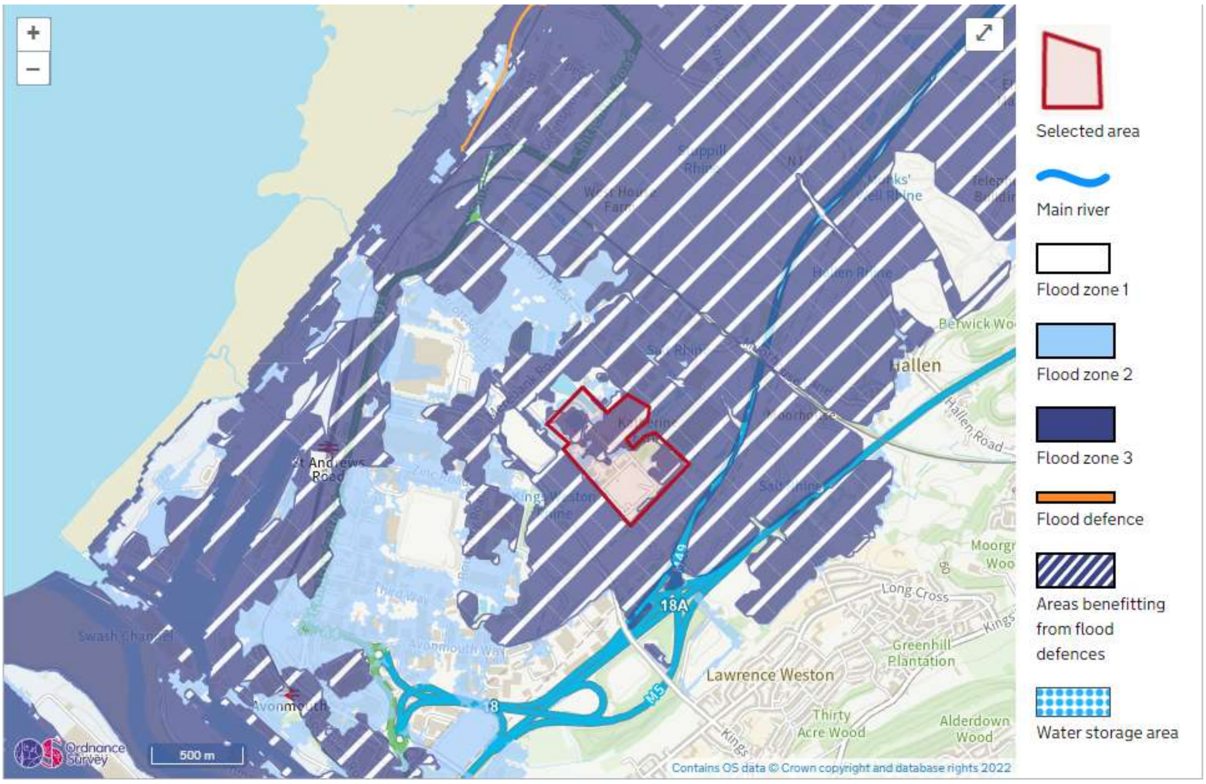

Figure 2.2: Flood Risk Map for Avonmouth BC from https://flood-map-for-planning.service.gov.uk/.

2.3 Receptors

Receptors will normally consist of permeable ground and aquifers beneath the site, surface water bodies within or near to the site, sites with environmental designations, and local commercial or residential properties.

The adjacent water recycling centre (WRC) is not normally considered to be a direct receptor but could act as a pathway if the spill overwhelms the treatment processes and leads to a final effluent consent failure and subsequent pollution event. It's ability to effectively treat following a spill event is therefore considered in the risk assessment.

Section 3.36 of the ADBA Guidance indicates the type of receptors that could lead to a higher hazard rating than "Low". This information is principally used to justify the hazard ratings for receptors in the risk assessments.

2.4 Approaches to Solutions

Proposed secondary containment solutions shall be developed, in accordance with the 110% and 25% rule outlined in CIRIA 736. Additional volume allowances for rainwater and firefighting agents will be considered where applicable. Solutions shall also include appropriate measures to safeguard against specific failure modes such as a vehicle collision leading to jetting from a pipe.

Two principal approaches have been taken to reach a practicable solution:

1) Fully compliant Secondary Containment solution in accordance with CIRIA 736.

   This approach is based on constructing a reinforced concrete structure locally around one or several existing primary assets to contain a volume of inventory in accordance with the 110% and 25% rules outlined in CIRIA. The impact of the solution on the operability and maintainability of the tank itself and surrounding assets is then considered with the BC's site operators.

2) Solution that prevents sludge from leaving site following Catastrophic Failure.

   This is not necessarily a "pure" CIRIA 736 secondary containment solution but can achieve an equivalent level of containment appropriate to BAT 19c. The approach is based on maximising the benefits of existing site infrastructure, such as forming shallow bunds and ramps around existing impermeable hardstanding and road areas, to minimise impact on the operability and maintainability of the site. The solution will incorporate measures to demonstrate that containment infrastructure, including existing impermeable hardstanding and drainage, is in an appropriate condition.

   It is acknowledged that this approach will often involve much larger impermeable surface areas and therefore the potential for significant rainfall volumes accumulating following the catastrophic failure of an asset. Alternative methods of managing additional run off are therefore considered with this approach, which includes a controlled pumped discharge back to Avonmouth WRC for treatment, or the use of the tankers to maintain a volume in the bund until the 1 in 10-year storm event subsides.

   It is also acknowledged that this type of solution will result in numerous primary assets within a common containment bund. In this case, containment volume may be based on 25 percent of the total asset volume rule outlined in CIRIA 736 if the calculated volume is greater than the volume based on 110% of the largest tank within the bund.

> The Environment Agency were consulted about whether they would accept this approach in principle on 15/06/22. Tommy Wager from the EA confirmed that they would accept such proposals as long as the solution provides an equivalent level of containment appropriate to BAT 19c, and clear supporting justification and evidence is provided.

Secondary containment solutions will be designed to provide an equivalent level of containment appropriate to BAT 19c and justification will be provided alongside the preferred approach. The detailed design of the proposed containment solution, including walls, paving, joint details, refurbishment of existing assets, and maintenance regime specification will be reviewed by a chartered structural engineer.

Any areas designated as part of a primary or secondary containment system will be classed as such on Wessex Water's asset database and will be subject to a routine inspection/maintenance regime to ensure ongoing structural integrity. This will include monthly checks by trained operators who will refer signs of deterioration to a chartered structural engineer for review. A chartered structural engineer will also carry out their own review on a suggested two-yearly basis to verify the integrity of the containment assets.

3. Information Sources

The following information sources have been used for the study presented in this report:

- General and site-specific information provided by the Operator relating to the sludge treatment process; infrastructure details / records and other relevant operational information and Process Flow Diagram, tank condition reports and P&ID.

- Environmental data report and mapping provided by GroundSure based on various publicly available information sources. - Information provided by the Environment Agency following a specific data request which included license abstraction, rainfall data (not used), discharge consents, water quality data (but nothing near the site and therefore not used).

- Additional publicly accessible information from the UK Government and the British Geological Survey (BGS).

Site visits were also conducted. The purpose of these visits was to obtain additional information from the Operator, undertake visual inspections of the BC assets and infrastructure and the immediate surrounding area to provide contemporary information for the purposes of this assessment. Preliminary discussions have also taken place with the Operator on the draft secondary containment solutions considered.

4. Site Context

Avonmouth Water Recycling Centre (WRC) is located in the Avonmouth Severnside industrial area, approximately 1.35km to the northwest of Bristol (NGR: ST5339179395), and 1.8km to the southeast of the Severn Estuary.

The operational area covers approximately 20 Ha, which includes the assets that comprise Avonmouth BC, WRC where wastewater is treated, and the renewable energy centre (REC). These are collectively referred to as 'the Avonmouth Site' or 'the Site' in this report.

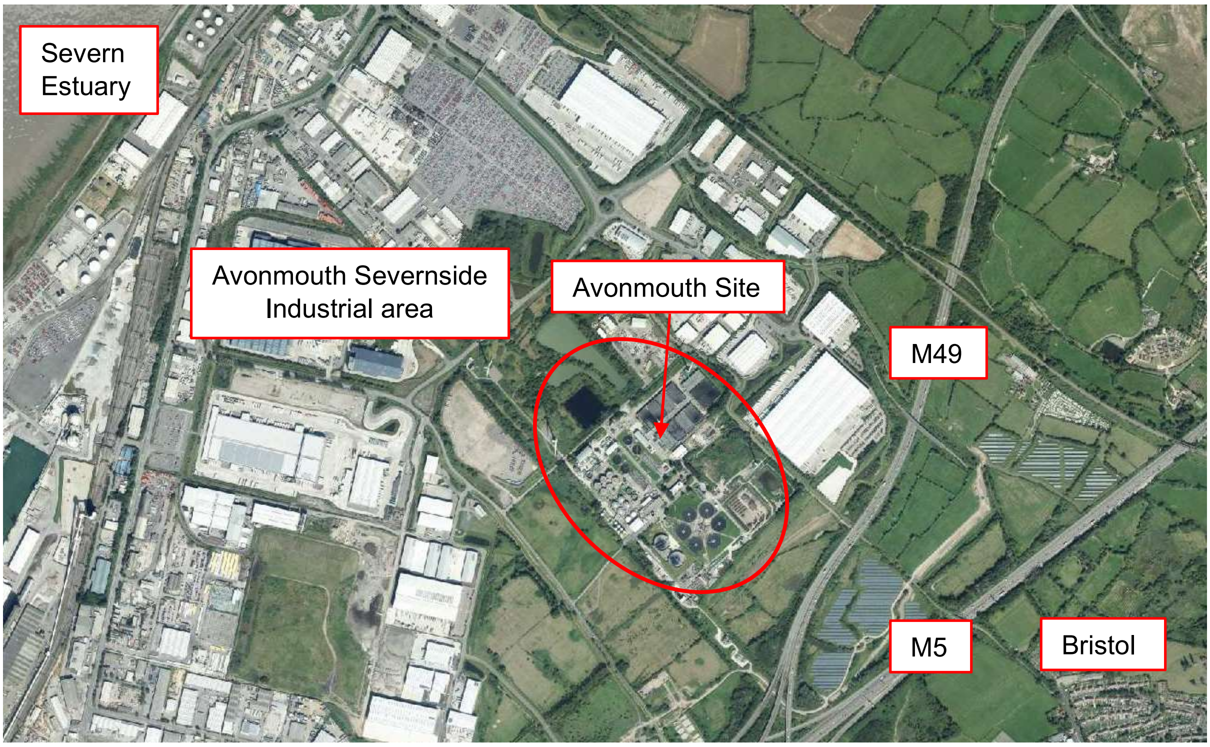

Figure 4.1: Avonmouth Site Setting

5. Bio-resources Centre Overview

This section provides a summary of the sludge treatment process including the key assets and associated infrastructure at the Bioresources Centre (BC). It also summarises the general topography, ground finishes, and drainage features serving the BC.

BC assets that are considered as part of the CIRIA 736 ERAs are indicated in Table 5.1 below and shown in Figure 5.1.

Table 5.1: Assets Considered for CIRIA 736 ERAs

Asset name	Ref
SBR SAS Balancing Tank	**M1**
Thickened SAS Transfer Tank	**N**
Import Sludge Reception Tank	**D**
Avonmouth Consolidation Tanks	**I**
Bellmer Feed Tank	**J**
Thickened Sludge Bellmer tank	**L**
APD GBTs 1, 2 and 3 Feed Tank	**F**
APD Feed Tank	**H**
Acid Phase Digestion (APD)	**O1-O6**
Mesophilic Anaerobic Digestion (MAD)	**P1-P8**
Secondary Sludge Storage Tanks (SSST)	**Q**
Centrifuge Feed Sludge Tank	**R**
Raw Break Tank	**T**

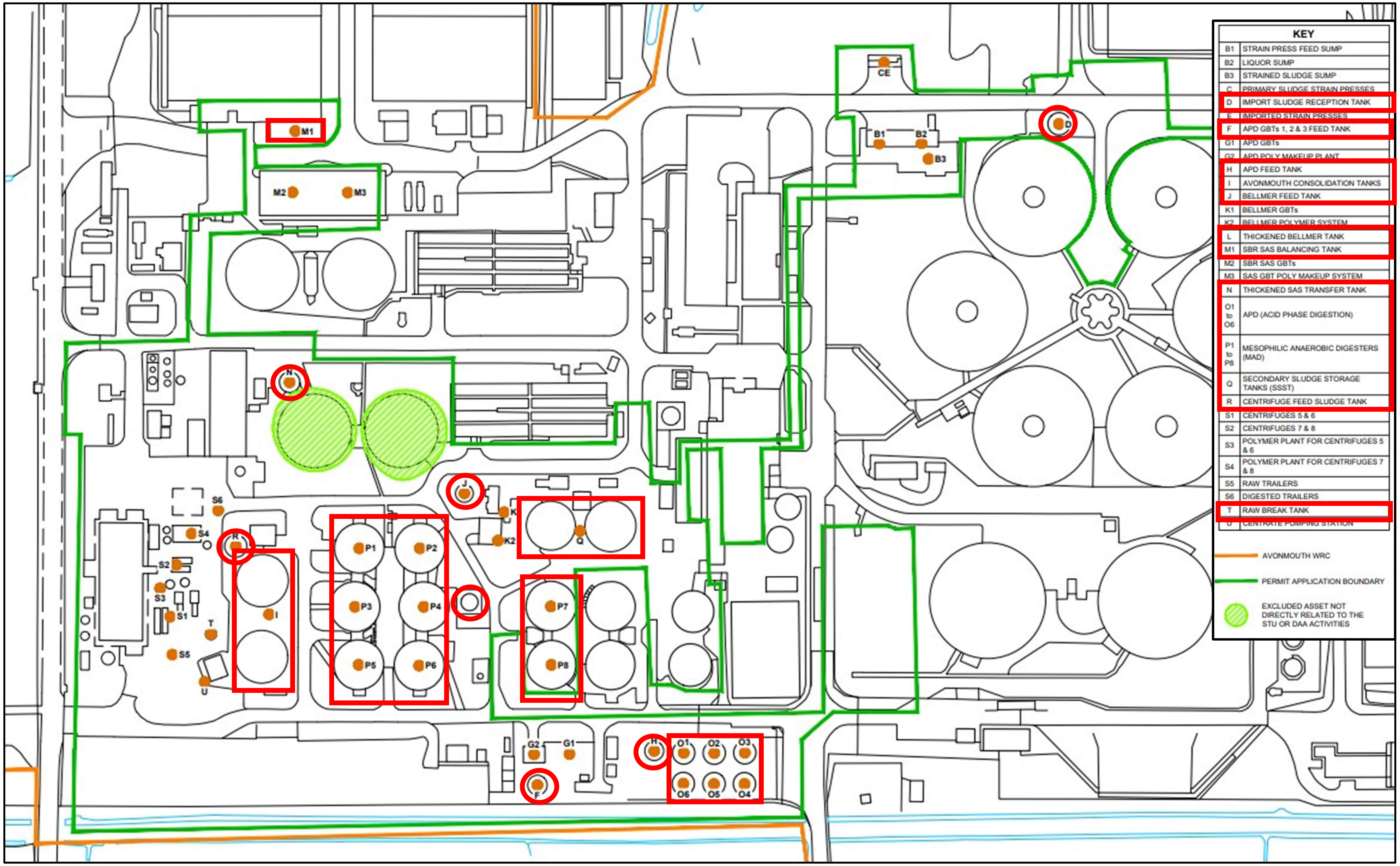

Figure 5.1 – Site and Installation Boundary, and Position of BC Assets (Assets Considered for CIRIA 736 ERAs Outlined in Red)

5.1 Sludge Treatment Process

The Avonmouth BC treats indigenous sewage sludges arising from sewage treatment processes operated within the wider Avonmouth WRC (Water Recycling Centre), as well as sewage sludges generated by smaller WW ‘satellite’ WRCs. The principal activities undertaken within the BC is outlined below. Each asset in the summary description is provided with a corresponding letter which is referenced in the Avonmouth Asset Plan to show its location within the installation.

- Sludge from the Primary Sedimentation Tanks, located at the wider wastewater treatment works, flows into the internal pumping station (IPS) and into the strain press feed sump [B1].
- Raw sludge is then processed through the 3no primary sludge strain presses [C], the strained sludge is delivered to the strained sludge sump at the IPS [B3].
- Imported sludge from satellite sites across the Wessex Water portfolio are transported by road tanker and are discharged into the import sludge reception tank [D].
- The imported sludge is then pumped to 2no imported strain presses [E] and transferred to the IPS [B3] strained sludge sump .
- The screenings from the strain presses are collected in a skip and taken for composting. Any liquors removed are returned to the head of the works via the liquor sump in the internal PS [B2].
- Strained sludge from the IPS [B3] can then take 2 routes, the primary route is to Acid Phase Digestion (APD) GBTs 1, 2 and 3 feed tank [F].
- Sludge is passed forward and thickened in the 3no APD GBTs [G1], assisted by polymer addition from the poly makeup plant [G2]. It is then pumped to the APD feed tank [H].
- The IPS strained sludge sump [B3] can also pump to the 2no consolidation tanks [I]. These tanks then pump to the Bellmer Feed Tank [J]. The tank supplies the 2no Bellmer GBTs [K1] which, with the aid of polymer injection [K2], thickens sludge before it is fed into the thickened Bellmer tank [L]. Thickened raw sludge is then pumped to the APD feed tank [H].
- SAS originates from the SBRs and passes through the SBR SAS balancing tank [M1] before being thickened by injecting polymer from [M2] into the feed sludge to the SBR SAS GBTs [M1]. It is then transferred via the thickened SAS transfer tank [N] to the APD feed tank [H] where it is mixed with thickened raw sludge from the Bellmer thickened tank [L] and APD GBT feed GBTS [G1].
- The liquors from all sets of GBTs are collected and returned through the site foul water drainage into the liquor sump at the IPS [B2] to be returned to the head of the works for re-treatment through the WRC plant.
- Sludge from the APD feed tank [H] is fed to APD vessel 1 [O1] and heated via a hot water/sludge heat exchanger. The feed is batch fed through a series of 6no tanks forming the APD (Acid Phase Digestion) [O1-6] process.
- The APD sludge is pumped to 8 concrete mesophilic anaerobic digesters (MAD) [P1-8]. 6 digesters [P1-6] form what is known as MAD 1, whilst 2 digesters [P7+ P8] form MAD 2.

