



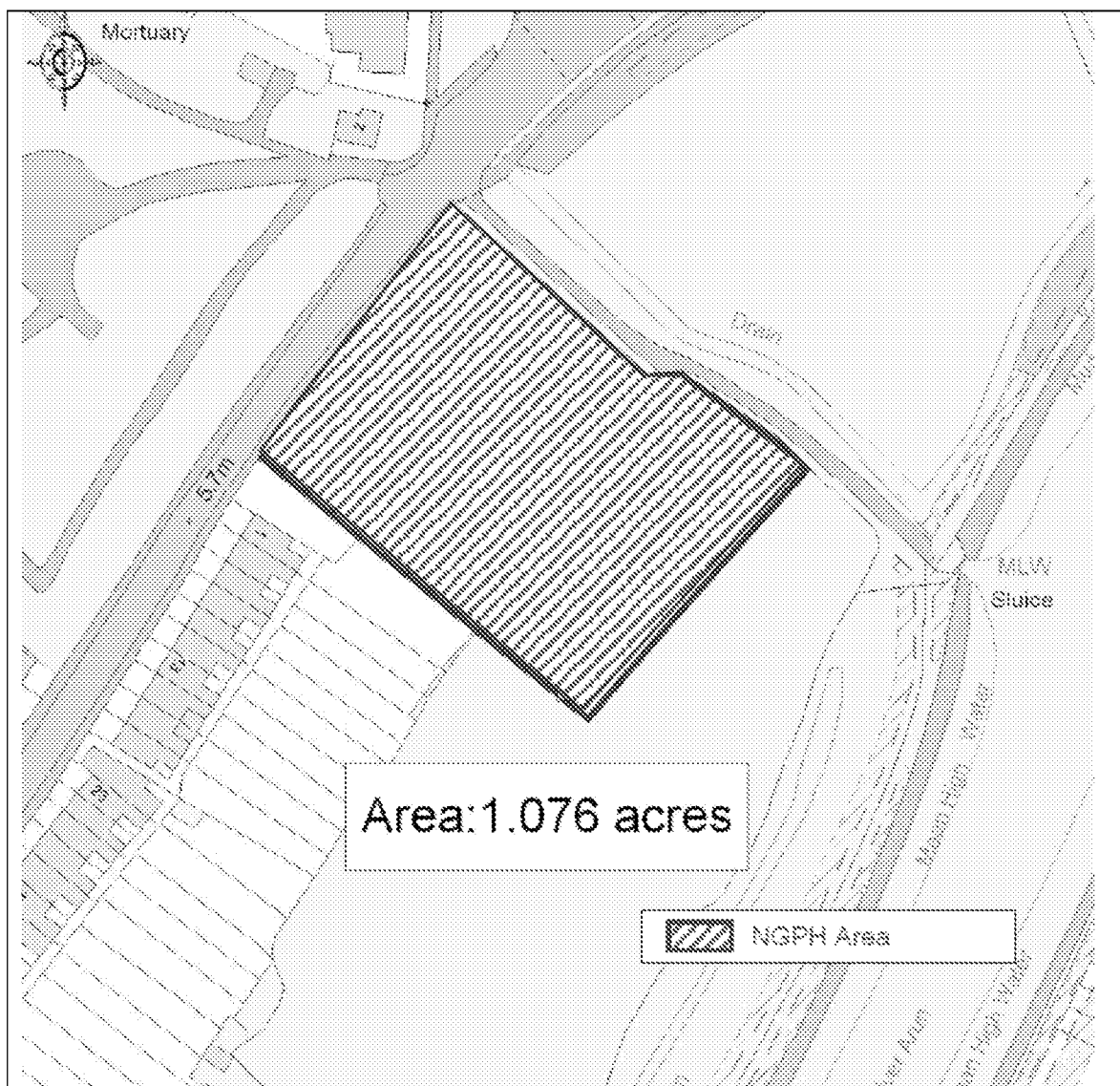
FORD ROAD, ARUNDEL  
NATIONAL GRID PROPERTY  
HOLDINGS

R1820/21/5045

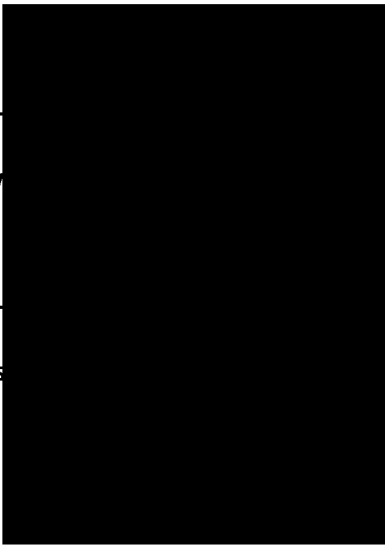
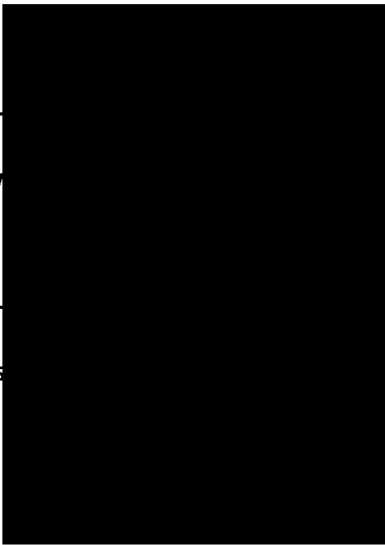
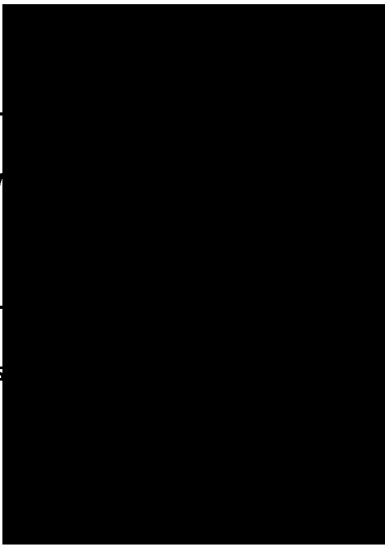
REMEDIATION IMPLEMENTATION  
AND VERIFICATION PLAN

REV 2

MARCH 2021



|                                  |                                                                       |                               |                                     |
|----------------------------------|-----------------------------------------------------------------------|-------------------------------|-------------------------------------|
| Site Address:                    | Ford Road, Arundel,<br>West Sussex BN18<br>9DX                        | NGP Document<br>Tracking Code |                                     |
| Report Title                     | Ford Road, Arundel – Remediation Implementation and Verification Plan |                               |                                     |
| Report Type:                     | Contamination                                                         | Retention Period              |                                     |
| Site Code                        | 2551                                                                  | Author (Company)              | Celtic Technologies                 |
| Report Date                      | March 2021                                                            | Factual/Interpretative        | Interpretative                      |
| Draft / Final                    | Final                                                                 | H & S File?                   | No                                  |
| Work Stage                       | Remediation                                                           |                               |                                     |
|                                  |                                                                       |                               |                                     |
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| Access Permitted                 | NGP Land<br>Regeneration Team                                         | NGP Contact                   | Gareth Taylor<br>eAOC Nicola Carver |

|                               |                                                                                                        |
|-------------------------------|--------------------------------------------------------------------------------------------------------|
| <b>Client:</b>                | <b>National Grid Property Holdings</b>                                                                 |
| <b>Report Number:</b>         | <b>R1820/21/5045</b>                                                                                   |
| <b>Report Title:</b>          | <b>Ford Road, Arundel<br/>Remediation Implementation Plan</b>                                          |
| <b>Report Status:</b>         | <b>Rev 2</b>                                                                                           |
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## 1.0 INTRODUCTION AND OBJECTIVES

Celtic EnGlobe (Celtic) has been commissioned by National Grid Property Holdings (NGPH) to design and implement ground contamination remediation works at the former Gasworks Site, Ford Road, Arundel, West Sussex (the 'site'). The location of the site is shown on Drawing D1820/2410/A1, Appendix A.

