# Esholt Secondary Containment Assessment

October 2024

YorkshireWater

Stantec

Sign-Off Sheet

| Project details | |
|---|---|
| Project number | 41527729 0301 |
| Project name | Environmental permitting for IED sites |
| Date | October 2024 |
| **Client details** | |
| Client name | Yorkshire Water Service Ltd |
| Client address | Western House<br>Halifax Road<br>Bradford<br>West Yorkshire<br>BD6 2SZ |
| **Document details** | |
| Document title | October 2024 |
| Document version | V4 |
| Report author | Kiran Parmar |
| Report reviewed by | |
| Report approved by | |
| Report by | Stantec<br><<Add address>> |

Disclaimer

## Contents

## List of Figures

## List of Tables

# 1 Introduction

As part of the Industrial Emissions Directive (IED) permit application for Esholt Sludge Treatment Facility (STF), Yorkshire Water (YW) has undertaken an assessment of the significance and potential environmental risks associated with a loss of containment of process vessels. YW has also reviewed existing provisions and potential improvement options against Best Available Techniques (BAT) principles, in alignment with CIRIA 736[1].

Esholt STF falls under the IED as a Part A(1) installation by virtue of exceeding the 100t/d capacity limit for anaerobic digestion (AD). The permit will cover sludge import, sludge screening, sludge dewatering, the thermal hydrolysis plant (THP), sludge digestion, biogas processing and utilisation, liquor balancing, and cake management. This document focuses on the secondary containment aspects of the permit requirements, in particular the application of BAT, and should be viewed in parallel with the main permit application document, in particular Section II: Technical Description, Section III: Accident Risk Assessment and Section V: Site Condition Report.

## 1.1 Site details

Figure 1 shows an aerial view of Esholt STF. Esholt is a large STF and is situated to the northeast of Bradford, England. The site treats indigenous sludge from the co-located wastewater treatment works which serves a population equivalent of 427,210 from Bradford and surrounding Leeds area, it also receives imports of sludge from other YW sites. Figure 2 indicates the key activities at Esholt STF via a process flow diagram. The key activities are the sludge reception and screening, sludge dewatering plant, THP, anaerobic digestion, biogas handling and combustion, dewatering, and associated routes of gaseous, liquid, and solid materials and energy. These processes are further discussed in Section 3.2.1.

*Figure 1. Esholt STF aerial view. Permit boundary in green.* © Google, 2021

[1] CIRIA (2014) Containment systems for the prevention of pollution: Secondary, tertiary, and other measures for industrial and commercial premises (C736; 2014)

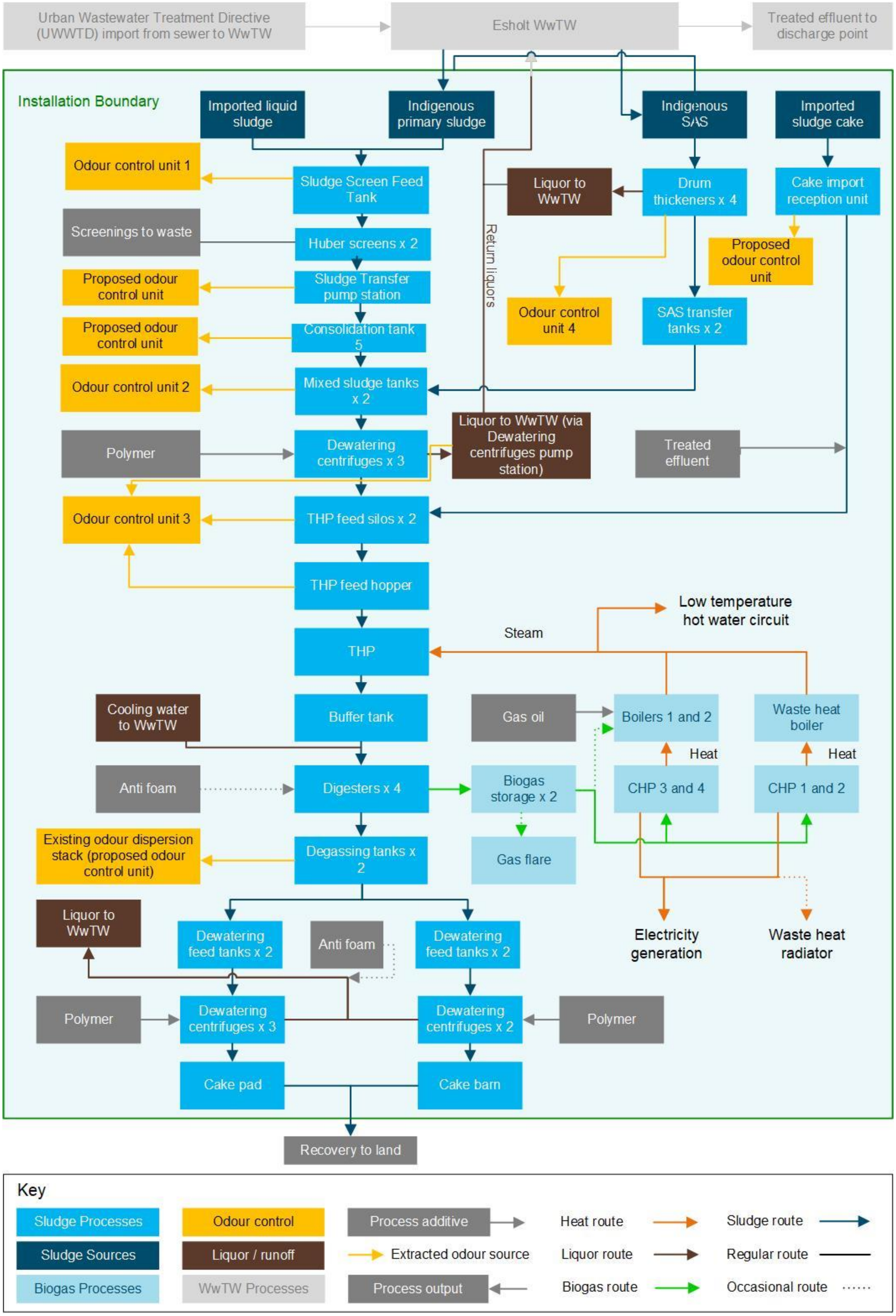



*Figure 2. Process flow diagram Esholt STF.*

## 1.2 Overview

YW commissioned Stantec to assess existing provisions and, where necessary, improvement options for secondary containment at the site. Stantec have provided risk-based supporting evidence to accompany the permit application, which demonstrates the most appropriate solution(s) for IED BAT compliance using CIRIA 736 standards. To fully understand the requirement for secondary containment and to provide environmental protection at Esholt, two different industry standard tools have been used, these are shown within the flow chart in Figure 3.

Firstly, the Anaerobic Digestion and Biogas Association (ADBA) secondary containment risk assessment tool has been applied to assets at Esholt. The ADBA assessment tool provides a methodology for determining the specific design of secondary containment systems at a site, based on an assessment of sources, pathways and receptors which are at highest risk, and the types of control options which would provide protection. However, as an existing installation in continuous operation, retrospectively applying a standard secondary containment bund to all sludge tanks and containers presents significant technical, operational, safety and logistical challenges. It is also noted that the location of Esholt STF within a wider wastewater treatment works (WwTW) presents opportunities in terms of utilising other existing YW assets as part of the pollution containment and prevention solution, and the ADBA tool does not have the flexibility to reflect this in the solutions it recommends.

Having regard to this limitation, a bespoke source, pathway, receptor approach has been developed by Stantec and applied to identify and risk assess bunding solutions favoured by the ADBA approach, as well as additional site-specific options for secondary containment.

Whilst these tools are discrete pieces of work, they come together to provide a detailed evidence base for intervention at Esholt.

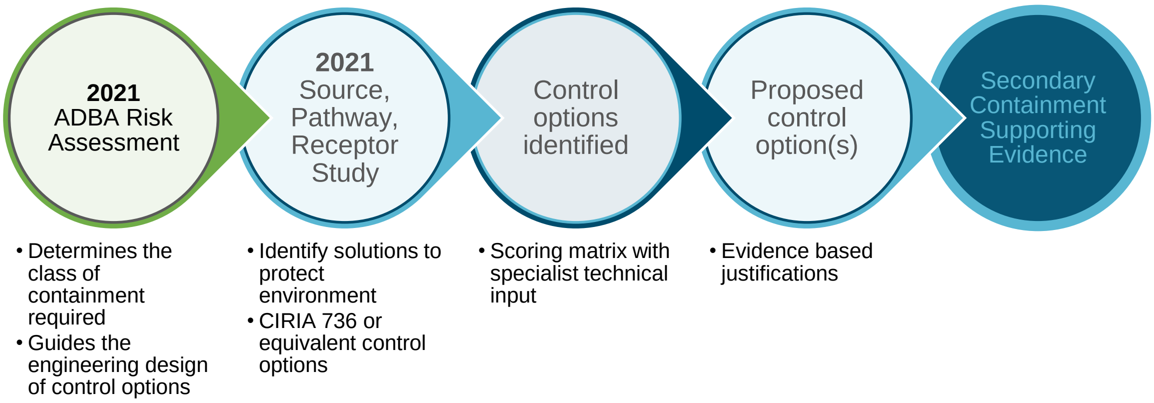



*Figure 3. Flow chart showing the approach taken to provide secondary containment supporting evidence.*

# 2 ADBA risk assessment tool findings

The ADBA Risk Assessment Tool is based on CIRIA 736 requirements for the prevention of pollution: including secondary and tertiary containment, and other measures for industrial and commercial premises. An assessment is presented in Appendix 1 and the findings are summarised in this chapter.

## 2.1 Class of required secondary containment for Esholt

To identify the class of containment deemed to provide sufficient environmental protection in the ADBA Risk Assessment, the tool uses a source, pathway, receptor model. This identifies hazards posed to the environment and assigns a class of containment based on the site hazard rating and likelihood of loss of primary containment. The approach is summarised in Figure 4 below.

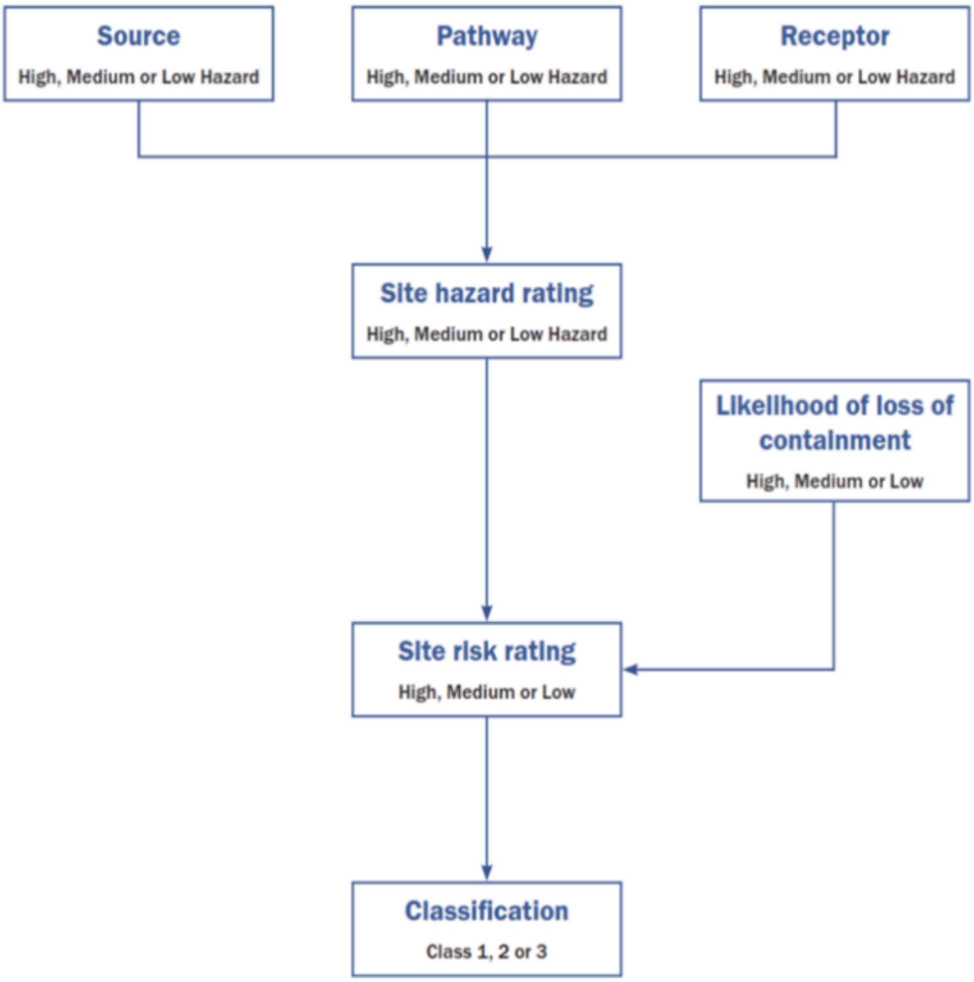



*Figure 4. ADBA risk assessment classification flowchart.*

The ADBA Risk Assessment Tool scored the source element as ‘High risk’, pathway elements as ‘High risk’ and the receptor element as ‘High risk’ at Esholt owing to the significant volumes of sewage sludge stored onsite and due to the surface runoff and site drainage pathways to the sensitive receptor, the River Aire. Leeds Liverpool canal is not considered as a high-risk receptor as although it is close to the STF, it is significantly uphill of all process tanks and will not be affected by potential sludge spills. In summary, this assessment approach indicates that Esholt STF has an overall site hazard rating of ‘High Risk’. The likelihood of failure was ‘Low Risk’ due to the type of infrastructure involved and the mitigations at the site e.g., regular tank inspections and level sensors.

According to Table 4 within the ADBA tool (box 2.2 CIRIA 736), reproduced in Figure 5 below, the combination of a high site hazard rating and a low likelihood rating, gives the overall site risk as medium. The indicated class of secondary containment for **Esholt STF was therefore deemed as being Class 2.**

Table 4: Overall site risk rating as defined by combining ratings of site hazard and probability of containment failure *(Box 2.2 CIRIA 736)*

| Possible combination | Overall Risk Rating | Indicated class of secondary containment |
|---|---|---|
| HH, HM, OR MH | HIGH | Class 3 |
| MM, HL, OR LH | MEDIUM | Class 2 |
| LL, ML, OR LM | LOW | Class 1 |

*Figure 5. ADBA classification matrix.*

The ‘Esholt STF ADBA Secondary Containment Risk Assessment’ outlines the information and data utilised in greater detail, as well as the assumptions applied to undertake a secondary containment risk assessment. The requirement for ‘Class 2’ type secondary containment within Esholt STF has been used to inform the next stage of the risk assessment, spill modelling and the site-specific options appraisal carried out by Stantec in 2021 to support the permit application process (See Chapter 3).

# 3 Solution appraisal

## 3.1 Objectives

The purpose of this stage of the assessment is to determine the significance and potential environmental risks associated with a loss of containment from sludge vessels within the Esholt STF, and to review existing provisions and a potential improvement solution against BAT principles, including CIRIA C736. As described previously, this stage of the process is informed by the outputs of the ADBA tool, but also considers options which are outside the scope of the ADBA scoring system utilising a bespoke methodology which adopts source-pathway-receptor principles in a qualitative risk-based framework.

## 3.2 Sources in the anaerobic digestion and dewatering areas

The sources of risk which have been identified at Esholt are shown in Figure 6 below. These assets occupy two areas of the site, which are considered separately within this report:

- the anaerobic digestion facility – 'AD Area'.
- the dewatering area (east of the River Aire) – referred to as 'DW Area'.

A third permitted area located to the north-west, the SPC area, is used for storage of legacy conditioned materials. This area contains no storage vessels and is not in active use for any current STF operations. This area is therefore outside the scope of this report.


*Figure 6. Esholt sources of risk and site areas.*

### *3.2.1 Bulk storage vessels (anaerobic digestion area)*

Tanks within the AD area are labelled within Figure 7 and a detailed discussion of risk sources and existing control and mitigation measures associated with the AD Area is provided below.

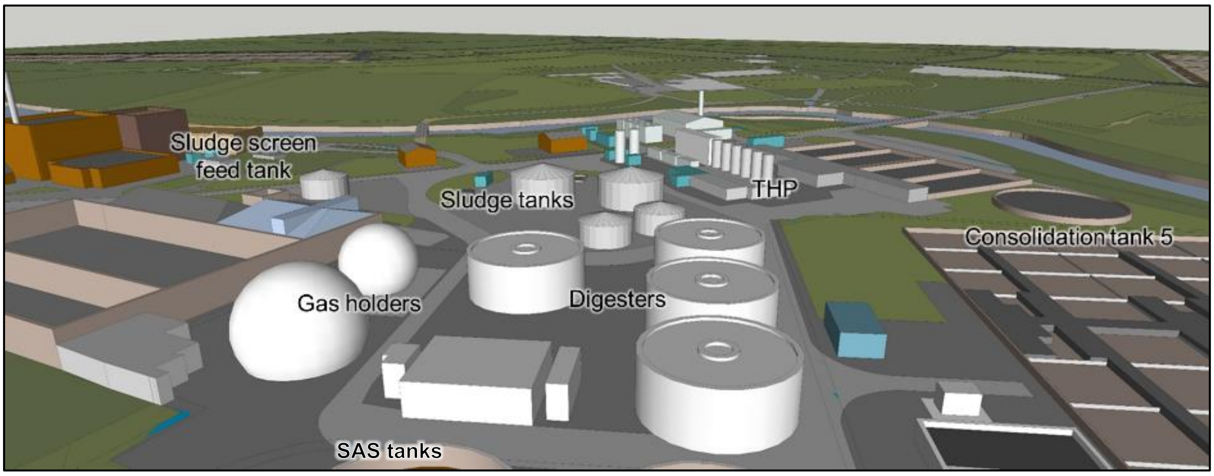



*Figure 7. Tanks within the AD area.*

### *3.2.1.1 Sludge reception, treatment and handling*

Sewage sludges and sludge cake treated within the STF originates from several sources:

- Indigenous sewage sludges, including indigenous primary sludge and indigenous surplus activated sludge (SAS) arising from sewage treatment processes operated within the wider Esholt WwTW are piped directly to the STF.
- Sewage sludges generated by smaller YW sewage works (with lower capacity or capability for treating sludges on-site) are imported to Esholt STF for additional treatment. This may be received in the form of either liquid sludge or sludge cake.

Liquid sludge and sludge cake are delivered to the site by tanker / covered tipper lorry, the maximum load typically being 28 tonnes with unloading routinely taking up to 30 minutes. Only appropriately authorised vehicles can discharge at the site as shown in Figure 8. This is controlled using ‘WaSP’ loggers, valves on the discharge pipework will only open when a driver presents appropriate authentication to the system. The WaSP loggers record the source of the sludge, the time and date of delivery, the total volume discharged and average percentage dry solids of the load.

*Figure 8. Sludge unloading area via WaSP loggers.*

#### 3.2.1.2 Sludge screen feed tank (1 no.)

Imported liquid sludge is delivered to site by tanker. The tanker unloads at the dedicated sludge import area and sludge is pumped (using vehicle mounted pumps) into the sludge screen feed tank (Figure 9, 655 $m^3$ concrete tank) where it is mixed with indigenous primary sludge pumped directly via underground pipework from Esholt WwTW. Headspace air from this tank is routed to a local Odour Control Unit (referred to as OCU 1). This is currently operated as a dispersion only stack. The sludge is screened using two Huber enclosed rotating screens.

*Figure 9. Sludge screen feed tank.*

#### 3.2.1.3 Consolidation tank 5 (1 no.)

After screening, sludge is pumped via a sub-surface pipework, to consolidation Tank 5 (Figure 10, 2,500 $m^3$ uncovered concrete tank) (referred to on site as 'console tank 5') where sludge is blended and mixed using air injection.

*Figure 10. Consolidation tank 5.*

#### *3.2.1.4 Indigenous SAS storage tanks (2 no.), thickening polymer tanks (3 no.) and SAS transfer tanks (2 no.).*

Liquid surplus activated sludge (SAS) is pumped directly from the co-located Esholt WwTW to two SAS storage tanks (Figure 11, 2 x 2000 m$^3$ uncovered concrete tanks). These tanks are air mixed and operate on a fill/draw basis over a 24-hour period.

*Figure 11. SAS storage tanks.*

Sludge from the SAS tanks is transferred to the drum thickener building, via above and below ground pipework. There are four individual drum thickeners (with separate pipes feeding them) located within the building, these are operated manually as and when the process requires.

Liquid polymer is delivered to site either by tanker (bulk delivery) or is delivered in 1 m$^3$ IBCs. The bulk tanker delivery point is located on the eastern side of the building. Bulk polymer deliveries are transferred into a 10 m$^3$ bunded GRP bulk storage tank located within the thickener building and from there are transferred to the 3 m$^3$ bunded GRP polymer prep tank. IBC deliveries directly feed the liquid polymer prep tank. Liquid polymer is diluted with potable water within the 3 m$^3$ bunded GRP polymer prep tank before being transferred to the adjacent 3 m$^3$ bunded GRP polymer make up tank. Both the make-up and prep tanks are located within a common bund. A spillage within any of the three polymer tanks would be manually removed from the bunds and disposed off outside of the installation site. From the make-up tank the polymer solution is injected into the sludge stream within the flocculation tank (one flocculation tank per pair of drum thickeners) with final treated effluent added as a ‘carrier’ before being transferred to thickener drums. The polymer encourages separation of water from the sludge as the sludge is rotated in the drum to remove excess liquid. The thickener liquors are returned via the liquor return supernatant pumping station (uncovered below ground sump) to Esholt WwTW for full treatment. The thickened sludge is passed forward to the SAS transfer tanks (see below for further detail).

The drum thickeners are equipped with automatic spray bars which provide continual self-cleaning. The automatic spray bars operate using treated final effluent. A manual jet wash is available for additional cleaning requirements; this system utilises potable water. A full drum cloth clean is also carried out periodically (approximately every 1-2 months, as required).

The thickened sludge is then transferred to the SAS transfer tanks (Figure 12, 2 x 400 m$^3$ uncovered concrete tanks). The thickened sludge tanks are mixed via pumps.

*Figure 12. SAS transfer tanks (side by side images).*

### 3.2.1.5 Mixed sludge tanks (2. No).

From the SAS transfer tanks the thickened SAS is then pumped to the mixed sludge tanks where it is mixed with indigenous primary and imported liquid sludges which are pumped from consolidation tank 5. There are two covered concrete mixed sludge tanks with a capacity of 1,200 and 1,130 m$^3$ respectively (Figure 13).

*Figure 13. Mixed sludge tanks.*

#### *3.2.1.6 Sludge dewatering: (polymer tanks 2 no.)*

From the mixed sludge tanks, sludge is transferred to three dewatering centrifuges. A polymer solution is introduced to the sludge stream to encourage separation of water and sludge within the centrifuges. This polymer is stored as a dry powder within a silo (15 tonne storage capacity) and is mixed with towns (potable) water within the polymer mixing tank (25 $m^3$ capacity) located adjacent to the centrifuges. The liquid centrate is transferred via the liquor pumping station and returned for full treatment within Esholt WwTW.

#### *3.2.1.7 Wetted imported sludge cake: (THP feed silos 2no. and THP feed hopper 1 no.)*

Imported sludge cake is tipped from an enclosed wagon to the dedicated sludge cake reception unit which is enclosed when tipping operations are not taking place. Sludge is moved from the sludge cake hopper and is rewetted with final treated effluent (to target ~21% dry solids) and pumped to the Thermal Hydrolysis Process (THP) feed silos (refer to description below for further detail of these process tanks and the THP itself). The sludge cake is rewetted to provide feedstock consistency and mobility. Transfer lines are trace heated and insulated to reduce the risk of freezing and pipe rupture.

Dewatered sludge is passed forward to the THP feed silos (2 no. 210 $m^3$ steel tanks, refer to Section 3.2.1.8 for further detail of this process) where it is combined with re-wetted imported sludge cake. It is rewetted to provide feedstock consistency and mobility. Feedstock from THP feed silos is then transferred to the THP feed hopper (16.2 $m^3$ steel tank).

#### *3.2.1.8 Thermal hydrolysis plant (THP)*

At Esholt STF, thermal hydrolysis technology is used prior to anaerobic digestion to enhance sludge treatment; the process acts to make the sludge more biodegradable, increasing biogas production within the digesters and assisting with pathogen kill in the final product. The THP at Esholt, as shown in Figure 14 and Figure 15, comprises 6 no. 22.7 $m^3$ reactor vessels, which operate in pairs. Each pair of reactors operates a batch process as follows: a reactor pair is filled with dewatered sludge and heated to around 165°C using steam generated by boilers. The reactors are held at this temperature for 30 mins and act like a pressure cooker to break down organic matter in the sludge making it more digestible for the microbes in the anaerobic digester. After 30 minutes the steam is flashed out to the next pair of reactors (as a pre-heat stage) and the reactor tanks are emptied. Activity within each pair of reactors is staggered with one pair being filled, one pair undergoing active reaction and the final pair being emptied at any one time.

*Figure 14. Thermal hydrolysis plant (THP).*

Steam is transferred from one pair of reactors to the next to supplement boiler steam supply and maximise operational efficiencies. The plant is equipped with safety features including pressure relief vents to allow emergency venting of steam and prevent damage to equipment.

The THP achieves 96% pathogen kill, in combination with the normal anaerobic digestion process, this eliminates the need for post-digester liming or cake storage and maturation prior to land spreading.

### *3.2.1.9 Sludge digestion: buffer tank (1 no.) and digesters (4 no.)*

Following THP, sludge is transferred to a steel buffer tank (Figure 15, 39.5 m$^3$) and from there is passed forward via digester feed lines to the digesters. Heat exchangers are located within the digester feed lines to reduce sludge temperature to the optimal temperature range for mesophilic anaerobic digestion activity (37-43 °C). Cooling water is discharged to the WwTW for treatment.

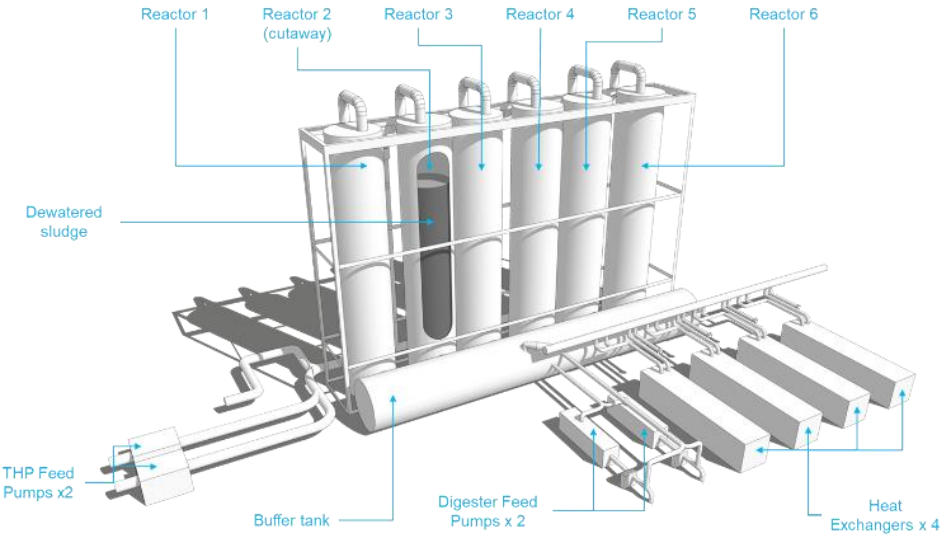



*Figure 15. Digester steel buffer tank within the THP.*

There are 4 no. aluminium-clad and insulated concrete digester tanks located on site, each with a capacity of 3,533 m$^3$ (Figure 16) The anaerobic digesters operate as a continuous process with sludge being continually fed into the base of the digester and treated sludge being displaced from the top. The digesters operate independently of each other and have a maximum feed rate of around 127.5 tonnes / day dry solids (at 10% dry solids) or 1,272 m$^3$ /day across the four digesters. Digester retention time is determined by the feed rate (which is dependent on other site operations such as the THP and sludge import activities) but is typically 10-11 days. The digesters are mixed by gas mixing systems, which utilise biogas from the headspace of each digester; the gas is compressed and then reintroduced using an array of mixing nozzles on the floor of the digester. The digesters do not require any supplementary heating due to the temperature of the sludge being passed forward from the THP.

Grit build up within digesters is a normal feature of operation, the digesters are cleaned out (including accumulated grit) every 10 years as part of the planned periodic inspection which also includes an internal and external inspection of tank integrity and replacement of instrumentation and gas mixing equipment as required. The planned hydrocyclone (to be added between the sludge import screens and Consolidation Tank 5) will help to reduce future grit build up, although internal cleaning will still be required.

An automatic anti-foam dosing system is in place to control digester foaming. This system uses a radar level probe in the digester headspace and compares this to the pressure level sensor at the bottom of the digester to determine the depth of foam. Upon detection of foam, final treated effluent is sprayed into the digester head space through nozzles in the digester roof. If this is not effective in breaking up the foam, a chemical anti-foam is mixed with final treated effluent and dosed into the headspace of the digester via the same spray nozzles. This system includes operator-adjustable dosing setpoints and failsafe systems; if the foam level continues to increase mixing systems are inhibited and if this continues the digester feed will be inhibited. Antifoam is stored in an 1m$^3$ IBC located on a bunded spill pallet.

*Figure 16. Four digesters.*

### 3.2.1.10 Degassing tanks (2 no.)

Sludge extracted from the digesters is fed to the degassing tanks (2 no. 685 m$^3$ GRP coated concrete tanks) prior to onward processing. These tanks are equipped with air mixing to introduce oxygen and prevent the anaerobic generation of methane. The tanks are covered, and headspace air is extracted and discharged via an odour dispersal unit with a stack approximately 5 m high.


Figure 17. Degassing tanks.

### 3.2.2 Bulk storage vessels (dewatering area)

A detailed discussion of risk sources and existing control and mitigation measures associated with the dewatering area (DW area) is provided below.

### 3.2.2.1 Digested sludge treatment, handling and disposal:

Digested sludge is pumped from the degassing tanks located adjacent to the anaerobic digesters to the digested sludge dewatering facility via a combination of above and below ground pipes, including a short section crossing the River Aire. The pipe crosses the river alongside the STF access roadway and is located at road level, on the far side and downstream of the road bridge barrier. The height above the river and roadside barrier provides protection for the pipe in the event of serious flooding which may bring large debris down river.

### 3.2.2.2 Export dewatering feed tanks (2 no.) and cake export barn

There are two separate sets of facilities for digested sludge dewatering. The first of these, which is used preferentially, is known as the sludge export facility. Sludge is transferred from the degassing tanks to two export dewatering feed tanks (Figure 18), each of which is of steel construction and 1,604 m$^3$ capacity. These tanks are not covered and have air mixing systems to prevent settlement and inhibit generation of methane. Powdered polymer stored within a 25 m$^3$ storage silo, or liquid polymer stored in IBCs located within a GRP kiosk, is mixed with potable water within a polymer mixing tank. The polymer solution is injected into the sludge stream and taken to one of two export centrifuges where the sludge coagulates and supernatant liquor is removed by centrifugal forces. Dewatered liquor drops from the centrifuges into the export centrate sump and is pumped back to the WwTW for treatment.

The final digested and dewatered sludge cake is transferred via conveyers from the centrifuges up over a push-wall and into the covered sludge cake export barn (Figure 19). The whole area under the conveyer and sludge cake barn is an engineered impermeable surface, with water runoff draining to the WwTW for treatment.

*Figure 18. Export dewatering feed tanks.*

*Figure 19. Export cake barn.*

#### *3.2.2.3 Conditioning feed tanks (2 no.)*

In addition to the export dewatering facility there is a second dewatering area, which provides additional capacity for digested sludge treatment and handling. This takes place in what is known as the conditioning area. When the THP/digestion plant are running at full capacity, sludge would typically be diverted to this second dewatering facility for approximately 5-10 minutes in each hour. During these periods, sludge is transferred from the degassing tanks to two conditioning feed tanks, each of which is of concrete construction and have a capacity of 1,200 and 1,130 $m^3$ (Figure 20). These tanks are not covered and have air mixing both to prevent settlement and inhibit generation of methane. Powdered polymer stored in 750kg bags are suspended over a hopper dosing system which feeds a make-up tank where the powdered polymer is mixed with potable water and transferred to an ageing tank and finally a storage tank. The polymer solution is injected into the sludge stream and taken to one of three centrifuges where the sludge coagulates, and supernatant liquor is removed by centrifugal forces.

*Figure 20. Conditioning feed tanks.*

#### *3.2.2.4 Centrate balance tanks (2 no.) and cake pad.*

Dewatered liquor drops from the centrifuges into the centrate sump and is pumped back to WwTW, via centrate balance tanks, for treatment (Figure 21, capacity of 400 and 600 $m^3$).

*Figure 21. Centrate balance tanks.*

The final digested and dewatered sludge cake is transferred via conveyers on to the cake pad (Figure 22). The area under the conveyer and cake pad is an engineered impermeable surface, with water runoff draining the head of the works for treatment. The digested sludge cake produced by this facility does not require liming or storage to ensure adequate pathogen kill and is suitable for immediate despatch from site to be land spread for agricultural benefit. The THP stage increases destruction of volatile sludge components within the digester, meaning that the final sludge cake has reduced odour generation potential.

The conditioning cake pad also serves certain contingency functions, both for operations at Esholt and for the wider strategic regional sludge treatment infrastructure operated by YW. The cake pad may on a temporary basis be used for interim storage of digested sludge cake produced at other YW sites, in circumstances such as the failure of assets or non-availability of normal disposal routes. It may also be used for interim storage of raw undigested sludge cake from Esholt or from other YW sites before being treated at Esholt STF, treated at another YW STF or sent off site to an alternative treatment/disposal route (subject to all applicable regulatory constraints).

*Figure 22. Conditioning cake pad.*

### 3.2.3 Tank volumes

Tank volumes are summarised in Table 1 below.

*Table 1. STF tanks at Esholt STF and associated capacities and construction.*

| Tank | Area | Size m$^3$ (each tank) | Constructed | Construction |
|---|---|---|---|---|
| 1 no. sludge screen feed tank | AD | 655 | 2013 | Concrete |
| 1 no. consolidation tank 5 | AD | 2,500 ([a]1,250) | 2007 | Concrete (partially subsurface) |
| 2 no. mixed sludge tanks | AD | 1,200 / 1,130 | 2013 | GRP coated steel |

| Tank | Area | Size m$^3$ (each tank) | Constructed | Construction |
|---|---|---|---|---|
| 2 no. SAS storage tanks | AD | 400 | 2007 | Concrete |
| 1 no. thickening polymer storage tank | AD | 10 | 2007 | GRP |
| 1 no. thickening polymer make up tank | AD | 3 | 2007 | GRP |
| 1 no. thickening polymer prep tank | AD | 3 | 2007 | GRP |
| 2 no. SAS transfer tanks | AD | 2,000 | 2007 | Concrete |
| 1 no. pre-THP centrifuges polymer make up tank | AD | 25 | 2013 | GRP |
| 2 no. post-THP centrifuges polymer make-up tank (a and b) | AD | 16 / 1 | 2013 | GRP |
| 2 no. THP feed silos | AD | 210 | 2013 | Steel |
| 1 no. THP feed hopper | AD | 16 | 2013 | Steel |
| 6 no. THP reactor vessels | AD | 23 | 2013 | Stainless steel |
| 1 no. digestate buffer tank | AD | 40 | 2013 | Steel |
| 4 no. digesters | AD | 3,533 | 2008-2013 | Concrete with aluminium cladding and insulation |
| 2 no. degassing tanks | AD | 685 | 2007 | Concrete |
| 2 no. export dewatering tanks | DW | 1,604 | 2013 | GRP coated steel |
| 2 no. conditioning feed tanks | DW | 1,200 / 1,130 | 1998-2006 | Concrete |
| 2 no. centrate balance tanks | DW | 400 / 600 | 2014 | Concrete/GRP steel |

[a] volume of sludge stored above ground for subsurface installations.

### *3.2.4 Engineering and maintenance standards*

YW maintain in-house standards which define the types of assets that meet the requirements of their business, how they should be built and then maintained. In relation to Esholt this covers:

- Design and construction of all assets, including selection of appropriately qualified design and build contractors.
- Procedures for inspection and testing of storage vessels, including internal and external inspections, thickness assessment and non-destructive testing.
- Regular inspections of above ground assets and associated pipework at defined intervals.
- Documented log of any actions arising as a result of these inspections.

YW's asset standards have been developed over many years and where relevant require compliance with Civil Engineering Specification for the Water Industry (CESWI) Seventh Edition March 2011 and the Water Industry Mechanical and Electrical Specifications (WIMES 9.02).

Contractors involved in the design/build of the Esholt scheme were YW framework contractors, appointed following a rigorous EU tender process; this process involved an assessment of past experience, technical competency, design capability and quality procedures.

The combination of all these measures significantly reduces the risk of a catastrophic tank failure, thus reducing the likelihood of secondary containment being required. Nonetheless, it is recognised that the risk of a catastrophic tank failure cannot be eliminated, and external factors could always arise leading to very low likelihood, high consequence events (such as missile generation arising from other plant failure, domino effects or *force majeure*, for example an aircraft impact or terrorist attack).

### 3.3 Existing site surfaces

Most of the active process areas within the installation are covered by buildings and hardstanding, with some peripheral areas of soft landscaping (grass and gravel cover). Surfacing was generally observed to be in good condition across the site with no significant evidence of cracks or erosion. Site surfacing for the AD and DW area is illustrated in Figure 23 and Figure 24 respectively.

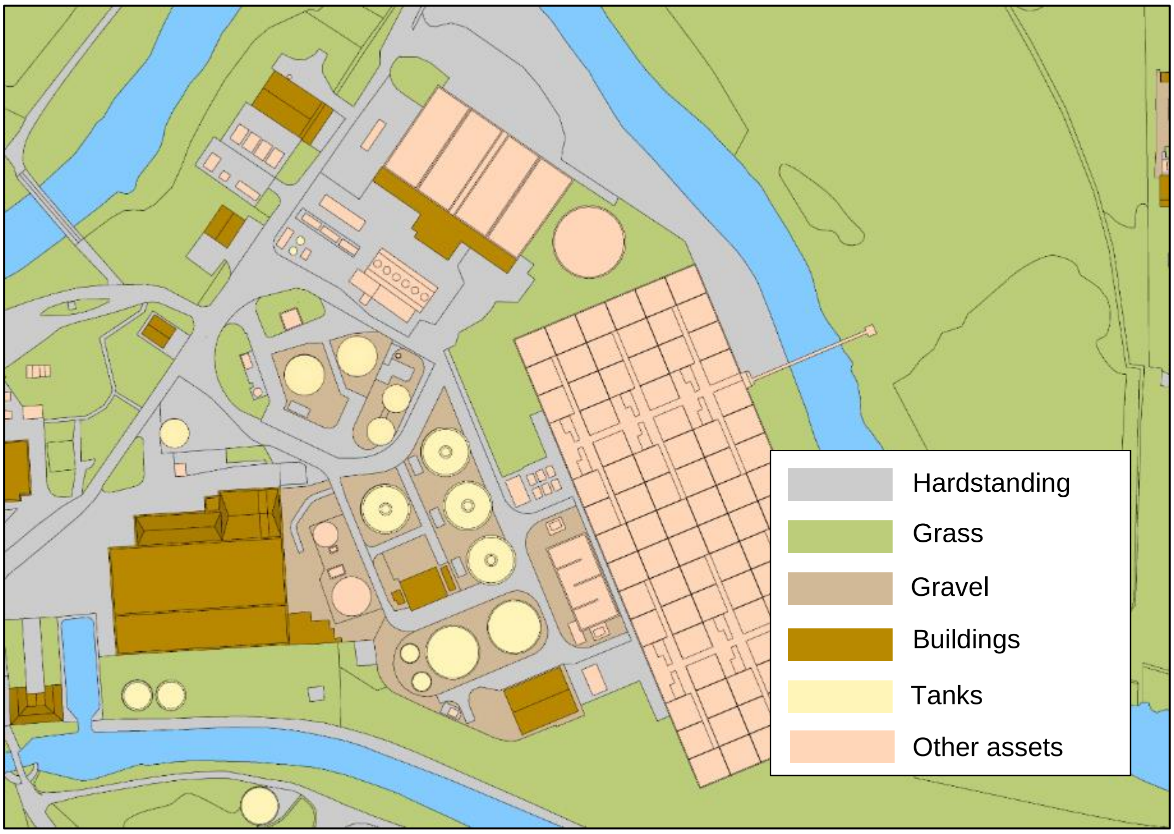



*Figure 23. Esholt AD area site surfaces.*

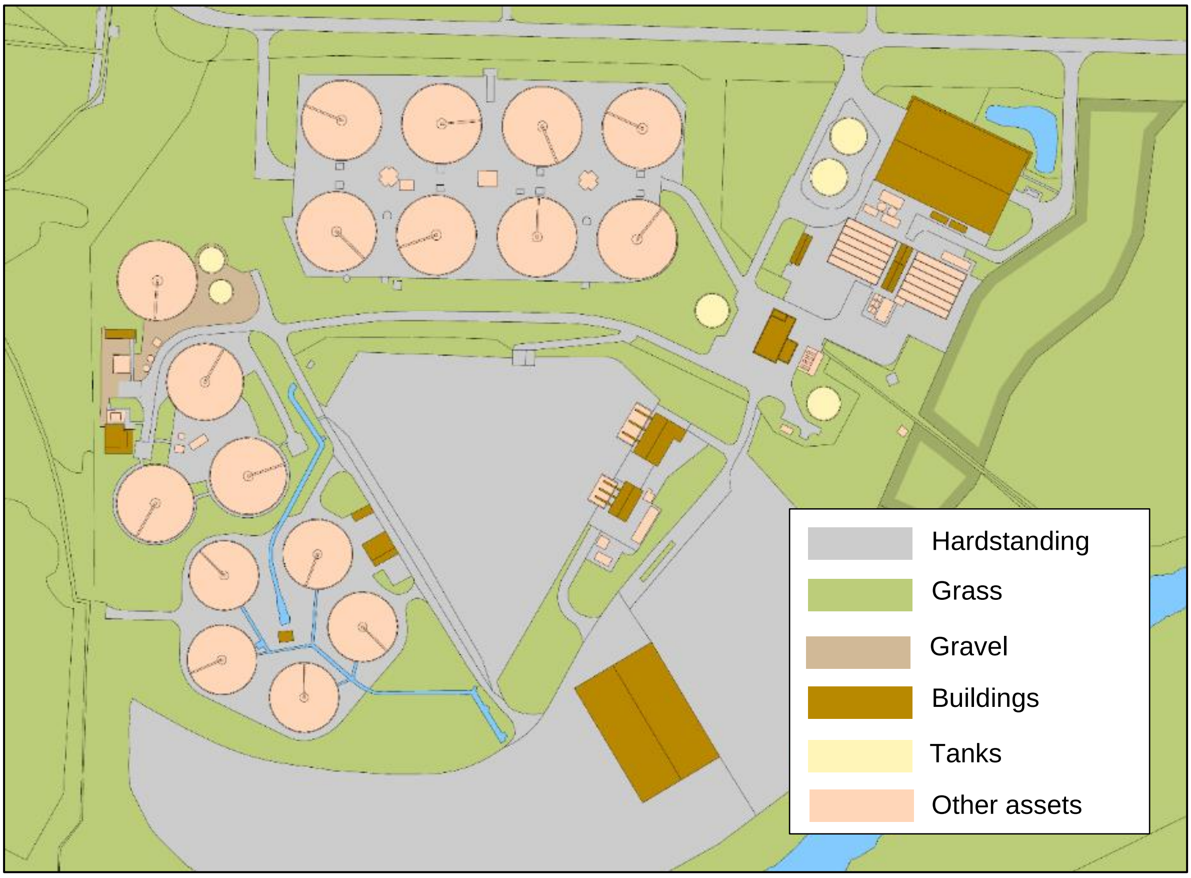



*Figure 24. Esholt DW area site surfaces.*

## 3.4 Pathways

Pathways are the routes by which pollutants could potentially travel from a source to the point where they could cause damage, the receptor. The potential pathways in this assessment were determined using computation flow modelling using defined source spillage volumes. The modelling approach, limitations and spill volumes are outlined in the following sections, allowing the principal pathways to be identified.

### *3.4.1 Spill modelling*

To model the potential impact of spills to the environment from the various sludge treatment assets at Esholt STF and defined credible pathways, YW has used PondSIM, a computational overland flow modelling tool. PondSIM can represent the flow of a liquid spill across an area of ground, taking account of local topography and flow restrictions (such as barriers). Applying this to the Esholt site has allowed visualisation of the likely effects of a spill occurring within each of the key areas of the permitted installation.

#### *3.4.1.1 Modelling limitations and uncertainties*

As with any computational modelling tool, there are a number of assumptions required and associated modelling limitations and uncertainties:

- PondSIM is designed to model the overland flow of water; as such it is not able to account for the typically higher viscosities associated with sludge, which results in a larger modelled inundation extent than would be expected in reality.

- The model cannot allow for flow to drains and other subsurface features.
- Surge is not accounted for within the model. Instead, this will be allowed for by ensuring final designs consider CIRIA C736 recommendations, while recognising the loss of kinetic energy as viscous sludge travels over flat ground.
- The model assumes that no mitigation measures are put in place following an incident to curtail flow.
- The model assumes that the full modelled volume spills from a single point.
- Assets are treated as simple flow barriers in the model, which may result in deflections being observed where in reality flow would spread out.

Therefore, the modelled outputs are considered to be a worst-case inundation scenario resulting from sludge spills at Esholt. Notwithstanding these limitations, the use of PondSIM is considered appropriate for the purpose intended in this study and allows for the rapid screening and assessment of asset risks to support prioritisation of risk mitigation.

To counter these limitations, several worst-case assumptions were selected relating to the potential failure events, including spill volumes.