- Digested sludge is gravity fed to the 2 x Secondary Sludge Storage Tanks (SSST) [Q].
- Sludge from the SSST [Q] is transferred to the centrifuge feed sludge tank [R] where the digested sludge is dewatered to cake using centrifuges 5 & 6 [S1] and 7 & 8 [S2]. Polymer is injected to the feed for centrifuges 5 & 6 from plant [S3] and into 7 & 8 from plant [S4] to aid dewatering of the digestate.
- The cake is discharged by conveyor into trailers and transferred out the permit boundary for removal off site for recycling to agricultural land.
- Raw sludge can be dewatered using centrifuges 5 & 6 [S1] which are fed from the 2no consolidation tanks [I] via a raw break tank [T]. Any raw cake produced is then sent off-site for treatment.
- Raw dewatered cake is delivered to raw trailers [S5] which are transported out of the permitted boundary for treatment. Digested dewatered cake is delivered to digested trailers [S6] and then transported out of the permitted boundary for recycling.
- Centrate from centrifuges 7 & 8 enters the centrate pumping station [U] before returning with centrate from centrifuges 5 & 6 and GBT filtrate via the site foul water drainage into the internal pumping station [B2]. All liquors are then passed back to Avonmouth WRC for treatment.
- Heat is primarily supplied to the APD and MAD digesters from a natural gas boiler [BH], or 5x combined heat and power engines (CHPs) [BI1-5].
- The biogas generated from the digestion process is collected and stored within the Gas Holders (x2) [V]
- Biogas from the digesters can either be used as fuel for the site CHPs [BI1-5] or cleaned and injected into the gas to grid process depending on site requirements. The primary source of biogas consumption is the gas to grid process.
- There are various condensate pots on the biogas pipelines which collect condensate. This is collected and returned through the site foul water drainage into the liquor sump at the IPS [B2] to be returned to the head of the works for re-treatment through the WRC plant.

The following additional assets contain or use chemicals and / or other potential contaminants that could pose a risk of pollution to ground or the local water environment. A secondary containment system is present for each and the volume is adequate for the size of the asset.

- Plant used to store and prepare liquid polymer.
- The Combined Heat Plant includes lubricant oil storage tanks.

5.2 Topography, Surfacing, and Drainage

The topography of the Site is generally flat with the BC at an elevation of approximately 7-8 m AOD.

The BC consists of impermeable surfacing, sealed drainage, and kerbing that directs spills and surface run off to a local pumping station (LPS) situated on the opposite side of the road to the APD tanks. As outlined in Section 5.1, all process liquors and overflow flows are directed to the Internal Pumping station (IPS).

Both the LPS and IPS transfer incoming flows downstream of the storm overflow, to avoid risk of discharging to the storm tanks. The pumped flows also discharge upstream of the primary settlement tanks (PSTs) for full treatment.

The approximate impermeable surface extents are indicated in Figure 5.2. This infrastructure will have been designed principally for appropriate access and management of surface water run-off and small spills associated with general operation and maintenance. A portion of surfacing of the BC is impermeable with sealed drainage. These extents have the potential to be incorporated into a wider bund solution, subject to a condition assessment and associated repairs.

Figure 5.3 displays the below ground site drainage arrangements which highlights the Storm water sewers and pipelines in blue and foul water sewers and pipelines in red. The route of the outfall culvert is also shown.

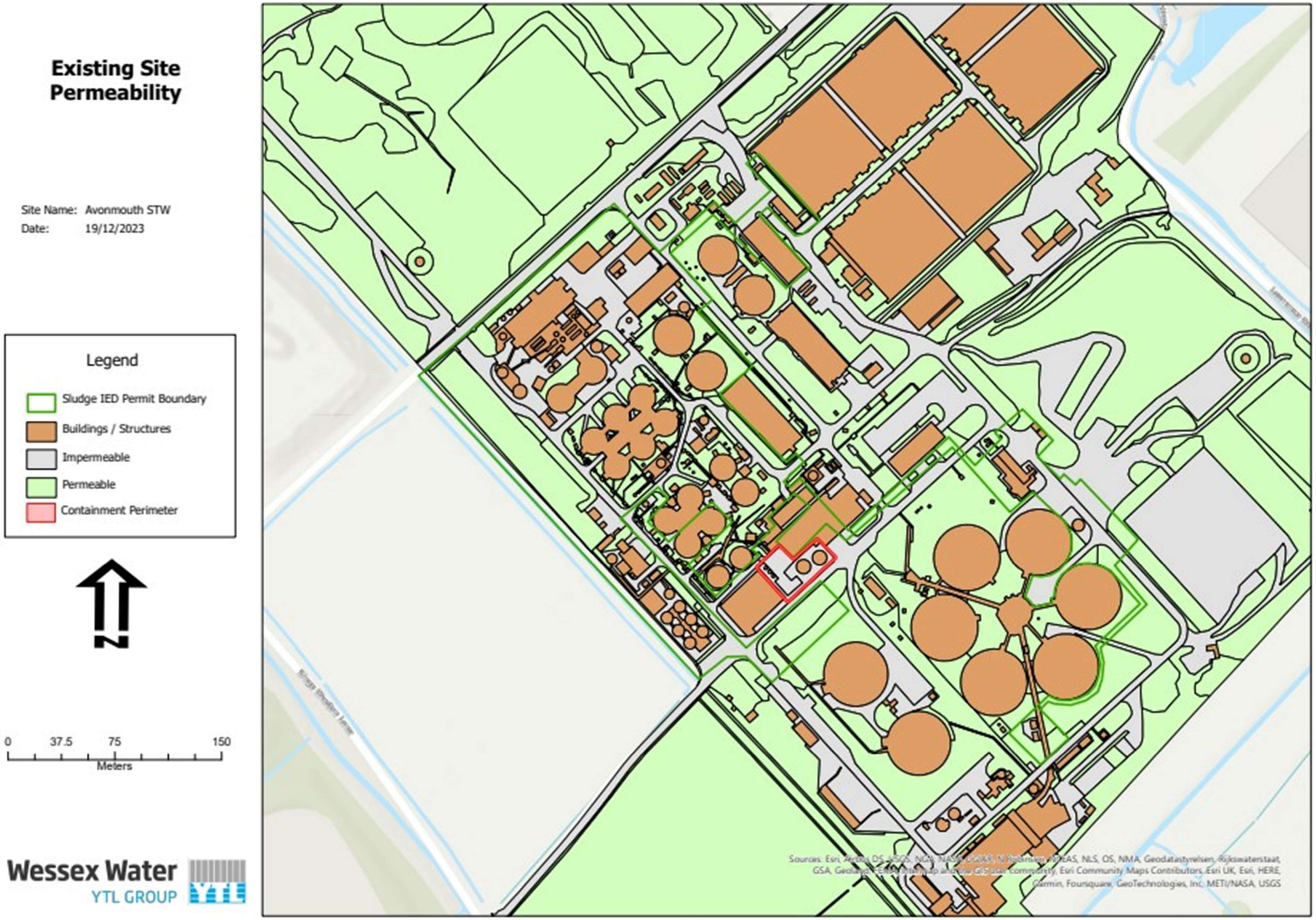

Figure 5.2: Existing Site Permeability Plan

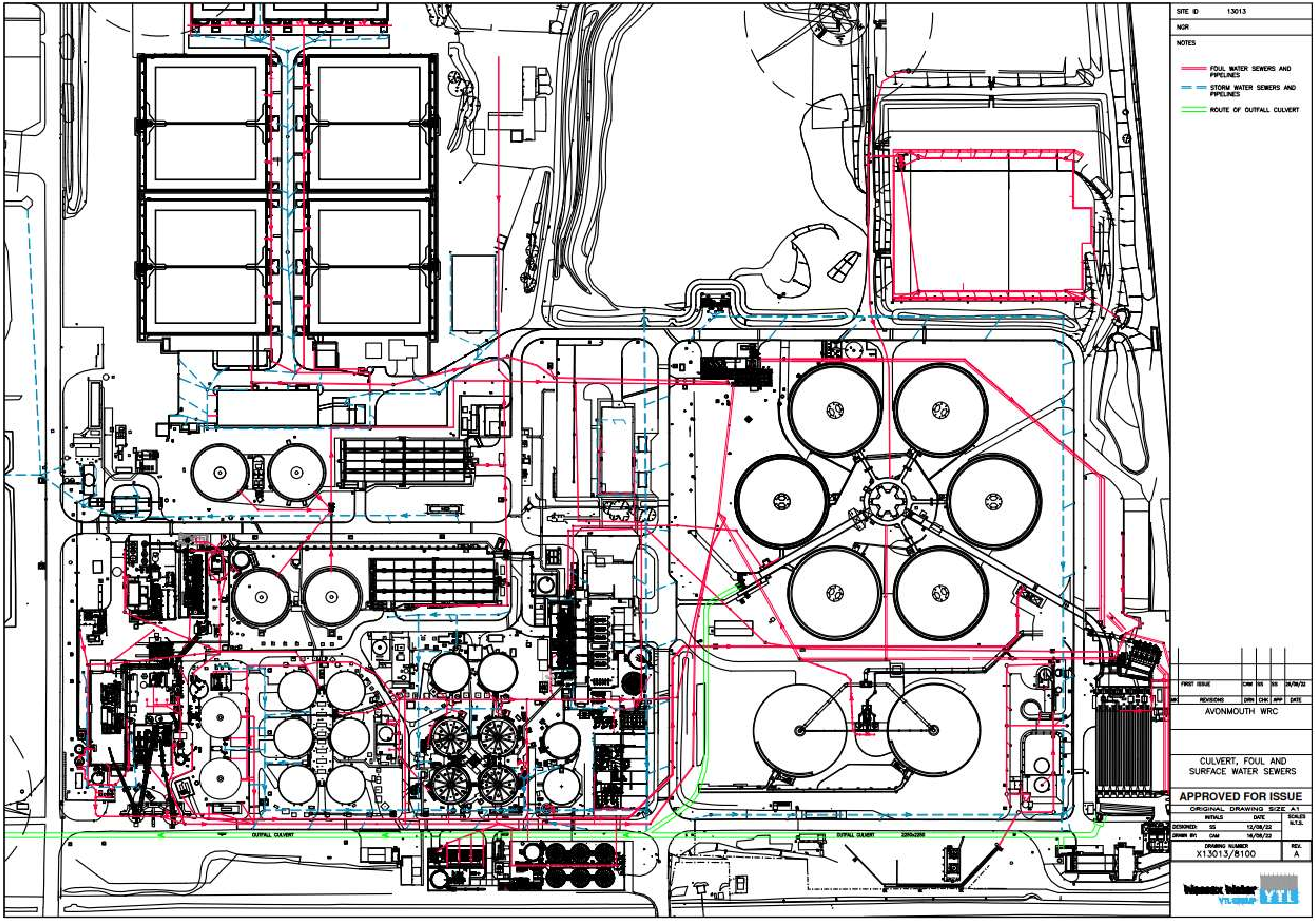

Figure 5.3: Below Ground Site Drainage Arrangements at the Avonmouth Site.

6. Environmental Setting

6.1 Geology

The geology at the Site may be summarised as follows:

- Made Ground is encountered in the majority of locations and is described as firm to stiff, brown silty clay, with some fine to coarse subangular gravel. Where identified, the Made Ground is present at a thickness of between 0.4 m to 4.2 m across the Site but is generally 1 m to 2 m thick.
- Superficial deposits are recorded either underlying the Made Ground or directly beneath the topsoil. The Tidal Flat Deposits are comprised of interbedded layers of clay and silt at a confirmed thickness of between 13.7 m and 20.3 m across the Site. This ranges from firm grey-brown mottled orange slightly sandy slightly gravelly clay to very soft to soft, brown-blue-grey slightly sandy silt and clay. Intermittent thin layers of peat were recorded in numerous boreholes at thicknesses of approximately 0.15 m.
- The Mercia Mudstone Group transitions through a weathered zone between the Tidal Flat Deposits and into the mudstone/siltstone however the zone is not well defined. The weathered zone is generally described as very stiff red-brown silty clay with gravel sized lithorelicts. This then transitions downwards into very weak thinly laminated reddish brown mudstone and strong, red-brown occasionally grey-green mottled thinly bedded siltstone.

6.2 Hydrology

Two drains lie along the south-western boundary of the Site, which are separated by the monument ‘Mere Bank’, which is a historic linear flood defence. The most north-eastern of these two drains is named ‘Mere Bank Rhine’; and the other is not named.

The eastern drain runs parallel to the south-eastern boundary of the Site and the northern drain is present along the north-eastern boundary of the Site. The latter extends into the operating boundary of the Site.

The topography of the land in the centre of the site generally falls gently towards all drains from within the northern centre of the Site. All of these drains are interconnected across the adjacent fields. The area around the main BC generally drains towards the Mere Bank Rhine.

Three surface water bodies (the western lagoons) lie approximately 40m to the north-west of the Site on Wessex Water owned land. The southern-most square-shaped lagoon receives final effluent from the WRC. The northern two lagoons are nature reserves used for fishing. The lagoons lie at a similar elevation to the Site and the assets that make up the BC.

There were further old lagoons in the northeast corner of the site. These were dewatered and are understood to have become compost heaps, however the northern most lagoon has been left to refill naturally (rainfall).

Surface water in the regional area is expected to generally drain to the north-west towards the Severn Estuary approximately 1.8km to the northwest of the Site.

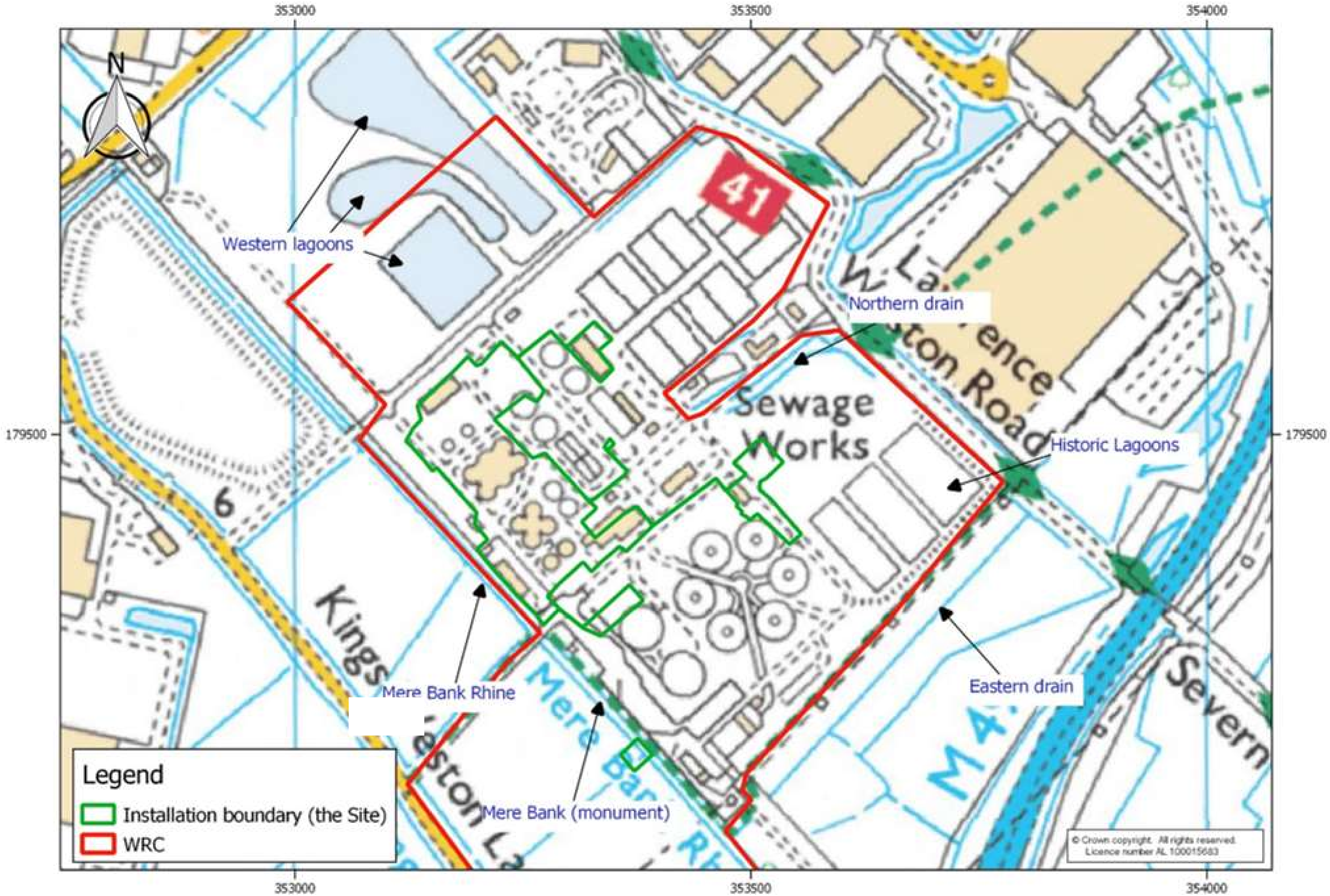

Figure 6.1 - Surface Water Features in relation to Avonmouth BC

6.3 Hydrogeology

The superficial deposits present at and within the vicinity of the Site are classified as unproductive aquifers. The Mercia Mudstone bedrock beneath the Site is classified as a Secondary B aquifer.

Rainfall, or liquors, entering the ground is likely to migrate downwards within the Made Ground deposits and Tidal Flat Deposits until it reaches the upper surface of the Mercia Mudstone Group present beneath the Site.

This liquor may mix and be diluted within the limited perched groundwater that may be present locally within the Made Ground and Tidal Flat Deposits. Alternatively, local conditions may allow liquors to continue to migrate downwards and mix and be diluted by groundwater present within the Mercia Mudstone Group. From here, it may be transported laterally according to the local hydraulic gradient. However, groundwater flows are expected to be limited due to the low permeability nature of these units.

7. Receptors

Key receptors, and the risks posed from emissions to surface water, groundwater, sewage, based on the information in Section 6 include:

- Shallow Aquifer - Made ground/Tidal Flat Deposits
- Deep Aquifer - Mercia Mudstone Secondary B aquifer
- Severn Estuary (SSSI, SPA, SAC, and Ramsar)
- Surface Waters - The mere Bank Rhine including the Mere bank monument (Scheduled Ancient Monument).
- Surface Waters – Other site surrounding drains.
- Western Lagoons (Local Nature Reserve) to the North of the Site.
- Lawrence Weston Moore Nature Reserve.
- Avonmouth WRC.

The most sensitive receptors that may be impacted by a loss of containment at Avonmouth BC is the Severn Estuary, due to its nationally significant environmental designations, and the Mere bank monument due to its heritage value.

The above factors are all considered in the CIRIA 736 ERAs to determine a site hazard rating.

8. Environmental Risk Assessment

An environmental risk assessment (ERA) has been prepared for the assets holding sludge inventory within the BC to determine the class of secondary containment required. The ERA adopts the source-pathway-receptor linkage principle outlined in the CIRIA 736 and is based on the information presented within Sections 4 to 7 of this report.

Figure 8.1: Aerial view of Avonmouth BC

To support the ERA further, a general overview of the inspected assets (outlined in Table 8.1 below) and the immediate surrounding area is presented in this section.

All tank assets are subject to daily visual operator inspection. Tanks include connecting pipework at both high and low level and feature a high-level overflow that discharges into the local drainage system or to downstream processes. They also include level indication via pressure transducers, ultrasonic instruments, or radar instruments, linked to associated auto-inhibit controls and alarms to alert operators of abnormal conditions. The site is manned at all times.

Spill model outputs are included to demonstrate the typical overland and below ground flow paths following a catastrophic failure of inventory from critical assets. These outputs also indicate the receptors that are currently at risk.