The site has a long history of town gas production and various investigations carried out to date have generally identified widespread low-level gasworks contamination within the Made Ground. Further deeper contamination encountered within the Alluvium and Chalk has been found to generally be focused in the north eastern area of site, likely associated with the high frequency of gasworks structures in this area of site.

As a result of the site historical use, a legacy of soil and groundwater contamination is present along with remnant in-ground foundations/obstructions associated with former process buildings/plant. A phase of risk mitigation design has been undertaken and remediation is required to address residual contamination sources, with the primary remediation objective being to render the site suitable for 'Commercial Open Storage' use.

Supplementary investigation has recently been undertaken by Celtic to further assess the degree and extent of contamination and to capture additional data to develop and refine the conceptual site model and undertake detailed quantitative risk assessment (DQRA) for human health and controlled water receptors (*controlled waters as defined by Section 104 of the Water Resources Act 1991*).

Based on the above the risk mitigation and remediation works approach broadly comprises:

- Undertake DQRA to provide supporting technical evidence to assist with remedial design, the re-use of site-won materials and remedial validation/verification works;
- Undertake remediation options appraisal, site-specific trials and develop a remediation strategy;
- Consult and agree the remediation strategy with key stakeholders and regulatory bodies;
- Implement the remediation works on-site in line with agreed plans; and
- Collate data and validate the remediation works within a Verification Report.

In delivering these works, Celtic further understands key issues for NGPH include:

- Ensuring that the works are managed sensitively, with respect to potential nuisance to local residents by mitigating any potential impact of noise, vibration, dust and odour resulting from remediation activities;
- Gaining regulatory approval to the proposed Remediation Implementation Plan and timely 'sign-off' of the Verification Report; and
- Working collaboratively with NGPH and the Construction Phase team of Consultants to achieve the above objectives.

### 1.1 Outlines Roles and Responsibilities

Specific roles of the Remediation Contractor delivery are described as follows:

**Client – NGPH**

**Environmental Consultant – Atkins Ltd**

**Remediation Contractor – Celtic Technologies Ltd**

**Implementation Manager (IM)**

The IM has overall responsibility to deliver this project in compliance with the approved Remediation Strategy. It is their responsibility to liaise between all parties involved in the project and coordinate their actions and duties. Statutory and site owner liaison will also be the responsibility of the IM.

**Site Manager (SM)**

The SM is responsible for day to day implementation on site in accordance with this document. The SM is responsible for briefing all Operatives regarding the requirements of the Remediation Strategy.

**Technical Manager (TM)**

The TM is responsible for managing any technical queries and interfacing with client, the client supervisor and site staff.

**Technically Competent Manager (TCM)**

The TCM (WAMITAB qualified) is responsible for the maintenance of the Environmental (Mobile Treatment License) Permit and all necessary environmental controls therein.

**Health & Safety Officer (HS)**

The HS will maintain overall responsibility for H&S issues on site. He will ensure safe systems of work are adopted and will visit frequently to audit site activities against the H&S plan.

**CDM Advisor (CDM-A)**

The CDM-A will be responsible for advising and assisting the client on all H&S aspects of works, notifying the HSE and facilitating good communication between the client, designers and contractors

**Temporary Works Coordinator (TC)**

The TC will be responsible for all design aspect of the temporary works.

## **2.0 SITE INFORMATION AND BACKGROUND**

### **2.1 Site Details**

The site is situated approximately 40 m north west of the River Arun. The site is owned by NGPH, is currently unoccupied and comprises secure vacant land. The site has a postal address of Former Holder Station, Ford Road, Arundel BN18 9DX and is located at approximate National Grid Reference 501308E, 106749N.

The site entrance can be accessed from Ford Road off an access track which runs along the north-eastern site boundary. The site is then accessed from the east through a secure pair of metal access gates. The site is an approximately rectangular shaped area of land covering approximately 0.44 hectares (Ha).

An electricity sub-station is located on the north-eastern site boundary adjacent to the site entrance and concrete slab foundations are in the northern and eastern corners of the site. No other above ground structures or buildings are present on the site.

The existing site surface comprises approximately 15% tarmac, with the remainder comprising of either gravel, wood chippings or bare earth. The site is generally level at an approximate elevation of 3 m above ordnance datum (mAOD). The site is generally level with surrounding land, except for residential properties to the west of the site which are raised above the site level by approximately 2 m.

Site location and surrounding areas are presented in Appendix A of this report (Drawing D1820/5045/A1).

### **2.2 Neighbouring Land**

The site is surrounded by a combination of residential properties, grazing land and a cemetery as follows:

- South-west: Residential houses with gardens;
- South-east: Private grazing land with the River Arun behind;
- North-west: Ford Road, beyond which is a cemetery; and
- North-east: an access track leading off Ford Road, beyond which is a small surface water drain (which runs towards the River Arun via a sluice gate), and private grazing land.

### **2.3 Historical Development**

The site was operated as a gasworks from at least 1840, expanding in the west circa 1899, and in the south and south east in circa 1937. It is understood that the gasworks continued operation until the mid-20<sup>th</sup> century.

The historical features are denoted on Drawing D1820/5045/A2, Appendix A.

In summary, the historical gasworks structures comprised up to 4 No. gasholders, a Retort House, including chimney/ tank, a Boiler House, condensers, governor compound, liquor/ tar tanks, and associated offices and stores.

The gasworks structures were widespread across the site, however, they are concentrated in the north eastern corner, where two of the four former gasholders were located, along with the retort house, including chimney and the liquor/ tar tank.

## **2.4 Previous Investigations at the Site**

The following reports (redacted to remove interpretative information) have been provided to Celtic by NGPH and these reports contain background information detailing ground conditions, hydrogeology, contamination testing and previous phases of works:

- British Gas Environmental Liability Report, Report ref. E5347/LR860.NL/gp, Atkins April 1994;
- Environmental Assessment Site Investigation, Final Factual Report, Report ref. A71430/GTG.20000078/R002rev1/December2000, Atkins December 2000;
- Environmental Groundwater Monitoring Letter Report, Ford Road, Arundel, Mentor No. 015162, Report ref. A71430/GTG.2000078/Arundel/R004rev0/mg, Atkins July 2001;
- Ford Road, Arundel (Site No. 2551) Site Investigation Report, Report ref. 5104362/GTG.20100923/Arundel2011/R001v0, Atkins October 2011;
- Detailed Quantitative Risk Assessment, Report Ref. 5104362/GTG.20100923/2012/R002v1, Atkins October 2012; and
- Site Information, Report Ref. 5156428/R001/V4, Atkins July 2019.

The recent Celtic investigation works are detailed in:

- Supplementary Site Investigation, Factual Report, Ford Road, Arundel, Report ref. R1820/20/5043, Celtic Technologies Ltd. December 2020.

The locations of intrusive investigation trial pits/trenches, boreholes, vapour monitoring positions etc. are shown on Drawing D1820/5045/A3, Appendix A.

## **2.5 Geology, Hydrogeology and Hydrology**

### **2.5.1 Geology**

The geology in the vicinity of the site is identified on the British Geological Survey (BGS) Sheet 317, Chichester and is understood to comprise the Spetisbury Chalk Member overlain by 2 to 5 m of clay, silt, sand and gravel alluvium (Raised Marine Deposits) associated with the River Arun.