### *3.4.2 Spill volumes*

YW has followed CIRIA C736 guidance on spill volumes to be modelled i.e., values equivalent to the containment provided by bunded tanks have been used. For a single tank the volume should be calculated on the basis of 110 per cent of the capacity of that tank. For multi-tank installations, the containment volume should be calculated on the basis of 25 per cent of the total capacity of all the tanks in a common area (which is based on the assumption that it is unlikely that more than 25 per cent of tanks will fail simultaneously), or 110 per cent of the largest tank, whichever is greatest.

The Esholt sludge treatment processes are installed over a large geographical area. The topography of this area means site spills need to be considered using a number of scenarios and catchment locations, listed in Table 2 and described below:

- AD Area
  - The AD area would require containment sufficient to hold 25 per cent of the total stored volume to achieve equivalent protection to a transitional multi-tank installation. Consolidation tank 5 has been included in this scenario due to its continuous use within the treatment process, additionally a large proportion is contained underground, therefore only the above ground volume of this tank has been modelled.
- DW area - will be modelled using multi-spill containment catchment areas as per Figure 25.
  - DW area 1 – the south conditioning feed tank containment will need to hold 110 percent of tank volume.
  - DW area 2 – the export dewatering tanks are hydraulically linked and containment will need to hold 110 percent of combined volume.
  - DW area 3 – the centrate balance tanks are hydraulically linked and containment will need to hold 110 percent of combined volume.
  - DW area 4 – the north conditioning tank containment will need to hold 110 percent of tank volume.

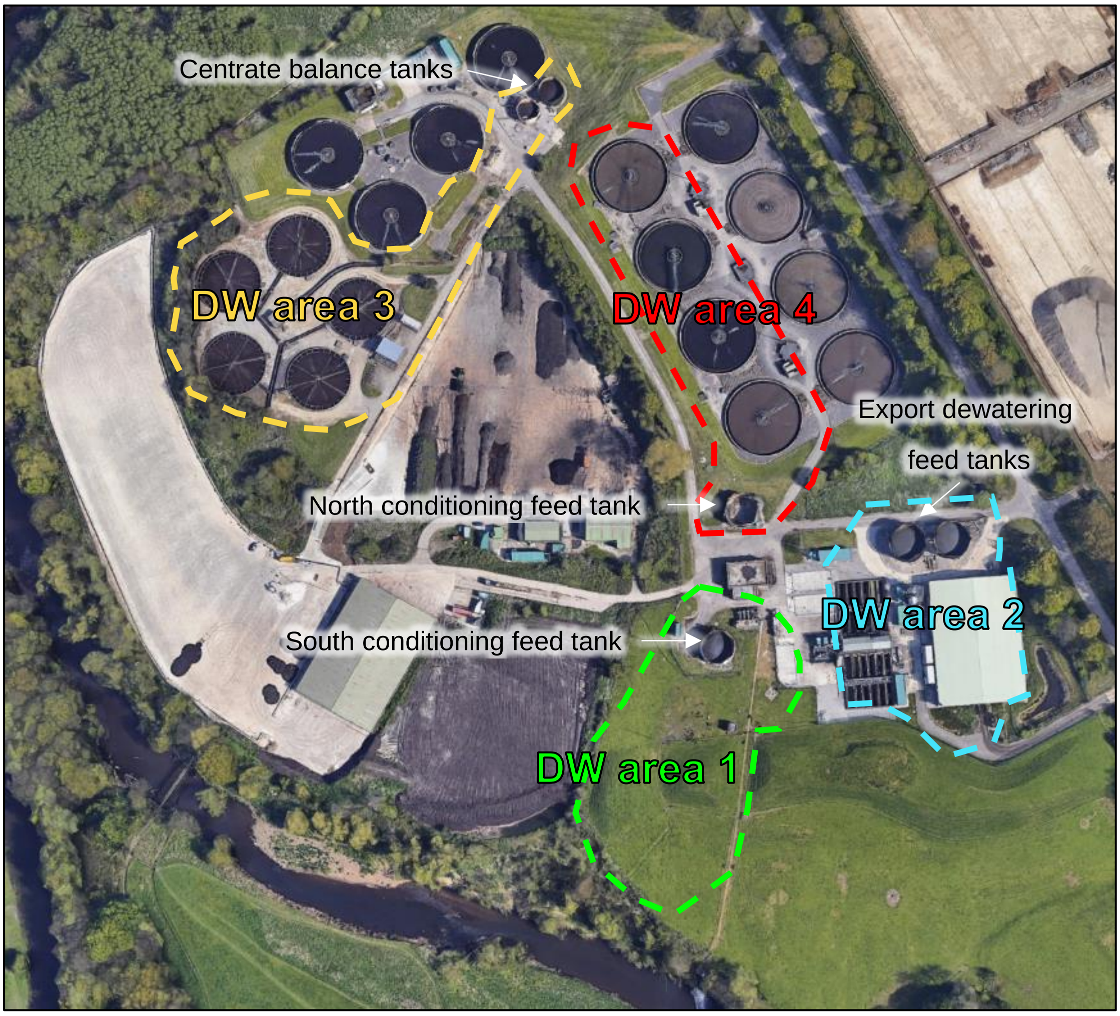



*Figure 25. DW area 1, 2, 3 and 4 spill containment catchments used in the spill model.*

*Table 2. Volume of material used in spill modelling scenarios.*

| Scenario | Capacity calculation | Material containment volume ($m^3$) | Modelling reference |
|---|---|---|---|
| AD area | 25% total capacity of tanks in 'AD area'. | 6,195 | Figure 26 |
| DW area | 110% total capacity of south conditioning feed tank in 'DW area 1' | 1,243 | Figure 27 |
| | 110% total capacity of export dewatering feed tanks in 'DW area 2' | 3,529 | |
| | 110% total capacity of centrate balance tanks in 'DW area 3' | 1,100 | |
| | 110% total capacity of north conditioning tank in 'DW area 4' | 1,320 | |

## 3.5 PondSIM modelling of unmitigated pathways

This section presents the modelling outlining the potential unmitigated flow routes from the identified source, via surface pathways as calculated by PondSIM to the identified receptors.

This first stage of the modelling assessment considered the effect of a simultaneous loss of containment at both AD and DW areas.

It is important to note that owing to the limitations described in 3.4.1.1, and the specific topography of the site, it is not felt that PondSIM outputs at Esholt are representative of the likely impact of a tank collapse. The detail of this is discussed in following sections, but common themes are:

- PondSIM models fluids as having very low viscosity. This leads to fluids travelling significant distances. In practice, pooling is likely to occur i.e., large spread in a small area, rather than long ‘streams’ covering significant distances.
- The aerial survey used to support the modelling is imperfect. At Esholt there are several small surface features which would be likely to retain sludge, that were not captured in the aerial survey. See photos in the following section for additional detail.
- PondSIM cannot model capture of liquid within site drainage system. In practice, the modelled flows travel over some areas of ground that has contained drainage which will capture a proportion of spilt material.

*Figure 26. AD area: model showing unmitigated result of spills from existing tanks.*


*Figure 27. DW area: model showing unmitigated result of spills from existing tanks in DW area's 1 to 4.*

### 3.6 Spill pathways

Figure 28 illustrates the potential pooling of sludge from the AD area in the central access section of hardstanding surface south of the THP plant which is met by grassy permeable surface west of consolidation tank 5. This section is a legacy discharge channel and has been dammed by two earth bunds directly adjacent to Consolidation Tank 5, however the potential spill over topples this and creates a direct pathway to the River Aire.

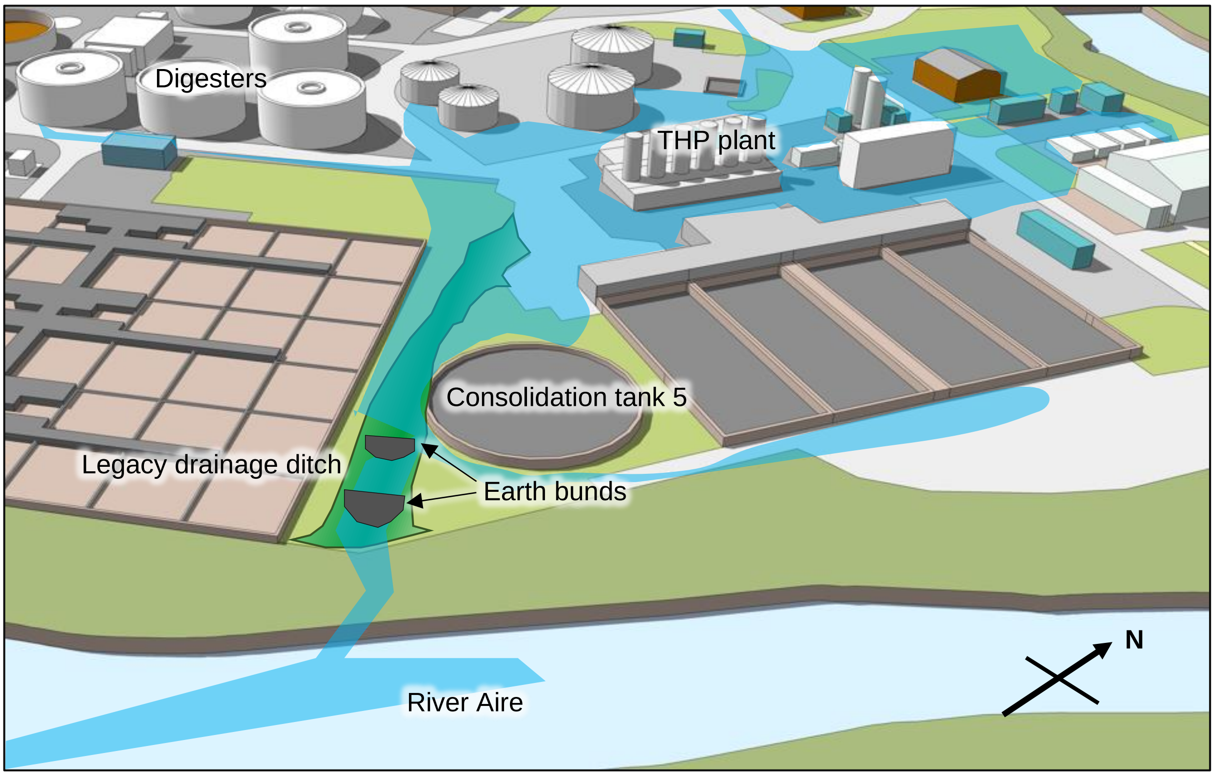



*Figure 28. Central access section of the AD area.*

Tanks within DW area 2 shows the potential for sludge spills from the export dewatering tanks to pool on the hardstanding surfaces directly adjacent to the tank, and alongside the west side of the cake barn leading up to the small sections of grassy areas as shown in Figure 29.

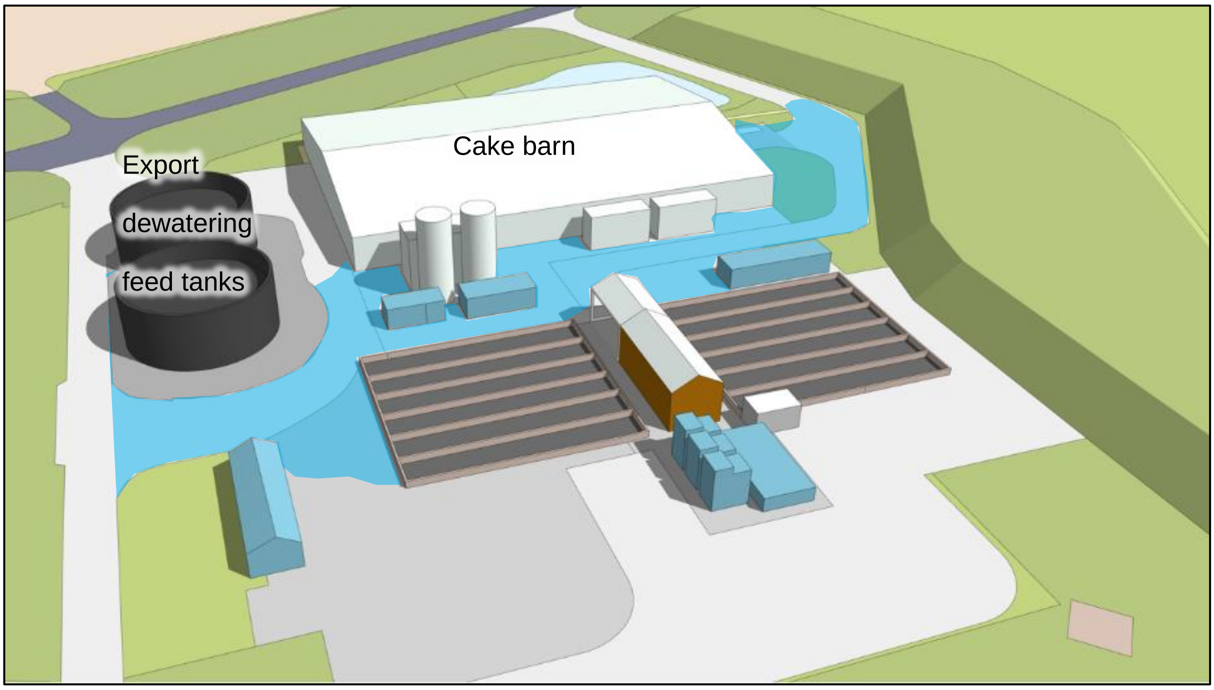



*Figure 29. Hardstanding areas surrounding and alongside the export dewatering tanks and cake barn in the DW area (east).*

Spill modelling shown for DW area 4, namely from the north conditioning feed tank has the potential to inundate half the surface area surrounding the final settlement tanks (FSTs), as shown in Figure 30. Due to the limitation of the LIDAR data, the FST lip height was not accurately represented in the modelling result. As shown in Figure 31, the FSTs themselves have 1.1m high concrete walls around their perimeter, therefore sludge will not flow into the tanks.

There is no surface water drainage around the FSTs, any surface water will run-off from areas of hardstanding towards surrounding areas of gravel. A surge or spill emanating from this tank to this area will need to be mitigated to avoid sludge from contaminating permeable sections of land. A sludge surge will also have minimal impact to nearby assets (recirculation pump building) due to sufficient ground clearance via concrete lips and slopes, and entrances to the building utilise steel roller shutters strong enough to deflect sludge.

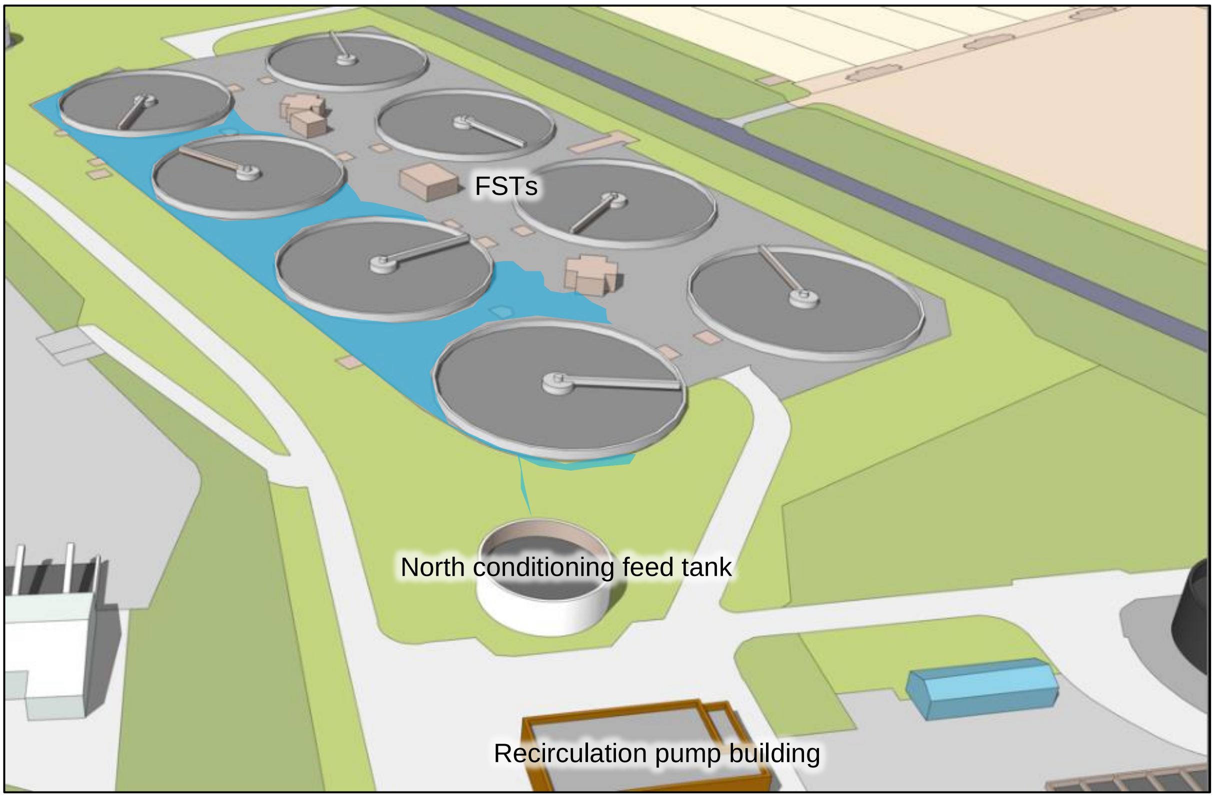



*Figure 30. FSTs located north to the north conditioning feed tank in the DW area (east)*

*Figure 31 - Photo showing height of FST walls. There is no realistic pathway for sludge to enter these.*

A direct pathway to the River Aire exists from the south conditioning feed tank, where sludge has the potential to pool and lead though the channels between the grass banks toward the river, as shown in Figure 32. Whilst a pathway to the river exists, the likelihood of the loss of containment via this route is low due to the vegetation cover and the permeable surface along the route. PondSIM cannot model porous surfaces and treats all ground surfaces as hardstanding.

Whilst surge from these tanks creates the potential for a pathway to nearby receptors, catastrophic failure is highly unlikely due to the construction of the tanks. The north conditioning tank is constructed with post-tensioned panels lined with in-situ poured concrete. The south conditioning feed tank, closest to the river, has double thickness poured concrete walls in its lower section, meaning even direct vehicle impact would be unlikely to rupture the tank walls. Surface water drainage in these areas is initially captured on hardstanding before passing to soakaways.

Although not shown in modelling, our review of the area around the south conditioning feed tank identified that in the highly unlikely event of catastrophic failure, a sludge surge has the potential to reach the final effluent chamber wet well as shown in Figure 33. Mitigation against this has been considered, including spill to permeable sections of land.

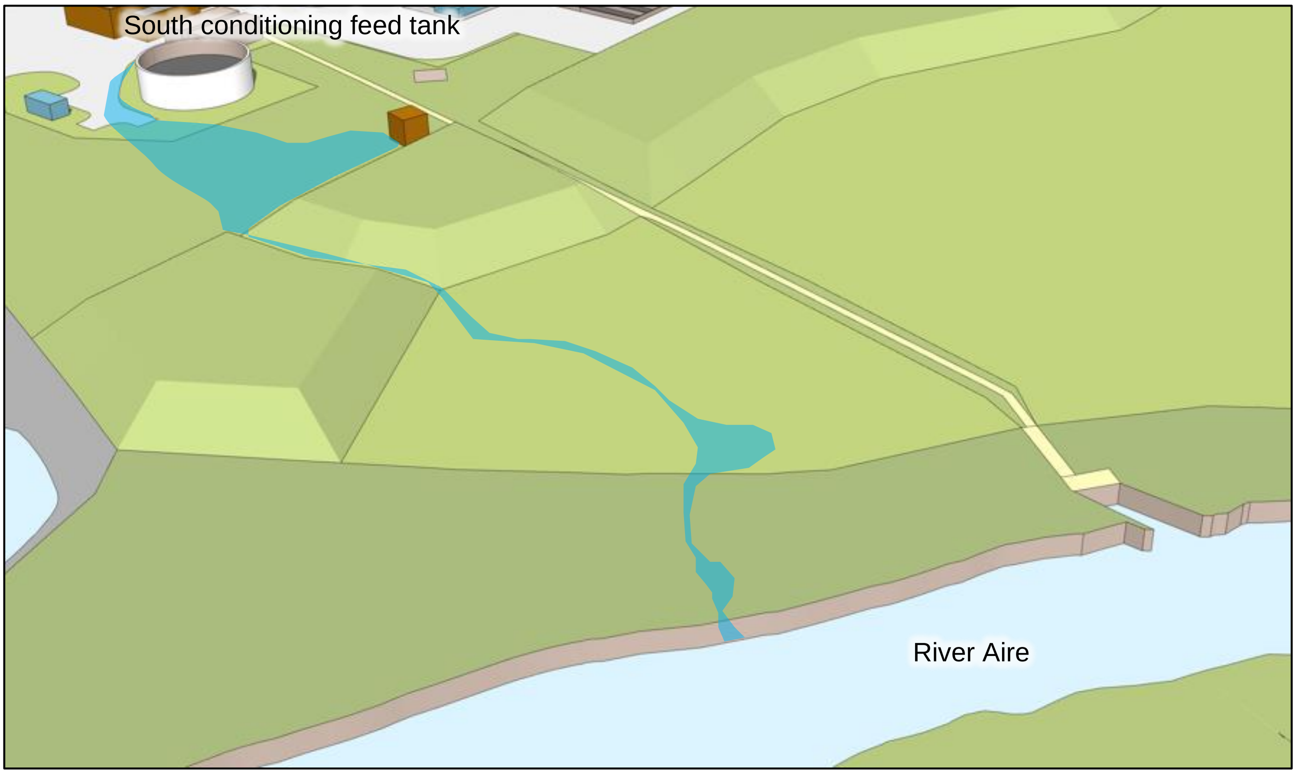



*Figure 32. Direct spill pathway to River Aire via the south conditioning feed tank in the DW area (east).*

*Figure 33. Final effluent chamber near the south conditioning feed tank in the DW area (west).*

An unmitigated spill from the centrate balance tanks is predicted to travel along the hardstanding road surfaces leading toward, and pooling within, the permeable surface surrounding the five humus settlement tanks treating trade effluent, as shown in Figure 34. There is potential in this scenario for the spill to enter the humus tanks feed channel along several sections of open decking, see Figure 35 for an example. Therefore, an indirect pathway to the River Aire exists.

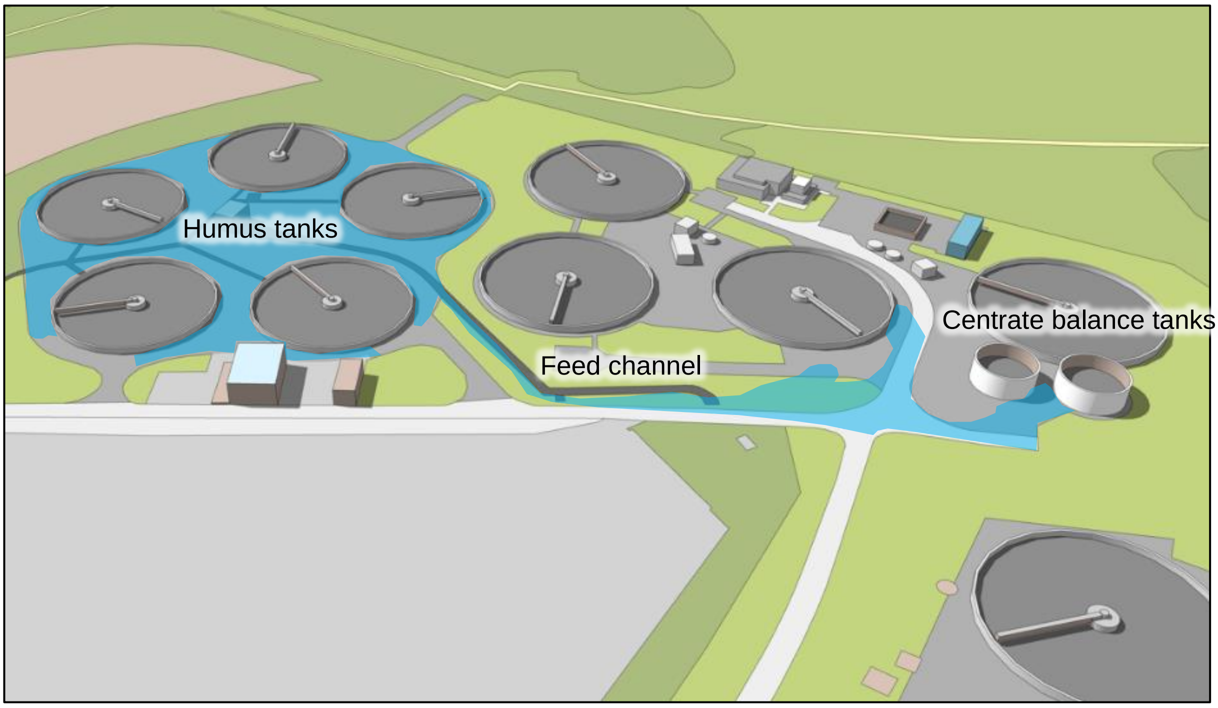



*Figure 34.Centrate balance tanks spill pathway to humus settlement tanks in the DW area (west).*

*Figure 35. Sections of open decking on the channel feeding the humus tanks in the DW area (west).*

### 3.6.1 Surface drainage

Surface water drainage routes at Esholt are shown in Figure 36 and Figure 37. Surface water drainage routes shown in red which are routed to the inlet of the WwTW i.e., contained. Routes shown in blue are for uncontaminated roof water, which is released to the environment without further treatment.

No requirements for rerouting of surface water drainage have been identified at Esholt. This issue will also be considered during detailed design of secondary containment to ensure that any new assets installed do not adversely affect existing drainage infrastructure.

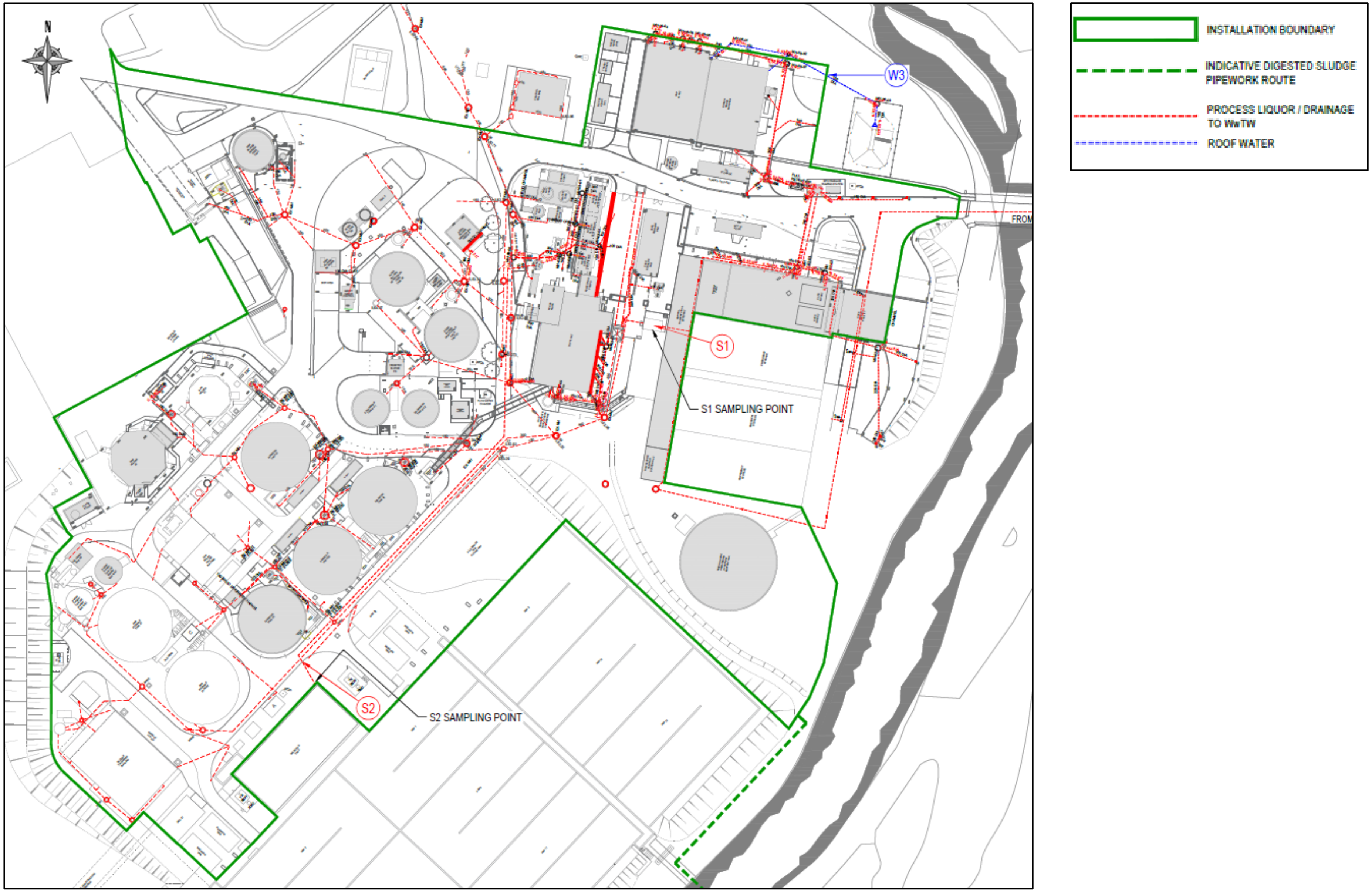



*Figure 36. Drainage in main AD area.*

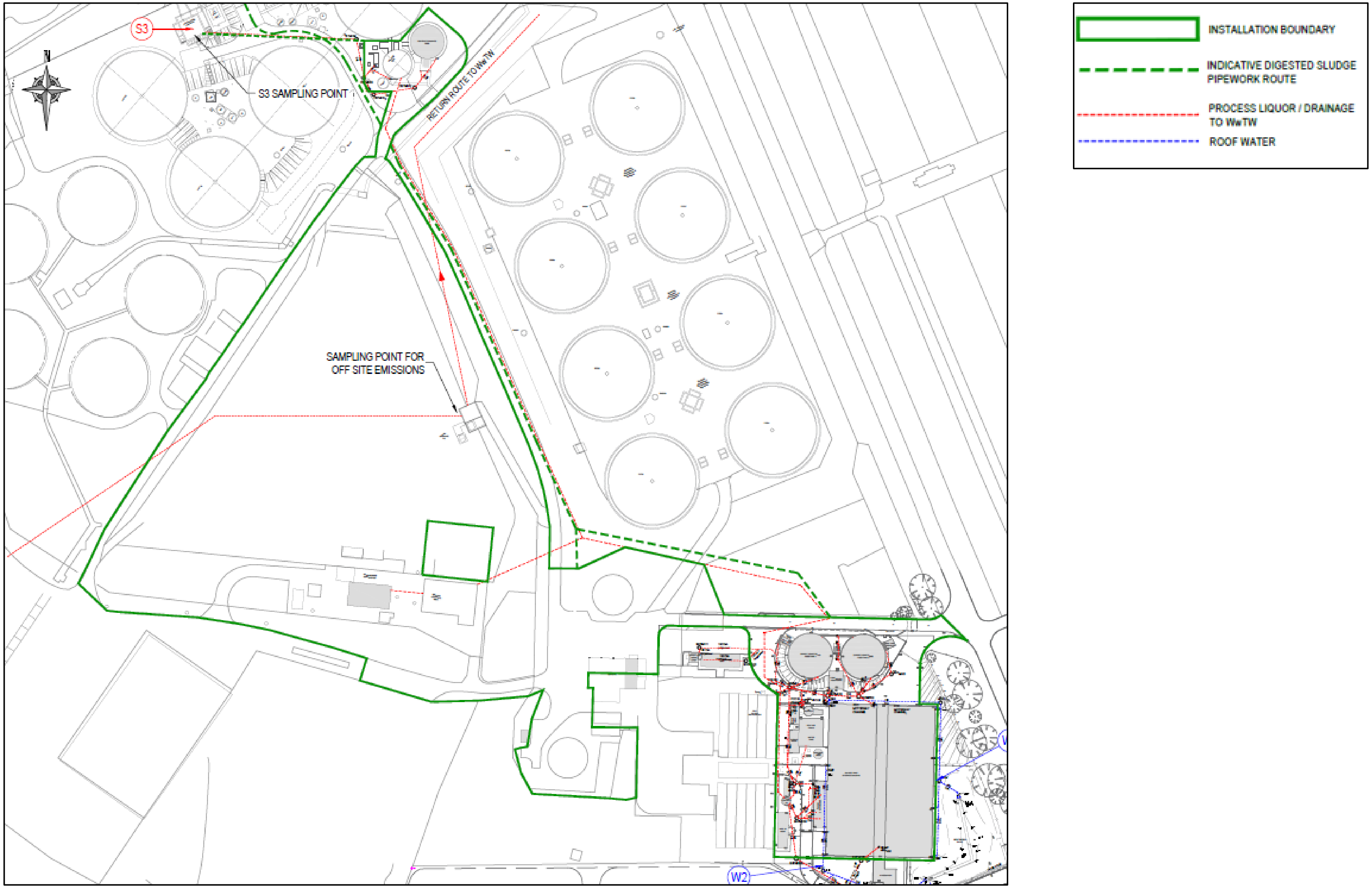



*Figure 37. Drainage in DW area.*

### *3.6.2 Spill pathway summary*

The table below lists the resulting pathways associated with tank failure at Esholt determined using the PondSIM model. Full model results are presented in Section 3.5.

*Table 3. Surface pathways from the key assets at Esholt.*

| Area | Tank / Tank Area | Surface Pathways | Comments |
|---|---|---|---|
| AD Area | Sludge screen feed tank (1 no.)<br>Consolidation tank 5 (1 no.)<br>Mixed sludge tanks (2 no.)<br>SAS storage tanks (2 no.)<br>Thickener polymer tanks (3 no.)<br>SAS transfer tanks (2 no.)<br>THP polymer tanks (3 no.)<br>THP feed silos (2 no.)<br>THP feed hopper (1 no.)<br>THP reactor vessels (6 no.)<br>Digestate buffer tank (1 no.)<br>Digesters (4 no.)<br>Degassing tanks (2 no.) | Overland run-off over mostly sealed surface to:<br>• North of the site surrounding the CHP plant and control building.<br>• East of the mixed sludge tanks surrounding the THP plant.<br>• North of the ASP unit and surrounding the westerly section of consolidation tank 5.<br>• Under limited circumstances, from SE side of consolidation 5 tank, over grassed area and into former drainage ditch. | Principal spill volume captured on existing site hardstanding area adjacent to THP plant.<br>Some spill pooling on permeable grassy section near ASP and consolidation tank 5.<br>Surface water drainage in this area is connected to the main WwTW.<br>Spill from the main AD area and consolidation tank 5 to drainage ditch over topples existing earth bunds, therefore a route to river exists. |
| DW Area | Export dewatering tanks (2 no.) | **DW Area 2**<br>Overland run-off to:<br>• Northwest, west and south area of the sludge cake storage barn. | Spill flows and is captured on a mix of existing site roads, hardstanding, and a small section of grassy area south of the barn in DW area 2.<br>Surface water drainage in these areas is connected to the main WwTW. |
| | Conditioning feed tanks (2 no.) | **DW Area 1**<br>South tank overland run-off to:<br>• South of the site through earth bank into River Aire. | South tank spill flows across permeable grassy area, between mound and into the River Aire in DW area 1. |
| | | **DW Area 4**<br>North tank overland run-off to:<br>• North of the site to areas around FSTs | North tank spill flows down grassy bank and surrounds the FSTs on areas of gravel and hardstanding surfaces in DW area 4. There is no surface drainage for the hardstanding sections around the FSTs, surface water will run off into the gravel. |
| | Centrate balance tanks (2 no.) | **DW Area 3**<br>Overland run-off to:<br>• South westerly leading to and surrounding trade effluent treatment assets. | Spill mostly flows across hardstanding and road surfaces and surrounds the humus tanks treating trade effluent in DW area 3.<br>There is no surface drainage for around the humus tanks, surface water will run off into the gravel. |

## 3.7 Receptors

To complete the source pathway receptor model, a review of sensitive receptors was conducted. These were identified based on judgement, modelling results and potential flow paths which may take any cardinal direction. Figure 38 shows the receptors identified which could theoretically be impacted by a loss of containment of process vessels at Esholt.

Table 4 lists the type of pathway potentially leading to each receptor e.g., indirect, such as via FSTs or permeable surfaces or direct to the environment, e.g., a flow path into the River Aire.

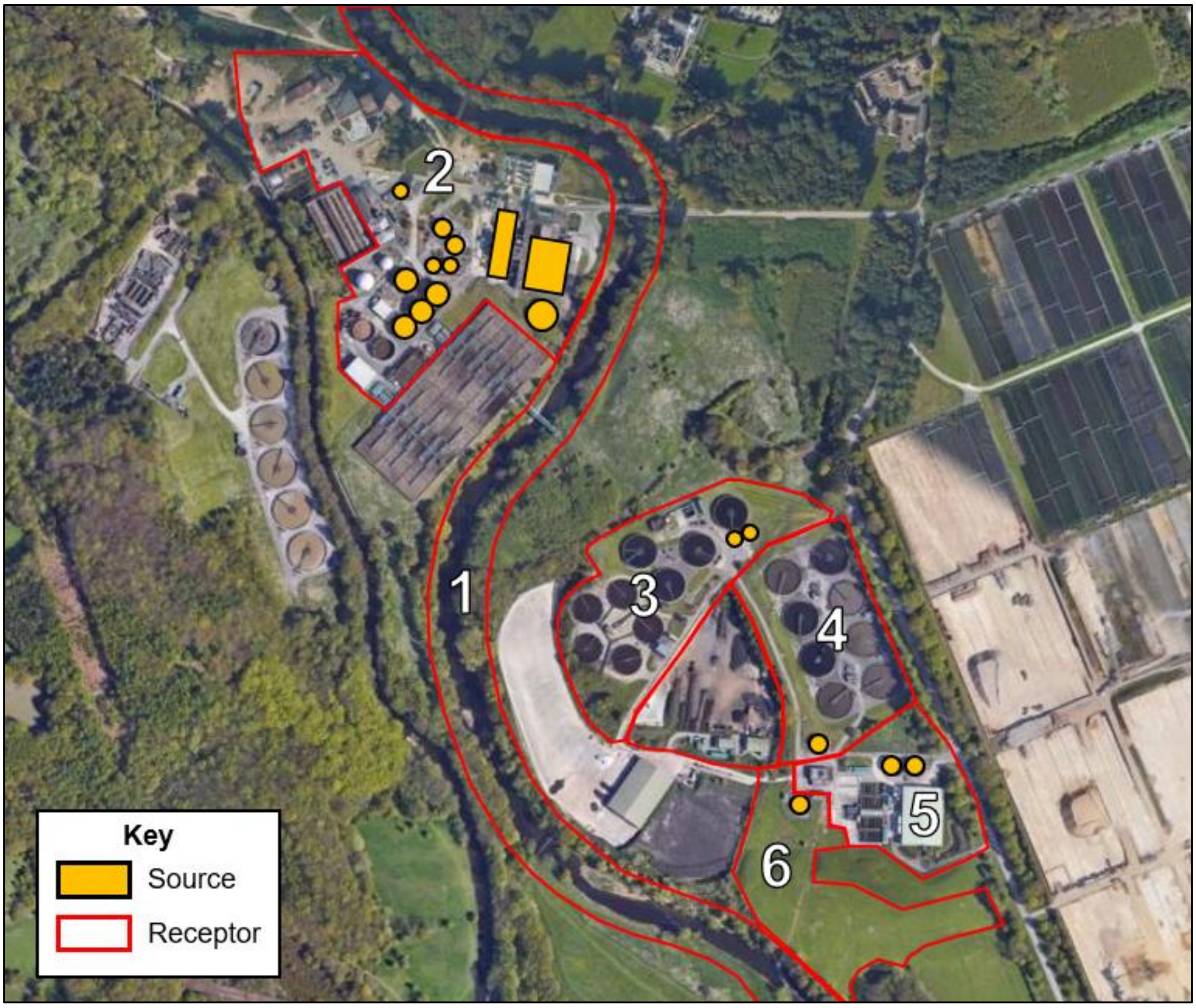



*Figure 38. Map of numbered receptors at Esholt. © Google, 2021*

*Table 4. Receptors*

| Receptor No. | Receptor |
|---|---|
| 1 | River Aire (including adjacent habitats). |
| 2 | Ground / groundwater – areas within the AD Area (sludge screening, pre-treatment, digestion area). |
| 3 | Ground / groundwater - area around liquor treatment assets and humus tanks (DW Area 3). |
| 4 | Ground / groundwater - areas around final settlement tanks (DW Area 4). |
| 5 | Ground / groundwater - areas around export dewatering tanks and sludge barn (DW Area 2). |
| 6 | Ground / groundwater - areas south of south conditioning tank (DW Area 1). |

## 3.8 Source-pathway-receptor summary

The outcome of the source pathway receptor identification is summarised in Table 5.

*Table 5. Source-pathway-receptor summary*

| Area | Tank / Tank Area | Pathways | Receptors at risk |
|---|---|---|---|
| AD area | Sludge screen feed tank (1 no.)<br>Consolidation tank 5 (1 no.)<br>Mixed sludge tanks (2 no.)<br>SAS storage tanks (2 no.)<br>Thickener polymer tanks (3 no.)<br>SAS transfer tanks (2 no.)<br>THP polymer tanks (3 no.)<br>THP feed silos (2 no.)<br>THP feed hopper (1 no.)<br>THP reactor vessels (6 no.)<br>Digestate buffer tank (1 no.)<br>Digesters (4 no.)<br>Degassing tanks (2 no.) | Overland run-off over mostly sealed surface to:<br>• North of the site surrounding the CHP plant and control building.<br>• East of the mixed sludge tanks surrounding the THP plant.<br>• North of the ASP unit and surrounding the westerly section of Consolidation tank 5.<br>• SE side of Consolidation 5 tank, over grassed area and over former drainage ditch into River Aire. | • Receptor 1 – River Aire (including adjacent habitats).<br>• Receptor 2 - Ground / groundwater areas within the AD Area (sludge screening, pre-treatment, digestion area). |
| DW area | Export dewatering tanks (2 no.) | **DW Area 2**<br>Overland run-off to:<br>• Northwest, west and south area of the sludge cake storage barn. | • Receptor 5 - Ground / groundwater - areas around export dewatering tanks and sludge barn (DW Area 2). |
| | Conditioning feed tanks (2 no.) | **DW Area 4**<br>North tank overland run-off to:<br>• North of the site to areas around FSTs | North tank:<br>• Receptor 4 - Ground / groundwater - areas around final settlement tanks in DW area 4.<br>• In the event of surge; Receptor 5 - Ground / groundwater - areas around export dewatering tanks and sludge barn (DW Area 2). |
| | | **DW Area 1**<br>South tank overland run-off to:<br>• South of the site through earth bank into River Aire. | South tank:<br>• In the event of surge; Receptor 5 - Ground / groundwater - areas around export dewatering tanks and sludge barn (DW Area 2).<br>• Receptor 6 - Ground / groundwater - areas south of south conditioning feed tank (DW Area 1).<br>• Receptor 1 - River Aire (including adjacent habitats). |
| | Centrate balance tanks (2 no.) | **DW Area 3**<br>Overland run-off to:<br>• South westerly leading to and surrounding trade effluent treatment assets. | • Receptor 3 - Ground / groundwater area around liquor treatment assets and humus tanks (DW Area 3).<br>• Receptor 1 - River Aire (including adjacent habitats). |

### 3.9 Mitigation solutions

An iterative process was completed to develop bunding options that provide environmental protection in accordance with CIRIA C736, including different methods for achieving impermeable surfaces within the bunded area. Determination of the preferred solution considered financial viability, sustainability to reduce impacts from embodied carbon and availability of materials to allow timely implementation given the timeframes of meeting compliance.

The solutions identified is illustrated in Figure 39, Figure 40 and Figure 42 with further specification and dimensions given in Appendix Table 1. This solution achieves CIRIA C736 compliance, including approaches for improving the sustainability of construction in the following ways:

- **Bund height:** calculated using the CIRIA 25/110 percent rule, divided by the area encompassing the bunded area not including the footprint of tanks, buildings, and other obstructions. Rainwater handling was also considered.
- **Surge allowance:** CIRIA C736 table 6.3 specifies the freeboard required to protect against surge. Recognising these recommendations, an allowance of 0.25m for walling and 0.75m for earth works has been added to the bund heights to protect against surge.
- **Drainage**: all surface drainage infrastructure will be assessed during the design phase to confirm sufficient capacity is available to deal with rainwater falling into the bund.
- **Walling**: in-situ or pre-cast products are considered to allow for installation where space is limited and considers pre-existing walling as part of the installation.
- **Permeable areas:** all permeable areas of land (as represented in 3.3 Existing site surfaces, and shown within Figure 39, Figure 40 and Figure 42 as red areas) will be made impermeable using solutions such as poured concrete and matting or bentonite clay matting.
- **Ramps & flood gates:** will be used as required to provide access into bunds. Ramps are the preferred solution, as they provide access without affecting the integrity of the bund. Floodgates may be installed where the need for access is very infrequent, and installation of a ramp is not practical. Where floodgates are required an appropriate management system will be implemented to ensure an appropriate level of environmental protection is maintained when they are in use.
- **Hardstanding areas:** existing areas of hardstanding that will form part of the containment solution (in-situ concrete, access roads) will be assessed to ensure that they provide a level of containment consistent with the requirements of CIRIA C736.

YW have committed to install these containment solutions that complies with CIRIA C736, as discussed in the next section. The current preferred designs are shown below but may be subject to minor modifications and amendments during detailed design phase.

The total containment volume required within the bund was calculated as per Table 6. Following the CIRIA requirement to contain the larger volume of 110% of the largest tank or 25% of all tanks, bund volumes of 6,199 $m^3$, 1,764 $m^3$ and 1,100 $m^3$ are necessary for sludge containment within the AD area, DW areas 1,2 and 4, and DW area 3 respectively. Additional volumes will be allowed for freeboard to handle surge (Appendix Table 1).

