ARCADIS Design & Consultancy for natural and built assets

NORTHSTOWE PHASE 2 DEVELOPMENT

Remediation Method Statement

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Incorporating

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Northstowe Phase 2 Development

Remediation Method Statement

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This report dated 09 March 2018 has been prepared for Homes and Communities Agency (the "Client") in accordance with the terms and conditions of appointment dated20 September 2017(the "Appointment") between the Client and **Arcadis Consulting (UK) Limited** ("Arcadis") for the purposes specified in the Appointment. For avoidance of doubt, no other person(s) may use or rely upon this report or its contents, and Arcadis accepts no responsibility for any such use or reliance thereon by any other third party.

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1 Introduction

1.1 Terms of Reference

Arcadis Consulting (UK) Limited (Arcadis) was commissioned by the Homes England (formerly Homes and Communities Agency) ("the Client") to compile a remediation method statement for the Phase 2 development of Northstowe development site in Cambridge, ("the Site").

Condition 17 of the planning conditions states the following;

"*Unless otherwise agreed in writing, no development other than agreed enabling works, approved by this planning permission, shall commence on any sub-phase until a remediation strategy that includes the following components to deal with the risks associated with contamination on that sub-phase (unless the strategy states any remedial actions should be applicable across phases) has been submitted to and approved, in writing, by the Local Planning Authority:*

1. *A Preliminary Risk Assessment (PRA) including a Conceptual Site Model (CSM) of that phase of the site indicating potential sources, pathways and receptors, including those off site.*
2. *The results of supplementary investigation and recording of contamination as recommended in the Northstowe Phase 2 Geo Environmental Assessment and Outline Remedial Strategy Report (dated August 2014) and a detailed risk assessment, including a revised CSM.*
3. *Based on the risk assessment in (2) an options appraisal and Remediation Method Statement giving full details of the remediation measures required and how they are to be undertaken. The Remediation Method Statement shall include a plan providing details of how the remediation works shall be judged to be complete and arrangements for contingency actions. The plan shall also detail a long term monitoring and maintenance plan as necessary.*
4. *If, during development, including the remediation phase, contamination not previously identified is found to be present at the site then no further development (unless otherwise agreed in writing with the Local Planning Authority) shall be carried out until the developer has submitted a supplementary Remediation Method Statement detailing how this contamination shall be dealt with and obtained written approval from the Local Planning Authority. The contamination shall be remediated in accordance with the approved supplementary Remediation Method Statement.*
5. *No development shall be brought into use or occupied on any sub-phase until a verification report demonstrating completion of works on that sub phase as set out in the Remediation Method Statement(s) (parts 3 and 4 above) have been completed. The verification report shall be submitted to and approved in writing by the Local Planning Authority, and demonstrate that the land is suitable for the proposed end use. The long term monitoring and maintenance plan in (3) shall be updated and be implemented as approved.*"

Items 1 and 2 of the above planning condition have been delivered, as discussed in Section 1.4 below.

This Remediation Method Statement document is in response to item 3 above and to provide details of a watching brief protocol required in item 4.

Item 5 will be undertaken once the remedial works have been completed.

This method statement provides a pragmatic and sustainable approach to remediation for the site. It takes due cognisance of the background levels of compounds found within the soils across the site. Remedial targets are provided for soils to be protective to human health and groundwater.

The Northstowe development includes several different proposed land uses and to be consistent with the previous Arcadis reports, this Remediation Method Statement uses the same Land Use (LU) terminology.

The land uses were derived based on their historic and proposed land uses. A plan showing the different land uses (LU) is included in Appendix A.

1.2 Limitations

This report has been prepared for the client in accordance with the terms and conditions of appointment.

Arcadis cannot accept any responsibility for any use of or reliance on the contents of this report by any third party. The copyright of this document, including the electronic format shall remain the property of Arcadis.

This report has been compiled from a number of sources, which Arcadis believes to be trustworthy. However, Arcadis is unable to guarantee the accuracy of information provided by others. The report is based on information available at the time. Consequently, there is a potential for further information to become available, which may change this report's conclusion and for which Arcadis cannot be responsible.

The intrusive ground investigation undertaken to date has been designed to provide a reasonable coverage across the whole site, with a bias toward locations or zones considered more likely to have had the potential for anthropogenic contaminative impacts to occur. However, sub soils are by their nature hidden from view and no investigation can be exhaustive to the extent that all soil contamination is revealed. The site has a long history as an airfield / base and therefore conditions may be present beneath the site that are not identified by exploratory holes deployed, such as narrow linear features or isolated pockets of differing ground conditions that may exist.

1.3 Previous Work / Reports

The Northstowe development is centred on the former WWII Oakington Airfield and surrounding farm land. Previous specialist work has been undertaken across the site and is detailed in the following reports. These should be read in conjunction with this report to provide further information / context to the site.

- ***WSP, Interim Factual Report, Northstowe, Cambridgeshire, Zone B (Ref 1)***
- ***WSP Interim Factual Report, Northstowe, Cambridgeshire, Zone C (Ref 2)***
- ***WSP Interim Factual Report, Northstowe, Cambridgeshire, Zone D (Ref 3)***

The WSP reports provided desk study information such as historical mapping and environmental data for the Northstowe site. WSP undertook extensive ground investigations across the proposed development. The area was split up into different zones and the factual data corresponding to that zone is included in associated reports.

- ***Hyder Consulting (UK) Limited, Northstowe – Phase 2 - Geo Environmental Assessment and Outline Remedial Strategy Report (Ref 4)***

The Hyder report provides desk based details regarding the site such as physical setting, background information and investigations undertaken by others. A geo-environmental assessment of the WSP chemical data for the Phase 2 development area was undertaken by Hyder to establish the contamination status of the site in relation to the masterplan development. The Hyder report concluded that whilst elevated concentrations had been recorded in some areas when screened against the appropriate guidelines (in 2014), the site was not considered to be grossly contaminated. Recommendations were made relating to further investigation works.

- ***Arcadis Consulting (UK) Limited, Northstowe Phase 2 Ground Investigation Report, (Ref 5)***

Further investigation was undertaken across the majority of the Phase 2 development to supplement the previous WSP investigations. The factual details of this investigation are included within this report.

- ***Arcadis Consulting (UK) Limited, Northstowe Phase 2 Development - Geo Environmental Assessment Report / Outline Remedial Strategy (Infrastructure), (Ref 6)***

This report provides a geo environmental assessment for the Phase 2 development area and Southern Access Road West (SARW) using the WSP and the 2017 Arcadis investigation data. Revised Conceptual Site Models for the different proposed land uses are included within this report. An outline remedial strategy for the infrastructure (water park and SARW) was also included in this report. Whilst potential contaminant linkages with regards to human health and controlled waters were identified, the contamination was not considered to be widespread and gross contamination was not found to be present.

The Arcadis Geo Environmental Assessment report (Ref 6) is the basis for this Remediation Method Statement.

- ***Zetica, Northstowe Phases 2 Planning Condition Discharge Unexploded Ordnance – Condition 38(i) UXO Clearance Report (Ref 7)***

A survey was commissioned by Zetica to delineate and determine the nature of three potential burnt waste pits. The results are detailed within this condition report and are included within this Remediation Method Statement.

1.4 Items 1 and 2 of Planning Condition 17

1.4.1 Item 1

Item 1 relates to a Preliminary Risk Assessment for the Northstowe site. The WSP reports (Ref 1, 2, 3) and the Hyder report (Ref 4) provide historical mapping and physical setting information for the site. A Conceptual Site Model is included within the Hyder Report.

In combination, these reports satisfy item 1 of the planning condition.

1.4.2 Item 2

Item 2 of Condition 17 relates to the recommendations detailed within the Hyder report (Ref 4). The recommendations included the following;

- *Once further investigation data is obtained at detailed design stage that detailed assessment is undertaken to establish the risks for the particular land use under consideration i.e. commercial / residential*.

  Further supplementary investigation has been undertaken and assessment has been conducted based on the proposed land end use.
- *It is recommended that areas which were previously not investigated due to access constraints are investigated to determine the land quality and establish any remedial measures that need to be undertaken in these areas*.

  Further investigation has been undertaken, however it is noted that not all previously un-investigated areas were investigated during the latest works as these will be developed later in the programme. Archaeological works are also being undertaken across the site which has restricted access to some areas of archaeological interest. The investigation works is an on-going process and these areas will be investigated, prior to development.
- *Monitoring of ground gases and groundwater should be undertaken to establish the current regimes and if remediation is required.*

  Further gas and groundwater monitoring has been undertaken and assessed.
- *Elevated concentrations of Arsenic and Vanadium were encountered. It was recommended that bioaccessibility analysis is undertaken on soil samples to determine the fraction of Arsenic / Vanadium that is available to receptors. The standard exposure model assumes that 100% is available but this is generally not the case. If the bioaccessible fraction is known then the guideline can be re-calculated and a less precautionary (higher) SSV adopted.*

  Bioaccessibility testing for Arsenic has been undertaken and site specific assessment criteria derived. New screening values (Suitable 4 Use Levels (S4ULs)) for Vanadium were published by LQM (Ref 8) which meant the soil concentrations recorded where below the revised standard screening value. Bioaccesibility testing for Vanadium was therefore no longer required.

These recommendations were implemented (wherever possible) during the latest Arcadis investigation and reported in the Arcadis Geo Environmental Assessment report (Ref 6).

The Arcadis Geo Environmental Assessment Report satisfies item 2 of the planning condition.

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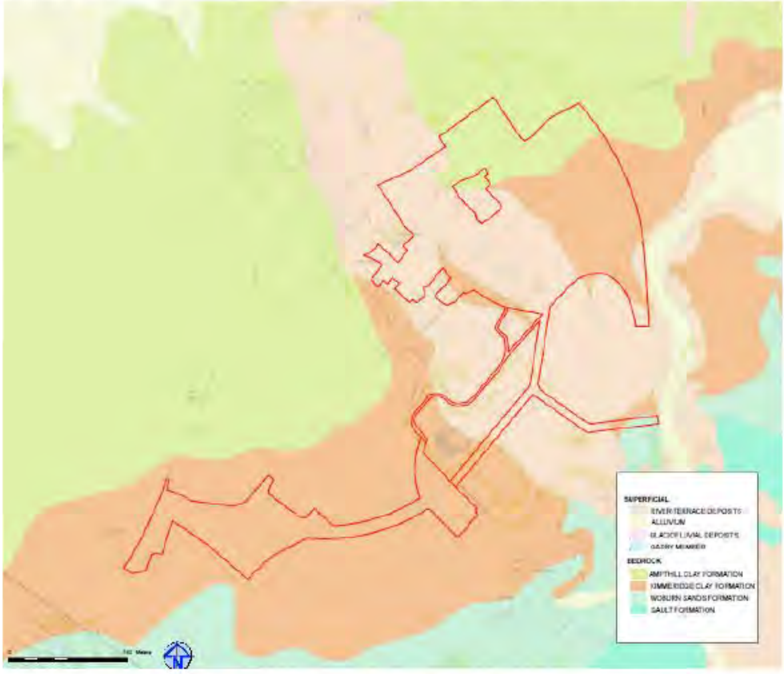
2 Site Setting and Description

Table 2.1 below is a summary of site information to assist with providing context to this Remediation Method Statement report. A more detailed baseline description is included within the Arcadis and Hyder reports.

Table 2.1 – Summary of site details

Site Location / NGR / Area	The site is located to the north west of Cambridge, between the villages of Longstanton and Oakington. Approximate Ordnance Survey National Grid Reference for the site is 541000, 266000. The area of the main Phase 2 development is approximately 165 hectares in size.
Site Description	The site is the former WWII Oakington airfield which included runways / airfield, a disused sewage treatment works (north east corner), 3 remaining buildings (Administration building, Officers Mess and Guardhouse), foundations / floor slabs / hardstanding associated areas with former bomb storage, barracks, offices, storage facilities, vehicle maintenance, garages and fuel storage areas. The majority of the buildings have been demolished to ground level with the floor slabs remaining in place. The airfield roads and the perimeter track remain and a number of listed pill boxes / water tower. Part of the site was used as the location of the Oakington Immigration Reception Centre but this has now closed and the majority of buildings demolished. Much of the grassed areas within the airfield are used by local farmers for grazing cattle. To the south and north of the former airfield, the area is mainly agricultural land with farmsteads / small buildings and outbuildings.
Published Geology	Based on Geological Mapping at 1:50,000 scale, Sheet 187 (drift) Huntingdon and Sheet 188 (solid and drift) of Cambridge, the geological sequence underlying the site is River Terrace Deposits over Kimmeridge Clay and Ampthill Clay. Below is a plan showing the published geology across the application site.  Details of the geology / ground conditions encountered during the site investigation is included in previous report (Ref 4 and 6).

Hydrogeology	Superficial Drift – Secondary A aquifer. Solid Bedrock geology – Unproductive Strata. Site is not within a Groundwater Source Protection Zone. Groundwater flow across the site is thought to be largely associated with superficial drift deposits and be contained within the sand and gravel lenses in the River Terrace Deposits. On the northern half of the site, groundwater flow is likely to be towards the north and northeast and it is considered likely that groundwater is in continuity with Beck Brook to the east of the site.
Hydrology	Beck Brook is located approximately 50m to the east of the site boundary and is considered to be main surface water receptor.

3 Conceptual Site Model

3.1 Investigation Results / Contaminants of Concern

Details of supplementary ground investigation undertaken by Arcadis, including a summary of ground conditions and visual / olfactory evidence of contamination encountered is provided in the Arcadis report (Ref 6). The geo environmental assessment utilised all existing data (WSP and Arcadis) for the Phase 2 development area.

As detailed in Section 1.1, the development includes several different proposed land uses. The Phase 2 development area has been split up into these different land uses, to aid the scoping of the investigation and assessment of the data. The land uses were derived based on their historic and proposed land uses.

A plan showing the different land uses (LU) is included in Appendix A. An appropriate sampling strategy was proposed for each LU as detailed in Section 3.1 of the Arcadis (Ref 6) report.

Full details of the geo environmental assessment are included in Arcadis report (Ref 6) and summary tables detailing the exceedances are included in Appendix B within this report to provide additional context.

The supplementary investigation targeted areas of previously known contamination especially the hydrocarbon contamination in LU11 (former maintenance area). The investigation methods included the use of LIF, PID and visual evidence, as the work progressed.

These techniques have demonstrated that “hot spot” impacts have occurred but that no extensive spatial scale impact or gross local impact is present on the Phase 2 development site.

The sections below provide discussions of the contaminants where elevated concentrations were recorded and are therefore considered Contaminants of Concern. A Contaminant of Concern is one that could result in above minimal risk when a complete pollutant linkage is present. It triggers further action which could involve remediation of the source or severance of the pathway e.g. by the nature of the scheme design.

3.1.1 Soils

- **Inorganic contaminants (arsenic, lead, cadmium, nickel);**
- **Organics contaminants (PAH compounds including Benzo(a)pyrene, TPH)**
- **Asbestos;**

The table below provides a summary of which contaminants are elevated within each LU area.

Plans showing the locations of exceedances in soils/ Made Ground are shown in Appendix C.

Table 3.1 Summary of Contaminants of Concern for the proposed land uses

LU Area	Proposed Land Use Type	Contaminant of Concern (Soil) (number of exceedances)	Potential source of contamination / Former Land Use
LU4	Residential	No exceedances recorded.	Former sports ground with barracks
LU6	Public open space/ sports playing fields / education campus / water park	Asbestos (8), benzene (1), PAH compounds (1) Burning pit	Former sewage works (north east corner) and open fields
LU7 *	Residential	Cadmium (1), Lead (1), TPH (1), PAH compounds (3)	Part of military base adjacent to runway, mainly undeveloped
LU8	Residential	Asbestos (1)	Barracks area / Oakington Immigration centre.

LU Area	Proposed Land Use Type	Contaminant of Concern (Soil) (number of exceedances)	Potential source of contamination / Former Land Use
LU9	Residential	TPH (1), PAH compounds (3)	Area part of base, grassed area, north eastern part supporting the bomb storage area.
LU10	Commercial / Industrial	Asbestos (1)	Part of RAF base/ barracks
LU11	Residential	Arsenic (1), Nickel (1), Lead (2), PAH compounds (12), TPH (9)	Location of fuel storage and vehicle maintenance at former RAF base.
LU12 (outside Phase 2 – SARW)	Commercial / Industrial	No exceedances recorded.	Former agricultural land
LU13 (outside Phase 2)	Residential	PAH compounds (2)	Part of RAF base/ grassed area

* limited investigation due to archaeological works

In the geo-environmental assessment (Ref. 6) the soil results for all land use areas, including from LU6 were screened against S4ULs (Ref 8) for a residential with plant uptake scenario as a precautionary approach and exceedances were identified for metals, TPH and PAH. To provide further clarification on the contamination status, since LU6 is proposed to be used for sports fields, green space and attenuation ponds, it is considered appropriate to re-screen the results against the S4ULs for a public open space land use scenario.

When assessed to this exposure model, no exceedances of the public open space values were identified in samples from LU6 apart from the concentration of benzene in TPB001E 0.3m (100 mg/kg) which exceeded the S4UL (72 mg/kg). In addition, asbestos fibres were identified in 8 samples, with 6 of these being likely associated with the former sewage treatment works, in the north eastern part of LU6. However, with the exception of TP607 0.4 m bgl (chrysotile loose fibres), the benzene exceedance and asbestos are located in areas that will be excavated for the ponds. The excavated soils are planned for use as part of earth embankment for bridge, and used in this manner, will therefore be buried and "locked" in place. There will be no future linkage to create impact.

The proposed education campus is located within LU6 and LU9 with the majority of the buildings associated with the campus being on the western side and contained within LU9. LU9 was screened for a residential with plant uptake scenario and only isolated PAH / TPH contamination was encountered in the area of the campus. These can be remediated as detailed in 4.1.1 (See below)

When the locations of the sports pitches were screened against a residential with plant uptake scenario, there was only an exceedance of PAH compounds in one location (TPB010 0.2m).

The soil contamination across the Phase 2 area is mainly in isolated places. It is recommended that these areas are delineated and considered, for planned re-use in less sensitive applications, where this is possible. Once delineated, consideration should be first given to the final design layout and whether they would pose a risk if left in place. For example, if areas of permanent hardcover are part of the design, there would be no exposure pathway and the risk would be mitigated. Such action is more sustainable compared to excavation and re-use or off-site disposal.

The development has the need to create significant earth embankments for the bridge, and thus the site-wide remedial strategy will include re-use of such materials that are suitable for use within the core of embankments and similar earthworks. Used in this way infiltration will be low and exposure pathway to humans will have been removed.

Whilst exceedances for sensitive land uses have been recorded, the concentrations on site are not significant and for less sensitive developments would not need to be remediated. These materials could therefore be re-used on site if considered suitable for the proposed end use in the area.

Such re-use will be subject to detailed design and appropriate design specific risk assessment with integration into the construction environmental management plan (CEMP) and materials management plan (MMP).

UXO and Radioactive Materials

Zetica are Unexploded Ordnance (UXO) specialists, commissioned by the client to undertake a UXO survey across the site in 2016 / 2017.

During their initial surveys, Zetica identified 3 potential burning pits (WP1, WP2 and WP3) associated with the former RAF base and near surface anomalies. As part of the Arcadis work (Ref 5) these burning pits and anomalies were investigated via trial pitting and trenching and soil samples were collected for chemical analysis. This investigation delineated the burning pits to enable remediation to be targeted. WP3 in the south western part of the site was found to be contain demolition rubble and was considered to be clear of UXOs. No further action was required in this area. WP1 and WP2 near the eastern boundary were found to contain a thin layer of buried waste (about 1.4m bgl). The waste contained masonry, brick rubble, ash, clinker and other burnt materials including ordnance related items. This is indicative of an ordnance disposal pit or burial of waste from a burning ground. This remedial strategy recommends that these areas are excavated and removed to an appropriately licenced landfill site.

In the Hyder report, it was noted that low levels of radioactive material was previously recorded in shallow ashy soils in TPB83 (0.15m and 0.35m depth). This sample location is within the area that has been stripped for the archaeology works. During the stripping process, the ashy material was encountered and placed in a stockpile of non-natural material which will be disposed of. The radiological issue in this location is therefore considered to have been removed from site. No further screening was required during the intrusive works.

Archaeological Works

Extensive archaeological works is taking place across the Phase 2 area. This includes removal of topsoil and subsoil in areas of interest. The soils are being stockpiled (topsoil and subsoil separately) and a watching brief approach is adopted during the works. Any visually contaminated materials are being kept stockpiled separately. Prior to re-use of the soils within the stockpiles, validation testing will be undertaken as detailed in Section 4.4.5.

It is noted that due to the archaeological excavation works, some shallow soil contamination may be removed and included within the stockpiled material. This contamination is not likely to be significant as this should be noted during the excavation works. The validation testing as detailed above and in Section 4.4.5 should provide evidence that this only suitable soils are re-used within the development.

3.1.2 Ground Gases

Based on the monitoring to date and the gas screening values (GSV) calculated, the methane GSV is considered to be Characteristic Situation 1 (Situation A) or Amber 1 (Situation B) due to methane concentration over 1% being recorded. The carbon dioxide GSV equates to a Characteristic Situation 2 (Situation A) and Amber 1 (Situation B).

These results indicate a low gas risk on site and this finding is consistent with the conceptual site model i.e. no potential high hazard source of gas is believed to exist. The Characteristic Situation 2 and Amber 1 situations requires basic gas protection measures to be incorporated into the design of new buildings. This comprises a membrane and ventilated sub floor void. See Section 4.3 for details.

It is noted that the calculated gas regime discussed adopts a precautionary approach and is based on limited monitoring and within relatively few standpipes. It is anticipated that further detailed site investigation will be undertaken to inform the ground conditions for foundations; and which may confirm whether a precautionary approach based on gas concentrations would be warranted across the entire site.

Radon

The site is in an area of <1% Radon potential. No special protection measures are required to protect homes from radon gas. This should be confirmed with the Local Authority Contaminated Land Officer and Building Control.

3.1.3 Groundwater

- **Inorganics contaminants (Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Selenium, Vanadium, Zinc)**
- **Organic contaminants (TPH, PAH compounds, Phenol)**

A relatively low number of exceedances of the inorganic and organic contaminants were identified in groundwater samples across the Phase 2 development area. In total 68 samples were analysed from 2 rounds. The majority of exceedances are relatively marginal and in the case of some of the metal contaminants (such as Selenium and Zinc) the widespread occurrence where there is generally no evidence of anthropogenic impairment which leads to the hypothesis that it is likely to represent natural background levels. Exceptions to this include BH1103 where anthropogenic impairment is in evidence.

Table 3.2 below presents a summary of data from the groundwater quality results obtained during the 2016 / 2017 Arcadis investigation. The metal exceedances are illustrated on a drawing in Appendix D.

Table 3.2 Summary of groundwater analysis (68 samples)

Determinand	Range of Concentrations (ug/l)	WQS (EQS / DWS) (ug/l)	Exceedances (Yes / No) (Number)	Location of exceedance
Arsenic	<0.15 - 30.6	50 / 10	No EQS / Yes DWS (1)	**BH1103 (W2)**
Cadmium	<0.02 – 0.35	0.15	Yes (6)	BH610 W1, BH1003 (1), BH601 (1) **BH601 (2),** BH1206, BH1205
Chromium (hexavalent)	<5.0	3.4 / 50	No	-
Chromium	<0.2- 180	4.7 / 50	Yes (EQS -3, DWS -1)	BH602 (W1), BH609 (W1), **BH1103 (W2)**
Copper [1]	1.5 - 120	47 / 2000	Yes EQS (1)	**WS901 (W1)**
Lead	<0.2 - 69	12 / 10	Yes (EQS -1, DWS - 1)	**BH1103 (W2)**
Mercury	<0.05 - 0.44	0.5 / 1.0	No	-
Nickel	1 - 88	24 / 20	Yes (EQS - 3, DWS – 3)	**BH1103 (W2)** BH1205 (W1 and W2)
Selenium	<0.6 – 1200 (82)	10 DWS	Yes (22)	Maximum recorded in **BH1103 (W2)**
Vanadium	<0.2 - 280	20 EQS	Yes (1)	**BH1103 (W2)**

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[1] the WFD guideline for copper, zinc, lead and nickel are based on bioavailability. Site specific PNECs (Predicted No Effect Concentration) has been calculated using the site specific pH (7.4), a Ca^{2+} value of 93mg/l (maximum value that can be used) and a DOC value of 10mg/l (assumed).

Determinand	Range of Concentrations (ug/l)	WQS (EQS / DWS) (ug/l)	Exceedances (Yes / No) (Number)	Location of exceedance
Zinc	2.7 - 140	40 / 2000	Yes (EQS -14)	Maximum recorded in **BH1004 (W1)**
pH	6.6 - 8.8	6 - 9	No	-
PAH compounds	66.5 (total)	N/A	Yes (DWS) (1)	WS1103 (W1)
Phenol	7.7 - 48	85	Yes (3)	BH1103 (W2) BH610, BH601
TPH aliphatic	<10 - 12000	10	Yes (2)	WS1103 (W1)* BH1103
TPH aromatic	<10 - 730	10	Yes (1)	WS1103 (W1)*, BH1108

Bold = location of maximum value

Inorganic Contaminants

The map of spatial exceedances in groundwater demonstrates that Selenium is found across the majority of the site, mainly in the River Terrace Deposits (superficial deposits) but also in the deeper Kimmeridge Clay in a few places.

If the highest concentration of Selenium at 1200 µg/l is considered an outlier, i.e. removed from the main dataset, the range of concentrations is then between <0.6 to 82 µg/l. The high result in WS1103 (W2) is not consistent with concentrations across the rest of the site. There is no EQS value for Selenium, so it is noted that the concentrations recorded have been compared to a stringent DWS. The Selenium soil concentrations range from <1 to 11 mg/kg and are all below the residential S4ULs. No source of Selenium contamination has been identified on the Phase 2 development site. The leachate testing (which is discussed more in the following section) indicates leachate concentrations ranging from below the limit of detection to 57ug/l which whilst above the DWS, does not indicate that the soil is a significant source of Selenium. It is therefore postulated that this is a natural background level and not related to anthropogenic uses.

Zinc concentrations in the groundwater from both the River Terrace Deposits and Kimmeridge Clay have exceedances. The source of this Zinc is uncertain, but anthropogenic impacts do not appear to be credible as the source.

The zinc soil concentrations across the whole site range form 16 – 40,000 mg/kg. The highest concentration relates to materials encountered in one of the Zetica located burning pits in LU6 (ZBP3). As the groundwater flow is towards the east, this is unlikely to contribute to the elevated zinc concentrations in other parts of the site. When the highest concentration is removed the next highest concentrations are 4200 mg/kg (TP626), 1900mg/kg and 1500mg/kg (TP627) and 1800 mg/kg (ZBP4). When these are considered, these are also located on the eastern side of the site and therefore it is unlikely that these contribute to elevated results within groundwater samples to the west and especially in the boreholes relating to the SARW (BH1206, BH1203 and BH1205). Similarly, to the Selenium results, the leachate analysis does not indicate that the soils is a significant source of Zinc contamination.

It is noted that the EQS values used to assess the copper, lead, nickel and zinc concentrations are all calculated using bioavailability fractions which may lead to conservative values.

Groundwater samples were taken from 4 boreholes to the south west of the site associated with the proposed road. These would be considered to be down hydraulic gradient of the other boreholes on site.

The 4 boreholes are in an area which is, and has always been, fields / undeveloped land (i.e. no potential contamination source). The samples from these locations also show elevated concentrations of selenium, cadmium, zinc and nickel.

This finding indicates that groundwater from the wider groundwater environment have higher metal concentrations than the WQS applied and are considered to be representative of natural background concentrations.

Many of the maximum concentrations recorded are from BH1103 (W2) (LU11). From the borehole log, Made Ground was recorded in this area to a depth of 0.4m. This comprised a concrete slab at the surface with light brown, slightly sandy, slightly gravelly clay. A soil chemical results from 0.0-0.3m was taken from BH1103 but this indicated relatively low concentration of metals. This made ground therefore does not appear to be the source of the elevated results recorded. Two water samples were taken from BH1103. W2 is from the shallower monitoring well, with W1 taken from depth. Results for W1 are much lower than W2 with only selenium and zinc showing exceedances. Thus there would appear to be a localised source of inorganic contamination in the influence of BH1103 that has yet to be delineated.

The drawing highlights that groundwater samples from adjacent wells e.g. WS1103 did not record exceedances for any of the metals. The exceedances in BH1103 appear to be an isolated case. Further monitoring should be undertaken in this borehole to see if these concentrations are sustained. Further soils investigation of made ground in this area is also warranted.

Organic Contaminants

Organic (TPH, PAH and phenol) contamination was encountered in groundwater samples from WS1103, BH1103, BH1108, BH610 and BH601 (phenol only). The main hydrocarbon contamination was encountered in LU11 which is in the location of historic fuel storage and vehicle maintenance of the former RAF base. However, no conclusive evidence of gross hydrocarbon contamination capable of creating a groundwater plume was encountered in the investigation work in this area; as demonstrated by the below summary of conditions encountered in each location;

- WS1103 – A hydrocarbon odour was recorded from 1.80m to 2.55m depth (strong to 2m).
- BH1103 – No evidence of hydrocarbon contamination observed during investigation.
- BH1108 - No evidence of hydrocarbon contamination observed during investigation.

BH1108 is located on the southern boundary of Phase 2 and therefore groundwater contamination may have migrated to this location, or be associated with a localised event. WS1103 and BH1103 are within the LU11 area and are likely associated with former uses, as mentioned above. Soil contamination has been encountered in this area which may be source of elevated results but as stated above no gross hydrocarbon contamination has been encountered.

No source of contamination, nor non-aqueous phase liquid, has been encountered within the groundwater itself. The remedial strategy will therefore be to remove or treat “hotspot” soil contamination that could be acting as a continuing source of input to groundwater. This action would prevent future inputs to groundwater. It is not considered necessary to undertake remediation of the groundwater itself as once the source of impact has been treated and/or removed no further impact will be occurring.

3.1.4 Detailed Quantitative Risk Assessment – Controlled Waters

To define the risk from soil contamination on the water environment, a detailed quantitative risk assessment has been undertaken using Environment Agency Remedial Target Methodology. This methodology has derived level 3 soil, and soil pore water, concentrations which are considered to be protective of groundwater. The modelling has adopted a compliance point of 50m away from the source of contamination (as detailed in GP3 (Ref 9)). Beck Brook which is considered to be the main controlled surface water receptor is over 50m from the contaminated area (within LU11) and therefore adoption of this distance in the modelling is considered to be conservative.

To derive level 3 soil values, the model applies partition coefficients based upon metallic species that are plausible within anthropogenic contamination. However, soil analysis reports only total metals, and the species actually present is uncertain.