Table 8.1: Asset Overview

Asset name	Ref	Above Ground Volume Per Tank (m3)	Brim full capacity Per Tank (m3)	Height (m)	Material (m)	Year built
SBR SAS Balancing Tank	**M1**	395	534	4.2	RC	1999
Thickened SAS Transfer Tank	**N**	719	744	12.4	GFS	2000
Import Sludge Reception Tank	**D**	269	279	4.7	GFS	2010
Avonmouth Consolidation Tanks	**I**	1227	1460	4.1	RC	1960s
Bellmer Feed Tank	**J**	341	359	5.5	GFS	2015
Thickened Sludge Bellmer tank	**L**	313	329	8.5	GFS	2015
APD GBTs 1, 2 and 3 Feed Tank	**F**	417	483	10.4	SS	2023
APD Feed Tank	**H**	380	434	9.7	SS	2023
Acid Phase Digestion (APD)	**O1-O6**	813	878	14.0	SS	2015
Mesophilic Anaerobic Digesters (MAD)	**P1-P6**	2728	3252	10.0	RC	1974
Mesophilic Anaerobic Digesters (MAD)	**P7, P8**	2332	2769	8.8	RC	1963
Secondary Sludge Storage Tanks (SSST)	**Q**	1840	2226	6.6	RC	1960s
Centrifuge Feed Sludge Tank	**R**	552	555	9.7	GFS	2010
Raw Break Tank	**T**	61	67	4.1	GFS	2010

GFS – Glass Fused Steel; RC – Reinforced Concrete; SS – Stainless Steel

8.1 Asset Overviews and Spill Model Outputs

8.1.1 SBR SAS Balancing Tank

Sludge derived from the WRC Sequential Batch Reactor (SBR) process is stored in the Surplus Activated Sludge (SAS) balancing tank, prior to being transferred onwards to the SAS GBTs, which are located in a building on the opposite side of the main access road.

The tank is constructed from in-situ reinforced concrete and is founded on piles. The condition of the tank is generally very good, but with some observed minor weathering and bio-deterioration near to and at coping level.

Two inlet pipes from the two streams of SBR tanks pass through the base of the structure, as does the overflow pipe. The GBT feed pipes pass through the wall of the structure just above ground level. A shallow drainage apron provides a degree of containment for leaks and small spills from the above ground GBT feed pipework, before the pipes are routed below ground. All pipework is ductile iron.

The two inlet pipes can be diverted to liquor drains that returns to the internal pumping station. The overflow discharges to a settled sludge pumping station close to the tank. All returns from this tank are ultimately routed upstream of the PSTs in the WRC for treatment.

The pipes feeding the tank are equipped with flow meters and the tank level is monitored using an ultrasonic level instrument. Feed to the SAS balancing tank can be automatically inhibited on high-high level.

The tank is located close to the main access gate into the site and is offset 2m from the access road with only standard kerbing providing vehicle containment. Gravel and grassed areas surround the tank on three sides with the fourth side featuring the drainage apron, which is integrally tied to the structure.

Figure 8.2: SBR SAS Balancing Tank and Surrounding Area.

The spill modelling output for the Import Sludge Reception tank in Figure 8.3 demonstrates that a catastrophic failure could lead to contamination of shallow groundwater via the permeable grass and gravel areas.

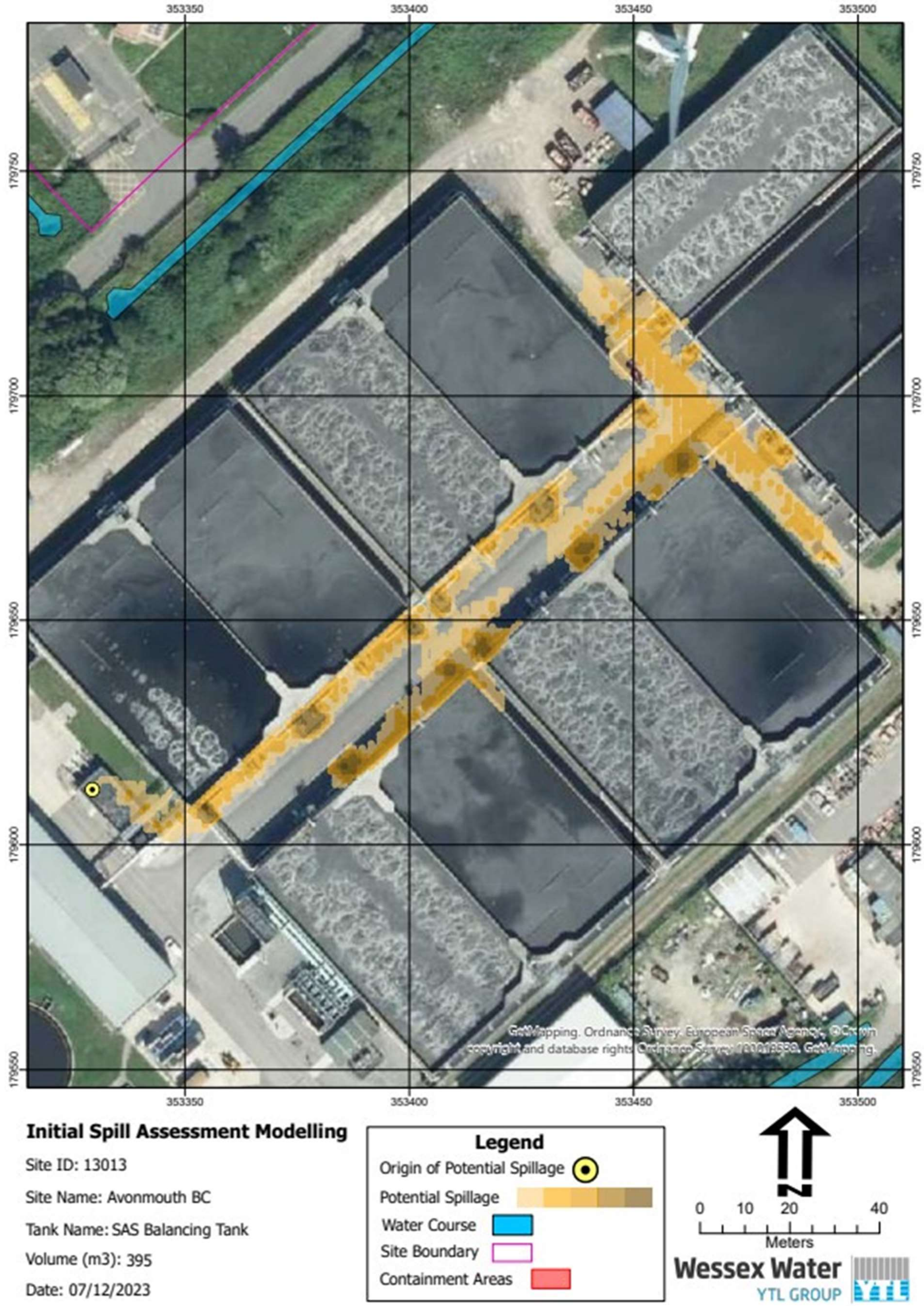

Figure 8.3: Spill Assessment for SBR SAS Balancing Tank

8.1.2 Thickened SAS Transfer Tank

The Thickened SAS Transfer tank receives pumped sludge from all SAS Gravity Belt Thickeners (GBTs). The thickened SAS has approximately 5-6% Dry Solids (DS). From the SAS Tank the sludge is then pumped to the APD Feed Tank. The Thickened SAS Transfer tank is adjacent to one of the Final Settlement Tanks (FSTs).

The tank material is GFS and was constructed in 2000. It holds a total volume of 744m^3 of which above-ground volume is 719m^3.

A large proportion of the ground around the tank consists of granular material and grass with small areas of concrete pavement. The tank itself is in a reasonable condition considering its age but is showing minor signs of deterioration in isolated locations.

Figure 8.4: Thickened SAS Tank

The spill modelling output for the Thickened SAS Tank in 8.5 demonstrates that a catastrophic failure could lead to contamination of groundwater via the permeable grass areas around the tank and the adjacent FST tanks. By inspection, there is also a high risk that a considerable proportion of the contents may contaminate the adjacent FST following failure, due to the proximity and potential surge and jetting effects.

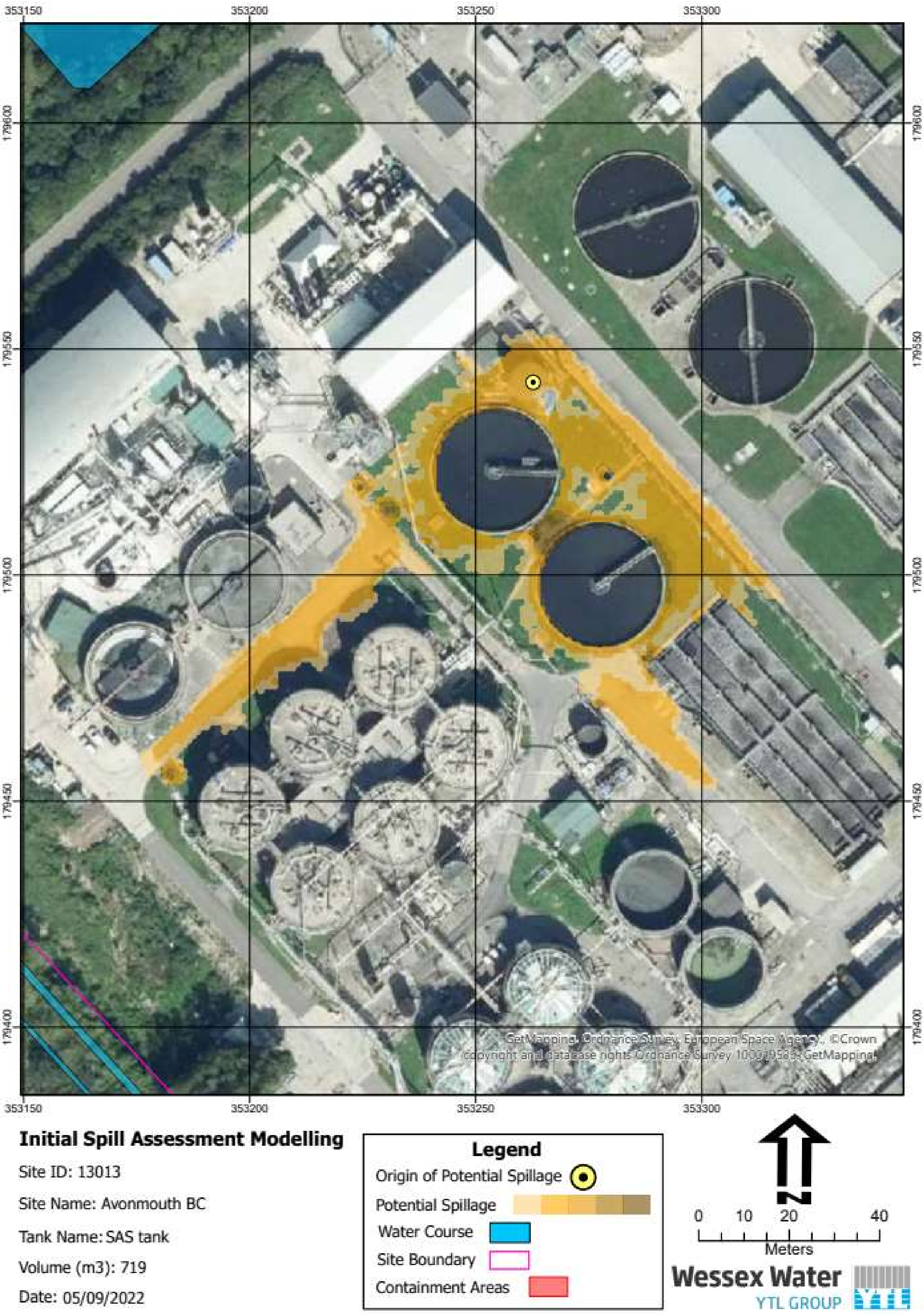

Figure 8.5: Spill assessment model for SAS Tank

8.1.3 Import Sludge Reception Tank

Sludge is imported into Avonmouth WRC via road tanker from satellite sites and stored in the import sludge reception tank, prior to further processing. This sludge can be made of primary sludge and surplus activated Sludge (SAS). Imported sludge accounts for approximately 20% of the sludge treated at Avonmouth BC. The Import Sludge Reception Tank is located near the internal pumping station and primary tanks, and away from the other tanks under consideration.

The tank is a Glass Fused Steel structure, installed in 2010. It holds a total volume of 297m^3 of which above-ground volume is 269m^3. The tank height is approximately 4.7m.

The tank includes a tanker connection point, an external mixing system, pipework to sludge transfer pumps and a high-level overflow to the local drainage system. Level indication is achieved using pressure transducers and associated high level alarms.

The tank was previously inspected internally in July 2023, by Hayes, and some repairs were carried out following the inspection, including repairs on inlet connections, repairs on the manway frame and sheets. The inspection report recommends that the tank is fully inspected every 3 years due to its age. A scheme is proposed to replace the tank with a new stainless steel structure on the same reinforced concrete base.

A large proportion of the ground around all the tank consists of concrete pavement and roads. The tank further benefits of a local concrete containment wall for minor to moderate spills. The concrete is in reasonable condition.

Figure 8.6: Imported Sludge Reception Tank Showing the Shallow Reinforced Concrete Bund, and External Pipework.

The spill modelling output for the Import Sludge Reception tank in Figure 8.7 demonstrates that a catastrophic failure could lead to contamination of shallow groundwater via the permeable grass areas around the adjacent primary tanks.

Figure 8.7: Spill Assessment for Imported Sludge Reception Tank

8.1.4 Avonmouth Consolidation Tanks

Avonmouth Consolidation Tanks receive primary sludge from the Internal Pumping Station. They have dewatering valves at various levels in the tank which allows for liquors to be removed from the top layer of the tank as sludge settles and thickens when this is required (standard operating procedure is not to decant). The thickened sludge is transferred to the Bellmer Feed Tank.

The Avonmouth Consolidation Tanks are located near the dewatering facilities at Avonmouth. They are reinforced concrete structures with no roofs. The total volume of one tank is 1460m^3 of which 1227m^3 is above ground volume. The tanks are visually in good condition, which is to be expected for non-covered reinforced concrete tanks.

Figure 8.8: Avonmouth Consolidation Tank and surrounding area

A large proportion of the surrounding ground is concrete pavement, which is in visibly reasonable condition. Sections of permeable gravelled areas are as well present.

The spill modelling output for the Avonmouth consolidation tanks in 8.7 shows a similar spill extent to that of the SAS tank. In addition to the contamination of groundwater via the permeable grass areas around the tanks, the model also shows the spill reaching the nearby Mere Bank Rhine.

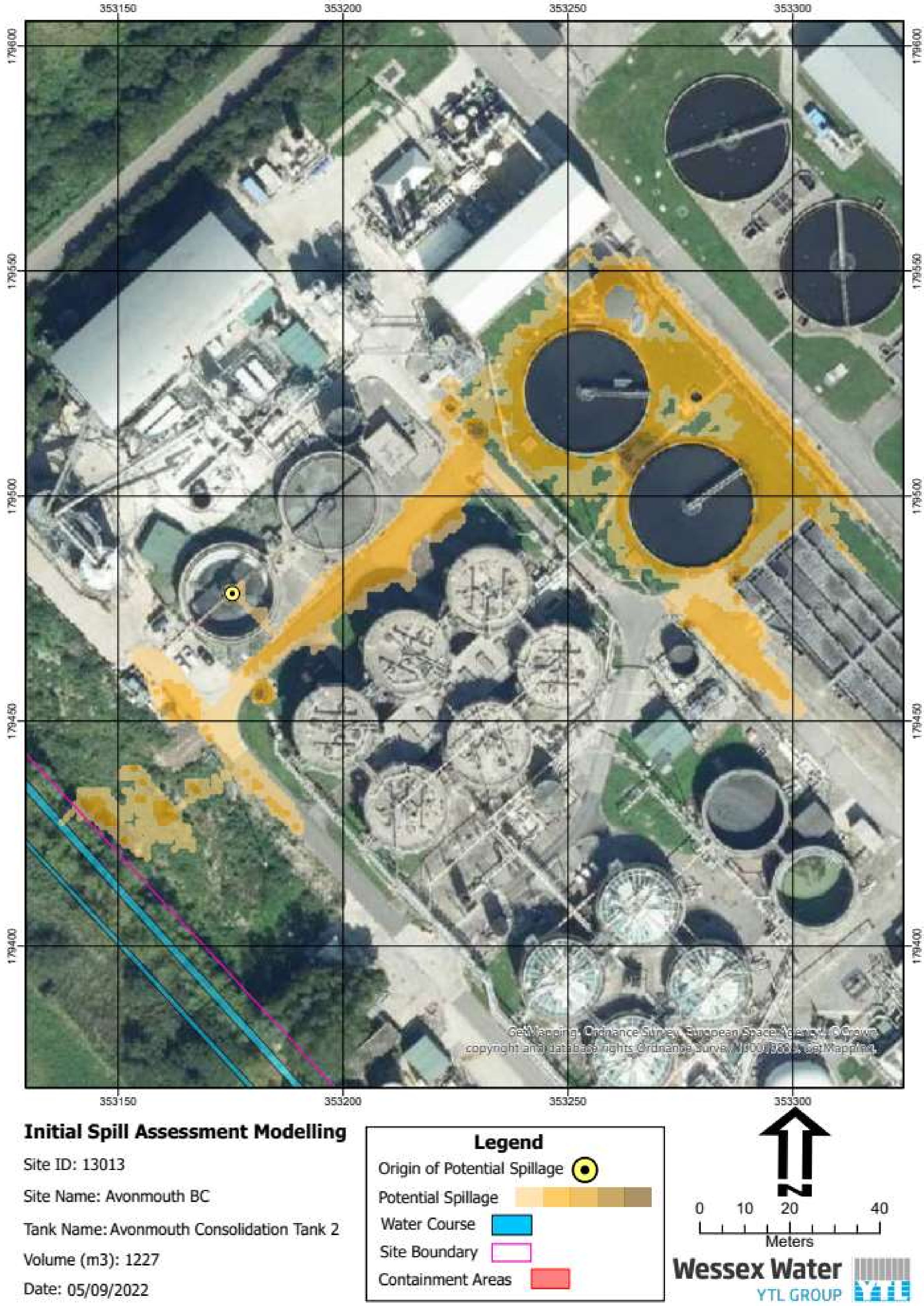

Figure 8.9: Spill assessment model for consolidation tank

8.1.5 Bellmer Feed Tank

The Bellmer Feed Tank receives sludge from Avonmouth Consolidation tanks and sludge is then further pumped to 2no. Bellmer Belt Thickeners.

The Bellmer Feed Tank is adjacent to the sludge Digester 5 and the Secondary Storage tanks.

The Bellmer Feed Tank is an uncovered above-ground Glass Fused Steel structure. The total volume of one tank is 359m^3 of which 341m^3 is above ground volume. The height of the walls is approximately 5.5m. The tank is in a reasonable condition given its age, with evidence of some surface weathering and minor rust staining on the upper rings.

Figure 8.10: Bellmer Feed Tank, Circled in Red

The surrounding ground is predominantly permeable consisting of gravelled and grassed areas.

The spill modelling output for the Bellmer Feed Tank in Figure 8.9 demonstrates that a catastrophic failure could lead to contamination of groundwater via the permeable gravel and grass areas around the FSTs.