*Table 6. Containment volume calculations.*

| Tank | Area | Hydraulically linked to another tank? | Volume m³ (per tank) | Total volume m³ (group) | 110% size m³ |
|---|---|---|---|---|---|
| 1 sludge screen feed tank | AD | No | 655 | 655 | 721 |
| Console tank 5 | | No | 1,250 | 1,250 | 1,375 |
| 1 mixed sludge tank (1 of 2) | | No | 1,200 | 1,200 | 1,320 |
| 1 mixed sludge tank (2 of 2) | | No | 1,130 | 1,130 | 1,243 |
| 2 un-thickened SAS storage tanks | | No | 2,155 | 4,310 | 2,371 |
| 1 thickening polymer tanks (storage) | | No | 10 | 10 | 11 |
| 2 thickening polymer tanks (make-up + prep) | | Yes | 3 | 6 | 6.6 |
| 2 thickened SAS storage tanks | | No | 400 | 800 | 440 |
| 1 pre THP centrifuges polymer make-up tank | | No | 25 | 25 | 28 |
| 1 post THP centrifuges polymer make-up tank (stream a) | | No | 16 | 16 | 18 |
| 1 post THP centrifuges polymer make-up tank (stream b) | | No | 1 | 1 | 1 |
| 2 THP feed silo | | No | 210 | 420 | 231 |
| 1 THP feed hopper | | No | 16 | 16 | 18 |
| 6 THP reactor vessels | | No | 23 | 136 | 25 |
| 1 digestate buffer tank | | No | 40 | 40 | 43 |
| 4 digesters | | No | 3,353 | 13,412 | 3,688 |
| 2 de-gassing tanks | | No | 685 | 1,370 | 754 |
| | | | Largest 110% size | | 3,688 |
| | | | Total volume | 24,797 | |
| | | | 25% of total volume | 6,199 | |
| 2 export dewatering tanks | DW 1,2,4 | No | 1,604 | 3,208 | 1,764 |
| 1 conditioning tank (1 of 2) | | No | 1,200 | 1,200 | 1,320 |
| 1 conditioning tank (2 of 2) | | No | 1,130 | 1,130 | 1,243 |
| | | | Largest 110% size | | 1,764 |
| | | | Total volume | 5,538 | |
| | | | 25% of total volume | 1,385 | |
| Centrate balance tanks (1 of 2) | DW3 | Yes | 400 | 1,000 | 1,100 |
| Centrate balance tanks (2 of 2) | | | 600 | | |
| | | | Largest 110% size | | 1,100 |
| | | | Total volume | 1,000 | |
| | | | 25% of total volume | 250 | |

Figure 39 illustrates a wide bunding solution for the AD area, particularly due to the number of STF tanks in this area and requirements for operational access of vehicles. The natural bowl shape of the sites topography is utilised, and the proposed mitigation protects potential inundation of spill within main access routes, including the direct route to the River Aire.

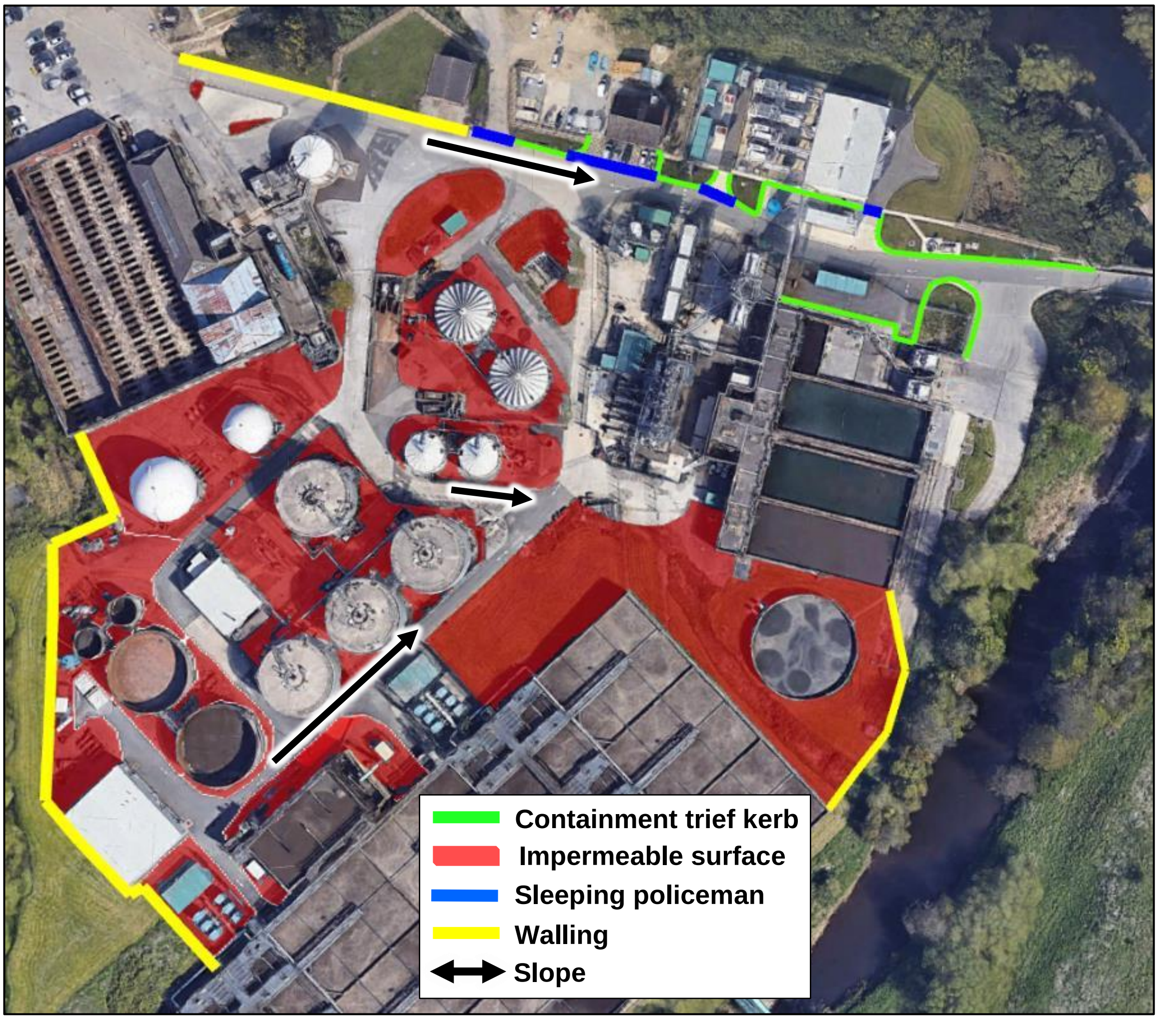



*Figure 39. Mitigation solution for Esholt AD area.*

Figure 40 illustrates a localised bunding solution for multiple tanks in the dewatering and cake barn area. Given the site topography the bunding boundary has been extended to utilise most of the flat surface available to avoid pooling against a section of bund wall where alleviation drops. Additionally, the cake barn has been utilised since it contains an engineered impermeable surface and using this approach increases the containment area sufficiently to reduce the wall height requirements and allow for sleeping policemen across the multiple access road entry points. The use of long ramps on access roads is not suitable in these areas as the turning circles for articulated lorries is tight and narrow. Furthermore, a sloping hardstanding access road is utilised as containment, this is evidenced in Figure 41, where the road shows a significant gradient with a retaining wall adjacent to the tanks.

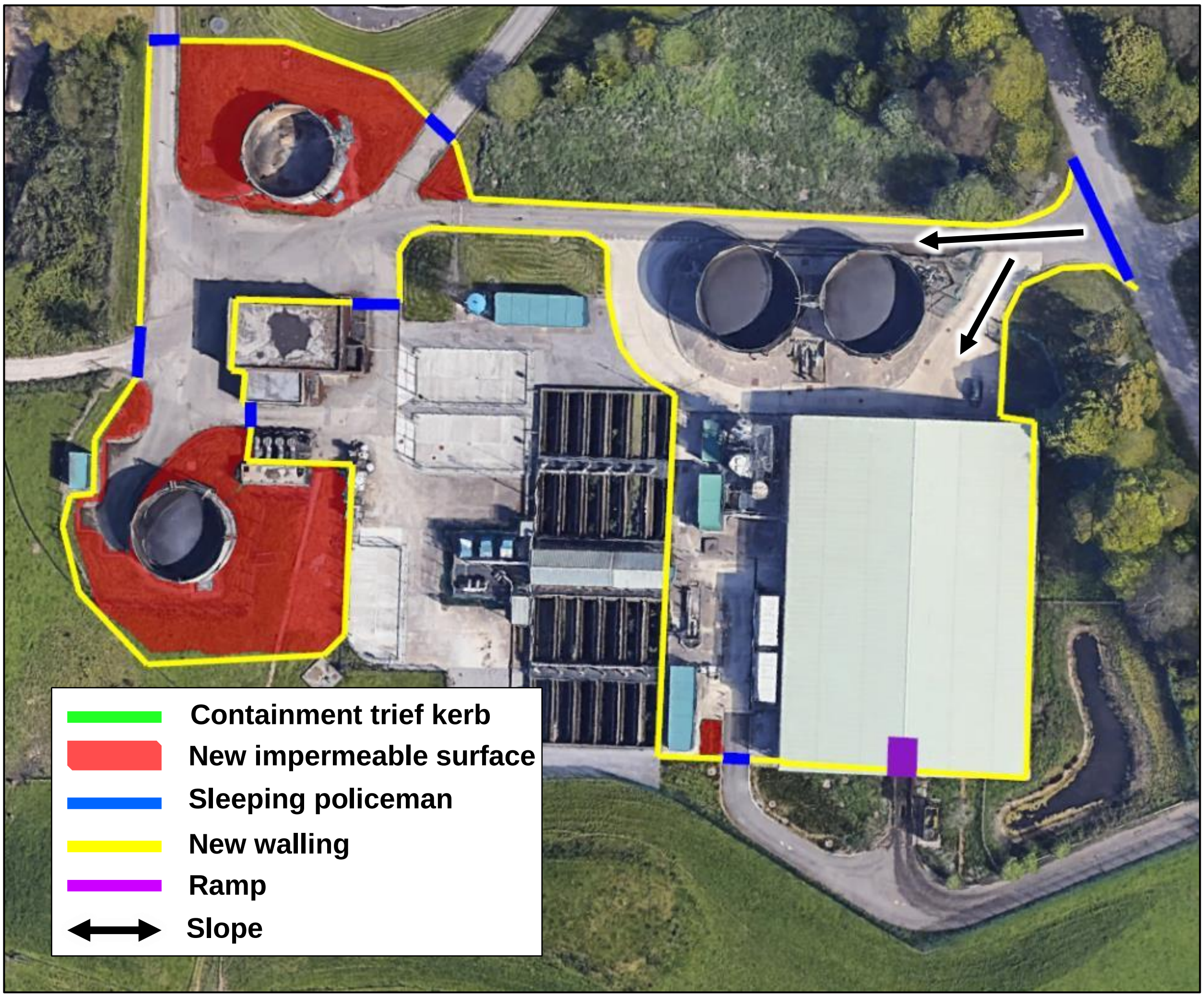



*Figure 40. Mitigation solution for Esholt DW areas 1,2 and 4.*

*Figure 41. Access road slope and retaining wall utilised within bunding solution.*

Finally, Figure 42, shows a mitigative solution for the centrate balance tanks (DW area 3). This solution is a localised bund wall with a sleeping policeman to maintain operational access. A localised bund was chosen as to keep a potential spill within the permit boundary.

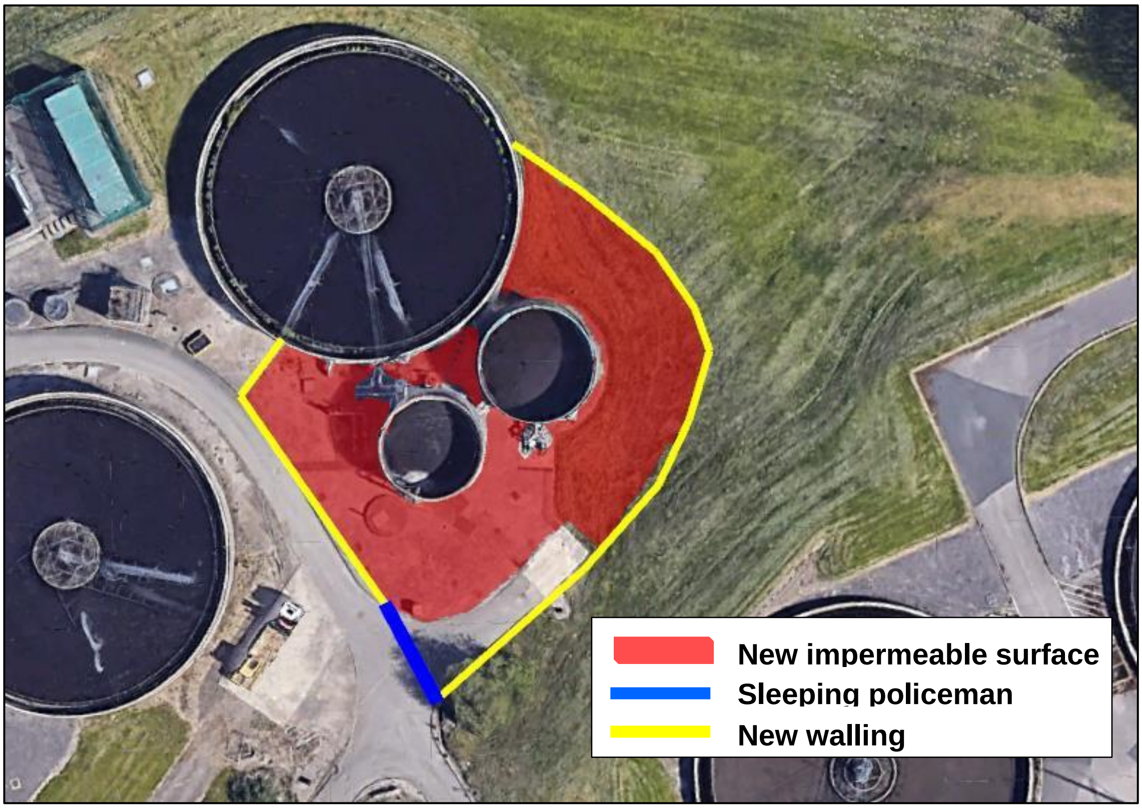



*Figure 42. Mitigation solution for Esholt DW area 3, centrate balance tanks.*

### *3.9.1 Surge*

The catastrophic collapse of a tank would lead to a rapid release of sludge which will then flow across the surrounding area. This is particularly true on steep gradients, which will encourage flow to travel further. As flow travels across flat ground, it will lose speed and the risk from surge will rapidly decrease.

Sludge released in this way will tend to flow over obstacles, but physics limits the height of barrier which it can pass. It is possible, but complex to calculate the extent of flow over obstacles using specialist software, but it would be prohibitively expensive to do this for every site where containment is being considered. The options considered within this document have been developed with surge protection as a key functional requirement and in the absence of detailed modelling, CIRIA C736 provides guidance on the additional height of bund wall (Figure 43), above settled spill level, that is required to ensure surge flow does not pass containment walls.

***Table 4.7 Surge allowance (in the absence of detailed analysis)***

| Type of structure (see Part 3) | Allowance |
|---|---|
| *In situ* reinforced concrete and blockwork bunds | 250 mm |
| Secondary containment tanks | 250 mm |
| Earthwork bunds | 750 mm |

*Figure 43. Surge protection requirements. Taken from CIRIA C736 pg. 54.*

Esholt is a large site, with significant distances between assets. The gradient of the site is relatively flat which means sludge has a reduced potential to travel a significant distance, furthermore the velocity of the flow is expected to decrease rapidly because of its rheology, ground conditions and surface drainage features.

A surge flow from south conditioning feed tank has been identified a potential for surge of sludge to flow over existing kerbing and enter a wet well containing final effluent, providing a pathway to the River Air. Figure 44 shows a mitigative solution in the form of legator concrete blocks that focuses on deflecting and redirecting any surge flows which travel in a northerly direction from the south conditioning feed tank towards the wet well and onto areas of hardstanding from where a full clean up can take place.

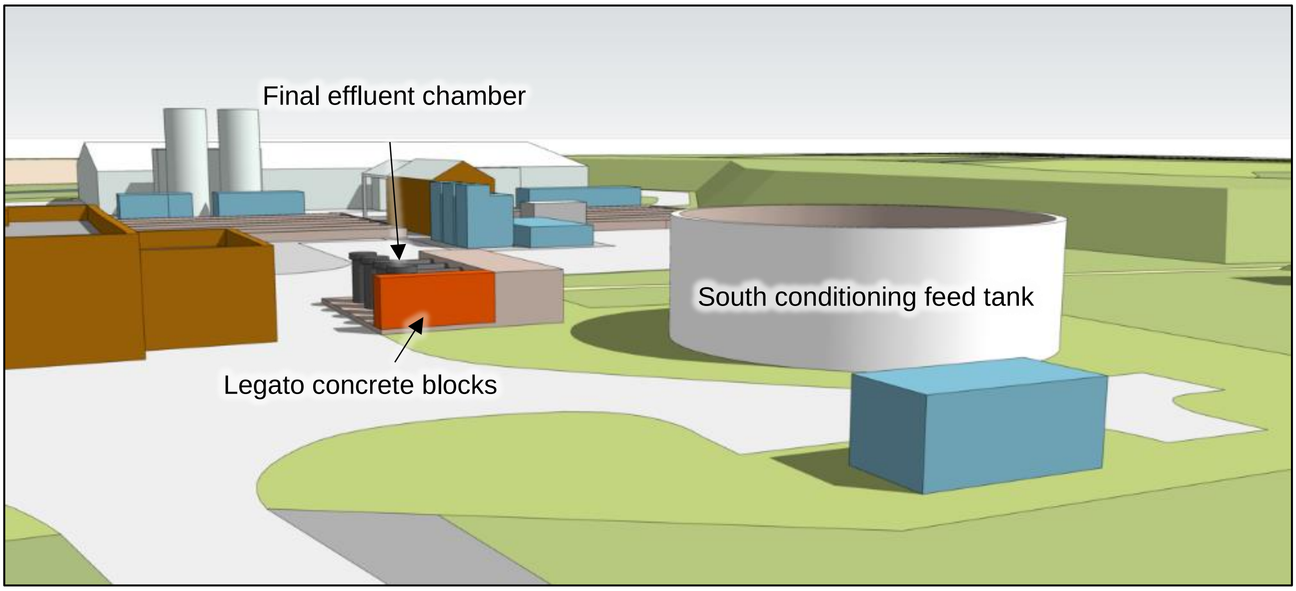



*Figure 44. South conditioning feed tank surge containment concrete wall solution.*

### *3.9.2 Jetting*

The recently issued EA guidance on spills to permeable surfaces means YW is reconsidering its approach to jetting and recognises that surfaces which could receive a sludge spill because of tank failure will require an impermeable surface. This means tank leaks, including jetting, within the tank locations at Esholt will be contained as the immediate and surrounding surfaces will be made impermeable.

The risk of environmental harm as a result of jetting from these tanks has been assessed as low for the following reasons:

- YW design, construction and monitoring controls ensure tanks are constructed to a high standard and would identify any critical weaknesses at an early stage, and well before catastrophic failure occurred.
- The concrete tank construction means that formation of a hole large enough to allow jetting, but small enough to avoid total tank collapse is hard to envisage. If failure were to occur, it is much more likely to initially show as cracking, giving time to respond before significant sludge escaped.
    - A technical note has been provided in Appendix 3 that validates the failure mechanism of a tank constructed from concrete.
- The sludge in the concrete digesters is relatively viscous and this is likely to reduce the extent of jetting as viscous materials will travel relatively slowly through an orifice.
- The most likely cause, albeit it still very unlikely, of a tank wall puncture that would allow jetting is a direct impact. If this were to happen, it would almost certainly be at ground level. The impermeable surfaces and trief kerbing which YW have committed to build would contain this kind of release, deflect the sludge from infiltrating permeable land and protect the sensitive receptors.

Yorkshire Water understand that while risk is low, consideration of jetting remains a requirement of CIRIA C736.

The blue circles in Figure 45, Figure 46 and Figure 47 show areas which could be affected by jetting from external non-bunded tanks. These have been calculated according to CIRIA C736 guidelines, Appendix 4.

Within the AD area, Figure 45 shows that jetting will be contained within the bunded area and will land of either existing hand standing/ road surfaces or new sections of impermeable surfaces (red areas). The drainage system is believed to have sufficient capacity to deal with the relatively high volume, but short duration, flow typical of a jetting event, this will be confirmed during detailed design work on the bund area.

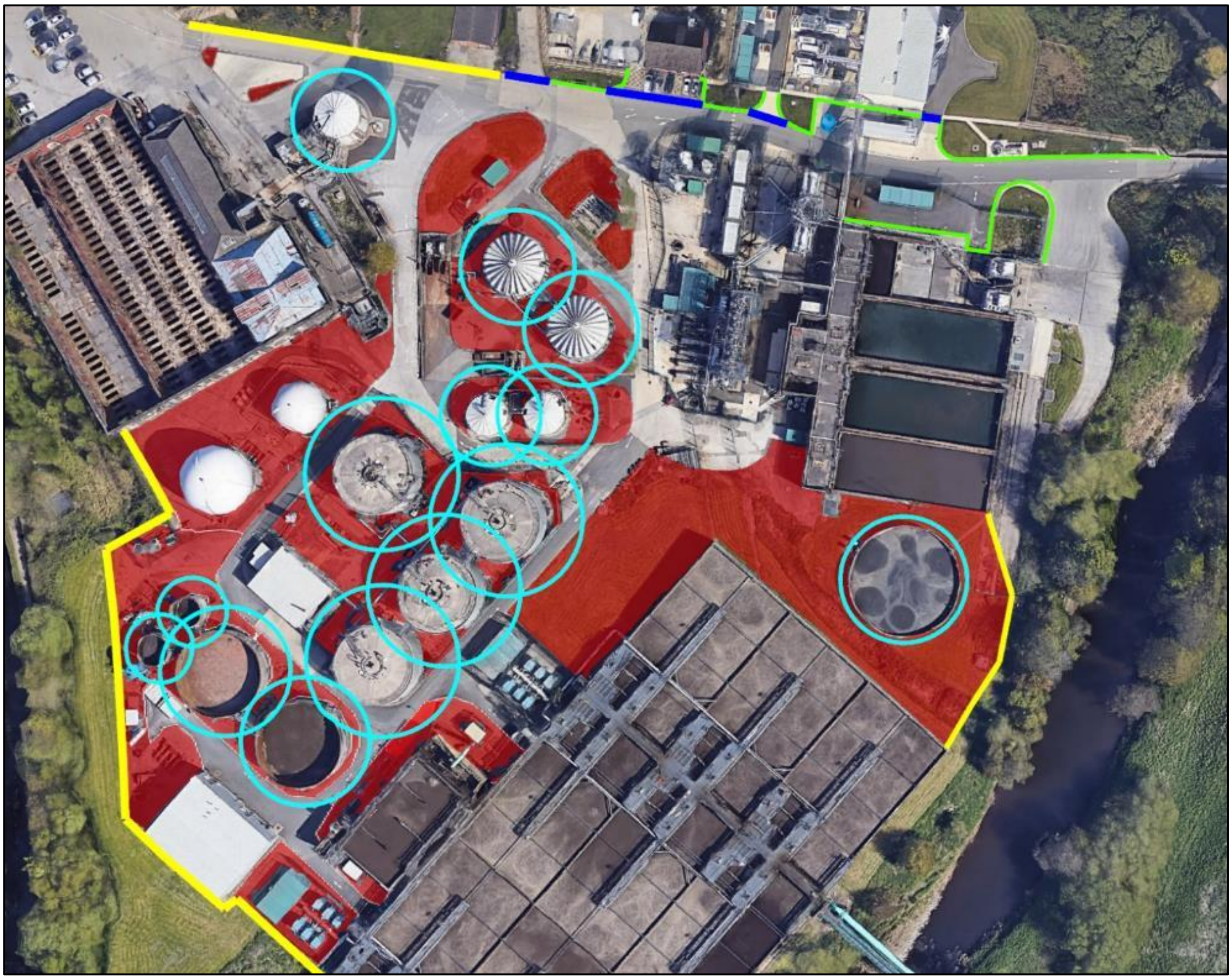


*Figure 45. Jetting potential in the AD area (blue circles).*

There are two jetting concerns within the DW area. Figure 46 and Figure 47 show a slight overlap of the jetting areas of the export dewatering tanks to the adjacent new walling, and northern centrate balance tank adjacent to the settlement tank. The walling section here will be made taller to accommodate the increased risk of jetting overtopping the new bund walling and settlement tank respectively. To satisfy the CIRIA C736 jetting calculation (Appendix Figure 2) the 0.45m bund wall adjacent to the export dewatering tanks, which is adequate in contain a spill in this area will be raised at least 1m high as mitigation. Similarly, to provide sufficient jetting protection from the centrate balance tank the existing settlement tank lip walling will be increased by also 1m.

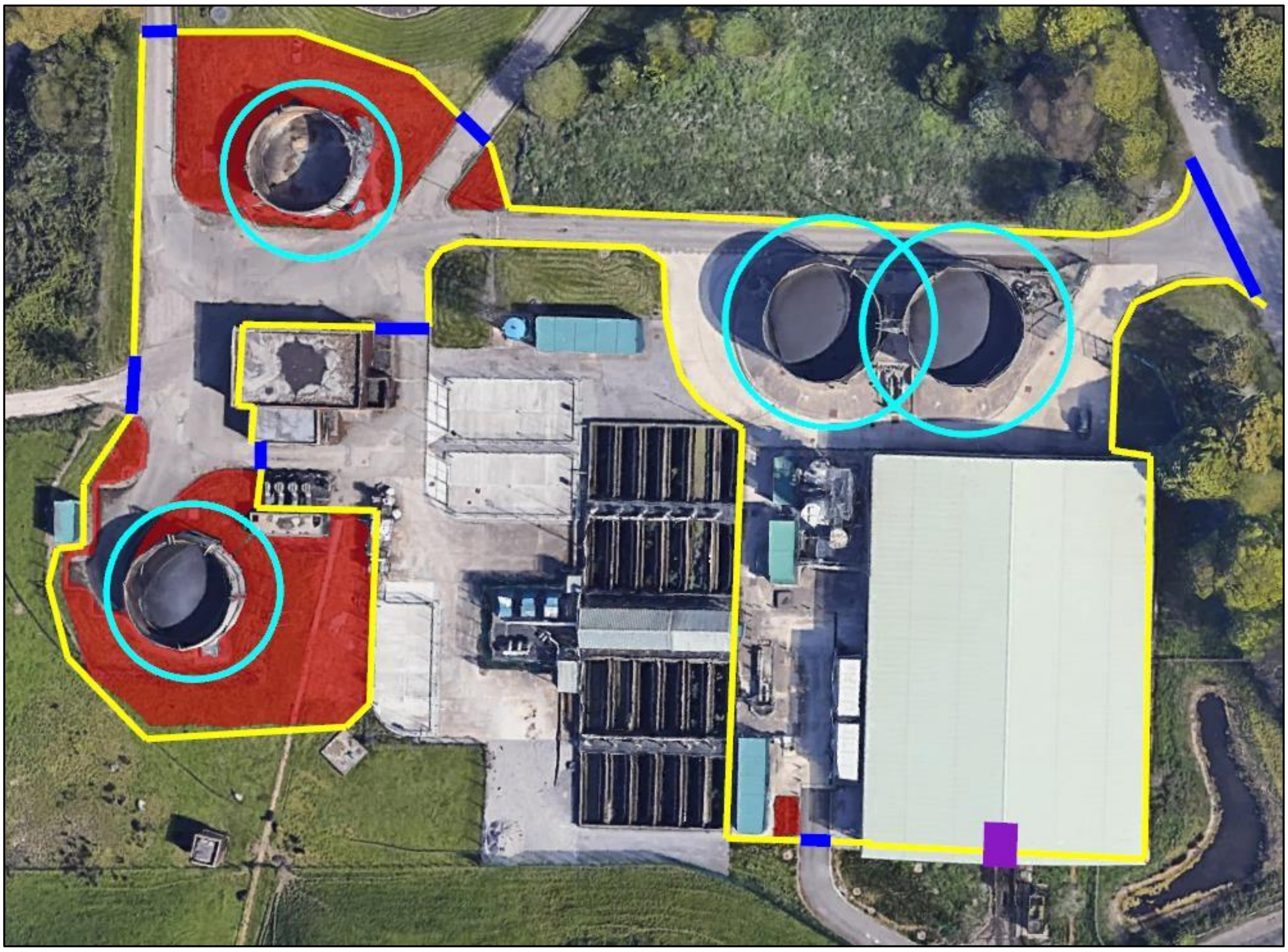


*Figure 46. Jetting potential in the dewatering and cake barn area (DW areas 1,2 and 4) (blue circles).*

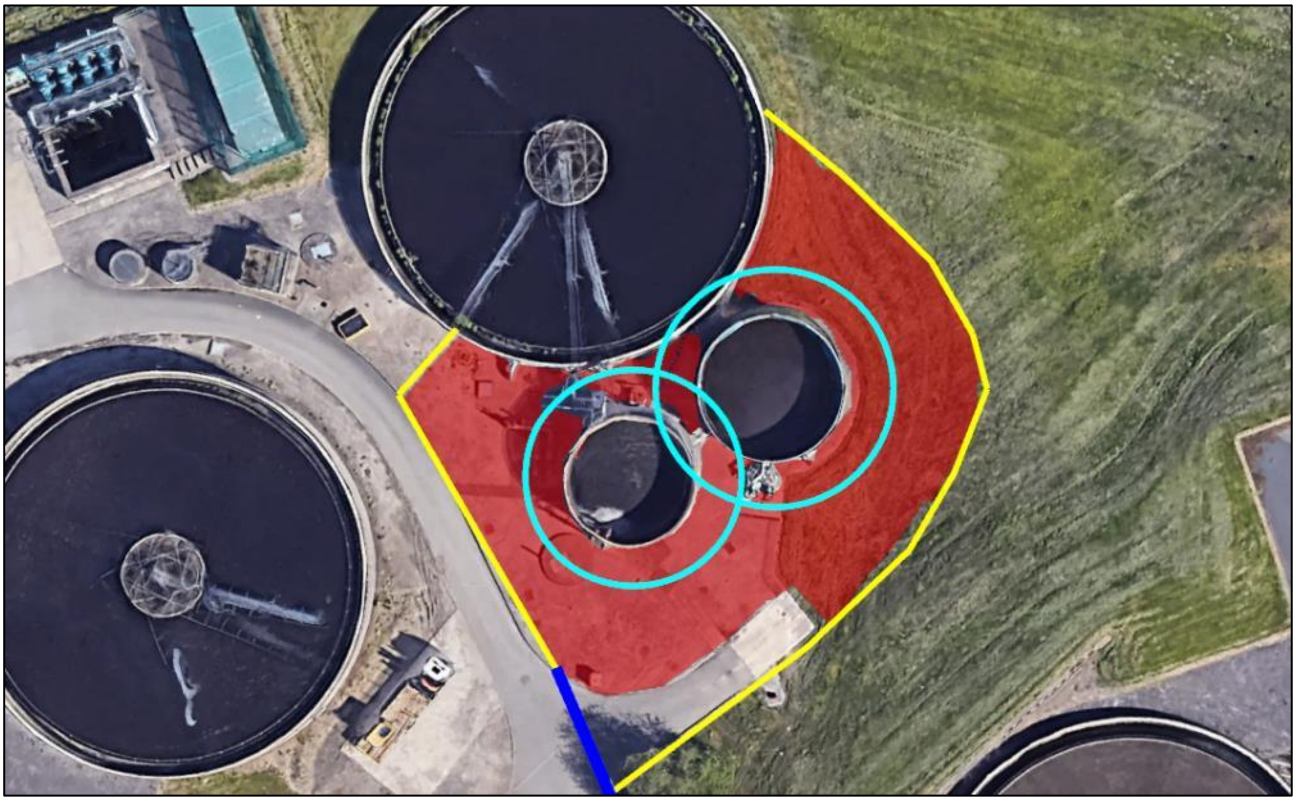


*Figure 47. Jetting potential in the dewatering area, centrate balance tanks (DW area 3) (blue circles).*

In summary, all tanks in the AD area show no risk of jetting directly or indirectly into sensitive receptors. Whilst there are two areas of concern in the DW area. Additionally, land that could be affected by jetting i.e., the area within the blue circles will have an impermeable surface, protecting the underlying ground from contamination. It is also important to note the screen feed, consolidation, digesters (with aluminium cladding and insulation), degassing, conditioning feed and northern centrate balance tanks are constructed of concrete. Concrete is a structurally robust material, but in the unlikely event that it does start to fail, it would typically crack rather than develop a hole. This would lead to a very slow release of contained material, not a long jet of liquid. See Appendix 3 for additional information on this.

YW understand the CIRIA C736 requirements linked to jetting, their relevance to environmental protection and commit to complying with CIRIA736 requirements on jetting as part of secondary containment design.

### 3.10 CIRIA C736 compliance and construction

The secondary containment solution at Esholt will be implemented by contractors chosen via YW's procurement process. This process is designed to ensure contractors have the knowledge and experience to build a secondary containment solution that complies with CIRIA C736.

The effectiveness of the containment and jetting solution will be confirmed using a 3D model and spill modelling software. YW will confirm that the final bunding solution is acceptable to the EA prior to commencement of the build.

# 4 Preventative maintenance and inspection regime

## 4.1 Above ground tanks

All tanks are tested and inspected as part of initial construction quality assurance checks; an example of a tank check is shown in Appendix 6.

The tanks at Esholt are regularly inspected by a qualified engineer. As part of these inspections, the reinspection period of each tank will be determined by the inspection engineer (anywhere from 6-months to 3 years depending on the condition of the tank). Any defects identified during inspections will be actioned and remedial works carried out as soon as possible.

Visual checks on tanks also form part of daily/weekly operational checks. These ensure that any damage or major degradation of tanks is identified as a risk and is reported before a hazard can develop.

## 4.2 Below ground level tanks/chambers

Yorkshire Water understand the environmental risk associated with underground structures and are committed to identifying and rectifying any leaks from them at the earliest possible opportunity. To support this aim, YW commit to the following:

- Daily visual inspection (Mon-Fri on certain sites) of subsurface tanks, wells, and surrounding ground by site operational team. These checks will identify major structural issues visible above liquid/ground level and any changes in ground conditions.
- Monthly visual inspection of subsurface tanks, wells, and surrounding ground by a technically competent manager.
- Apply additional monitoring.
    - Three monitoring techniques have been identified as appropriate for subsurface tanks/chambers. For each subsurface, liquid containing structure, the single most appropriate monitoring technique will be confirmed and implemented.
        - Borehole monitoring – sampling of up- and down-hydraulic gradient boreholes located around a tank perimeter will allow leaks from the tank to be detected and investigated as required. Following an initial period of monitoring to establish a baseline, trigger levels will be set and agreed with the EA.
        - Drop testing - the chamber/tank will be filled to normal maximum operating level, covered to prevent loss by evaporation, and left for 24 hours. For each tank an acceptable drop in level will be specified, if this is passed during the test, a repair will be completed
        - Empty and inspect – tanks will be emptied, cleaned and a visual inspection completed.
- Risk assessments in line with CIRIA C736 will be completed to confirm inspection frequencies on all subsurface tanks.
- Repair timescales.
    - Where a leak is detected using any of the above techniques, YW will isolate the source of the leak e.g., empty or bypass the tank as soon as practicable, with a target time of less than 14 days. The tank will not be returned to service until a repair has been completed

The use of inlet/outlet flowmeters to detect leaks has been considered, but the large volumes of flow passing through pipes combined with accuracy limitations of the instrument mean that leaks are likely to have already had an environmental impact, visible at ground level, by the time they are large enough to be detected. On this basis YW do not consider flow comparison to be a useful tool for leak detection

### 4.3 Pipe bridge

Digested sludge from the main AD area at Esholt is transferred to the dewatering area via a pipe. The pipe route includes a crossing over the river Aire. If this pipe were damaged, it is likely that there would be a significant release of sludge directly into the river Aire.

YW recognise that this presents an unacceptable environmental risk and commit to installing secondary containment on existing single-skinned pipework carrying liquids entirely related to sludge treatment over the pipe bridge at Esholt by the end of 2024.

### 4.4 Underground pipes

To mitigate the risk of failure of underground pipework, e.g., cracks and splits, surveys are completed using in-pipe crack detection technology every 2 years if mechanical joints are present, and 5 years if they are not. For future pipe installations, underground pipework will be avoided. Where this is not possible, pipes will be installed with secondary containment and leak detection.

In the event of an incident/ accident a team will be deployed immediately to isolate the damaged pipe and a spill management procedure will be followed. Thereafter, repairs to the damaged pipework will be arranged. Additionally, the incident will be logged, and hazard assessed to reduce or eliminate the risk of occurrence.

### 4.5 Impermeable surfaces

Appropriate containment of potential spills in large part relies on capturing them on impermeable surfaces that protect underlying ground. At Esholt these surfaces are typically made of concrete and YW are committed to keeping these in good condition to ensure that any potentially polluting liquids cannot pass the impermeable layer. The most likely path for liquids is through cracks and other damaged areas.

Responsibility for monitoring the condition of impermeable surfaces sits with two roles within YW.

- Site operators will carry out daily visual inspection of impermeable surfaces as part of their normal duties.

- The Technically Competent Manager (TCM) with responsibility for the site will carry out a monthly inspection of impermeable surfaces.

Where damage is identified a high priority job will be raised for repairs to be completed through the YW reactive maintenance system. In cases of severe damage, temporary protection will be installed around the damaged area to ensure that effective liquid capture is maintained.

# 5 Implementation and timescales

## 5.1 Monitoring

- At present YW do not have any boreholes installed for leak detection. YW commit to completing site surveys to confirm where these are an appropriate monitoring technique by 31st November 2023.
- After completion of surveys, YW commit to providing the EA with an updated list of all subsurface tanks, with detail of monitoring technique, frequency and how results will be recorded by 31st November 2023.
- YW commit to supplying detailed procedures covering the three key monitoring techniques of borehole testing, drop testing and emptying and inspection, by 31st November 2023.

## 5.2 Construction

A plan outlining the implementation of containment solutions identified is shown in Table 7. The timescales and estimated dates are indicative, and subject to timely external contract appointment, including acceptance of the procedures and ideal weather conditions for construction. Furthermore, bottlenecks, such as resource availability due to ongoing number of installations has not been factored in. These will be revisited once contractors are appointed, and capacities understood.

*Table 7. Secondary containment implementation stages and schedule.*

| Stage | Estimated date complete |
|---|---|
| Procurement, tender and award of contractor for outline bunding design | 28th February 2023 |
| Completed outline design | 1st July 2023 |
| Procurement, tender and award of contractor for detailed bunding design | 1st September 2023 |
| Completed detailed final design | 1st Jan 2024 |
| Commence construction | 30th April 2024 |
| Complete construction | December 2024 |

# 6 Conclusions and recommendations

This study has considered risks associated with credible worst-case loss of containment scenarios in each of the two main working areas of the Esholt STF installation, through the adoption of the widely used source-pathway-receptor model. A computation modelling study has been undertaken, which has adopted conservative assumptions to address known limitations of this type of modelling tool. This enabled the potential effects of a substantial, unmitigated loss of containment to be considered; in doing so a need for enhanced mitigation was identified to achieve an equivalent level of environmental protection for the identified sensitive receptors (the metric of compliance being an equivalence to a traditional 25 / 110 per cent capacity secondary containment bund in line with CIRIA 736 via the ADBA study).

An appropriately skilled and experienced working group was established to identify control options based on the application of engineering judgement. Selection of an appropriate solution for environmental protection through secondary containment at Esholt had to consider many different factors, including:

**Operability**

- The construction of a standard, complete concrete bund around all tanks within the STF would introduce significant operational issues around vehicle access to those assets and a health and safety risk in the event of a catastrophic failure associated with potentially trapped personnel.

**Buildability**

- Adding secondary containment to an existing, operational, site presents significant challenges. Whilst a solution may 'on paper' present itself as a viable and effective candidate option, reality and practicality dictates that it must be deliverable, or it would not fall under the 'available' definition of BAT.

**Likelihood**

- Whilst the potential for catastrophic tank failure can never be wholly mitigated when sites are operated with large tank inventories, the likelihood of substantial failure is very low, as evidenced by YW's own track record of operating sludge storage/treatment vessels across its asset base.
- In support of likelihood of failure YW has reviewed actual failure data. YW has over 40 years of experience in operating AD plants and STF's. YW has 14 AD sites. In this time YW has not experienced the catastrophic collapse of a storage vessel.
- YW has found from experience that 'failures' of concrete tanks are generally associated with ancillaries such as joints, waterstops, seals, etc, rather than any inherent defect with the actual civil structure. YW has experienced one incident of note, and this was at Hull STF digester number 5. This example is a case in point; the release of sludge that occurred was caused by the failure of a 'link seal' mechanical coupling that should have provided a watertight seal around the outside of a mixer pipe intrusion. In comparison with a catastrophic collapse scenario, this resulted in relatively controlled spill of small volume.

**Environmental impact**

- Receptors in the area must be protected from the effects of major sludge spills.
- The carbon impact of creating entirely impermeable containment areas is significant and counter to YW's aim of achieving net zero carbon emissions by 2030, it also potentially alters the catchment flow characteristics of what is a very large site in immediate proximity to a major river, with a demonstrable history of flooding in recent years.

Considering the conservative assumptions of the modelling (such as the viscosity of sludge compared to water) and the scoring approach which considers multiple decision factors including the significant carbon impact of the CIRIA 736 standard options, YW concludes that the identified combination of potential solutions will deliver an optimal balance between:

**Use of existing infrastructure**

- Site drains in the AD area are able to return liquid to the inlet works for treatment, providing containment and flow mitigation.
- The cake pad has been engineered to drain liquid contents, which returns to the inlet works of the WwTW, acting as remote containment.
- For most spills, leaks and catastrophic pipe failures the site surfacing and drainage would transfer liquid to the WwTW, which would contain and minimise potential effects of loss of containment.

- **Continuation of the measures already in place** to minimise the likelihood of catastrophic failure of sludge vessels, through the use of stringent technical standards and regular visual inspections.

- **Minimising the potential impact to sensitive receptors** from sludge spills resulting from a worst-case scenario of catastrophic tank failure.

- **Reducing the carbon footprint** associated with the construction and operation of the solution; and

- Ensuring that the solution has **no negative health and safety implications** for staff on the site.

The study undertaken, although considered comprehensive and robust, does represent an initial feasibility / conceptual stage design exercise and extensive further work will be required to validate a solution for a potential build. Once it is confirmed that the preferred options put forward in this report are acceptable in principle to the EA, YW commits to commence a technical feasibility and detailed design study, with associated timetable for implementation of the resulting final mitigation measures. This will allow remaining uncertainties regard engineering integrity, modelled flow extents, design safety, cost engineering and constructability to be resolved.

# 7 Arup Design Overview

The Stantec containment outline, as described in Section 4, was passed to Arup for detailed design.

The design of the secondary containment has been developed to standards as set out in the *establishing best available techniques (BAT) conclusions for waste treatment, under Directive 2010/75/EU of the European Parliament and of the Council" document; specifically, BAT 19c and 19d. The design proposals for the site have been developed to be compliant with the recommendations and best practice set out in CIRIA C736. The secondary containment proposals at Lundwood have been developed to contain sludge tanks in bunded areas within the site. The Tuflow modelling was carried out and can be seen in Secondary Containment Lundwood Maximum Containment Depth Sheet (appendix 6).

The secondary containment design will involve bunds within the installation area that will act as a physical barrier, preventing any sludge from escaping the designated areas. The defence shall include containment walls. The design also includes resurfacing the bunded areas to ensure the ground impermeability within the containment area. This will effectively prevent any seepage or penetration of sludge into the surrounding soil. The design includes, where appropriate, alterations to the existing drainage and utility infrastructure. These modifications are necessary to redirect any potential spillage or leakage of inventory to the designated containment systems.

As the secondary containment design is being retrofitted, there are elements of the CIRIA 736 guidance which cannot be achieved. In these instances, an alternative measure will be implemented to achieve an equivalent standard to provide the same level of environmental protection.

Surface Water Drainage

The site benefits from an existing drainage system which will be used as part of the design. The design will be used to manage surface water accumulating within the containment area.

Ciria C736 dictates that a new site would have a fully bunded and blind drainage system. This is difficult to retrofit on an existing site. YW is proposing an alternative level of protection would be to install new drainage (where necessary) to accommodate the increase in surface water that will be created by the additional impermeable surface area. A gate valve (or similar) would be provided to enable the bund to be isolated in the event of a spill. It would remain open as standard.

Furthermore, Ciria C736 states the bund should be sized to accommodate a 10% AEP 24 hour storm event preceding a spill incident and an 10% AEP 8 day event following an incident. This would require a significant storage vessel for rainwater. As described previously, the bund would be maintained in an empty state up until the point of a spill event. Therefore YW is proposing to retain the AEP 8 day volume post spill but remove the 10% AEP 24hour storm event volume.

Impermeability

Ciria c736 states the replacement of permeable areas with impermeable surfaces and directs the use of reinforced concrete pavements for class 1-3. Ciria c736 requires a clay liner under concrete. This existing site was not designed with a clay liner situated underneath the existing concreted areas.

YW is proposing that existing concrete and paved areas within the installation bund will not be lifted to replace with a clay liner. To lift the existing surfaces would result in many tonnes of waste material. It's proposed we would retain existing flexible pavements (concrete and tarmac) and undertake repairs to ensure surface integrity where needed. Permeable liners would be installed on the current landscaped area with drainage at the base. It's proposed a clay liner would not be required under this liner.