In running the model, (using assumed partition coefficients), it is noted that the level 3 soil remedial target values derived for some of the metals are substantially lower than residential soil criteria. As an example, for Arsenic the derived Level 3 soil value is 3.24 mg/kg (to be protective of Controlled Waters), compared to the residential value of 37mg/kg, (protective of human health). These model derived values, if applied, would result in all soils failing including natural soils that have no sign of, nor plausible impact from, “contamination”. Thus if these risk based values were adopted as remedial criteria, all the soil results (Made Ground and natural) from the entire Phase 2 development area would exceed. This, therefore, is not considered credible and is not the approach that has been taken.

To take the site’s naturally elevated (background) metals component into consideration, results of leach test on soils have been reviewed. The Level 3 Soil Remedial Targets method also provide for comparison with pore water concentrations (i.e. soil leach test results). Taking this approach does not rely on an assumed partition coefficients.

When soil leach test results are compared to Level 3 soil pore water criteria these provide directly applicable remedial criteria that are equally protective of Controlled Waters. Where applicable, these criteria have been derived using EQS values. Worksheets are provided in Appendix E.

Leachate testing was undertaken on 29 soil samples during the Arcadis Phase 2 investigation works (Ref 5 and 6). When these are compared to the Level 3 remedial criteria derived, there is just one exceedance of cadmium recorded and one marginally exceeded mercury result. All the other results are below the soil pore water criteria (See Table 3.3 below).

All but one of the soil samples analysed were from natural soils. Thus although metals within the natural (uncontaminated) soils can leach they do not do so to a degree to cause unacceptable impact to Controlled Waters. Thus no remedial action needs to be undertaken, other than to address specific hotspots (i.e. where contamination has occurred).

Table 3.3 Summary of leachate analysis compared with Level 3 pore water criteria

Determinand	Range of Soil Leachate Concentrations (ug/l)	WQS (EQS / DWS) (ug/l)	Level 3 pore water remedial criteria (ug/l)	Exceedances of Level 3 criteria (Yes / No) (Number)	Location of exceedance
Arsenic	1.1 - 2.8	50 / 10	124	No	-
Cadmium	<0.08 – 2.4	0.15 / 0.15	1.86	Yes (1)	BH601
Chromium (VI)	<5.0	3.4 / 50	-	No – All BLOD	-
Chromium (III)	<0.4 – 8.5	4.7 / 250	58.2	No	-
Copper	3.6 – 100	47 / 2000	582	No	-
Lead	1 - 66	12 / 10	124	No	-

Determinand	Range of Soil Leachate Concentrations (ug/l)	WQS (EQS / DWS) (ug/l)	Level 3 pore water remedial criteria (ug/l)	Exceedances of Level 3 criteria (Yes / No) (Number)	Location of exceedance
Mercury*	<0.5 – 0.9	0.5 / 1.0	-	Yes (1)	TP633 (marginally)
Nickel	0.3 – 14	24 / 20	248	No	-
Selenium	<4.0 – 57	10 DWS	124	No	-
Vanadium	<1.7 - 16	20 EQS	248	No	-
Zinc	1.1 - 320	12.1 / 2000	496	No	-
pH	7.6 – 8.2	6 - 9	-	No	-

*A pore water value was not derived for mercury as no groundwater exceedances where encountered.

Organic contaminants

Leach testing of soils for organic contamination is not a valid method, as contamination can be retained or lost during the leach preparation or test process. Where elevated groundwater concentrations were detected, Level 3 Soil Values have been derived and these are proposed to be set as the remedial criteria that, if exceeded, would trigger remedial action to be protective of controlled waters. Worksheets are included in Appendix E.

Given the evidence from the targeted investigation of no widespread impacts (as discussed in Section 3.1) we have modelled a hotspot area of contamination to be present (50m in direction of groundwater flow and 5m width).

In the case of the aliphatic hydrocarbon (C8-10 and C10-12) and aromatic C8-10 values derived, these are considerably higher than values derived for a residential with plant uptake scenario. The values are above the saturation limit for those fractions. Thus the human health criteria will take precedence and will be protective of controlled waters.

The level 3 soil values derived for aromatic hydrocarbons (C10-12 and C12-16) are slightly lower than the human health criteria. However they are of the same order as residential with plant uptake criteria.

For simplicity of application within a site wide programme of works, it is proposed that human health criteria (residential with plant uptake criteria) are adopted to be protective of controlled waters for these organic contaminants. This would apply in all land use scenarios, residential, commercial, and public open space, where soils would be left exposed to leaching potential in the “as constructed” development.

3.2 Conceptual Site Model

3.2.1 Contaminants of Concern

As detailed in the sections above, there are several contaminants of concern which have been identified and need to be considered further. Below is a table which summarises the Contaminants of Concern for each land use.

Table 3.4 Summary of Contaminants of Concern

Soils	Groundwater
Residential land use (LU4, LU7, LU8, LU9, LU11) • Inorganics contaminants • Organics – PAH Compounds, TPH • Ground Gases • Asbestos	• Inorganic contaminants • TPH, PAH compounds, Phenol
Commercial / Industrial land use (LU10) • Ground Gases • Asbestos	• Inorganic contaminants
Open Space / Water Park / Sports Fields (LU6) • Organics – Benzene, PAH compounds • Asbestos	• Inorganic contaminants • Phenol
SARW (LU12) None	• Inorganics contaminants

3.2.2 Receptors

The site is mainly a residential development, however there is a town centre and school facilities planned; along with areas of recreation and open space. The receptors for the whole site are therefore considered to be the following;

Human Health

- Future site users (residents, members of the public, visitors, school children / teachers, users of the education campus, employees in town centre, users of public open space / water park area).
- Construction and maintenance workers

It should be noted that contamination risks to construction / site workers are not appraised by chronic (long term) exposure human health risk assessments. Site specific construction workers risk assessment and appropriate health and safety practices to adequately mitigate the potential risks are recommended for any future works. Works should be conducted in accordance with the Health and Safety Executive publication entitled "Protection of Workers and the General Public during the Development of Contaminated Land", 1991, the CDM Regulations (2015) and other relevant guidance.

Controlled Waters

- Underlying Secondary A aquifer (River Terrace Deposits)
- Beck Brook to the east of the site

Infrastructure

- Building foundations, Buried services and infrastructure
- Internal air quality and confined spaces from ground gases

3.2.3 Pathways

Potential pathways are the routes that link the receptor the contamination. The potential pathways for this site are provided in Table 3.5 below.

Table 3.5 Potential Contaminant Pathways

Receptor	Pathways
Humans health (future site users / maintenance workers)	Accidental ingestion of contaminants within soil, water and dust. Ingestion of contaminated vegetables and soil attached to vegetables (housing only) Indoor and outdoor inhalation of dust, vapours and ground gases. Dermal contact with contaminants within soil, water and dust.
Controlled Waters	Leaching of contaminants from the unsaturated zone into underlying groundwater. Horizontal migration of contaminants into via groundwater into surface water. Surface runoff.
Infrastructure	Direct contact of building /structures / services with contaminants in the soil Gas and/or vapour accumulation in confined and poorly ventilated spaces.

3.3 Risk Assessment Methodology

Risk assessment is the process of collating known information on a hazard or set of hazards (to determine the potential severity of any impact) along with details on the likelihood of impact on detailed receptors. Risks are generally managed by isolating the sensitive receptor or by intercepting or interrupting the exposure pathway, thus no pollutant linkages are formed and there is no risk. The following risk assessment focuses on the potential contaminants identified on the site in the context of the proposed development of the site.

CIRIA guidance C552 (Ref. 10) states that the designation of risk is based upon a consideration of both:

- The likelihood of an event (probability); (takes into account both the presence of the hazard and the receptor and the integrity of the pathway).
- The severity of the potential consequence (takes into account both the potential severity of the hazard and the sensitivity of the receptor)

Under such a classification system the following categorisation of risk has been developed and the terminology adopted as follows:

Table 3.6 Summary of Risk Classification Categories

Term	Description
Very High Risk	There is a high probability that significant harm could arise to a designated receptor from an identified hazard at the site without appropriate remedial action.
High Risk	Significant Harm is likely to arise to a designated receptor from an identified hazard at the site without appropriate remedial action.
Moderate Risk	It is possible that without appropriate remedial action, harm could arise to a designated receptor but it is relatively unlikely that any such harm would be severe and if any harm were to occur, it is likely that such harm would be relatively mild.
Low Risk	It is possible that harm could arise to a designated receptor from an identified hazard but it is likely that at worst this harm if realised would normally be mild.
Very Low Risk	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised, it is not likely to be severe.

3.4 Relevant Contaminant Linkages

Based on the contaminant sources and the potential receptors and pathways identified in previous sections, the following tables provide an assessment of each identified relevant contaminant linkage (RCL) to establish the risk and appropriate remedial approach that is protective of the identified sensitive receptors.

Table 3.7 Conceptual Site Model

RCL No	Contaminant Source	Sensitive Receptor	Pathway	Hazard (Severity)	Likelihood	Potential Risk	Remedial Action
RCL1	Inorganic and organic contaminants It should be recognised that overall the number of occurrences and severity of are relatively low.	Human Health	Ingestion / Inhalation / Dermal Contact / Veg uptake (residential only)	Chronic damage, carcinogenic compounds (**Medium**)	**Residential Land Use** **Low to Likely** Contaminant concentrations have been found to be elevated in hotspot locations across the site including proposed residential areas. In areas of proposed gardens / soft landscaping, it is likely that receptors would come into contact with contaminants if present in the surface soils if no remediation / mitigation is undertaken.	**Moderate / Low to Moderate**	Contamination has been encountered in the near surface soils in specific sample locations across the site, however contamination is not found to be widespread. The level of remediation / mitigation required will depend on the final design of the development in the areas where elevated results have been encountered but some basic cover protection is likely to be warranted, focused in soft landscaping areas including residential gardens.
					Commercial Land Use **Unlikely** Contaminant concentrations are below the commercial end use screening values.	**Low**	
					Open Space Land Use **Low** One elevated benzene result has been recorded within this area.	**Moderate / Low**	
					SARW **Unlikely** Contaminant concentrations are below the appropriate screening values	**Low**	
RCL2		Controlled Waters (Groundwater and Surface water)	Leaching and migration into water environment	Reduction of water quality, although unlikely to be a potable resource (**Low**)	**Low.** Some exceedances of WQS have been recorded in the groundwater analysis undertaken. This indicates that contaminants are available if infiltration occurs. Leachate results of inorganics are however below Level 3 pore water remedial targets and therefore the risk to controlled waters is considered to be low.	**Low**	Relatively few elevated contaminant concentrations believed to be associated with soils contamination have been encountered in the groundwater. Background presence of inorganic contaminants is observed. No remedial action is considered necessary for inorganics, with hotspot removal or treatment or

RCL No	Contaminant Source	Sensitive Receptor	Pathway	Hazard (Severity)	Likelihood	Potential Risk	Remedial Action
							isolation from infiltration, where organic remedial criteria are exceeded.
RCL3		Buildings / Services	Contact of contaminants with buildings and structures ()	Damage to structures (**Low**)	**Low.** Identified contaminants are unlikely to cause significant damage to new buildings, if appropriate concrete design is used. Contamination is not widespread across the site.	**Low**	pH concentrations outside the normal range of 6-9 units have been detected, with one slightly acidic result of 5.7 units. Appropriate concrete design should be used to safeguard the underground structures from the alkaline or acidic soil conditions.
RCL4	Asbestos fibres It is to be noted that this is not a widespread issue across the site.	Human Health	Inhalation of fibres	Chronic damage, carcinogenic compounds (**Medium**)	**Low to Likely.** Asbestos fibres have been detected in sample locations (in LU8) within the residential development area. These were encountered within the soil matrix. Inhalation of fibres could occur if disturbed causing a risk to site end users if left on site. Low likelihood relates to majority of sampling positions where no asbestos was encountered.	**Moderate / Low to Moderate**	Remedial action / watching brief will be required prior to development to ensure that the risk from asbestos is mitigated. Where present, either hotspot removal or creation of a basic cover system in areas of soft landscaping / residential gardens will mitigate low risks.
RCL5	Ground Gases (low methane and carbon dioxide – recorded within on-site soils, but no high gas generation source has identified or is believed to be present) i.e. there is no significant Made Ground or other potential sources such as landfill sites.	Human Health	Inhalation in confined spaces	Asphyxiation (**Severe**)	**Low.** Low concentrations of methane and carbon dioxide were recorded in areas across the site. Based on the current information, the risk to residential end users is considered to be low.	**Moderate**	Based on the recent (but limited) ground gas monitoring data and using CIRIA guidance, basic ground gas precautionary measures (traffic light situation Amber 1) are indicated to be required in proposed residential development. This finding warrants further monitoring of the gas regime, as default to protection is not consistent with the conceptual site model or SI findings –
RCL6		Buildings (on-site)	Accumulation in confined spaces	Explosion (**Severe**)	**Low.** Low concentrations of methane and carbon dioxide were recorded in areas across the site. Based on the current information, the risk to the proposed buildings is considered to be low.	**Moderate**	

RCL = Relevant Contaminant Linkage

4 Remedial Method Statement

4.1 Human Health / Soil Contamination

The following presents the Remediation Method Statement to be undertaken for areas proposed for residential housing, the town centre, the open space / water park and the SARW.

The level of remediation/ mitigation required will depend on the final detailed layout design of the development (i.e. where there is soft or hard landscaping). The remedial strategy approach specific to each proposed land use is set out below along with the contaminant linkages it relates to (see CSM tables above).

4.1.1 Residential Housing / Education Campus (LU9)

- **Land Uses - LU4, LU7, LU8, LU9 and LU11**
- **Contaminant Linkages – RCL1 and RCL4 (see Table 3.7)**

Potential contaminants have been identified with regards to exposure to metals, PAH compounds, TPH and asbestos in Made Ground and shallow natural soils in areas designated for residential land use.

It has been assumed that further targeted ground investigation will be proposed in the areas designated for residential housing, including chemical analysis and to inform the ground conditions for foundations.

In areas where exceedances of the appropriate Soil Screening Values (SSVs), or asbestos fibres have been identified from the existing data, the targeted ground investigation should be concentrated in these areas to delineate the contamination encountered and confirm the below remedial approach to be undertaken. This is particularly relevant if the area is within proposed gardens or soft landscaped area.

It should be noted that extensive archaeology works is taking place across areas of the Phase 2 site including LU7. Some of the shallow contamination encountered may have therefore been removed during the excavation works (See section 3.1.1 and 4.4.5).

Based on the outcome of the additional targeted investigation, the remedial action / requirements are as follows;

1. In areas where **no exceedances of SSVs** are encountered (see Appendix C). No remedial action is required. In areas of gardens / soft landscaping, if the physical composition (amenity value) of the soils are not suitable (e.g. Made Ground) as a growing medium consideration will need to be given to import suitable materials.
2. In areas where **exceedances** of SSVs are encountered (see Appendix C), the contaminated materials will need to be assessed and determined if removal or other form of risk mitigation is required. This will depend on depth of contamination and if it is under proposed hardstanding or on areas of gardens / soft landscaping. If removal is deemed necessary, hotspot removal should be undertaken and validation of the sides and base of the pits undertaken to ensure that all affected soils have been removed.
3. If exceedance of organic criteria is present, remediation will first need to be undertaken to protect controlled waters.
4. Excavated areas are backfilled with suitable “clean” material (either site won or imported).

Clean Cover

Provided action has first been taken to protect controlled waters, in gardens / soft landscaped areas the following should be adopted;

- Minimum of 600mm “clean cover” in residential private (back) gardens.
- Minimum of 300mm” clean cover” in areas designated for front gardens or soft landscaping
- The depths can be achieved by excavation or placing clean cover on the surface if the site levels can be increased or a combination (i.e. excavation of 300mm and clean cover of 600mm to increase the site levels by 300mm).
- If site levels are to be raised a check of the leaching potential of contamination left in place should be undertaken, as this could cause a risk to controlled waters.

- Validation testing should be undertaken of clean cover which should include depth of material and quality of material placed.
- The clean cover material could be site won or brought on to site from an external source. Analytical testing should be undertaken prior to placing to determine that it is suitable for the intended use.

Watching Brief

During any additional investigation undertaken, a watching brief approach should be adopted (see Section 4.4.1) and if suspected contamination is encountered, the investigation should be extended to delineate the affected areas. Appropriate chemical testing of soils should be undertaken and screened against the appropriate Soil Screening Values (SSVs) (Appendix F) to determine required approach.

4.1.2 Education campus / sports fields / open space and ponds

- **Land Uses – LU6**
- **Contaminant Linkages ‐ RCL1 and RCL4 (see Table 3.7)**

Asbestos fibres were identified in 8 samples and there was an exceedance of the benzene SSV in 1 sample location (TPB001E). These are within the area proposed as the ponds. It is understood that this area is to be excavated and removed. The excavated soils from the ponds are intended to be used to create bridge embankments required on the SARW. As discussed in Section 3.1.1, these soils will therefore be buried and “locked” in place. There will be no future linkage to create impact.

In the location of the sports fields there is an exceedance of PAH compounds in TPB010 at 0.2m depth.

As detailed in Section 3.1.1, two ordnance disposal / burning pits (WP1 and WP2) were encountered in LU6 near the eastern boundary. Whilst soils from this area do not show exceedances against the appropriate land use SSVs, the thin layer of waste materials recorded at approximately 1.4m bgl should be excavated and disposed off site to remove the ordnance risk from these areas.

The waste material should be excavated, spread out and raked to remove any ordnance items which may be contained within the waste. It should be noted that these items are not high risk / large UXOs but small fragments of ordnance. Once the ordnance items have been removed, the waste materials should be disposed of at an appropriately licensed landfill site. Validation testing should be undertaken to confirm all waste materials have been removed.

For other areas within LU6, the following remedial actions should be undertaken:

- Removal of areas where contamination (asbestos / benzene / PAH compounds) has been encountered prior to the large excavation of the ponds. This will ensure that these contaminated soils do not get spread across the site during the earthworks and cross contaminate “clean” excavated soils. These soils are to be re-used within the bridge embankments as detailed above. The location / depth that they are placed within the embankment should be recorded in the H&S file for information for future workers.
- Validation testing of the sides and base of the pits undertaken to ensure that all affected soils have been removed.
- Watching brief approach during removal of hotspots and large excavation of proposed drainage attenuation ponds (see Section 4.4.1)
- Undertake good material management of excavated soils / Made Ground (see Section 4.4.4).
- Excavated areas are backfilled with suitable “clean” material (either site won or imported).

4.1.3 Commercial / Industrial Land Use

- **Land Uses ‐ LU10**
- **Contaminant Linkages ‐ RCL1 and RCL4 (see Table 3.7)**

No exceedances of the SSVs for a commercial / industrial land use have been encountered in the proposed town centre. However in one sample (ZTR9 0.0 – 0.1) loose chrysotile asbestos fibres were identified. Assessment of where this sample is in relation to the final design layout should be undertaken to determine if it can remain in place (i.e. under hardstanding) or requires removal (i.e. if it were in a soft landscaping area).

It has been assumed that further targeted ground investigation will be proposed in the areas designated for the town centre to inform the ground conditions for foundations. Chemical testing should be undertaken, especially in proposed soft landscaped areas to provide further confidence and data to help validate soils are suitable for use.

Where contamination is present, the remedial action / requirements are as follows;

1. In areas where **no exceedances of SSVs** are encountered (see Appendix B). No remedial action is required. In areas of soft landscaping, if the soils are not of suitable amenity value (e.g. Made Ground) or as a growing medium consideration will need to be given to import suitable materials.
2. In areas where **exceedances** of SSVs **(none currently found)** are encountered (see Appendix B), the contaminated materials will need to be assessed and determined if removal is required – this will depend on depth of contamination, if it is under proposed hardstanding or on areas of soft landscaping. If removal is deemed necessary, hotspot removal should be undertaken and validation of the sides and base of the pits undertaken to ensure that all affected soils have been removed.
3. If exceedance of residential organic criteria is present, remediation will first need to be undertaken to protect controlled waters.
4. Excavated areas are backfilled with suitable “clean” material (either site won or imported).

Clean Cover

In soft landscaped areas the following should be adopted;

- Minimum of 300mm” clean cover” in areas designated for soft landscaping
- The depths can be achieved by excavation or placing clean cover on the surface if the site levels can be increased or a combination (i.e. excavation of 200mm and clean cover of 300mm to increase the site levels by 100mm).
- Validation testing should be undertaken of clean cover which should include depth of material and quality of material placed.
- The clean cover material could be site won or brought on to site from an external source. Analytical testing should be undertaken prior to placing to determine that it is suitable for the intended use.

Watching Brief

During any additional investigation undertaken, a watching brief approach should be adopted (see Section 4.4.1) and if suspected contamination is encountered, the investigation should be extended to delineate the affected areas. Appropriate chemical testing of soils should be undertaken and screened against the appropriate SSVs (Appendix F) to determine required approach.

4.1.4 Southern Access Road West (SARW)

- **Land Uses – LU12**
- **Contaminant Linkages ‐ RCL1 (see Table 3.7)**

The SARW is mainly to the south of the main Phase 2 development area and mainly crosses greenfield land. Due to the less sensitive nature of this part of the development, the chemical results were screened against a commercial / industrial land use. No exceedances were encountered.

No specific remediation is required in the construction of the road.

4.2 Groundwater

- **Contaminant Linkages - RCL2 (see Tables 3.7)**

As detailed above, gross widespread groundwater contamination was not encountered and therefore direct remediation of groundwater is not warranted. Protection of groundwater would be by mitigation of soil sources (see previous section 4.1.1 to 4.1.3. Currently no action is required.

As further investigation is undertaken, as part of detailed design to development parcel areas, then the following approach to evaluation should be followed.

Soil (leachate) remedial criteria have been derived for metals (RMT Level 3) which are protective of controlled waters. If these values are exceeded a risk to groundwater and the water environment could exist and action is required. Level 3 soil criteria have been derived for organics.

The approach to assess the risk to groundwater would be as follows;

- During further ground investigations for detailed design (as detailed in sections above), soil leachate analysis would be scheduled for inorganic contaminants, and soil totals testing for organics. These would be compared to the remedial criteria derived (Appendix G).
- If no exceedances of remedial criteria are encountered, no action is required.
- If exceedances of remedial targets are encountered, the soils / area affected will not be protected from leaching by proposed permanent hardcover, they should be delineated and soils removed. Validation testing of the sides and base of the pits undertaken to ensure that all affected soils have been removed.
- Excavated areas are backfilled with suitable "clean" material (either site won or imported).

With regards to hydrocarbon contamination. Elevated soil concentrations have been recorded and these areas will be removed as part of the soil remedial strategy to reduce the source potential (see sections 4.1.1 to 4.1.3 above).

4.3 Ground Gas

- **Contaminant Linkages - RCL5 and RCL6 (see Tables 3.7)**

Existing data indicates the site to be transitional from very low risk (no special measures required) to low risk, basic protection required.

From the current data available, and if a precautionary approach were to be applied**, a "low risk" is identified and the site is considered to be represented by Characteristic Situation 2 in CIRIA C665 (Ref 11).

From CIRIA 665, basic precautionary measures would be required in any new building.

In new residential properties, measures at Characteristic Situation 2 would include;

- Reinforced Concrete cast in situ floor slab (suspended, non – suspended or raft) with at least a 1200g DPM (damp proof membrane), or
- Beam and block or pre cast concrete slab and minimum 2000g DPM/reinforced gas membrane,

In a new Office/Commercial/Industrial development, measures for Characteristic Situation 2 should include;

- Reinforced Concrete cast in situ floor slab (suspended, non – suspended or raft) with at least a 1200g DPM (damp proof membrane), or
- Beam and block or pre cast concrete slab and minimum 2000g DPM/reinforced gas membrane, or
- Possibly under floor venting or depressurisation in combination with the above 2 options depending on use/

During installation all joints and penetrations would be sealed.

Verification would be undertaken by an independent consultant during the installation to ensure that their joints are sealed and that there are no tears in the membrane before any concrete pours.

The design of the precautionary measures would be in accordance with BS8485 (2015) (Ref 12) and the type of membrane to be used should be agreed with Building Control and the Contaminated Land Officer prior to installation.

** A precautionary approach is not warranted at this stage of development investigation and a more comprehensive data set is required.

However, if additional monitoring, including some continuous gas monitoring is undertaken to better understand the ground gas regime then the above remedial strategy may not be needed. It is anticipated that given the development cost consequences between no special measures and equipping every structure with basic gas protection, more detailed monitoring is likely to be undertaken prior to construction of each development parcel.

4.4 Site-Wide Remedial Measures

4.4.1 Watching Brief

It should be noted that the current site investigation is generally based upon a 50 or 100 metre grid based on proposed land use.

A general watching brief should be undertaken during enabling and construction works, and during any further ground investigation. If visual / olfactory evidence of contamination is encountered e.g. free product, appropriate analysis should be undertaken to confirm if the soil meets the required criteria to be protective of human health and controlled waters.

If concentrations above the criteria are encountered, further investigation and chemical testing may be required to delineate areas impacted. Assessment of the significance of such finds will need to be made.

Current site investigation information should be included within the Contractor's Health and Safety risk assessment and method statement for the works. This should include measures such as appropriate use of PPE and dampening stockpiles of excavated material to prevent dust generation. Construction workers should be briefed to be extra vigilant during the works. If ashy material is encountered, this could represent a burning pit and additional screening (e.g. radiological screening) may be required.

Should potential contamination not previously encountered be identified during the enabling / construction phase, a suitably experienced Geo Environmental Engineer should be contacted to take samples of any potentially contaminated material to determine the risks present and the appropriate cause of action. If significant contamination is encountered which requires a different approach to those detailed above, a discussion should be sought with the Local Authority Contaminated Land Officer to gain agreement with the way forward.

4.4.2 Validation Testing

If contaminated material is identified which requires removal, validation testing of the remaining soils should be undertaken by a qualified Geo-Environmental Engineer. This should include the sides and base of the pits excavated with at least one 1 sample per face. This should be documented and included within a verification report to detail the contamination encountered and, the works undertaken to remove it / treatment along with validation testing results for the remaining soils. Photographs should be taken to provide further evidence.

Imported material which is brought to site for use as engineering fill / clean cover should be tested to ensure that it is fit for purpose (both geo-environmentally and geotechnically). Testing should be undertaken prior to soils being brought to site at an appropriate testing regime based on the source. For example, if the source is greenfield, a rate of 1 sample per 1000m^3 may be appropriate, however if the source is from a brownfield location a higher rate of sampling should be adopted. Testing should then be undertaken when it is placed in final location. In garden areas, at least one location per plot should be sampled and analysed. This should be reviewed for larger garden plots.

Criteria for imported material is included is Appendix F. The criteria used should be appropriate for the proposed end use where the material is to be placed.

4.4.3 Verification Reporting

The details of all remedial actions undertaken should be recorded in a verification report, which should detail the action undertaken (e.g. watching brief, targeted ground investigation, hotspot removal) along with the chemical testing results and assessment criteria.

4.4.4 Materials and Stockpile Management

Separate areas should be designated for stockpiles of excavated Made Ground and natural soil / contaminated and uncontaminated soils. Made Ground / contaminated soils should be stored on impermeable material to prevent leaching (i.e. from metals and organics into groundwater). Stockpiles should be dampened to prevent dust generation and covered to prevent rainwater ingress.

Made Ground / contaminated soils should be segregated from natural material and should not be used elsewhere on site as engineering fill or backfilling unless it can be proven to be suitable for use, both geotechnically and geo-environmentally (chemically suitable).

Materials which are deemed not suitable to be re-used within the development should be removed off site to a suitably licenced disposal facility. Further testing may be required e.g. Waste Acceptance Criteria to ensure that the appropriate waste classification is determined and therefore the appropriate facility. The waste producer has the Duty of Care for the appropriate disposal of waste soils / materials.

4.4.5 Validation of Stockpiled Materials

Stockpiles of topsoil and subsoil have been created from the extensive archaeological works that have been taking place across the Phase 2 works. Further stockpiles may be created for example due to surface (topsoil) scraps or excavation for service trenches.

Prior to the soils in the stockpiles being placed in their final location, validation sampling and appropriate chemical analysis should be undertaken to confirm that the soils are suitable for the intended end use (e.g. in gardens or landscaping in the town centre) of these soils. This should be on the basis of at least 1 sample per 1000m^3 of material.

Once the material is in its final place, validation sampling and chemical analysis should be undertaken to provide additional evidence that the soil is suitable for the proposed end use. If appropriate the depth of placed material should also be recorded.

Detailed records of where stockpiled material is placed within the development should be taken and included in the validation report along with the chemical results, placed depths and appropriate photographs.

4.4.6 Drinking Water Pipes

To be protective of water supply pipes the guidance from UK Water Industry Research (UKWIR) should be used to determine the appropriate pipeline to be used within the development areas.

5 Regulatory Review

The Remediation Method Statement was sent to the Contaminated Land Officer (CLO) of South Cambridgeshire District Council (SCDC) and the Environment Agency for review and to discharge Item 3 of Condition 17 of the planning permission as detailed in Section 1.1 of this report. Below are details of their responses.

5.1 Contaminated Land Officer

A letter providing comments from the CLO from SCDC (dated 24th April 2018) is included in Appendix H.

A memo (dated 30th April 2018) detailing the response from Arcadis is in Appendix H. Relevant changes have been included within this report (Issue 5).

5.2 Environment Agency

All correspondence between the EA and Arcadis is included in Appendix I. This includes the following;

- A letter (dated 4th May 2018) providing comments from the EA on the Remediation Method Statement.
- Arcadis' memo (dated 16th May 2018) in response to EA letter.
- A subsequent letter (dated 30th May 2018) from the EA.
- Arcadis' memo (dated 14th June 2018) in response EA letter.
- A letter (dated 25th June 2018) confirming acceptance from the EA.

It is noted that the EA comments were related more to the justification of modelling and groundwater contaminant levels and Arcadis's response does not change the Remediation Method Statement. No amendments to this report have been made in relation to the EA changes.