A summary of the geology beneath the site, based upon published geology and the results of previous intrusive investigations, is provided in Table 1.

**Table 1 – Summary of Published and Previously Identified Geology**

| Stratum                                                                                                                                                                              | Description                                                                                                                                                                                                   | Proven thickness<br>range<br>m | Additional Detail                                                                                                                                       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| Made Ground                                                                                                                                                                          | Variable across the site, but generally comprised firm, sandy, gravelly clay and fine to medium, gravelly, clayey sand with frequent brick, chalk and flint gravels and fragments of clinker, coal and metal. | 0.0 – 2.7                      | Greatest depths in the areas that were recorded to be formerly occupied by gas holders and pipes. BH202 potentially records Made Ground to 7.2 m depth* |
| Alluvium                                                                                                                                                                             | Stiff, silty, very gravelly clay or clayey gravel.                                                                                                                                                            | 0.7 – 5.1                      | Locally absent                                                                                                                                          |
| Chalk (Spetisbury Chalk)                                                                                                                                                             | Structureless fine chalk composed of gravels and chalk cobbles in a soft off white/grey clay matrix.                                                                                                          | >3.8 – >7.6                    | Base not proven                                                                                                                                         |
| *Note: A reported depth of Made Ground at BH202 (7.2 m) is very thick compared to the rest of the site, although the borehole log notes that ‘possibly becoming natural below 4.5 m. |                                                                                                                                                                                                               |                                |                                                                                                                                                         |

The encountered thickness of the Raised Marine Deposits is relatively thin, locally absent, in the northern site area, with the Chalk relatively close to the surface. This is consistent with the published geology that shows the Raised Marine Deposits thinning to the west.

The Spetisbury Chalk Member is the uppermost Chalk unit; this means the site is underlain by a significant thickness of Chalk strata (i.e. the whole Chalk sequence believed to be 250 m to 300 m thick). The shallow Chalk site is described *Structureless fine chalk composed of gravels and chalk cobbles in a soft off-white/grey clay matrix*. Silts/clays of the Lambeth Group outcrop to the south and west (where they overlay the Chalk)

Figure C1 in Appendix C shows the inferred contours for the base of the made ground, with Figure C2 in Appendix C showing the inferred contours for the top of the Chalk.

## 2.5.2 Hydrogeology

The hydrogeology of the area and site is detailed in Appendix C and summary information is provided below. The summary includes discussion of groundwater/tidal and ditch monitoring by Celtic and Atkins.

The site has a very shallow groundwater that is typically encountered at depths in the range 1 m to 3 m below ground level (mbgl); the water table has been well documented by the site investigation works to be heavily influenced by tidal fluctuations in the River Arun (discussed further below).

The Raised Marine Deposits are classified by the EA as a Secondary A Superficial Aquifer, with the Chalk classified as a Principal Bedrock Aquifer; the site does not lie within any EA defined groundwater source protection zones. The closest licensed groundwater abstraction is approximately 0.75 km to the northwest; this abstraction appears to be associated with a trout fish farm and is likely to be drawing groundwater from the Chalk.

The Chalk aquifer is locally partly confined by the Raised Marine Deposits, which are generally clayey, but is unconfined to the west and northwest of the site. Further south the Lambeth strata confine the chalk. The drainage ditches to the south of the site are likely to be partly perched on the Raised Marine

Deposits and are probably hydraulically isolated from the Chalk aquifer, although some of the ditches do show some tidal fluctuation.

The net direction of near surface groundwater flow below the site is easterly with shallow groundwater discharging to the River Arun; groundwater enters the site from the west/northwest. Surface infiltration down through the site will contribute some additional flow to the groundwater exiting the site eastwards towards the Arun.

The land to the south/east that is 'downstream' of the site in terms groundwater flow is of limited width (<50 m) and given the proximity to the Arun and the tidal nature of the groundwater, it is not credible that the superficial/chalk aquifers in that area would ever be exploited for potable use. As such, it is considered that the River Arun represents the critical controlled waters receptor, rather than the shallow groundwater Chalk aquifer.

However, the simple conceptual model discussed above is significantly complicated by the effect of tidal fluctuations on groundwater levels, as illustrated within the Figures in Appendix C.

Groundwater levels have been recently measured by Celtic with data loggers. The data is summarised within Figures C5 to C8 in Appendix C, along with the anticipated tidal cycle in the River Arun.

The data shows a tidal range in the River Arun during that period of ~2.7 m, with the maximum fluctuation in the boreholes of ~1.8 m in BH105 located in the easternmost tip of the site. The amplitude of the fluctuation decreases westwards and is ~1 m on the western site margin, as shown in Figure C9 in Appendix C. As expected, the high/low groundwater levels in the boreholes lag behind the Arun tidal cycle with the lag generally increasing further from the river.

The significant and constant fluctuation in groundwater levels makes estimation of the net groundwater flow regime difficult. The average borehole water levels from the recent Celtic data logging provides a relatively shallow average hydraulic gradient to the east of about 0.0025.

### 2.5.3 Hydrology

There is a 300 mm diameter surface water drain bisecting the site running from the south west to the north east. The drain is approximately 1.3 m deep and there are two access chamber on-site. The drain discharges to a surface water ditch to the north east of the site. The drainage ditch is located approximately 5 m from the north eastern site boundary and flows in a south easterly direction discharging into the River Arun via a sluice gate.

The River Arun is located approximately 40 m south east of the site. The river is tidally influenced in the local area and generally flows in a southerly direction discharging to the English Channel at Littlehampton ~6 km south of the site (note: river flow can be reversed when the tide is rising). The river is tidal for more than 20 km from the coast. The tidal channel is ~35 m wide at the location of the site. The River Arun at Arundel is within the 'Arun Lower' EA operational catchment and is classified as a '*transitional waterbody*' at Arundel, which reflects its estuarine tidal nature.

The land to the west of Ford Road is at a higher elevation and ground levels then rise steadily to the northwest. The low-level plain along the Arun west bank is drained by a series of ditches. One of these flows southeast close to the north eastern site boundary and this ditch has a 'sluice gate' where

it discharges into the River Arun. Another ditch (flowing south), originates between the site and the river and joins a network of other ditches to the south of the site. The ditch to the north may have been a natural stream (based on OS contour arrangement); the ditches to the south are probably mainly artificial features.

Away from the river, a network of generally southerly flowing streams drain the land to the south and east of the site where the Lambeth Group and London Clay strata overlie the Chalk; further north, where the Chalk outcrops (or is present below superficial head deposits), there are few surface water features.

The long-term water level of the Arun at Arundel Queen St Bridge (0.7 km upstream) is generally between -0.3 and 2.5 mAOD. The more recent water level data for the Arun (last 12 months) is between -0.4 and 3.2 mAOD. The highest identified recorded level in Arundel is 3.7 mAOD (December 2013).

Much of the southern/western site areas are currently within an EA defined Flood Zone 3 for planning purposes, with a limited area in Flood Zone 2 and the remainder in Flood Zone 1 (viewed online January 2021 at <https://flood-map-for-planning.service.gov.uk>). There is a flood defence berm along the western Arun bank (marked on the flood mapping).

## **2.6 Identified Contamination**

The various investigations carried out to date have generally identified widespread low-level gasworks contamination within the Made Ground, with more elevated concentrations recorded towards the north and east of the site associated with the identified former gasworks features. Further deeper contamination encountered within the Alluvium and Chalk has also been found to be focused in the north eastern area of site where sources of non aqueous phase liquid (NAPL) may be present. A summary of the identified contamination is provided below with further discussion of specific contaminants and substances of concern described within Section 3.2.3:

- Inorganic and organic contaminated shallow soils across the whole of the site; and
- Hydrocarbon / NAPL impacted soils and perched water in the gasworks process areas in and around former structures (mainly in the north and east, but with localised impact in other areas of the site).