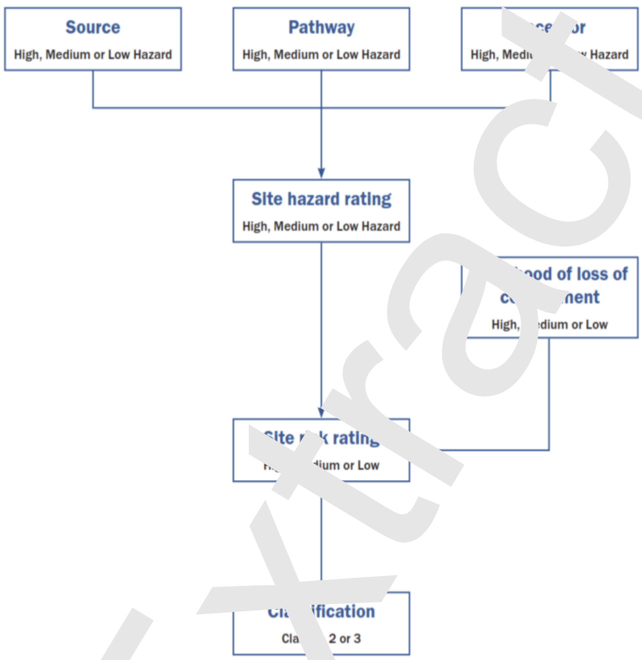
# Appendices

# Appendix 1 - ADBA assessment tool

Although this tool works as a standalone tool, we recommend you read this first: ADBA CIRIA736 Bund Classification Assessment

**There are 5 steps to follow:**

1) Identify the hazard posed to the environment by the inventory of materials held on the site and the location of the site
   a. Categorise the source
   b. Identify the pathways
   c. Identify the receptor
2) The Site Hazard Rating is derived by this tool from the combination of the hazards assessed above
3) Calculate the likelihood of a loss of primary containment event occurring
4) The combination of the Site Hazard Rating and the likelihood of a loss of containment occuring gives the site risk rating and required secondary containment classification
5) From the class of containment needed, identify suitable designs from the 'Standard Containment Designs' sheet




Additional Guidance

As detailed in section ... of CIRIA C736, determining an overall hazard rating for the site is largely subjective, and assessing the ... effects is a judgement based on knowledge, experience and the degree of confidence in the information available.

Section 2.4 of CIRIA C736 states: *"where there is uncertainty about the correct categorisation of any of the individual source, pathway or receptor hazard ratings, it may be appropriate to move the overall site hazard category to the next higher rating".*

The worksheets in this spreadsheet are protected to prevent inadvertant damage to the tool. To remove the protection, the password is CIRIA736

*Appendix Figure 1. ADBA spreadsheet screenshot.*

# Appendix 2 – CIRIA C736 compliant solution

*Appendix Table 1. Esholt bunding solution design specification and dimensions.*

| Category | Criteria | Unit | Value |
|---|---|---|---|
| **AD AREA** | | | |
| Design specification | CIRIA C736 spill volume [25/110%] | $m^3$ | 6,195 |
| | Bund perimeter length | m | 1,252 |
| | Total containment surface area | $m^2$ | 26,244 |
| | Maximum final spill depth | m | 0.24 |
| Bunding requirements | Concrete bund height | m | 0.49 |
| | Total concrete wall length | m | 1,252 |
| Build required | Required concrete walling length | m | 486 |
| | Impermeable surfacing area | $m^2$ | 11,072 |
| **DW AREAS (1,2,4) - Dewatering zone** | | | |
| Design specification | CIRIA C736 spill volume [25/110%] | $m^3$ | 1,764 |
| | Bund perimeter length | m | 640 |
| | Total containment surface area | $m^2$ | 9,009 |
| | Maximum final spill depth | m | 0.20 |
| Bunding requirements | Concrete bund/ sleeping policemen height | m | 0.45 |
| | Total concrete wall length | m | 640 |
| Existing bunding | Existing concrete walling length | m | 105 |
| Build required | Required concrete walling/ sleeping policemen length | m | 535 |
| | Impermeable surfacing area | $m^2$ | 2,325 |
| | No. ramps | | 1 |
| **DW AREA (3) - Centrate balance tanks** | | | |
| Design specification | CIRIA C736 spill volume [25/110%] | $m^3$ | 1,100 |
| | Bund perimeter length | m | 489 |
| | Total containment surface area | $m^2$ | 1,489 |
| | Maximum final spill depth | m | 0.74 |
| Bunding requirements | Concrete bund/ sleeping policemen height | m | 0.99 |
| | Total concrete wall length | m | 1,447 |
| Existing bunding | Existing concrete walling length | m | 42 |
| Build required | Required concrete walling / sleeping policeman length | m | 489 |
| | Impermeable surfacing area | $m^2$ | 1,116 |

# Appendix 3 – Structural integrity note for concrete tanks

## Technical Note

aquaconsultants
water · environment · energy

Project: Yorkshire Water – IED

Title – Leakage of water through concrete sections.

Author – Imran Nawaz MEng CEng MICE

Date 08/06/2022

1. Introduction

This Technical Note discusses the possibility of concrete tank walls developing an aperture through which fluids could be ejected at speeds resembling a jet. In fluid terms a jet develops when laminar flow is achieved at significant velocity at 90 degrees from the plane of the aperture.

2. Concrete section construction

Concrete is formed from angular aggregate suspended in a matrix of cement paste and sand. Upon pouring and vibrating fresh concrete the aggregates settle at the bottom of the mixture while being fully surrounded and immersed in the cement and sand paste. During this process the excess water and cement paste rises to the top and careful mix design and match management is needed to ensure this paste is not too much or too little; in both cases the result would be poor surface finish and weaker concrete.

The final product is well compacted angular aggregate with a good degree of interlock bound by the hardened cement paste.

3. Concrete in service.

Concrete in service is subject to many effects that cause expansion and contraction. These include drying shrinkage as the water which is not chemically bound by hydration evaporates; autogenous shrinkage as the product of the chemical reaction takes up a smaller volume than the constituents; thermal strain; and differential settlement. In addition to these, the structural stresses in the concrete cause tension and bending, both of which cause a tension force in the concrete. All the effects described here contribute to cracks developing on the face and within the interior of the concrete. In all reinforced concrete section including those that are structurally sound, the concrete will crack and redistribute the tension force to the steel reinforcement by a combination of chemical bonding (between steel and cement paste) and aggregate interlock with the ribbed bars. Cracks are generally designed to be 0.3mm, although acceptable crack width will be less than 0.2m for water retaining concrete, which will allow water retention while keeping water egress through the cracks to a small an acceptable level.

4. Concrete deterioration.

Concrete hardens and strengthens over time as the hydration reaction continues along an asymptotic curve. However, processes such as chlorine attach, carbonation and freeze-thaw can cause weakening and deterioration of the concrete. In addition to this, acidity, ground conditions and the nature of the retained material within a tank can accelerate deterioration.

# Technical Note

aquaconsultants
water · environment · energy

In extreme cases the effects of this can be:

- Severe weakening of the concrete leading to crushing failure.
- Severe delamination of surface layers over a great length exposing the steel reinforcement, causing it to corrode so the section fails in tension.
- Severe steel and/or concrete deterioration at junctions i.e., slab/wall/beam/column interfaces leading to shear failure and adjacent sections becoming detached.

Although exceedingly rare, the cases above describe total failure conditions. In these cases, leakage of fluids is not so much of a problem as structural collapse. Less extreme cases allowing water or fluid egress a tank are described below.

- Significant damage or corrosion to reinforcement leading to excessive crack width and significant leakage. In this situation the crack can be significant and even penetrate the full section of concrete wall. The water flowing through follows a tortuous path around the aggregate before it leaks out of the surface.
- Significant spalling and loss of material from a zone on the inside and outside of the concrete wall. In this situation the remaining thickness can retain the water. If this location also coincides with a crack, water will flow through a tortuous path as described above.

This type of damage allows water leakage, water jetting would not occur as long as a small intact section of concrete is present to impede laminar flow.

Considering the possibility of an aperture opening in the wall, this could in theory occur if spalling, and loss of cement and aggregate became so severe that it penetrated the section. Although it is not rare for severe material loss to occur, for conditions to be this aggressive they would affect a large area or the majority of the structure, causing significant loss of section leading to structural failure in stages preceding development of a full thickness aperture.

## 5. Conclusions

When the concrete is in service or subject to significant concrete deterioration, spalling and loss of section, the condition of laminar flow through an aperture will not develop.

Under severe concrete deterioration, any conditions approaching aperture formation will lead to structural failure before an aperture can form therefore the likelihood of this happening are considered to be negligible.

- End -

# Appendix 4 – CIRIA C736 jetting calculation

For a small diameter sharp edged discharge orifice, it can be demonstrated that:

$$l^2 = 4\,C_v^{\,2}\,(z-h)\,(H-z)$$

where $C_v$ = coefficient of velocity

In practice, $C_v \cong 0.99$. Assuming $C_v = 1$ leads to the conservative solution:

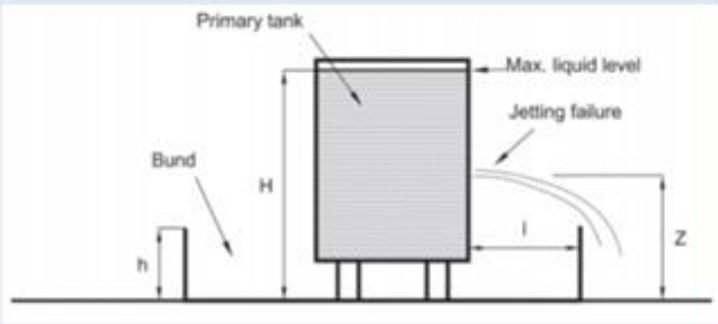
$$l^2 = [4(z-h)(H-z)]^{0.5}$$

For a given value of $h$, it may be shown the $l$ is a maximum when:

$$z = 0.5H + 0.5h$$

which leads to the solution:

$$l_{max} = H - h$$




*Appendix Figure 2. CIRIA C736 jetting calculation to determine jetting solution.*

# Appendix 5 – Example tank inspection report

A full copy of the example document below is included as an attachment with the RFI response.

Form No: YW-INSP-FRM-1, Issue 1, 2018 08 09

**Yorkshire Water Limited**
**INSPECTION GROUP**

YorkshireWater

**EQUIPMENT INSPECTION REPORT**
*Knostrop Top Site New Sulphuric Acid Tank Inspection*

| | | | |
|---|---|---|---|
| Report Number: | KNO2-INSP-003 | Written Scheme No. | N/A |
| Equipment Number: | N/A | Category: | Visual |
| Service: | Sulphuric Acid Tank | Equipment Used: | Camera |
| P&ID Number: | N/A | Site Operator: | N/A |
| Associated IAN's: | | Site Manager: | N/A |

**Inspection to be as defined in the INSPECTION MANUAL**

| Type of Inspection: | Scheduled Interval (months): | Date of Last Inspection (mth-YYYY): | Next Inspection Date (mth-YYYY): | Maximum Interval (months): |
|---|---|---|---|---|
| Thorough External Inspection: | 5 | Nov-2018 | March-2019 | 60 |
| Thorough Internal Inspection: | N/A | N/A | N/A | N/A |
| On-Stream Thickness Survey: | N/A | N/A | N/A | N/A |

An Opportunistic site visit to the Knostrop Top Site was undertaken on the 26/11/2018 on available equipment where access allowed. The purpose of the visit was to review the condition of the new Sulphuric Acid Tank after repairs to the Tee's was carried out by the manufacturer. The Plant was built in 2018, Due to be commissioned 2019.

The site is situated within the Knostrop Site Complex.

*Appendix Figure 3. Example equipment inspection report.*

# Appendix 6 – Arup Spill Modelling Report

ARUP

# Technical Note

| | |
|---|---|
| **Project title** | Yorkshire Water IED |
| **Job number** | 293261 |
| **File reference** | IED_ESH-ARP-TRT-ZZ-TN-Z-0001 |
| **cc** | |
| **Prepared by** | Andy Pittam |
| **Date** | 12 February 2024 |
| **Subject** | Esholt Flow Modelling - Supporting Note |

Admiral House Rose Wharf 78 East Street Leeds LS9 8EE United Kingdom
t +44 113 242 8498 d +44 113 301 6040
arup.com

## 1. Introduction

A detailed assessment using Tuflow© modelling software has been undertaken to simulate potential spill scenarios at the Esholt site. These model results have then been assessed to determine appropriate defence elevations for the proposed bunds, resurfacing and extents of the containment design.

This technical note outlines the modelling process that has been undertaken, any key assumptions, the model results and how these have been used to inform the secondary containment design at the Esholt Digester Area. Outputs from the Tuflow modelling are included in Appendix A.

The 2no. Esholt Dewatering Areas have not been assessed with Tuflow modelling. The assessment of these areas has been undertaken using a Civils 3D static model, as illustrated on drawings IED_ESH-ARP-TRT-ZZ-DR-C-0007 and IED_ESH-ARP-TRT-ZZ-DR-C-0008. This note refers to the Tuflow modelling only, for details of the Civils 3D modelling refer to the Design Basis Report (IED_ZZZ-ARP-TRT-ZZ-RP-C-0001).

## 2. Modelling Process

A TUFLOW model was produced to simulate breaches in each of the tanks. Breaches were applied in turn, at the following tanks:

| Spill Model Reference Number | Primary Containment Tanks |
|---|---|
| 1 | Liquid Sludge Screen Feed Tank |
| 2 | Consolidation Tank 5 |
| 3 | Mixed Sludge Tank 1 |
| 4 | Mixed Sludge Tank 2 |
| 5 | Consolidation Tank 3 |
| 6 | Consolidation Tank 2 |
| 7 | Consolidation Tank 1 |
| 8 | THP Silo 1 |
| 9 | THP Silo 2 |

ARUP

**Job number** 293261
**Date** 12 February 2024

| | |
|---|---|
| 10 | THP Feed Hopper |
| 11 | THP Reactor 6 |
| 12 | THP Reactor 5 |
| 13 | THP Reactor 4 |
| 14 | THP Reactor 3 |
| 15 | THP Reactor 2 |
| 16 | THP Reactor 1 |
| 17 | Sludge Buffer Tank |
| 18 | Digestor Tank 1 |
| 19 | Digestor Tank 2 |
| 20 | Digestor Tank 3 |
| 21 | Digestor Tank 4 |
| 22 | De-gassing Tank 1 |
| 23 | De-gassing Tank 2 |
| 24 | SAS Storage Tank 2 |
| 25 | SAS Storage Tank 1 |
| 26 | Sludge Transfer Tank 2 |
| 27 | Sludge Transfer Tank 1 |

This was achieved by calculating a maximum water level within each tank based on known above-ground capacities and dimensions of the tanks. This level was applied spatially at the location of the tank as an Initial Water Level (IWL) within the software. When the model simulation commences, this level spills onto an applied LiDAR level obtained from DEFRA, following the flow path that the contents of the tank would take should a breach occur.

Additionally, known rainfall depths for a 1 in 10-year return period (10% AEP) was applied simultaneously to each spill scenario, to give an indication of the combined depths of rainfall and the contents of each breached tank. Rainfall is based on the sum of a 1 in 10-year 24-hour and 8-day storm event, as per the Ciria C736 guidance.

The outputs of this modelling exercise will be used to inform the design of suitable works to contain the flow, be it bunds, walls, kerbs or similar, to be determined on a case-by-case basis.

## 3. Modelling Assumptions

A limitation of the below method is that the modelling assumes the contents of the tanks have the same physical properties of water, and will propagate across the site in the same manner as water would. This results in a worse-case scenario for the initial surge maximum depths that if the spills were to be modelled using effluent. However, the impact on the settled results is negligible, as consistent rainfall would mix with the effluent, resulting in similar material properties to water.

Additionally, in using IWL's to simulate the breach, it assumes all sides of the tanks instantaneously burst. Therefore, maximum spill depths around the tanks immediately after breach are excessively conservative.

ARUP

**Job number** 293261
**Date** 12 February 2024

## 4. Results

Two sets of results have been produced as part of the Tuflow modelling and included within Appendix A:

1. **The maximum spill depths** – these plans show the maximum spill depths recorded within the modelled area, across the full duration of the simulated storm and spill, for each tank. This data shows the dynamic impacts of an instantaneous spill.
2. **The final spill depths** – these plans show the spill depths of at the end of the spill event, i.e. on the completion of the simulated storm and once the spill inventory has dissipated and settled within the contained area to the final depths.

Typically, the final spill depths equate to the maximum spill depths across the site. Where there are instances that the maximum spill depths are greater than the final spill depth, this highlights a risk of surge effects from the spill influencing the containment depths.

In designing the containment defences, both sets of results have been used with the following approach:

- Minimum defence heights across the site have been set based on the final spill depths. Unlike other sites that form the IED package of works, the varying levels across the site results in a range of different required elevations.
- Where the final spill depth is greater than 0m above existing ground level and the maximum spill depths are greater than the final spill depths, a surge freeboard has been added to the minimum defence heights.
- Where the final spill depth is 0m and the maximum spill depth is greater than 0m above existing ground level heights, a surge freeboard has been added to the existing ground level.
- Surge freeboard has been based on the Ciria C736 guidance, see (below).

| Type of structure (see Part 3) | Allowance |
|---|---|
| *In situ* reinforced concrete and blockwork bunds | 250 mm |
| Secondary containment tanks | 250 mm |
| Earthwork bunds | 750 mm |

Figure 1 Surge Allowance Extract from CIRIA 736

- Where the maximum spill depths are equal to the final spill depths, freeboard has not been included. This is because the Tuflow modelling has not identified a risk of surge impacts at these locations.

A summary plan of the minimum defence height requirements, based on the above methodology, is included in Appendix B.

ARUP

| | |
|---|---|
| Job number | 293261 |
| Date | 12 February 2024 |

## DOCUMENT CHECKING

| | Prepared by | Checked by | Approved by |
|---|---|---|---|
| Name | Andy Pittam | Iain Dillon | |
| Signature | [signature] | [signature] | |

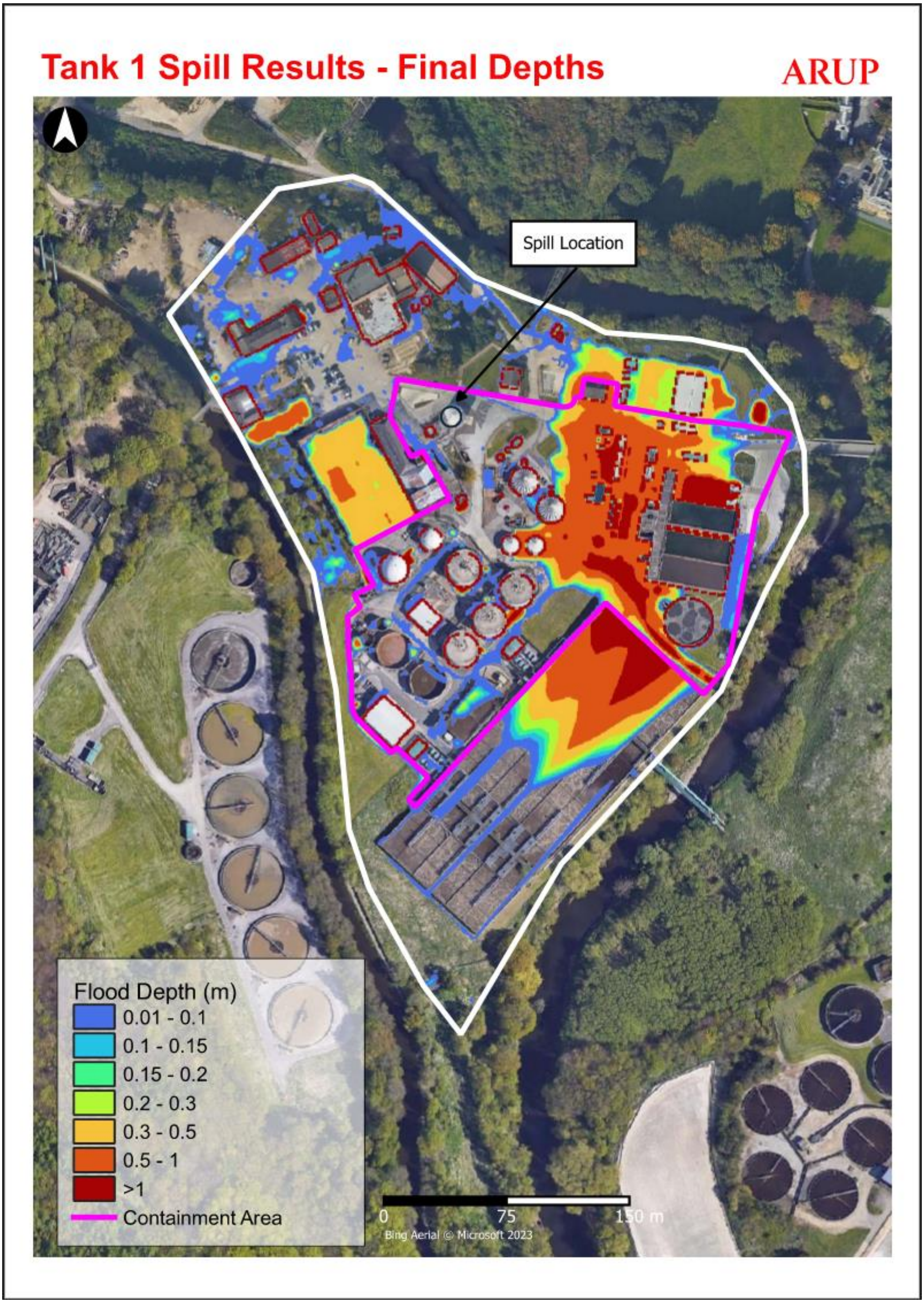
Page 4 of 6

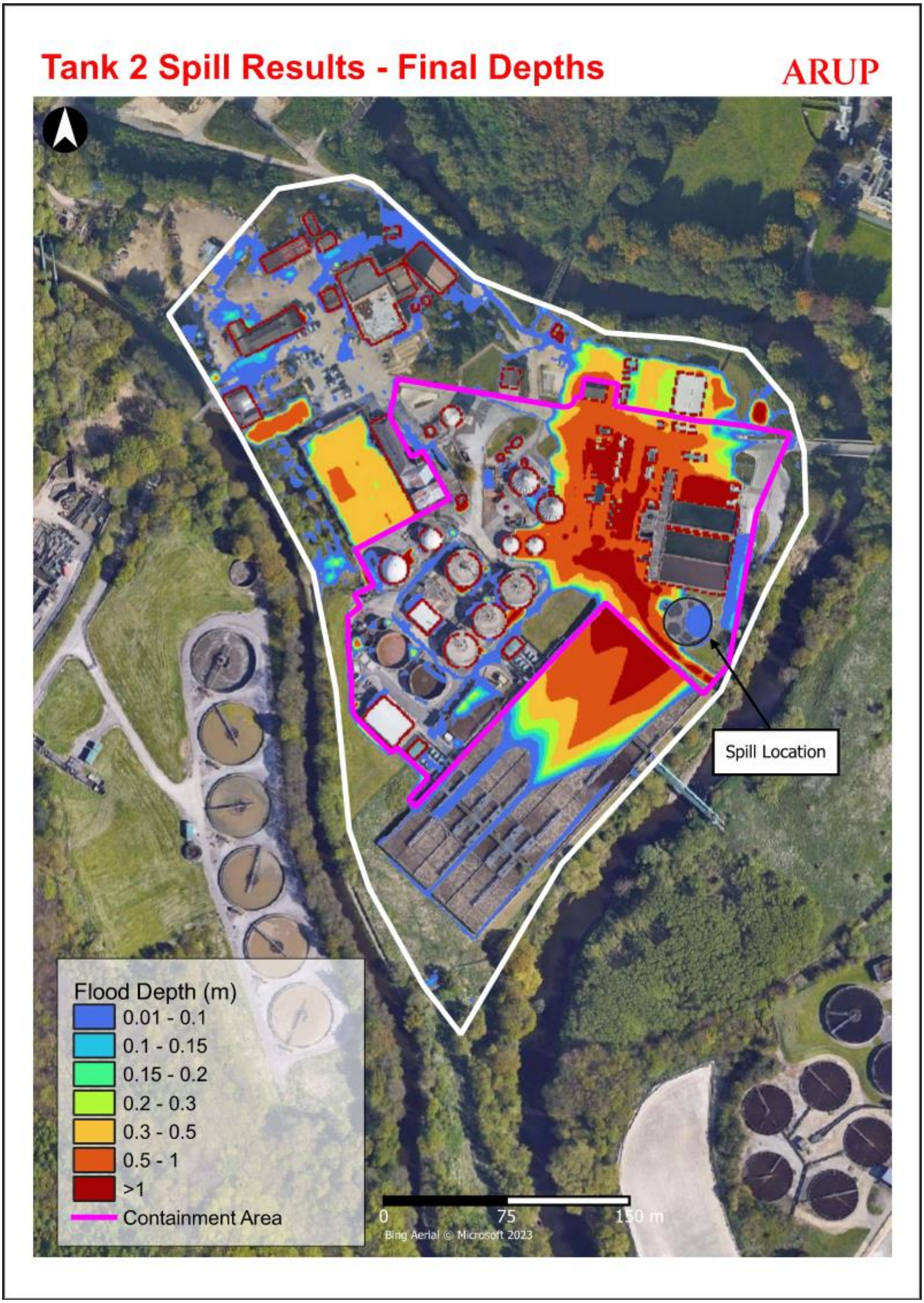
ARUP

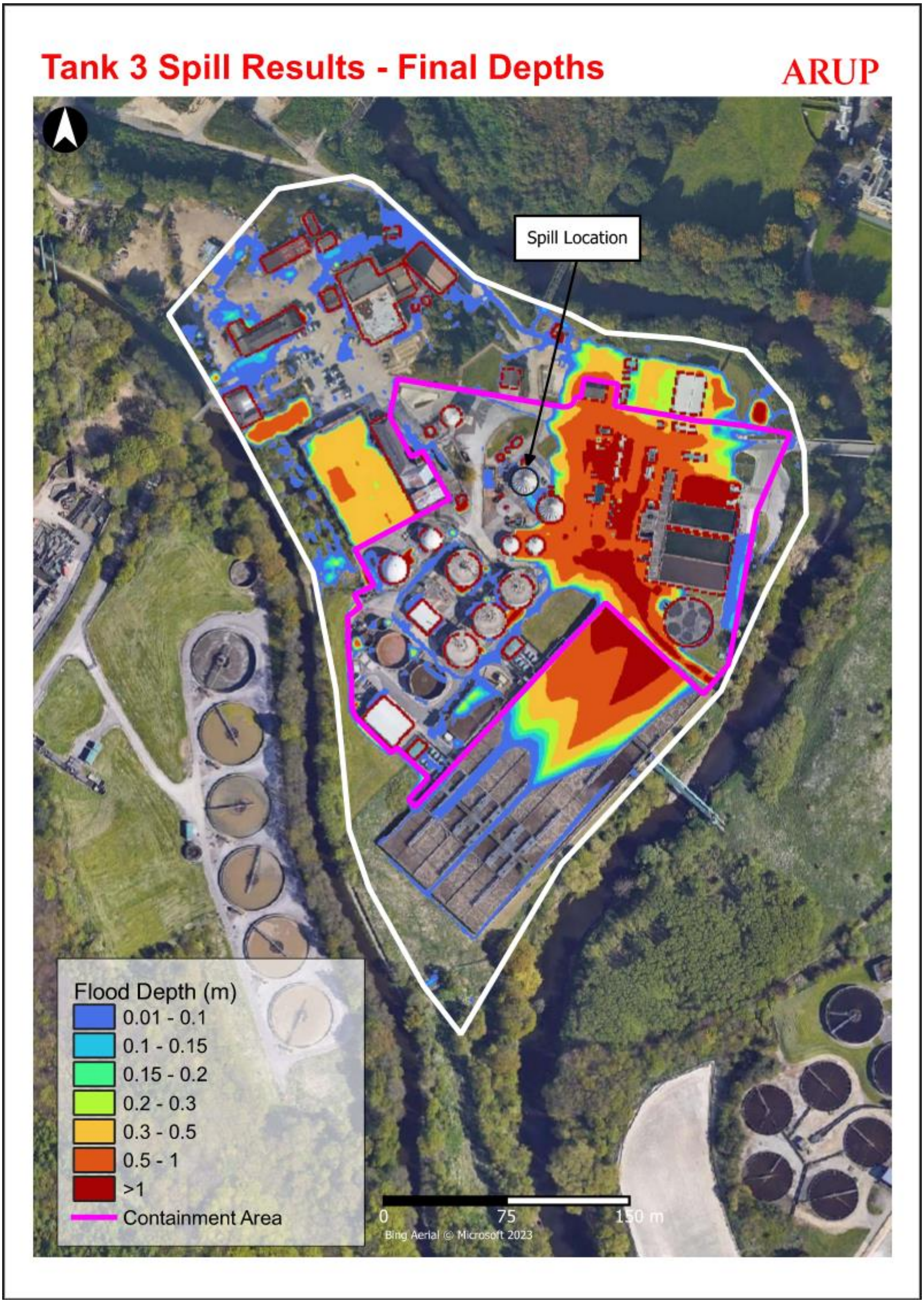
| | |
|---|---|
| **Job number** | 293261 |
| **Date** | 12 February 2024 |

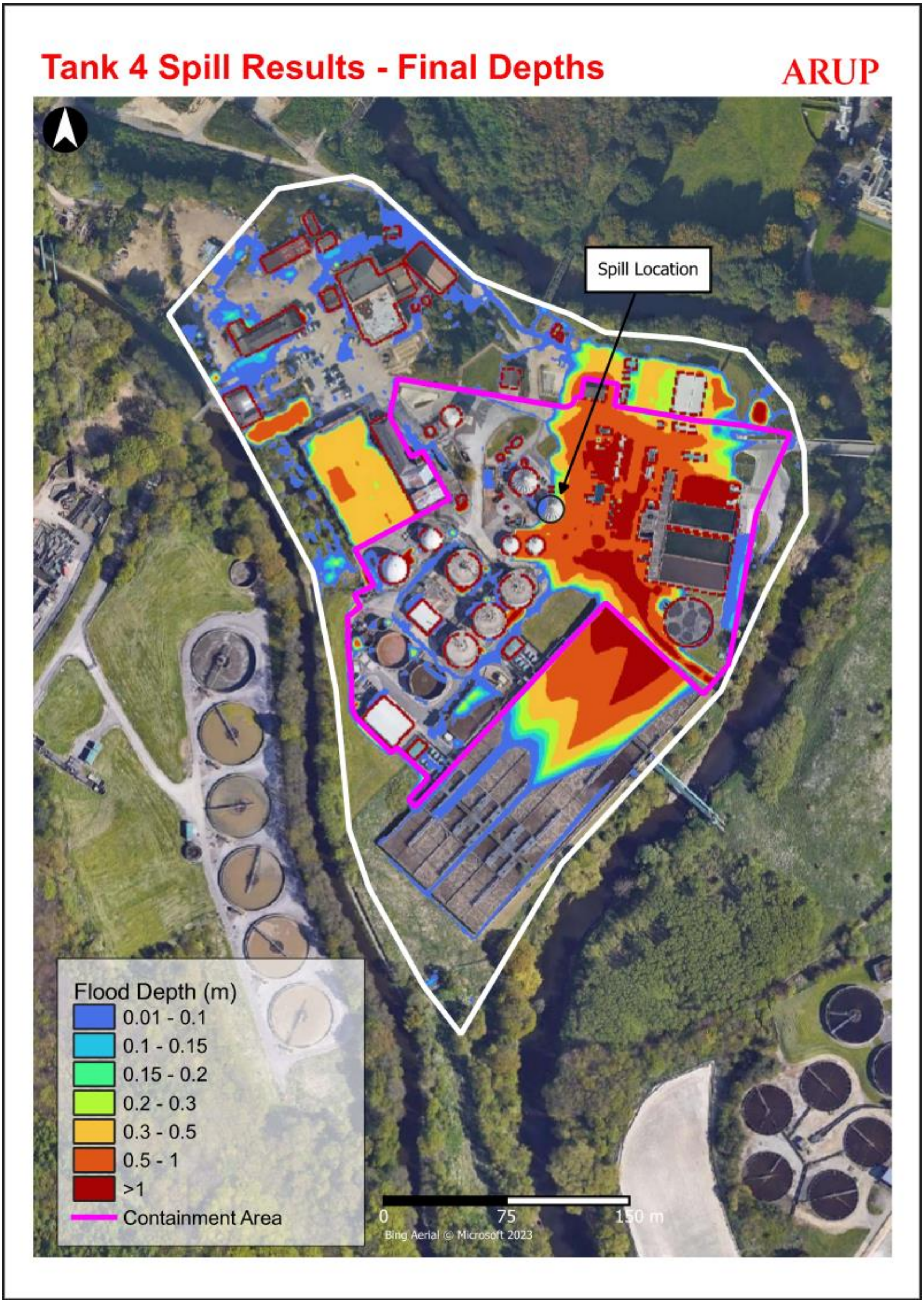
## Appendix A – Tuflow Modelling Results

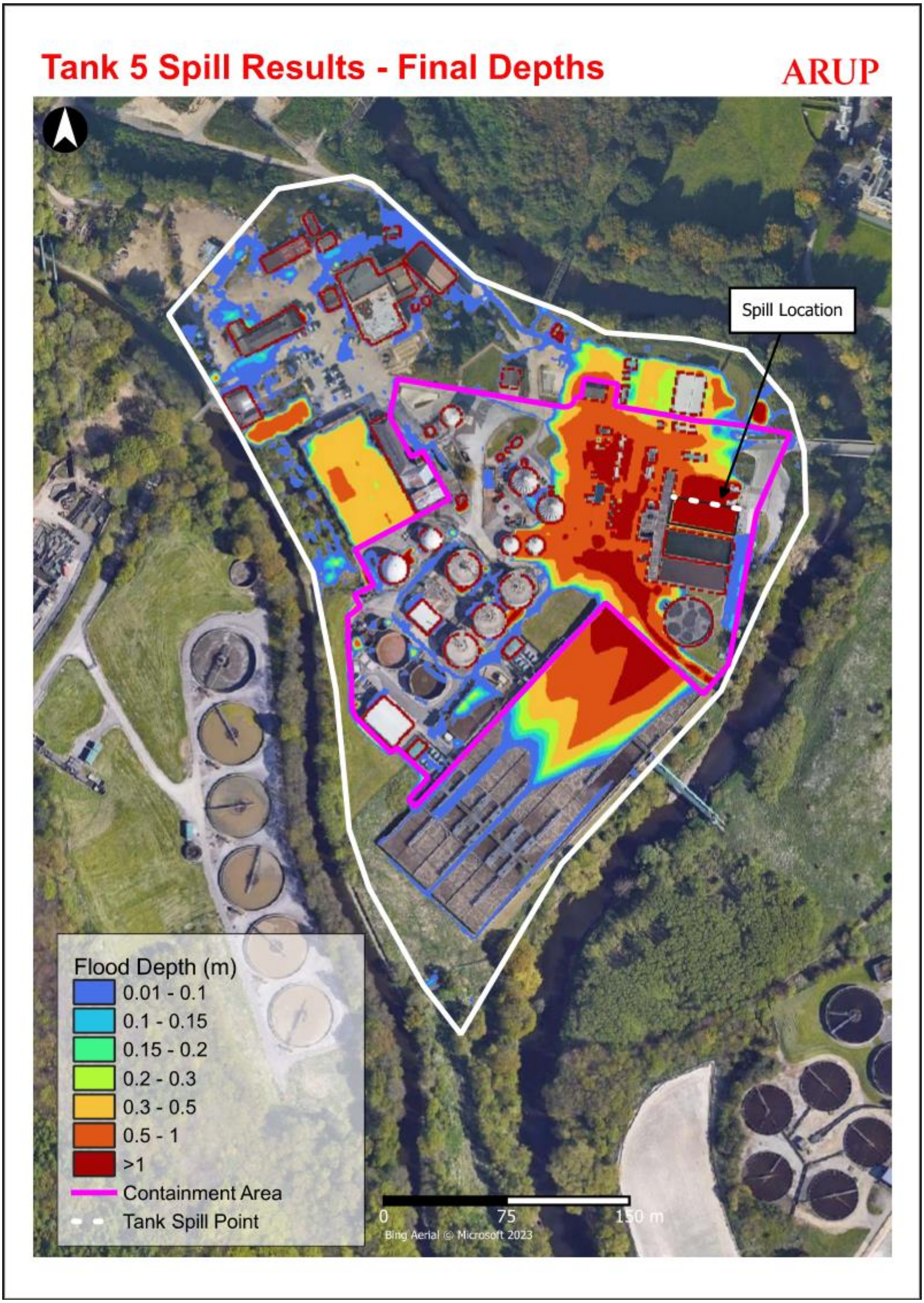
Page 5 of 6

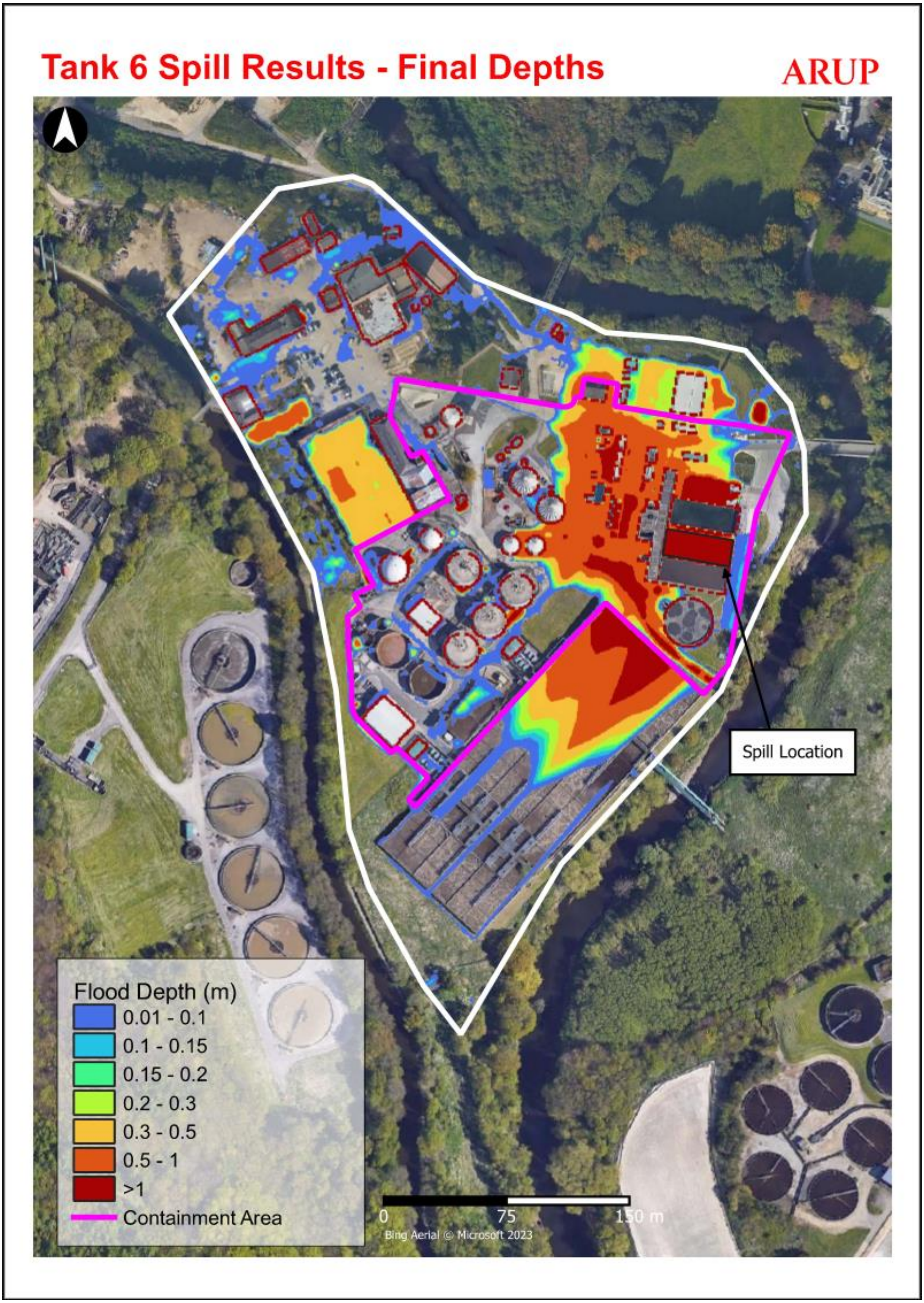

Tank 1 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 2 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

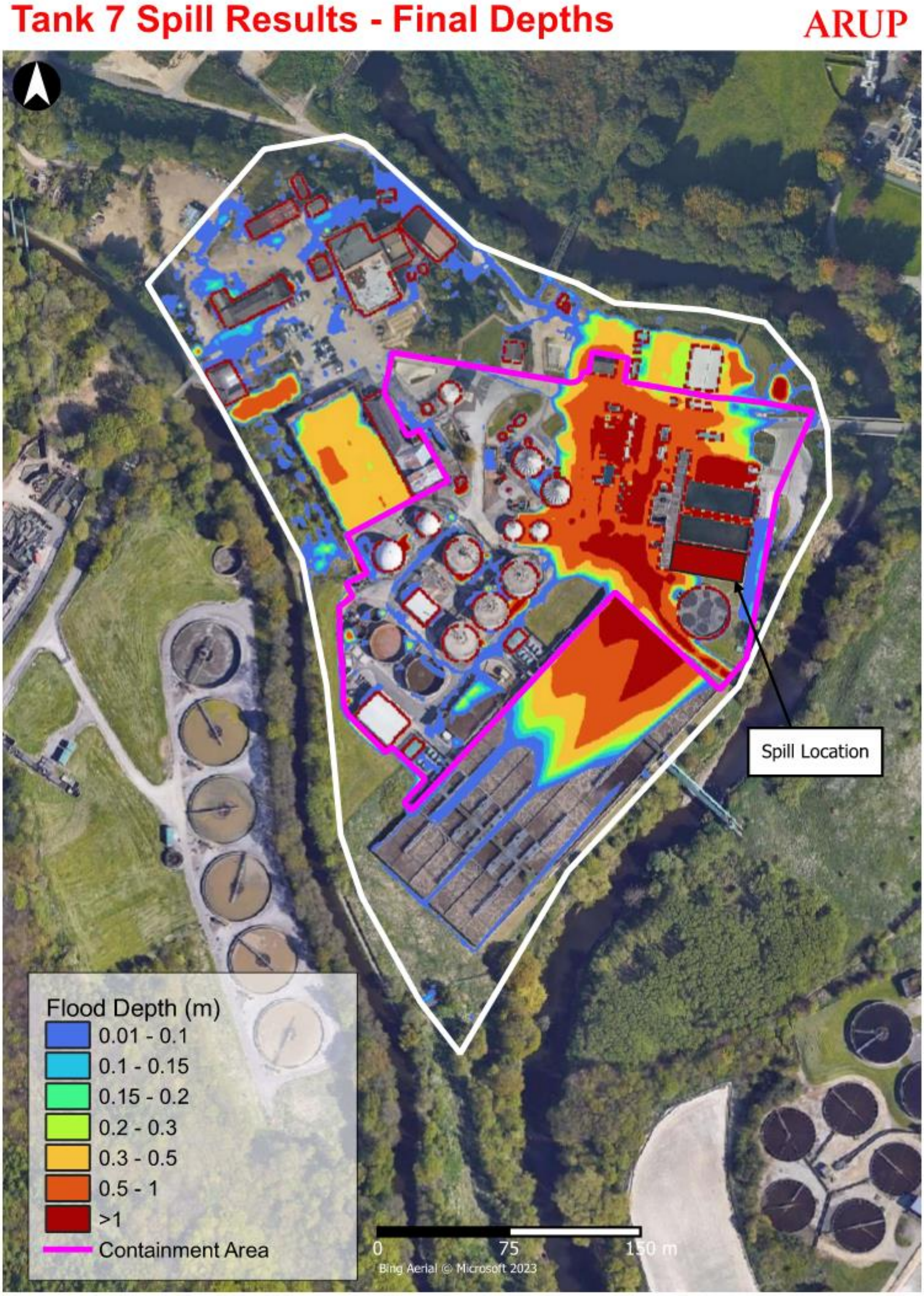

Tank 3 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 4 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 5 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
Tank Spill Point
0
75
150 m
Bing Aerial © Microsoft 2023