6 References

1. WSP (2007), Interim Factual Report, Northstowe, Cambridgeshire, Zone B (Project Number 12170626)
2. WSP (2007) Interim Factual Report, Northstowe, Cambridgeshire, Zone C (Project Number 12170626)
3. WSP (2007) Interim Factual Report, Northstowe, Cambridgeshire, Zone D (Project Number 12170626)
4. Hyder Consulting (UK) Limited (2014) Northstowe – Phase 2 Geo Environmental Assessment and Outline Remedial Strategy Report (Report Number 5025-UA006156-UP31R-01)
5. Arcadis Consulting (UK) Limited (2017), Northstowe Phase 2 Ground Investigation Report, (Report Number UA008426-AFS-GLR-G001)
6. Arcadis Consulting (UK) Limited (2017) Northstowe Phase 2 Development - Geo Environmental Assessment Report / Outline Remedial Strategy (Infrastructure) (Report number NOR-ARC-P2-XXX-RP-G-0137-P01)
7. Zetica (2018) Northstowe Phase 2 Planning Condition Discharge, Unexploded Ordnance – Condition 38(i) UXO Clearance Report
8. LQM / CIEH (2015) The LQM / CIEH S4ULs for Human Health Risk Assessment [2]
9. Environment Agency (2013) Groundwater Protection: Principles and practice (GP3)
10. CIRIA C552 (2001) Contaminated land risk assessment. A guide to good practice
11. CIRIA C665. (2007) Assessing Risks Posed by Hazardous Ground Gases to Buildings
12. British Standard (2015) Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings (BS8485)

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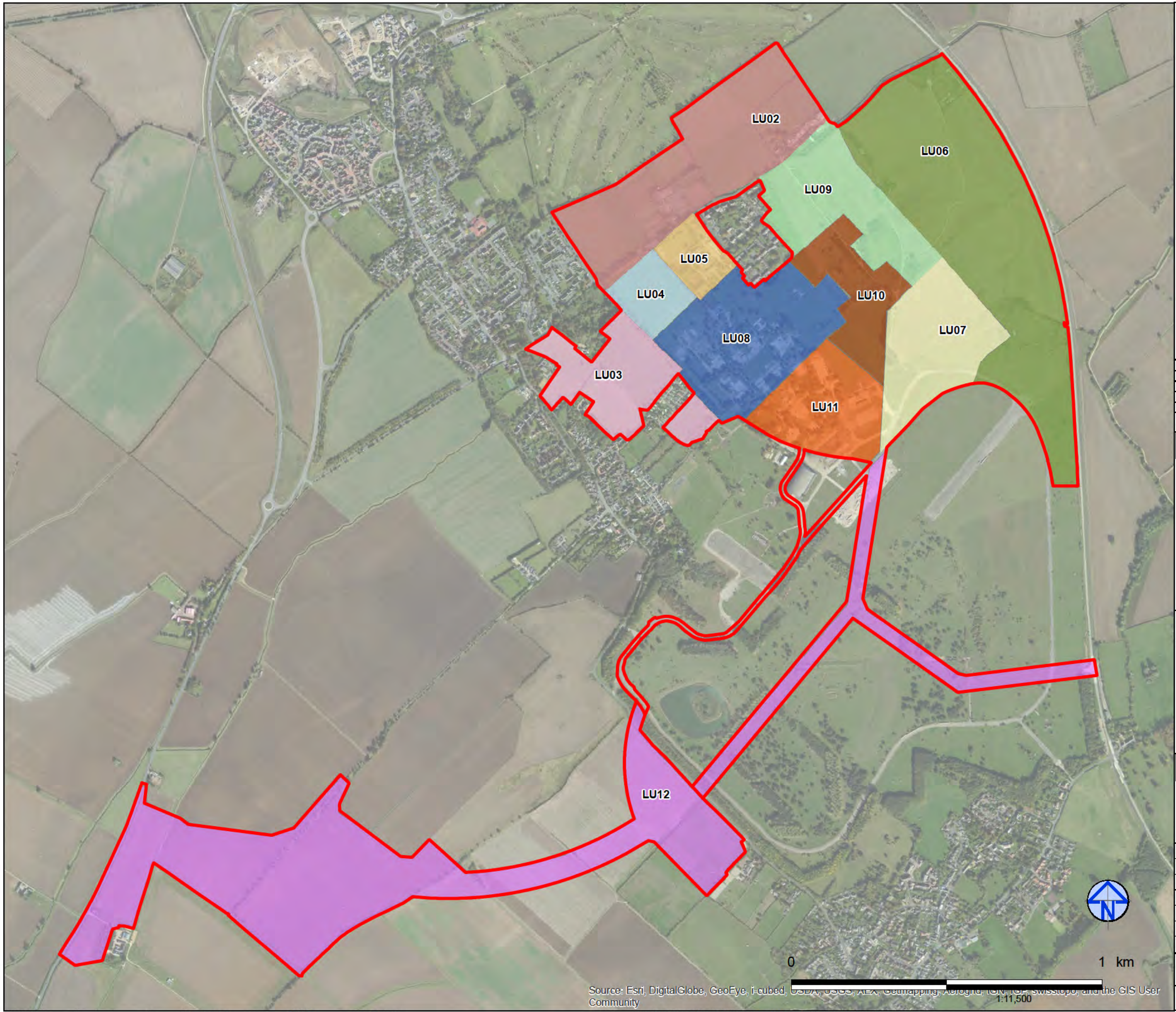
APPENDIX A

Land Use Plan



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

1:11,500

Land Use Areas

- LU02
- LU03
- LU04
- LU05
- LU06
- LU07
- LU08
- LU09
- LU10
- LU11
- LU12
- Phase 2 Planning Boundary

REV	Date	Description	Drawn	Check	Approv
01	01/06/2017	Issue 01	FW	AP	GF

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TITLE

SITE LAYOUT PLAN

Designed	Reg.	Date 01/06/2017	Signed
Drawn	Reg.	Date 01/06/2017	Signed
Checked	Reg.	Date 01/06/2017	Signed
Approved	Reg.	Date 01/06/2017	Signed
Scale	As shown	Datum:	AOD
Original Size	A3	Grid:	OS
Suitability Code	S2	Project Number:	UA008426

Suitability Description:
PRELIMINARY
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Drawing Number: Figure 2

Revision: 01

50mm on Original   Print Date 2017-06-01 15 59 57

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APPENDIX B

Soil Exceedance Tables

(taken from Arcadis Geo Environmental Assessment report (Ref 6))

The reader should note that these are taken from the Arcadis report (Ref 6). Further discussion is within the Arcadis report and should be read in conjunction with this Appendix.

Soils - Tier 1 Screening Assessment

Inorganics

The chemical results were assessed against the SSV for a residential with plant uptake land use (i.e. the most sensitive land use). The table below provides a summary of the contaminants which have exceedances and the location where this was recorded. The Hazard Index (HI)[3] has been included to provide an indication of the relative severity of the exceedance.

Table 1 Contaminants with exceedances against the relevant residential with plant uptake SSV

Determinand	SSV (mg/kg) (Residential with plant uptake)	Location of exceedance / depth m (stratum)	Concentration (mg/kg)	Hazard Index (HI)
Arsenic	37	*WSC27 0.9-1.0 (NS)*	*73*	*2*
		TPB2 0.15 (NS)	*45.7*	*1.2*
Cadmium	11	TP626 0.4-0.7 (MG)	40	3.7
		TP627 0.1 (MG)	19	1.7
		TP627 0.35 (NS)	16	1.5
		BH601 0.3-0.8 (NS)	27	2.5
		TPB73 0.45 (NS)	*28.9*	2.6
		TPB2 1.1 (NS)	*84*	**7.6**
		TPB1E 0.15 (MG)	*16.5*	1.5
		TPB1C 0.4 (MG)	*16.8*	1.5
Chromium (hexavalent)	6	TP626 0.4-0.7 (MG)	7.8	1.3
Copper	2400	TP626 0.4-0.7 (MG)	12000	5.0
Lead	220	TP626 0.4-0.7 (MG)	1700	7.7
		ZTR3 0.0-0.1(MG)	670	3.0
		BH601 0.3-0.8 (NS)	830	3.8
		TP627 0.1(MG)	1000	4.5
		TP627 0.35 (MG)	580	2.6
		TPB2 1.1 (LU6) (NS)	1490	6.8
		ZBP3 1.0-1.1(MG) (LU6)	620	2.8
		ZTR7A 0.2-0.3 (MG)	530	2.4
		LIF1004 0.1-0.3 (MG)	470	2.1
		TPB73 0.45 (NS)	*330*	1.5
		TPC19 0.2 (MG)	*541*	2.5
		TPC13 1.1 -1.2 (MG)	*372*	1.7
		TPB1C 0.4m (MG)	*471*	2.1
		TPB1E 0.15m (MG)	*576*	2.6
Nickel	130	TP626 0.4-0.7 (MG)	180	1.4
		TPB2 1.1 (LU6) (NS)	*165*	1.3
		TPC13 1.1-1.2 (MG)	*372*	2.9
Zinc	3700	TP626 0.4-0.7 (MG)	4200	1.1

---

[3] HI = Concentration encountered / SSV

Determinand	SSV (mg/kg) (Residential with plant uptake)	Location of exceedance / depth m (stratum)	Concentration (mg/kg)	Hazard Index (HI)
		ZBP3 1.0-1.1(MG)	40000	10.8
pH	6-9	ZTR3 0.0 – 0.1(MG)	10.1	n/a
		TP907 0.1 *(NS)*	5.7	
		LIF1004 0.1-0.3 (MG)	10	
		LIF1003 0.1-0.3 (NS)	11.5	
		LIF1102 0.1-0.3 (MG)	10.8	
		LIF1103 0.2-0.5 (MG)	11.5	
		WS1103 0.1-0.2 (NS)	11	
		TP1108 0.15-0.25 (MG)	10.1	
		TP1206 0.4 (NS)	9.4	
		TP1202 0.4 (MG)	9.7	
		WSC027 0.2 (NS)	11.3	
		WSC03 0.4 (MG)	11.2	
		TPB72 0.8 (MG)	*9.5*	
		TPB179F 1.5 (MG)	*10.20*	
		WSC16 0.4 (MG)	*9.3*	
		TPC28 0.46 (MG)	*9.2*	
		TPC10 0.8 (MG)	*10.3*	
		BHC21 1.5 (NS)	*10.7*	

Italics = WSP 2007 data   MG = Made Ground   NS = Natural Soils

Polycyclic Aromatic Hydrocarbons (PAH)

The chemical results were assessed against the SSV for a residential with plant uptake land use (i.e. the most sensitive land use). Due to the large number of exceedance encountered the table below provides a summary of the PAH compounds which have exceedances and the LU areas where they are recorded.

Table 2 Summary of exceedances encountered for PAH compounds

Determinand	SSV (mg/kg) Residential with plant uptake (Commercial SSV mg/kg)	Number of exceedances - Land Use Area	Concentration Range above SSV (mg/kg) (Location of Max Concentration)
Naphthalene	2.3 (190)	2 LU11	6.9 – 54 (WSC009 0.5m (LU11))
Benzo(a)anthracene	7.2 (170)	12 LU6 / LU7 / LU9 / LU10 / LU11 / LU12	7.3 – 22 (TP1118 (0.0-0.25m) (LU11) / TP1201 0.1m (LU12) and ZTR7B 0.0-0.1m (LU10))
Chrysene	15 (350)	5 LU9 / LU11 / LU12	18 - 23 (TP1232 0.1m (LU12))
Benzo(k)fluoranthene	77 (1200)	1	233 (TPB092 0.3m)

Determinand	SSV (mg/kg) Residential with plant uptake (Commercial SSV mg/kg)	Number of exceedances - Land Use Area	Concentration Range above SSV (mg/kg) (Location of Max Concentration)
		LU7	
Benzo(b)fluoranthene	2.6 (44)	32 LU6 / LU9 / LU10 / LU11 / LU12 / LU13	2.9 – 29 (TPSA1201 0.1m (LU12))
Benzo(a)pyrene	2.2 (35)	36 LU6 / LU7 / LU9 / LU10 / LU11 / LU12 / LU13	2.4 – 25 (TP1118 0.0-0.25m (LU11))
Dibenz(a,h)anthracene	0.24 (3.5)	34 LU6 / LU7 / LU9 / LU10 / LU11 / LU12 / LU13	0.27 – 8 (TPB037 1.3-1.6m (LU9))

Total Petroleum Hydrocarbons (TPH)

TPH analysis was undertaken on the majority of samples (230 in latest Arcadis investigation) and in most cases the results were below the limit of laboratory detection. Exceedances above the SSV for residential land use were however recorded which are detailed in the table below.

Table 3 Summary of exceedances encountered for TPH fractions

Determinand	SSV (mg/kg) Residential with plant uptake	Location of exceedance / depth mbgl (stratum)	Concentration (mg/kg)	Hazard Index (HI)
TPH Aliphatic C8-C10	27	WS1103 1.9-2.0 (NS) TPC016B 1.5 (NS) *TPB001E 0.3 (MG)* *WSC033 1.1* (NS) *TPC019 (0.2m) (MG)* *TPC24A (0.65m) (NS)*	78 120 52 35.01 *339 (total C8-16)* *271 (total 8-10)*	2.9 4.4 1.9 1.3 12.6 10.0
TPH Aliphatic C12-C16	1100	TPC051 0.5 (NS)	1400	1.3
TPH Aromatic C8-C10	34	*TPB001E 0.3 (MG)*	100	2.9
TPH Aromatic C10-C12	74	*TPB001E 0.3 (MG)* *TPC24A (0.65m) (NS)*	290 *770 (total C10-12)*	3.9 10.4
TPH Aromatic C12-C16	140	TPC051 0.3 (NS) TPC051 0.5 (NS) TPC051 0.9 (NS) WSC027 1.1 (NS) WSC027 2.0 (NS) TP024A 0.8 (NS) WWC03 0.7 (NS) WWC03 1.2 (NS) TPC016A 1.2 (NS)	320 1500 180 470 150 210 150 180 500	2.3 10.7 1.3 3.4 1.1 1.5 1.1 1.3 3.6

Determinand	SSV (mg/kg) Residential with plant uptake	Location of exceedance / depth mbgl (stratum)	Concentration (mg/kg)	Hazard Index (HI)
		TPC24A (0.65m) (NS)	*1020 (total C12-16)*	7.3
		TPC51 1.8m (NS)	*1170 (total C16-24)*	8.4
		WSC33 1.1-1.3 (NS)	*541 (total C12-16)*	3.9
TPH Aromatic C16-C21	260	TP1232 0.1 (NS)	280	1.1
		TP1118 0.0-0.25 (NS)	320	1.2
		TPC051 0.3 (NS)	1100	4.2
		TPC051 0.5 (NS)	2600	10.0
		TPC051 0.9 (NS)	280	1.1
		WSC027 1.1 (NS)	750	2.9
		TPB028 0.1 (MG)	*480*	1.8
		WSC027 0.9 (NS)	*2110*	8.1
		TPC009 0.7 (MG)	*698 (total C16-21)*	2.7
		TPC019 (0.2) (MG)	*3000 (total C16-24)*	11.5
		TPC51 1.8m (NS)	*1170 (total C16-24)*	4.5
		TPC38 0.15-0.25 (MG)	*286 (total C16-21)*	1.1
TPH Aromatic C21-C35	1100	*TPB028 0.1(MG)*	2300	2.1
		TPB073 (0.45m)	*1140 (total C21-35)*	1.0
		TPC019 (0.2m)	*2430 (total C24-40)*	2.2
		TPC38 0.15-0.25 (MG)	*1400 (total C21-35)*	1.3
		TPC009 0.7 (MG)	1940 (total C21-35)	1.8
Benzene	0.087	*TPB001E 0.3 (MG)*	100	1149.4

Asbestos

Soil samples were screened for asbestos fibres and the table below indicates the locations where fibres or fragments were encountered. If asbestos was detected above the laboratory analysis limit during the recent investigation, quantification testing was scheduled to obtain a percentage result for the asbestos present. This is presented in the table below.

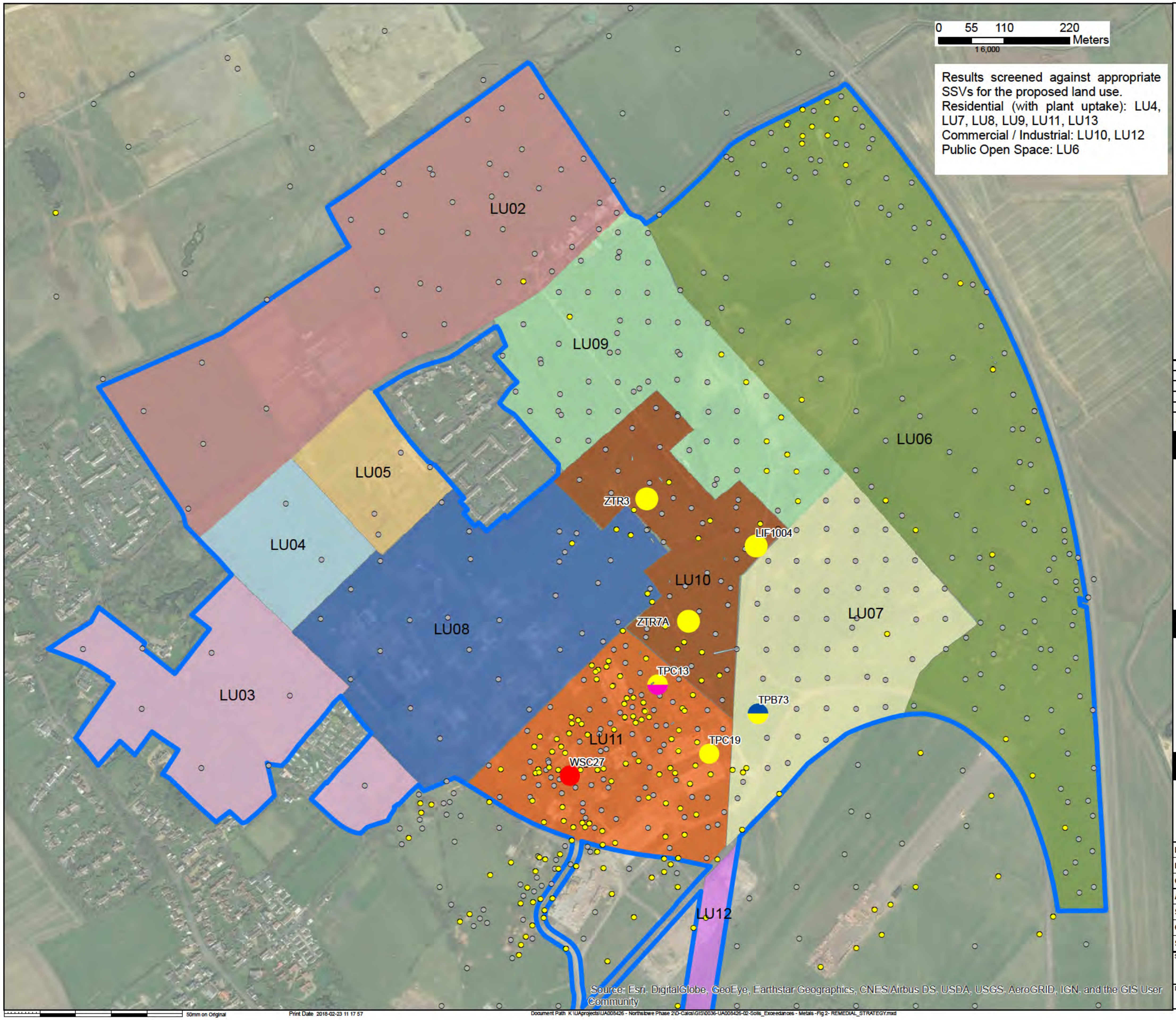
Table 4 Locations where asbestos fibres were detected (above the limit of detection)

LU Area	Location / depth (m) / Strata	Type of asbestos	ACM Type Detected	Quantification Result
LU6	TP626 0.1-0.2m (MG)	Chrysotile	Insulation Lagging	<0.001%
	TP626 0.4-0.7m (MG)	Chrysotile-	Insulation lagging, loose fibres	<0.001%
	TP627 0.1m (MG)	Chrysotile-	Insulation lagging, loose fibres	0.014%
	TP627 0.35 (MG)	Chrysotile, Amosite	Insulation lagging	0.016%
	TP607 0.4 (MG)	Chrysotile	Loose fibres	<0.001%

LU Area	Location / depth (m) / Strata	Type of asbestos	ACM Type Detected	Quantification Result
	BH601 0.3-0.8	Chrysotile	Insulation lagging	<0.001%
	TPB1C 0.4m (MG)	*Crocodiolote, Amosite, Chrysotile*		0.1%
	TPB1D 0.4m (MG)	*Amosite*		0.1%
	TPB1B (MG)		*Asbestos Tile fragment*	
LU8	ZTR4b 0.3-0.4m (MG)	Chrysotile, Amosite	Loose fibres	<0.001%
LU10	ZTR9 0.0-0.1m (MG)	Chrysotile	Loose fibres	<0.001%

APPENDIX C

Plans showing Soil Exceedances



Results screened against appropriate SSVs for the proposed land use.
Residential (with plant uptake): LU4, LU7, LU8, LU9, LU11, LU13
Commercial / Industrial: LU10, LU12
Public Open Space: LU6

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Exceedances of metals in soil samples analysed

◕	🟩 Copper
🟥 Arsenic	🟨 Lead
🟦 Cadmium	🟪 Nickel
🟪 Chromium VI	🟩 Zinc

Exploratory Holes

- ● Made Ground encountered
- ● Made Ground not encountered

▬ Phase 2 Planning Boundary

REV	Date	Description	Drawn	Check	Approv
01	23/02/2018	FIRST ISSUE	FW	AP	GF

Client

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LOCATION OF METALS
EXCEEDANCES IN SOILS

Designed	[redacted]	Date 23/02/2018	Signed
Drawn	[redacted]	Date 23/02/2018	Signed
Checked	[redacted]	Date 23/02/2018	Signed
Approved	[redacted]	Date 23/02/2018	Signed
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Original Size	A3	Grid:	OS
Suitability Code	S2	Project Number:	UA008426

Suitability Description:
PRELIMINARY
NOT FOR CONSTRUCTION

Drawing Number: Figure 2
Revision: 01

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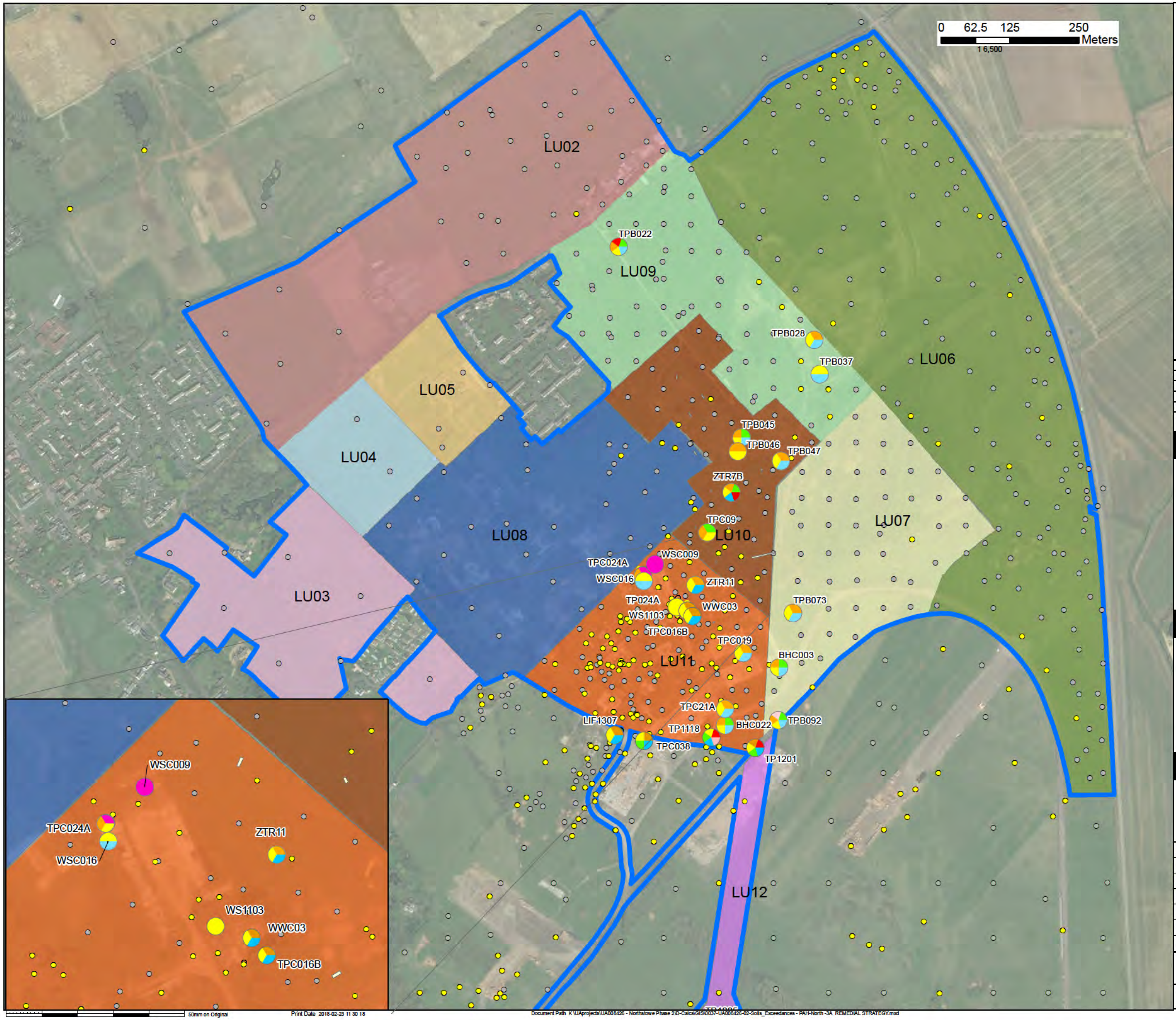

Exceedances of PAH in soil samples analysed

- 🟪 Naphthalene
- 🟩 Benzo-A-anthracene
- 🟥 Chrysene
- ▨ Benzo-K-fluoranthene
- 🟧 Benzo-B-fluoranthene
- 🟨 Benzo-A-pyrene
- 🟦 Dibenzo-AH-anthracene

Exploratory holes

- ● Made Ground encountered
- ● Made Ground not encountered
- ━ Phase 2 Planning Boundary

Results screened against appropriate SSVs for the proposed land use.
Residential (with plant uptake): LU4, LU7, LU8, LU9, LU11, LU13
Commercial / Industrial: LU10, LU12
Public Open Space: LU6

REV	Date	Description	Drawn	Check	Approv
10	23/02/2018	FIRST ISSUE	FW	AP	GF

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34 York Way
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N1 9AB

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TITLE

LOCATION OF PAH EXCEEDANCES IN SOIL AND MADE GROUND (NORTHERN AREA)

Designed	Reg. [redacted]	Date 23/02/2018	Signed
Drawn	Reg. [redacted]	Date 23/02/2018	Signed
Checked	Reg. [redacted]	Date 23/02/2018	Signed
Approved	Reg. [redacted]	Date 23/02/2018	Signed
Scale	See Layout	Datum:	AOD
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Suitability Description:
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NOT FOR CONSTRUCTION

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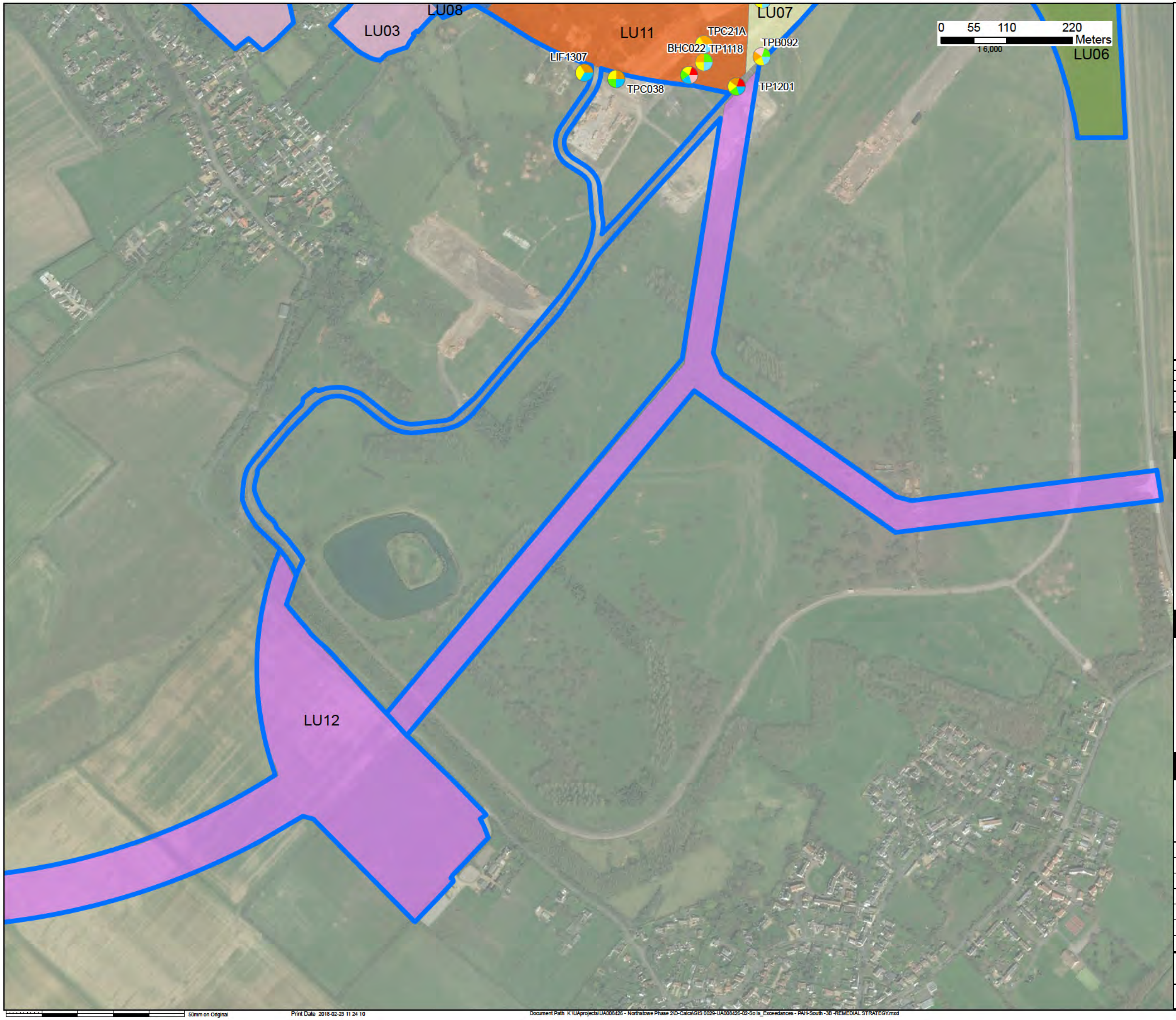
Revision: 01



Exceedances of PAH in soil samples analysed

- 🟪 Naphthalene
- 🟩 Benzo-A-anthracene
- 🟥 Chrysene
- ⬜ Benzo-K-fluoranthene
- 🟧 Benzo-B-fluoranthene
- 🟨 Benzo-A-pyrene
- 🟦 Dibenzo-AH-anthracene

Exploratory holes

— Phase 2 Planning Boundary

Results screened against appropriate SSVs for the proposed land use.
Residential (with plant uptake): LU4, LU7, LU8, LU9, LU11, LU13
Commercial / Industrial: LU10, LU12
Public Open Space: LU6

10	23/02/2018	FIRST ISSUE	FW	AP	GF
REV	Date	Description	Drawn	Check	Approv

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Cambridgeshire

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London
SW1P 4DF

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London
N1 9AB

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TITLE

LOCATION OF PAH
EXCEEDANCES IN SOIL
AND MADE GROUND
(SOUTHERN AREA)

Designed	Reg.	Date 23/02/2018	Signed
Drawn	Reg.	Date 23/02/2018	Signed
Checked	Reg.	Date 23/02/2018	Signed
Approved	Reg.	Date 23/02/2018	Signed
Scale	See Layout	Datum:	AOD
Original Size	A3	Grid:	OS
Suitability Code	S2	Project Number:	UA008426