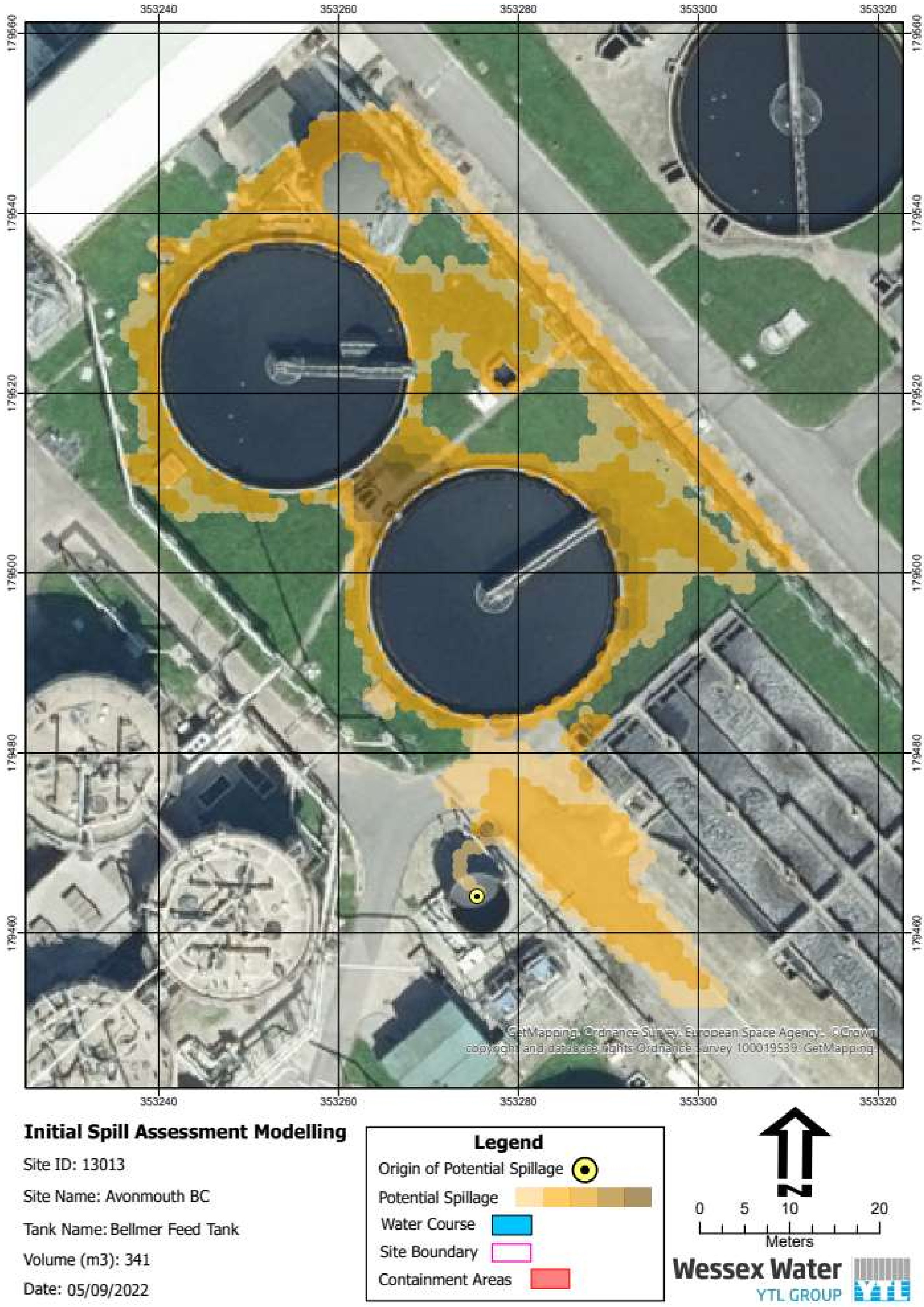

Figure 8.11: Spill assessment model for Bellmer Feed Tank

8.1.6 Bellmer Thickened Sludge Tank

The Bellmer Thickened Sludge Tank is situated between the digesters and receives pumped, thickened sludge (to approximately 5-6% DS) from both Bellmer Gravity Belt Thickeners. The thickened sludge is then pumped from the Bellmer Thickened Sludge Tank to the Acid Phase Digester (APD) Feed Tank.

The tank is a covered above-ground Glass Fused Steel and appears to be in a reasonable condition for its age with evidence of some surface weathering and minor rust staining on the upper rings. The total volume of the tank is 329m^3 of which 313m^3 is above-ground volume. The height of the tank is approximately 8.5m.

Figure 8.12: Bellmer Thickened Sludge Tank

A large proportion of the ground around all the tank consists of concrete pavement and roads. The tank further benefits from a local concrete containment wall for minor to moderate spills. The concrete is in visually good condition.

The spill modelling output for the Bellmer Thickened Sludge Tank in Figure 8.11 demonstrates that a catastrophic failure could lead to contamination of groundwater via the permeable gravel and grass areas around the tank, as well as at the grass area by the Mere bank rhine. More critically, the spill is also shown in the model to reach the Mere bank rhine directly overland.

Figure 8.13: Spill assessment model for Bellmer Thickened Sludge Tank

8.1.7 APD GBTs 1, 2 and 3 Feed Tank

The tank is located adjacent to the southwestern edge of the BC, in proximity to the Mere bank Rhine, on the other side of the site boundary. It receives sludge from the internal sludge transfer pumping station, that has previously been through the strain presses.

The tank material is stainless steel founded on a reinforced concrete base. This stainless-steel tank was installed onto the existing base in 2023 and replaces the old GFS tank. The new tank is in very good condition with no observed defects.

Figure 8.14: APD GBTs 1, 2 and 3 Feed Tank

The surrounding ground around the tank consists of a concrete pavement. The tank further benefits of a local concrete containment wall for minor to moderate spills. The concrete is in visually reasonable condition.

The spill model output for the Raw Sludge Feed to APD GBTs in Figure 8.20 demonstrates that if the tank were to catastrophically fail, the spill would promptly flow to the Mere Bank Rhine, causing a pollution incident. The ground water could also be contaminated as the spill is seen to flow over the permeable grass area by the rhine.

Figure 8.15: Spill assessment model for APD GBTs 1, 2 and 3 Feed Tank

8.1.8 APD Feed Tank

The Acid Phase Digester (APD) Feed Tank is located adjacent to the APD tanks. Thickened sludge from upstream sludge treatment streams is combined and mixed in this tank, prior to being pumped into the APD plant.

Figure 8.16: APD Feed Tank

The tank material is stainless steel founded on a reinforced concrete base. This stainless-steel tank was installed onto the existing base in 2023 and replaces the old GFS tank. The new tank is in very good condition with no observed defects.

The surrounding ground is predominantly concrete pavement, although permeable (gravelled) areas are also present. The concrete pavement is in visibly reasonable condition.

The APD feed tank has not been modelled, as it is adjacent to the APD tanks, which have a larger volume. Any spill from the catastrophic failure of the APD feed tank would be within the footprint of the catastrophic failure of the APD tanks themselves. The APD tanks have been modelled and the spill assessment is shown in Figure 8.14.

8.1.9 Acid Phase Digester (APD) Tanks

The APD tanks are located near the southern site access, which is a low topographical point for this local part of site.

The APD Tanks receive pumped sludge from the APD Feed Tank, which is heated to 36 degrees Celsius via a hot water heat exchanger. The feed to APD vessel 1 is a batched process. Sludge is transferred from one APD vessel to another via a gas-lift process, until it reaches APD vessel 6.

The tanks are above-ground covered stainless steel structures. The tanks are insulated which would complicate a visual survey of the stainless-steel structure condition. The total volume of one tank is 878m^3 of which 813m^3 is above-ground volume The height of the walls is approximately 14m.

Figure 8.17: APD Tanks

Surrounding ground consists of concrete pavement, roads and permeable (gravelled) areas. The concrete pavement is in visually reasonable condition.

The spill modelling output for the APD tank in Figure 8.14 demonstrates that a catastrophic failure could lead to contamination of groundwater via the permeable gravel areas around the tank. More critically, the spill is also shown in the model to quickly reach the Mere bank Rhine watercourse just outside the site boundary.

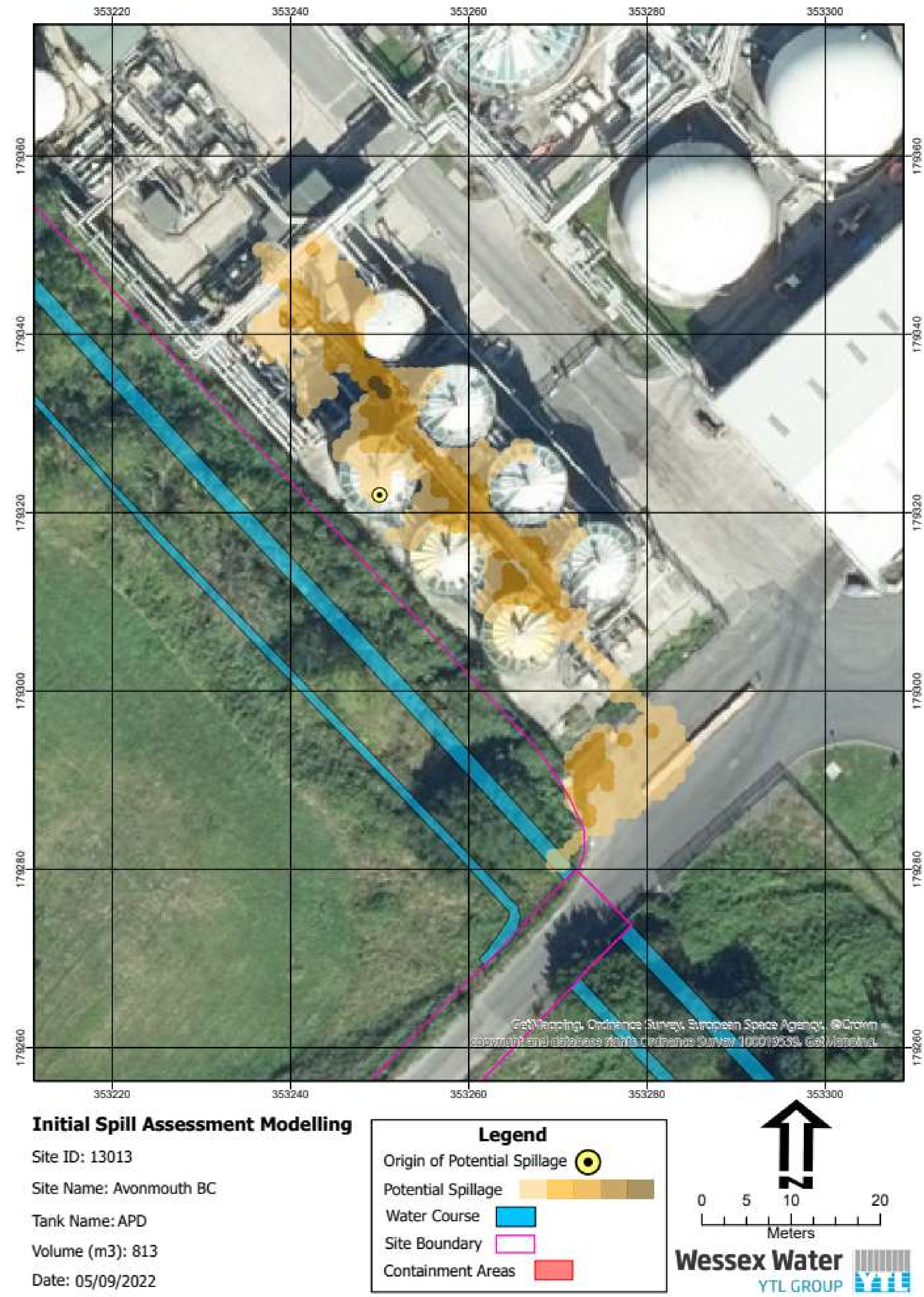

Figure 8.18: Spill assessment model for Acid Phase Digester (APD) Tanks

8.1.10 Mesophillic Anaerobic Digesters

These tanks are located centrally in the BC, but the westernmost tanks run parallel to the site boundary and the Mere bank Rhine at a distance of about 50m. There are two groups of tanks, MAD 1, and MAD 2. There are 8 tanks operating in the BC in total and all tanks are of similar construction.

The digesters are fed sludge from the APD Tanks in batches. Digestate overflows from the digester and gravitates to two Secondary Sludge Storage Tanks (SST).

The digesters are in-situ reinforced concrete cylindrical structures with a concrete roof and conical bottomed slab. The approximate above-ground volume of the tanks is 2728m3 and total volume 3252m3. The external roof has a slat perimeter walkway, and a sloping roof. Access inside the Anaerobic Digester is via an access hatch at ground level.

The assets are in a reasonable condition given their age. A refurbishment programme of works is currently being undertaken on all of the digesters, with one being taken out of service at a time. This includes in internal inspection of the tanks and the roofs.

Figure 8.19: Mesophilic Anaerobic Digester P6

The large proportion of the surrounding area is permeable (grassed and gravelled areas) with sections of concrete pavement and access roads.

Figure 8.20 demonstrates that a catastrophic failure of Digester 9, which is close to the Mere bank Rhine would rapidly reach the watercourse. There is potential for a large volume of sludge to spill into this watercourse. There is also potential for ground water contamination.

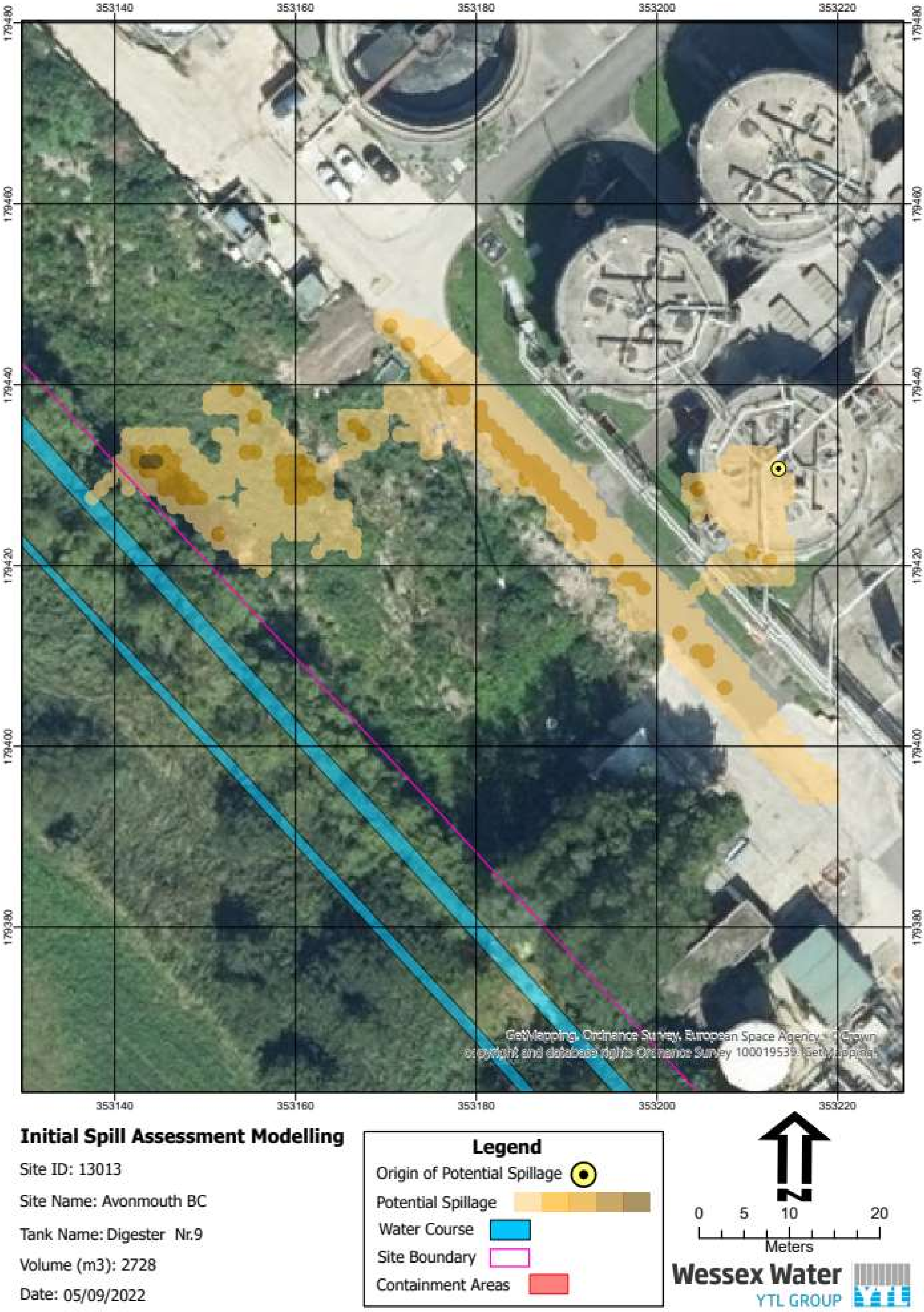

Figure 8.20: Spill assessment model for Digester P6

8.1.11 Secondary Sludge Storage Tanks

The two Secondary Sludge Storage Tanks are located to the northeast of the Food Waste Digesters, and on the Eastern side of the BC.

The tanks are fed sludge from the mesophilic digesters via gravity. The outlet flows are then pumped to the dewatering plant.

The Secondary Storage Tanks are non-covered reinforced concrete cylindrical structures constructed in the 1960s. The total volume of each tank is 2226m^3 of which 1840m^3 is above-ground volume. The height of the walls is approximately 6.6m.

Figure 8.21: Secondary Sludge Storage Tank (SST2)

A large proportion of the ground around all the tank consists of concrete pavement and roads with sections of permeable (gravelled) areas.

The spill modelling output for the Secondary Sludge Storage Tank in Figure 8.18 shows the spill surrounding the area encompassed by the SAS tank and the FSTs. The overland spill path also continues on to Mere bank Rhine. This indicates potential contamination of groundwater and the Mere bank Rhine.

Initial Spill Assessment Modelling

Site ID: 13013

Site Name: Avonmouth BC

Tank Name: Secondary Sludge Storage Tank Nr.

Volume (m3): 1840

Date: 05/09/2022

Legend

Origin of Potential Spillage

Potential Spillage

Water Course

Site Boundary

Containment Areas

N

0 10 20 40

Meters

Wessex Water
YTL GROUP

Figure 8.22: Secondary Sludge Storage Tank

8.1.12 Centrifuge Feed Sludge Tank

The centrifuge feed sludge tank is located amongst the sludge cake area of the site, next to the sludge consolidation tanks. The digested sludge from the outlet of the SSTs is pumped to the Digested Centrifuge Feed Tank, which supplies sludge to Centrifuges 7&8 for dewatering.

The tank is a non-covered above-ground Glass Fused Steel structure. The total volume of the tank is 555m^3 of which 552m^3 is above ground volume. The height of the walls is approximately 9.7m.

Figure 8.23: Centrifuge Feed Sludge Tank

A large proportion of the surrounding ground is gravel, which is in visibly good condition. Sections of concrete are also present and are in reasonably good condition.

The spill modelling output for the Centrifuge Feed Sludge Tank in Figure 8.24 demonstrates that a catastrophic failure could lead to contamination of groundwater via the permeable grass areas between the hard standing and the lagoon. The spill also extends towards the lagoon. This is only one of two assets with a spill direction to the north of the site, and the only asset with the potential to impact the lagoon following catastrophic failure.