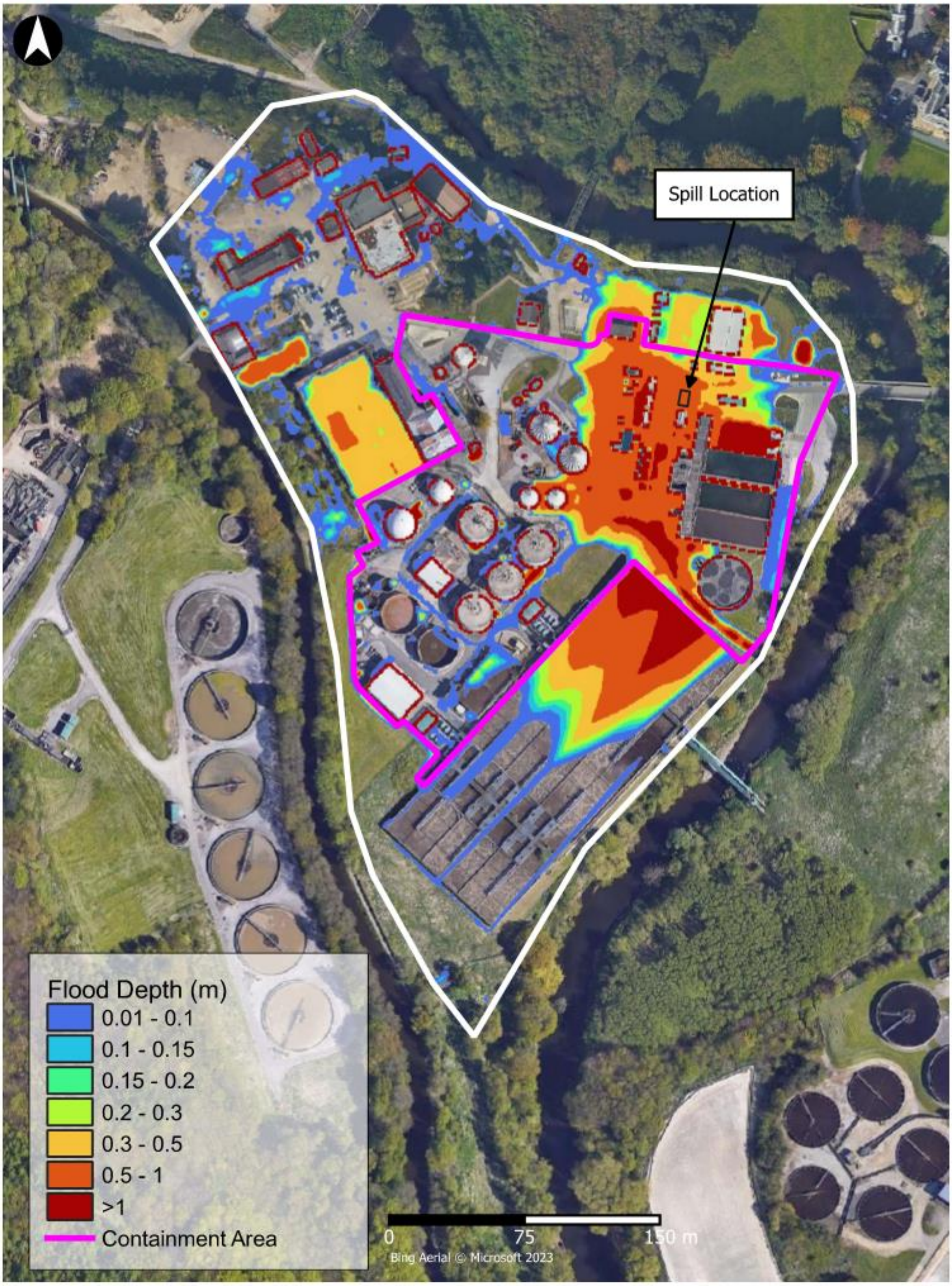

Tank 6 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

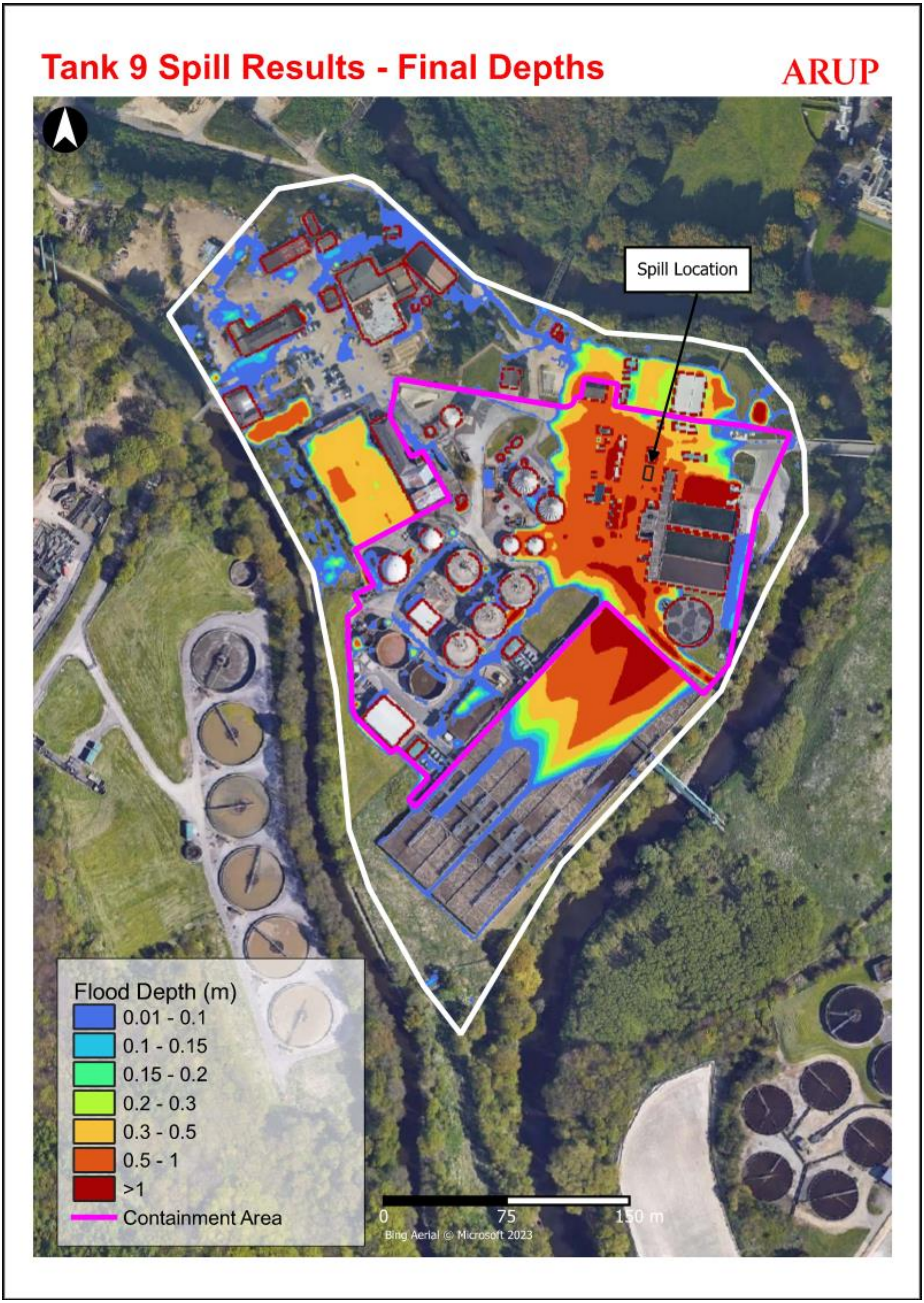
# Tank 7 Spill Results - Final Depths

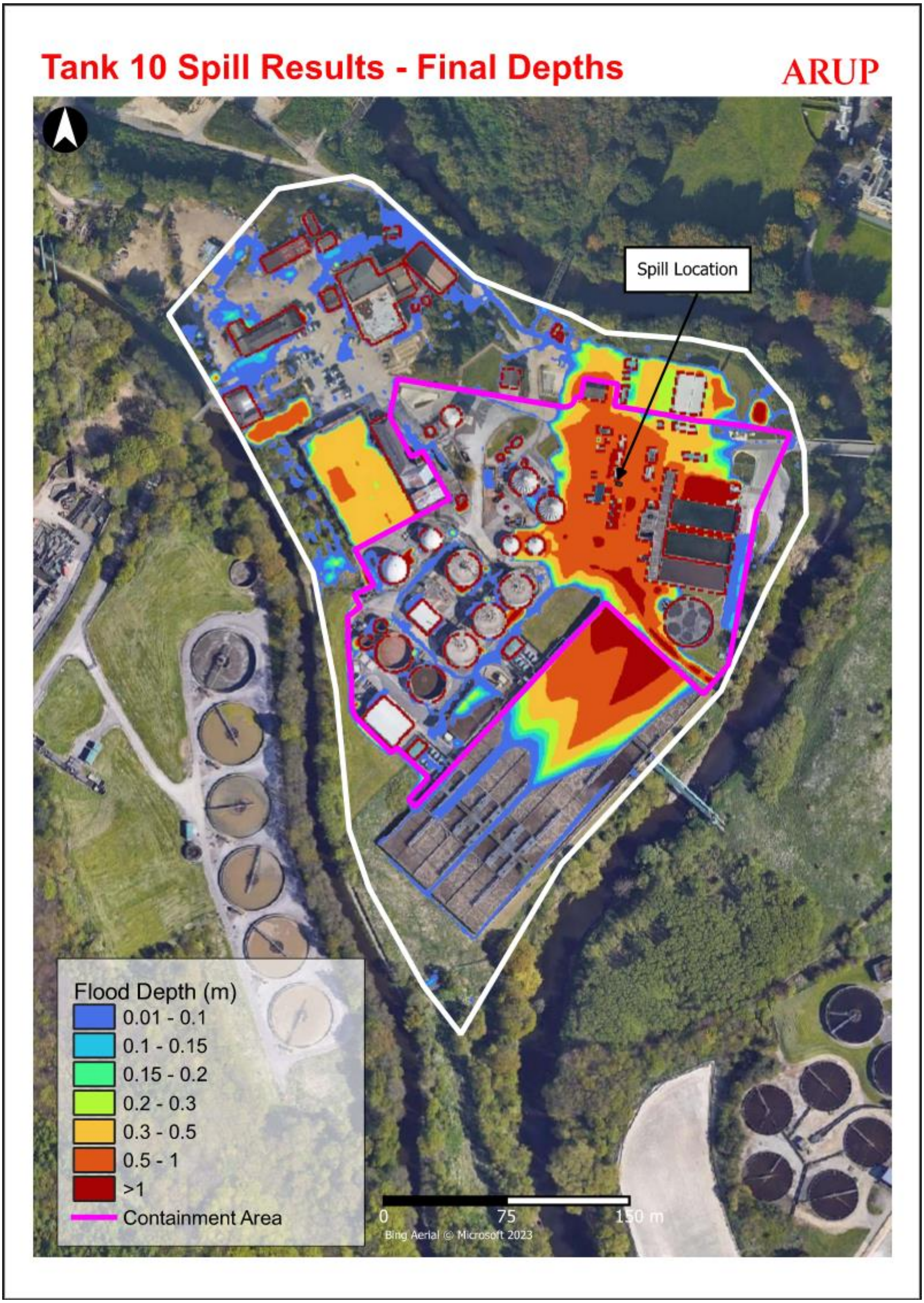


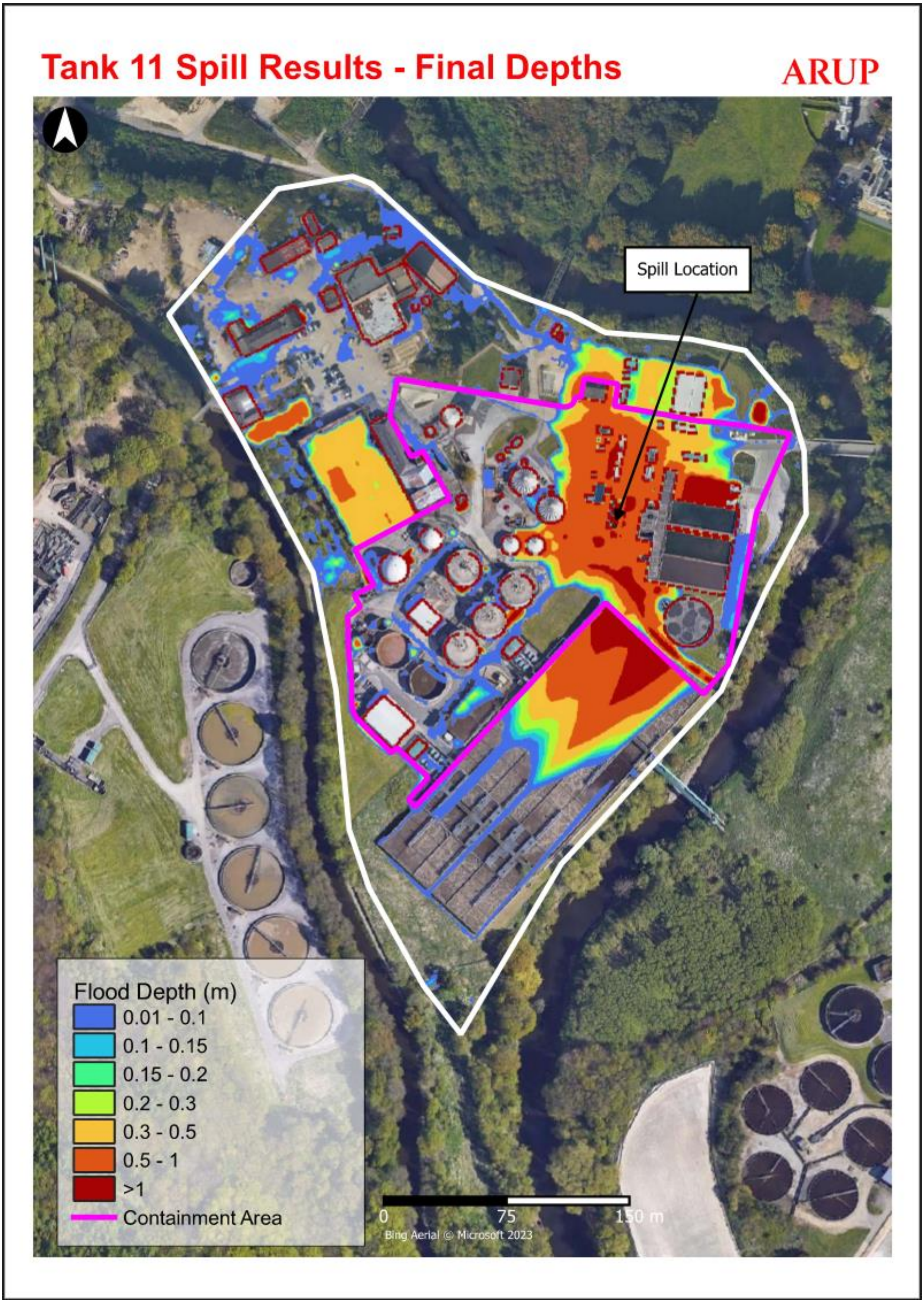
# Tank 8 Spill Results - Final Depths

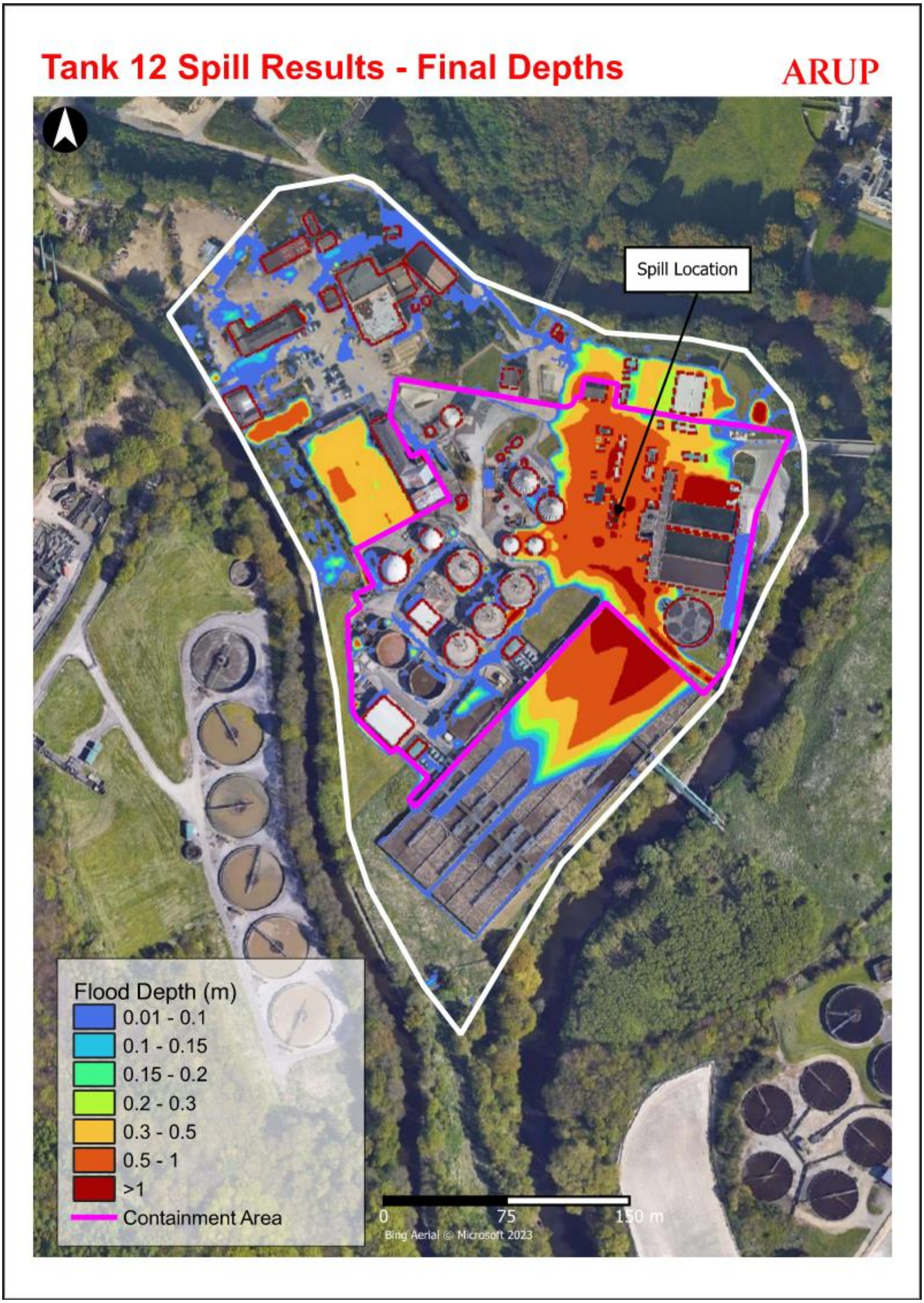
ARUP




Tank 9 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

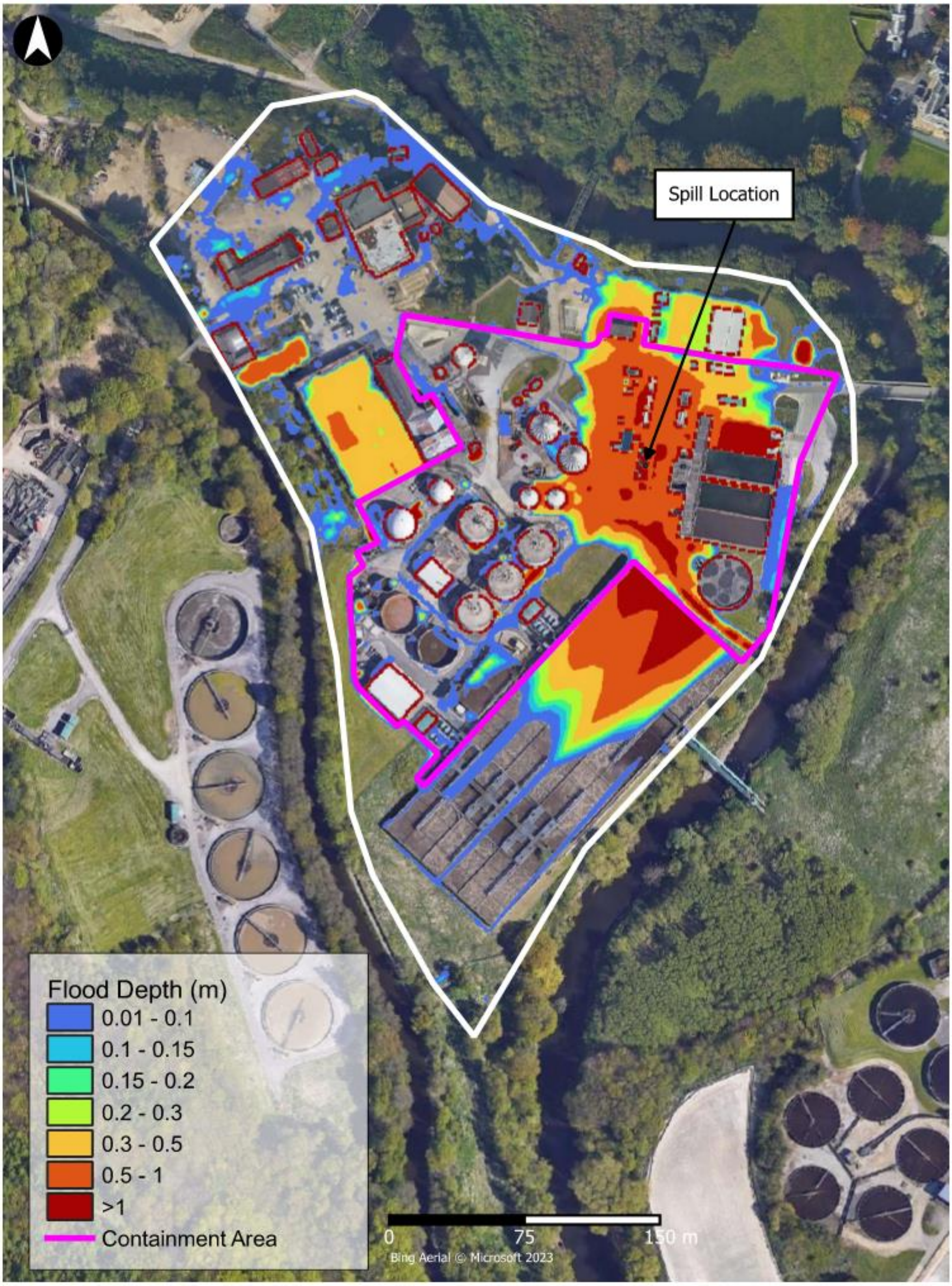

Tank 10 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

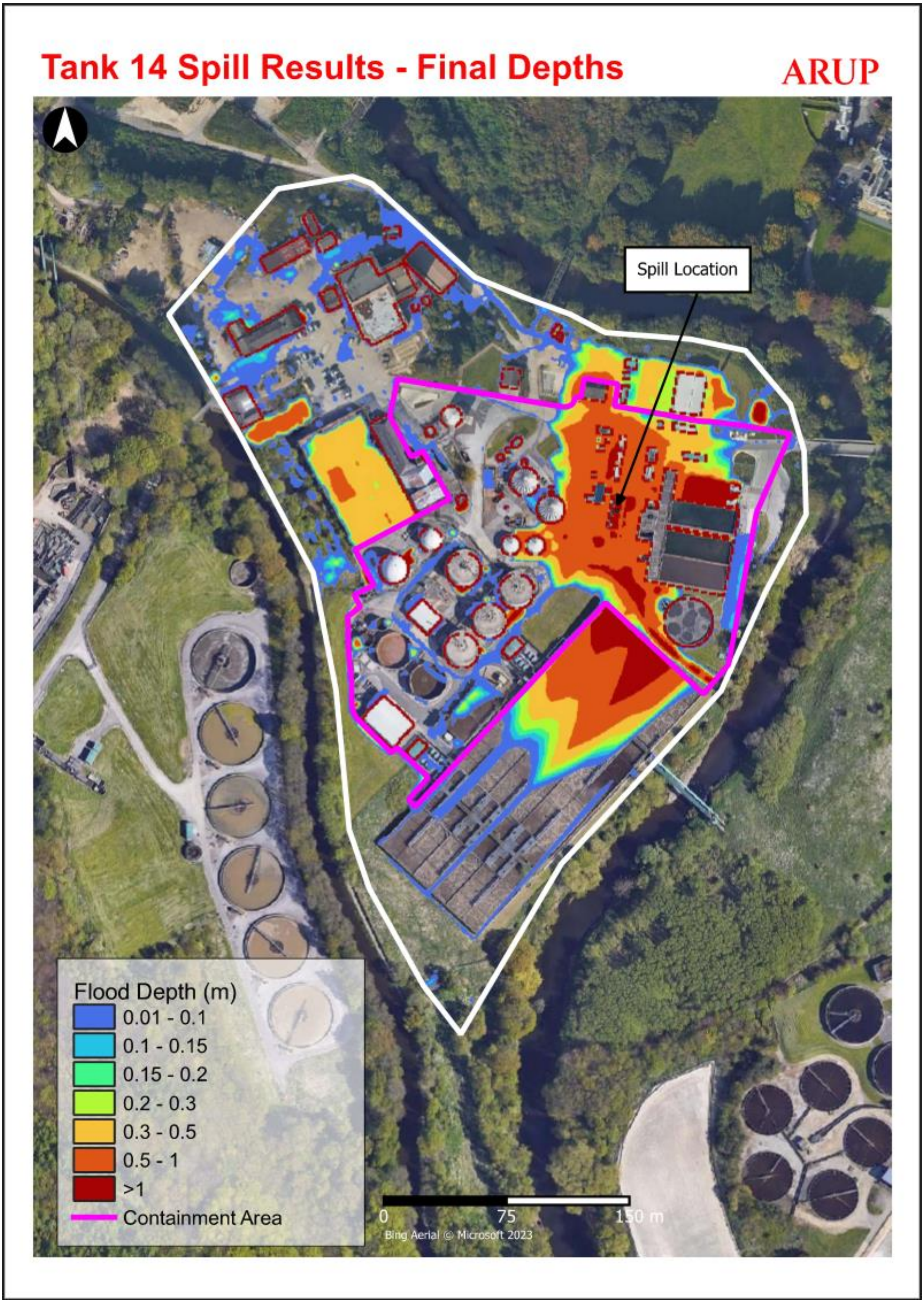

Tank 11 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

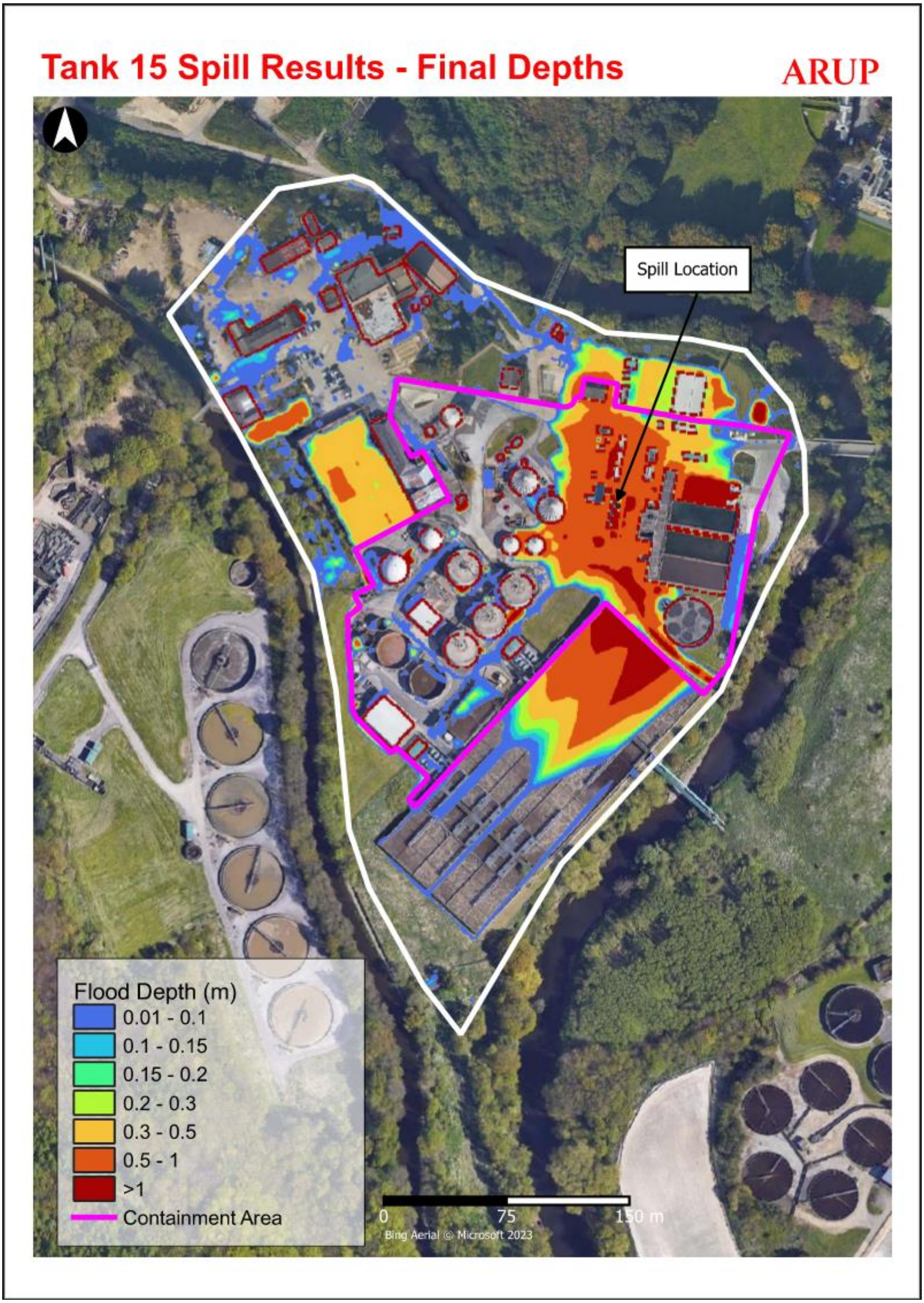

Tank 12 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

# Tank 13 Spill Results - Final Depths

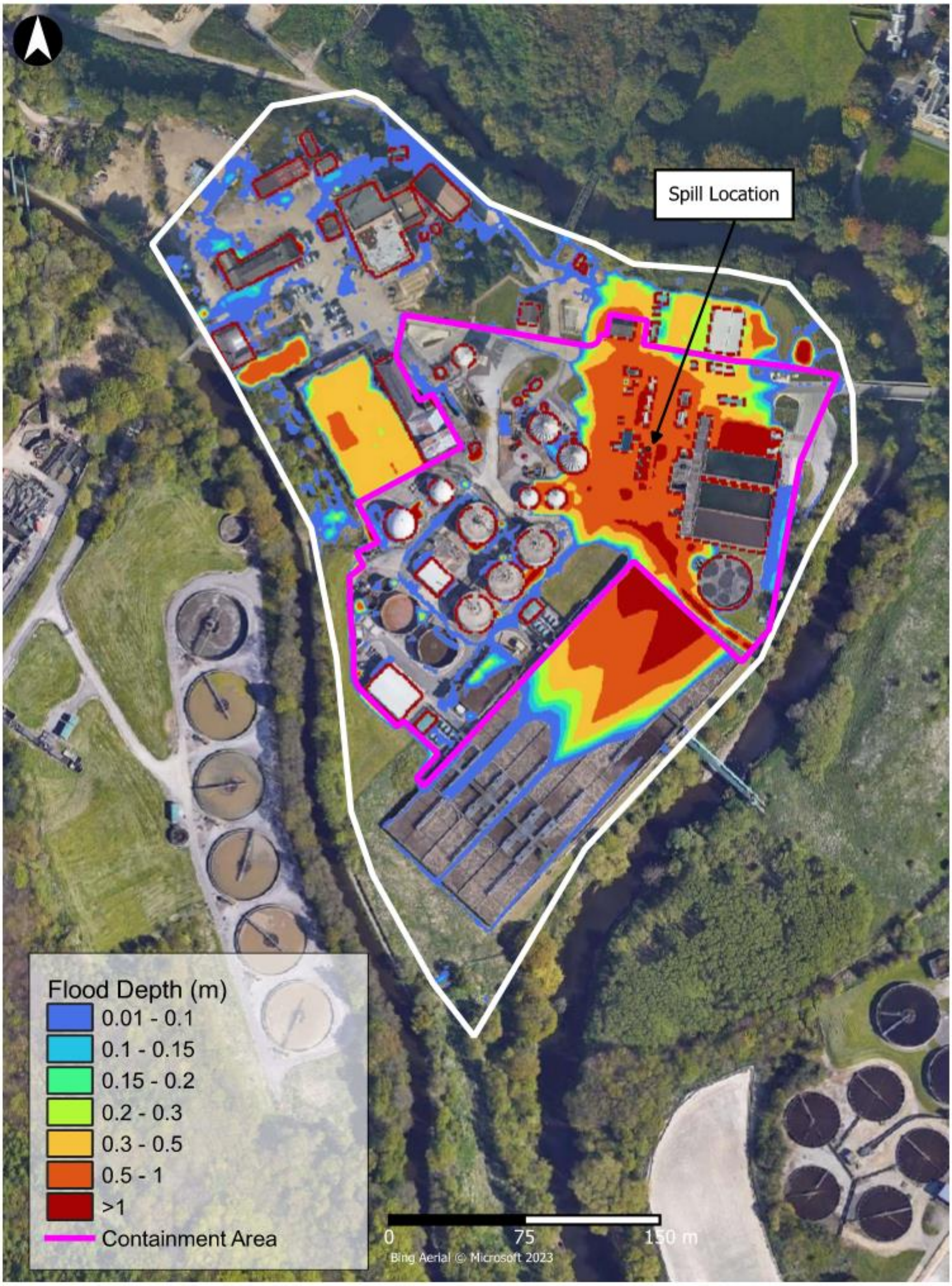
ARUP

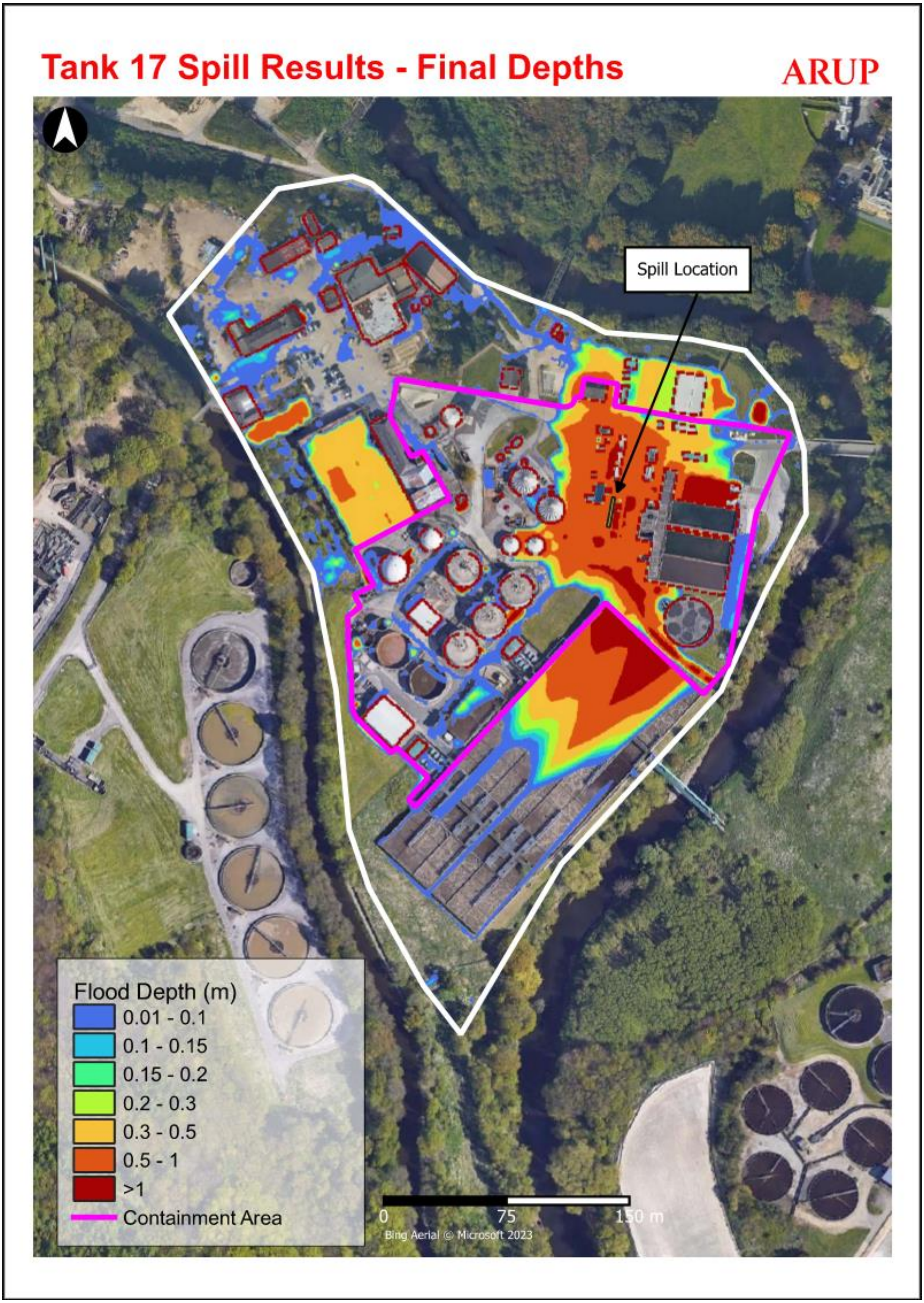


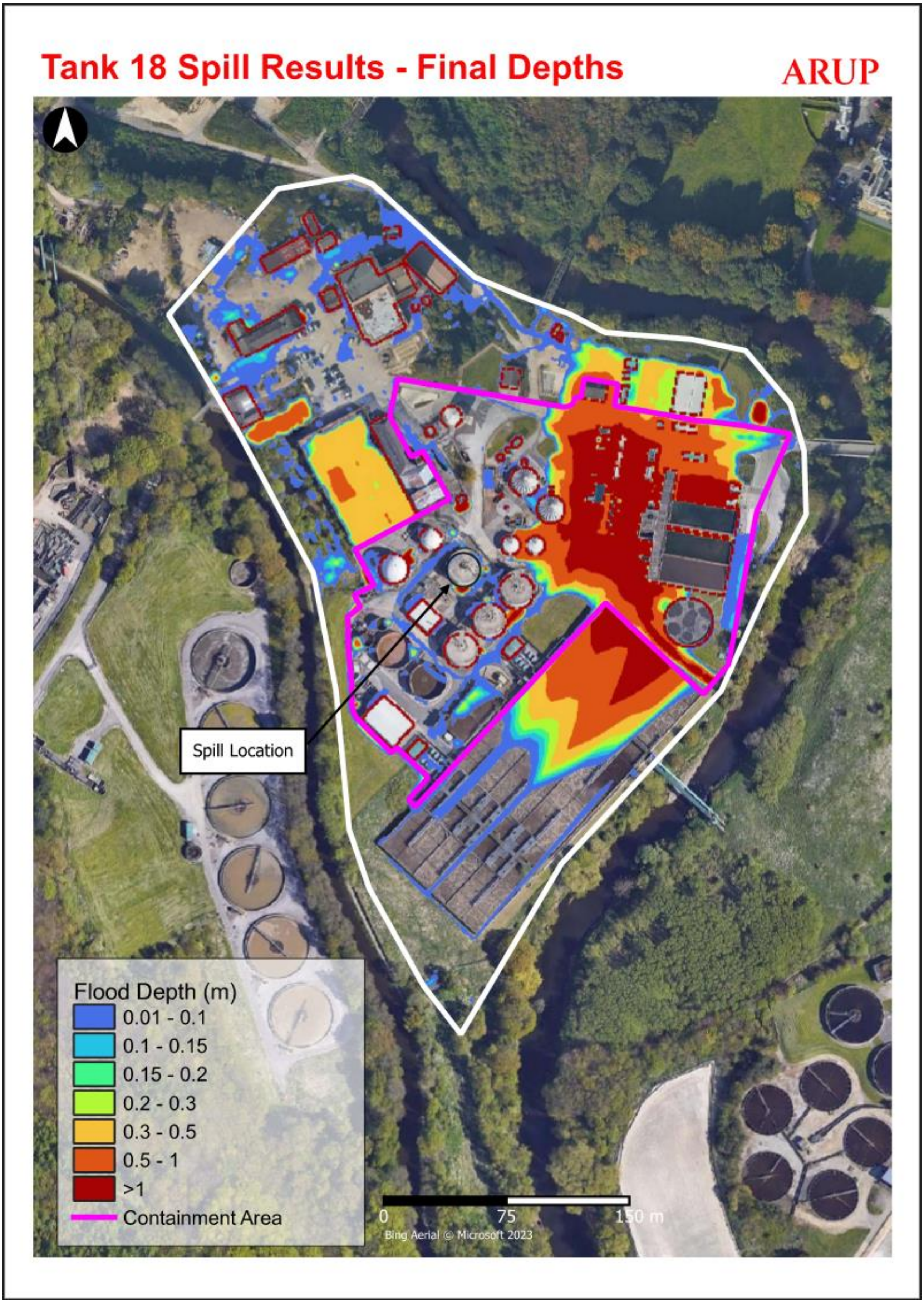

Tank 14 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

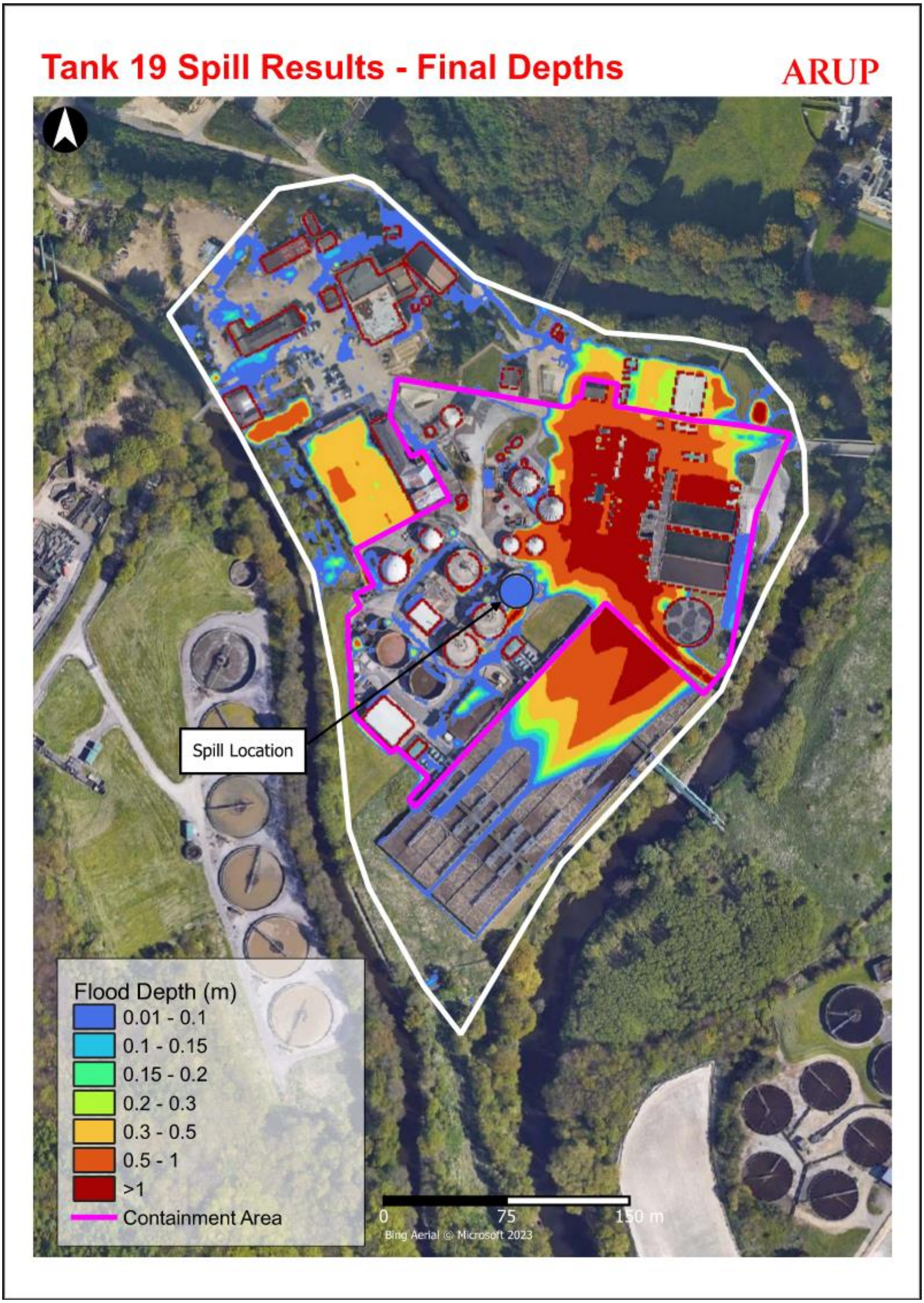

Tank 15 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

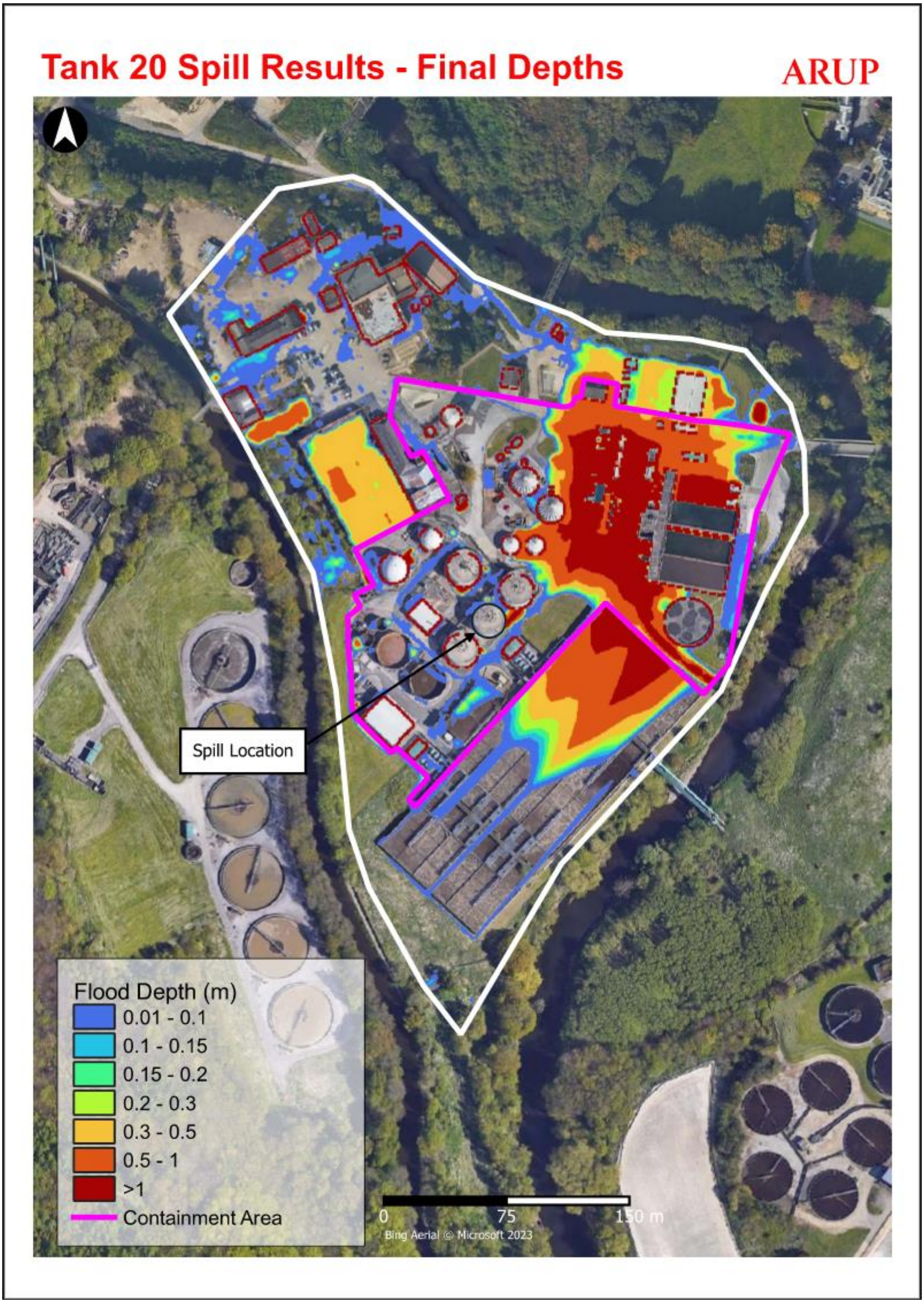
**Tank 16 Spill Results - Final Depths** ARUP