Suitability Description:
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Drawing Number: Figure 3b
Revision: 01

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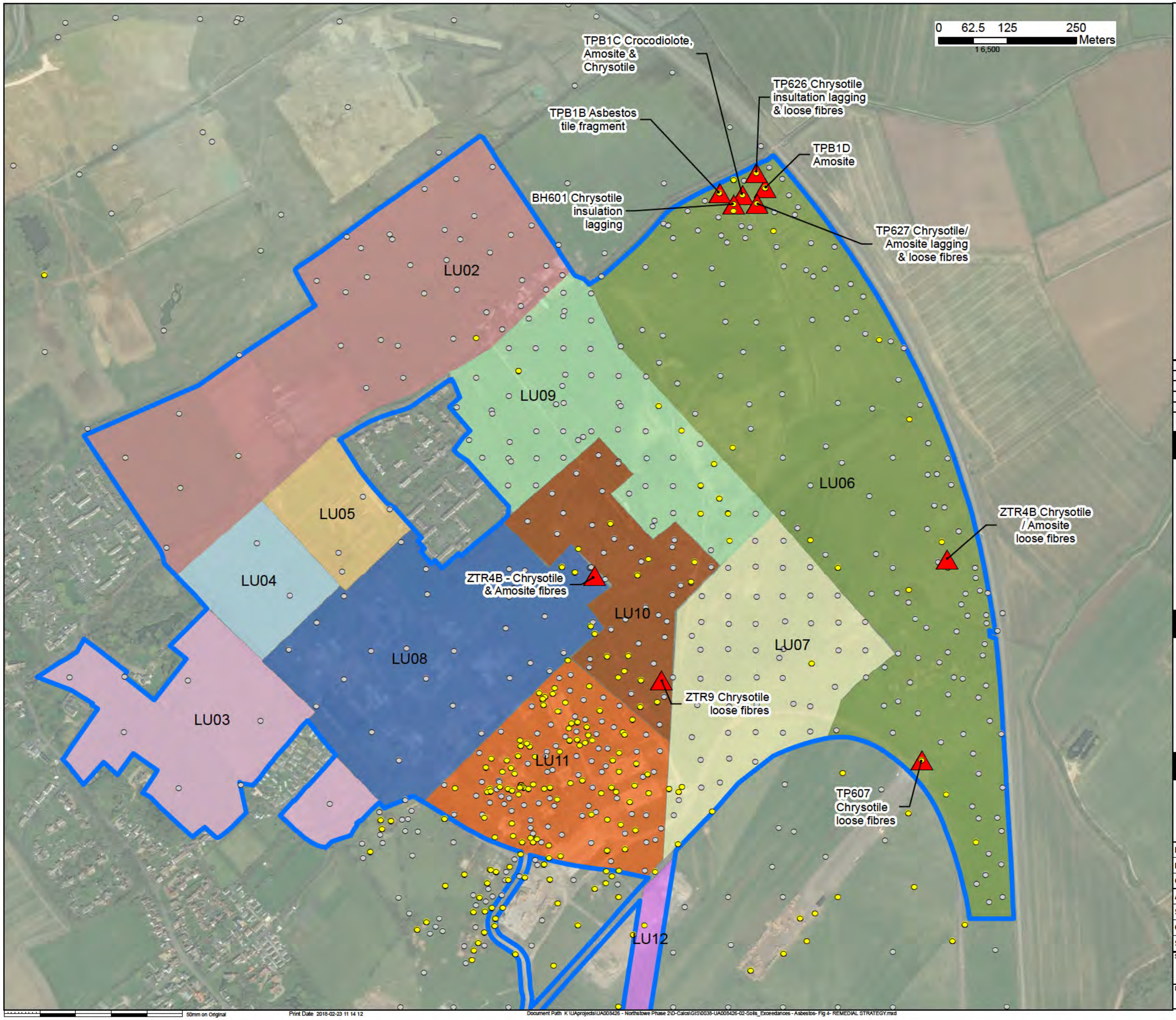

Asbestos presence

🔺 Asbestos identified in sample

Exploratory Holes

● Made Ground encountered

● Made Ground Not Encountered

— Phase 2 Planning Boundary

Note: Asbestos was not tested for in every exploratory hole location

Results screened against appropriate SSVs for the proposed land use.
Residential (with plant uptake): LU4, LU7, LU8, LU9, LU11, LU13
Commercial / Industrial: LU10, LU12
Public Open Space: LU6

REV	Date	Description	Drawn	Check	Approv
01	23/02/2018	FIRST ISSUE	FW	AP	GF

Client

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Cambridgeshire

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London
SW1P 4DF

ARCADIS Design & Consultancy for natural and built assets

Registered office:
Arcadis House
34 York Way
London
N1 9AB

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TITLE

LOCATION OF ASBESTOS IDENTIFIED IN SOIL SAMPLES

Designed	[redacted]	Date 23/02/2018	Signed
Drawn	[redacted]	Date 23/02/2018	Signed
Checked	[redacted]	Date 23/02/2018	Signed
Approved	[redacted]	Date 23/02/2018	Signed
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Original Size	A3	Grid:	OS
Suitability Code	S2	Project Number:	UA008426

Suitability Description:
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Drawing Number: Figure 4

Revision: 01

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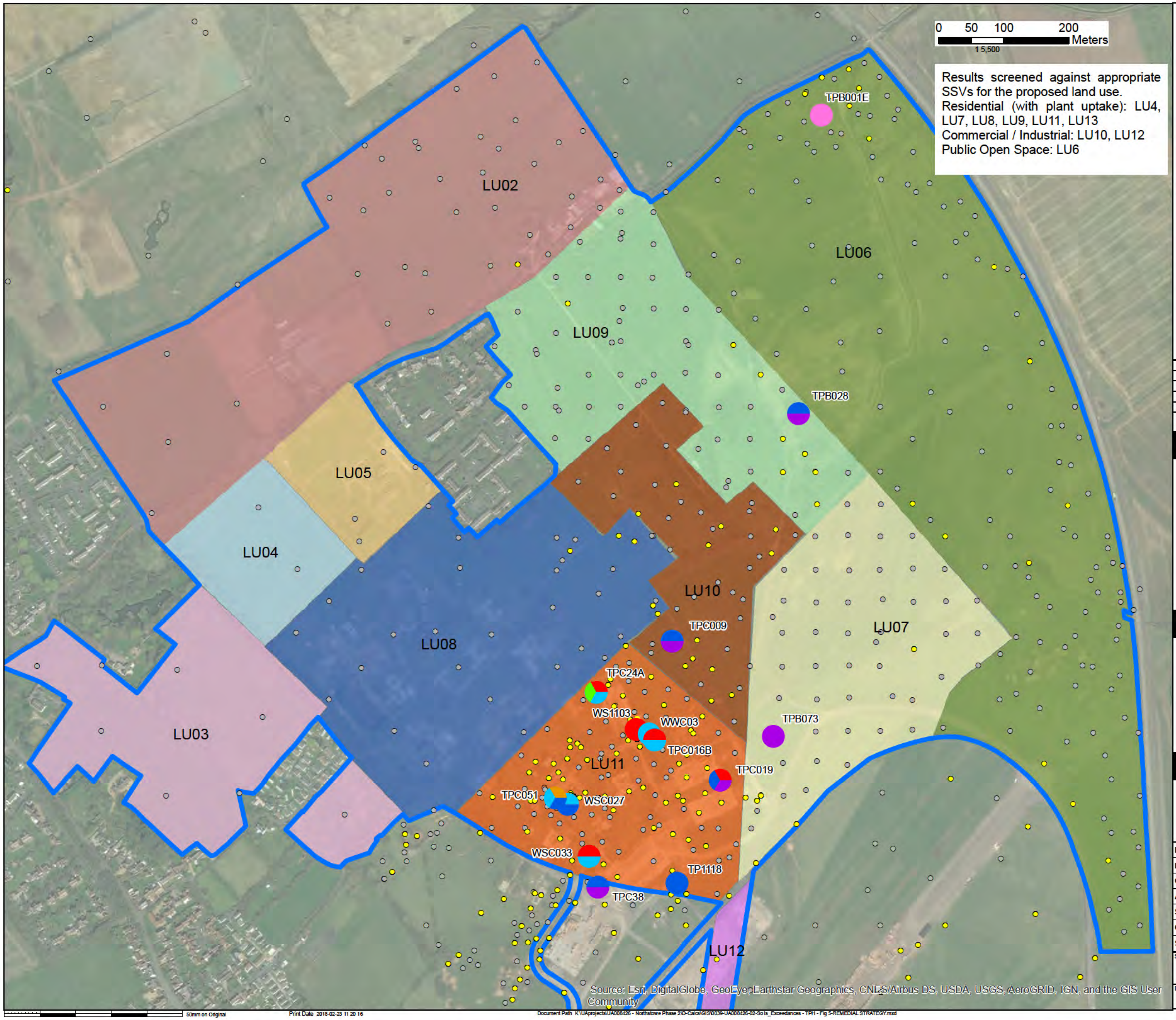


Results screened against appropriate SSVs for the proposed land use.
Residential (with plant uptake): LU4, LU7, LU8, LU9, LU11, LU13
Commercial / Industrial: LU10, LU12
Public Open Space: LU6

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

50mm on Original

Print Date 2018-02-23 11 20 16

Document Path K:\UAprojects\UA008426 - Northstowe Phase 2\D-Calcs\GIS\0039-UA008426-02-Soils_Exceedances - TPH - Fig 5-REMEDIAL STRATEGY.mxd

Exceedances of TPH in soil samples analysed

- 🟥 Aliphatic C8-10
- 🟧 Aliphatic C12-C16
- 🟨 Aromatic C8-C10
- 🟩 Aromatic C10-C12
- 🟦 Aromatic C12-C16
- 🟦 Aromatic C16-C21
- 🟪 Aromatic C21-C35
- 🟪 Benzene

Exploratory Holes

- ● Made Ground encountered
- ● Made Ground not encountered
- ▬ Phase 2 Planning Boundary

REV	Date	Description	Drawn	Check	Approv
P1	23/02/2018	FIRST ISSUE	FW	AP	GF

Client

HOMES AND
COMMUNITIES
AGENCY

PROJECT:
NORTHSTOWE
REMEDIAL
STRATEGY

Site
Northstowe
Cambridgeshire

Client
Fry Building
2 Marsham Street
London
SW1P 4DF

ARCADIS Design & Consultancy for natural and built assets

Registered office:
Arcadis House
34 York Way
London
N1 9AB

www.arcadis.com

TITLE

LOCATION OF TPH EXCEEDANCES IN SOILS

Designed	Reg. [redacted]	Date 23/02/2018	Signed
Drawn	Reg. [redacted]	Date 23/02/2018	Signed
Checked	Reg. [redacted]	Date 23/02/2018	Signed
Approved	Reg. [redacted]	Date 23/02/2018	Signed
Scale	See Layout	Datum:	AOD
Original Size	A3	Grid:	OS
Suitability Code	S2	Project Number:	UA008426

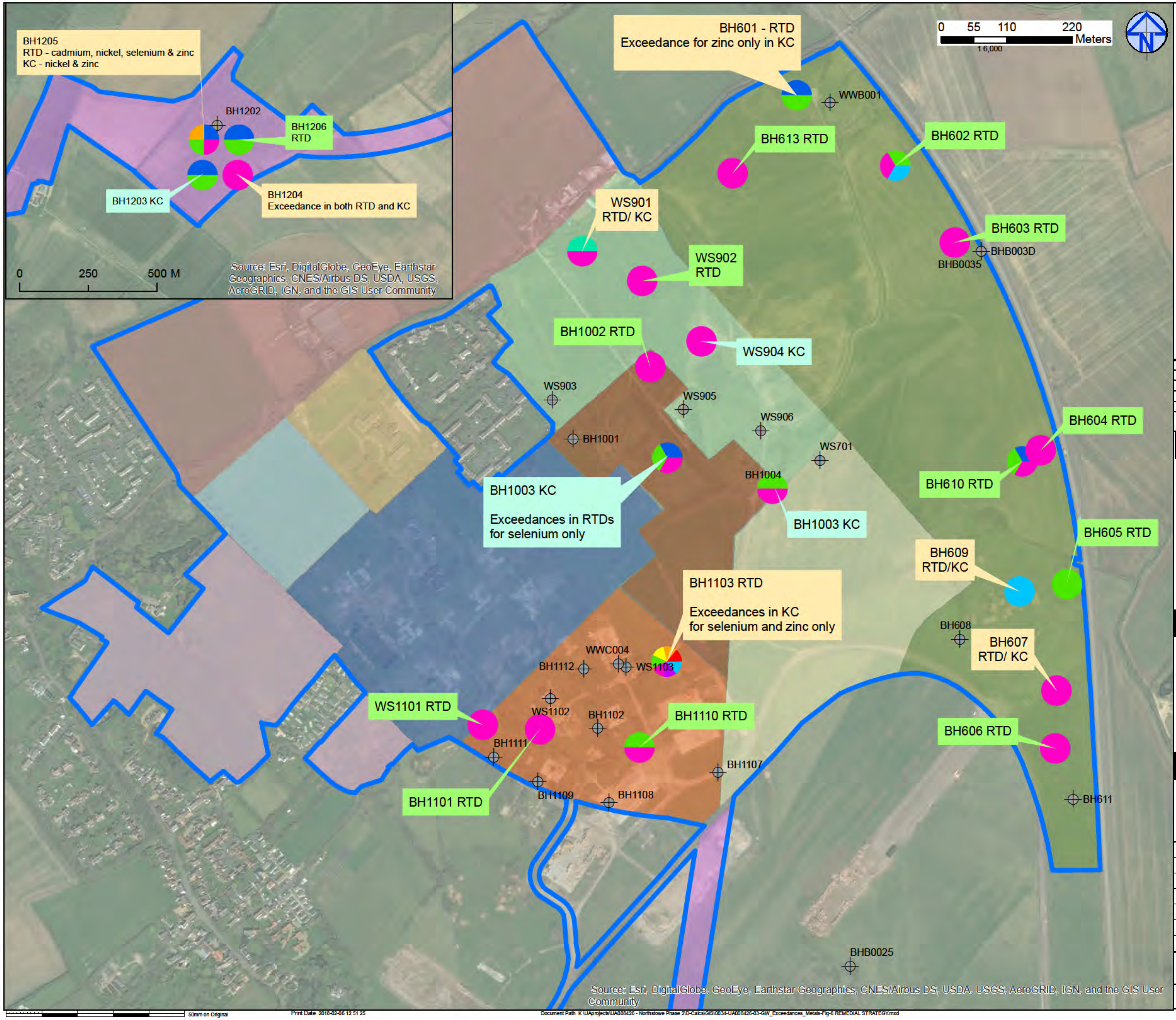
Suitability Description:
PRELIMINARY
NOT FOR CONSTRUCTION

Drawing Number: Figure 5

Revision: 01

APPENDIX D

Plan showing Inorganic Groundwater Exceedances



REV	Date	Description	Drawn	Check	Approv
02	06/02/2018	Issue 02	FW	AP	GF
01	15/01/2018	FIRST ISSUE	FW	AP	GF

Client

HOMES AND
COMMUNITIES
AGENCY

PROJECT:
NORTHSTOWE
REMEDIAL
STRATEGY

Site
Northstowe
Cambridgeshire

Client
Fry Building
2 Marsham Street
London
SW1P 4DF

ARCADIS Design & Consultancy for natural and built assets

Registered office:
Arcadis House
34 York Way
London
N1 9AB

www.arcadis.com

TITLE

LOCATION OF METALS EXCEEDANCES IN GROUNDWATER SAMPLES

Designed	[redacted]	Date 06/02/2018	Signed
Drawn	[redacted]	Date 06/02/2018	Signed
Checked	[redacted]	Date 06/02/2018	Signed
Approved	[redacted]	Date 06/02/2018	Signed
Scale	See Layout	Datum:	AOD
Original Size	A3	Grid:	OS
Suitability Code	S2	Project Number:	UA008426

Suitability Description:
PRELIMINARY
NOT FOR CONSTRUCTION

Drawing Number: Figure 6
Revision: 02

APPENDIX E

RTM Worksheets

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	**Northstowe**			
Site Address:	**Northstowe**			
Completed by:	Reg. 13(1)			
Date:	**11-Dec-17**		**Version:**	**1**
Contaminant	**Arsenic**			
Target Concentration (C_T)	**0.01**	**mg/l**	**Origin of C_T:**	**DWS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Environment Agency

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

User specified value for partition coefficient

Contaminant		Arsenic		
Target concentration	C_T	**0.01**	mg/l	
Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	2.24E-01	fraction	
Air filled soil porosity	θa	1.03E-01	fraction	
Bulk density of soil zone material	ρ	1.87E+00	g/cm^3	
Henry's Law constant	H	0.00E+00	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	2.60E+01	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**2.60E+01**	**l/kg**	*Specified value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**2.61E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.01	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Environment Agency

Contaminant		Arsenic		from Level 1
Target concentration	C_T	0.01	mg/l	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.00E-04	m/d		
Area of contaminant source	A	2.50E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	5.00E+01	m		
Saturated aquifer thickness	da	3.00E+00	m		
Hydraulic Conductivity of aquifer in which dilution occurs	K	8.64E+00	m/d		
Hydraulic gradient of water table	i	6.00E-03	fraction		
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m		Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		Calculate			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	3.00E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.14E+01**		
Level 2 Remedial Target		**1.14E-01** **or**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentrat**
		2.97E+00	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Arsenic		from Level 1
Target Concentration	C	0 01	mg/l	from Level 1
Dilution Factor	DF	1 14E 01		from Level 2

Select analytical solution (click on brown cell below, then on pull down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull down menu)

Approach or simulating degradation of pollutants: Apply degradation rate to dissolved pollutants only

	Variable	Value	Unit	Source of parameter value
Enter source concentration	Determine remedial target based on assumed concentration			
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E 99	days	
Calculated decay rate	λ	6.93E-100	days⁻¹	calculated
Width of plume in aquifer at source	Sz	5.00E 01	m	from Level 2
Plume thickness in aquifer at source	Sy	3.00E 00	m	from Level 2
Bulk density of aquifer materials	ρ	1.75E 00	g/cm³	
Effective porosity of aquifer	n	2.60E-01	fraction	
Hydraulic gradient	i	6.58E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	8.6 E 00	m/d	from Level 2
Distance to compliance point	x	5.00E 01	m	
Distance (lateral) to compliance point perpendicular to flow direction	z	[redacted]	m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	9.00E 99	days	time variant options only
Parameters values determined from options				
Partition coefficient	Kd	2.60E 01	l/kg	see options
Longitudinal dispersivity	ax	2.980	m	see options
Transverse dispersivity	az	0.298	m	see options
Vertical dispersivity	ay	0.030	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.19E-01	m/d
Retardation factor	Rf	1.76E 02	fraction
Decay rate used	λ	3.9 E-102	d⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	6.58E-03	fraction
Rate of contaminant flow due to retardation	u	1.2 E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	9.18E-01	fraction
Attenuation factor (C /C)	**AF**	**1 09E 00**	**fraction**

Remedial Targets

Level 3 Remedial Target	**1 24E 01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	3 24E 00	**mg/kg**	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point	**50**	**m**	
Ratio of Compliance Point to Source Concentration c /c	**9.18E 01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E 99

Enter method of defining partition co efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd	2.60E 01	l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	[redacted]	fraction
Organic carbon partition coefficient	Koc		l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$	[redacted]	l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.60E 01	l/kg

Define dispersivity (click brown cell and use pull down list)

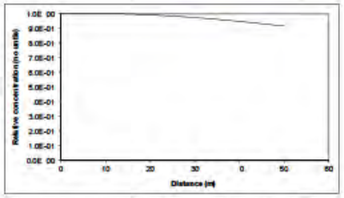
User defined values for dispersivity

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	2.98E 00	[redacted]	[redacted]	m
Transverse dispersivity	**az**	2.98E-01	[redacted]	[redacted]	m
Vertical dispersivity	**ay**	2.98E-02	[redacted]	[redacted]	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E 99.

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-12-17
Version:	1

Calculated (relative) concentrations for distance concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)
0	1.0E+00
2.5	1.00E+00
5.0	1.00E+00
7.5	1.00E+00
10.0	1.00E+00
12.5	9.99E 01
15.0	9.98E 01
17.5	9.97E 01
20.0	9.94E 01
22.5	9.90E 01
25.0	9.86E 01
27.5	9.81E 01
30.0	9.75E 01
32.5	9.69E 01
35.0	9.62E 01
37.5	9.55E 01
40.0	9.48E 01
42.5	9.41E 01
45.0	9.33E 01
47.5	9.25E 01
50.0	9.18E 01

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	**Northstowe**			
Site Address:	**Northstowe**			
Completed by:	Reg. 13(1)			
Date:	**11-Dec-17**		**Version:**	**1**
Contaminant	**Cadmium**			
Target Concentration (C_T)	**0.00015**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Environment Agency

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

User specified value for partition coefficient

Contaminant		Cadmium	
Target concentration	C_T	0.00015	mg/l

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	2.24E-01	fraction	
Air filled soil porosity	θa	1.03E-01	fraction	
Bulk density of soil zone material	ρ	1.87E+00	g/cm^3	
Henry's Law constant	H	0.00E+00	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	2.30E+01	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**2.30E+01**	**l/kg**	*Specified value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**3.47E-03**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.00015	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Environment Agency

Level 2 - Soil

Contaminant		**Cadmium**		from Level 1
Target concentration	**C_T**	**0.00015**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Infiltration	Inf	3.00E-04	m/d	
Area of contaminant source	A	2.50E+03	m^2	Not used in calculation
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	5.00E+01	m	
Saturated aquifer thickness	da	3.00E+00	m	
Hydraulic Conductivity of aquifer in which dilution occurs	K	8.64E+00	m/d	
Hydraulic gradient of water table	i	6.00E-03	fraction	
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l	
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**		
Enter mixing zone thickness	Mz		m	
Calculated mixing zone thickness	Mz	3.00E+00	m	

Calculated Parameters

Dilution Factor	**DF**	**1.14E+01**		
Level 2 Remedial Target		**1.71E-03**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentrat**
		or		
		3.94E-02	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Cadmium		from Level 1
Target Concentration	C_T	0.00015	mg/l	from Level 1
Dilution Factor	DF	1.14E+01		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — **Equations in HRA publication**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration	**Determine remedial target based on assumed concentration**			
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+99	days	
Calculated decay rate	λ	6.93E-100	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	3.00E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.75E+00	g/cm^3	
Effective porosity of aquifer	n	2.60E-01	fraction	
Hydraulic gradient	i	6.58E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	8.64E+00	m/d	from Level 2
Distance to compliance point	x	5.00E+01	m	
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	9.00E+99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.30E+01	l/kg	*see options*
Longitudinal dispersivity	ax	2.984	m	*see options*
Transverse dispersivity	az	0.298	m	*see options*
Vertical dispersivity	ay	0.030	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	2.19E-01	m/d
Retardation factor	Rf	1.56E+02	fraction
Decay rate used	λ	4.45E-102	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	6.58E-03	fraction
Rate of contaminant flow due to retardation	u	1.40E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	9.18E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.09E+00**	**fraction**

Remedial Targets

Level 3 Remedial Target		**1.86E-03**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		4.30E-02	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**50**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**9.18E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd	2.30E+01	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc		fraction
Organic carbon partition coefficient	Koc		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.30E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

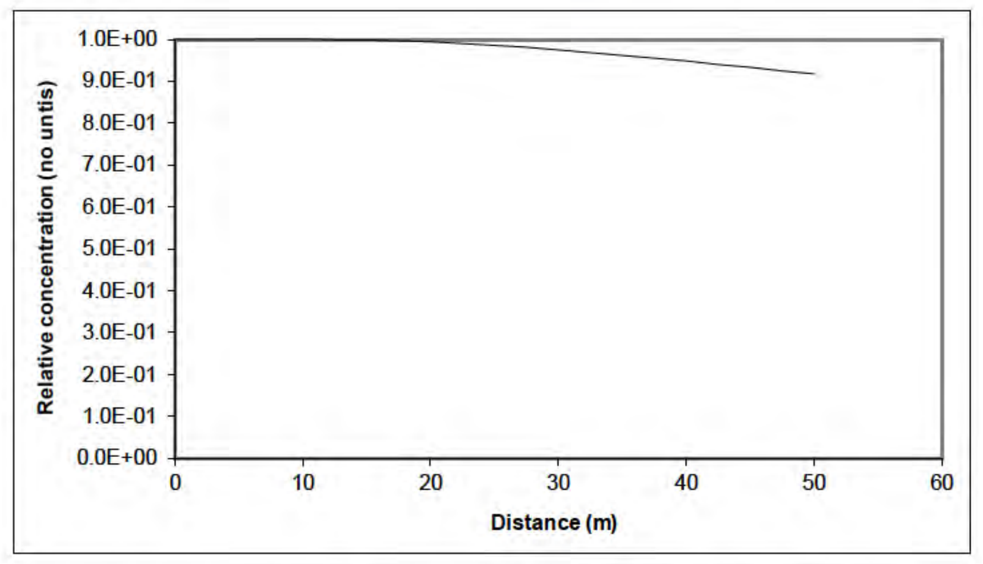
Dispersivity based on Xu & Eckstein (1995)

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	2.98E+00	5.00E+00	2.98E+00	m
Transverse dispersivity	**az**	2.98E-01	5.00E-01	2.98E-01	m
Vertical dispersivity	**ay**	2.98E-02	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; $az = ax/10$, $ay = ax/100$ are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-12-17
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)
0	1.0E+00
2.5	1.00E+00
5.0	1.00E+00
7.5	1.00E+00
10.0	1.00E+00
12.5	9.99E-01
15.0	9.98E-01
17.5	9.97E-01
20.0	9.94E-01
22.5	9.90E-01
25.0	9.86E-01
27.5	9.81E-01
30.0	9.75E-01
32.5	9.69E-01
35.0	9.62E-01
37.5	9.55E-01
40.0	9.48E-01
42.5	9.40E-01
45.0	9.33E-01
47.5	9.25E-01
50.0	9.18E-01

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name: Northstowe
Site Address: Northstowe

Completed by: Reg. 13(1)
Date: 11-Dec-17 **Version:** 1

Contaminant Chromium
Target Concentration (C_T) 0.0047 mg/l **Origin of C_T:** EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Environment Agency

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

User specified value for partition coefficient

Contaminant		**Chromium**	
Target concentration	C_T	**0.0047**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	2.24E-01	fraction	
Air filled soil porosity	θa	1.03E-01	fraction	
Bulk density of soil zone material	ρ	1.87E+00	g/cm^3	
Henry's Law constant	H	0.00E+00	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	9.66E+02	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**9.66E+02**	**l/kg**	*Specified value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**4.54E+00**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.0047	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Chromium**		from Level 1
Target concentration	**C_T**	**0.0047**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.00E-04	m/d		
Area of contaminant source	A	2.50E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	5.00E+01	m		
Saturated aquifer thickness	da	3.00E+00	m		
Hydraulic Conductivity of aquifer in which dilution occurs	K	8.64E+00	m/d		
Hydraulic gradient of water table	i	6.00E-03	fraction		
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m		Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		Calculate			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	3.00E+00	m		

Calculated Parameters				
Dilution Factor	**DF**	**1.14E+01**		
Level 2 Remedial Target		**5.34E-02**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentrat**
		or		
		5.16E+01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor				
Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Chromium		from Level 1
Target Concentration	C_T	0.0047	mg/l	from Level 1
Dilution Factor	DF	1.14E+01		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — **Equations in HRA publication**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration	**Determine remedial target based on assumed concentration**			
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+99	days	
Calculated decay rate	λ	6.93E-100	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	3.00E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.75E+00	g/cm^3	
Effective porosity of aquifer	n	2.60E-01	fraction	
Hydraulic gradient	i	6.58E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	8.64E+00	m/d	from Level 2
Distance to compliance point	x	5.00E+01	m	
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	9.00E+99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	9.66E+02	l/kg	*see options*
Longitudinal dispersivity	ax	2.984	m	*see options*
Transverse dispersivity	az	0.298	m	*see options*
Vertical dispersivity	ay	0.030	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	2.19E-01	m/d
Retardation factor	Rf	6.50E+03	fraction
Decay rate used	λ	1.07E-103	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	6.58E-03	fraction
Rate of contaminant flow due to retardation	u	3.36E-05	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	9.18E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.09E+00**	**fraction**

Remedial Targets

Level 3 Remedial Target		**5.82E-02**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		5.63E+01	**mg/kg**	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point		**50**	**m**	
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**9.18E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd	9.66E+02	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc		fraction
Organic carbon partition coefficient	Koc		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	9.66E+02	l/kg

Define dispersivity (click brown cell and use pull down list)

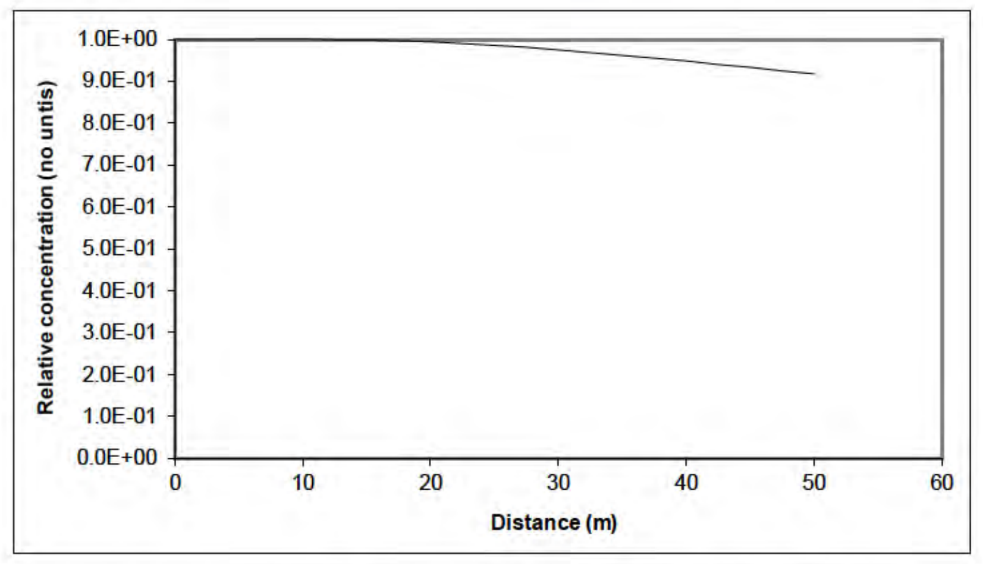
Dispersivity based on Xu & Eckstein (1995)