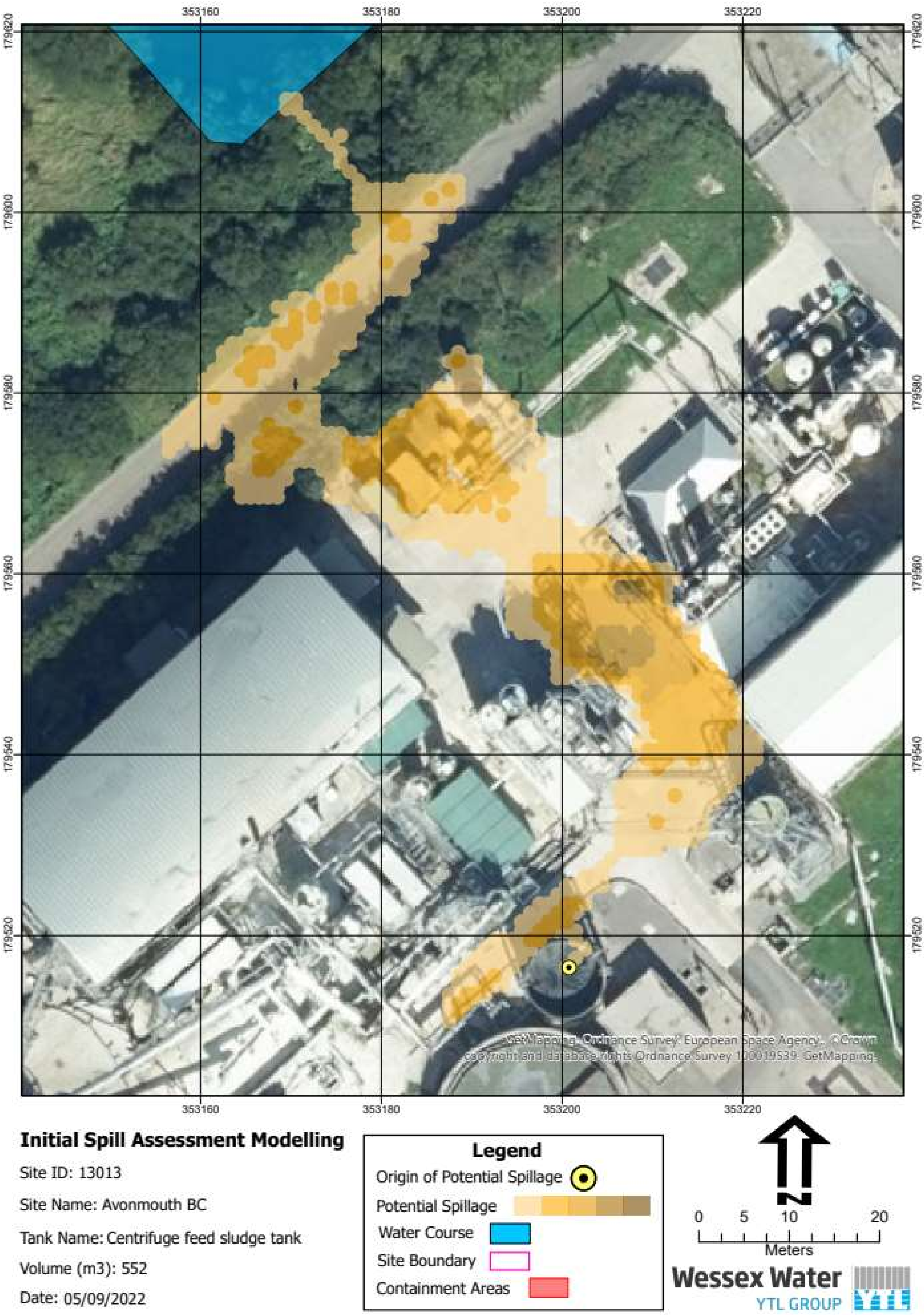

Figure 8.24: Spill assessment model for Centrifuge Feed Sludge Tank

8.1.13 Raw Break Tank

The Raw Break Tank is located amongst the sludge cake area of the site, next to the sludge consolidation tanks. The tank receives by-passed sludge from the sludge consolidation tanks before it is transferred to centrifuges for de-watering.

The tank is GFS and is not covered. The total volume of one tank is 65m^3 of which 61m^3 is above ground volume. The height of the walls is approximately 4.1m.

Figure 8.25: Centrifuge No.5-No.6 Raw Feed Tank

A Large proportion of the surrounding ground is concrete pavement, which is in visibly good condition. Sections of permeable gravelled areas are present.

The spill modelling output for the Centrifuge Raw Feed Sludge Tank in Figure 8.26 demonstrates that a catastrophic failure of this tank would be mostly contained within the impermeable concrete hardstanding by the sludge cake area of the site. There is a risk of contamination of groundwater via the permeable gravel area on the far side of the kerb from the tank. However, the spill model shows a minimal amount of sludge flowing this way.

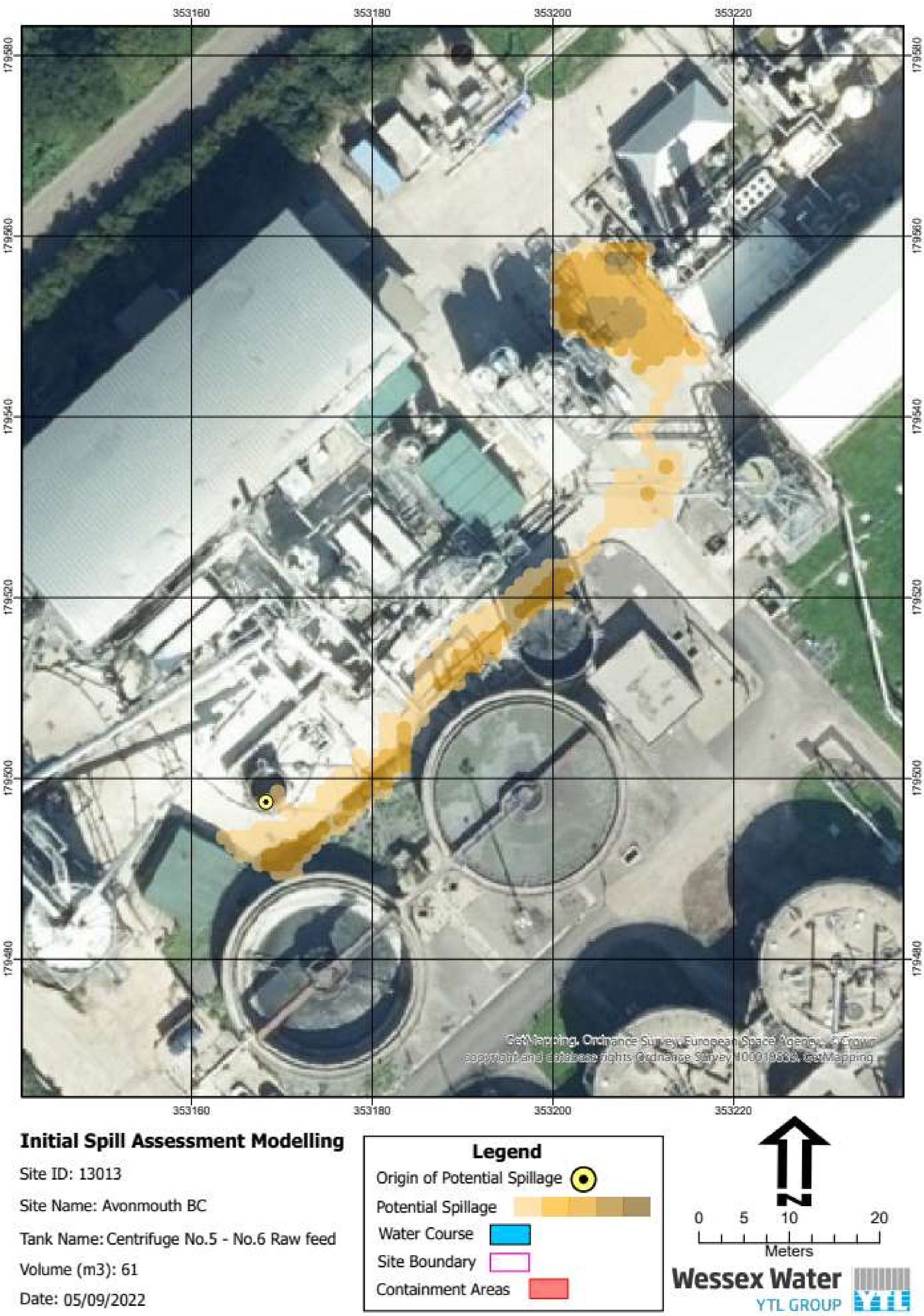

Figure 8.26: Spill assessment model for the Raw Break Tank

8.2 Source – Pathway – Receptor ERA Summary

The ERA has been developed considering the BC as a whole. The ERA acknowledges specific and higher risk assets where appropriate. The main sources, credible pathways and the most severe receptors are highlighted to determine the overall and the most severe source-pathway-receptor linkage. This Risk Assessment includes the source (Table 8.2), and Pathway – Receptor linkage including the risk rating of all three linkages (Table 8.3).

Table 8.2: Source Summary

Source	Contents	Flammability	Corrosive	Hazard rating
Raw Sludge Tanks	Unthickened raw imported and indigenous sludge (2 - 3% DS Typ). Thickened raw sludge (4.5 - 6% DS Typ)	Not Flammable	Slightly	H
Acid Phase, Mesophilic Phase (Primary) Digestion Tanks, and Secondary Storage Tanks.	Partially digested screened sludge (3 - 4% DS Typ)	Not Flammable	Slightly	H
Centrifuge Feed Tank	Fully digested screened sludge (3 - 4% DS Typ)	Not Flammable	Slightly	M
Rainwater run-off	Surface water, mixed with sludge	Not Flammable	No	L

Table 8.3: Pathway and Receptor Summary

Pathway to receptor	Time of concentration / duration of source outside containment	Transport Potential rating	Receptor	Damage Potential Rating	S-P-R Hazard Combinations Existing	Environmental Hazard Rating Existing	S-P-R Hazard Combinations with Solutions	Environmental Hazard Rating with Solutions
Infiltration of Inventory into Ground and the Shallow Aquifer in the Made ground/Tidal Flat Deposits The majority of GFS tanks and the APD feed tanks benefit from having a localised drainage apron or more extensive areas of concrete hardstanding around them. The in-situ RC mesophilic anaerobic digesters (MADs) benefit from some secondary containment provided by the central buildings which contains connecting pipework. These features will help to contain sludge for small to medium scale escapes of inventory. However, there are existing significant permeable areas of ground in relatively close proximity to most of the tanks in the BC. Hence any catastrophic failure and complete loss of containment would lead to a large proportion of sludge flowing onto the permeable ground. Some of this sludge will continue to migrate according to the site topography, which is demonstrated on the existing spill model outputs. However, a proportion of the sludge and associated liquors will percolate into the ground and quickly into the shallow aquifer typically present 1.5 to 2 metres below ground level. From here there is limited potential for gradual, onward lateral movement towards other pathways and receptors. There is likely to be adsorption of contaminants in the ground as the sludge liquors and solids migrate and spread outward, so the magnitude of the hazard will reduce exponentially with distance. This suggests that tanks located adjacent to the Mere bank Rhine (Western MADs, APDs, Raw Sludge feed to APD GBTs 1-2-3 tank) represent a higher hazard than tanks further away (SAS tanks & Import Sludge Reception tank). **Solution Recommendation:** Replace any permeable areas around the perimeter of the tanks with impermeable surfacing to change the pathway hazard rating to Low.	Minutes	M to L	**Groundwater - Shallow Aquifer - Made ground/Tidal Flat Deposits** The superficial deposits present at and within the vicinity of the site are classified as unproductive aquifers. The aquifer may be contaminated by percolation of sludge or sludge liquors through the made ground which is typically 1-2m deep. The consequence of contamination of aquifer itself is considered to be low given its insignificance for water supply and unproductive designation.	L	HML	L	HLL	L

Pathway to receptor	Time of concentration / duration of source outside containment	Transport Potential rating	Receptor	Damage Potential Rating	S-P-R Hazard Combinations Existing	Environmental Hazard Rating Existing	S-P-R Hazard Combinations with Solutions	Environmental Hazard Rating with Solutions
Vertical Migration into the Mercia Mudstone bedrock group Secondary B Aquifer There is effectively no risk that contaminants within the shallow aquifer could subsequently migrate vertically down to the deep aquifer. Any vertical movement will lead to scrubbing of any contaminants. The tidal flat deposits above this aquifer range from approximately 15 to 20m deep across the site and predominantly consist of clay and silts with very low permeability.	N/A	(V)L	**Groundwater - Mercia Mudstone bedrock group Secondary B Aquifer** The aquifer consists of predominantly lower permeability layers such as fissures, thin permeable horizons and weathering which may store/yield limited amounts of groundwater due to these localised features. There are no localised groundwater abstractions - the nearest is located 1.2km away for dust suppression and there are no source protection zones within 5km of the site. The consequence of contamination is considered to be Medium given it's WFD designation. However, it's storage of limited amounts of groundwater, general low permeability, and distance from abstractions and source protection zones is important to note.	M	H(V)LM	L	H(V)LM	L
Drainage Pathway to the Water Recycling Centre (WRC) An engineered drainage system serves the main BC containment areas and roadways. This drains surface run-off to a drainage pumping station at a central location within the site, which in turn returns flows upstream of primary treatment. Catastrophic loss of containment would lead to sludge overwhelming this drainage system, which is designed for management of rainfall run-off. A proportion of sludge would still rapidly find its way to the local drainage pump station and also into pipework draining to the internal pumping station via process liquor drainage pipework. The pump stations means there is a control point that can be managed by operators and would limit flows back to the treatment process in accordance with the maximum pumping rate. This reduces the pathway risk from high to moderate.	Minutes to Hours	M	**Water Recycling Centre (WRC) Upstream of Primary Settlement Treatment and Final Effluent Discharge** Avonmouth WRC may be impacted via BC inventory spills through the underground engineered drainage network and internal pumping station, which pumps upstream of the primary settlement tanks. The size of the works (treating up to 3.2 cumecs) is significant in relation to the volume of any spill. This means there will be a high degree of treatment resilience to the spill event. The consequence of contamination of the WRC and subsequent pollution event at the final effluent discharge point is therefore low.	L	HML	L	HML	L

Pathway to receptor	Time of concentration / duration of source outside containment	Transport Potential rating	Receptor	Damage Potential Rating	S-P-R Hazard Combinations Existing	Environmental Hazard Rating Existing	S-P-R Hazard Combinations with Solutions	Environmental Hazard Rating with Solutions
Direct Pathway to the Water Recycling Centre (WRC) Final Settlement Tank (FST) This is a specific potential immediate pathway upon catastrophic failure of the SAS tank. Depending on the failure mode, this could lead to a significant proportion of sludge directly impacting an adjacent FST. This is only partially mitigated given the tank walls are at least 0.7m to 0.8m above the surrounding ground level. **Solution Recommendation:** Implement a temporary barrier between the two structures or consider replacing the tank with a double skinned equivalent or replace in a different location. Any of these would reduce the pathway hazard from High to Low.	Seconds	H to L	**Water Recycling Centre (WRC) Final Settlement Treatment (FST) and Final Effluent Discharge** Avonmouth WRC may be impacted via BC inventory spills specifically from tanks local to treatment processes. The specific receptor in this instance is one the FSTs which is adjacent to the SAS tank. If the SAS tank failed, it may lead to a single compliance failure at the final effluent discharge point. The damage potential rating is therefore moderate. The same situation exists with the import sludge reception tank and one PST. However, there is enough downstream treatment resilience in that case.	M	HHM (Asset Specific)	H (Asset Specific)	HLM (Asset Specific)	L (Asset Specific)
Overland and Below Ground Pathways to Local Surface Waters - The mere Bank Rhine including the Mere bank Scheduled Ancient Monument. The closest surface water body to the BC is the Mere bank Rhine and the majority of existing catastrophic spill model outputs from the various tanks on site indicates sludge eventually reaching it via overland routes as the immediate local topography tends to from Northeast to Southwest. As expected, primary assets closest to the Southwestern boundary (APDs, APD GBTs 1,2 and 3 feed tank, MADs, Sludge Consolidation Tanks) represent the greatest hazard in terms of time to reach the surface water body and volume entering it. Sludge or sludge liquors that have infiltrated into the shallow aquifer have the potential to reach the Mere Bank Rhine, but this pathway is far less significant when considering a catastrophic failure event. **Solution Recommendation:** Construct a wall to prevent overland migration to the Mere Bank Rhine.	Seconds to Minutes	H to L	**Surface Waters - The mere Bank Rhine including the Mere bank Scheduled Ancient Monument.** This surface water body, and connecting surface water ditches, could be contaminated by loss of inventory from the BC. The Mere bank has a local designation and value from a heritage perspective. The Mere bank structure itself would be resilient to contamination of sludge and given the low ecological value along the network of connecting surface waters, the sensitivity is considered to be low overall.	L	HHL	M	HLL	L

Pathway to receptor	Time of concentration / duration of source outside containment	Transport Potential rating	Receptor	Damage Potential Rating	S-P-R Hazard Combinations Existing	Environmental Hazard Rating Existing	S-P-R Hazard Combinations with Solutions	Environmental Hazard Rating with Solutions
Onward surface water flows via the Rhine network towards the Severn Estuary. Any contaminants that reach the Mere bank Rhine will continue to flow along a series of drainage networks. A significant proportion of this sludge will settle, or be retarded, diluted and dispersed along the circa 2km route. The pathway hazard is therefore considered to be low. **Solution Recommendation:** Construct a wall to prevent overland migration to the Mere Bank Rhine (same solution as previous row).	Hours	L	**Surface Waters - Severn Estuary SSSi, SPA, SAC and Ramsar site.** The receptor is situated approximately 1.6km away from the site but there could be a potential for some contamination from a significant spill event at the BC due to hydraulic connectivity with the large network of Rhines draining the area. This is a high hazard receptor due to its multiple national designations. However its sheer scale in relation to relatively negligible volume of contaminants potentially reaching it from a catastrophic spill event is important to note.	H	HLH	M	HLH	L
Overland Pathways to Local Surface Waters - Square Lagoon and then onto the Lagoon Local Nature Reserves. There is no risk of direct contamination of this surface water from overland flows. However overland spill modelling indicates that a catastrophic sludge spill from the centrifuge feed tank will migrate northwards towards, and eventually reach the square lagoon serving the power station. From here, there will be some settlement treatment but it's possible some contaminants could subsequently reach the other two lagoons. There is potential for sludge consolidation tank 1 to follow a similar path depending on the position of failure on that tank. No other BC tanks pose a hazard. The hazard rating is low due to the significant dilution potential. **Solution Recommendation:** A shallow wall or ramp will prevent overland migration of sludge in this direction.	Hours	L	**Lagoon Local Nature Reserves** Two of the three lagoons to the West of the site are nature reserves and are used for fishing. They are assumed to be hydraulically connected to the lagoon used to serve a local power station. Given the local environmental designations of the two lagoons, their sensitivity to contamination is considered to be moderate.	M	HLM	M	HLM	L
Onward surface water flows via the Rhine network towards the Lawrence Weston Moor Nature Reserve. The nature reserve is only 700m away from the BC. However, it's situated in the opposite direction to the prevailing surface water direction of flow adjacent to the BC. Therefore, there is effectively no risk of contaminants reaching the reserve.	N/A	(V)L	**Lawrence Weston Moor Nature Reserve**. This is a local designated site approximately 700m away from the BC. It consists of an extensive network of wet meadows and reedbeds. Given it's local designation and likely ecological distinctiveness, it's sensitivity is considered to be moderate.	M	H(V)LM	L	H(V)LM	L

Overall Environmental Hazard Rating for the site is **MEDIUM.**

8.3 Frequency of Loss of Containment

As part of the Environmental Risk Assessment, a frequency of Loss of Containment assessment has been completed for all of the sludge storage and reactor tanks. This considers likely causes and probability of partial loss of containment and potential causes and probability of catastrophic loss of containment.