### 3.0 DETAILED QUANTITATIVE RISK ASSESSMENT (DQRA)

#### 3.1 Risk Assessment Approach

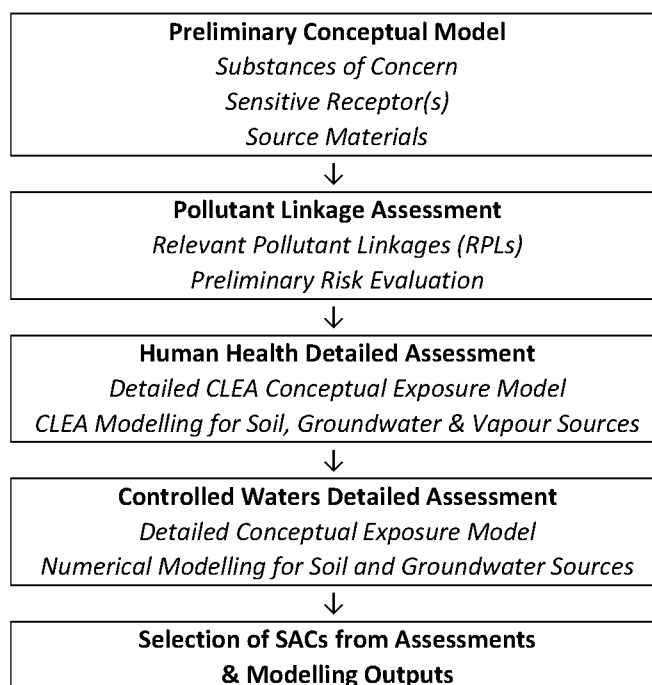
The DQRA has been undertaken to consider the identified residual soil and groundwater contamination at the site. The purpose of the DQRA is to provide supporting technical evidence to assist with remedial design, the reuse of site-won materials and remedial validation/verification works.

The DQRA considers a 'Commercial Open Storage' for the site with existing site levels maintained. The open storage use will include a validated cover layer that will break the majority of potential pollutant linkages to human health.

The DQRA provides a preliminary risk assessment and human health & controlled waters risk assessments with associated quantitative modelling. The assessments and modelling outputs have been used as the technical basis for selecting site assessment criteria (SAC). The detailed assessments are presented in Appendix B and C, with the adopted SACs for the remedial works presented in Section 3.4.

The site has been recently investigated by Celtic and previously investigated by others (see following section) where provided by NGPH, the previous investigation information has been utilised in the assessment.

The DQRA has adopted the following overall process:



The assessment has been prepared under the umbrella framework laid out in non-statutory UK guidance provided by the online gov.uk 'Land Contamination: Risk Management' (LCRM) guidance along with R&D66:2008 ('Guidance for the safe development of housing on land affected by contamination', which is broadly applicable across all land affected by contamination). The LCRM

guidance is based on the now withdrawn CLR-11 '*Model Procedures for the Management of Land Contamination*'; the EA have stated that the scope, framework and purpose of the LCRM guidance remains the same as CLR-11.

The human health assessment has been undertaken within the 2009 DEFRA/Environment Agency (EA) SR3 CLEA (contaminated land exposure model) framework. The 2009 CLEA methodology has been amended to take into account relevant conceptual model updates outlined in documents associated with the 2015 LQM/CIEH Suitable for Use Levels (S4ULs), the 2014 DEFRA funded Category 4 Screening Levels (C4SL) and DEFRA CLEA model v1.071 with associated handbook Version 1.05. Additional human health guidance for organic vapour risks has been drawn from BS8485, CIRIA C665/C682/C716/C735/C748, and the CIEH Ground Gas Handbook.

The controlled waters assessment has been undertaken within the 2006 Environment Agency (EA) Remedial Target Methodology (RTM), with additional guidance provided by the EA/DEFRA Groundwater Protection collection (previously covered by GP-3) at [www.gov.uk/government/collections/groundwater-protection](http://www.gov.uk/government/collections/groundwater-protection).

For controlled waters, numerical catchment and predicted contaminant modelling (under pumping/non-pumping conditions) has been undertaken using a SEEP/W flow model and a CTRAN/W model calibrated using available catchment data and site-specific groundwater data. Simulations were then undertaken using a calibrated bespoke Excel model that uses the RTM algorithms provided in the EA Remedial Targets Worksheet V3.2 and associated guidance. Additional site-specific attenuation modelling was also undertaken to account for the relatively large effects of tidal fluctuations on the site groundwater levels.

The DQRA should only be used by competent persons for its intended purpose and it is beyond the scope of this report to present a detailed summary of the risk assessment methodologies, supporting documents and their technical basis. This report was finalised in March 2021 and should be read in the light of any subsequent changes in legislation, statutory requirements, statutory & non-statutory guidance, relevant research and industry practices.

Technical and literature DQRA references are provided in Appendix B and C.

## **3.2 Preliminary Conceptual Model**

### **3.2.1 Overview**

The preliminary conceptual model considers the primary plausible pathways (relevant pollutant linkages, RPLs) through which contaminants could impact upon sensitive human health and controlled waters. This is assessed via a pollutant linkage assessment that considers the following components:

**Receptors** The identification of sensitive human health and controlled waters receptors.

**Sources** The identification of contamination source media.

**Pathways** The presence of migration or exposure pathways linking contamination source media to receptors.

### 3.2.2 Sensitive Receptors

The assessment considers the following potentially sensitive receptors for the site:

#### Human Health: Future Site Use

- Future employees/users on the commercial open storage use for the site.
- This land use can be considered using a modified standard CLEA commercial land use without buildings.

#### Human Health: Existing Adjacent Use

- Occupiers of adjacent/nearby residential land.
- There are three residential dwellings in close proximity (<15 m) from the northern part of the southwestern boundary (Nos. 1, 3, & 5 California Terrace on Ford Road). These dwellings are part of a long terrace row of two storey brick dwellings that date back to the late 1800s. Other dwellings in the terrace are >15 m from the site boundary.
- There is a detached 'gatehouse' dwelling approximately 25 m to the north (north of Ford Road).
- The bordering sensitive land use is considered consistent with the standard CLEA residential land use.
- *There is no residential land currently down groundwater gradient of the site.*

#### Controlled Waters

- Chalk Principal Bedrock Aquifer (Groundwater)
- River Arun (Surface Water)

The critical human receptor for the commercial use is a female worker aged 16 to 65 years old (CLEA age class AC17). The critical human receptor for the bordering residential land use is a female child, with the duration of the exposure from the ages of 0 to 6 years old (CLEA age classes AC 1-6). The critical off-site buildings are to the west comprise two storey terrace dwellings.

The critical controlled waters receptor is the River Arun. To assess risks to the river, the detailed assessment considers a primary point of compliance (POC) in groundwater downgradient of a modelled localised on-site source. The adopted POC is before dilution in the receiving surface water; an additional groundwater attenuation factor has been considered in the modelling to account for dilution by tidal fluctuations.

### 3.2.3 Substances of Concern

The substances of concern considered by the assessment are detailed in Table 2 and Table 3.

The provision of engineering interventions (principally a validated cover layer) on the remediated site for the open storage use means that the DQRA only needs to consider sufficiently volatile hydrocarbon substances for human health.