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	2.98E+00	5.00E+00	2.98E+00	m
Transverse dispersivity	**az**	2.98E-01	5.00E-01	2.98E-01	m
Vertical dispersivity	**ay**	2.98E-02	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Relative concentration (No units)**
0	**1.0E+00**
2.5	**1.00E+00**
5.0	**1.00E+00**
7.5	**1.00E+00**
10.0	**1.00E+00**
12.5	**9.99E-01**
15.0	**9.98E-01**
17.5	**9.97E-01**
20.0	**9.94E-01**
22.5	**9.90E-01**
25.0	**9.86E-01**
27.5	**9.81E-01**
30.0	**9.75E-01**
32.5	**9.69E-01**
35.0	**9.62E-01**
37.5	**9.55E-01**
40.0	**9.48E-01**
42.5	**9.40E-01**
45.0	**9.33E-01**
47.5	**9.25E-01**
50.0	**9.18E-01**

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-12-17
Version:	1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	**Northstowe**			
Site Address:	**Northstowe**			
Completed by:	Reg. 13(1)			
Date:	**11-Dec-17**		**Version:**	**1**
Contaminant	**Copper**			
Target Concentration (C_T)	**0.047**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Environment Agency

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

User specified value for partition coefficient

Contaminant		Copper	
Target concentration	C_T	0.047	mg/l

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	2.24E-01	fraction	
Air filled soil porosity	θa	1.03E-01	fraction	
Bulk density of soil zone material	ρ	1.87E+00	g/cm^3	
Henry's Law constant	H	0.00E+00	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	4.30E+02	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**4.30E+02**	**l/kg**	*Specified value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**2.02E+01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.047	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Environment Agency

Contaminant		**Copper**		from Level 1
Target concentration	**C_T**	**0.047**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.00E-04	m/d		
Area of contaminant source	A	2.50E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	5.00E+01	m		
Saturated aquifer thickness	da	3.00E+00	m		
Hydraulic Conductivity of aquifer in which dilution occurs	K	8.64E+00	m/d		
Hydraulic gradient of water table	i	6.00E-03	fraction		
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m		Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	3.00E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.14E+01**		
Level 2 Remedial Target		**5.34E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentrat**
		or		
		2.30E+02	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Environment Agency

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Copper		from Level 1
Target Concentration	C_T	0.047	mg/l	from Level 1
Dilution Factor	DF	1.14E+01		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — **Equations in HRA publication**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration	**Determine remedial target based on assumed concentration**			
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+99	days	
Calculated decay rate	λ	6.93E-100	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	3.00E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.75E+00	g/cm^3	
Effective porosity of aquifer	n	2.60E-01	fraction	
Hydraulic gradient	i	6.58E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	8.64E+00	m/d	from Level 2
Distance to compliance point	x	5.00E+01	m	
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	9.00E+99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	4.30E+02	l/kg	*see options*
Longitudinal dispersivity	ax	2.980	m	*see options*
Transverse dispersivity	az	0.298	m	*see options*
Vertical dispersivity	ay	0.030	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	2.19E-01	m/d
Retardation factor	Rf	2.90E+03	fraction
Decay rate used	λ	2.39E-103	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	6.58E-03	fraction
Rate of contaminant flow due to retardation	u	7.55E-05	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	9.18E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.09E+00**	**fraction**

Remedial Targets

Level 3 Remedial Target		**5.82E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		2.50E+02	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**50**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**9.18E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd	4.30E+02	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc		fraction
Organic carbon partition coefficient	Koc		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	4.30E+02	l/kg

Define dispersivity (click brown cell and use pull down list)

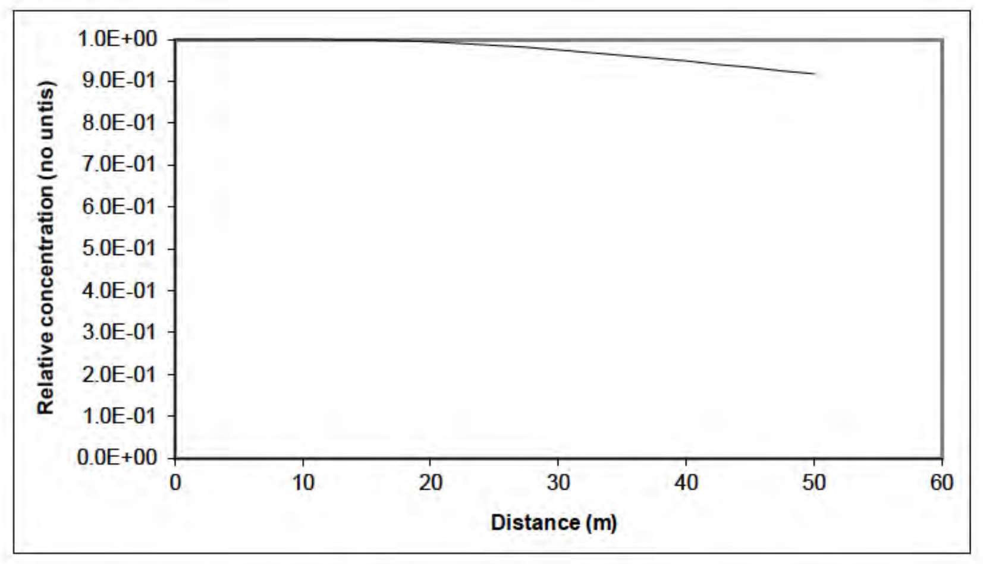
User defined values for dispersivity

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	2.98E+00	5.00E+00	2.98E+00	m
Transverse dispersivity	**az**	2.98E-01	5.00E-01	2.98E-01	m
Vertical dispersivity	**ay**	2.98E-02	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed: Northstowe
Completed by: Reg. 13(1)
Date: 11-12-17
Version: 1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)
0	1.0E+00
2.5	1.00E+00
5.0	1.00E+00
7.5	1.00E+00
10.0	1.00E+00
12.5	9.99E-01
15.0	9.98E-01
17.5	9.97E-01
20.0	9.94E-01
22.5	9.90E-01
25.0	9.86E-01
27.5	9.81E-01
30.0	9.75E-01
32.5	9.69E-01
35.0	9.62E-01
37.5	9.55E-01
40.0	9.48E-01
42.5	9.41E-01
45.0	9.33E-01
47.5	9.25E-01
50.0	9.18E-01

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely respons ble for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	**Northstowe**			
Site Address:	**Northstowe**			
Completed by:	Reg. 13(1)			
Date:	**11-Dec-17**		**Version:**	**1**
Contaminant	**Lead**			
Target Concentration (C_T)	**0.01**	**mg/l**	**Origin of C_T:**	**DWS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

User specified value for partition coefficient

Contaminant		Lead	
Target concentration	C_T	0.01	mg/l

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	2.24E-01	fraction	
Air filled soil porosity	θa	1.03E-01	fraction	
Bulk density of soil zone material	ρ	1.87E+00	g/cm^3	
Henry's Law constant	H	0.00E+00	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	9.00E+02	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**9.00E+02**	**l/kg**	*Specified value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**9.00E+00**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.01	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Lead**		from Level 1
Target concentration	**C_T**	**0.01**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.00E-04	m/d		
Area of contaminant source	A	2.50E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	5.00E+01	m		
Saturated aquifer thickness	da	3.00E+00	m		
Hydraulic Conductivity of aquifer in which dilution occurs	K	8.64E+00	m/d		
Hydraulic gradient of water table	i	6.00E-03	fraction		
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m		Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	3.00E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.14E+01**		
Level 2 Remedial Target		**1.14E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentrat**
		or		
		1.02E+02	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Lead		from Level 1
Target Concentration	C_T	0.01	mg/l	from Level 1
Dilution Factor	DF	1.14E+01		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — **Equations in HRA publication**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration	**Determine remedial target based on assumed concentration**			
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+99	days	
Calculated decay rate	λ	6.93E-100	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	3.00E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.75E+00	g/cm^3	
Effective porosity of aquifer	n	2.60E-01	fraction	
Hydraulic gradient	i	6.58E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	8.64E+00	m/d	from Level 2
Distance to compliance point	x	5.00E+01	m	
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	9.00E+99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	9.00E+02	l/kg	*see options*
Longitudinal dispersivity	ax	2.984	m	*see options*
Transverse dispersivity	az	0.298	m	*see options*
Vertical dispersivity	ay	0.030	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	2.19E-01	m/d
Retardation factor	Rf	6.06E+03	fraction
Decay rate used	λ	1.14E-103	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	6.58E-03	fraction
Rate of contaminant flow due to retardation	u	3.61E-05	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	9.18E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.09E+00**	**fraction**

Remedial Targets

Level 3 Remedial Target		**1.24E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		1.12E+02	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**50**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**9.18E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd	9.00E+02	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc		fraction
Organic carbon partition coefficient	Koc		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	9.00E+02	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivity based on Xu & Eckstein (1995)

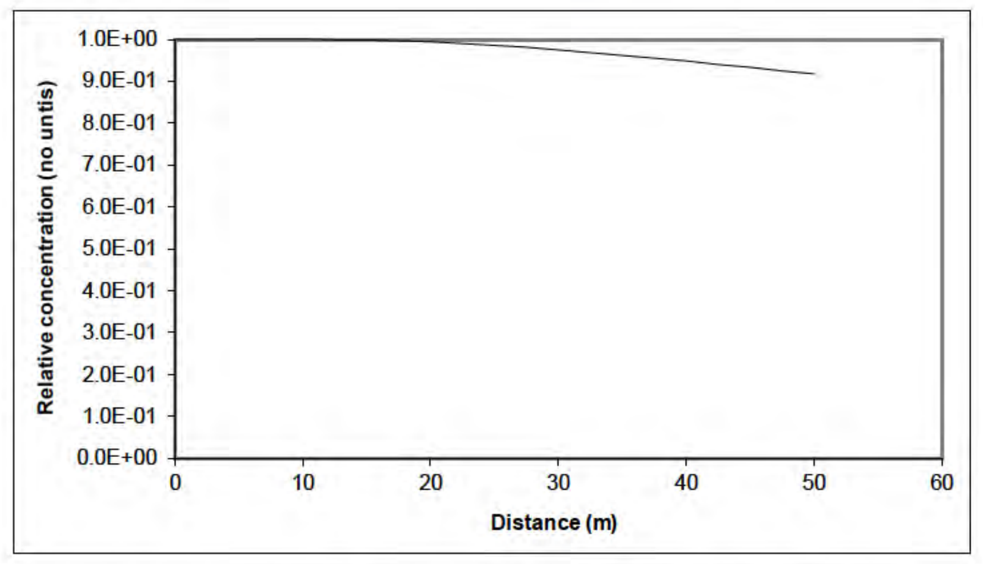
		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	2.98E+00	5.00E+00	2.98E+00	m
Transverse dispersivity	**az**	2.98E-01	5.00E-01	2.98E-01	m
Vertical dispersivity	**ay**	2.98E-02	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used

Environment Agency



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-12-17
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)
0	1.0E+00
2.5	1.00E+00
5.0	1.00E+00
7.5	1.00E+00
10.0	1.00E+00
12.5	9.99E-01
15.0	9.98E-01
17.5	9.97E-01
20.0	9.94E-01
22.5	9.90E-01
25.0	9.86E-01
27.5	9.81E-01
30.0	9.75E-01
32.5	9.69E-01
35.0	9.62E-01
37.5	9.55E-01
40.0	9.48E-01
42.5	9.40E-01
45.0	9.33E-01
47.5	9.25E-01
50.0	9.18E-01

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	**Northstowe**			
Site Address:	**Northstowe**			
Completed by:	Reg. 13(1)			
Date:	**11-Dec-17**		**Version:**	**1**
Contaminant	**Nickel**			
Target Concentration (C_T)	**0.02**	**mg/l**	**Origin of C_T:**	**DWS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

User specified value for partition coefficient

Contaminant		Nickel	
Target concentration	C_T	0.02	mg/l

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	2.24E-01	fraction	
Air filled soil porosity	θa	1.03E-01	fraction	
Bulk density of soil zone material	ρ	1.87E+00	g/cm^3	
Henry's Law constant	H	0.00E+00	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	2.40E+01	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	[redacted]	fraction	
Organic carbon partition coefficient	Koc	[redacted]	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$	[redacted]	l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$	[redacted]	l/kg	
pH value	pH	[redacted]	pH units	
Acid dissociation constant	pKa	[redacted]		
Fraction of organic carbon (in soil)	foc	[redacted]	fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**2.40E+01**	**l/kg**	*Specified value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**4.82E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.02	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Environment Agency

Contaminant		Nickel		from Level 1
Target concentration	C_T	0.02	mg/l	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.00E-04	m/d		
Area of contaminant source	A	2.50E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	5.00E+01	m		
Saturated aquifer thickness	da	3.00E+00	m		
Hydraulic Conductivity of aquifer in which dilution occurs	K	8.64E+00	m/d		
Hydraulic gradient of water table	i	6.00E-03	fraction		
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m		Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		Calculate			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	3.00E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.14E+01**		
Level 2 Remedial Target		**2.27E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentrat**
		or		
		5.48E+00	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters

Input Parameters	Variable	Value	Unit	Source
Contaminant		Nickel		from Level 1
Target Concentration	C	0 02	mg/l	from Level 1
Dilution Factor	DF	1 14E 01		from Level 2

Select analytical solution (click on brown cell below, then on pull down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull down menu)

Approach or simulating degradation of pollutants: Apply degradation rate to dissolved pollutants only

	Variable	Value	Unit	Source of parameter value
Enter source concentration	Determine remedial target based on assumed concentration			
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E 99	days	
Calculated decay rate	λ	6.93E-100	days⁻¹	calculated
Width of plume in aquifer at source	Sz	5.00E 01	m	from Level 2
Plume thickness in aquifer at source	Sy	3.00E 00	m	from Level 2
Bulk density of aquifer materials	ρ	1.75E 00	g/cm³	
Effective porosity of aquifer	n	2.60E-01	fraction	
Hydraulic gradient	i	6.58E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	8.6 E 00	m/d	from Level 2
Distance to compliance point	x	5.00E 01	m	
Distance (lateral) to compliance point perpendicular to flow direction	z	[redacted]	m	
Distance (depth) to compliance point perpendicular to flow direction	y	[redacted]	m	
Time since pollutant entered groundwater	t	9.00E 99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2. 0E 01	l/kg	*see options*
Longitudinal dispersivity	ax	2.98	m	*see options*
Transverse dispersivity	az	0.298	m	*see options*
Vertical dispersivity	ay	0.030	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	2.19E-01	m/d
Retardation factor	Rf	1.63E 02	fraction
Decay rate used	λ	.26E-102	d⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	6.58E-03	fraction
Rate of contaminant flow due to retardation	u	1.35E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	9.18E-01	fraction
Attenuation factor (C /C)	**AF**	**1 09E 00**	**fraction**

Remedial Targets

Level 3 Remedial Target	**2 48E 01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	5 88E 00	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	**50**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration c /c	**9.18E 01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E 99

Enter method of defining partition coefficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd	2. 0E 01	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	[redacted]	fraction
Organic carbon partition coefficient	Koc	[redacted]	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$	[redacted]	l/kg
Sorption coefficient for ionised species	$K_{oc,i}$	[redacted]	l/kg
pH value	pH	[redacted]	
Acid dissociation constant	pKa	[redacted]	
Fraction of organic carbon in aquifer	foc	[redacted]	fraction
Soil water partition coefficient	Kd	2. 0E 01	l/kg

Define dispersivity (click brown cell and use pull down list)

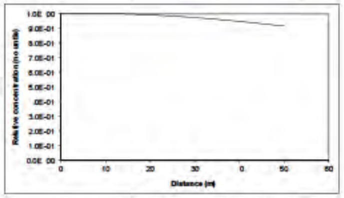
Dispersivity based on Xu & Eckstein (1995)

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	2.98E 00	5.00E 00	2.98E 00	m
Transverse dispersivity	**az**	2.98E-01	5.00E-01	2.98E-01	m
Vertical dispersivity	**ay**	2.98E-02	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log $_{10}$x)$^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)
0	1.0E+00
2.5	1.00E+00
5.0	1.00E+00
7.5	1.00E+00
10.0	1.00E+00
12.5	9.99E 01
15.0	9.98E 01
17.5	9.97E 01
20.0	9.94E 01
22.5	9.90E 01
25.0	9.86E 01
27.5	9.81E 01
30.0	9.75E 01
32.5	9.69E 01
35.0	9.62E 01
37.5	9.55E 01
40.0	9.48E 01
42.5	9.40E 01
45.0	9.33E 01
47.5	9.25E 01
50.0	9.18E 01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note If contaminant is not subject to first order degradation, then set half life as 9.9E 99.

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-12-17
Version:	1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	**Northstowe**			
Site Address:	**Northstowe**			
Completed by:	Reg. 13(1)			
Date:	**11-Dec-17**		**Version:**	**1**
Contaminant	**Selenium**			
Target Concentration (C_T)	**0.01**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

User specified value for partition coefficient

Contaminant		**Selenium**	
Target concentration	C_T	**0.01**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	2.24E-01	fraction	
Air filled soil porosity	θa	1.03E-01	fraction	
Bulk density of soil zone material	ρ	1.87E+00	g/cm^3	
Henry's Law constant	H	0.00E+00	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	1.40E+01	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	[redacted]	fraction	
Organic carbon partition coefficient	Koc	[redacted]	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$	[redacted]	l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$	[redacted]	l/kg	
pH value	pH	[redacted]	pH units	
Acid dissociation constant	pKa	[redacted]		
Fraction of organic carbon (in soil)	foc	[redacted]	fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.40E+01**	**l/kg**	*Specified value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**1.41E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.01	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		**Selenium**		from Level 1
Target concentration	**C_T**	**0.01**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.00E-04	m/d		
Area of contaminant source	A	2.50E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	5.00E+01	m		
Saturated aquifer thickness	da	3.00E+00	m		
Hydraulic Conductivity of aquifer in which dilution occurs	K	8.64E+00	m/d		
Hydraulic gradient of water table	i	6.00E-03	fraction		
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m		Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		Calculate			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	3.00E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.14E+01**		
Level 2 Remedial Target		**1.14E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentrat**
		or		
		1.61E+00	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
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Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters	Variable	Value	Unit	Source
Contaminant		Selenium		from Level 1
Target Concentration	C_T	0.01	mg/l	from Level 1
Dilution Factor	DF	1.14E+01		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — **Equations in HRA publication**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration	**Determine remedial target based on assumed concentration**			
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+99	days	
Calculated decay rate	λ	6.93E-100	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	3.00E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.75E+00	g/cm^3	
Effective porosity of aquifer	n	2.60E-01	fraction	
Hydraulic gradient	i	6.58E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	8.64E+00	m/d	from Level 2
Distance to compliance point	x	5.00E+01	m	
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	9.00E+99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.40E+01	l/kg	*see options*
Longitudinal dispersivity	ax	2.984	m	*see options*
Transverse dispersivity	az	0.298	m	*see options*
Vertical dispersivity	ay	0.030	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	2.19E-01	m/d
Retardation factor	Rf	9.52E+01	fraction
Decay rate used	λ	7.28E-102	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	6.58E-03	fraction
Rate of contaminant flow due to retardation	u	2.30E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	9.18E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.09E+00**	**fraction**

Remedial Targets

Level 3 Remedial Target		**1.24E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		1.75E+00	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**50**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**9.18E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd	1.40E+01	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc		fraction
Organic carbon partition coefficient	Koc		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.40E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

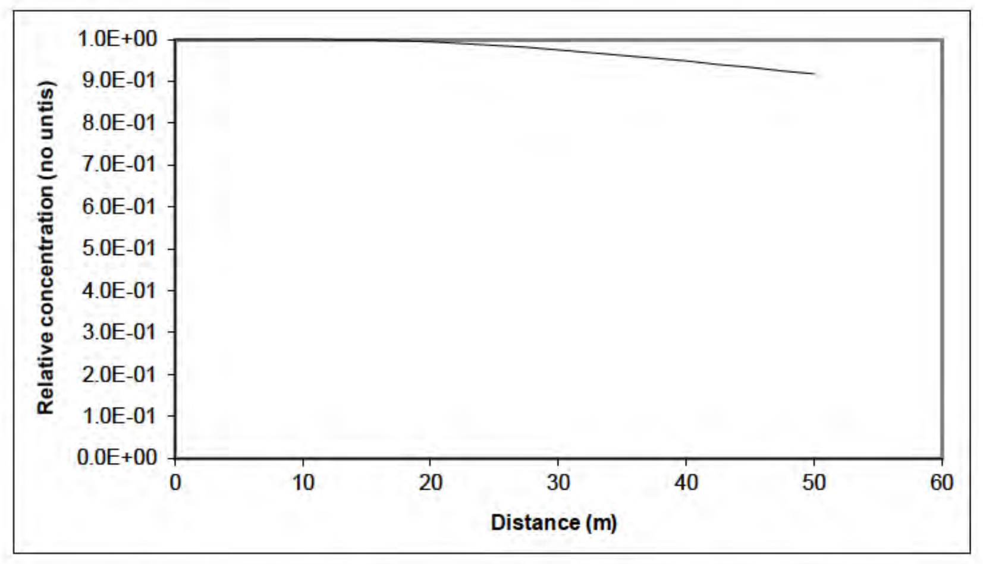
Dispersivity based on Xu & Eckstein (1995)

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	2.98E+00	5.00E+00	2.98E+00	m
Transverse dispersivity	**az**	2.98E-01	5.00E-01	2.98E-01	m
Vertical dispersivity	**ay**	2.98E-02	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-12-17
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	**Relative concentration (No units)**
0	**1.0E+00**
2.5	**1.00E+00**
5.0	**1.00E+00**
7.5	**1.00E+00**
10.0	**1.00E+00**
12.5	**9.99E-01**
15.0	**9.98E-01**
17.5	**9.97E-01**
20.0	**9.94E-01**
22.5	**9.90E-01**
25.0	**9.86E-01**
27.5	**9.81E-01**
30.0	**9.75E-01**
32.5	**9.69E-01**
35.0	**9.62E-01**
37.5	**9.55E-01**
40.0	**9.48E-01**
42.5	**9.40E-01**
45.0	**9.33E-01**
47.5	**9.25E-01**
50.0	**9.18E-01**

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	**Northstowe**		
Site Address:	**Northstowe**		
Completed by:	Reg. 13(1)		
Date:	**11-Dec-17**	**Version:**	**1**
Contaminant	**Vanadium**		
Target Concentration (C_T)	**0.02** mg/l	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
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The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

User specified value for partition coefficient

Contaminant		**Vanadium**	
Target concentration	C_T	**0.02**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	2.24E-01	fraction	
Air filled soil porosity	θa	1.03E-01	fraction	
Bulk density of soil zone material	ρ	1.87E+00	g/cm^3	
Henry's Law constant	H	0.00E+00	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	1.00E+03	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.00E+03**	**l/kg**	*Specified value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**2.00E+01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.02	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Environment Agency

Contaminant		**Vanadium**		from Level 1
Target concentration	C_T	**0.02**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.00E-04	m/d		
Area of contaminant source	A	2.50E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	5.00E+01	m		
Saturated aquifer thickness	da	3.00E+00	m		
Hydraulic Conductivity of aquifer in which dilution occurs	K	8.64E+00	m/d		
Hydraulic gradient of water table	i	6.00E-03	fraction		
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m		Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		Calculate			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	3.00E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.14E+01**		
Level 2 Remedial Target		**2.27E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentrat**
		or		
		2.27E+02	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Vanadium		from Level 1
Target Concentration	C_T	0.02	mg/l	from Level 1
Dilution Factor	DF	1.14E+01		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — **Equations in HRA publication**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration	**Determine remedial target based on assumed concentration**			
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+99	days	
Calculated decay rate	λ	6.93E-100	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	3.00E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.75E+00	g/cm^3	
Effective porosity of aquifer	n	2.60E-01	fraction	
Hydraulic gradient	i	6.58E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	8.64E+00	m/d	from Level 2
Distance to compliance point	x	5.00E+01	m	
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	9.00E+99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.00E+03	l/kg	*see options*
Longitudinal dispersivity	ax	2.984	m	*see options*
Transverse dispersivity	az	0.298	m	*see options*
Vertical dispersivity	ay	0.030	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	2.19E-01	m/d
Retardation factor	Rf	6.73E+03	fraction
Decay rate used	λ	1.03E-103	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	6.58E-03	fraction
Rate of contaminant flow due to retardation	u	3.25E-05	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	9.18E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.09E+00**	**fraction**

Remedial Targets

Level 3 Remedial Target		**2.48E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		2.48E+02	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**50**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**9.18E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd	1.00E+03	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc		fraction
Organic carbon partition coefficient	Koc		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.00E+03	l/kg

Define dispersivity (click brown cell and use pull down list)

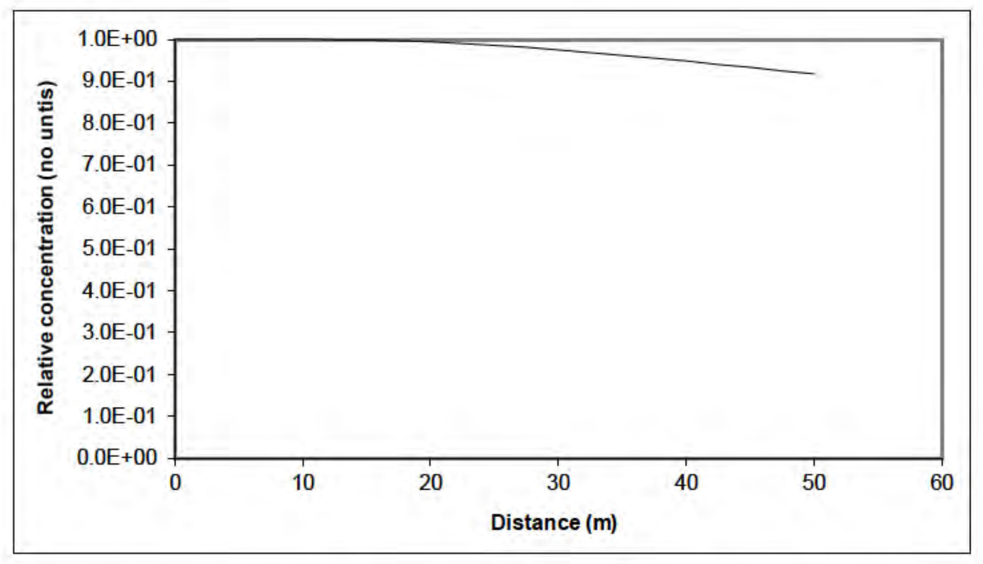
Dispersivity based on Xu & Eckstein (1995)

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	2.98E+00	5.00E+00	2.98E+00	m
Transverse dispersivity	**az**	2.98E-01	5.00E-01	2.98E-01	m
Vertical dispersivity	**ay**	2.98E-02	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-12-17
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)
0	1.0E+00
2.5	1.00E+00
5.0	1.00E+00
7.5	1.00E+00
10.0	1.00E+00
12.5	9.99E-01
15.0	9.98E-01
17.5	9.97E-01
20.0	9.94E-01
22.5	9.90E-01
25.0	9.86E-01
27.5	9.81E-01
30.0	9.75E-01
32.5	9.69E-01
35.0	9.62E-01
37.5	9.55E-01
40.0	9.48E-01
42.5	9.40E-01
45.0	9.33E-01
47.5	9.25E-01
50.0	9.18E-01

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	**Northstowe**			
Site Address:	**Northstowe**			
Completed by:	Reg. 13(1)			
Date:	**11-Dec-17**		**Version:**	**1**
Contaminant	**Zinc**			
Target Concentration (C_T)	**0.04**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

User specified value for partition coefficient

Contaminant		**Zinc**	
Target concentration	C_T	**0.04**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	2.24E-01	fraction	
Air filled soil porosity	θa	1.03E-01	fraction	
Bulk density of soil zone material	ρ	1.87E+00	g/cm^3	
Henry's Law constant	H	0.00E+00	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	2.30E+01	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**2.30E+01**	**l/kg**	*Specified value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**9.25E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.04	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Environment Agency

Level 2 - Soil

Contaminant		Zinc		from Level 1
Target concentration	C_T	0.04	mg/l	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.00E-04	m/d		
Area of contaminant source	A	2.50E+03	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	5.00E+01	m		
Saturated aquifer thickness	da	3.00E+00	m		
Hydraulic Conductivity of aquifer in which dilution occurs	K	8.64E+00	m/d		
Hydraulic gradient of water table	i	6.00E-03	fraction		
Width of contaminant source perpendicular to groundwater flow	w	5.00E+01	m		Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		Calculate			
Enter mixing zone thickness	Mz	[redacted]	m		
Calculated mixing zone thickness	Mz	3.00E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.14E+01**		
Level 2 Remedial Target		**4.55E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentrat**
		or		
		1.05E+01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Zinc		from Level 1
Target Concentration	C_T	0.04	mg/l	from Level 1
Dilution Factor	DF	1.14E+01		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — **Equations in HRA publication**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration	**Determine remedial target based on assumed concentration**			
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+99	days	
Calculated decay rate	λ	6.93E-100	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	3.00E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.75E+00	g/cm^3	
Effective porosity of aquifer	n	2.60E-01	fraction	
Hydraulic gradient	i	6.58E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	8.64E+00	m/d	from Level 2
Distance to compliance point	x	5.00E+01	m	
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	9.00E+99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.30E+01	l/kg	*see options*
Longitudinal dispersivity	ax	2.984	m	*see options*
Transverse dispersivity	az	0.298	m	*see options*
Vertical dispersivity	ay	0.030	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	2.19E-01	m/d
Retardation factor	Rf	1.56E+02	fraction
Decay rate used	λ	4.45E-102	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	6.58E-03	fraction
Rate of contaminant flow due to retardation	u	1.40E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	9.18E-01	fraction
Attenuation factor (C_O/C_{ED})	**AF**	**1.09E+00**	**fraction**

Remedial Targets

Level 3 Remedial Target		**4.96E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		1.15E+01	**mg/kg**	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point		**50**	**m**	
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**9.18E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd	2.30E+01	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc		fraction
Organic carbon partition coefficient	Koc		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.30E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivity based on Xu & Eckstein (1995)

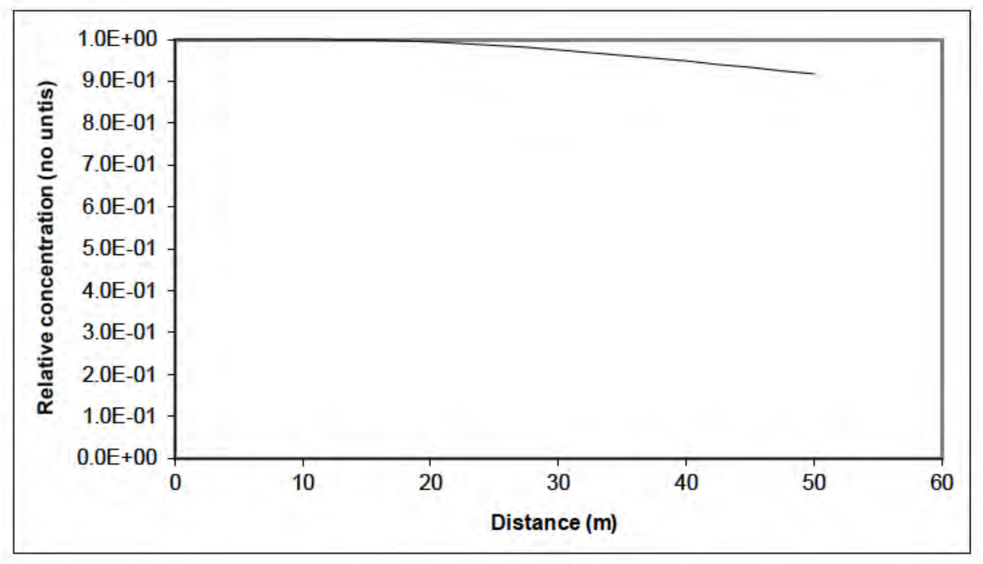
		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	2.98E+00	5.00E+00	2.98E+00	m
Transverse dispersivity	**az**	2.98E-01	5.00E-01	2.98E-01	m
Vertical dispersivity	**ay**	2.98E-02	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; $az = ax/10$, $ay = ax/100$ are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used