The assessment is based on standard failure mode risk assessments developed for the types of tank material – Glass Fused Steel, Stainless Steel, or Reinforced Concrete, combined with the operational purpose of the tank. These risk assessments were referred to alongside the individual asset specific features such as condition of the tank, surroundings, and pipework penetrations outlined in Table 8.1.

Risk ratings for potential failure modes are assigned based on CIRIA 736 methodology, where:

- low risk means a probability of less than 1 in 1 million years,
- medium / moderate risk means a probability between 1 in 100 and 1 in 1million years,
- high risk means a probability greater than 1 in 100 years.

The output is summarised in Table 8.4 and broadly indicates that the frequency of loss of containment is likely to fall within the medium / moderate frequency category, with marginal or partial loss of scenarios having a probability of occurrence closer to 1:100. Catastrophic scenarios identified have significantly lower probabilities of occurrence. The assets that are likely to be at the greatest risk of an appreciable loss of containment is the stainless steel APDs, because they have additional failure scenarios linked to operational process deviations. The MADs may experience similar operational process deviations. However, their reinforced concrete construction means the assets are significantly more robust.

The Overall Risk Rating for the site based on the assessment is considered to be **MEDIUM**.

Table 8.4: Frequency of Loss of Containment Summary

Asset ID	Asset Name	Material	Condition	Catastrophic Loss of Containment Frequency Risk in Line with CIRIA 736 Method	Probability of Catastrophic Failure in Line with CIRIA 736 Method	Comments
M1	SBR SAS Balancing Tank	Reinforced Concrete	Very Good	M	In line with CIRIA 736, all of the assets lie between the 1% (1 in 100) and 0.001% (1 in 1 million) Less than 0.001% (1 in 1 million) (moderate risk) category. Marginal or partial loss of containment scenarios will have a probability of occurrence closer to 1:100 years. Catastrophic loss of containment scenarios, linked to global stability, natural or man-made disasters, major exceptional defects in the fabrication and installation, or explosion / flash fire are, to varying degrees, far less probable but are difficult to quantify. At this site, the assets most at risk of catastrophic failure is the APDs because of their construction material and because they have additional failure scenarios linked to process deviations.	Tank is approaching 25 years old, so well within its design life for an RC asset. The asset was subject to technical supervision during installation and water testing prior to commissioning. Simple operation to receive, balance, and transfer SAS sludge. Good observed condition and very resilient material to corrosion and abrasion used for both the tank and ductile iron pipework. High level overflow physical safeguard is in place. Control inhibits and level indication in place. Ability to isolate and internally inspect the asset. Tank is just offset from vehicle routes with standard kerbing acting as the only containment. Low level pipework present secured in a localised drainage apron. Partial loss of containment possible due to operator error with low level pipework, which would be quickly rectified.
N	Thickened SAS Transfer Tank	Glass Coated Steel	Moderate	M	In line with CIRIA 736, all of the assets lie between the 1% (1 in 100) and 0.001% (1 in 1 million) Less than 0.001% (1 in 1 million) (moderate risk) category. Marginal or partial loss of containment scenarios will have a probability of occurrence closer to 1:100 years. Catastrophic loss of containment scenarios, linked to global stability, natural or man-made disasters, major exceptional defects in the fabrication and installation, or explosion / flash fire are, to varying degrees, far less probable but difficult to quantify. At this site, the assets most at risk of catastrophic failure is the APDs because of their construction material and because they have additional failure scenarios linked to process deviations. The probability of total failure is still extremely remote for these assets.	Tanks subject to technical supervision during installation and water testing prior to commissioning. Simple operation to store thickened SAS and imported sludge prior to pumping to downstream processes. Moderate condition and moderately resilient material to corrosion and abrasion used for the tank. Thickened SAS transfer tank is 23 years old and import sludge tank 13 years old. The latter is holding relatively aggressive inventory, therefore rolling internal maintenance inspections are being completed by a competent tank supplier. Scheme raised to replace the Import Sludge Reception tank with new stainless-steel tank in the same location. High level overflow physical safeguards are in place. Control inhibits and level indication in place. Both tanks are offset from vehicle routes. Import sludge reception tank separated from road by the shallow containment bund. Low level pipework is over the impermeable shallow containment bund for the import sludge tank. Loss of containment possible due to corrosion pin holes at sludge air interface or failure of low-level pipe connections if the tanks are no longer maintained. Loss of containment due to operator error with low level pipework possible, which would be quickly rectified.
D	Import Sludge Reception Tank	Glass Coated Steel	Moderate	M		

Asset ID	Asset Name	Material	Condition	Catastrophic Loss of Containment Frequency Risk in Line with CIRIA 736 Method	Probability of Catastrophic Failure in Line with CIRIA 736 Method	Comments
I	Avonmouth Consolidation Tanks	Reinforced Concrete	Moderate	M	In line with CIRIA 736, all of the assets lie between the 1% (1 in 100) and 0.001% (1 in 1 million) Less than 0.001% (1 in 1 million) (moderate risk) category. Marginal or partial loss of containment scenarios will have a probability of occurrence closer to 1:100 years. Catastrophic loss of containment scenarios, linked to global stability, natural or man-made disasters, major exceptional defects in the fabrication and installation, or explosion / flash fire are, to varying degrees, far less probable but are difficult to quantify. At this site, the assets most at risk of catastrophic failure is the APDs because of their construction material and because they have additional failure scenarios linked to process deviations.	The tanks were constructed in the 1960s. However, despite some weathering, they appear to be in reasonable condition. Simple operation to store, maintain, and thicken sludge prior to being pumped to downstream processes. Resilient material to corrosion and abrasion used for the tank. High level overflow physical safeguard is in place. Control inhibits are in place. Each individual tank may be isolated for inspection purposes. Assets are offset from vehicle routes and would be resilient to vehicle impact. The most probable cause of loss of sludge is due to partial loss of containment from one of the connecting pipes due to operator error. Even this is extremely unlikely.
J	Bellmer Feed Tank	Glass Coated Steel	Moderate	M	In line with CIRIA 736, all of the assets lie between the 1% (1 in 100) and 0.001% (1 in 1 million) Less than 0.001% (1 in 1 million) (moderate risk) category. Marginal or partial loss of containment scenarios will have a probability of occurrence closer to 1:100 years. Catastrophic loss of containment scenarios, linked to global stability, natural or man-made disasters, major exceptional defects in the fabrication and installation, or explosion / flash fire are, to varying degrees, far less probable but difficult to quantify. At this site, the assets most at risk of catastrophic failure is the APDs because of their construction material and because they have additional failure scenarios linked to process deviations. The probability of total failure is still extremely remote for these assets.	Assets are approximately 8 years old and their condition is reasonable, with some surface weathering noted on the top rings. Simple operation to store and buffer sludge prior to transferring to thickeners or to the APD feed tank. Moderately resilient material to corrosion and abrasion used for the tank. High level overflow physical safeguards are in place. Control inhibits and level indication in place. Both tanks are offset from vehicle routes. The Thickened Sludge Bellmer tank has its own shallow containment bund to manage any small to moderate spills. The Bellmer feed tank has no such containment. Loss of containment possible due to corrosion pin holes at sludge air interface or failure of low-level pipe connections if the tanks are no longer maintained. Loss of containment due to operator error with low level pipework possible, which would be quickly rectified.
L	Thickened Sludge Bellmer Tank	Glass Coated Steel	Moderate	M		

Asset ID	Asset Name	Material	Condition	Catastrophic Loss of Containment Frequency Risk in Line with CIRIA 736 Method	Probability of Catastrophic Failure in Line with CIRIA 736 Method	Comments
F	APD GBTs 1, 2, and 3 Feed Tank	Stainless Steel	Very Good	M	In line with CIRIA 736, all of the assets lie between the 1% (1 in 100) and 0.001% (1 in 1 million) Less than 0.001% (1 in 1 million) (moderate risk) category. Marginal or partial loss of containment scenarios will have a probability of occurrence closer to 1:100 years. Catastrophic loss of containment scenarios, linked to global stability, natural or man-made disasters, major exceptional defects in the fabrication and installation, or explosion / flash fire are, to varying degrees, far less probable but are difficult to quantify. At this site, the assets most at risk of catastrophic failure is the APDs because of their construction material and because they have additional failure scenarios linked to process deviations.	These tanks are of recent construction and were designed to current standards, constructed under supervision, and water tested prior to being put into service. Simple operation to store and buffer sludge prior to transferring to APD feed tank and the APD process. Material is very resilient to corrosion. APD GBTs 1, 2, and 3 Feed Tank is set back from the local site roads, hardstandings and turning areas etc. However, the APD feed tank connecting pipework may be at remote risk from certain access, maintenance, or construction vehicles. Most likely cause of loss of containment is operator error with low level pipework or vehicle impact to connecting low level pipework in the case of the APD tank.
H	APD Feed Tank	Stainless Steel	Very Good	M		
O1-O6	Acid Phase Digestion	Stainless Steel	Good	M	In line with CIRIA 736, all of the assets lie between the 1% (1 in 100) and 0.001% (1 in 1 million) Less than 0.001% (1 in 1 million) (moderate risk) category. Marginal or partial loss of containment scenarios will have a probability of occurrence closer to 1:100 years. Catastrophic loss of containment scenarios, linked to global stability, natural or man-made disasters, major exceptional defects in the fabrication and installation, or explosion / flash fire are, to varying degrees, far less probable but difficult to quantify. At this site, the assets most at risk of catastrophic failure is the APDs because of their construction material and because they have additional failure scenarios linked to process deviations. The probability of total failure is still extremely remote for these assets.	These tanks are 8 years old and were subject to technical supervision during installation and water testing prior to commissioning. Relatively complex operation to hydrolyse sludge so operational failure modes such as foaming and subsequent overtopping, or under-pressurisation become credible scenarios if operating parameters are not maintained, and other protection safeguards fail. Presence of biogas means explosion and short-lived flame in the tank headspace, could occur in extreme instances when multiple safeguards fail. Anti-foaming dosing in place and radar instrumentation in place to inhibit feed on detection of high-high level cause by foam. Material very resilient to corrosion, although external cladding may increase risk of external corrosion over a prolonged period of time. High level overflow physical safeguards are in place. Control inhibits, pressure and level indication in place. Tanks are offset from vehicle routes but there currently is a extremely remote possibility of vehicle collision or impact from construction vehicles. Low level pipework present over impermeable surfacing. Partial loss of containment possible due to operator error with low level pipework, which would be quickly rectified. Partial loss of containment possible if site is not operated within defined parameters and other controls fail. Although deemed moderate risk, the likelihood of catastrophic failure is greater for these tank assets compared to other tanks due to their operating complexity and given that they are of metallic rather than RC construction.

Asset ID	Asset Name	Material	Condition	Catastrophic Loss of Containment Frequency Risk in Line with CIRIA 736 Method	Probability of Catastrophic Failure in Line with CIRIA 736 Method	Comments
P1-P8	Mesophilic Anaerobic Digesters	Reinforced Concrete	Moderate	M	In line with CIRIA 736, all of the assets lie between the 1% (1 in 100) and 0.001% (1 in 1 million) Less than 0.001% (1 in 1 million) (moderate risk) category. Marginal or partial loss of containment scenarios will have a probability of occurrence closer to 1:100 years. Catastrophic loss of containment scenarios, linked to global stability, natural or man-made disasters, major exceptional defects in the fabrication and installation, or explosion / flash fire are, to varying degrees, far less probable but are difficult to quantify. At this site, the assets most at risk of catastrophic failure is the APDs because of their construction material and because they have additional failure scenarios linked to process deviations.	These tanks are of RC construction. 6 were built years 50 years ago and the other two 60 years ago. The tanks are each being isolated, drained, and refurbished under a current project. Relatively complex operation to digest sludge so operational failure modes such as foaming and subsequent overtopping, become credible scenarios if operating parameters are not maintained, and other protection safeguards fail. Presence of biogas means explosion and short-lived flame in the tank headspace, could occur in extreme instances when multiple safeguards fail. Anti-foaming dosing in place and radar instrumentation in place to inhibit feed on detection of high-high level cause by foam. Material very resilient to corrosion. High level overflow physical safeguards are in place. Control inhibits, pressure and level indication in place. Tanks are offset from vehicle routes and construction and would be more resilient to vehicle impact than metal tanks. Low level pipework is contained within the buildings between these tanks, which provides partial secondary containment. Partial loss of containment possible due to operator error with low level pipework, which would be quickly rectified. Partial loss of containment by overtopping possible if site is not operated within defined parameters and other controls fail. Catastrophic failure of the tanks is extremely unlikely due to the robust construction.
Q	Secondary Sludge Storage Tanks	Reinforced Concrete	Moderate	M	In line with CIRIA 736, all of the assets lie between the 1% (1 in 100) and 0.001% (1 in 1 million) Less than 0.001% (1 in 1 million) (moderate risk) category. Marginal or partial loss of containment scenarios will have a probability of occurrence closer to 1:100 years. Catastrophic loss of containment scenarios, linked to global stability, natural or man-made disasters, major exceptional defects in the fabrication and installation, or explosion / flash fire are, to varying degrees, far less probable but difficult to quantify. At this site, the assets most at risk of catastrophic failure is the APDs because of their construction material and because they have additional failure scenarios linked to process deviations. The probability of total failure is still extremely remote for these assets.	The tanks were constructed in the 1960s. However, despite some weathering, they appear to be in reasonable condition. Simple operation to store, maintain, and thicken sludge prior to being pumped to downstream processes. Resilient material to corrosion and abrasion used for the tank. High level overflow physical safeguard is in place. Control inhibits are in place. Each individual tank may be isolated for inspection purposes. Assets are slightly offset from vehicle routes and are more resilient to vehicle impact than metal tanks. The most probable cause of loss of sludge is due to partial loss of containment from one of the connecting pipes due to operator error. When tanks are covered (assuming the structure can accommodate covers) the operating complexity will increase.

<table>
<tr><th>Asset ID</th><th>Asset Name</th><th>Material</th><th>Condition</th><th>Catastrophic Loss of Containment Frequency Risk in Line with CIRIA 736 Method</th><th>Probability of Catastrophic Failure in Line with CIRIA 736 Method</th><th>Comments</th></tr>
<tr><td>R</td><td>Centrifuge Feed Sludge Tank</td><td>Glass Coated Steel</td><td>Good</td><td>M</td><td rowspan="2">See above.</td><td rowspan="2">Assets are approximately 13 years old but their condition is very good considering their age. Some surface weathering is noted on the top rings.
Simple operation to store and buffer raw or digested sludge prior to transferring to the de-watering process.
Moderately resilient material to corrosion and abrasion used for the tank.
High level overflow physical safeguards are in place. Control inhibits and level indication in place.
Both tanks are offset from vehicle routes and predominantly surrounded by impermeable surfacing.
Loss of containment possible due to corrosion pin holes at sludge air interface or failure of low-level pipe connections if the tanks are no longer maintained.
Loss of containment due to operator error with low level pipework possible, which would be quickly rectified.</td></tr>
<tr><td>T</td><td>Raw Break Tank</td><td>Glass Coated Steel</td><td>Good</td><td>M</td></tr>
</table>

Overall Loss of Containment Risk Rating for the Site is MEDIIUM

8.4 Overall Risk Rating and Containment Class

Based on both, Source-Pathway-Receptor and Frequency of loss of containment risk assessments, the BC has an overall site rating (before recommendations) of moderate, which requires implementation of Class 2 containment solutions as a minimum. Refer to Table 8.5 below.

Table 8.5: Overall Rating and Containment Class

Description	Hazard Rating Before Recommendations	Comments	Rating After Recommendations
Worst Case **BC Site Wide** Source-Pathway-Receptor hazard rating	HHL = M & HLH = M	Source hazard is **H** due to large inventory volumes, high BOD, and high microbial content. Worst case pathway potential is overland sludge flows into the Mere Bank Rhine from local sludge tanks. However, the Rhine has no environmental designation, so the receptor damage potential is Low. The worst-case receptor is the Severn Estuary Receptor hazard is **H**, principally due to the Severn Estuary's environmental designations.	H(V)LH= L
Catastrophic Loss of containment risk rating	M	Based on Table 2.3 in Ciria 736, **M** risk equates to: 1 in 100 years < significant spill event probability < 1 in 1 million years.	M
Overall BC Site Rating	M	Based on Box 2.2 in Ciria 736. This demonstrates that action is required, and this will consist of new secondary containment equivalent to a Class 2 standard.	M

9. Containment Solutions

Proposals for the sludge import reception tank area, the SAS balancing tank area, and for the main BC area are presented in this section. This includes a plan of the scope of works needed to achieve a secondary containment solution equivalent to BAT 19c, and spill modelling outputs to demonstrate the effectiveness of the proposals following a failure of the primary asset. For each area, the preferred option is presented first. Options that have been considered, but are not preferred, are also briefly discussed.

As explained within Section 2.4, a chartered structural engineer will be consulted throughout the detailed design of the selected solution and will complete full review of the proposal. Inspection and maintenance plans, as specified by a structural engineer, will be developed, and will be incorporated into Wessex Water's asset management systems. It is anticipated that monthly checks will be routinely carried out by trained operators and any signs of deterioration will be flagged to a chartered structural engineer for review. A chartered structural engineer will also be requested to carry out an independent review on a suggested two-yearly basis to verify the integrity of the containment assets.

The solutions being proposed can adopt any of the following two principal approaches as outlined within Section 2.4. These being:

1) Fully compliant Secondary Containment solution in accordance with Ciria 736.
2) A solution that prevents sludge from leaving the site following a Catastrophic Failure.

9.1 General Considerations for Containment Proposals

Perimeter Walls

The default approach to perimeter walls is to construct them from reinforced concrete and to meet a minimum requirement of tightness class 1 to BS EN 1992-3:2006. The strip footing shall be integrally tied to the wall and a water stop shall be installed at any required cold joints. The foundation and structural design shall consider local ground conditions to manage differential settlement risks along the wall's alignment. Alternative approaches, including pre-cast solutions, may be considered for certain wall sections if they provide an equivalent level of environmental protection.

Wall heights are dependent on the depth of spills simulated in the spill modelling outputs and a 100mm freeboard allowance is always applied. C736 recommends not exceeding a wall height of 1500mm and this will be achievable in most cases at Avonmouth. Wall heights will only exceed this value in areas which are open, with limited operational activity and with simple means of egress, so no safety risks or inspection challenges are introduced. Perimeter wall heights are generally no lower than 400mm and are normally located where the containment area only transfers sludge to another location within the same bund.