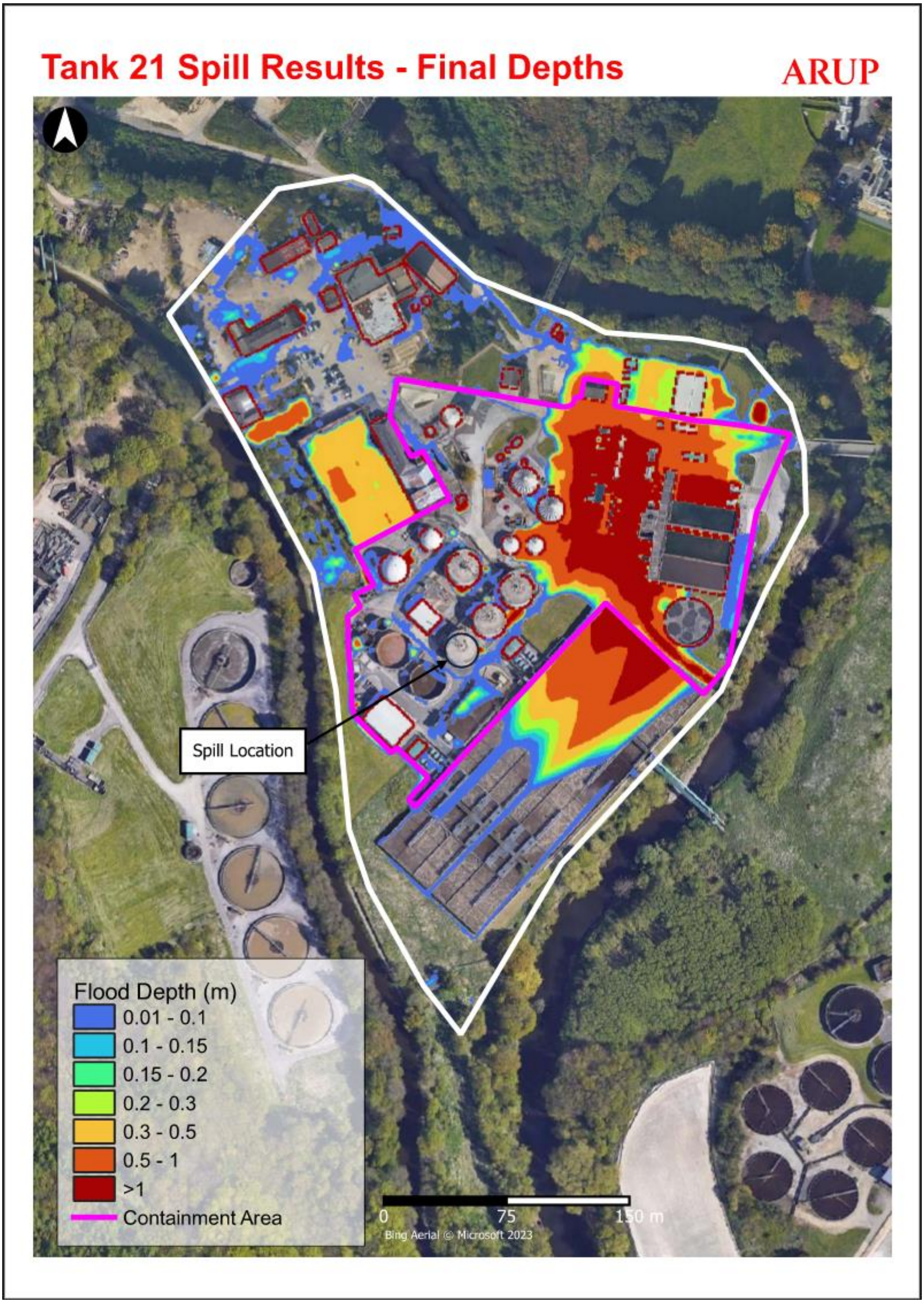


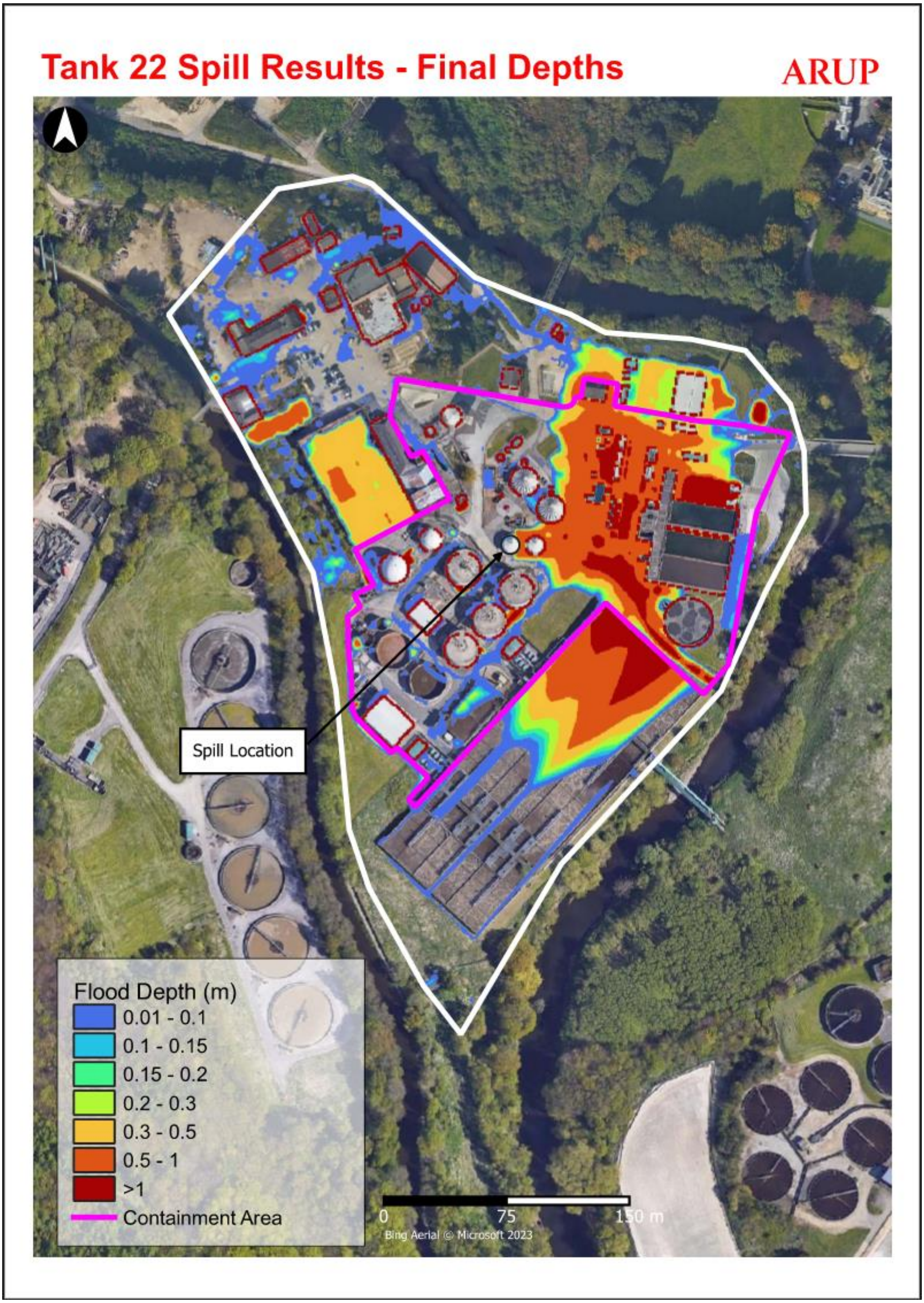

Tank 17 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

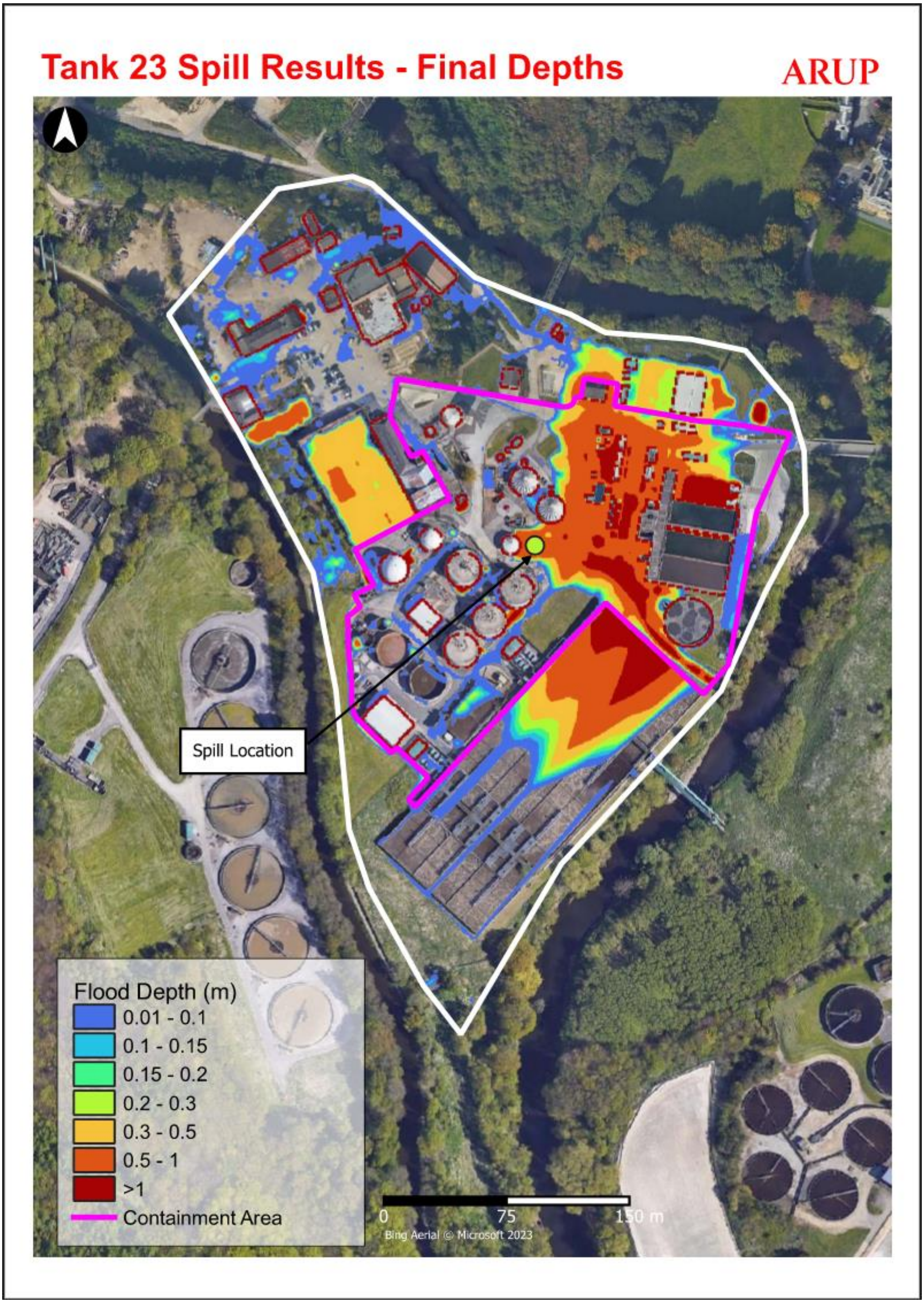

Tank 18 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 19 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 20 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

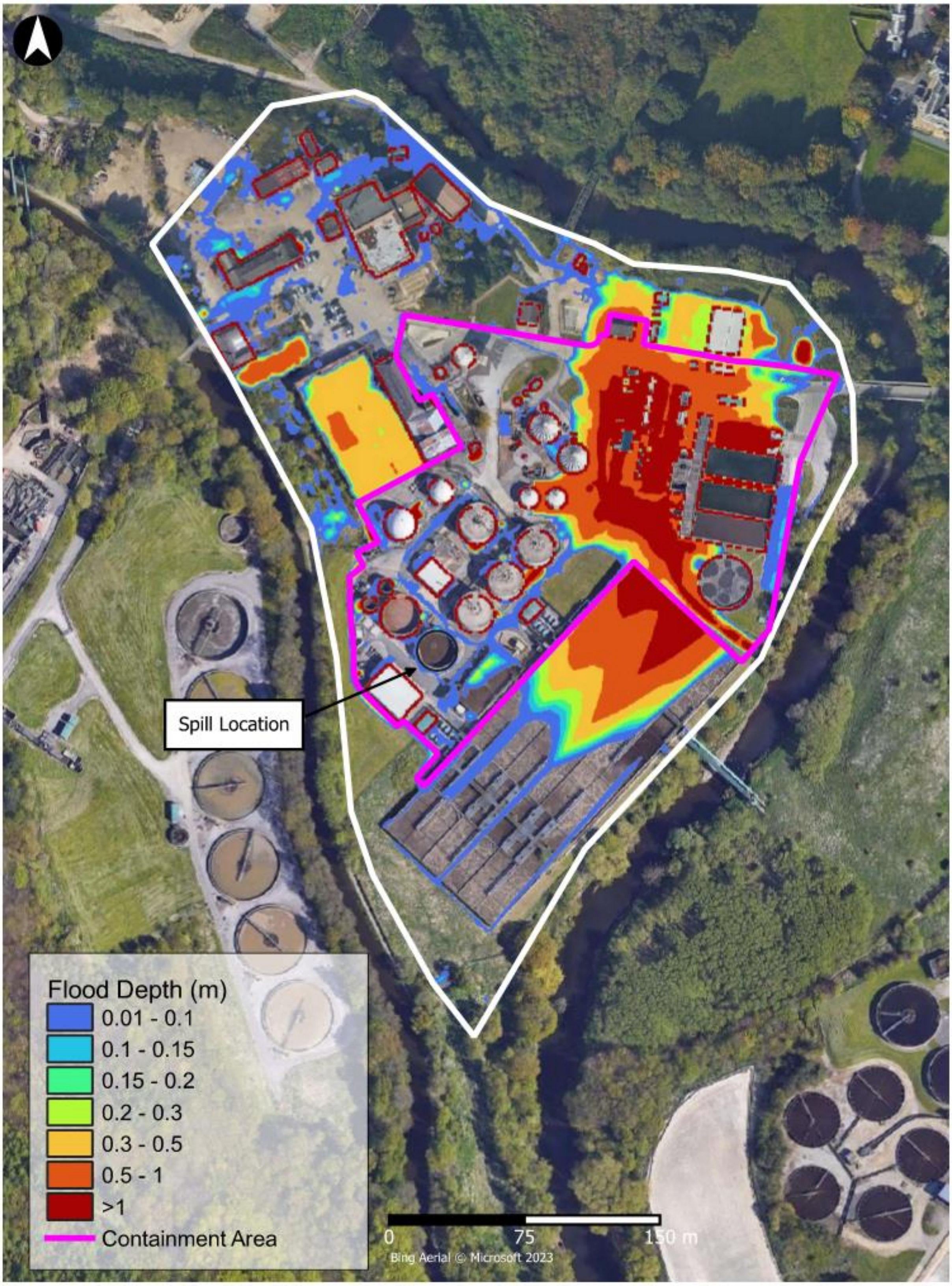

Tank 21 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

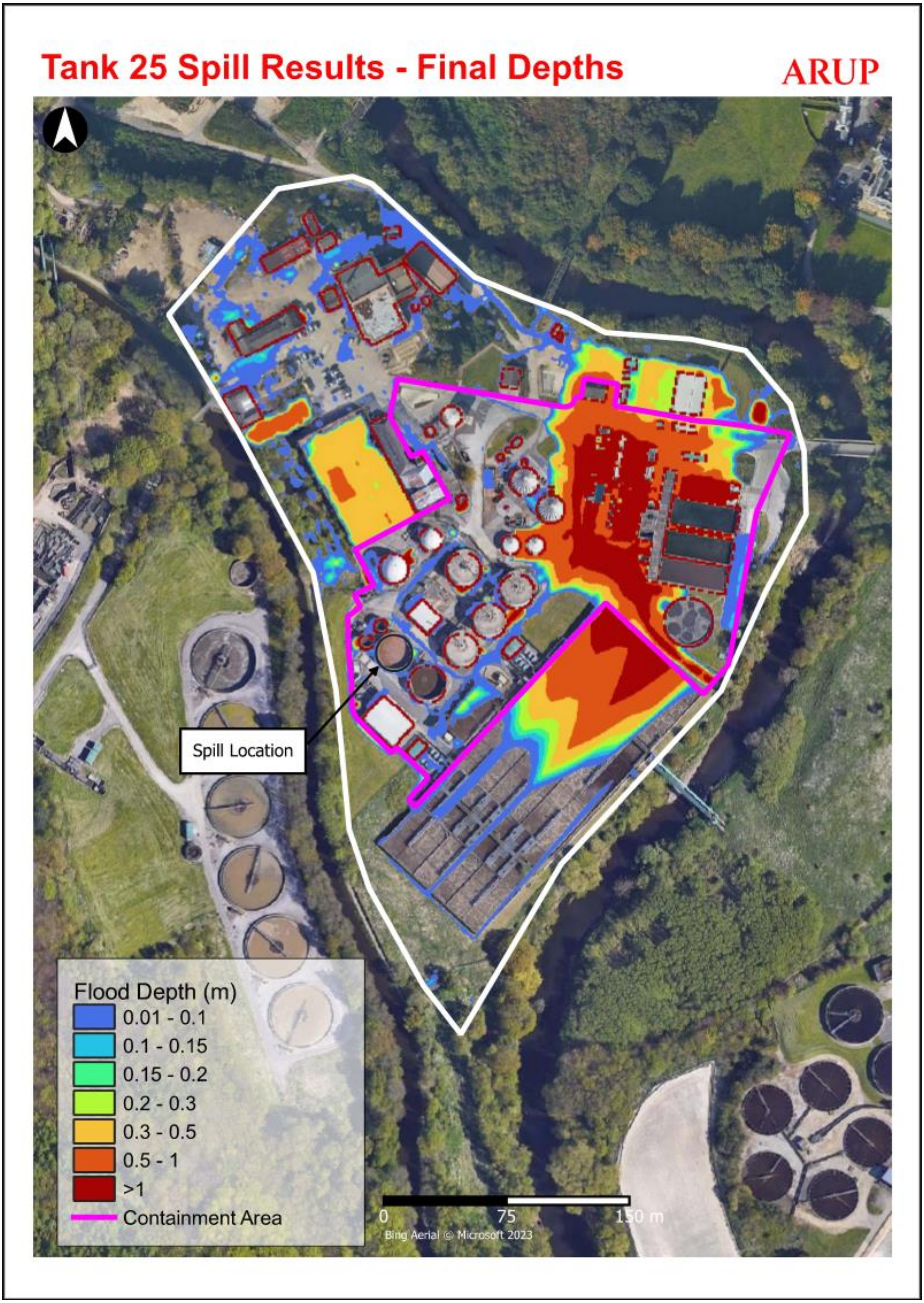

Tank 22 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

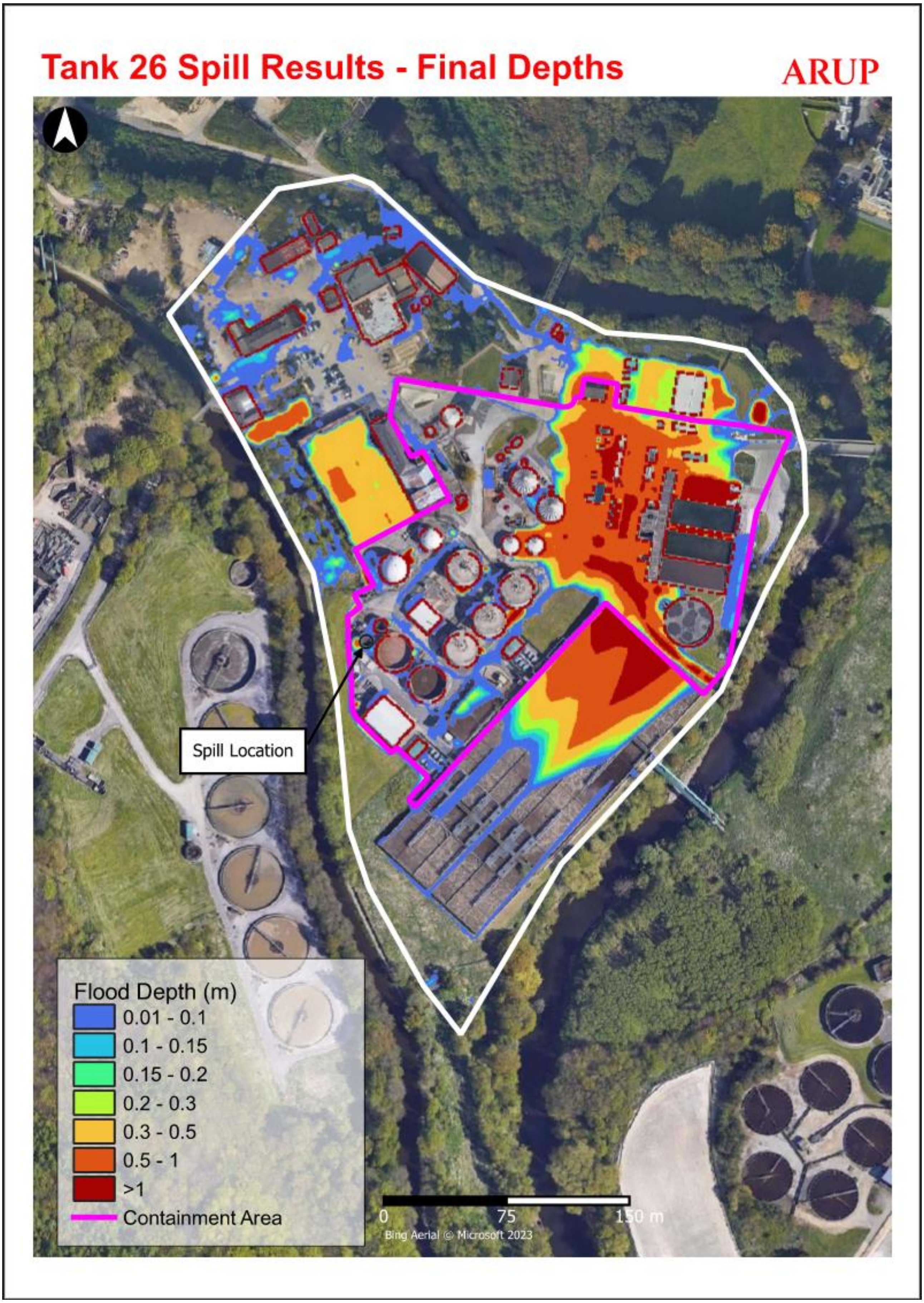

Tank 23 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

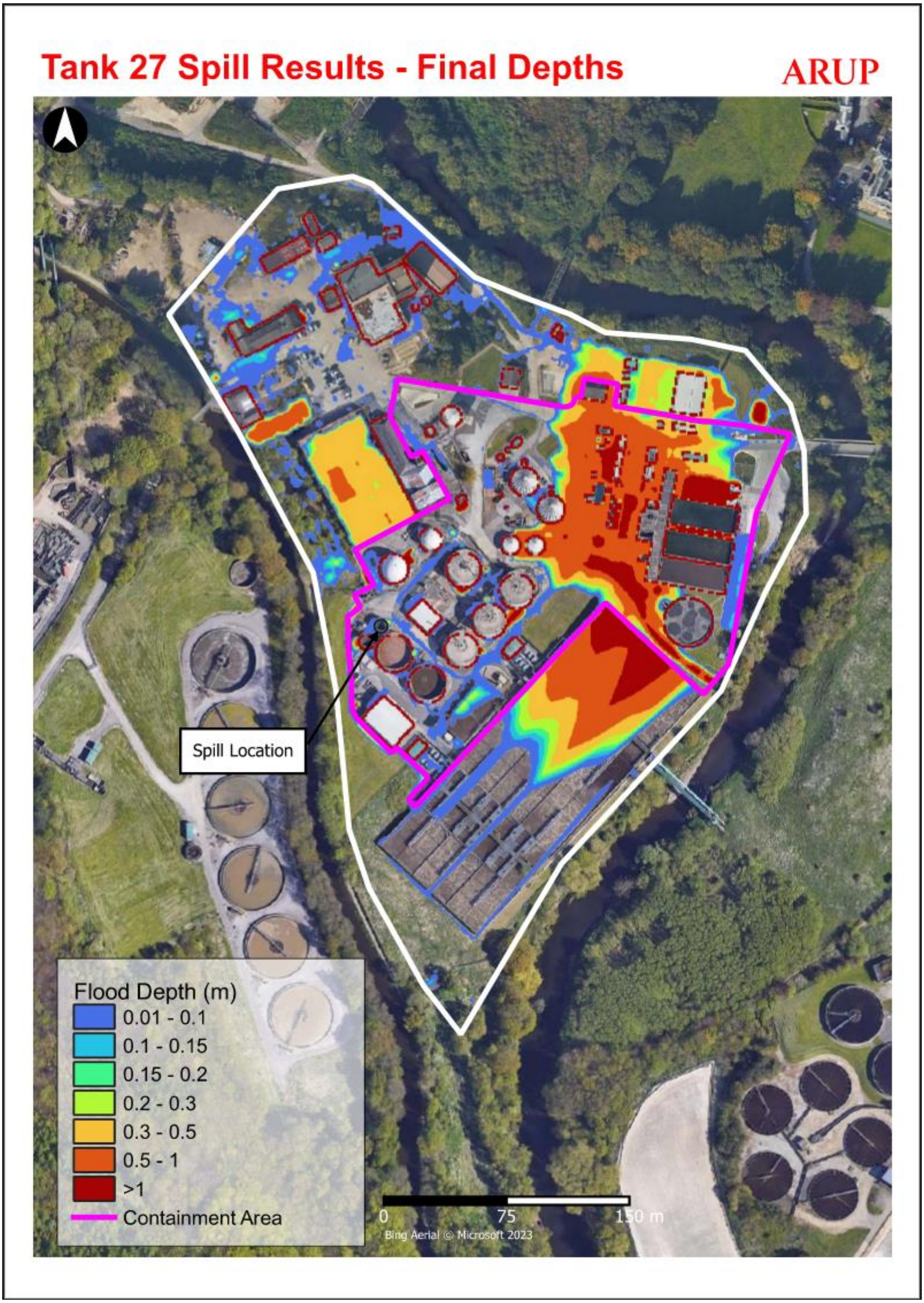
**Tank 24 Spill Results - Final Depths**

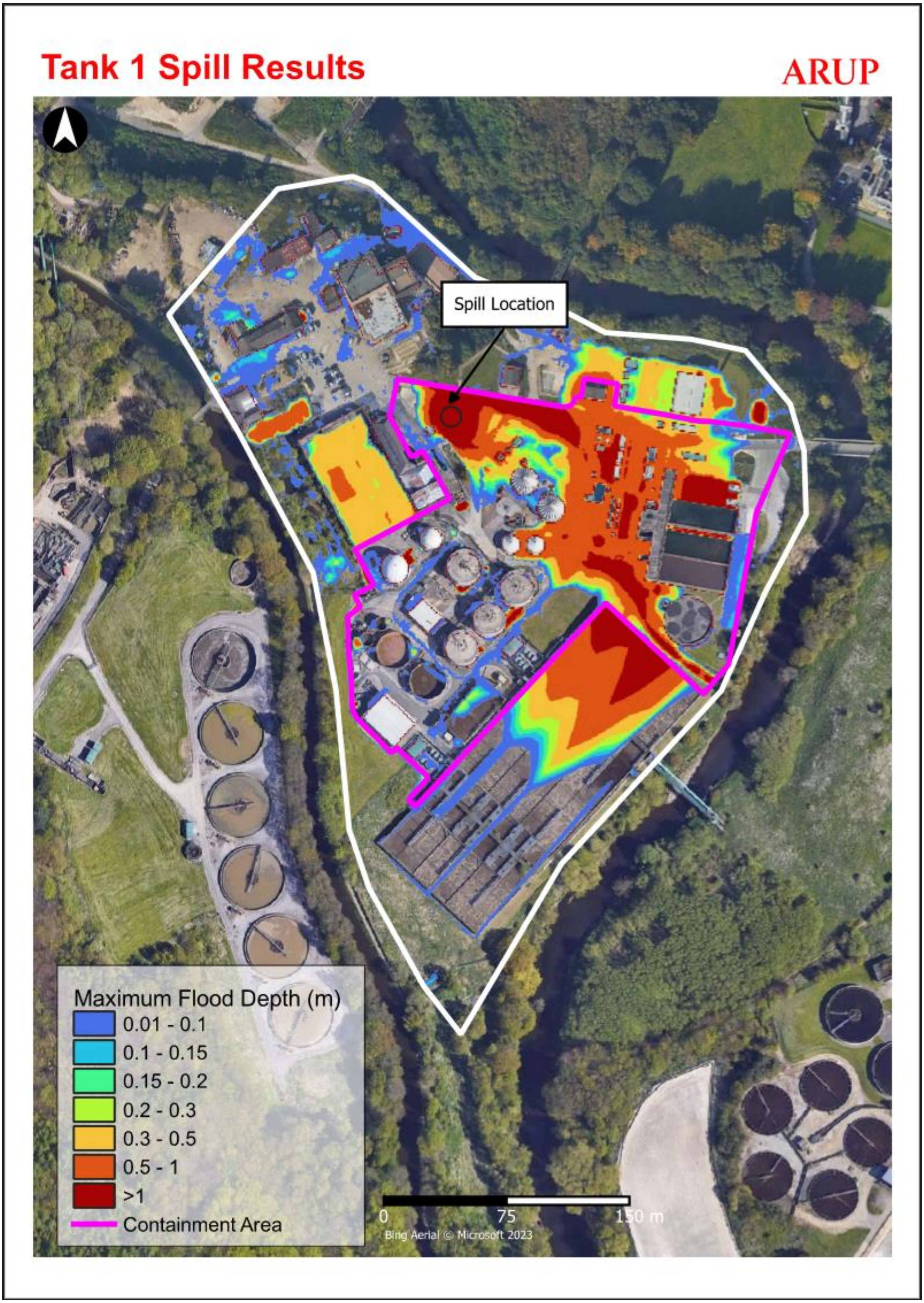
ARUP

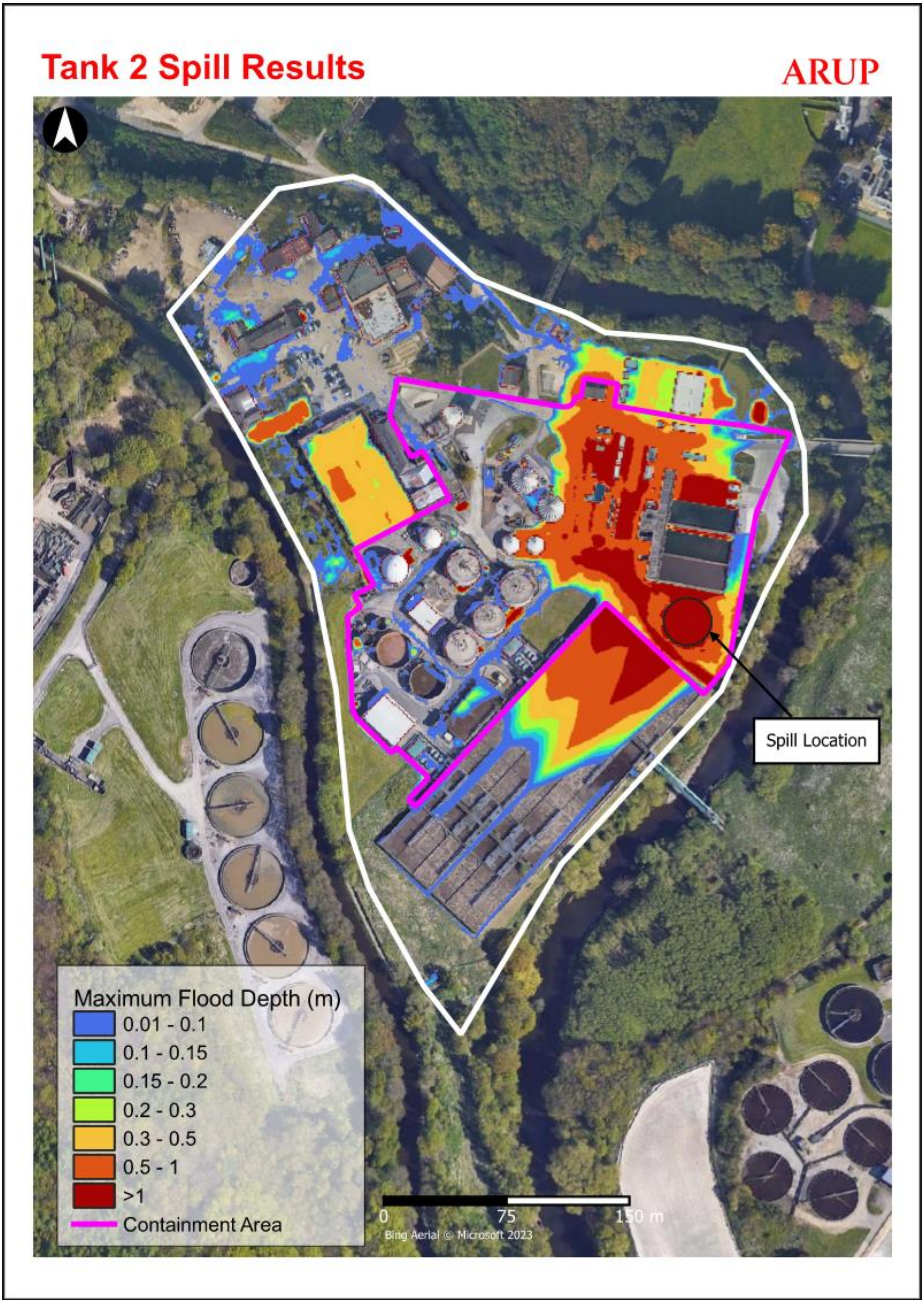


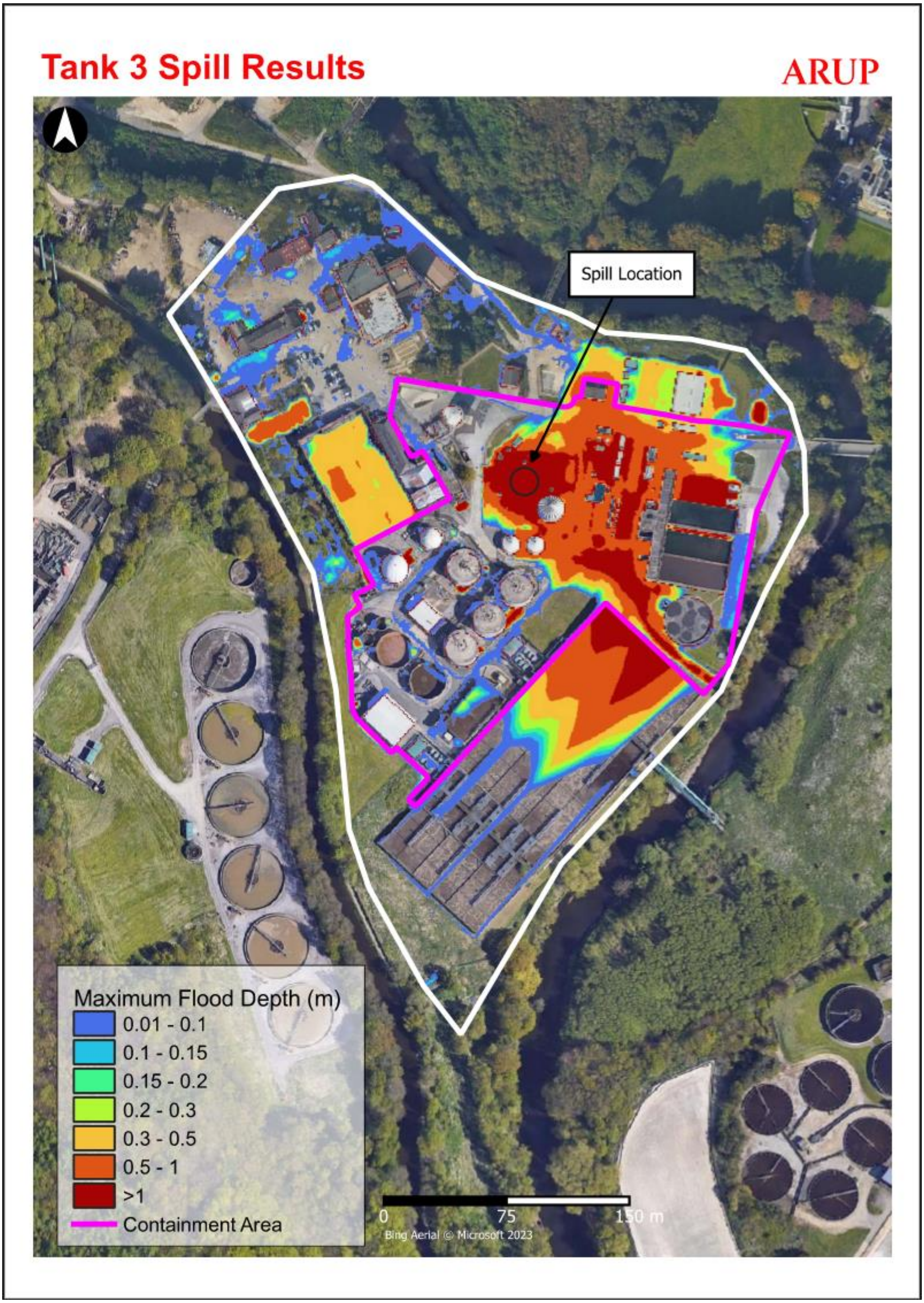

Tank 25 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

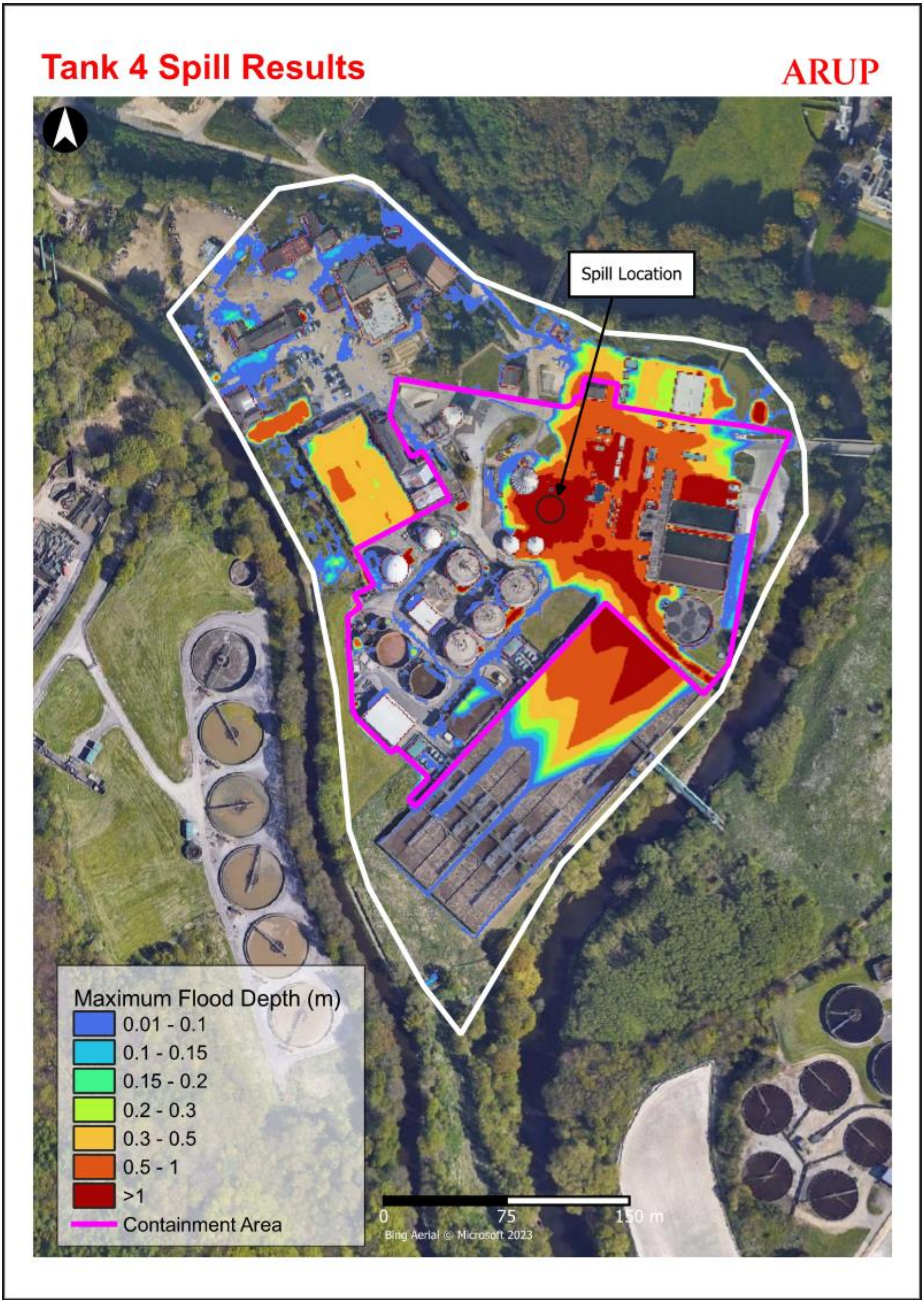

Tank 26 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

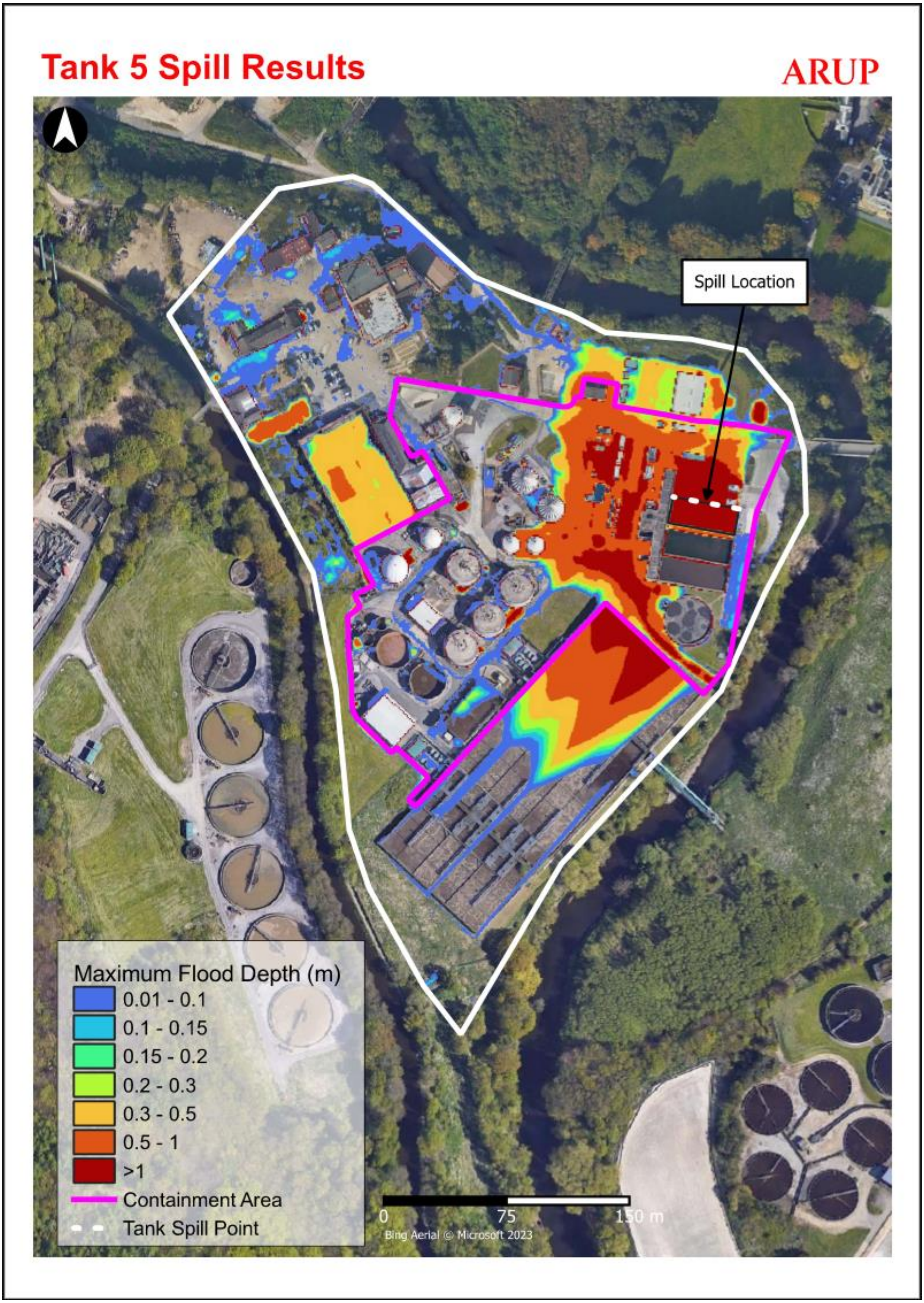

Tank 27 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 1 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