Environment Agency



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)
0	1.0E+00
2.5	1.00E+00
5.0	1.00E+00
7.5	1.00E+00
10.0	1.00E+00
12.5	9.99E-01
15.0	9.98E-01
17.5	9.97E-01
20.0	9.94E-01
22.5	9.90E-01
25.0	9.86E-01
27.5	9.81E-01
30.0	9.75E-01
32.5	9.69E-01
35.0	9.62E-01
37.5	9.55E-01
40.0	9.48E-01
42.5	9.40E-01
45.0	9.33E-01
47.5	9.25E-01
50.0	9.18E-01

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-12-17
Version:	1

Environment Agency

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	**Northstowe**			
Site Address:	**Northstowe**			
Completed by:	Reg. 13(1)			
Date:	**11-Dec-17**		**Version:**	**1**
Contaminant	**Aliphatic >C8-C10**			
Target Concentration (C_T)	**0.3**	**mg/l**	**Origin of C_T:**	**CL:AIRE**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		Aliphatic >C8-C10	
Target concentration	C_T	0.3	mg/l

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θw	2.24E-01	fraction	
Air filled soil porosity	θa	1.03E-01	fraction	
Bulk density of soil zone material	ρ	1.87E+00	g/cm^3	
Henry's Law constant	H	8.20E+01	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	4.64E-03	fraction	
Organic carbon partition coefficient	Koc	3.20E+04	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.48E+02**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**4.59E+01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.3	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Environment Agency

Level 2 - Soil

Contaminant		Aliphatic >C8-C10		from Level 1
Target concentration	C_T	0.3	mg/l	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.00E-04	m/d		
Area of contaminant source	A	2.50E+02	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	5.00E+01	m		
Saturated aquifer thickness	da	3.00E+00	m		
Hydraulic Conductivity of aquifer in which dilution occurs	K	8.64E+00	m/d		
Hydraulic gradient of water table	i	6.00E-03	fraction		
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m		Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	3.00E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.14E+01**		
Level 2 Remedial Target		**3.41E+00**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		5.22E+02	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters	Variable	Value	Unit	Source
Contaminant		Aliphatic >C8 C10		from Level 1
Target Concentration	C	0.3	mg/l	from Level 1
Dilution Factor	DF	1.14E+01		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to dissolved pollutants only

	Variable	Value	Unit	Source of parameter value
Enter source concentration	Determine remedial target based on assumed concentration			
Half life for degradation of contaminant in water	$t_{1/2}$	7.30E+02	days	
Calculated decay rate	λ	9.50E-04	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	3.00E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.75E+00	g/cm^3	
Effective porosity of aquifer	n	2.60E-01	fraction	
Hydraulic gradient	i	6.58E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	8.64E+00	m/d	from Level 2
Distance to compliance point	x	5.00E+01	m	
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	9.00E+99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.48E+02	l/kg	*see options*
Longitudinal dispersivity	ax	2.984	m	*see options*
Transverse dispersivity	az	0.298	m	*see options*
Vertical dispersivity	ay	0.030	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	2.19E-01	m/d
Retardation factor	Rf	1.00E+03	fraction
Decay rate used	λ	9.49E-07	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	6.58E-03	fraction
Rate of contaminant flow due to retardation	u	2.19E-04	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	2.61E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**3.83E+00**	**fraction**

Remedial Targets

Level 3 Remedial Target		**1.31E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		2.00E+03	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**50**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**2.61E 01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	4.64E-03	fraction
Organic carbon partition coefficient	Koc	3.20E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.48E+02	l/kg

Define dispersivity (click brown cell and use pull down list)

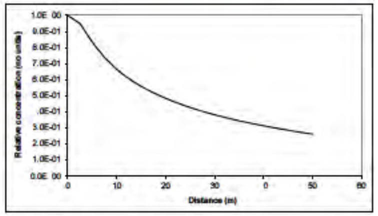
Dispersivity based on Xu & Eckstein (1995)

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	2.98E+00	5.00E+00	2.98E+00	m
Transverse dispersivity	**az**	2.98E-01	5.00E-01	2.98E-01	m
Vertical dispersivity	**ay**	2.98E-02	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax $0.83(\log_{10}x)^{2\ 1}$; az ax/10, ay ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO etc than an alternative solution should be used



Note "Relative concentration" is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation then set half life as 9.9E+99.

Site being assessed	Northstowe
Completed by	Reg. 13(1)
Date	11-12-17
Version	1

Calculated (relative) concentrations for distance concentration graph

Ogata Banks
From calculation sheet

Distance	**Relative concentration (No units)**
0	1.0E+00
2.5	9.49E 01
5.0	8.34E 01
7.5	7.39E 01
10.0	6.65E 01
12.5	6.06E 01
15.0	5.59E 01
17.5	5.19E 01
20.0	4.84E 01
22.5	4.54E 01
25.0	4.27E 01
27.5	4.03E 01
30.0	3.82E 01
32.5	3.62E 01
35.0	3.44E 01
37.5	3.28E 01
40.0	3.12E 01
42.5	2.98E 01
45.0	2.85E 01
47.5	2.73E 01
50.0	2.61E 01

Environment
Agency

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	**Northstowe**			
Site Address:	**Northstowe**			
Completed by:	Reg. 13(1)			
Date:	**11-Dec-17**		**Version:**	**1**
Contaminant	**Aliphatic >C10-C12**			
Target Concentration (C_T)	**0.3**	**mg/l**	**Origin of C_T:**	**CL:AIRE**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		Aliphatic >C10-C12	
Target concentration	C_T	0.3	mg/l

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	2.24E-01	fraction	
Air filled soil porosity	θ_a	1.03E-01	fraction	
Bulk density of soil zone material	ρ	1.87E+00	g/cm^3	
Henry's Law constant	H	1.30E+02	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	[redacted]	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	4.64E-03	fraction	
Organic carbon partition coefficient	Koc	2.50E+05	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$	[redacted]	l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$	[redacted]	l/kg	
pH value	pH	[redacted]	pH units	
Acid dissociation constant	pKa	[redacted]		
Fraction of organic carbon (in soil)	foc	[redacted]	fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.16E+03**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	3.50E+02	mg/kg	(for comparison with soil analyses)
	or		
	0.3	mg/l	(for comparison with leachate test results)

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		Aliphatic >C10-C12		from Level 1
Target concentration	C_T	0.3	mg/l	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.00E-04	m/d		
Area of contaminant source	A	2.50E+02	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	5.00E+01	m		
Saturated aquifer thickness	da	3.00E+00	m		
Hydraulic Conductivity of aquifer in which dilution occurs	K	8.64E+00	m/d		
Hydraulic gradient of water table	i	6.00E-03	fraction		
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m		Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	3.00E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.14E+01**		
Level 2 Remedial Target		**3.41E+00** **or** **3.98E+03**	**mg/l** **mg/kg**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra** **For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Aliphatic >C10 C12		from Level 1
Target Concentration	C	0.3	mg/l	from Level 1
Dilution Factor	DF	1.14E+01		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to dissolved pollutants only

	Variable	Value	Unit	Source of parameter value
Enter source concentration	Determine remedial target based on assumed concentration			
Half life for degradation of contaminant in water	$t_{1/2}$	1.80E+03	days	
Calculated decay rate	λ	3.85E-04	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	3.00E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.75E+00	g/cm^3	
Effective porosity of aquifer	n	2.60E-01	fraction	
Hydraulic gradient	i	6.58E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	8.64E+00	m/d	from Level 2
Distance to compliance point	x	5.00E+01	m	
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	9.00E+99	days	time variant options only
Parameters values determined from options				
Partition coefficient	Kd	1.16E+03	l/kg	*see options*
Longitudinal dispersivity	ax	2.984	m	*see options*
Transverse dispersivity	az	0.298	m	*see options*
Vertical dispersivity	ay	0.030	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	2.19E-01	m/d
Retardation factor	Rf	7.81E+03	fraction
Decay rate used	λ	4.93E-08	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	6.58E-03	fraction
Rate of contaminant flow due to retardation	u	2.80E-05	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	2.97E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**3.37E+00**	**fraction**

Remedial Targets

Level 3 Remedial Target		**1.15E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		or		This assumes Level 1 Remedial Target is based on Target Concentration.
		1.34E+04	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**50**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**2.97E 01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	4.64E-03	fraction
Organic carbon partition coefficient	Koc	2.50E+05	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.16E+03	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivity based on Xu & Eckstein (1995)

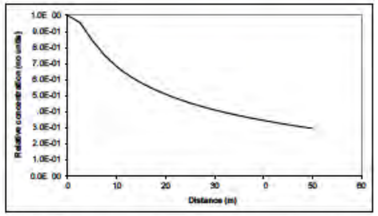
		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	2.98E+00	5.00E+00	2.98E+00	m
Transverse dispersivity	**az**	2.98E-01	5.00E-01	2.98E-01	m
Vertical dispersivity	**ay**	2.98E-02	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax 0.83(log₁₀x)$^{2.414}$; az ax/10, ay ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO etc than an alternative solution should be used

Environment Agency



Note 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) t will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation then set half life as 9.9E+99.

Site being assessed	Northstowe
Completed by	Reg. 13(1)
Date	11-12-17
Version	1

Calculated (relative) concentrations for distance concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)
0	1.0E+00
2.5	9.55E 01
5.0	8.45E 01
7.5	7.53E 01
10.0	6.82E 01
12.5	6.26E 01
15.0	5.80E 01
17.5	5.42E 01
20.0	5.09E 01
22.5	4.81E 01
25.0	4.55E 01
27.5	4.33E 01
30.0	4.12E 01
32.5	3.93E 01
35.0	3.76E 01
37.5	3.60E 01
40.0	3.46E 01
42.5	3.32E 01
45.0	3.19E 01
47.5	3.08E 01
50.0	2.97E 01

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	**Northstowe**			
Site Address:	**Northstowe**			
Completed by:	Reg. 13(1)			
Date:	**11-Dec-17**		**Version:**	**1**
Contaminant	**Aromatic >EC8-EC10**			
Target Concentration (C_T)	**0.3**	**mg/l**	**Origin of C_T:**	**CL:AIRE**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		Aromatic >EC8-EC10	
Target concentration	C_T	0.3	mg/l

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_W	2.24E-01	fraction	
Air filled soil porosity	θ_a	1.03E-01	fraction	
Bulk density of soil zone material	ρ	1.87E+00	g/cm^3	
Henry's Law constant	H	4.90E-01	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	4.64E-03	fraction	
Organic carbon partition coefficient	Koc	1.60E+03	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**7.42E+00**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**2.27E+00**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.3	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Environment Agency

Contaminant		Aromatic >EC8-EC10		from Level 1
Target concentration	C_T	0.3	mg/l	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.00E-04	m/d		
Area of contaminant source	A	2.50E+02	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	5.00E+01	m		
Saturated aquifer thickness	da	3.00E+00	m		
Hydraulic Conductivity of aquifer in which dilution occurs	K	8.64E+00	m/d		
Hydraulic gradient of water table	i	6.00E-03	fraction		
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m		Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	3.00E+00	m		

Calculated Parameters

Dilution Factor	DF	1.14E+01		
Level 2 Remedial Target		**3.41E+00**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		2.58E+01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Aromatic >EC8 EC10		from Level 1
Target Concentration	C	0.3	mg/l	from Level 1
Dilution Factor	DF	1.14E+01		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to dissolved pollutants only

	Variable	Value	Unit	Source of parameter value
Enter source concentration	Determine remedial target based on assumed concentration			
Half life for degradation of contaminant in water	$t_{1/2}$	7.30E+02	days	
Calculated decay rate	λ	9.50E-04	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	3.00E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.75E+00	g/cm^3	
Effective porosity of aquifer	n	2.60E-01	fraction	
Hydraulic gradient	i	6.58E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	8.64E+00	m/d	from Level 2
Distance to compliance point	x	5.00E+01	m	
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	9.00E+99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	7.42E+00	l/kg	*see options*
Longitudinal dispersivity	ax	2.984	m	*see options*
Transverse dispersivity	az	0.298	m	*see options*
Vertical dispersivity	ay	0.030	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	2.19E-01	m/d
Retardation factor	Rf	5.10E+01	fraction
Decay rate used	λ	1.86E-05	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	6.58E-03	fraction
Rate of contaminant flow due to retardation	u	4.29E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	2.61E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**3.83E+00**	**fraction**

Remedial Targets

Level 3 Remedial Target		**1.31E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		9.88E+01	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**50**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**2.61E 01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	4.64E-03	fraction
Organic carbon partition coefficient	Koc	1.60E+03	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	7.42E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

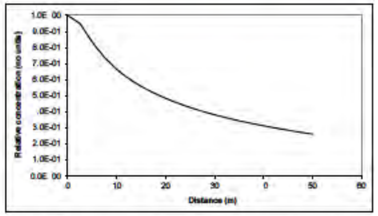
Dispersivity based on Xu & Eckstein (1995)

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	2.98E+00	5.00E+00	2.98E+00	m
Transverse dispersivity	**az**	[illegible]	5.00E-01	2.98E-01	m
Vertical dispersivity	**ay**	[illegible]	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax $0.83(\log_{10}x)^{2.414}$; az ax/10, ay ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO etc than an alternative solution should be used



Note 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation then set half life as 9.9E+99.

Site being assessed	Northstowe
Completed by	Reg. 13(1)
Date	11-12-17
Version	1

Calculated (relative) concentrations for distance concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)
0	1.0E+00
2.5	9.49E 01
5.0	8.34E 01
7.5	7.39E 01
10.0	6.65E 01
12.5	6.06E 01
15.0	5.59E 01
17.5	5.19E 01
20.0	4.84E 01
22.5	4.54E 01
25.0	4.27E 01
27.5	4.03E 01
30.0	3.82E 01
32.5	3.62E 01
35.0	3.44E 01
37.5	3.28E 01
40.0	3.12E 01
42.5	2.98E 01
45.0	2.85E 01
47.5	2.73E 01
50.0	2.61E 01

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	**Northstowe**			
Site Address:	**Northstowe**			
Completed by:	Reg. 13(1)			
Date:	**11-Dec-17**		**Version:**	**1**
Contaminant	**Aromatic >EC10-EC12**			
Target Concentration (C_T)	**0.09**	**mg/l**	**Origin of C_T:**	**CL:AIRE**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		Aromatic >EC10-EC12	
Target concentration	C_T	0.09	mg/l

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	2.24E-01	fraction	
Air filled soil porosity	θ_a	1.03E-01	fraction	
Bulk density of soil zone material	ρ	1.87E+00	g/cm^3	
Henry's Law constant	H	1.40E-01	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	4.64E-03	fraction	
Organic carbon partition coefficient	Koc	2.50E+03	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.16E+01**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**1.06E+00**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.09	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 2 - Soil

Contaminant		Aromatic >EC10-EC12		from Level 1
Target concentration	C_T	0.09	mg/l	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.00E-04	m/d		
Area of contaminant source	A	2.50E+02	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	5.00E+01	m		
Saturated aquifer thickness	da	3.00E+00	m		
Hydraulic Conductivity of aquifer in which dilution occurs	K	8.64E+00	m/d		
Hydraulic gradient of water table	i	6.00E-03	fraction		
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m		Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		Calculate			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	3.00E+00	m		

Calculated Parameters

Dilution Factor	DF	1.14E+01		
Level 2 Remedial Target		**1.02E+00**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		1.20E+01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Environment Agency

Input Parameters	Variable	Value	Unit	Source
Contaminant		Aromatic >EC10 EC12		from Level 1
Target Concentration	C	0.09	mg/l	from Level 1
Dilution Factor	DF	1.14E+01		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of po lutants: Apply degradation rate to dissolved pollutants only

	Variable	Value	Unit	Source of parameter value
Enter source concentration	Determine remedial target based on assumed concentration			
Half life for degradation of contaminant in water	$t_{1/2}$	1.80E+03	days	
Calculated decay rate	λ	3.85E-04	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	3.00E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.75E+00	g/cm^3	
Effective porosity of aqu fer	n	2.60E-01	fraction	
Hydraulic gradient	i	6.58E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aqu fer	K	8.64E+00	m/d	from Level 2
Distance to compliance point	x	5.00E+01	m	
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	9.00E+99	days	t me variant options only
Parameters values determined from opt ons				
Part tion coefficient	Kd	1.16E+01	l/kg	*see options*
Long tudinal dispersivity	ax	2.984	m	*see options*
Transverse dispersivity	az	0.298	m	*see options*
Vertical dispersivity	ay	0.030	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	2.19E-01	m/d
Retardation factor	Rf	7.91E+01	fraction
Decay rate used	λ	4.87E-06	d^{-1}
Hydraulic gradient used in aqu fer flow down-gradient	i	6.58E-03	fraction
Rate of contaminant flow due to retardation	u	2.76E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	2.97E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**3.37E+00**	**fraction**

Remedial Targets

Level 3 Remedial Target		**3.45E+00**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		4.05E+01	**mg/kg**	For comparison with measured so l concentration. This
Distance to compliance point		**50**	**m**	assumes Level 1 Remedial Target calculated from so l-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**2.97E 01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	4.64E-03	fraction
Organic carbon partition coefficient	Koc	2.50E+03	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.16E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

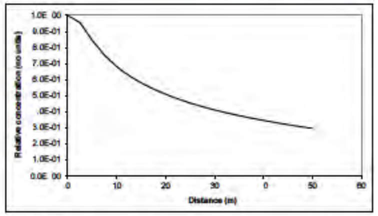
Dispersivity based on Xu & Eckstein (1995)

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	2.98E+00	5.00E+00	2.98E+00	m
Transverse dispersivity	**az**	2.98E-01	5.00E-01	2.98E-01	m
Vertical dispersivity	**ay**	2.98E-02	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax $0.83(\log_{10}x)^{2.\ 1}$; az ax/10, ay ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron lim ted degradation such as oxidation by O_2, NO_3, SO etc than an alternative solution should be used



Note 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aqu fer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydrau ic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) t will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation then set half life as 9.9E+99.

S te being assessed	Northstowe
Completed by	Req. 13(1)
Date	11-12-17
Version	1

Calculated (relative) concentrations for distance concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)
0	1.0E+00
2.5	9.55E 01
5.0	8.45E 01
7.5	7.53E 01
10.0	6.82E 01
12.5	6.26E 01
15.0	5.80E 01
17.5	5.42E 01
20.0	5.09E 01
22.5	4.81E 01
25.0	4.55E 01
27.5	4.33E 01
30.0	4.12E 01
32.5	3.93E 01
35.0	3.76E 01
37.5	3.60E 01
40.0	3.46E 01
42.5	3.32E 01
45.0	3.19E 01
47.5	3.08E 01
50.0	2.97E 01

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	**Northstowe**			
Site Address:	**Northstowe**			
Completed by:	Reg. 13(1)			
Date:	**11-Dec-17**		**Version:**	**1**
Contaminant	**Aromatic >EC12-EC16**			
Target Concentration (C_T)	**0.09**	**mg/l**	**Origin of C_T:**	**CL:AIRE**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Aromatic >EC12-EC16**	
Target concentration	C_T	**0.09**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θw	2.24E-01	fraction	
Air filled soil porosity	θa	1.03E-01	fraction	
Bulk density of soil zone material	ρ	1.87E+00	g/cm^3	
Henry's Law constant	H	5.40E-02	dimensionless	
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	4.64E-03	fraction	
Organic carbon partition coefficient	Koc	5.00E+03	l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**2.32E+01**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**2.10E+00**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.09	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Environment Agency

Level 2 - Soil

Contaminant		Aromatic >EC12-EC16		from Level 1
Target concentration	C_T	0.09	mg/l	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	3.00E-04	m/d		
Area of contaminant source	A	2.50E+02	m^2		Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	5.00E+01	m		
Saturated aquifer thickness	da	3.00E+00	m		
Hydraulic Conductivity of aquifer in which dilution occurs	K	8.64E+00	m/d		
Hydraulic gradient of water table	i	6.00E-03	fraction		
Width of contaminant source perpendicular to groundwater flow	w	5.00E+00	m		Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	3.00E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**1.14E+01**		
Level 2 Remedial Target		**1.02E+00**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		2.39E+01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Northstowe
Completed by:	Reg. 13(1)
Date:	11-Dec-17
Version:	1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		Aromatic >EC12 EC16		from Level 1
Target Concentration	C	0.09	mg/l	from Level 1
Dilution Factor	DF	1.14E+01		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to dissolved pollutants only

	Variable	Value	Unit	Source of parameter value
Enter source concentration	Determine remedial target based on assumed concentration			
Half life for degradation of contaminant in water	$t_{1/2}$	1.80E+03	days	
Calculated decay rate	λ	3.85E-04	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	Sy	3.00E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.75E+00	g/cm^3	
Effective porosity of aquifer	n	2.60E-01	fraction	
Hydraulic gradient	i	6.58E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	8.64E+00	m/d	from Level 2
Distance to compliance point	x	5.00E+01	m	
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	9.00E+99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.32E+01	l/kg	*see options*
Longitudinal dispersivity	ax	2.984	m	*see options*
Transverse dispersivity	az	0.298	m	*see options*
Vertical dispersivity	ay	0.030	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	2.19E-01	m/d
Retardation factor	Rf	1.57E+02	fraction
Decay rate used	λ	2.45E-06	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	6.58E-03	fraction
Rate of contaminant flow due to retardation	u	1.39E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	2.97E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**3.37E+00**	**fraction**

Remedial Targets

Level 3 Remedial Target		**3.45E+00**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		8.05E+01	**mg/kg**	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point		**50**	**m**	
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**2.97E 01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	4.64E-03	fraction
Organic carbon partition coefficient	Koc	5.00E+03	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.32E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

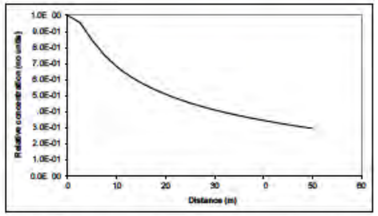
Dispersivity based on Xu & Eckstein (1995)

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	2.98E+00	5.00E+00	2.98E+00	m
Transverse dispersivity	**az**	2.98E-01	5.00E-01	2.98E-01	m
Vertical dispersivity	**ay**	2.98E-02	5.00E-02	2.98E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax 0.83(log$_{10}$x)$^{2.1}$; az ax/10, ay ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO etc than an alternative solution should be used



Note 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation then set half life as 9.9E+99.

Calculated (relative) concentrations for distance concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)
0	1.0E+00
2.5	9.55E 01
5.0	8.45E 01
7.5	7.53E 01
10.0	6.82E 01
12.5	6.26E 01
15.0	5.80E 01
17.5	5.42E 01
20.0	5.09E 01
22.5	4.81E 01
25.0	4.55E 01
27.5	4.33E 01
30.0	4.12E 01
32.5	3.93E 01
35.0	3.76E 01
37.5	3.60E 01
40.0	3.46E 01
42.5	3.32E 01
45.0	3.19E 01
47.5	3.08E 01
50.0	2.97E 01

Site being assessed	Northstowe
Completed by	Reg. 13(1)
Date	11-12-17
Version	1

APPENDIX F

Soil Screening Values

Soil Screening Values

Compound name	Soil Screening Values (mg/kg)		
	Residential with plants	Residential without plants	Public Open Space
Arsenic	37	40	170
Boron	290	11000	
Cadmium	11	85	532
Chromium	910	910	33000
Chromium (hexavalent)	6	6	220
Copper	2400	7100	44000
Lead	220	310	1300
Mercury	40	56	240
Nickel	130	180	3400
Selenium	250	430	1800
Zinc	3700	40000	170000
Free Cyanide	27	760	2900
Total Cyanide	27	760	2900
pH	6-9	6-9	
PAH compounds (1% SOM)			
Acenaphthylene	170	2900	29000
Anthracene	2400	31000	150000
Benzo(a)anthracene	7.2	11	49
Benzo(a)pyrene	2.2	3.2	11
Benzo(b)fluoranthene	2.6	3.9	13
Benzo(k)fluoranthene	77	110	370
Benzo(ghi)perylene	32	360	1400
Acenaphthene	210	3000	29000
Chrysene	15	30	93
Di-benzo(a,h)anthracene	0.24	0.31	1.1
Fluoranthene	280	1500	6300
Fluorene	170	2800	20000
Indeno(1,2,3-cd)pyrene	27	45	150
Naphthalene	2.3	2.3	1200 (76.4)^{sol}
Phenanthrene	95	1300	6200
Pyrene	620	3700	15000
Total Phenols (monohydric)	280	750	760
TPH Fractions (1%SOM)			
Aliphatic C5-6	42	42	95000 (304) ^{sol}
Aliphatic C6-8	100	100	150000 (144) ^{sol}

Compound name	Soil Screening Values (mg/kg)		
	Residential with plants	Residential without plants	Public Open Space
Aliphatic 8-10	27	27	14000 (78) ^{sol}
Aliphatic 10-12	130 (48) ^{vap}	130 (48) ^{vap}	21000 (48) ^{sol}
Aliphatic 12-16	1100 (24) ^{sol}	1100 (24) ^{sol}	25000 (24) ^{sol}
Aliphatic 16-35	65000 (8.48) ^{f,sol}	65000 (8.48) ^{f,sol}	450000 ^{f}
Aliphatic 35-44	65000 (8.48) ^{f,sol}	65000 (8.48) ^{f,sol}	450000 ^{f}
Aromatic C5-7	70	370	76000 (1220) ^{sol}
Aromatic C7-8	130	860	87000 (869) ^{vap}
Aromatic C8-10	34	47	7200 (613) ^{vap}
Aromatic C10-12	74	250	9200 (364) ^{sol}
Aromatic C12-16	140	1800	10000
Aromatic 16-21	260	1900	7600
Aromatic C21-35	1100	1900	7800
Aromatic C35-44	1100	1900	7800

APPENDIX G

Soil Remedial Targets - Soil Leachate Values

Soil Leachate Criteria for Metal Contaminants - Protective of Controlled Waters

Determinand	Level 3 Pore Water criteria (ug/l)
Arsenic	124
Cadmium	1.86
Chromium	58.2
Copper	582
Lead	124
Mercury	0.5
Nickel	248
Selenium	124
Vanadium	248
Zinc	496
pH	6 - 9

APPENDIX H

CLO Correspondence

South Cambridgeshire Hall
Cambourne Business Park
Cambourne
Cambridge,
CB23 6EA
www.scambs.gov.uk
03450 450 500

South Cambridgeshire
District Council

Internal Memo

Date: 24/04/2018

TO: Planning & New Communities – Reg. 13(1)

FROM: Health & Environmental Services – Contaminated Land

SUBJECT: **Discharge of condition 17 (Groundwater and contamination) of planning permission S/2011/14/OL - Northstowe Phase 2, Northstowe Phase 2, Longstanton, CB24 3EW**

REF: **S/0926/18/DC**

I wish to confirm that I have received a copy of the above application and have considered the implications of the proposals.

The above site comprises a large site with a mixed previous use including agricultural fields and Oakington Barracks, which may have potential for contamination to be present. The proposal is for Phase 2 of Northstowe new town, comprising residential housing (3500 dwellings), town centre, education campus, recreation and landscaping, bus way, sports hub plus infrastructure. A contaminated land condition (below) has been applied to the whole development of Northstowe under the original outline application (S/2011/14/OL), and as a result several reports have been submitted in an effort to satisfy the Condition.

"*Unless otherwise agreed in writing, no development other than agreed enabling works, approved by this planning permission, shall commence on any sub-phase until a remediation strategy that includes the following components to deal with the risks associated with contamination on that sub-phase (unless the strategy states any remedial actions should be applicable across phases) has been submitted to and approved, in writing, by the Local Planning Authority:*

1. A Preliminary Risk Assessment (PRA) including a Conceptual Site Model (CSM) of that phase of the site indicating potential sources, pathways and receptors, including those off site.

2. The results of supplementary investigation and recording of contamination as recommended in the Northstowe Phase 2 Geo Environmental Assessment and Outline Remedial Strategy Report (dated August 2014) and a detailed risk assessment, including a revised CSM.

3. Based on the risk assessment in (2) an options appraisal and Remediation Method Statement giving full details of the remediation measures required and how they are to be undertaken. The Remediation Method Statement shall include a plan providing details of how the remediation works shall be judged to be complete and arrangements for contingency actions. The plan shall also detail a long term monitoring and maintenance plan as necessary.

4. If, during development, including the remediation phase, contamination not previously identified is found to be present at the site then no further development (unless otherwise agreed in writing with the Local Planning Authority) shall be carried out until the developer has submitted a supplementary Remediation Method Statement detailing how this contamination shall be dealt with and obtained written approval *from the Local Planning Authority. The contamination shall be remediated in accordance with the approved supplementary Remediation Method Statement.*

5. *No development shall be brought into use or occupied on any sub-phase until a verification report demonstrating completion of works on that sub phase as set out in the Remediation Method Statement(s) (parts 3 and 4 above) have been completed. The verification report shall be submitted to and approved in writing by the Local Planning Authority, and demonstrate that the land is suitable for the proposed end use. The long term monitoring and maintenance plan in (3) shall be updated and be implemented as approved*."

Items 1 and 2 of the above planning condition have been addressed by previous reports, but confirmation of acceptance from the Local Authority is still required for the 2017 Arcadis reports:

WSP Interim Factual Reports x 3, 2007
Hyder: Phase 2 Geo-environmental Assessment and Outline Remedial Strategy 2014
Arcadis Phase 2 Ground Investigation April 2017
Arcadis Phase 2 Geo-environmental Assessment and Outline Remedial Strategy – infrastructure only June 2017

The latest submission relevant to this discharge of condition application is the Arcadis Remedial Method Statement (March 2018).
This report has been reviewed along with the two previous Arcadis reports which previously hadn't been submitted. Observations and comments are as follows, **any resultant relevant comments or queries are in bold:**

Arcadis Phase 2 Ground Investigation April 2017
This is a factual report detailing the investigation that has taken place and presenting the results. **We have no further comments on this report.**

Arcadis Phase 2 Geo-environmental Assessment Report and outline remedial strategy – infrastructure only.
This report details the geo-environmental assessment across the whole site, and presents an outline remedial strategy for the infrastructure only – namely the SARW and the ponds / water park area.
The site has been split into several land use areas depending upon previous and proposed uses, from LU2 to LU13. Investigations have concentrated in the eastern area due to the proposed order of development. Large areas of LU6 and LU7 have been omitted due to archaeological digs.