At certain points, vehicles will need to enter bunded areas from road access points. These are indicated by the green shaded areas in the proposal figures. The preferable approach (over flood gates) is to grade roads up to the required containment heights at the access points. From here they will grade back down to the existing road level within the bunded area. Gradients will be designed to ensure that vehicles can safely turn. In general, adjustments to roads must meet WWS design standard 224, which covers road design principles, and minimum expectations to ensure safe operation can be maintained.

Flood Gate and Access Provision

The objective will be to design out the need for flood gates during detailed design. This will be achievable within for the localised containment solutions but may be challenging in the Main BC area given the considerable volume that needs to be contained when applying the 25% rule. However, if one or more flood gates is necessary to facilitate construction and maintenance vehicle access into a bunded area, then the following approaches will be taken:

Specifying, Procuring, Installing, and Testing the Flood Gate.

The guidance outlined for prefabricated bunds in C736 shall be followed when specifying, procuring, installing, and testing a flood gate.

In particular, specifications will indicate that the product shall be water retaining and shall be capable of withstanding hydrostatic and hydrodyamic forces that it may experience following failure of primary containment. The anticipated forces shall be determined by calculation by a competent designer and referenced in the contract documents to the supplier.

A factory acceptance test (FAT) shall be required to confirm the product is capable of withstanding the forces it may be subjected to and to confirm that the product is water retaining. Any testing shall be witnessed and certified by a competent person not employed by the supplier of the product.

In addition to the FAT, site acceptance testing (SAT) shall be undertaken to ensure the as installed product is capable of retaining water to the required hydrostatic and hydrodynamic loads. The SAT test will be used to demonstrate effectiveness of the seal between the flood gate and concrete wall, and the threshold detail between the flood and the gate.

This will be achieved by installing a temporary flood dam, with the flood gate forming one side of the perimeter, to create a small volume. A water test shall then be carried out in accordance with section 6.3.7 of CIRIA 736. This test shall be undertaken prior to commissioning the gate and at regular intervals thereafter to demonstrate that integrity has not been compromised.

Operation of the Flood Gate

The following methods are suggested for access controls and arrangements into the bund. These will be confirmed by formal risk assessment considering HSE risks adopting ALARP principals.

The flood gate operation shall be manual and shall be limited to the following activities only:

- Vehicle entry into the containment area limited to construction purposes including new tanks, or repairs to existing primary or secondary containment where the work cannot safely be carried out using pedestrian access based on ALARP principals.
- Emergency access and egress where operator loss of life or livelihood is probable.
- Testing of gate open alarm.

At all other times the flood gate shall be locked and shall include "no entry by unauthorised persons" and "no opening by unauthorised persons" warning signage. Any workers or visitors on site shall be advised who is authorised at the site induction.

All other access to the bund will be via access staircases up and over the bund wall. These will be positioned to provide direct evacuation routes in the event of a potential or actual dangerous situation occurring within the bund. Note pedestrian access into the bund wall shall be restricted using risk assessment method statement procedures, and with locked gates and “no entry by unauthorised persons" warning signage at the access stairs.

Any works involving operation of the flood gate will be subject to a risk assessment method statement requiring review and approval from the Site Manager. For the first item, this will be task specific. For the latter two, it will be generic but reviewed prior to commencing the operation. Flood gates shall be manned by an individual who can operate the flood gate for a) for the duration in which they are open and b) while personnel are within the bunded area.

Flood gates will include instrumentation that will alarm to a central SCADA system to notify the Operator that the gate is open. The flood gate will remain open only for as long as required to allow the construction vehicle to be moved inside or for incapacitated personnel to be removed, or to prove the gate open alarm is functional.

Records of flood gate operation shall be logged and recorded by the Operator and will be available on request by the Regulator for review. The log will include time of opening, time of closing, evidence of alarm signal, approved RAMS record, and alarm testing record as appropriate.

Maintenance and Inspection of the Flood Gate

The supplier of the flood gate shall supply full instructions on inspection and maintenance requirements, including inspection frequencies, finishes and other protection measures, preventative routine maintenance, and damage repair, as outlined in Section 7.5.2 in CIRIA 736. This information will assist WWS in developing an inspection and maintenance plan for the flood gate.

The flood gate will be uniquely identified with an asset tag and included in WWS’s asset management system. The necessary inspection and maintenance requirements will then be assigned to the asset. Such activities would consist of weekly observational checks by Site Operators and an annual formal inspection and test of the asset by a competent engineer.

The final regime would be developed in consultation and agreed with the relevant environmental and safety regulators to ensure it is appropriate to the criticality of the asset. As with any asset, the frequency of inspection, testing, and any subsequent intervention will change during its design life.

Duration of Time for Spill to Reach the Flood Gate

The time taken for a spill to reach the flood gate is a function of the mode of failure and the location of that failure within the bund.

For the most severe events referenced in Ciria 736 it will be instantaneous from a human perspective.

For a jetting type loss of containment event in the direction of the flood gate, it will be seconds.

For jetting in other direction, overtopping, or other modes of failure leading to steadier loss of inventory, it will be minutes or hours.

New Impermeable Surfaces

Based on initial investigations Wessex Water are currently proposing to replace permeable surfaces with tarmac in lightly trafficked areas. Tarmac is now recognised as an appropriate material for chemical containment and has the following advantages over reinforced concrete:

- Relative ease of construction in impermeable areas around existing assets.

- Lower cost and embodied carbon.
- Simpler to inspect and maintain.
- No joint details.

Where new reinforced concrete is required, it will meet a minimum requirement of tightness class 1 to BS EN 1992-3:2006. Joint detailing shall comply with Section 7.2.4 in Ciria 736.

Existing Impermeable Surfaces

Existing impermeable surfaces will be retained where possible unless a condition is so poor that it becomes simpler to demolish and replace it. Retained concrete may not comply with the requirements set out in CIRIA 736 as Wessex Water design standards do not specify the requirement for water stops at construction joints in reinforced concrete roads and footpaths. Existing joints will therefore be inspected and reinstated with an appropriate surface poly-urethane sealant. The joints will be inspected regularly and proactively repaired to ensure they remain in good condition.

Additional proprietary waterproofing epoxy products from specialists will also be considered at a detailed design to improve the robustness at concrete joints and joints across existing kerb alignments transitioning between concrete and other surfaces. Detailed design material specifications will be developed in close consultation with suppliers offering these types of products.

Vehicle Impact Protection

Containment shall be provided where there is a credible risk of vehicles damaging existing tanks. This applies to certain areas of the GCS tanks and will normally consist of bollards, armco barriers or equivalent.

The vehicle containment product selection, positioning, and foundation design will be undertaken by a competent structural engineer and checked and approved in accordance with WWS quality assurance procedures. Final positioning of containment shall also be agreed with the Site Operator but shall be far enough away from the primary containment such that a horizontal force is not transferred directly from the vehicle containment to the asset it is protecting. The design will ensure that the containment is capable of withstanding the design force that it would be subjected to following a) collision from the largest vehicle that can drive into that area and b) a maximum credible speed.

Vehicle containment will be considered an integral component of the secondary containment asset and as such will be subject to routine inspection. If vehicle containment is subject to an impact, it shall be condemned and replaced as soon as possible to an equivalent standard of the original installation.

Drainage

Existing below ground drainage conveying surface run-off will be utilised as part of the containment solution where appropriate. The lines will be routinely surveyed using CCTV to confirm they remain in serviceable condition and any identified defects will be scheduled for repair. Newly installed drainage in the tertiary treatment area will be dual contained.

Flows from all containment areas will discharge to the LPS, IPS, or a new pumping station. The large containment area proposed for the main BC may require an attenuation tank to manage the additional flows generated by the significant increase of impermeable surfacing.

Following a catastrophic spill event, the receiving pump station may, subject to process design assessment, pump undigested sludge and surface water back to the head of the works at a controlled flow rate that maintains the performance of the WRC. The pump station will also include a tanker point for draining down or managing sludge spills and surface water volumes within the bunded area. In this instance, tankers would export the sludge to another site for processing.

Rapid loss of level in a given tank shall lead to an emergency alarm. The pump station serving the relevant containment area will be auto inhibited by the measured drop in level to give the Operator a period of time to determine the source and severity of the incident and to follow the appropriate course of action, outlined in the agreed emergency response procedure.

9.2 Sludge Import Reception Tank Area

The containment proposal protects against catastrophic failure of the import reception tank only, so the minimum volume to be contained is based on 110% of the above ground volume of the tank up to the overflow level, equating to 296m^3.

The proposal encompasses a relatively large area and utilises existing impermeable surfacing and the in-situ concrete walls forming the PSTs and connecting channels. Shallow containment perimeter walls would need to be constructed to complete the containment area.

An additional impermeable area is proposed on the opposite side of the road to the import reception tank to manage jetting and surge effects. The scale of this would be confirmed at detailed design and may be combined with road realignment. The type of bund proposed means the effective volume will be greater than 296m^3.

Drainage within the containment area will return to the IPS via a sump pump. The IPS then discharges combined return flows upstream of the PSTs for treatment. The import reception tank contains raw sludge, and the volume is marginal in relation to treated flows at the WRC. Therefore, sludge and surface water can be returned back to treatment at a controlled rate following catastrophic failure of the tank. Liquid sludge imports would be diverted elsewhere in such a scenario.

The current proposal is presented in Figure 9.1 and the spill model output is shown in Figure 9.2.

9.3 SAS Balancing Tank Area

The containment proposal protects against catastrophic failure of the SAS balancing tank only, so the minimum volume to be contained is based on 110% of the above ground volume of the tank up to the overflow level, equating to 395m^3.

The proposal encompasses an area that limits the bund volume to between 800mm and 900mm high, including freeboard and rainwater accumulation.

Drainage from this location also returns to the IPS via a nearby local pumping station. The SAS balancing tank contains raw sludge and may be returned for treatment at a controlled rate following a catastrophic loss of containment.

The tank is modern and constructed from in-situ reinforced concrete, which is an extremely robust material. Failure modes linked to collapse of the structure would ultimately cause the secondary containment and adjacent SAS tanks to collapse, and there are no other scenarios that would lead to surge transients. The key failure modes are therefore associated with failure of the low-level connecting pipework. The suggested wall heights are adequate to contain inventory loss from jetting. Any inventory that does overtop would land on impermeable surfacing with formal drainage to the nearby pumping station.

The spill model output, showing the suggested containment perimeter wall alignment, is shown in Figure 9.3.

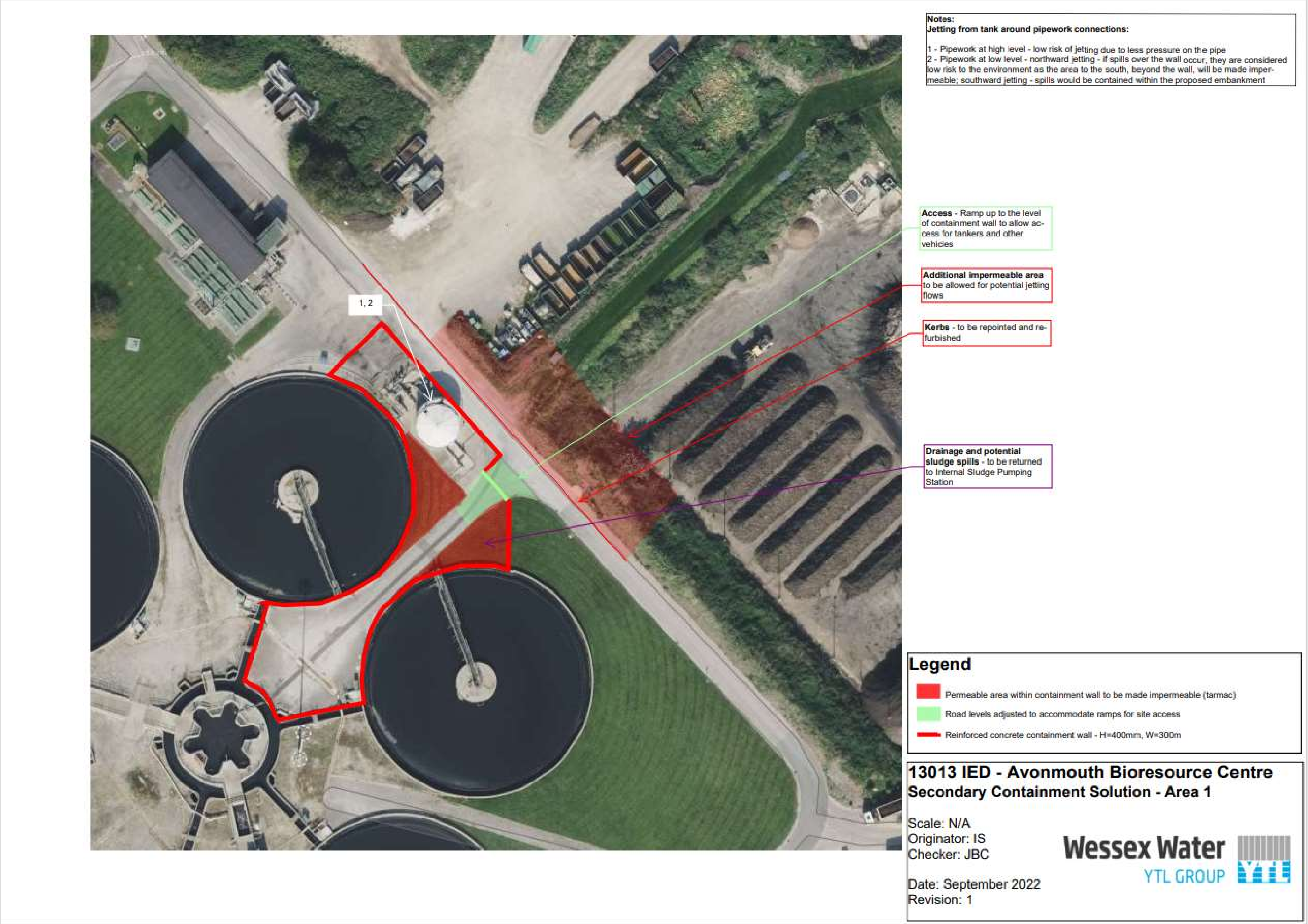

Figure 9.1: Import Sludge Reception Tank Containment Proposal

Figure 9.2: Import Sludge Reception Tank Containment Proposal Spill model.

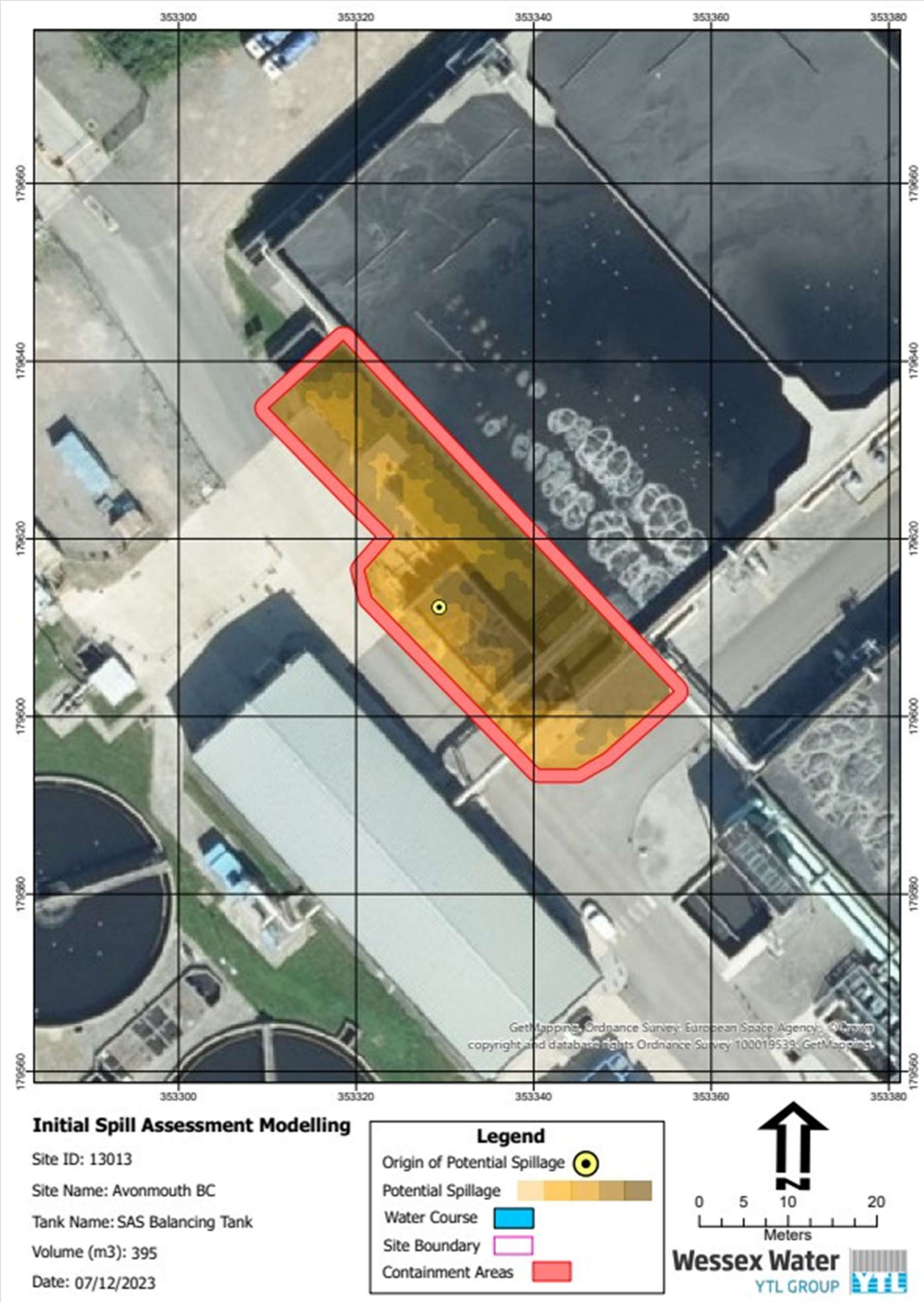

Figure 9.3: SAS Balancing Tank Containment Proposal Spill model.

9.4 Main BC Area

This proposal utilises a significant area of the Main BC and consists of constructing containment perimeter walls and replacing large areas of permeable ground with impermeable surfaces. It exploits the favourable topography along the Southwestern edge of the BC to contain any spilled sludge from a catastrophic failure of any of the GFS tanks, the RC Digesters and Sludge holding tanks.

The bund is designed to maintain access from all existing roads. It also minimises the impact on day-to-day inspection, operation, and maintenance activities by site personnel by maintaining the existing vehicle and personnel access routes. This is particularly important as the most of the Bioresources Centre will be located within the bund.

An area outside the bund has been provisionally allocated for siting an attenuation tank to store rainfall run-off water from additional impermeable surfaces within the bund. Flows from this attenuation tank will either discharge to the Internal PS, or be returned via a new PS.

Sludge and surface water run-off will be transferred to this attenuation tank, following the catastrophic failure of one or more assets. Therefore, the suitability of existing drainage will need to be reviewed with this approach. Depending on the nature of escaped sludge (raw or digested), lost inventory will be tankered away or returned to the Internal PS at a controlled rate ensuring that the WRC is not overwhelmed by the returns. The sizing and final location of the attenuation tank will be confirmed at detailed design stage.