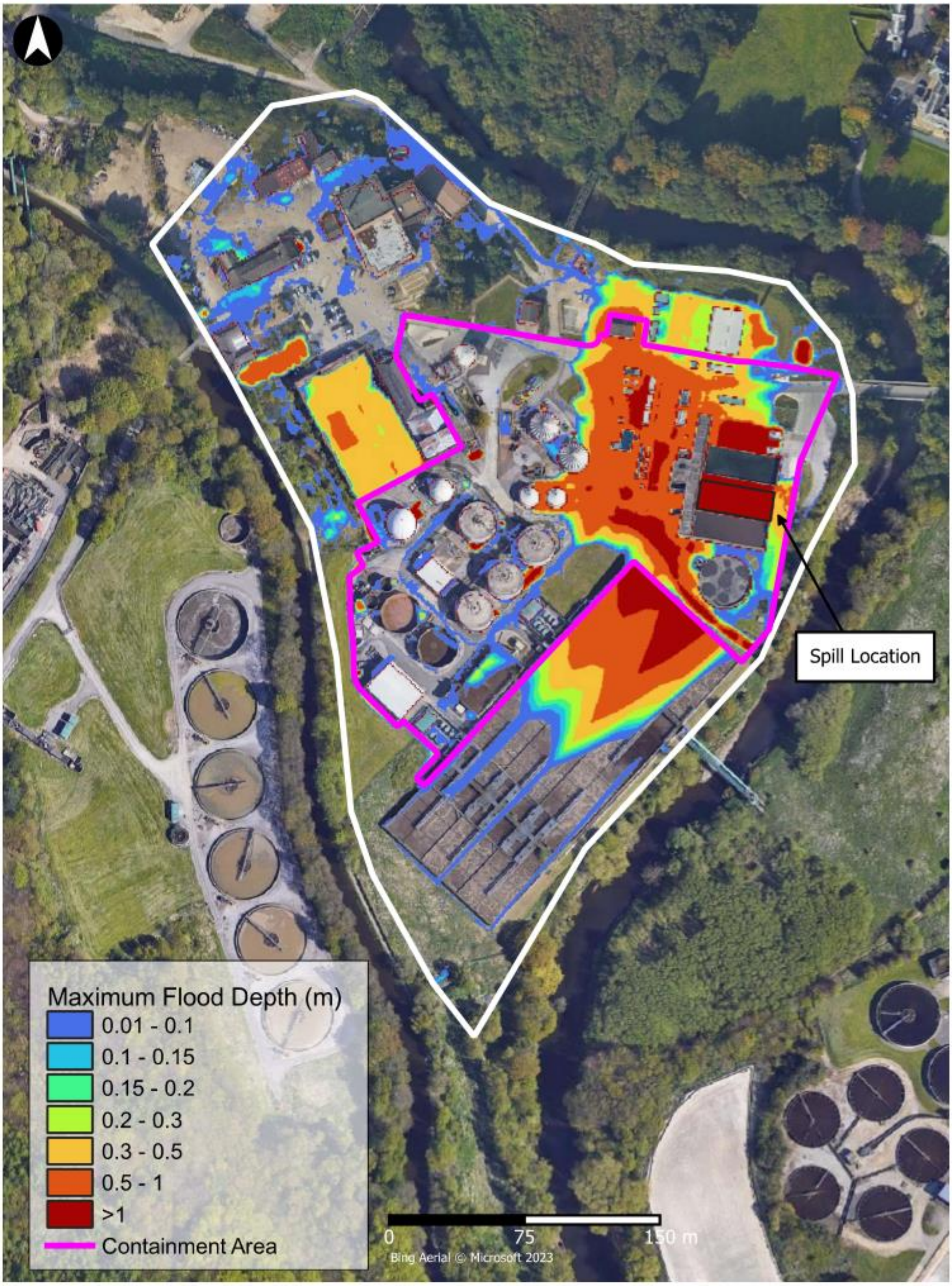

Tank 2 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

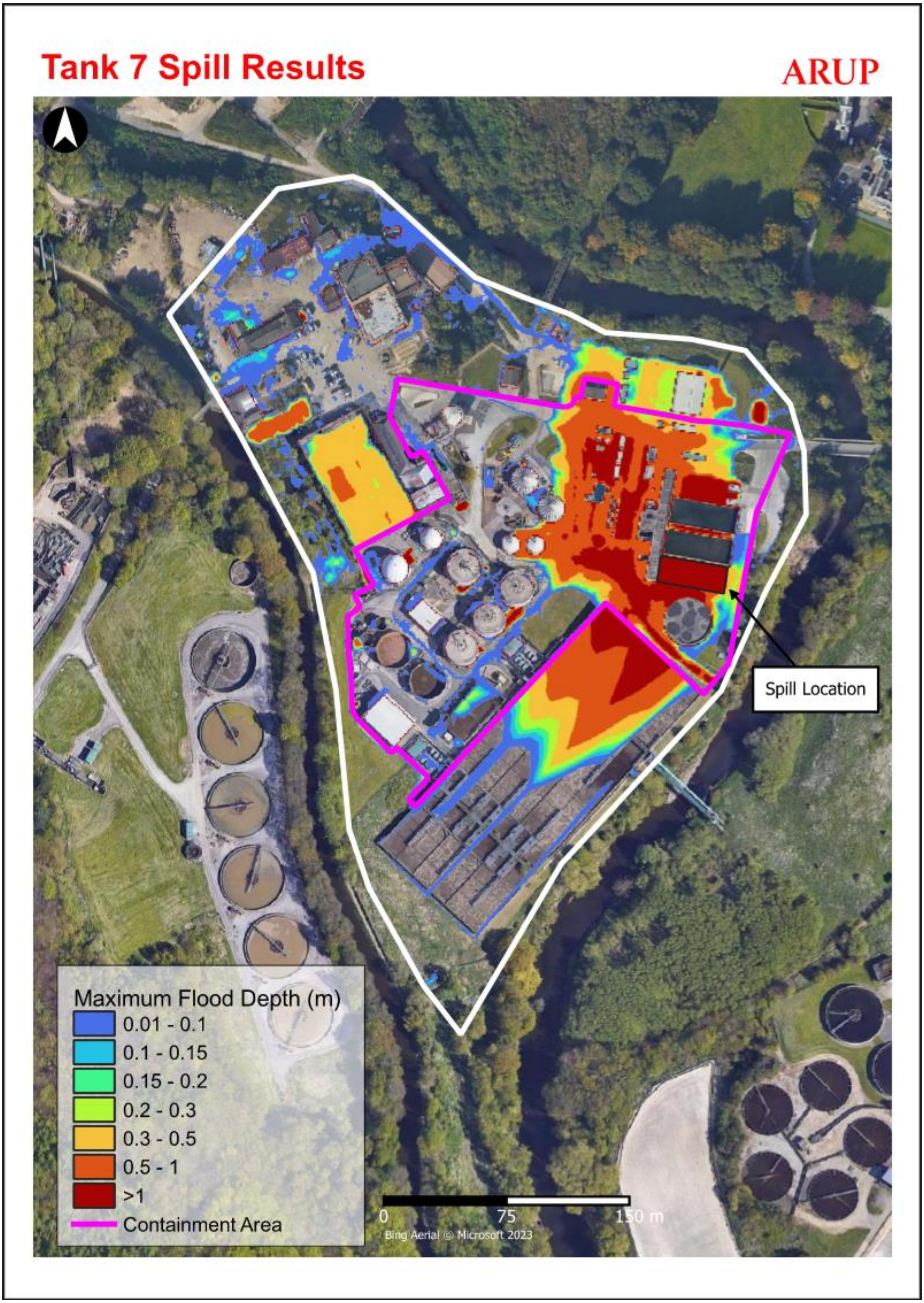

Tank 3 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

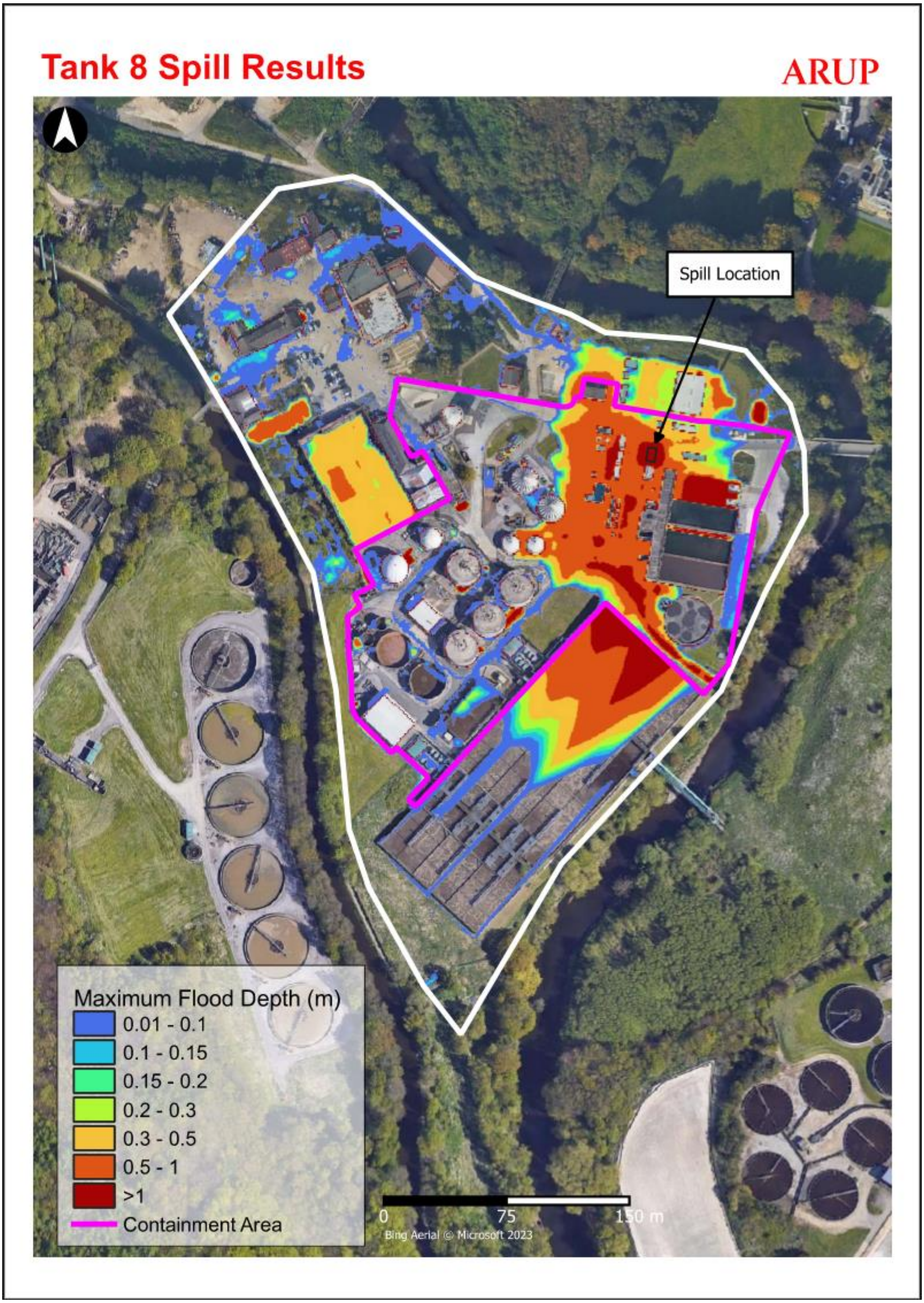

Tank 4 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 5 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
Tank Spill Point
0
75
150 m
Bing Aerial © Microsoft 2023