Appendix C of the Remediation Method Statement (2018) presents soil exceedance figures. Appendix A of the 2017 Geo-environmental Assessment also presents these figures, but they vary from each other. Why is this? Has there been some supplementary sampling resulting in an update of the datasets between the two reports?

Limited Gas readings have been taken across the site and currently suggest a Characteristic Situation 2 and Amber 1; resulting in basic gas protection measures across the site (ventilated sub floor void and membrane). **More gas monitoring is proposed and we agree with this approach.**

- Remedial strategy for the Ponds:

The water park and pond area is located in LU06. Contamination has been discovered in this area, partly related to the former sewage treatment works and a possible burning pit. Proposals are to remove the contamination prior to the excavation of the ponds, stockpile and then remove in order to prevent cross contamination. Validation of the ponds is to occur. This also applies to the burning pit area. **We agree with this approach.**

- Remedial Strategy for the SARW:

The site investigations here have returned no exceedences, the proposal is not overly sensitive and no remediation has been proposed. **We agree in part, but would recommend a watching brief is maintained to identify any unsuspected contamination. This was referred to in section 9.6. We also agree with points 9.3-9.8 and the recommendations in Section 10.2.**

Arcadis Remedial Method Statement 2018

This is the remedial method statement pertinent to the whole of Phase 2. It is in response to item 3 of the contaminated land condition and also to provide details of the watching protocol in item 4. Generally each Land Use area may be subject to further investigation depending upon the sensitive nature of the proposal (eg residential areas) or current gaps in data due to access issues or limited datasets (eg gas). Otherwise Remedial proposals are detailed in this report.

P8 section 3.1.1
You state that LU6 is for sports fields, green space and attenuation ponds, and results will be screened against S4UL for public open space. However the education campus is proposed here which introduces a range of receptors, and as such public open space may not be the appropriate screening level. Please could this be explored further?

P8 section 3.1.1
You plan to re-use contaminated soils from the pond excavations. But the previous report (2017) stated all comtaminated soils would be removed in order to reduce the chance of cross contamination across the site. Why has this changed please and will this be further discussed in the suggested CEMP / MMP?

P20 section 4.1.2
UXO reports by Zetica revealed areas of burning pits, which are to be removed and disposed of. Will these areas also be validated as per other removal areas?

Regarding gas we welcome the additional testing referred to.

Section 3.2.2 Receptors
The education campus needs to be included in LU6

Section 4 Remedial Method Statement
Further targeted investigation will be proposed in areas of housing – we agree with this approach.

Section 4.1.1
We agree with the details herein

Section 4.1.2
The proposals regarding re use of contaminated soil need to be discussed as these contradict the proposals previously put forward in the 2017 report.
Also need to discuss the S4UL to be used in light of the education campus being proposed in LU6.

Section 4.1.3
We agree with this

Section 4.2
We agree with this

Section 4.3
A greater dataset is required as proposed

Sections 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
All agreed EXCEPT we need justification as the testing of imported soils being 1 sample per 1000m3. We agree that at least one sample per plot should be tested in residential

areas. The report states (p23) that criteria for imported material is included at Appendix B, but it doesn't seem to be there (this is the soil exceedance tables).

I hope the comments are clear to the reader and more importantly the points requiring clarification. Apologies for the lengthy response but there is a lot of material to include.

Overall at this time I cannot recommend discharge of part 3 of the contaminated land condition until the queries have been satisfactorily addressed, but I can agree that the proposals for the watching protocol in relation to part 4 of the contaminated land condition are satisfactory. Of course part 4 cannot be discharged until the development is complete.

Please return a copy of the decision notice regarding this application when it has been determined.

Reg. 13(1)
Scientific Officer (Contaminated Land)

MEMO

ARCADIS Design & Consultancy for natural and built assets

SUBJECT
Northstowe – Remedial Method Statement

DATE
30 April 2018

DEPARTMENT
SER – Land Quality

COPIES TO
Peter Bosley, Phil Harker, Michael Bottomley

TO
[redacted] [redacted] - SCDC

OUR REF
NOR-ARC-XX-XXX-RP-G-0142-P01

PROJECT NUMBER
10018973

FROM
[redacted]
M [redacted] E [redacted]arcadis.com

Discharge of condition 17 (Groundwater and contamination) of planning permission S/2011/14/OL - Northstowe Phase 2, Northstowe Phase 2, Longstanton, CB24 3EW (Ref - S/0926/18/DC)

The table below is in response to comments from Health & Environmental Services – Contaminated Land, South Cambridgeshire District Council (SCDC) dated 24/04/2018

Comments from SCDC	Response from Arcadis
Arcadis Phase 2 Geo-environmental Assessment Report and outline remedial strategy – infrastructure only. Appendix C of the Remediation Method Statement (2018) presents soil exceedance figures. Appendix A of the 2017 Geo-environmental Assessment also presents these figures, but they vary from each other. Why is this? Has there been some supplementary sampling resulting in an update of the datasets between the two reports?	The drawings presented in Appendix A of the 2017 report show soil exceedances when screened against the most sensitive land use – residential with plant uptake. The drawings presented in Appendix C of the 2018 report show soil exceedance when the results are screened against the appropriate screening values for the proposed land use eg in LU6 – public open space / LU12 (proposed SARW) – commercial. As these are less sensitive land uses there are fewer exceedances and hence the drawings look different. See section 3.1.1 of the 2018 report for more details.
Remedial Strategy for the SARW: **The site investigations here have returned no exceedences, the proposal is not overly sensitive and no remediation has been proposed.** We agree in part, but would recommend a watching brief is maintained to identify any unsuspected contamination. This was referred to in section 9.6. We also agree with points 9.3-9.8 and the recommendations in Section 10.2.	A watching brief protocol is detailed in the Remedial Method Statement (RMS).
Arcadis Remedial Method Statement 2018 **P8 section 3.1.1** You state that LU6 is for sports fields, green space and attenuation ponds, and results will be screened against S4UL for public open space. However the education campus is proposed here which introduces a range of receptors, and as such public open space	In light of this comment we have reviewed the latest masterplan for the site – an extract is provided below. The education campus is the light grey area in LU6 and LU9. The majority of the buildings associated with the campus are on the western side of this area and contained within LU9. LU9 was screened for a residential with plant uptake

Comments from SCDC	Response from Arcadis
may not be the appropriate screening level. Please could this be explored further?	scenario and only isolated PAH / TPH contamination was encountered in the area of the campus. These can be remediated as detailed in 4.1.1 The sports pitches were screened against residential with plant uptake in the 2017 report and there was only exceedance of PAH compounds in one location (TPB010 0.2m). We will change the text in the report to reflect the above. 
P8 section 3.1.1 You plan to re-use contaminated soils from the pond excavations. But the previous report (2017) stated all contaminated soils would be removed in order to reduce the chance of cross contamination across the site. Why has this changed please and will this be further discussed in the suggested CEMP / MMP?	As mentioned above, the soil concentrations found in LU6 were previously screened for a residential end use and exceedances were recorded. When these were screened for a less sensitive land use such as open space, no exceedances were recorded. The concentrations on site are therefore not significant and for less sensitive developments would not need to be remediated. These materials could therefore be re-used on site if considered suitable for the proposed end use in the area. Further assessment would be undertaken as detailed in last paragraph on page 8 to ensure that materials are suitable for re-use. This would be further discussed / justified in the MMP. We would add that the term "contaminated materials" is conditional and directly linked to the end use (exposure model) and that concept is applied to re-use, i.e. "hot spots" needing to be removed from a

Comments from SCDC	Response from Arcadis
	residential area are frequently only marginally impacted, and are suitable for re-use in less sensitive parts of the development, e.g. construction of road embankments.
P20 section 4.1.2 UXO reports by Zetica revealed areas of burning pits, which are to be removed and disposed of. Will these areas also be validated as per other removal areas?	Validation would be undertaken as detailed at the end of paragraph 3 in 4.1.2 *Validation testing should be undertaken to confirm all waste materials have been removed.*
Section 3.2.2 Receptors The education campus needs to be included in LU6	School children and teachers are detailed in the receptor list (1st bullet point), however we will expand this to state users of education campus as it may be used for wider community activities.
Section 4.1.2 The proposals regarding re use of contaminated soil need to be discussed as these contradict the proposals previously put forward in the 2017 report. Also need to discuss the S4UL to be used in light of the education campus being proposed in LU6.	See previous comments for P8 section 3.1.1
Sections 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6 All agreed EXCEPT we need justification as the testing of imported soils being 1 sample per 1000m3. We agree that at least one sample per plot should be tested in residential areas. The report states (p23) that criteria for imported material is included at Appendix B, but it doesn't seem to be there (this is the soil exceedance tables).	The 1 sample per 1000m3 relates to imported material from a greenfield source. If the material is from a brownfield source then a higher rate of sampling should be adopted. Text will be added to the report. The criteria for imported material is included in Appendix F – the report will be amended and text added to state that the criteria used will depend on where the material is to be used within the development ie how sensitive which should be reflected in the criteria uses.

APPENDIX I

Environment Agency Correspondence

James Stone
Development Services
South Cambridgeshire District Council
South Cambridgeshire Hall (6010)
Cambourne
Cambridge
CB23 6EA

Our ref: AC/2018/126885/02-L01
Your ref: S/0926/18

Date: 04 May 2018

Dear Sir/Madam

DISCHARGE OF CONDITION 17 (GROUNDWATER AND CONTAMINATION) OF PLANNING PERMISSION S/2011/14/OL. NORTHSTOWE PHASE 2, LONGSTANTON, CB24 3EW - UPDATED DOCUMENTS.

Thank you for your consultation.

Documents reviewed:

1. Remediation Method Statement for Northstowe Phase 2 Development, Arcadis ref: NOR-ARC-P2-XXX-RP-G-0140-P01, dated March 2018.
2. Northstowe Phase 2 Ground Investigation Report, Arcadis ref: UA008426-AFS-GLR-G001, dated April 2017
3. Northstowe Phase 2 Development Geo Environmental Assessment Report / Outline Remedial Strategy (Infrastructure), Arcadis ref: NOR-ARC-P2-XXX-RPG-0137-P01, dated June 2017.

Condition 17 (land contamination). We are **unable** to recommend the discharge of Condition 17 for the following reasons;

Elevated concentrations of metals in groundwater were predominantly measured towards the eastern half of the site. No elevated metal concentrations were measured in the western part of the site. Therefore, further information is required to justify the fact that impacts measured represent natural background levels. We would also recommend review of the Desk Study, to preclude any anthropogenic source, which may be off site or potentially previous on site land spreading.

In general we accept the proposed soil remediation. However, more information should be submitted. A figure with soil treatment area together with validation programme for each treatment area and contingency plan should be submitted as a minimum. Most of the details provided appeared to be generic with no specific detailed plan.

We welcome the further investigation and soil testing to inform the detailed design of the site. Additional groundwater sampling should also be included.

Organic contamination has been identified both in soil and groundwater, particularly in the area of LU11. Therefore, we suggest additional investigation, together with refined monitoring wells, in areas of historic fuel storage and vehicle maintenance of the former RAF base where main hydrocarbon impacts were previously encountered. This should include groundwater sampling from existing and proposed new monitoring wells.

A Detailed quantitative risk assessment has been undertaken. However, no sensitivity analysis for the input parameters used has been carried out. Furthermore, no justification and source for input parameters used have been provided. It is also necessary to justify the adopted water quality used particularly for organic contaminations. Please provided a figure with the model source area.

Specific validation plan/programme should be produced for each treatment area. This should include frequency of sampling, laboratory analyses, and groundwater monitoring to further confirm that no further risk to controlled waters.

Yours faithfully

Mr. T.G. Waddams
Planning Liaison

Direct e-mail planning.brampton@environment-agency.gov.uk

Please note – Our hourly charge for pre application assessments is now £100 + VAT per hour.

MEMO

SUBJECT
Northstowe – Remedial Method Statement

DATE
14 May 2018

DEPARTMENT
Land Quality

COPIES TO
Peter Bosley, Phil Harker, Michael Bottomley

TO
Reg. 13(1) [redacted] - SCDC

OUR REF
NOR-ARC-XX-XXX-RP-G-0143-P01

PROJECT NUMBER
10018973

FROM
Reg. 13(1) [redacted]
M Reg. 13(1) [redacted] E Reg. 13(1) [redacted]arcadis.com

DISCHARGE OF CONDITION 17 (GROUNDWATER AND CONTAMINATION) OF PLANNING PERMISSION S/2011/14/OL. NORTHSTOWE PHASE 2, LONGSTANTON, CB24 3EW -UPDATED DOCUMENTS

Documents reviewed

- Remediation Method Statement for Northstowe Phase 2 Development, Arcadis ref: NOR-ARC-P2-XXX-RP-G-0140-P01, dated March 2018.
- Northstowe Phase 2 Ground Investigation Report, Arcadis ref: UA008426-AFS-GLR-G001, dated April 2017
- Northstowe Phase 2 Development Geo Environmental Assessment Report / Outline Remedial Strategy (Infrastructure), Arcadis ref: NOR-ARC-P2-XXX-RPG-0137-P01, dated June 2017.

The table below is in response to comments from Environment Agency dated 4th May 2018.

Comments from EA	Response from Arcadis
Arcadis Remedial Method Statement 2018 Elevated concentrations of metals in groundwater were predominantly measured towards the eastern half of the site. No elevated metal concentrations were measured in the western part of the site. Therefore, further information is required to justify the fact that impacts measured represent natural background levels. We would also recommend review of the Desk Study, to preclude any anthropogenic source, which may be off site or potentially previous on site land spreading.	The investigation undertaken by Arcadis concentrated on the areas to be developed first. These are in the eastern part of the site. Ground investigation (boreholes / installations) was not undertaken in the western or south western area from Rampton Drift. This is why there is no data, it has no correlation with relative or spatial contaminative status of groundwater. We have reviewed the desk study and there are no apparent sources for the metal contamination. We note your comment regarding the possibility of land spreading, however the soil metal concentrations recorded on site are generally below the most stringent (residential with plant uptake scenario) screening values. If land spreading was a source of metal contamination, soil concentrations would be higher. As detailed in the RMS report, groundwater to the south west (as shown in the inset of groundwater exceedance drawing) has comparable groundwater quality as the main Phase 2 development site. This provides further evidence that the contaminant concentrations are natural background.

Comments from EA	Response from Arcadis
In general we accept the proposed soil remediation. However, more information should be submitted. A figure with soil treatment area together with validation programme for each treatment area and contingency plan should be submitted as a minimum. Most of the details provided appeared to be generic with no specific detailed plan.	The RMS report is a method statement of the approach to remediation of the Phase 2 development based on current knowledge. Detailed design of the soil remediation / treatment area will be undertaken by the Contractors for each development parcel / plot once the final plot layout is agreed. This will include a validation programme of the works for that plot. The RMS detailed a watching brief (contingency plan) approach which would be adopted during the earthworks / construction works if unknown contamination is encountered. Localised "hotspots" areas are shown on the drawings in the RMS which provide general details of the treatment areas which will require further assessment and mitigation during detailed design.
We welcome the further investigation and soil testing to inform the detailed design of the site. Additional groundwater sampling should also be included.	As detailed in RMS, further investigation will take place across the Phase 2 development as the work progresses. This will include soil and groundwater testing.
Organic contamination has been identified both in soil and groundwater, particularly in the area of LU11. Therefore, we suggest additional investigation, together with refined monitoring wells, in areas of historic fuel storage and vehicle maintenance of the former RAF base where main hydrocarbon impacts were previously encountered. This should include groundwater sampling from existing and proposed new monitoring wells.	As detailed in RMS, we agree that additional investigation is required in LU11 to determine the remediation required in this area. From the work undertaken to date, no extensive plume has been identified with only localised pockets encountered. Further investigation would be undertaken by the Contractor commissioned to develop this area and remediation designed based on the final layout of the area.
A Detailed quantitative risk assessment has been undertaken. However, no sensitivity analysis for the input parameters used has been carried out. Furthermore, no justification and source for input parameters used have been provided. It is also necessary to justify the adopted water quality used particularly for organic contaminations. Please provided a figure with the model source area.	From the groundwater data recorded and assessment undertaken, no significant impact from site sources (other than in the immediate vicinity of located soils sources) has been identified. Further monitoring and measurement is proposed as part of detailed design development, and therefore we don't believe that further modelling or sensitivity analysis is warranted at this time. This would be kept under review pending additional sampling and analysis data. The water quality values adopted for the DQRA are as follows – for the metals the lowest of either EQS or DWS have been used. Where required by recent changes to EQS guidance, metals have been derived using the PNEC tool as detailed in the assessment report. For the hydrocarbons, in the absence of EQS or DWS the values adopted

Comments from EA	Response from Arcadis
	for the DQRA are based on the recently published document by CL:AIRE where WHO published values are detailed as suitable for these contaminants have been used. Other site specific input values used in the DQRA are taken from the ground investigation data / knowledge about the site. The compliance point is taken as 50m which is GP3 compliant and is stringent for this site (adopts the precautionary principle) as the main surface water receptor is at a greater distance. All existing evidence is that the Hydrocarbon impacts are localized. Nevertheless a precautionary approach has been adopted that models the source area as a zone of impact that could be 50m in direction of groundwater flow and 5m width (as detailed in RMS). For metal contamination, a model that considers the source area is 50m in direction of groundwater flow and 50m width has been adopted, reflecting current uncertainty of extent of hotspots, pending further investigation.
Specific validation plan / programme should be produced for each treatment area. This should include frequency of sampling, laboratory analyses, and groundwater monitoring to further confirm that no further risk to controlled waters.	As mentioned in our responses above, the Contractor commissioned for each development plot would produce a validation plan / programme based on the RMS and specific remediation required. This would be based on additional site investigation data and the final layout plan for the plots.

General Comment

Given the scale of this project, and in consideration that delivery will be undertaken in multiple phases, we would recommend that this pre-commencement condition is amended to reflect a phased development to enable partial discharge so that works can commence on site. Contractors can produce the plot specific remediation strategies once the design layout are finalised. This would be based on the approach in the RMS. These can then be signed off on a phase by phase basis.

Reg. 13(1)
Development Services
South Cambridgeshire District Council
South Cambridgeshire Hall (6010)
Cambourne
Cambridge
CB23 6EA

Our ref: AC/2018/126885/04-L01
Your ref: S/0926/18

Date: 30 May 2018

Dear Sir/Madam

DISCHARGE OF CONDITION 17 (GROUNDWATER AND CONTAMINATION) OF PLANNING PERMISSION S/2011/14/OL. NORTHSTOWE PHASE 2, LONGSTANTON, CB24 3EW - FURTHER DETAIL.

Thank you for your consultation.

Documents reviewed:

1. Memo on Northstowe – Remediation Method Statement, Arcadis ref: NOR-ARC-XX-XXX-RP-G-0143-P01, dated 16 May 2018.

Condition 17: We are unable to recommend the discharge of Condition 17 for the following reasons.

There is no information on metal concentrations in groundwater outside the Phase 2 submitted to justify that metal concentrations measured within the eastern part of the Phase 2 are natural background. Furthermore, there is no information available for the western part of the Phase 2 development, For example, no metal concentrations within the groundwater have been measured/provided within the areas of LU02, LU03, LU04, LU05 and LU08.

We cannot therefore recommend the discharge of Condition 17 prior to the completion of site investigation fully and development of specific remediation method statement to address the impacts identified with unacceptable risks to controlled waters.

In the absence of the sensitivity analysis and the sources for information, we are not able to accept the site specific assessment criteria developed by the detailed quantitative risk assessment. The information should be provided to justify the accuracy and applicability of the model used for the site. Notwithstanding, we welcome the proposal for further monitoring and re-evaluation of the potential risks at the detailed investigation scheme. An updated assessment may be required.

Regarding the adopted water quality standards, it is advised to consider both EQS and DWS and use the lowest of the two for organic contaminants as per the metals risk assessment. In the absence of EQS and DWS, alternative targets should be considered such as laboratory method detection limits or fraction of drinking water quality standards as defined by the Drinking Water Inspectorate. We consider that adopting WHO values

for TPH fractions may not necessarily be appropriate - the current and future resource potential of the aquifer beneath the site should also be considered as well as the risks to other controlled waters receptors.
A figure showing the modelled source area(s) should be provided.

We cannot recommend the full discharge of condition 17 until completion of specific validation plan and verification programme.

As further phase-specific investigations and assessments are required, and a revised remediation strategy may be required for individual phases or plots, we are unable to recommend the discharge of Condition 17 at this stage.

Yours faithfully

Reg. 13(1)

Planning Liaison

Direct e-mail planning.brampton@environment-agency.gov.uk

Please note – Our hourly charge for pre application assessments is now £100 + VAT per hour

Environment Agency, East Anglia Area (West), Bromholme Lane, Brampton, Huntingdon, Cambs. PE28 4NE.

www.gov.uk/environment-agency

MEMO

SUBJECT
Northstowe - Remediation Method Statement

DATE
14 June 2018

DEPARTMENT
Land Quality

COPIES TO
Peter Bosley, Phil Harker, Michael Bottomley, Steve Davies

TO
[redacted] - SCDC

OUR REF
NOR-ARC-XX-XXX-RP-G-0144-P01

PROJECT NUMBER
[Click here to type project number]

FROM
[redacted]
E [redacted]arcadis.com

This memo is in response to the letter from the EA to James Stone (SCDC) dated 30th May 2018. That letter provided commentary on Arcadis Remedial Method Statement (RMS) (Ref 1). We have provided additional information / assessment in line with the EA comments made.

The headings used below reflect the paragraph subject matter in a sequential manner.

Metal Concentration Data, evidence from Outside Phase 2 and on Western extent of Phase 2 and discussion of widespread slight exceedance of WQS

In the RMS, we used the data from Arcadis 2017 investigation. As explained in previous memo, the 2017 investigation did not extend to western side of the site, as this will form much later phases of development. In previous and more limited scope, 2007, WSP did however install some monitoring wells in the western part of the site. WSP were not able to extensively investigate this area as it was part of the immigration centre and access was restricted.

On reviewing the available WSP data, the following monitoring wells have groundwater quality data; BHA001, BHA033 (all LU02), BHC10 and BHC11 (all LU03). These have been installed typically within the RTD, but in some cases the response zone is screened across the RTD and Ampthill Clay, which is encountered in this western area, (with Kimmeridge Clay to the eastern part of Phase 2). These exploratory hole locations are shown on drawings attached to this memo.

On review of the results, no exceedances of the current WQS values (metals) have been recorded. Also, where analysed, TPH recorded below method limit of detection.

In terms of recorded presence of metals, it is noted that groundwater samples have also been taken outside the Phase 2 area within in LU12 (southern access road west) which is located to the south / south west of the main Phase 2 area. LU12 was not part of the former RAF base and has always been in agricultural use. Exceedances of contaminants, including zinc, nickel and selenium have been encountered in groundwater under LU12. LU12 is up gradient to the main Phase 2 Site and thus the presence of these metals is most unlikely to have an origin associated with the RAF base.

Within the main Phase 2, there is presence of metallic contamination within a few groundwater samples/locations, e.g. BH1103, which would appear to be associated with historic site activity, though noting that a specific soil source has yet to be discovered. Where soil sources are encountered, through future more detailed investigations, such impact would be remediated.

However the typical baseline groundwater quality, whilst exceeding WQS for some metals at frequent locations, (e.g. Selenium), appears to have no clear association with the former RAF use. No credible soil sources have been identified.

Further Assessment of Chemical Data

We have further assessed the groundwater data from the Arcadis investigation. We have separated the data depending on geological strata of the monitoring well response zone into River Terrace deposits (RTD) and Kimmeridge Clay (KC). Where response zones extended over the two strata we have excluded these from this further assessment.

During the 2016/2017 Arcadis investigation, two rounds of monitoring have been undertaken (noting a reduced scope in the second round). The tables below record the metal contaminant concentrations in each strata, the number of exceedances of either EQS or DWS criteria and the corresponding Hazard Index. The data is shown for the first and second monitoring rounds separately. It should be noted that the borehole (BH1103) with the highest metal concentrations and highest number of elevated contaminants is included in both rounds. Beyond reasonable doubt impacts at BH1103 are most likely associated with historic site activities.

Table 1 – Metal Contaminant Concentrations in RTD strata (1st and 2nd rounds)

Contaminant	EQS ug/l	DWS ug/l	Concentration Range ug/l (1st round – 31 samples)	Exceedances (HI value)	Concentration Range ug/l (2nd round – 7 samples)	Exceedances (HI value)
Arsenic	50	10	0.15-30.6	1 – DWS BH1103 (HI=3)	<0.15-3.89	None
Cadmium	0.15	0.15	0.02-0.29	2 – EQS / DWS BH1205 (HI=1.93) BH1206 (HI=1.86)	0.05-0.17	1 – BH1205 (HI=1.13)
Chromium VI	3.4	50	<5	All BLOD	<5	All BLOD
Chromium	4.7	50	0.2-180	1 – EQS **BH1103 (HI= 38.29)** 1 – DWS BH1103 (HI=3.6)	<0.2-11	1 – EQS - BH1103 (HI= 2.34)
Copper	47	2000	1.5-45	None	1.9-10	None
Lead	12	10	0.2-29	1 – EQS BH1103 (HI=2.42) 1 – DWS BH1103 (HI=2.90)	<0.2-11	1 – DWS BH1103 (HI=1.1)
Mercury	0.5	1	0.05-0.33	None	<0.05	All BLOD
Nickel	24	20	1-88	2- EQS BH1205 (HI=2.17), BH1103 (HI=2.6) 2- DWS BH1205 (HI=3.67), BH1103 (HI=4.4)	1-30	1- EQS - BH1205 (HI=1.25) 2- DWS - BH1205 (HI=1.5), BH1103 (HI=1.15)
Selenium	-	10	0.6-1200	9 – DWS **BH1103 (HI=120),** BH1101 (HI=2.1), WS1103 (HI=1.5), BH604 (HI=1.4), BH1003 (1.6), BH613 (HI=5.4),	1.4-92	2 – DWS – BH1103 (HI= 9.2), BH1205 (HI=3.9)

Contaminant	EQS ug/l	DWS ug/l	Concentration Range ug/l (1st round – 31 samples)	Exceedances (HI value)	Concentration Range ug/l (2nd round – 7 samples)	Exceedances (HI value)
				WS902 (HI=5.1), BH1204 (HI=2.8), BH1205 (HI=8.2)		
Vanadium	20	-	0.2-280	1 – EQS **BH1103 (HI=14)**	<0.2-23	1 – EQS - BH1103 (HI=2.3)
Zinc	40	2000	2.7-120	3 – EQS BH1205 (HI=3), BH1206 (HI=1.2), BH1103 (HI=2.45)	5.9-54	2 – EQS BH1103 (HI=1.35), BH1205 (HI=1.25)

Bold = HI above 10

The table above indicates that there are exceedances of both DWS and/ or EQS of 8 out of 11 metals within the RTD aquifer. It is noted that in majority of cases (normally distributed data) the Hazard Index is less than 10 indicating that the concentrations are within the same order of magnitude as the DWS / EQS criteria. The exceptions are all from BH1103 where concentrations from Chromium, Selenium and Vanadium have HI values of 38.29, 120 and 14 respectively. These are statistical outliers, and likely associated with previous site activity.

In the second round of analysis the HI / concentrations are lower for all the samples analysed and in particular for the 3 metals in BH1103. The HIs are all below 10 in the second round. This indicates that the groundwater concentrations fluctuate within the same locations in the RTD.

Table 2 details the concentration ranges in the KC for the first and second monitoring rounds.

Table 2 – Metal Contaminant Concentrations in KC strata (1st and 2nd rounds)

Contaminant	EQS ug/l	DWS ug/l	Concentration Range ug/l (1st round – 28 samples)	Exceedances (HI value)	Concentration Range ug/l (2nd round – 5 samples)	Exceedances (HI value)
Arsenic	50	10	0.15-2.23	None	0.24-0.55	None
Cadmium	0.15	0.15	0.02-0.22	3 – EQS / DWS BH601 (HI= 1.47), BH1003 (HI= 1.07), BH1203 (HI = 1.33)	0.04-0.08	None
Chromium VI	3.4	50	<5	All BLOD	<5	All BLOD
Chromium	4.7	50	0.3-11	2- EQS BH609 (HI= 1.14), BH602 (HI=2.34)	<0.2	All BLOD
Copper	47	2000	2.5-32	None	1.1-8.3	None
Lead	12	10	0.2-2.4	None	<0.2-0.3	None
Mercury	0.5	1	0.05-0.44	None	<0.05-0.16	None
Nickel	24	20	1.3-31	1 – EQS BH1205 (HI=1.29) 1 - DWS BH1205 (HI=1.55)	2.9-69	1 – EQS BH1205 (HI=2.85) 1 - DWS BH1205 (HI=3.45)

Contaminant	EQS ug/l	DWS ug/l	Concentration Range ug/l (1st round – 28 samples)	Exceedances (HI value)	Concentration Range ug/l (2nd round – 5 samples)	Exceedances (HI value)
Selenium	-	10	0.6-53	12-DWS BH1103 (HI=1.2), BH602 (HI=2.4), BH603 (HI=5.3), BH610 (BH1.1), BH607 (HI=1.3), BH606 (HI=1.5), BH1002 (HI=4.6), BH1003 (HI=2.3), BH1004 (HI=1.4), BH904 (HI=3.5), BH1110 (HI=3.9), BH1204 (HI=1.5)	2.5-14	1 – DWS BH1003 (HI= 1.4)
Vanadium	20	-	0.2-2.2	None	<0.2-0.8	None
Zinc	40	2000	3.1-140	10- EQS BH1103 (HI=1.87), BH605 (HI=1.12), BH602 (HI= 1.6), BH610 (HI= 1.78), BH1003 (HI=1.48), BH601 (HI=1.53), BH1004 (HI=3.5), BH1110 (HI=1.34), BH1203 (HI=3), BH1205 (HI=2.75)	14-160	2 – EQS BH1103 (HI= 1.18), BH1205 (HI= 4)

The table above indicates that there are exceedances of both DWS and / or EQS of 5 out of 11 metals within the KC. All the HI values are less than 10 (only 1 is slightly above 5) indicating that the concentrations are within the same order of magnitude as the DWS / EQS criteria. In the second round of analysis, concentrations are generally recorded to be lower, however two concentrations / HI values in BH1205 (Zinc and Nickel) were higher than in the first round.

Where exceedances in both the RTD and KC have been recorded, the concentrations within the KC are generally lower e.g. Nickel BH1205, Se BH1103, BH1204 and Zn BH1103, however exceedances have been encountered in the KC and not in the RTD in the same locations.

Hence there does not appear to be a correlation with strata type.

A drawing has been produced (which is attached) which shows the spatial distribution of the exceedances within each strata. This drawing also shows the WSP borehole locations which are discussed previously. The drawing highlights that the modestly elevated contaminants (especially in the case of Selenium) are widely distributed across the Phase 2 area including outside Phase 2 within LU12.