**Table 2 - Human Health Substances of Concern**

| Potential Substances of Concern                                                                        | Substances of Concern<br><i>Sufficiently Volatile</i>                                                                               | Not Substances of Concern<br><i>Insufficiently Volatile or below detection</i>   |
|--------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Total petroleum hydrocarbons<br>Risk banded TPH fractions                                              | Aliphatic C5-C16 fractions<br>Aromatic C8-C21 fractions<br>(see below)                                                              | <i>Non-Volatile</i><br>Aliphatic C16-C35 fractions<br>Aromatic C21-C35 fractions |
| Benzene, toluene<br>ethylbenzene, xylenes (BTEX)                                                       | BTEX<br><i>Benzene is solely aromatic C5-6<br/>Toluene is solely aromatic C7-8<br/>Ethylbenzene/ Xylenes also in Aromatic C8-10</i> | -                                                                                |
| 16-PAHs                                                                                                | Naphthalene                                                                                                                         | Remaining PAHs                                                                   |
| Arsenic, cadmium, chromium species, copper, inorganic lead, inorganic mercury, nickel, selenium & zinc | -                                                                                                                                   | All non-volatile                                                                 |
| Easily liberatable cyanide and total cyanide                                                           | -                                                                                                                                   | Non-volatile                                                                     |
| ACMs                                                                                                   | -                                                                                                                                   | Non-volatile                                                                     |
| Notes: The rationale with respect to sufficiently volatility is summarised in Appendix B.              |                                                                                                                                     |                                                                                  |

**Table 3 - Controlled Waters Substances of Concern**

| Potential Substances of Concern                                                                                                                                                                         | Adopted Substances of Concern                                                                                                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Risk banded TPH fractions                                                                                                                                                                               | Aliphatic C8-44 fractions (see below)<br>Aromatic C8-C44 fractions see below)                                                    |
| BTEX                                                                                                                                                                                                    | BTEX<br><i>Benzene is solely aromatic C5-6; Toluene is solely aromatic C7-8<br/>Ethylbenzene/ Xylenes also in Aromatic C8-10</i> |
| PAHs                                                                                                                                                                                                    | Priority 16-PAHs                                                                                                                 |
| Phenol                                                                                                                                                                                                  | Phenol                                                                                                                           |
| Metals                                                                                                                                                                                                  | Arsenic, cadmium, chromium species, copper, inorganic lead<br>inorganic mercury, nickel, selenium & zinc                         |
| Cyanides                                                                                                                                                                                                | Easily liberatable cyanide and total cyanide                                                                                     |
| Ammonium                                                                                                                                                                                                | Ammonium                                                                                                                         |
| Notes: Aliphatic fractions less than C12 have not been detected in groundwater. Fractions greater than C21 are unlikely to be significant with respect to controlled waters due to very low solubility. |                                                                                                                                  |

Benzene and toluene have their own aromatic C5-C7 & C7-C8 fractions (i.e. there are no other substances in these fractions); ethylbenzene & xylene isomers, 16-PAHs and others will also be detected within the aromatic C8 to C12+ fractions. It is important to ensure that potential 'double accounting' issues are considered when interpreting TPH/BTEX/PAH results.

### 3.2.4 Source Materials

The remediated site will predominately comprise permeable hardstanding (verified cover layer) and remnant areas of impermeable hardstanding. The bordering residential land includes the usual building cover, hardstandings (roads, pavements, parking, hard landscaping) and soft garden & landscaping areas.

To meet the project objectives, the following source media are considered by the DQRA:

#### **Human Health - Onsite Commercial Open Storage**

- Soils beneath hard/soft cover (Soil)
- Shallow groundwater (GW)

#### **Human Health - Off-site Residential**

- Soils beneath hard/soft cover along a Boundary Strip (Soil-B)
- Shallow groundwater along the Boundary Strip (GW-B)
- Soil vapour in unsaturated zone soils along the Boundary Strip (Soil-VapB)

#### **Controlled Waters**

- Soils beneath hard/soft cover (Soil)
- Soil pore water/leachate (Soil-L)
- Shallow Groundwater (GW)

The verified cover layer materials, combined with areas of impermeable hardstanding, are not contamination sources. This means that there will be no contamination sources at surface, so there will be no active soil ingestion, dermal contact, dust inhalation pathways or vapour inhalation pathways associated with these surface cover materials.

The Boundary Strip represents a 5 m wide zone along the part of the north western boundary to ensure that vapours generated by soil and groundwater sources in close proximity to this boundary are considered by the DQRA via lateral vapour migration through the unsaturated zone. Given that the existing off-site residential receptors are lateral to groundwater flow, it is implausible for sources further within the site to pose a lateral migration vapour risk to adjacent properties (this is in keeping with the findings of CIRIA 682). The residential property ~25 m from the north western boundary is also not considered a plausible receptor as the building is up-gradient of the site and vapours would have to diffuse under the main road and then into the property.

Residual NAPL sources (at the water table and within the unsaturated/saturated zones) are modelled as being part of the adopted source media. The site data sets also reflect the presence of minor residual NAPL sources.

### **3.2.5 Human Health Exposure Pathways**

#### **On-site Commercial**

The following primary plausible on-site exposure pathways for the source media (Soil/GW) are considered by the assessment:

- Outdoor inhalation of organic vapours generated by sufficiently volatile substances via vapour diffusion to surface.

- *There will be no contamination sources at surface, so there will be no soil ingestion, dermal contact or dust inhalation pathways.*

### Off-site Residential

The following primary plausible on-site exposure pathways for the source media (Soil-B, Soil-VapB & GW-B) are considered by the assessment:

- Indoor inhalation of organic vapours generated by sufficiently volatile substances via lateral vapour migration and vapour intrusion into immediately adjacent terrace buildings.
- Outdoor inhalation of organic vapours generated by sufficiently volatile TPH/BTEX/PAH substances via vapour diffusion to surface.
- *There will be no contamination sources at surface, so there will be no dust inhalation pathways.*

For human health, the primary source of organic vapours is considered to be soil and groundwater (which includes residual NAPL sources). For on-site receptors, the sources are directly under the site. For off-site receptors to the west, the conceptual model assumes that soil VOC vapours can diffuse laterally through the unsaturated from on-site sources within the Boundary Strip.

For completeness, separate soil vapour sources have been modelled for the adjacent residential use to allow future comparison against any soil vapour data set should the need arise.

### 3.2.6 Controlled Waters Migration Pathways

The following primary migration pathways for the source media (GW-onsite, Soil, pore-water) are considered by the assessment:

- Soil leaching to groundwater
- Lateral groundwater advection in the Chalk aquifer to a POCs in Groundwater
  - *For risks to the River Arun*
  - *For risks to the Chalk aquifer*
  - *POC within the Chalk aquifer*
  - *Considers additional attenuation by tidal effects on the groundwater*
  - *Ignores dilution in the receiving River Arun*

### 3.3 Pollutant Linkage Assessment

A pollutant linkage assessment has been undertaken to characterise the RPLs and includes the following elements:

#### **Critical Receptor → Sources → Relevant Human Health & RTM Pollutant Linkages**

Table 4 and Table 5 summarise the sources, relevant RPLs, preliminary risk evaluation/assessment (PRA) and detailed risk assessment approach to address the identified RPLs. The human health and controlled waters substances of concern are detailed in Table and Table. The risk classification matrix is provided in Appendix B.

The human health RPLs relate to vapour inhalation pathways and the human health assessment will consider these sufficiently volatile substances of concern. The rationale with respect to sufficiently volatility is summarised in Appendix B.