Main BC Area Revision 1 Containment Volume

The original proposal submitted in the EA was based on protecting receptors following a catastrophic loss of containment affecting the largest group of tanks in close proximity within the bund. The minimum volume to be contained was 25% of the sum of:

- The RC Mesophillic Anaerobic Digesters (MADs) 5 to 10 (6 x 2728m^3 = 16,368m^3)
- The GFS Bellmer Thickened Sludge Tank (313m^3)

Resulting in: (16,368m^3 + 313m^3) x 0.25 = **4170m^3**

Spill modelling was also completed to demonstrate the effectiveness of the proposal following complete failure of assets located in different parts of the bund.

Main BC Area Revision 2 Containment Volume

The containment volume has been re-assessed based on EA feedback on other permit applications. The volume is now based on the 25% rule, exactly as it is defined in Ciria 736. As a result, the minimum spill volume to be contained within the containment area is **10,341m^3**. Table 9.1 below lists the volumes per asset type and how the spill volume has been determined.

Table 9.1: Assets in Main BC Containment Area and Volume to be Contained Summary

Asset name	Ref	Above Ground Volume Per Tank (m3)	Number Of Tanks	Above Ground Vol Per Asset Type (m3)
SAS Transfer Tank*	**N**	719	2	719
Avonmouth Consolidation Tanks	**I**	1227	2	2454
Bellmer Feed Tank	**J**	341	1	341
Thickened Sludge Bellmer tank	**L**	313	1	313
APD GBTs 1, 2 and 3 Feed Tank	**F**	417	1	483
APD Feed Tank	**H**	380	1	434
Acid Phase Digestion (APD)	**O1-O6**	813	6	4,878
Mesophilic Anaerobic Digesters (MAD)	**P1-P6**	2728	6	16,368
Mesophilic Anaerobic Digesters (MAD)**	**P7, P8, REC**	2332	4	9,328
Secondary Sludge Storage Tanks (SSST)	**Q**	1840	**2**	3,680
Centrifuge Feed Sludge Tank	**R**	552	1	552
Raw Break Tank	**T**	61	1	61
Hydrolysis Buffer Tank**	**REC**	808	1	808
Post Digestion Storage Tank**	**REC**	863	1	863
Food Liquid Waste Tank**	**REC**	80	1	80

Sum of Above Ground Asset Volumes	41,362m^3
x0.25	**10,341m^3**

**Assuming the SAS Transfer Tank is relocated inside the proposed Main BC containment area*

***Includes the Renewable Energy Centre (REC) tanks, which are also situated within the Main BC containment area*

Applying this larger volume results in higher walls along the containment perimeter. The predicted increase varies from 0mm to 800mm, with approximate wall heights ranging from 400mm at high points of the bund away from tanks, up to 1.2m along the south-western perimeter. As a result, the access points into the bund become more challenging to implement. However, with careful design, it may still be possible to ramp or bridge over the containment perimeter at key locations and to avoid installing flood gates.

Containing the larger volume also rules out utilising the area surrounding the final settlement tanks (FSTs), unless the coping levels of those assets are raised significantly. The area along the Southwestern perimeter of the Site, has been proposed instead. In this instance, the SAS tank would be outside of the main bunded area, and it would be advantageous to install and commission a new SAS tank within perimeter of the main bund, given the risk it presents to contaminating the FSTs.

The proposal is unchanged for all other aspects.

A catastrophic failure of this magnitude would mean the BC would cease operations for a prolonged period of time. Indigenous sludge would need to be managed in accordance with the Site's Emergency Response Plan. The Site Operator is responsible for the correct implementation of the emergency response following catastrophic failure of primary containment.

The current proposal is indicated in Figure 9.4 and the spill modelling output in Figure 9.5. Final wall heights and alignment will be developed and confirmed at detailed design stage.

A proposed permeable impermeable surfacing plan with all three containment perimeters is shown in Figure 9.6.

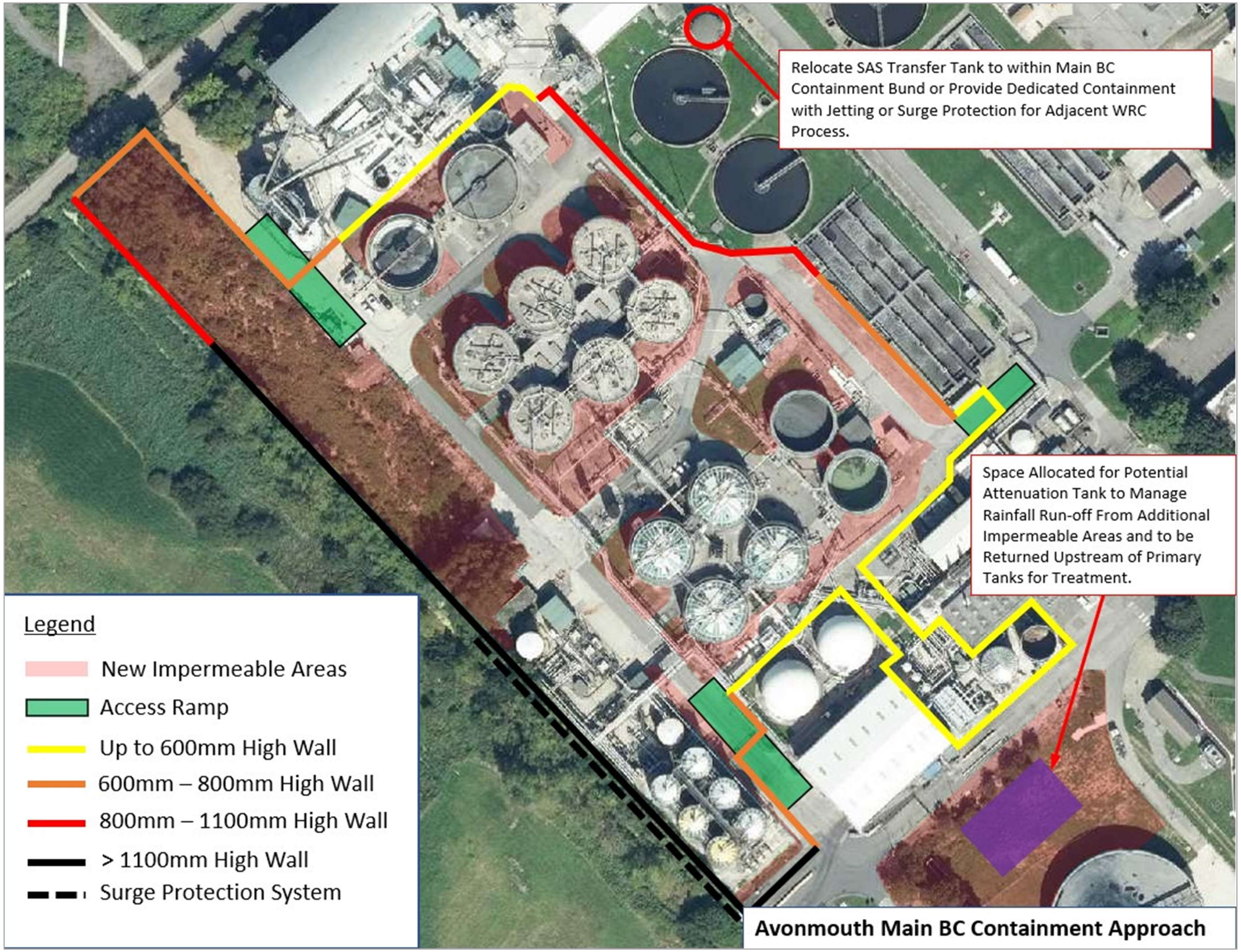

Figure 9.4 Main BC Area Proposed Secondary Containment Proposal (Revision 2 Proposal)

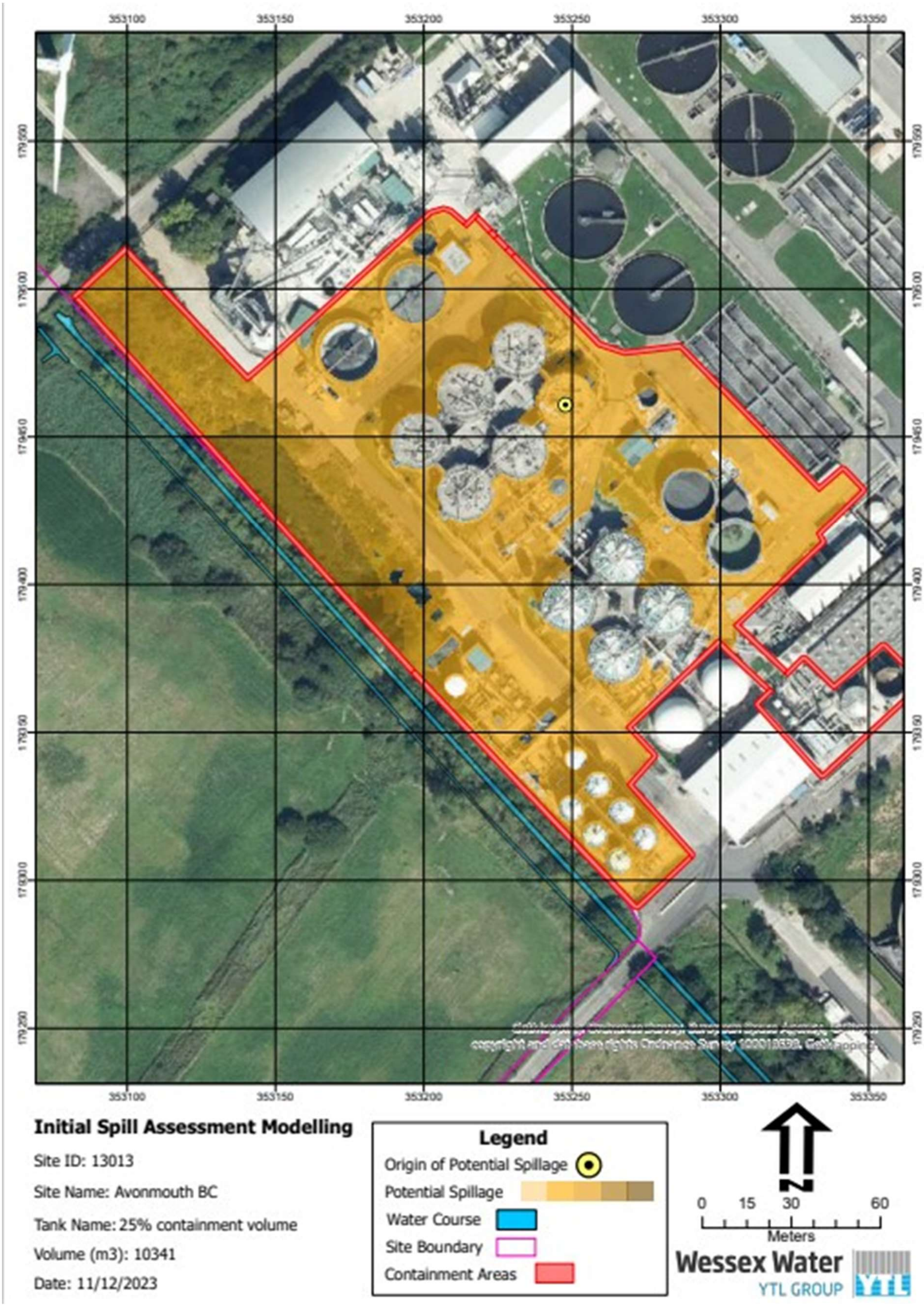

Figure 9.5 Main BC Area Spill Model with Proposal to Contain 10,341m^3 (Revision 2 Proposal)

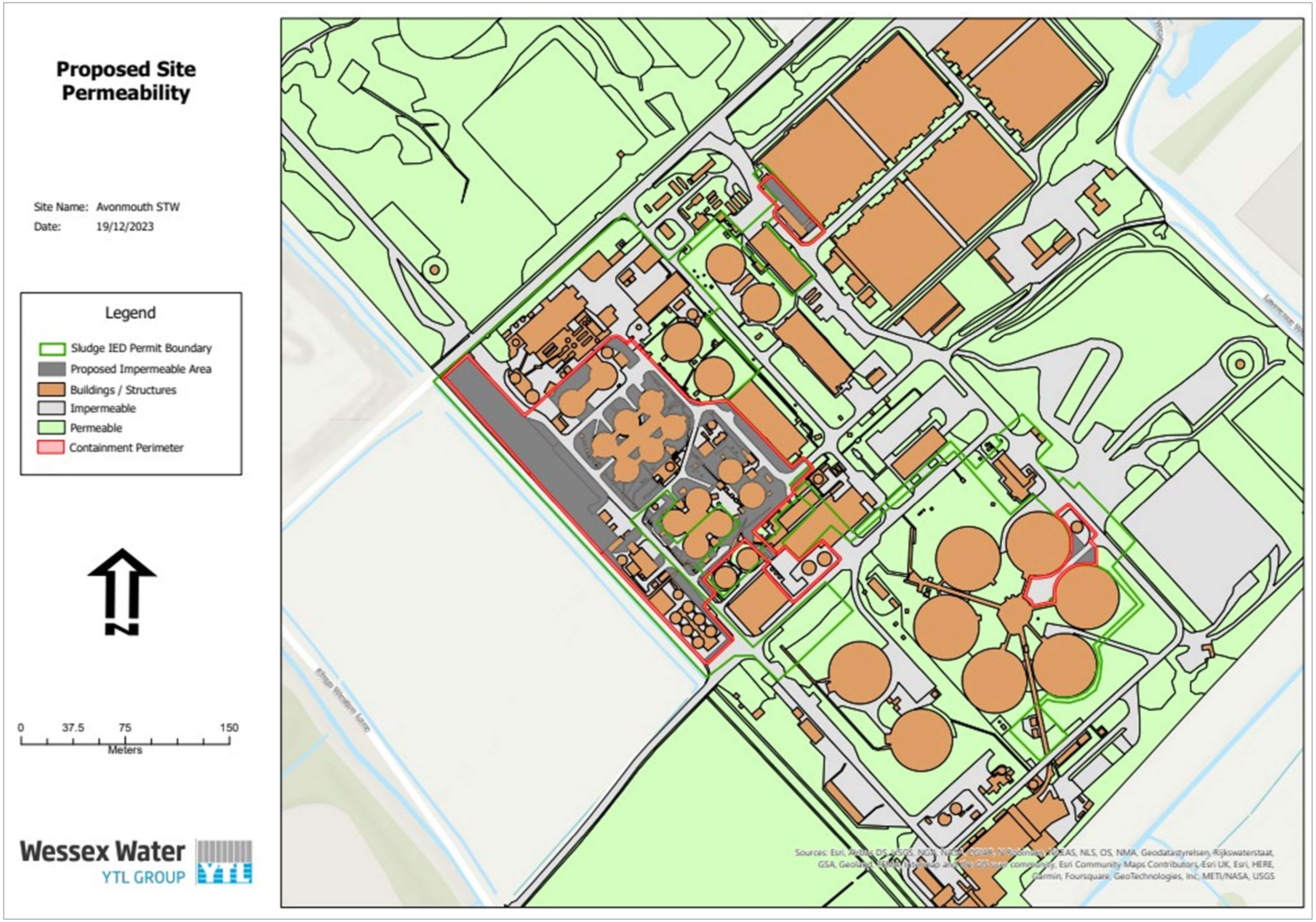

Figure 9.6 Proposed Avonmouth BC permeability Plan

9.5 CIRIA 736 Compliant Secondary Containment Solutions Considered.

As suggested in the preceding text, a fully compliant secondary containment solution in accordance with CIRIA C736 is not preferred primarily because of the impact on site operations, likely necessitating considerable reconfiguration of existing assets, and the missed opportunity to limit impact on the site through use of the large areas of existing impermeable surfacing.

9.6 Standard Precautionary and "Soft" Solutions

The following measures will be implemented as part of a detailed design solution.

Drainage and Services

- Impermeable surfacing and drainage to be provided beneath pipework that falls outside of the specified bund perimeters. Jetting effects to be considered for each pipe run.
- All existing site surface water drainage and newly installed surface drainage is reviewed to demonstrate adequate capacity for rainfall and spill events.
- Surface water drainage systems capacity to be established to demonstrate that lost inventory is not surcharging manholes or gullies outside of the bund perimeter.

BC Control and Telemetry Systems

- Process scientist to HAZOP the existing site processes and operation against current industry best safeguarding practices and propose proportionate improvement recommendations where required.
- Security expert to review current unauthorised access deterrence provisions against current industry best practice and propose proportionate improvement recommendations.
- Ultrasonic level sensors in tanks to be alarmed and to be visible remotely in the event of a rapid and unanticipated drop in level within a given tank e.g. tank level dropping, feed pump and draw off pump not running.
- Rising mains to be installed with pressure indication and inhibits if they do not already have them.

Structural Performance

- Consider early warning tank shell or reinforcement corrosion systems for tanks where this may not be obvious during an external physical inspection.
- Carry out condition assessment of existing hardstanding areas and, where required, propose remedial work to ensure an appropriate containment for the short period of time associated with an improbable spill event – Refer to Table 9.2 below.
- Propose locations for vehicle containment to avoid any risk of collision with primary containment assets.
- Commit to structural inspections of concrete, steel assets, and pipework and an appropriate frequency by a chartered structural engineer or competent independent consultant for steel tanks. Frequency to be based on the risk-based inspection plan.
- Secondary containment structures to be identified as assets on Wessex Water's asset register.
- Development of an operation and maintenance manual for the secondary containment structure by a chartered structural engineer.

Table 9.2 Example Inspection Plan for Existing Concrete Paving

Asset	Sub Asset	Theoretical Design Life	Inspection and Report By	Documentation	Typical Visual Observation & In Situ Testing	Method	Inspection Frequency (TBA)
Existing concrete pavement including Access Roads, and Footpaths and operational working areas.	Concrete Segments	40 years	**Originator**: Structural Engineer +2 years' experience. **Checker:** Chartered Civil or Structural Engineer. **Approver:** TBA	Inspection Report to Include: As Built Drawing or Standard Detail. Estimated Construction Date. Applicable Design Code. Observation Condition Assessments. Testing Condition Assessments.	Cracks > 0.3mm	Observation Crack Width Gauge	2 Yearly
					Cracks < 0.3mm	Observation Crack Width Gauge	2 Yearly
					Differential Settlement / Subsidence across segment or between Adjacent Segments	Observation Dumpy Level	2 Yearly
					Surface condition - Damp patches, Spalling, Biodegradation.	Observation Dumpy Level	2 Yearly
					Reinforcement	Ferroscan	First Inspection

9.7 Groundwater Monitoring

The following monitoring well requirements are proposed to help pro-actively identify below ground leaks originating from partially buried assets:

- 24 x 6m deep dynamic window sampler boreholes. Installed with 50mm screened standpipes to the base, typical response zone from 1 – 6m deep with gravel (non-calcareous) surround.
- Samples would be taken from soil (72 No.) and groundwater (24 No.) contamination during the investigation to provide a baseline. During the sample collection PID meters testing would be completed along with headspace analysis.
- Following the borehole completion a competent engineer would return to all boreholes, micro-purge and take samples (within 24hours to lab) and testing would include groundwater suite F x 24 samples - ICE Specification for Ground investigation testing suite – With addition of E.coli and Faecal Coliforms
- Monitoring / Sampling Frequency would be monthly for year 1. Twice a year from then on.

Preliminary monitoring borehole locations are indicated in Figure 9.7, but exact details are to be assessed and confirmed following further investigation.

Figure 9.7 Preliminary Monitoring Borehole Location Plan

<END>