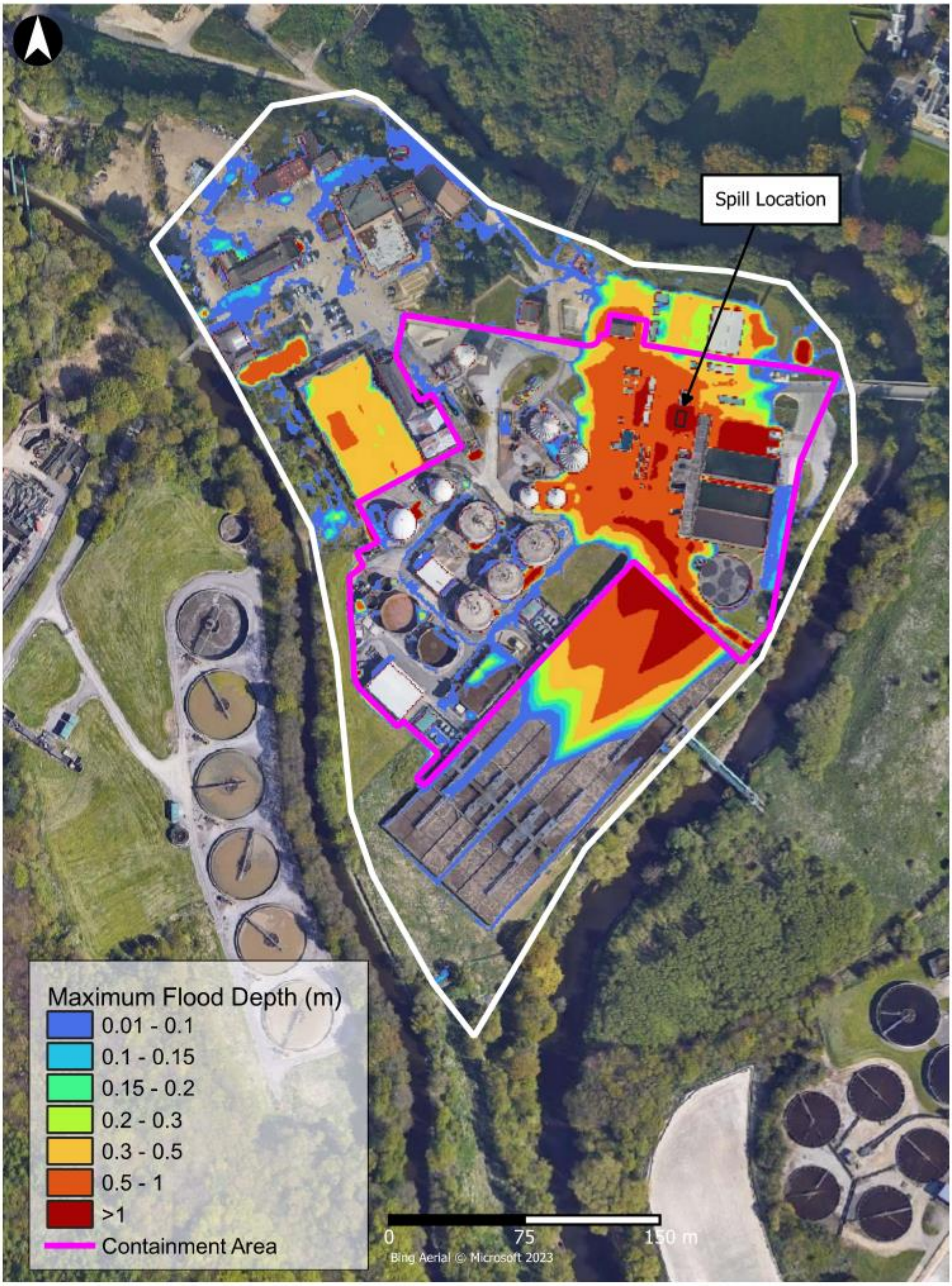
# Tank 6 Spill Results

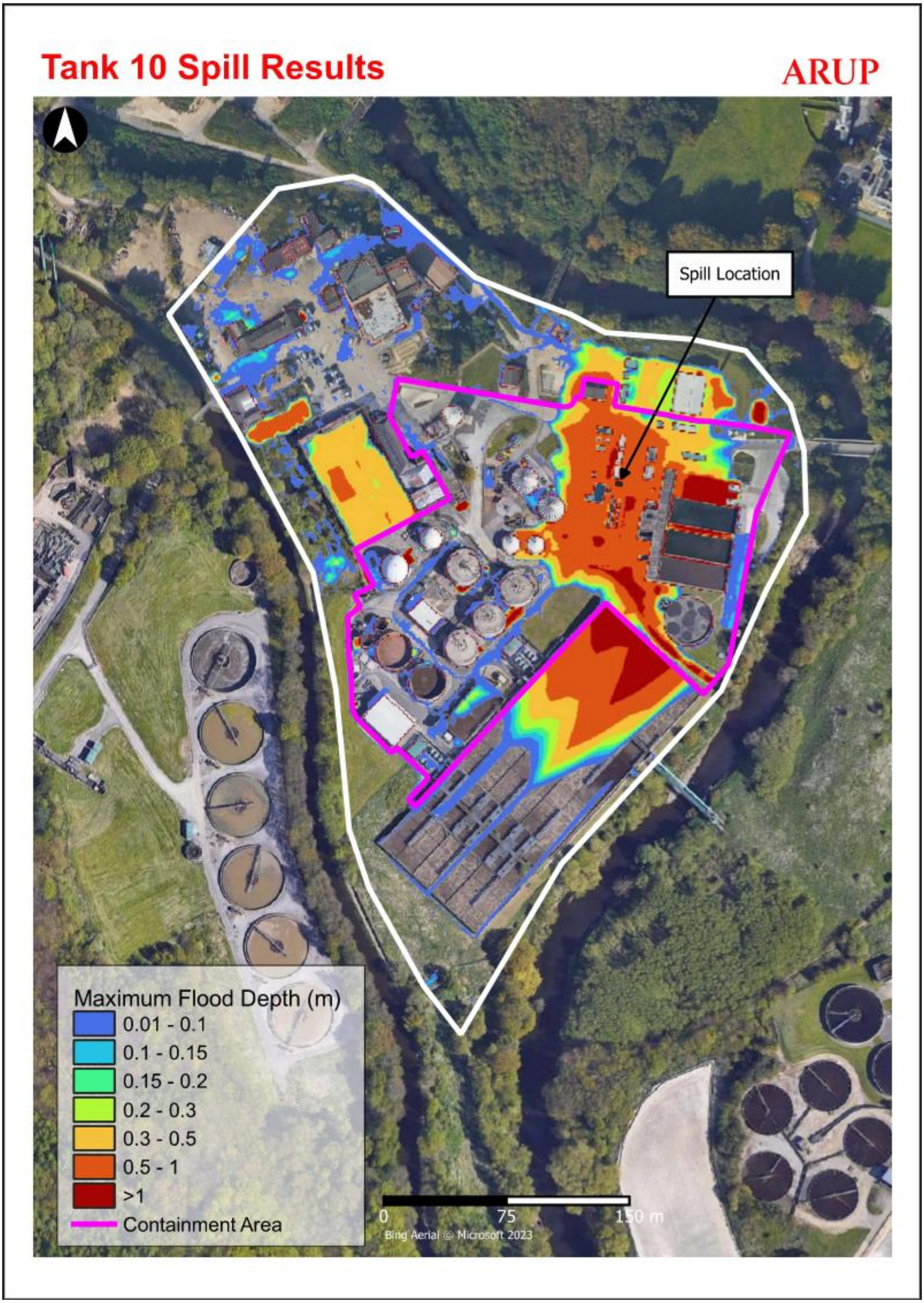


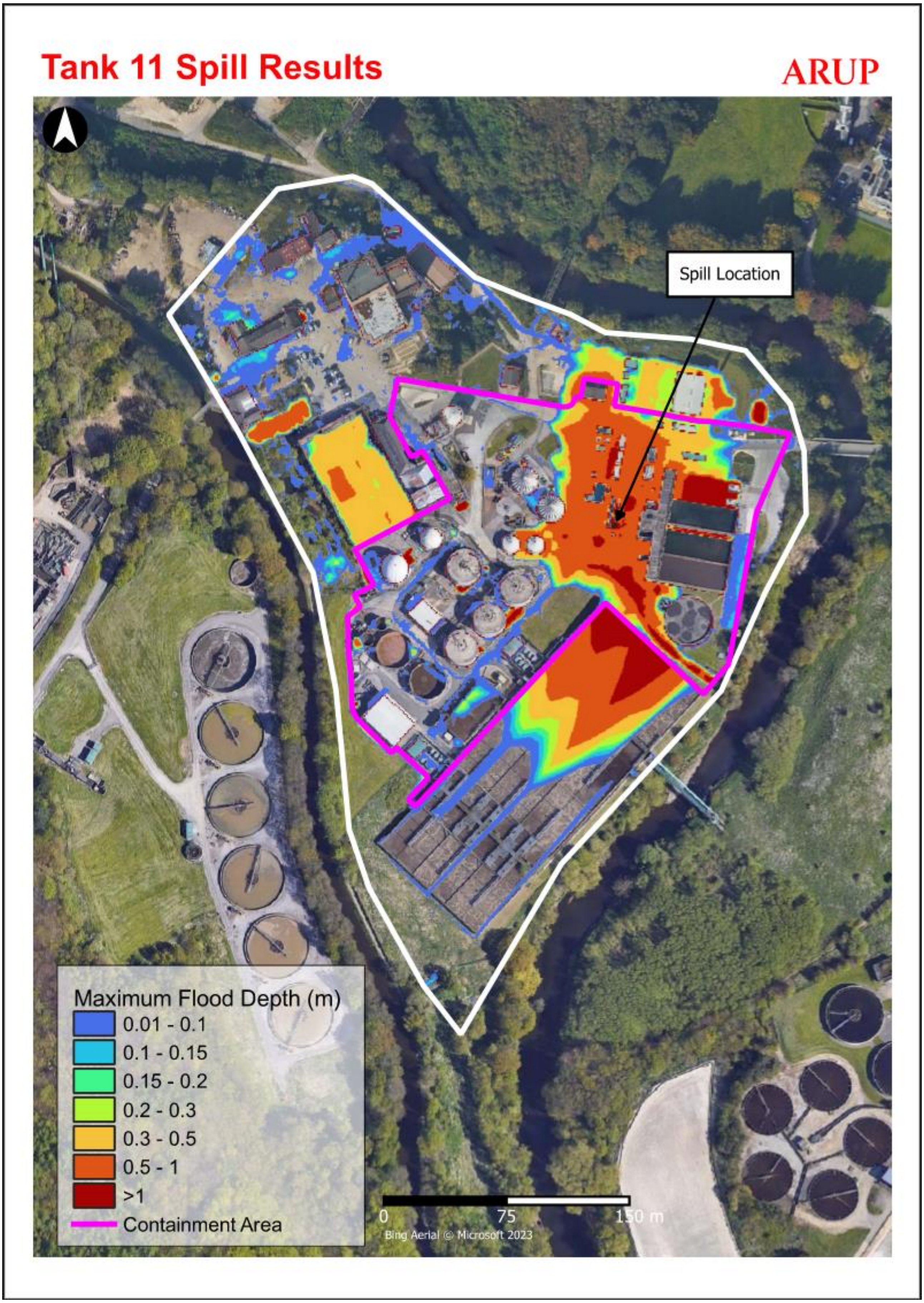

Tank 7 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

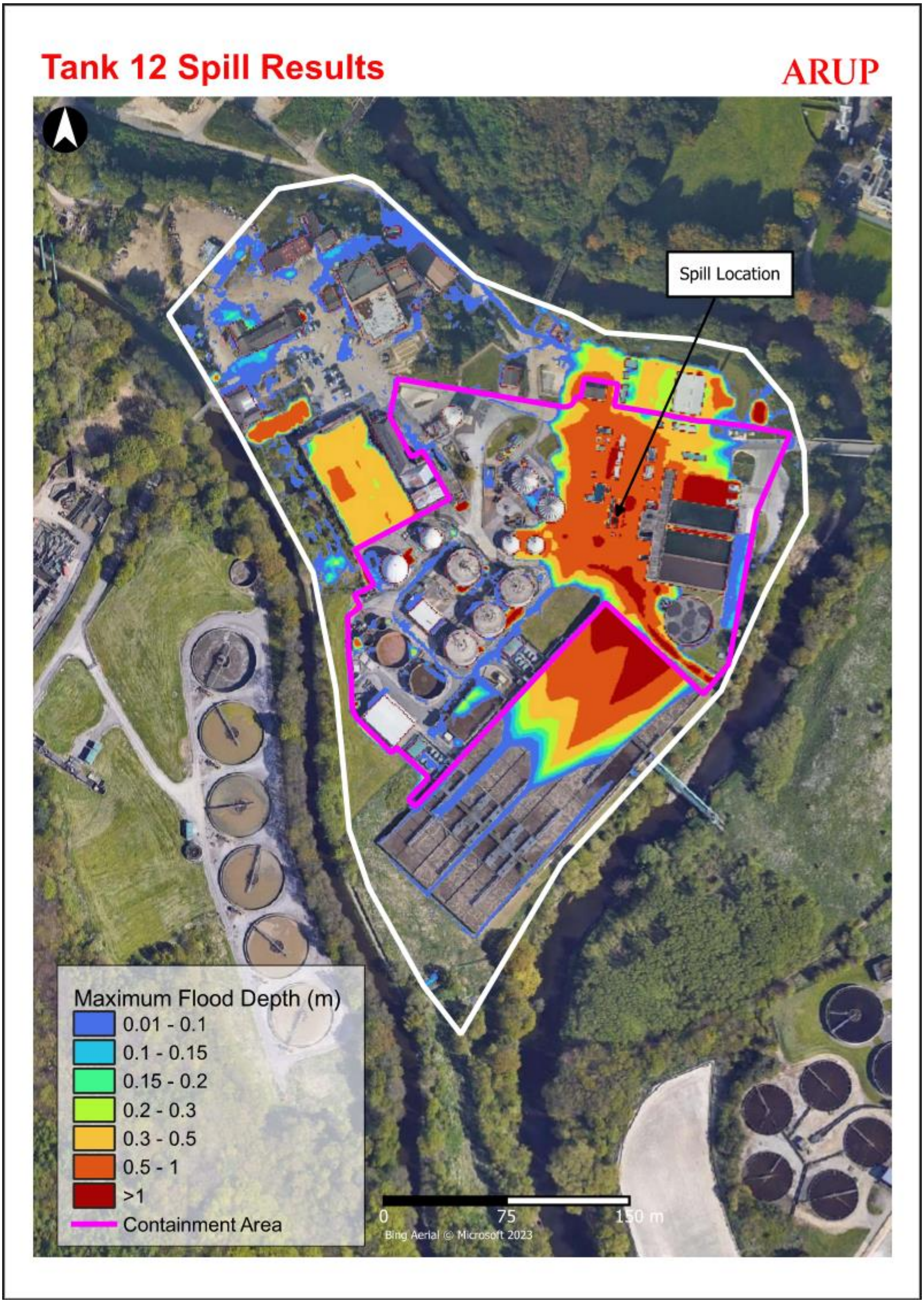

Tank 8 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

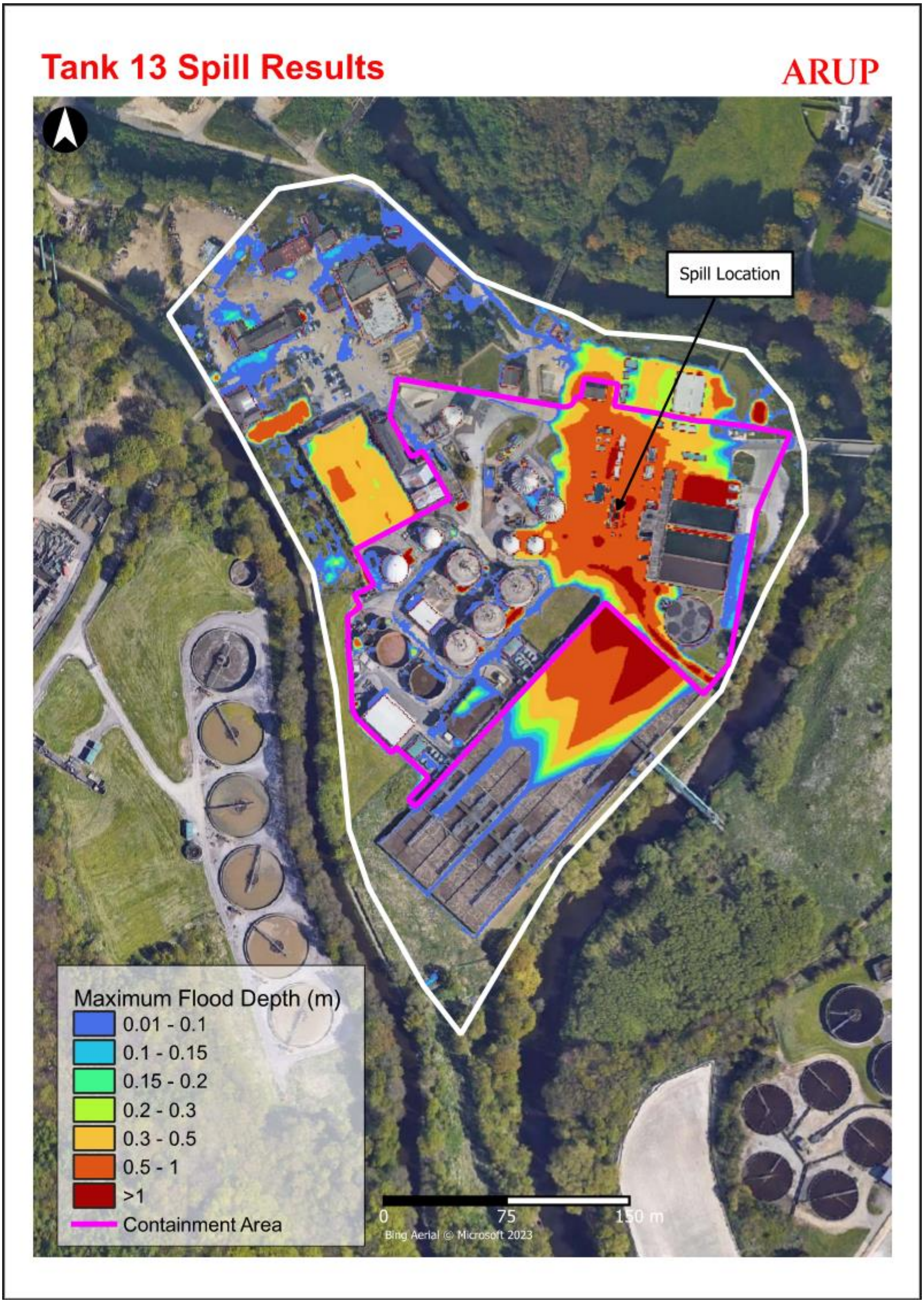
## Tank 9 Spill Results

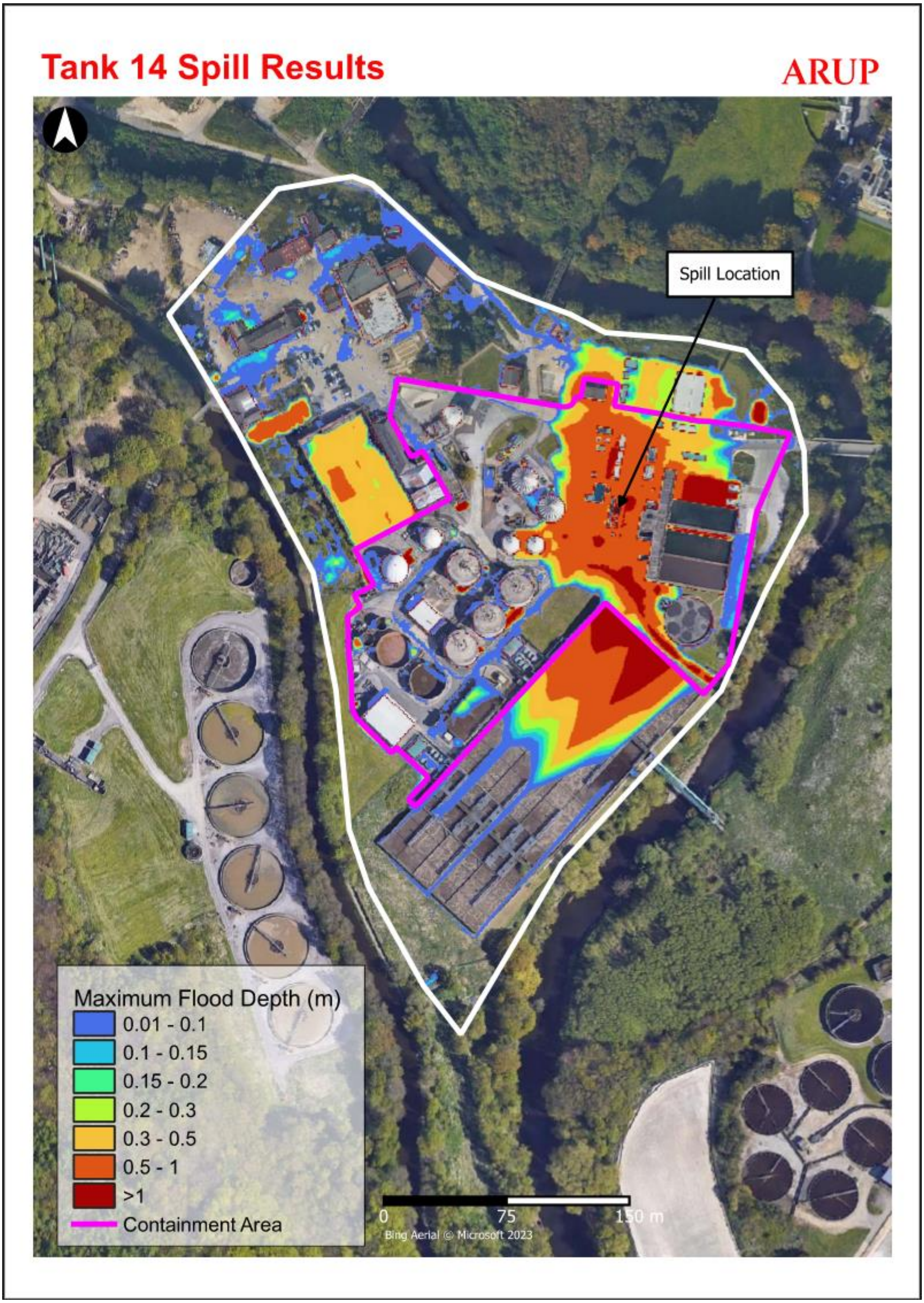


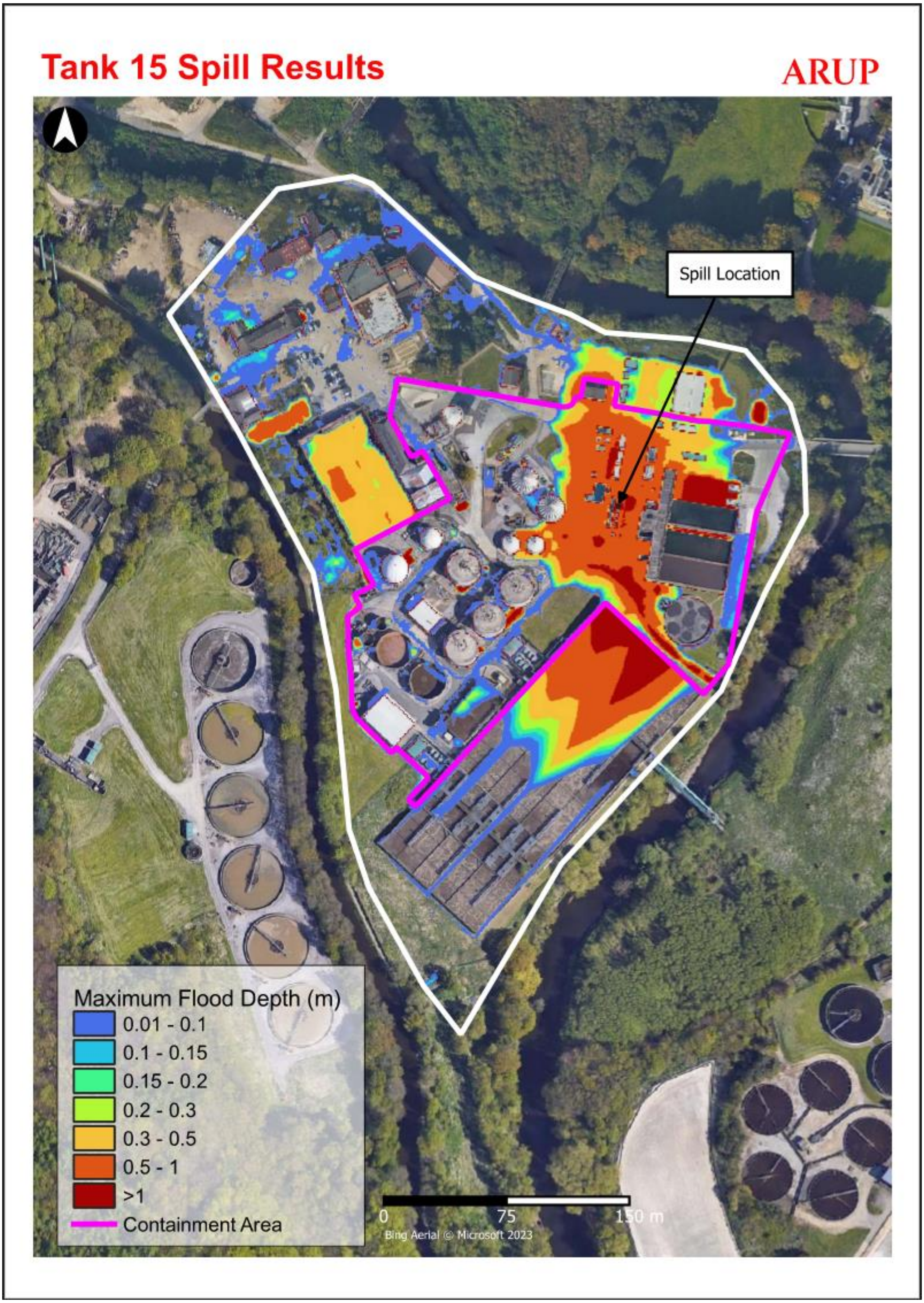

Tank 10 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

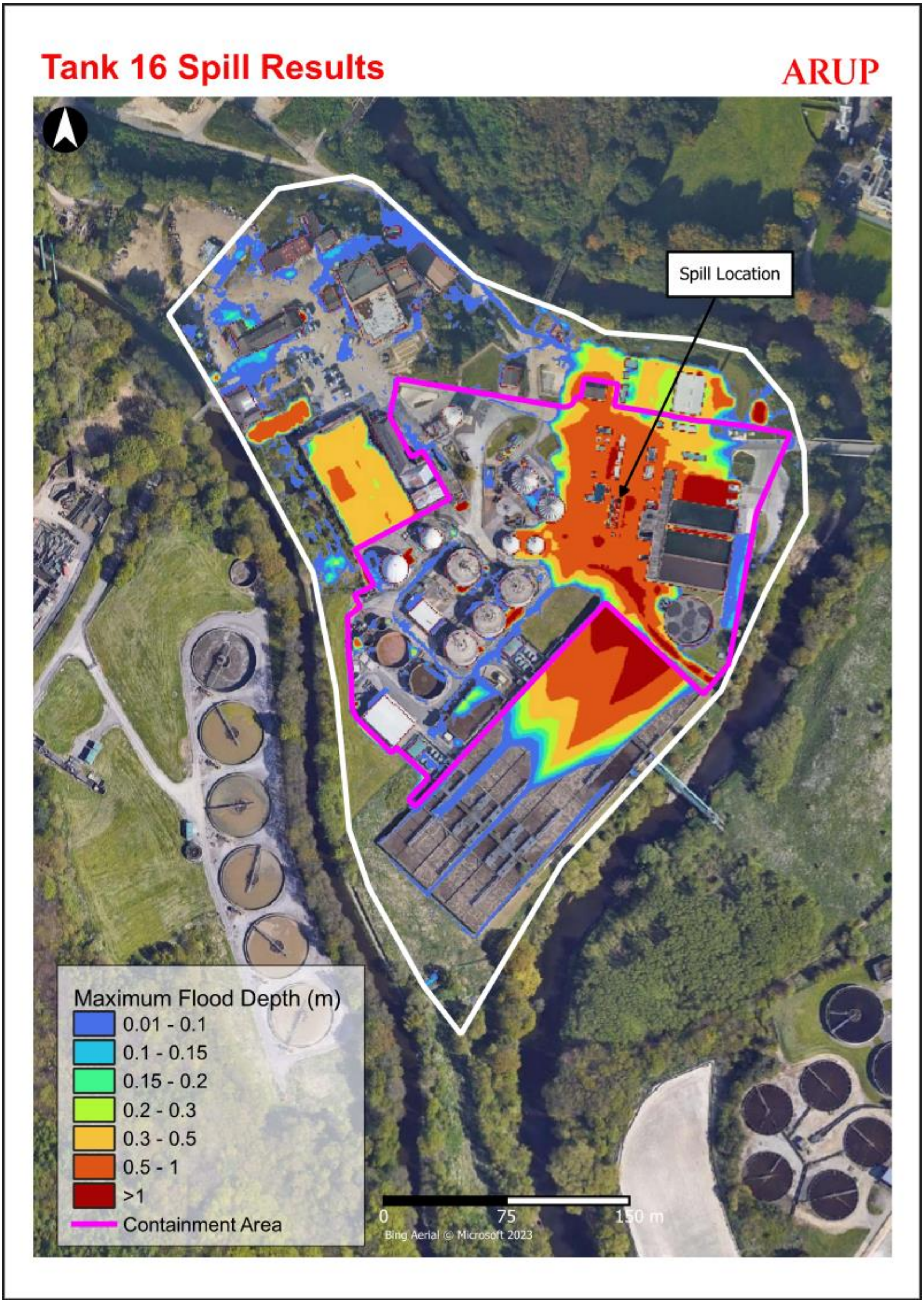

Tank 11 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

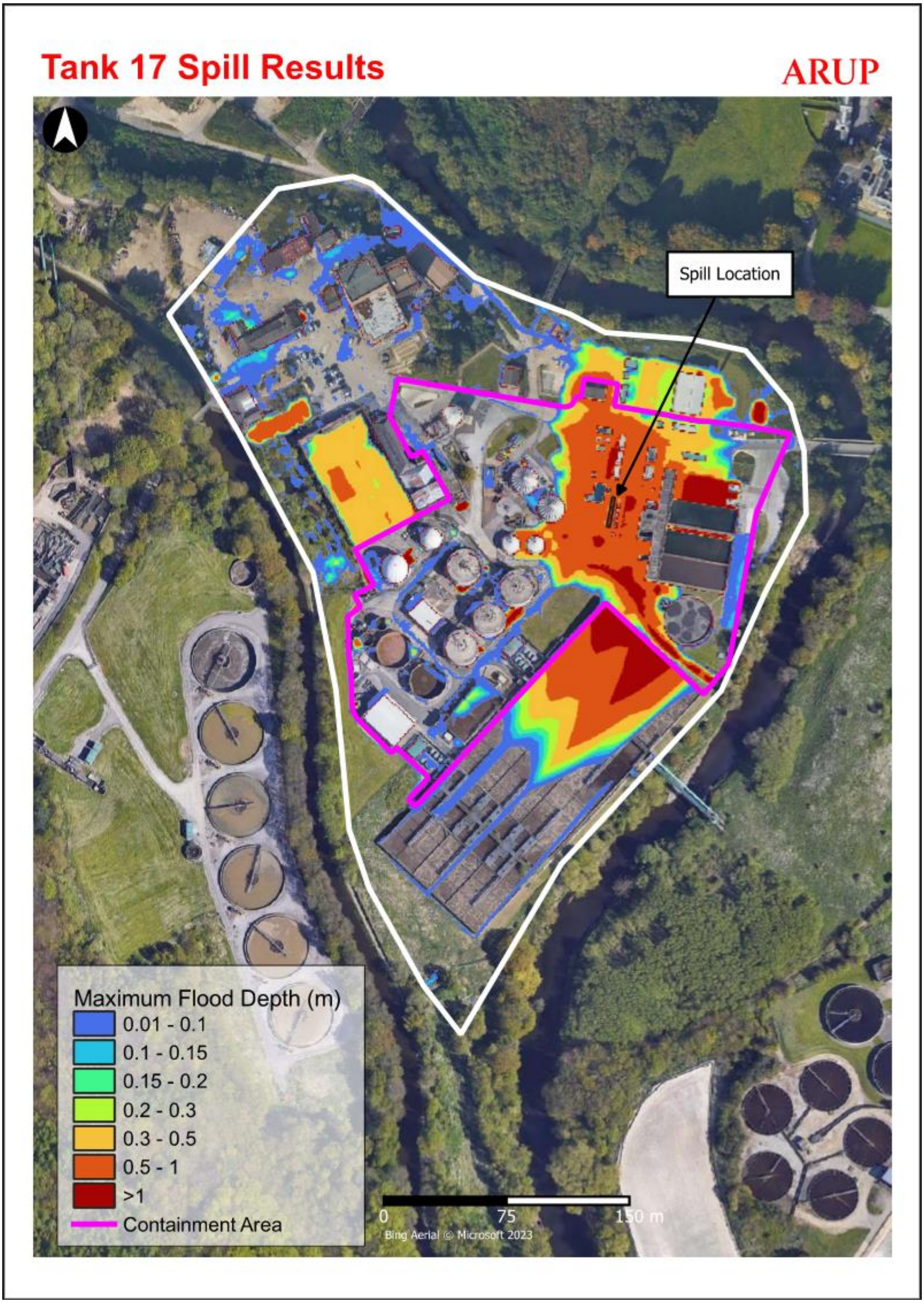

Tank 12 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

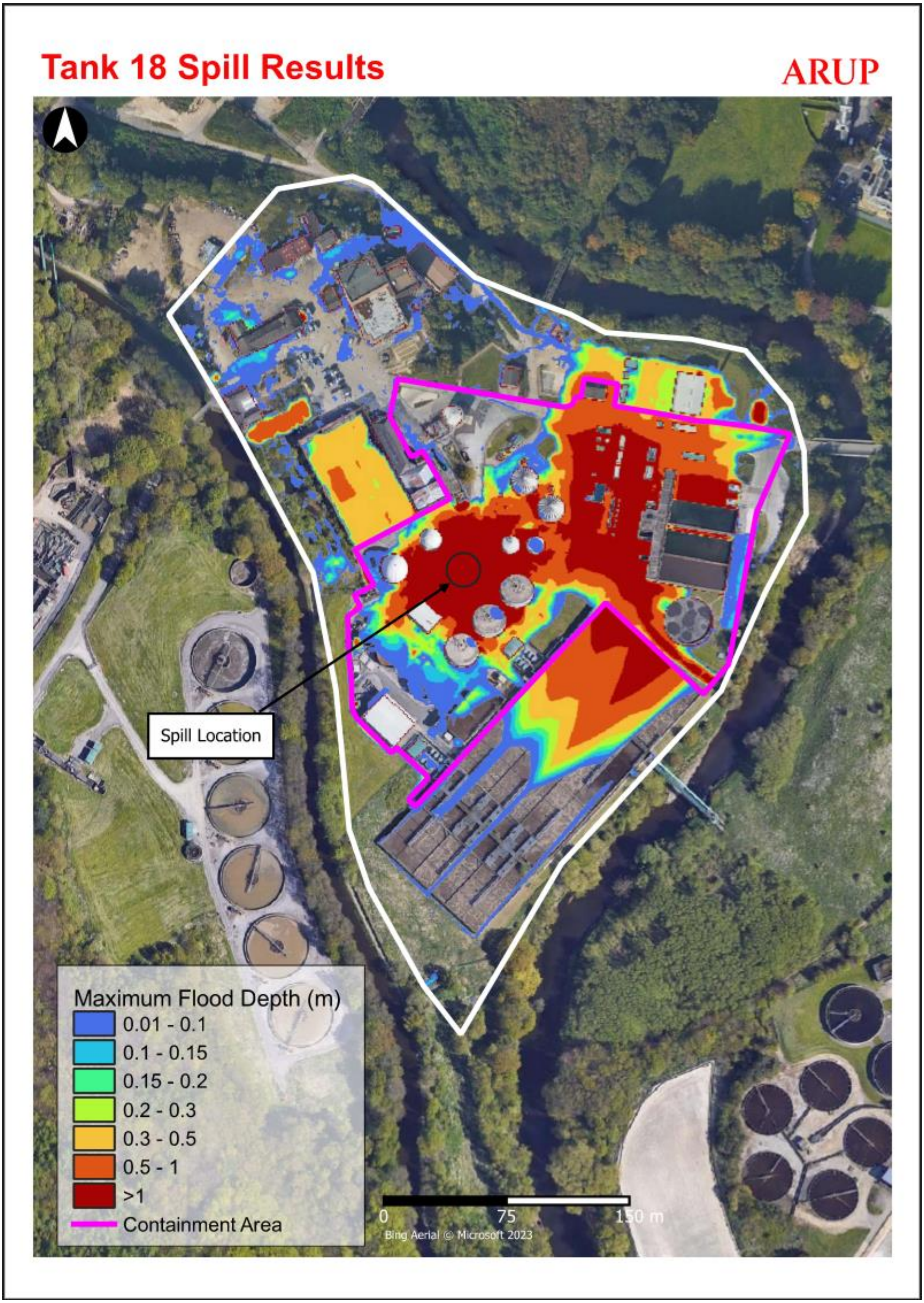

Tank 13 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

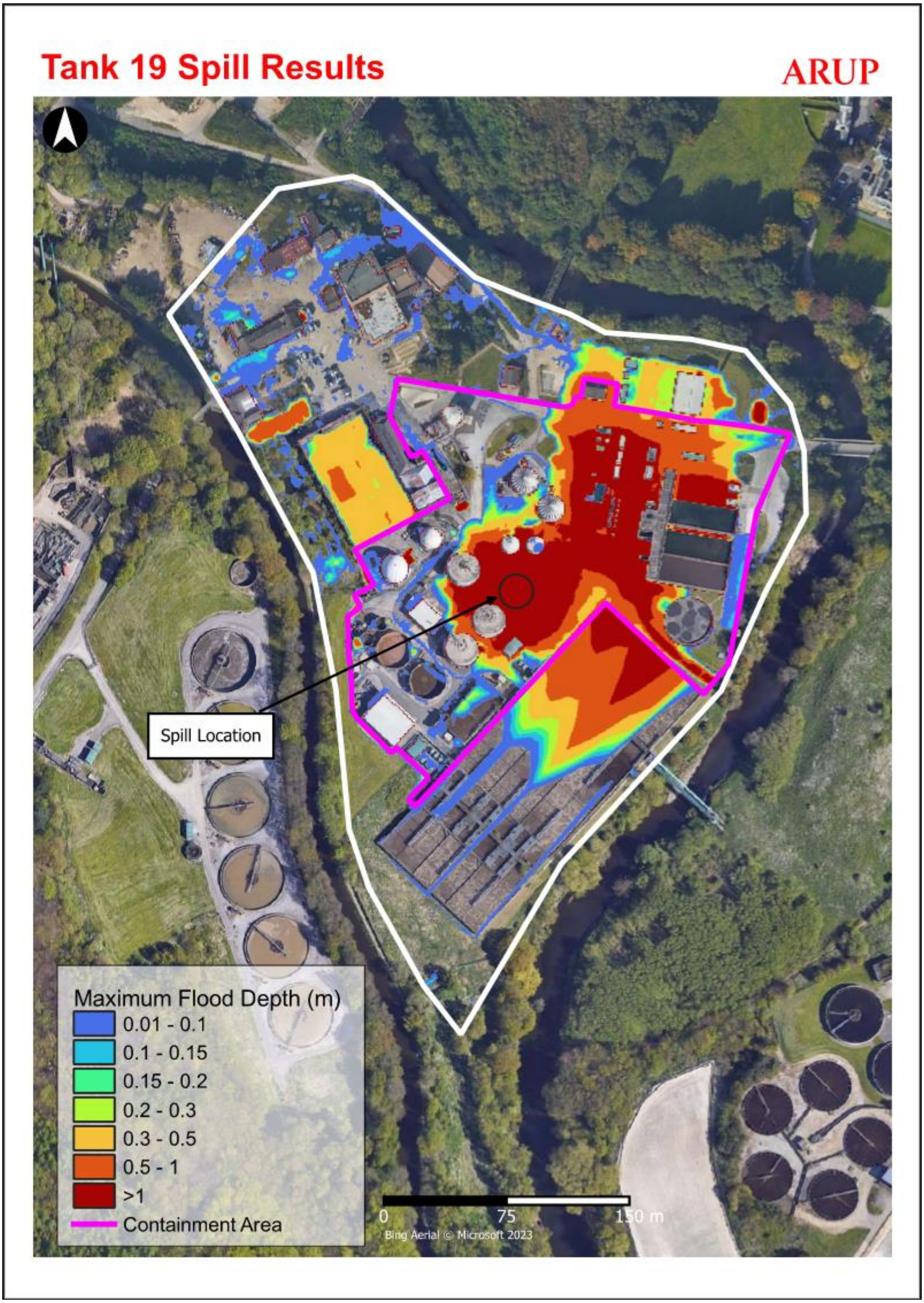

Tank 14 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 15 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 16 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

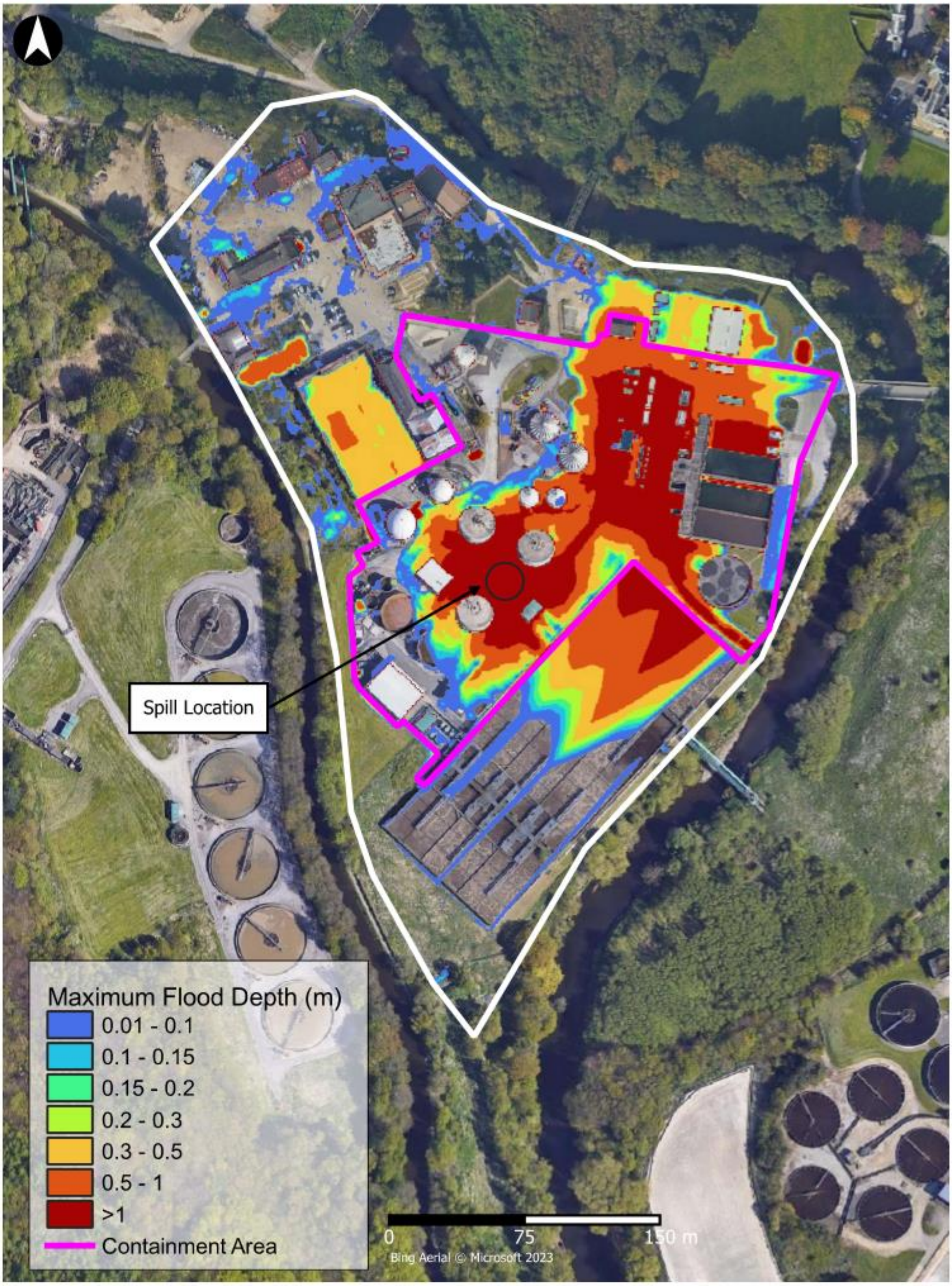

Tank 17 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

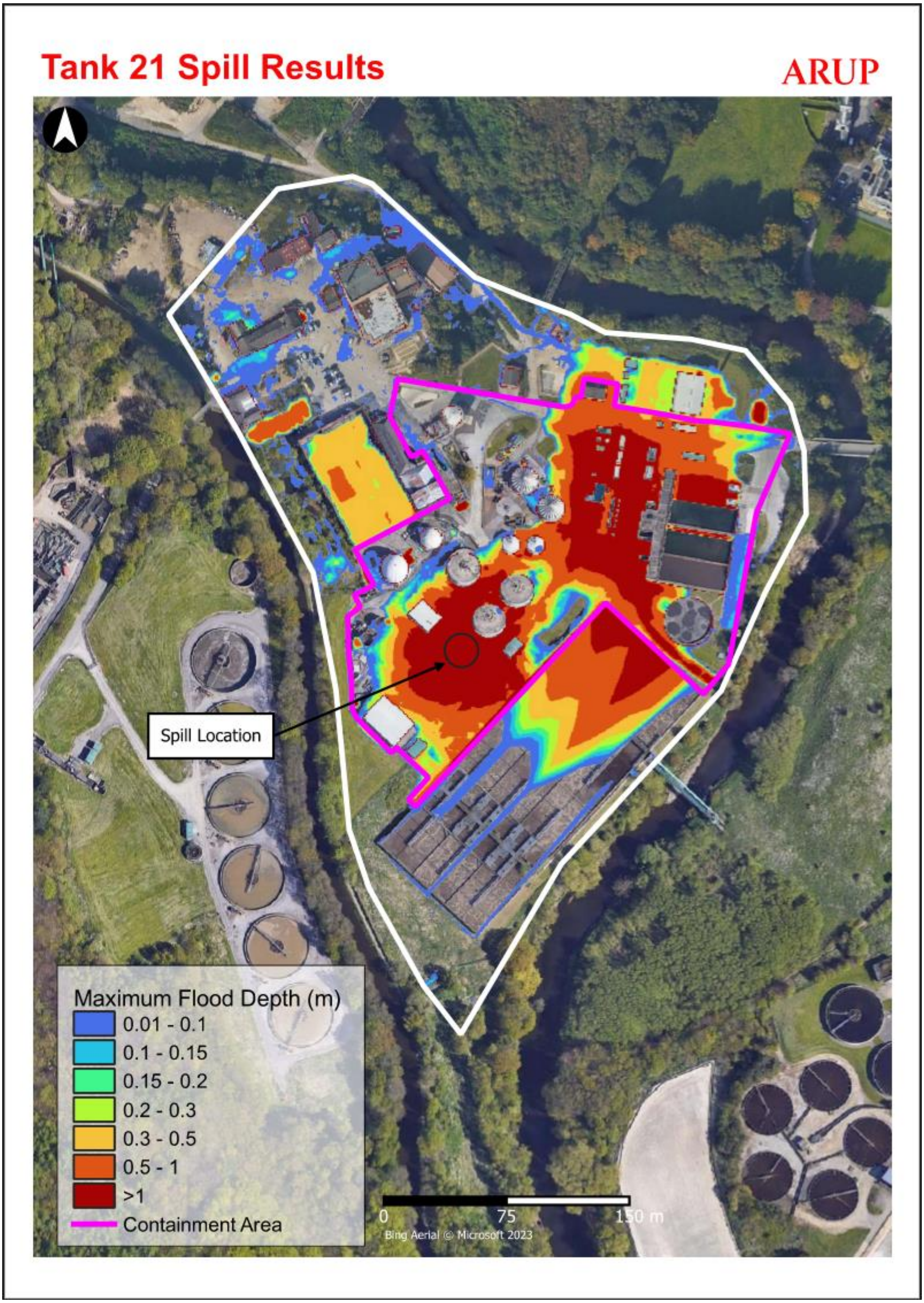

Tank 18 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

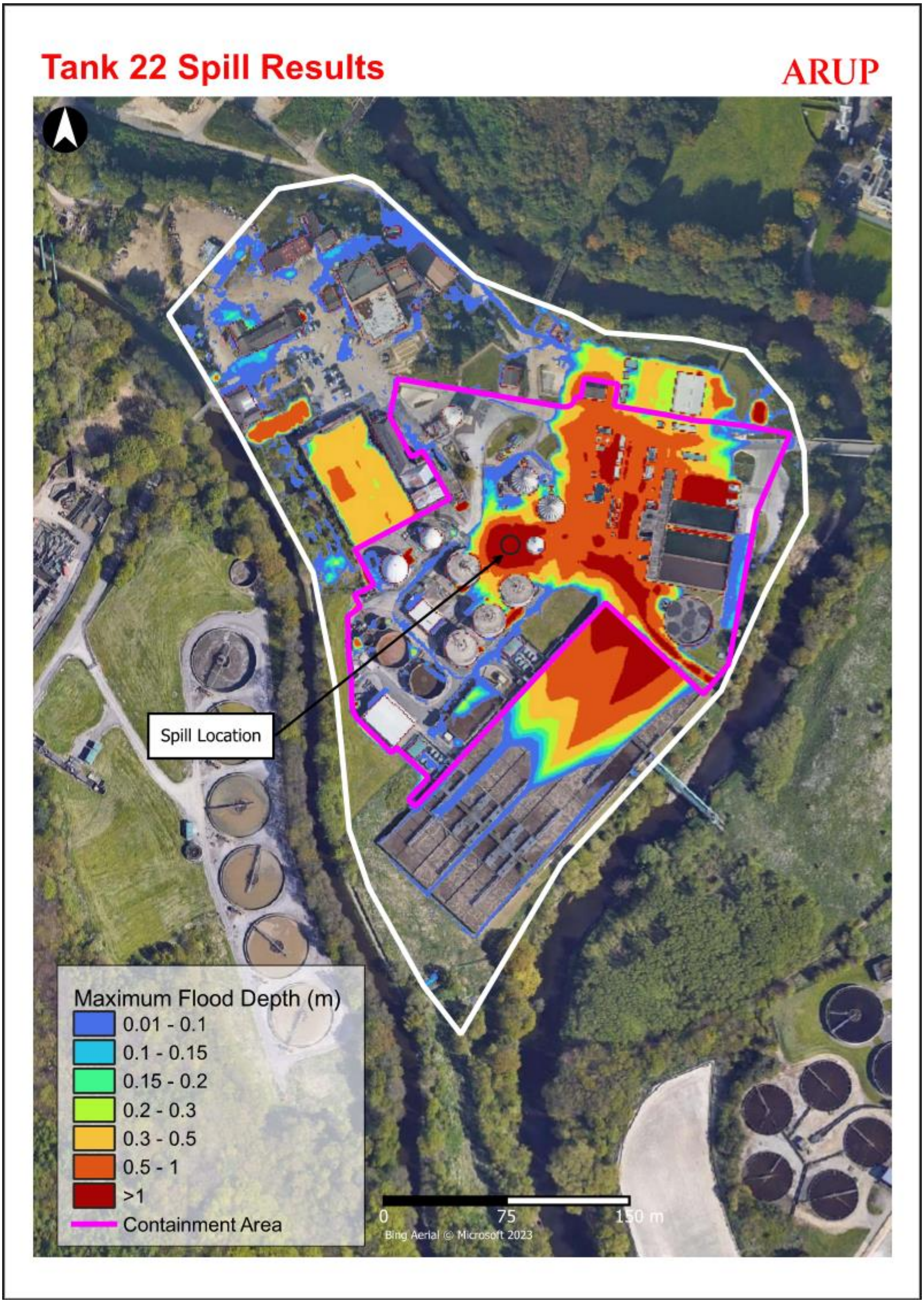

Tank 19 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

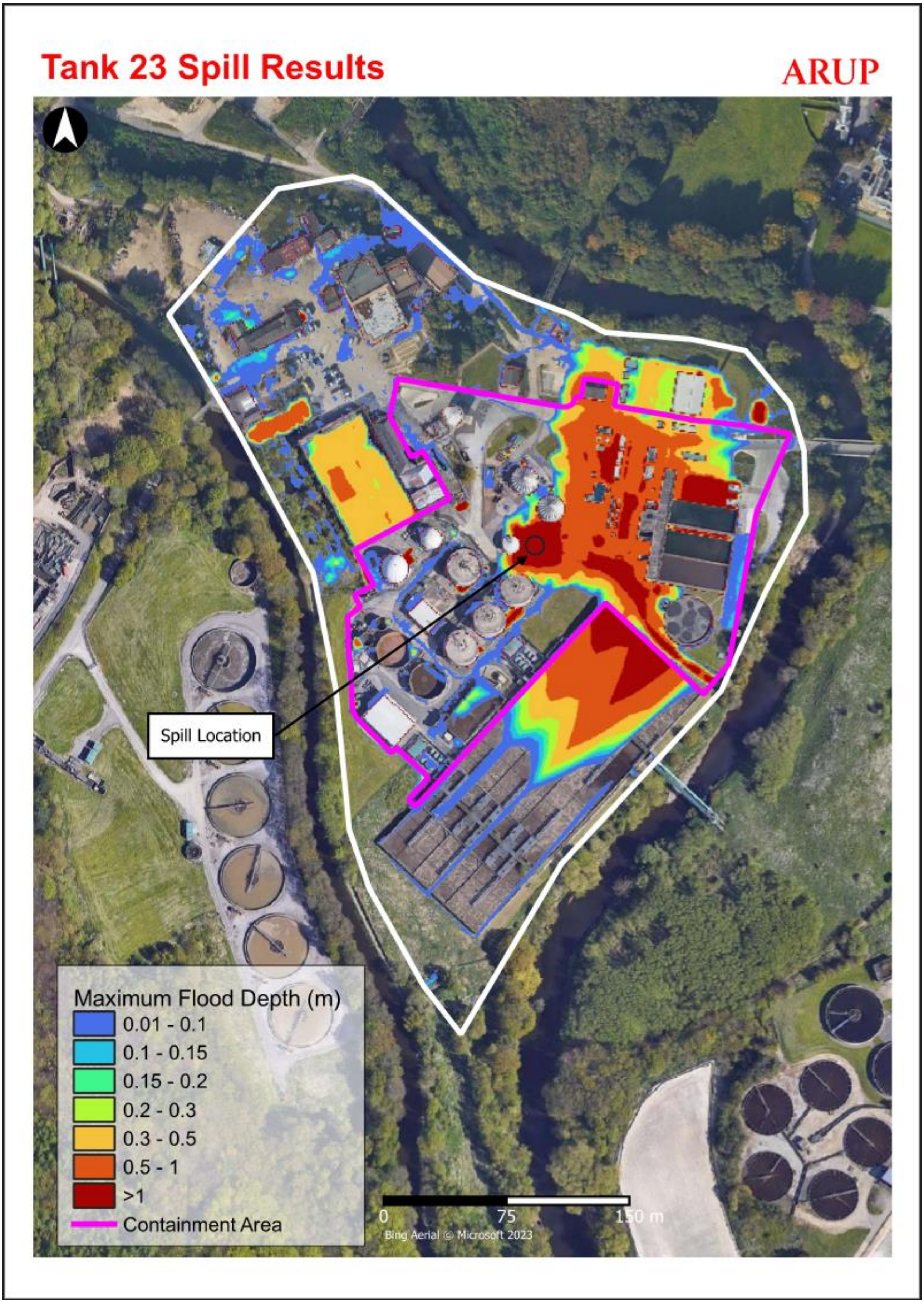
# Tank 20 Spill Results

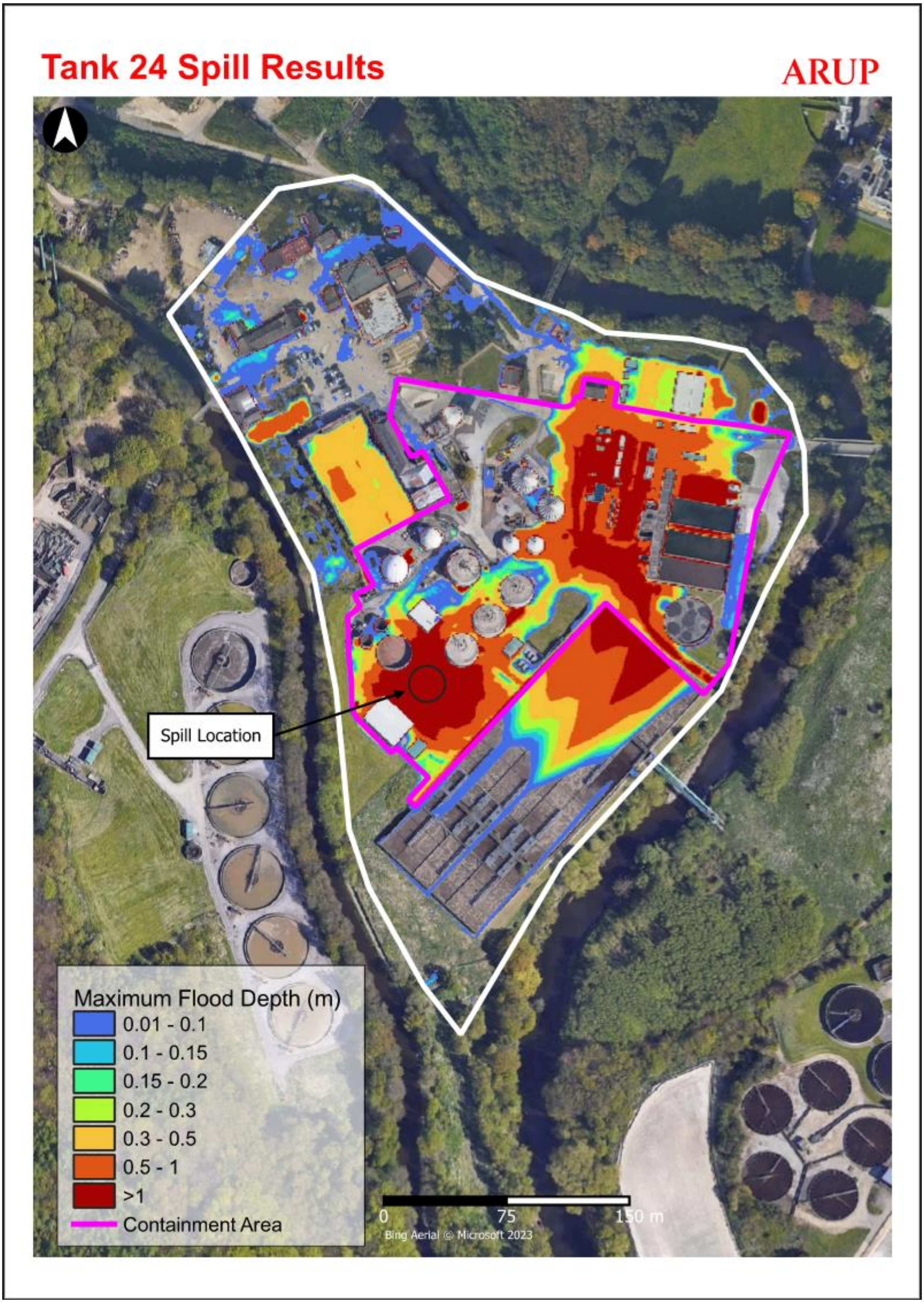
ARUP

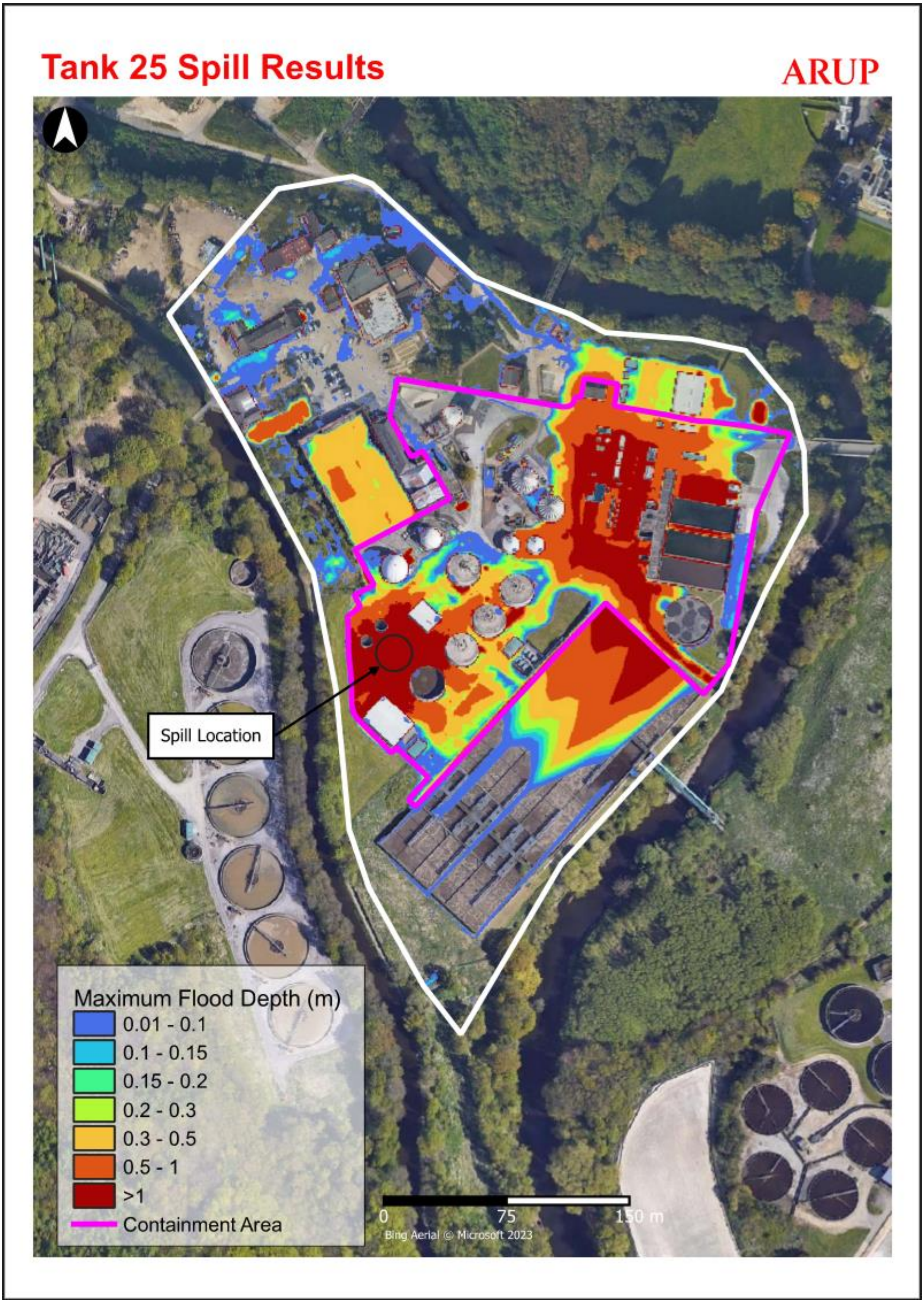



Tank 21 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 22 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

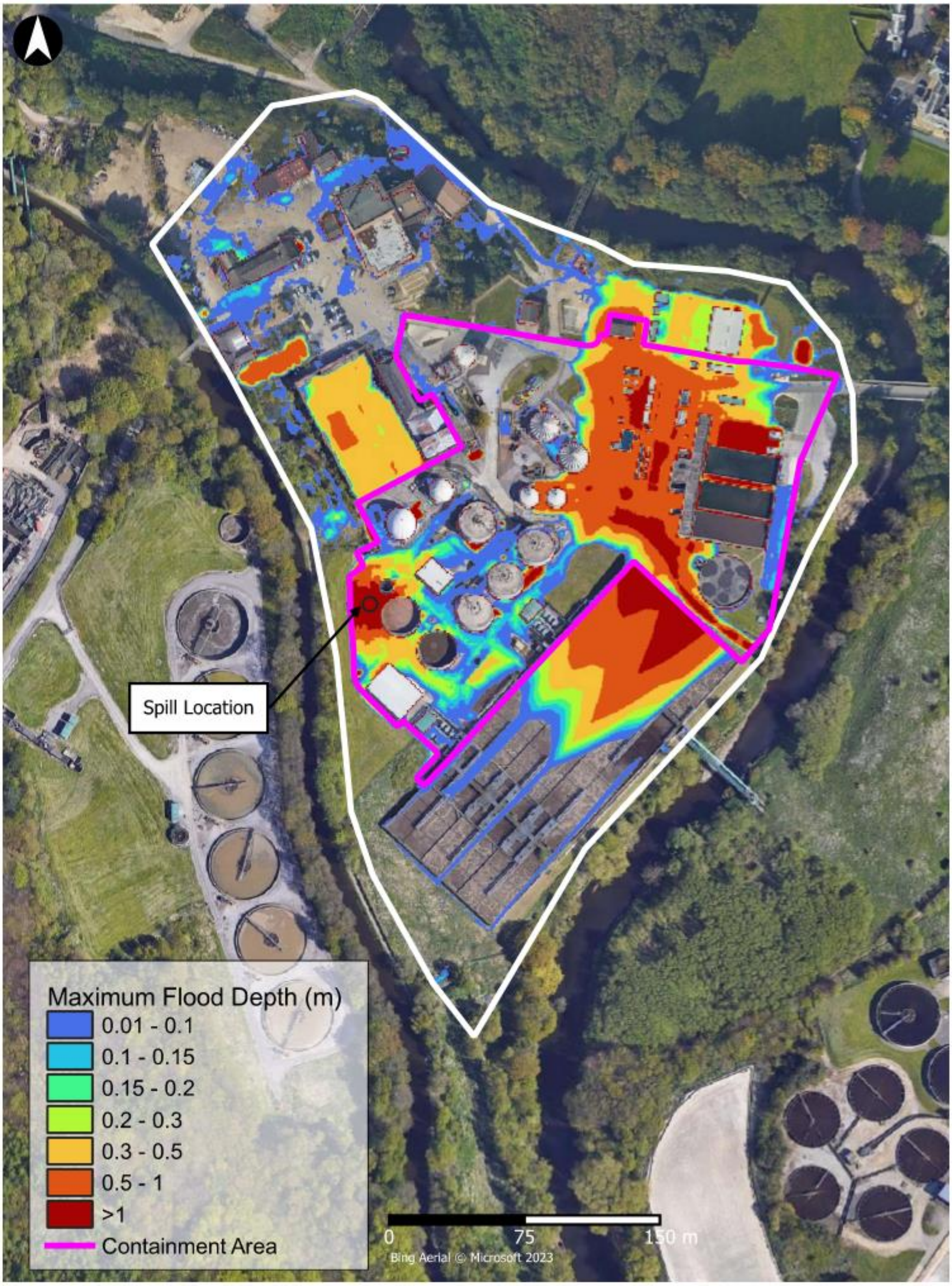

Tank 23 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 24 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 25 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
>1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

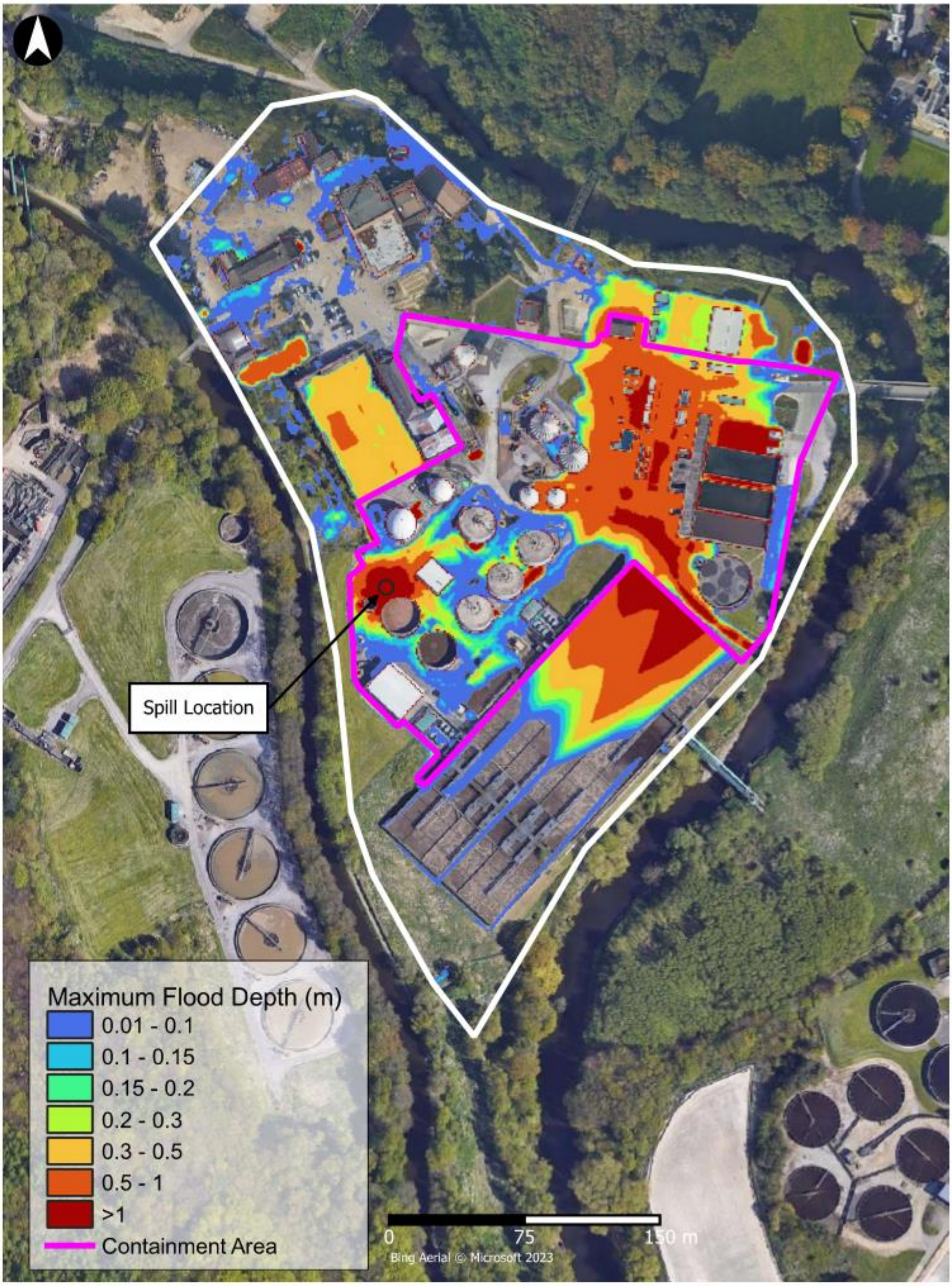
## Tank 26 Spill Results

ARUP



## Tank 27 Spill Results

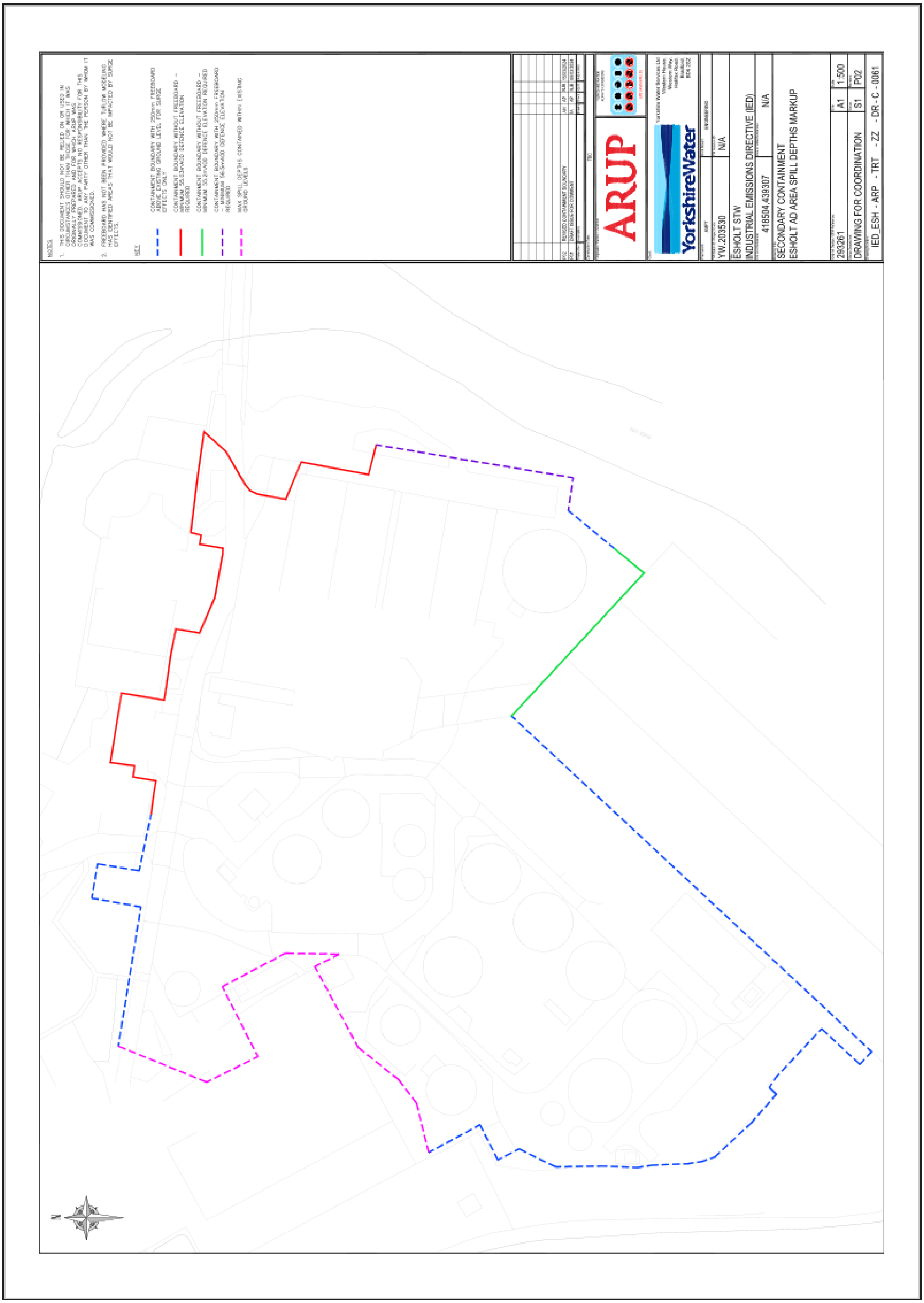
ARUP



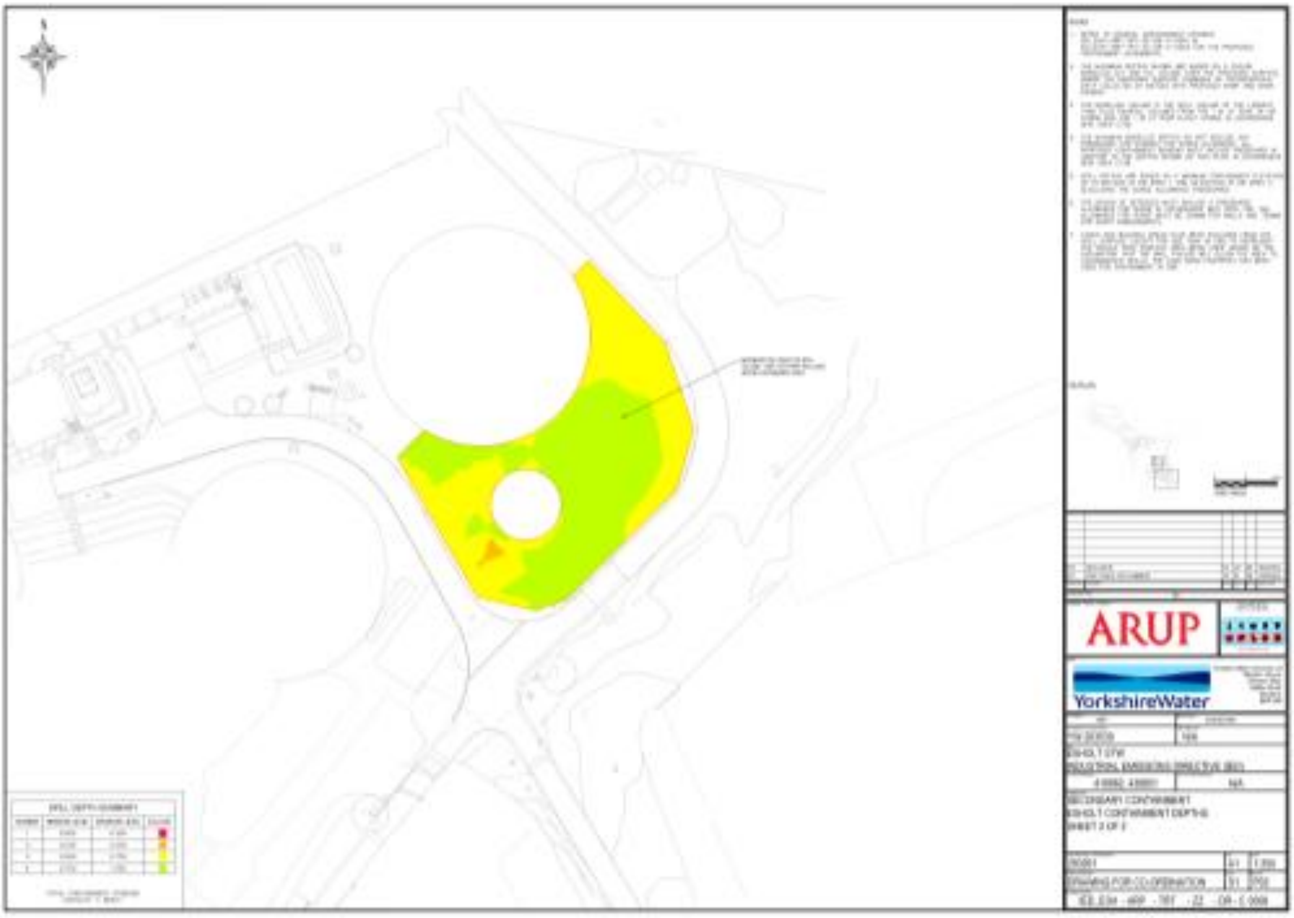
ARUP

| | |
|---|---|
| **Job number** | 293261 |
| **Date** | 12 February 2024 |

## Appendix B – Defence Design Markup based on Tuflow Modelling


ARUP
YorkshireWater
YW_203530
N/A
ESHOLT STW
INDUSTRIAL EMISSIONS DIRECTIVE (IED)
418504,439307
N/A
SECONDARY CONTAINMENT
ESHOLT AD AREA SPILL DEPTHS MARKUP
293261
A1
1:500
DRAWING FOR COORDINATION
S1
P02
IED_ESH - ARP - TRT - ZZ - DR - C - 0061


ARUP
YorkshireWater
ESHOLT STW
SECONDARY CONTAINMENT
ESHOLT CONTAINMENT DEPTHS
SHEET 1 OF 2
DRAWING FOR CO-ORDINATION


ARUP
YorkshireWater
ESHOLT STW
SECONDARY CONTAINMENT
ESHOLT CONTAINMENT DEPTHS
SHEET 2 OF 2
DRAWING FOR CO-ORDINATION