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**Table 4 - Human Health RPLs and Preliminary Risk Evaluation**

| Source Materials<br>Averaging Areas     | Human Health RPLs                            | Consequence                              | Likelihood | Preliminary Risk<br>Evaluation | Detailed Risk Assessment Approach   |
|-----------------------------------------|----------------------------------------------|------------------------------------------|------------|--------------------------------|-------------------------------------|
| On-Site Uses<br>Workers & Residents     |                                              |                                          |            |                                |                                     |
| Verified Cover                          | Surface cover<br>(Soils and hardstand)       | Not Required: Not a contamination source |            |                                |                                     |
| Soil                                    | Outdoor vapour inhalation                    | Mild                                     | Low        | Low Risk                       | CLEA Soil & Vapour Source Modelling |
| Groundwater GW                          |                                              | Mild                                     | Low        | Low Risk                       | CLEA Groundwater Source Modelling   |
| Residential Use<br>Immediately Adjacent |                                              |                                          |            |                                |                                     |
| Verified Cover                          | Surface cover<br>(Soils and hardstand)       | Not Required: Not a contamination source |            |                                |                                     |
| Boundary Zone<br>Soil-B & Soil-VapB     | Indoor vapour inhalation (lateral migration) | Medium                                   | Likely     | Moderate Risk                  | CLEA Soil & Vapour Source Modelling |
| Boundary Zone<br>Groundwater GW-B       | Outdoor vapour inhalation                    | Medium                                   | Likely     | Moderate Risk                  | CLEA Groundwater Source Modelling   |

**Table 5 - Controlled Waters RPLs and Preliminary Risk Evaluation**

| Source Materials<br>Averaging Areas   | Controlled Waters RPLs                                   | Consequence                              | Likelihood | Preliminary Risk<br>Evaluation | Detailed Risk Assessment Approach |
|---------------------------------------|----------------------------------------------------------|------------------------------------------|------------|--------------------------------|-----------------------------------|
| Verified Cover                        | Surface cover<br>(Soils and hardstand)                   | Not Required: Not a contamination source |            |                                |                                   |
| Soil / Soil Leachate<br>Soil & Soil-L | Soil Leaching to groundwater<br>Lateral groundwater flow | Medium                                   | Likely     | Moderate Risk                  | Calculate SOIL/SOIL-L SACs        |
| Groundwater GW                        | Lateral groundwater flow                                 | Medium                                   | Likely     | Moderate Risk                  | Calculate GW SACs                 |



### 3.4 Adopted SACS

The adopted soil and soil leachate SACS for human health and controlled waters are summarised in Tables 6 and 7. The full detailed assessments are provided in Appendix B and C.

The SAC values have been rounded as appropriate, with values in provided brackets where they are above theoretical saturation limits. The SACS have been selected using professional judgement based on the range of available modelling outputs and meeting the project objectives. Many of the SACS are lower than the modelling outputs to provide a further level of risk protection.

The TPH fraction SACS targets have also been simplified, whilst still ensuring they are risk protective in respect to the complex array of modelling TPH fraction outputs provided by the detailed assessments.

Any final adopted criteria based on the SAC should be used carefully when comparing with site data and their use should appropriately take into account adopted sampling strategies. Such criteria are typically compared to average or representative source/averaging-area concentrations, rather than maximum or isolated elevated/peak levels. If representative concentrations are significantly above an adopted criterion, then this would normally trigger further appropriate actions, such as additional investigation/verification, risk assessment or further/continuing remediation/mitigation.

In addition, many of the SACS for groundwater are based on modelling outputs that are above saturation/solubility limits; as such these must be applied with care/caution as the SACS may overestimate the risk posed to controlled waters and/or human health. Care should also be taken to ensure the laboratory results are representative of 'dissolved phase'.

**Table 6 – Soil SAC in mg/kg**

| Substance                  | Site Wide<br>Unsaturated Zone Soils | Boundary Strip (Area 2)<br>Unsaturated Zone Soils |
|----------------------------|-------------------------------------|---------------------------------------------------|
| Sum $\Sigma$ TPH           | 5,000                               | 1,000                                             |
| TPH Aliphatic C5-C6        | Via $\Sigma$ TPH                    | 650                                               |
| TPH Aliphatics C8-C10      |                                     | 440                                               |
| TPH Aromatics C8-C10       |                                     | 500                                               |
| Benzene                    | 2,900                               | 4                                                 |
| Sum $\Sigma$ TEX           | Via $\Sigma$ TPH                    | 500                                               |
| Phenols                    | 1,200                               | 1,200                                             |
| Sum $\Sigma$ 16-PAH        | 5,000                               | 1,000                                             |
| Benzo[a]pyrene             | 92                                  | 92                                                |
| Fluoranthene               | 400                                 | 400                                               |
| Indeno[123-cd]pyrene       | 680                                 | 680                                               |
| Naphthalene                | 4,600                               | 260                                               |
| Easily Liberatable Cyanide | 250                                 | 250                                               |

**Table 7 – Leachate SAC in mg/l**

| Substance                  | Site Wide Porewater Criteria |
|----------------------------|------------------------------|
| TPH Aliphatics C8-C10      | 2,500 <sup>(1)</sup>         |
| TPH Aliphatics C10-C12     | 4,300 <sup>(1)</sup>         |
| TPH Aromatic C8-C10        | 2,000 <sup>(1)</sup>         |
| TPH Aromatic C10-C12       | 2,000 <sup>(1)</sup>         |
| TPH Aromatic C12-C16       | 2,000 <sup>(1)</sup>         |
| TPH Aromatic C16-C21       | 2,000 <sup>(1)</sup>         |
| TPH Aromatic C21-C35       | 2,400 <sup>(1)</sup>         |
| TPH Aromatic C35-C44       | 2,400 <sup>(1)</sup>         |
| Benzene                    | 2,000 <sup>(1)</sup>         |
| Phenols                    | 1,600                        |
| Benzo[b]fluoranthene       | 6.9 <sup>(1)</sup>           |
| Benzo[k]fluoranthene       | 7.4 <sup>(1)</sup>           |
| Benzo[ghi]perylene         | 0.74 <sup>(1)</sup>          |
| Benzo[a]pyrene             | 0.041 <sup>(1)</sup>         |
| Fluoranthene               | 1.3 <sup>(1)</sup>           |
| Indeno[123-cd]pyrene       | 0.45 <sup>(1)</sup>          |
| Naphthalene                | 400 <sup>(1)</sup>           |
| Anthracene                 | 21 <sup>(1)</sup>            |
| Easily Liberatable Cyanide | 200                          |