The 2 contaminants which have most exceedances in RTD and KC are Selenium and Zinc. Below is a table which shows the average and 95% Normal UCL of the datasets in both strata for these contaminants. This has used the dataset from both first and second round. In the case of Selenium in the RTD, the highest value 1200ug/l has been removed as this is a statistical outlier and not considered to be representative. Where the result is below the LOD the value for the LOD has been used.

Table 3 Statistics for Se and Zn

Contaminant	EQS ug/l	DWS ug/l	Mean Concentration in RTD (ug/l)	95% Normal UCL in RTD (ug/l)	Mean Concentration in KC (ug/l)	95% Normal UCL in KC (ug/l)
Selenium	-	10	13.33 *	19.54 *	12.87	16.69
Zinc	40	2000	18.7	25.59	42.76	54.44

* Outlier from BH1103 removed

When the dataset is considered for Selenium, the calculated mean concentrations in both the RTD and KC are marginally above the DWS of 10ug/l and that the 95% UCL is not significantly higher. For Zinc the mean concentration in the RTD is below the EQS and the DWS. The mean concentration in the KC is slightly above the EQS of 40ug/l.

Based on the information above the following conclusions / lines of evidence can be drawn.

- No significant soil contaminant source has been identified on site. This includes with respect to Selenium which is the most widespread contaminant recorded in groundwater. The soil concentrations ranged between <1 to 11mg/kg and are all compliant with minimal risk criteria for a residential with plant uptake end use. As discussed in the RMS, the leachate testing indicates concentrations ranging from below the limit of detection to typically less than 10ug/l. Only three results exceed the DWS, and those derive from LU6 within the KC. These findings do not indicate that the near surface soil (site wide) above groundwater level is a significant source of Selenium.
- There is no discernible pattern to the spatial distribution of the elevated concentrations. The contaminants are recorded in both the RTD and KC to varying degrees and in different locations across the site. Groundwater samples taken from adjacent wells do not have similar concentrations. The data does not “point” to any one source area.
- Concentrations above the WQS have been found on LU12 to the south west which was not part of the former RAF base and is up gradient of the Phase 2 site.
- When considering the whole dataset, the mean / 95% normal UCL values for Selenium and Zinc are only slightly elevated with respect to the EQS or DWS.

Thus whether the presence of these metals in groundwater is entirely or partly natural background, or perhaps associated with, or has a contribution from, application of fertilizer[1] for agricultural/livestock purposes, the impact to groundwater is relatively slight and does not represent significant contamination.

Corrective action is not plausible nor warranted, as a source component to which remedial objectives could be applied has not been identified. Should future more detailed investigations record such a source, then remedial action would be applied to that identified source.

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[1] The source of the selenium in the groundwater is uncertain but may be related by the use of mineral fertilizers. Searching the internet, publication “*An investigation into the impacts of contaminants in mineral fertilisers*” indicates that inorganic contaminants, in particular selenium can be added to fertilisers as they are essential micronutrients for animal health/growth and are often used in the dairy industry. Such ‘selenium’ based fertilisers are designed to be soluble in water, which may account for their presence in groundwater but not in the overlying soils.

Ref: Investigation into the impacts of contaminants in mineral fertilisers, fertiliser ingredients and industrial residues and the derivation of guidelines for contaminants. Sovari J et al., 2009. CSIRO Land and Water Science Report 25-09.

RTM modelling

Modelling has been undertaken in the RMS to derive soil values which are protective of controlled waters.

Sources of Information / Parameters - A technical memo (Ref 2) was prepared as part of the drainage design. This has reviewed the site investigation data (including hydraulic conductivity testing, borehole data, groundwater levels) and derived aquifer / groundwater parameters. A Geotechnical Investigation Report (GIR) (Ref 3) was prepared to derive Geotechnical parameters for the Phase 2 area based on the investigation works undertaken. The parameters from the memo and GIR have been used within the RTM as they reflect the actual conditions on the Phase 2 site rather than literature values.

The source of the contaminants is conceptualised to be the Made Ground and the aquifer of concern is the RTD (Secondary A aquifer). The KC is designated as non-productive aquifer and therefore would not be suitable as a potable supply.

Below is a table detailing the input parameters used in for RTM detailed in the RMS.

Table 4 – Site Specific Input Parameters for RTM

Input Parameter	Value	Source / Justification
Site Specific Parameters		
Water filled soil porosity	0.224	Site Specific Porosity Calculator
Air filled soil porosity	0.103	Site Specific Porosity Calculator
Fraction of organic carbon (Made Ground)	0.00464	0.8% SOM BH1103 0.0 - 0.3 m laboratory derived and converted to foc (x 0.0058 SOM) Location of most elevated contaminants.
Moisture Content (Made Ground)	12%	BH1103 0.0 – 0.3 m (laboratory derived) Location of most elevated contaminants.
Dry Bulk Density (Made Ground)	1.87 g/cm3 (tonnes/m3)	From range in GIR
Infiltration	0.0003m/day	110mm/annum based on effective rainfall 0.0006m/d (220mm/annum) & 50% infiltration factor
Area of Contaminant Source (inorganic)	2500m	Area of large hotspot – assumed credible maximum, perhaps associated with a diffuse source
Width of Source (Inorganics)	50m	Assumed width of Inorganic hotspot
Area of Contaminant Source (Organic)	250m	Area of hotspot – assumed credible maximum
Width of Source (Organics)	5m	Assumed width of Organic hotspot associated with point source leak, such as fuel tank, or oil line.
Source Length	50m	Assumed length of hotspot.
Saturated aquifer thickness	3m	Average thickness of RTD – Technical Memo
Hydraulic Conductivity	8.64 m/day	Technical Memo
Hydraulic Gradient	0.006	3m change in water level over 500m
Bulk density of aquifer materials	1.75g/cm3	Median in range of RTD from GIR
Effective porosity of aquifer	0.26	Specific yield for a medium sand
Compliance Point Distance	50m	GP3 compliant

Sensitivity Analysis of RTM

Inorganic Contaminants

Within the modelling in the RMS, the target concentrations used are the lower of the EQS and DWS. Therefore when EQS are significantly lower than the DWS e.g. in case of Copper and Zinc, this provides a level of conservatism when considering the RTD aquifer as a potential potable source.

Selenium has the most exceedances in the RTD so this contaminant has been used in the sensitivity analysis. Below is a discussion about the parameters included and the influence on the Level 3 Remedial Target (soil leachate) derived.

As a point of reference, based on the input parameters detailed in Table 4 above, the Selenium Level 3 Remedial Target is 124 µg/l (as stated in RMS). The DWS (10ug/l) has been used for Selenium as EQS is not published.

Table 5 Sensitivity Analysis for Inorganic contaminants (Selenium)

Parameter	Discussion	Value Adopted
Changing water / air filled porosity and Bulk density of Source material	This has no effect on the remedial target derived in Level 3.	Use as in Table 4
Hydraulic Conductivity.	The hydraulic conductivity range derived for the RTD materials on site is detailed in the technical memo. The range is from 8 to 12 m/day. We have currently used the lower end of the range and therefore as a sensitivity we have increased the hydraulic conductivity to 12m/day. This increases the Level 3 Remedial Target to 168ug/l.	Use the **8.64m/day** which is currently within model. This is at the lower end of the range and allows for conservatism, i.e. results in the more stringent remedial target.
Width of contaminant source.	Changing this parameter does not have any influence on the derived remedial target.	Use as in Table 4.
Length of contaminant source in direction of groundwater flow.	Currently a length of 50m has been used. The soil sampling across the site is generally based on a 50m grid pattern and no widespread contamination has been found. Based on the sampling regime, it is unlikely that larger than 50m hotspots are present. Smaller hotspots could be present so as a sensitivity analysis a length value of 20m has been used in the model. This generates a higher, less conservative Level 3 Remedial Target of 252 µg/l.	Use 50m considered appropriate size of hotspot based on sampling and provides a reasonable degree of conservatism.
Distance to Compliance Point.	A value of 50m has been used which is compliant with GP3. With regards to Beck Brook, as previously stated this is conservative as the watercourse is at a further distance to the majority of the site. The RTD are known to decrease towards the east in the direction of Beck Brook. As a sensitivity analysis a reduce value of 10m has been used as this would be more protective of the RTD aquifer beneath the	Use the GP3 50m value as reasonably conservative assumptions have been applied elsewhere within the modelling.

Parameter	Discussion	Value Adopted
	site. The Level 3 Remedial Target would be is marginally lower at 114ug/l.	

Based on the sensitivity analysis undertaken and influence on the remedial targets observed, the soil remedial targets derived in the RMS are considered to be credible values to be used and are protective of the current and future resource potential of groundwater present within the aquifer.

Organic Contaminants

Organic contamination in the groundwater has been encountered in 3 locations in LU11 where the main workshops of the RAF base were located. One slightly elevated phenol concentration has been encountered in LU6 to the north east of the site which is likely to be associated with the former sewage works. In the 2007 WSP investigation, hydrocarbon groundwater contamination was mainly detected in LU11 which correlates to the findings of the more recent Arcadis monitoring. Other elevated samples (from across the site) detected in the WSP investigation have not been encountered in the more recent Arcadis monitoring which is consistent with the CSM that impacts are infrequent and limited in extent.

Organic soil contamination across the site is found to be in hotspot locations associated with made ground. The most exceedances were found in LU11.

As detailed in the RMS, no significant source of organic contamination, nor non-aqueous phase liquid, has been encountered within the groundwater itself. The remedial strategy is therefore to remove or treat “hotspot” soil contamination that could be acting as a continuing source of input to groundwater. This action would prevent future inputs to groundwater. It is not considered necessary to undertake remediation of the groundwater itself as once the source of impact has been treated and/or removed no further impact will be occurring.

Within the modelling in the RMS, the target concentrations used for the aliphatic and aromatic were the WHO values as presented within the 2017 published CL:AIRE document (Ref 4). This document provides guidance on assessing the risks to groundwater and surface water from hydrocarbon compounds. It was prepared by a steering group which incorporated the EA (Kirsten Johnstone), who have also given their support to the document.

The aliphatic and aromatic modelling undertaken in the RMS relates to the lighter TPH fractions (lower Equivalent Carbon (EC) fractions) where exceedances in the soil and groundwater concentrations have been recorded. It is noted that the groundwater has been screened against the criteria of 10ug/l which is the former (withdrawn) DWS, a value widely used (and accepted) to screen this contaminant. The source of the TPH is assumed to be from the soil, so in order to be protective of controlled waters soil remedial targets have been derived i.e. the concentrations that can remain in the soil and not pose a risk.

Within UK legislation and guidance there is limited groundwater criteria for TPH and the aliphatic / aromatic fractions. The Water Quality Standards (WQS) defined by the Drinking Water Inspectorate relate back to the Water Supply Regulations and Private Water Supply Regulations both published in 2016 ((these regulations are commonly called Drinking Water Standards (DWS)). Drinking Water Inspectorate do not publish values themselves.

In the WQS the are only 3 specific compounds (or group of compounds) detailed and given target DWS. These are Benzene (1.0ug/l), PAH (1.0ug/l) and Benzo(a)pyrene (0.01ug/l in Water Supply Regs only).

From the Environment Agency website, there are a number of EQS values available to be protective of surface water which are Toluene (74ug/l), Xylene (30ug/l), Benzene (10ug/l) and Naphthalene (2ug/l).

It is noted that these specific individual compounds were not found to be elevated within the groundwater during the Arcadis monitoring. The only exception is PAH compounds which were elevated in the first round of monitoring but not in the subsequent second round. This suggests that the PAH compounds are possibly not present in significant concentrations within the groundwater. Further monitoring will be undertaken to confirm this.

Below is a table extracted from the CL:AIRE publication which details the guide values for the TPH fractions. These values are considered to be protective of aquifer resources with human consumption as drinking water. Adopting these values would provide protection of the aquifer for future potential use as a resource.

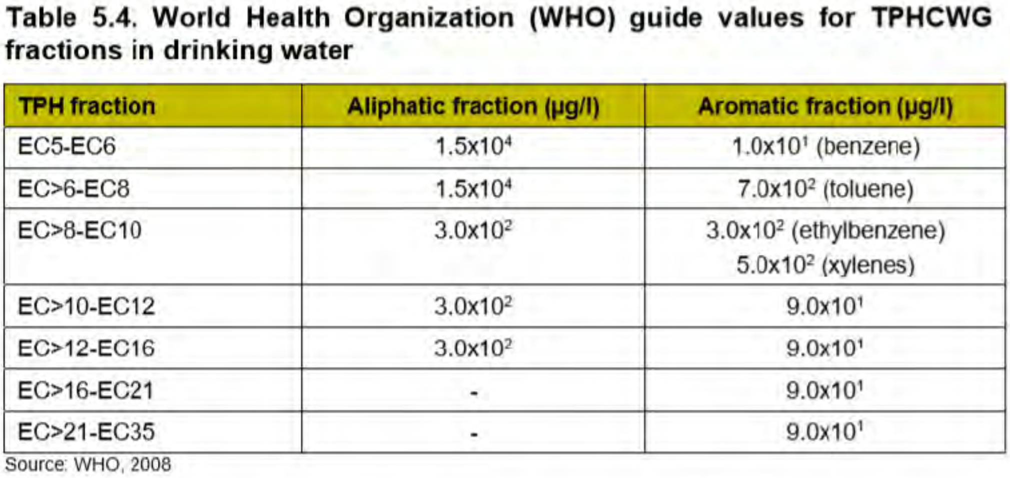


Table 5.4. World Health Organization (WHO) guide values for TPHCWG fractions in drinking water

TPH fraction	Aliphatic fraction (µg/l)	Aromatic fraction (µg/l)
EC5-EC6	1.5x10^{4}	1.0x10^{1} (benzene)
EC>6-EC8	1.5x10^{4}	7.0x10^{2} (toluene)
EC>8-EC10	3.0x10^{2}	3.0x10^{2} (ethylbenzene) 5.0x10^{2} (xylenes)
EC>10-EC12	3.0x10^{2}	9.0x10^{1}
EC>12-EC16	3.0x10^{2}	9.0x10^{1}
EC>16-EC21	-	9.0x10^{1}
EC>21-EC35	-	9.0x10^{1}

Source: WHO, 2008

For the sensitivity analysis we have used the Aromatic EC8-10 fraction to establish the effect that variation to selected parameters would make to the derived Soil Remedial Level.

Table 6 Sensitivity Analysis for Organic contaminants (Aromatic EC8-10)

Parameter	Discussion	Value Adopted
Change in Target Concentration.	In RMS a target concentration of 300ug/l has been used which is the WHO value (detailed in table above). It is noted that this is the lower guide value indicated by WHO as the value for Xylene in the same EC fraction is 500ug/l. Using the 300ug/l criteria has derived a Soil Remedial Target of 98.8mg/kg. As a comparison a target concentration of 10ug/l has been modelled keeping all other parameters the same. Reducing the target concentration to 10ug/l derives a Soil Remedial Target of 3.29mg/kg which is much significantly lower than the previously derived value. For comparison the human health criteria for this fraction for a residential end use is 34mg/kg. If the 10ug/l is split across the TPH fractions the Soil Remedial Target would be unrealistically low and would falsely identify clean natural site soils.	Both the guide values from WHO and the 10ug/l for each fraction has been modelled and values are given in Table 6 below.
Moisture Content.	The air and water filled porosity has been derived using the moisture content and bulk density in the porosity calculator. From the SI data the range of moisture content in the Made Ground is from 7.8% to 24%. Using these values in the porosity calculator, the RT changes from 98.5mg/kg to 99.2mg/kg	Use the **12%** currently adopted. This is mid-range of the MC for the MG.

Parameter	Discussion	Value Adopted
	and therefore MC does not influence the RT values significantly.	
Bulk Density.	The range of MG bulk density derived in GIR is from 1.75 to 2 Mg/m^3. Using these values in the porosity calculator, the remedial targets range from 99.1mg/kg to 98.6mg/kg.	Use the **1.87Mg/m^3** as this is within the range and bulk density does not influence the RT significantly.
Change in Fraction Organic Carbon	The model in RMS uses a calculated foc value (0.00464) from a specific Made Ground sample from BH1103. On review of the investigation data the range of foc in the Made Ground is from 0.00348 (0.6% Organic Matter) to 0.022 (3.7% Organic Matter) with the average being 0.011. Using the range of foc the derived Soil Remedial Target range from 74.6mg/kg to 461mg/kg. The Remedial Target with the average foc is 232mg/kg. This analysis indicates that the foc value has an influence on the RT derived.	Use the **0.00464 foc** derived from BH1103. This sample is from MG in the area where the hydrocarbon contamination has been used. It is at the lower end of the foc range for the MG and therefore is on the conservative side.
Hydraulic Conductivity	As detailed above the hydraulic conductivity range is from 8 to 12 m/day. We have currently used the lower end of the range and therefore as a sensitivity we have increased the hydraulic conductivity to 12m/day. This increases the Level 3 Remedial Target to 127ug/l.	Use the **8.64m/day** which is currently within model. This is at the lower end of the range and allows for conservatism.
Width of contaminant source.	The width of the contaminant source is set at 5m for a small hotspot area. If this value is increased to 10m and 25m the derived Remedial Target is reduced to 54.5mg/kg and 35.7mg/kg respectively. Increasing the width further to 50m or 100m does decrease the Remedial Target (to 34.9mg/kg) but not by such a significant value.	Where hydrocarbon contamination has been recorded, it is not widespread but recorded as hotspot, as shown in the drawing. The contamination is in LU11 and this area has been extensively investigated with no extensive source identified. Using a width of **5m** for the hotspot is deemed appropriate.
Length of contaminant source in direction of groundwater flow.	Currently a length of 50m has been used. The soil sampling across the site is generally based on a 50m grid pattern and no widespread contamination has been found with sampling points which indicates that the contamination is in discrete hotspot locations. If a larger hotspot is considered with a length of 100m, the RT reduces to 52.8mg/kg. If a smaller hotspot of length 20m the RT increases to 203mg/kg.	Use **50m** which is currently in the model. The sampling across the site is based on a 50m grid. Significant contamination has not been encountered so this value seems appropriate and allows for conservatism with in the model.
Distance to Compliance Point.	A value of 50m has been used which is compliant with GP3. With regards to Beck Brook, as previously stated this is conservative as the watercourse is at a further distance to the majority of the site.	Use the GP3 **50m** value as reasonably conservative assumptions have been applied elsewhere within the modelling.

Parameter	Discussion	Value Adopted
	The RTD are known to decrease towards the east in the direction of Beck Brook. As a sensitivity analysis a reduce value of 10m has been used as this would be more protective of the RTD aquifer beneath the site. The Level 3 Remedial Target derived is lower at 28.5mg/kg.	

Using the input parameters detailed in Table 4 but using different target concentrations (WHO and 10ug/l) the following remedial target concentrations have been derived for TPH fractions.

Table 7 Remedial Targets derived for TPH fractions and Human Health Criteria

TPH EC Fraction	Remedial target (mg/kg), with target concentrations in groundwater using WHO values	Remedial target (mg/kg) with target concentrations in groundwater using 10ug/l for each fraction	Human Health Criteria (mg/kg) for comparison with "clean" soils suitable for gardens
Aliphatic 8.-10	2000	66.6	27
Aliphatic 10-12	13,400	447	130
Aromatic 8-10	98.8	3.29	34
Aromatic 10-12	40.5	4.50	74
Aromatic 12-16	80.5	8.94	140

The Remedial Target derived using the lower target concentration of 10 µg/l are (as expected) lower than the values derived using the WHO criteria. However in the case of the aliphatic fractions, the same Remedial Targets are above the human health criteria for a residential end use.

Within the RMS, for simplicity of application within a site wide programme of works, it is currently proposed that human health criteria (residential with plant uptake criteria) are adopted to be protective of controlled waters for these organic contaminants. In additional to numerical criteria the RMS also adopts visual and olfactory evidence to define soils impacted by organic contamination as requiring remedial action. This would apply in all land use scenarios, residential, commercial, and public open space, where soils would be left exposed to leaching potential in the "as constructed" development.

In consideration of the criteria presented in Table 7 above, this pragmatic and deliverable approach will deliver protection of the aquifer as a current and future resource. No significant source terms will remain with the capacity to result in unacceptable or long term impact to groundwater.

Plans are included in the RMS and Assessment report (Ref 5) showing the locations were exceedances above residential human health criteria are present across the site. These are considered the hotspot locations which would need to be remediated to be protective of controlled waters.

Model Source Plan - Below is a model source plan showing the area modelled for organic contamination with a source area of 50m length and 5m width. This illustrates how large the site is, the number of sample locations analysed within LU11 and the small number of elevated concentrations within this area.

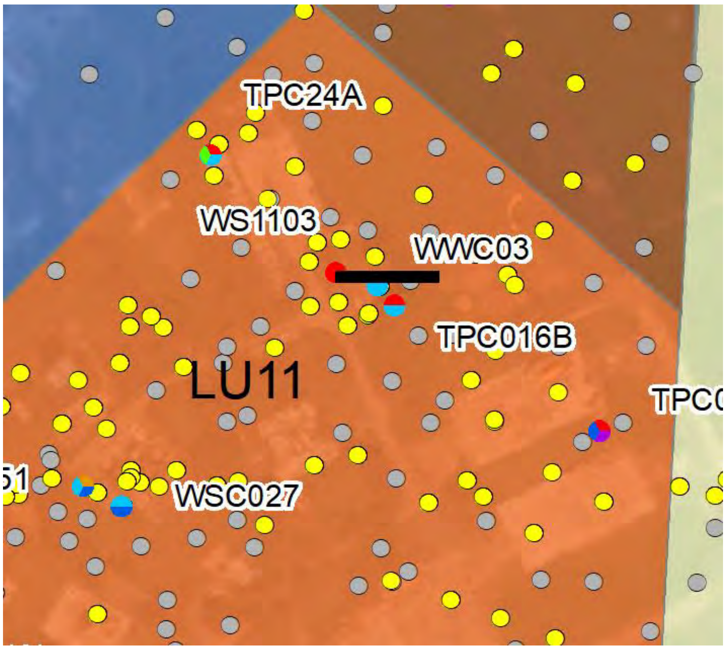


Plate 1 Model Source area for Organic contamination

Validation Plan - As mentioned in our previous responses, the Contractor commissioned for each development plot would produce a validation plan / programme. The RMS sets out the approach to the validation plan and specific remediation required within that plot.

Closure

We trust that the above information and justification of the input parameters used in the modelling provide you with the required confidence regarding the remedial strategy.

Further groundwater monitoring is programmed across the Phase 2 site which will increase the dataset of organic and inorganic contaminants. Ground investigation will be undertaken across the Phase 2 development as part of the hotspot identification and delineation works as the construction phase develops, to provide denser sampling and hotspot definition to inform remedial actions.

Ideally, we seek discharge for construction works to commence on site. As a minimum, we seek partial discharge so that the infrastructure works can commence on site. This includes the excavation of the proposed ponds on the eastern boundary, construction of the SARW and main road, the education campus and sports hub (on eastern side of site) and development parcel 1 as shown on the attached plan.

As demonstrated in the RMS and above, contamination is not widespread across this extremely large site either in the soils or groundwater. No source of the inorganic groundwater contamination has been identified on the site (soil concentrations are low with low leachability) and impact of organic contamination occurs in defined areas, with a clear origin associated with documented historic uses.

There is negligible risk that contamination, as yet undiscovered, is present of a severity that would warrant withholding planning permission to commence infrastructure and associated remedial works.

References

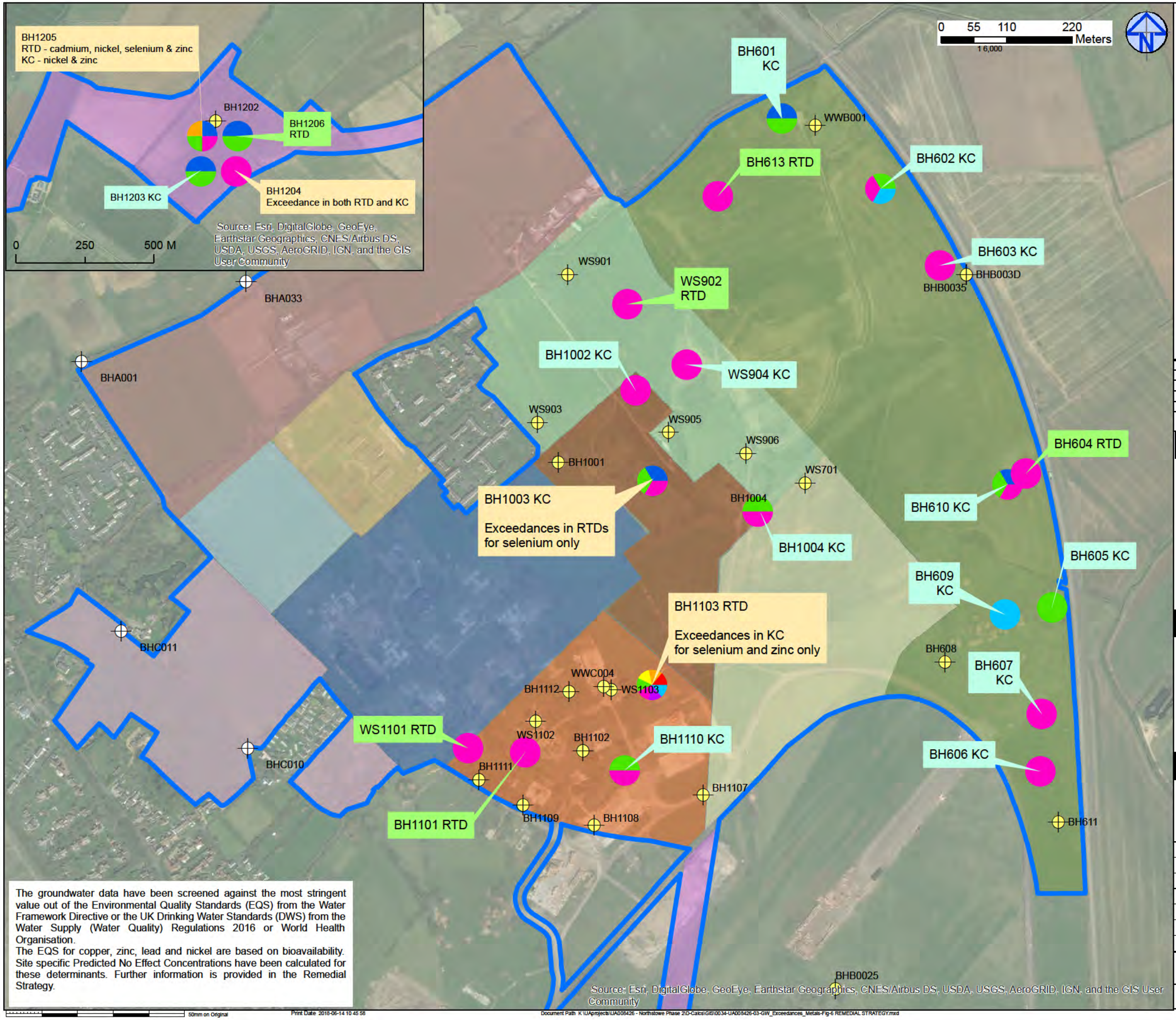
1. Arcadis Consulting (UK) Limited (2018) Remediation Method Statement for Northstowe Phase 2 Development, (NOR-ARC-P2-XXX-RP-G-0140-P01).
2. Arcadis Consulting (UK) Limited (2018) Northstowe Phase 2 Groundwater Levels (technical memo) (UA008426-ARC-XX-XX-VS-ZZ-P1-3-GWLevels)
3. Arcadis Consulting (UK) Limited (2017) Northstowe Phase 2, Geotechnical Investigation Report (NOR-ARC-P2-XXX-RP-G-0138-P01)
4. CL:AIRE (2017) Petroleum Hydrocarbons in Groundwater: Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies.
5. Arcadis Consulting (UK) Limited (2017) Northstowe Phase 2 Development Geo Environmental Assessment Report / Outline Remedial Strategy (Infrastructure) (NOR-ARC-P2-XXX-RPG-0137-P01)

Abbreviations

RMS	Remedial Method Statement	WHO	World Health Organisation
DWS	Drinking Water Standard	TPH	Total Petroleum Hydrocarbons
WQS	Water Quality Standard	RTD	River Terrace Deposits
EQS	Environmental Quality Standard	KC	Kimmeridge Clay
SARW	Southern Access Road West	LU	Land Use
CSM	Conceptual Site Model		

Drawings Attached

Drawing showing groundwater inorganic exceedances
Drawing showing groundwater organic exceedances
Plans showing the infrastructure works area



The groundwater data have been screened against the most stringent value out of the Environmental Quality Standards (EQS) from the Water Framework Directive or the UK Drinking Water Standards (DWS) from the Water Supply (Water Quality) Regulations 2016 or World Health Organisation.
The EQS for copper, zinc, lead and nickel are based on bioavailability. Site specific Predicted No Effect Concentrations have been calculated for these determinants. Further information is provided in the Remedial Strategy.

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Metals Exceedances of WQS in groundwater samples (Round 1 & 2 Groundwater Monitoring)

- 🟥 Arsenic
- 🟦 Cadmium
- 🟧 Nickel
- 🟩 Copper
- 🟨 Lead
- 🟩 Zinc
- 🟪 Selenium
- 🟪 Vanadium
- 🟦 Chromium
- ⊕ Boreholes monitored by Arcadis but no exceedances identified
- ⊕ Boreholes monitored by WSP but no exceedances identified

RTD	Exceedances of WQS in River Terrace Deposits
KC	Exceedances of WQS in Kimmeridge Clay
RTD/KC	Exceedances of WQS in Kimmeridge Clay and River Terrace Deposits

▬ Phase 2 Planning Boundary

REV	Date	Description	Drawn	Check	Approv
03	14/06/2018	Issue 03	FW	AP	GF
02	06/02/2018	Issue 02	FW	AP	GF
01	15/01/2018	FIRST ISSUE	FW	AP	GF

Client

HOMES AND
COMMUNITIES
AGENCY

PROJECT:
NORTHSTOWE
REMEDIAL
STRATEGY

Site
Northstowe
Cambridgeshire

Client
Fry Building
2 Marsham Street
London
SW1P 4DF

ARCADIS Design & Consultancy for natural and built assets

Registered office:
Arcadis House
34 York Way
London
N1 9AB

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TITLE

LOCATION OF METALS EXCEEDANCES IN GROUNDWATER SAMPLES (ARCADIS ROUND 1 & 2)

Designed	[redacted]	Date 14/06/2018	Signed
Drawn	[redacted]	Date 14/06/2018	Signed
Checked	[redacted]	Date 14/06/2018	Signed
Approved	[redacted]	Date 14/06/2018	Signed
Scale	See Layout	Datum:	AOD
Original Size	A3	Grid:	OS
Suitability Code	S2	Project Number:	UA008426

Suitability Description:
PRELIMINARY
NOT FOR CONSTRUCTION

Drawing Number: Figure 6
Revision: 03