(1) above theoretical saturation limits

## 4.0 REMEDIATION OPTIONS APPRAISAL

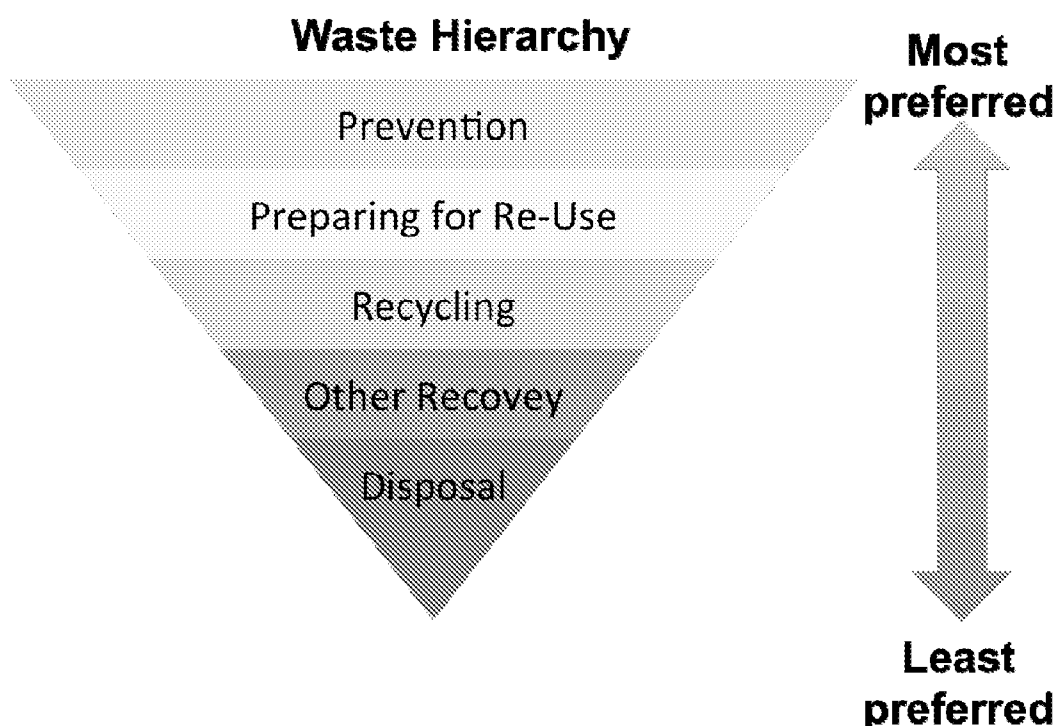
### 4.1 General Approach

Celtic's general approach for the site is broadly to ensure:

- That any soils, structures or areas on site containing tar or free phase NAPL are removed or remediated appropriately;
- That any soils containing contaminant concentrations that represent a risk to human health and controlled waters receptors are removed; and
- That uncertainty with respect to extents of contamination and undiscovered sources are reduced significantly.

Based on the assessment of the potential sources, pathways and receptor linkages, as discussed in Section 3, Celtic has determined the Best Practicable Technique (BPT) for the remediation of the Former Arundel Gasworks to render the site suitable for a commercial open storage end use. The BPT assessment has considered the Options Appraisal in Table 10 and the Waste Hierarchy.

The Waste Hierarchy forms part of the Waste Framework Directive and is a tool used in the evaluation processes that protect the environment alongside resource energy consumption from most favourable to least favourable actions. The hierarchy establishes preferred program priorities based on sustainability. Therefore, sustainable waste management cannot be solved only with technical end-of-pipe solutions and an integrated approach is necessary. A diagram showing the five stages of the Waste Hierarchy is shown within Graphic 1.



Graphic 1 – The 5 steps of the Waste Hierarchy

## 4.2 Remedial Options Appraisal

Celtic have carried out an Options Appraisal. This considered a range of remedial options selected based on Celtic's remediation experience and the constraints and objectives specific to the site as outlined. The considered techniques are viable within the UK market and regulatory framework.

The assessment of Remedial Options is provided in Table 8:

**Table 8 – Assessment of Remedial Options – Options Appraisal**

| Remedial Option                                                                 | Comments on Feasibility                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Confirmation of Feasibility            |
|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|
| Physical sorting                                                                | <ul style="list-style-type: none"> <li>Technique would be a feasible component of any site excavation works to remove unsuitable materials from the ground.</li> <li>Re-use of site-won materials in accordance with a CL:AIRE Code of Practice Materials Management Plan would reduce volumes of materials being deemed waste and requiring off-site disposal.</li> </ul>                                                                                                                                                                                                                                              | Feasible, but not standalone technique |
| Capping                                                                         | <ul style="list-style-type: none"> <li>Capping of site is not a suitable option as a standalone technique, given the current conceptual understanding. Capping is, however, a suitable option to mitigate risks from inhalation/ direct contact with dusts that could potentially blow off-site to neighbouring residents.</li> </ul>                                                                                                                                                                                                                                                                                   | Feasible, but not standalone technique |
| Product Recovery                                                                | <ul style="list-style-type: none"> <li>Product recovery may be a feasible option should sufficient volumes be encountered. The current understanding is that the presence of NAPL is associated with former gasworks structures and in pockets within the natural strata. Tidal waters underlying the site will complicate a recovery system, but it remains a feasible option for isolated areas.</li> </ul>                                                                                                                                                                                                           | Feasible, but not standalone technique |
| Excavation and Off-site Disposal at Landfill                                    | <ul style="list-style-type: none"> <li>Based on the identification of NAPL and spent oxide impacted soils, excavation and off-site disposal to landfill is a potential requirement if other remediation techniques not suitable.</li> <li>Taking into account sustainability, disposal to landfill, whilst feasible, shall, where possible, be limited. Emphasis will be on site segregation, treatment and re-use supported by appropriate verification.</li> </ul>                                                                                                                                                    | Feasible, but not standalone technique |
| In-situ or Ex-situ Treatments (e.g. Bio-physical, HVE, SVE, total pumping etc.) | <ul style="list-style-type: none"> <li>In-situ treatment of soil contamination is unlikely to be feasible given the known ground conditions, contaminant distribution and presence of below ground infrastructure.</li> <li>Ex-situ treatment options are available for soils but are likely to be limited to physical sorting followed by stabilisation /solidification for this site.</li> <li>Ex-situ treatment for encountered groundwater during excavation works would be feasible and a requirement in order to allow dewatering and subsequent disposal of treated waters under a discharge consent.</li> </ul> | Feasible, but not standalone technique |

| Remedial Option                                                                                | Comments on Feasibility                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Confirmation of Feasibility            |
|------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|
| Stabilisation/Solidification (S/S)                                                             | <ul style="list-style-type: none"> <li>• A tried and tested non-destructive technique.</li> <li>• Based on site area, distribution of contaminants and required site usage for open space storage, stabilisation would be ideally suited to this site and would minimise the need for offsite disposal.</li> <li>• Inexpensive compared to offsite disposal.</li> </ul>                                                                                                                                                                                                           | Feasible, but not standalone technique |
| Excavation and Off-site Recycling of Contaminated Materials at a Soil Treatment Facility (STF) | <ul style="list-style-type: none"> <li>• Short timescale.</li> <li>• Very high cost due to location and presence of trace asbestos, however, volume of material may be managed by physical sorting.</li> <li>• Not a completely effective standalone method for areas with NAPL/perched water.</li> <li>• Could be replaced by geotechnically sound imported granular fill at expense.</li> <li>• Recycling at an STF allows materials to be beneficially reused.</li> <li>• Low technical risks.</li> <li>• Provides greatest flexibility for future use of the site.</li> </ul> | Feasible, but not standalone technique |

Celtic's BPT to render the Former Arundel Gasworks suitable for an open storage end use is as follows:

1. *Prevention* – Risk mitigation through detailed Site Investigation and Risk Assessment. This has further defined the S-P-R linkages and subsequent areas for remediation that pose a definite future unacceptable risk;
2. *Preparing for Re-Use* – The areas that are found to categorically pose a future unacceptable risk will be subjected to remediation. Based on the Options Appraisal in Table 8 and the Waste Hierarchy, the remediation will be staged as followed:
  - Excavation of impacted soils followed by physical sorting, segregation and subsequent categorisation:
    - i. Suitable for re-use – no further treatment required;
    - ii. Suitable for treatment on-site – further ex-situ treatment required prior to re-use on-site (using stabilisation/solidification techniques);
    - iii. Unsuitable for treatment on-site – further treatment required but not suitable for on-site treatment, acceptable to a soil treatment facility; and
    - iv. Unsuitable for treatment on-site – treatment required but not suitable for on-site treatment, unacceptable to a soil treatment facility therefore requiring disposal to landfill.
  - Perched groundwater/ NAPL recovery:
    - i. Perched groundwater/ NAPL separation;
    - ii. Perched groundwater treatment on-site and disposal to foul sewer under consent;
    - iii. Disposal of NAPL to a waste transfer/ recycling facility.

Hydrocarbon impacted soils, trace ACMs and heavy metals can be treated using stabilisation/ solidification (S/S) techniques and used as backfill with suitable capping layer placed above.

For any significant inorganic contamination or ACMs encountered, the BPT is to excavate the impacted soils and dispose these off-site to an appropriately licensed facility such as STF or landfill. A proportion of this inorganic contaminated material may be treated using S/S techniques with the materials mixed with other contaminated materials for treatment. However; in general, S/S treatment with soils with high sulphur/ sulphate content is inappropriate due to the potential for breakdown of the treated soils.

Groundwater including perched waters and NAPL within the ground and historic infrastructure will need to be removed prior to backfill. A water treatment system of sufficient capacity to separate NAPL, reduce suspended solids, and treat water to agreed discharge criteria, will be required to facilitate the ground remediation works.

Excavations shall be backfilled to existing levels (minus capping layer thickness) with suitably verified site won soils and crushed site won hard materials meeting the remedial criteria. This legitimate re-use of materials under a materials management plan will prevent the materials being deemed a waste and subsequently outside of waste regulations, should the CL:aire Definition of Waste: Development Industry Code of Practice (DoWCoP) be implemented.

Following treatment activities, all areas will be backfilled with suitable imported or site won verified materials and capped using 300 mm of imported Granular capping layer (Class 1B/6F2 or similar) aggregate, overlying a geotextile alert barrier. Areas to be covered will be levelled, however, it is not intended that site levels will be reduced to incorporate the cover layer.

#### **4.3 Stabilisation and Solidification**

The options appraisal has identified that the most viable option for contaminated soil treatment at the site is excavation and treatment by stabilisation/ solidification (S/S) and on-site reuse. This method is considered appropriate based on the nature of contamination and considers identified site constraints and a drive for increased sustainability and material re-use across the project.

Based on the identification of stabilisation as a suitable, the following are additional benefits of the technique identified by Celtic based on extensive experience of stabilisation at former gasworks sites:

- A tried and tested technique, in which Celtic EnGlobe have a significant amount of experience on gasworks sites;
- Reduced site works programme;
- The works will be durable in the long-term (Celtic have completed previous investigation of stabilised materials to demonstrate continuing improvement of conditions in excess of 10 years);
- Cost-effective;
- Low technical risks;
- Ability to better control dust and odour generation during works through controlled designated working areas;

- Ability to deal with moderate volume and contamination variations within the same programme; and
- The technique is more sustainable than off-site disposal remedial options.

#### **4.4 Site Excavation / Turnover (Made Ground)**

A programme of site excavation and turnover is deemed to be the most appropriate technique to identify, segregate and treat contamination and minimise uncertainty of significant residual sources. Excavations should be extended to the base of Made Ground where feasible to prove natural strata. Where Made Ground extends below the saturated zone (below high tide groundwater level), verification sampling and surveying will be required to record residual ground conditions.

Where identified during site turnover works, soils containing the identified contaminants of concern will be segregated and subject to treatment using the methods detailed above.

In the event materials are excavated that may not be suitable for treatment, such as grossly contaminated infrastructure, fibrous asbestos or other high-risk substances, these shall be further segregated and stored so as to minimise nuisance emissions and potential risks to human health and the wider environment. Assessment of segregated materials, appropriate storage, classification and disposal of off-site under appropriate duty of care documentation will be required. Records of these materials will be maintained on-site in the waste register and included within the verification report.

Excavation works will need to remove obstructions to access contamination. Where existing obstructions and concrete slabs, such as those identified as former gasholder bases are encountered, further investigation sampling and testing may be required to verify that significant residual contamination is not present. Redundant pipes, conduits and potential contaminant pathways will be removed to minimise the potential for migration of residual contaminants. Topographic survey records of obstructions and features left in-situ shall be prepared and included within the final verification report.

#### **4.5 Constraints to the Remediation Works**

The site is known to have a number of constraints that are required to be considered and mitigated in order to allow proposed remedial activities to be undertaken. Identified constraints to remediation activities are as follows:

- Live electrical sub-station adjacent to the site entrance on the north eastern boundary and associated HC and LV cables, which run from this station along the access track to Ford Road;
- Surface water drain, which runs south west to north east, bisecting the southern half of the site; and
- The River Arun being a tidal waterway and located some 40 m to the south of the site boundary. Groundwater levels across the site are highly influenced by daily tidal variations.

## **5.0 REMEDIATION STRATEGY**

### **5.1 Preliminary Works**

The following preliminary works will be undertaken as required:

- Regulatory engagement and agreement of this Remediation Strategy;
- Submission of Planning Application for remedial works;
- Discussion with utility providers to agree any protection/mitigation requirements to protect existing services and agree a suitable foul sewer discharge consent (if required);
- EA Permit deployment to cover remedial treatment activities; and
- Completion of materials management plan (MMP) in compliance with CL:aire Definition of Waste: Development Industry Code of Practice (DoWCoP) and declaration by Qualified Person.

### **5.2 Initial Site Set-up / Compound and Pedestrian Access Routes**

In order to complete the works, Celtic will establish a site compound and welfare area to include office, canteen, decontamination unit / changing room, toilets, stores and parking. In addition, it is proposed that the site compound includes provision for nightly plant and equipment storage with lighting and includes CCTV coverage supported by out of hours surveillance and call out response.

The site compound will be situated on existing tarmac hardstand in the eastern corner of the site, with access via the existing gates off the access track which leads from Ford Road. Traffic management during the project will be controlled and the access gates will be kept closed when not in use. Given the preferred remediation strategy of stabilisation combined with off-site disposal, site traffic will be minimised and focussed around mobilisation/demobilisation activities together with limited truck movements for off-site disposal.

Segregated pedestrian routes using fencing and signage will be established to keep traffic and pedestrians separated. Suitable site signage and a location contact plan will be established at the site access gate and will be communicated to all stakeholders and visitors.

Dependant on discussions with SSE regarding the existing electrical substation and cables crossing below the access gates, there may need to be a temporary access gate constructed further along the access track. This would require the temporary removal of a section of chainlink fencing, which would be reinstated on completion of remedial works. A temporary gate would be installed to allow heavier vehicular access to the site without the need to cross and potentially damage existing electrical cables.

### **5.3 Proposed Remedial Areas**

In consideration of the investigation findings, development of the conceptual model, risk assessment and remedial options, the site has been notionally divided into four areas where specific measures and requirements have been identified. Performance specification is also described for the site's commercial open storage use.



Due to the onsite drainage Celtic have allowed for a 1 m easement on either side of the drain. No excavation works will be undertaken within this easement area in order to minimise the risk of damage and potential contaminant migration to the surface water drain. The existing investigation data does not indicate that there will be significant contamination within this 1 m easement; however, assessment of the materials will be made at this 1 m stand-off point and should significant contamination be encountered then this material will be removed and contingency measures applied to protect the surface water drain. A designated vehicular crossing point will be required to cross this easement and to facilitate this, a geotextile membrane and 0.5 m thickness of cover material (Class 1B/6F2 or similar) will be laid to provide a suitable running layer for vehicular access. Remediation areas shall be subject to groundworks, as follows and illustrated on Drawing D1820/5045/A4, Appendix A:

### **5.3.1 Area 1 (Orange Hatch) – Approximately 1,200 m<sup>2</sup>**

Previous observations have shown little in the way of any significant contamination in shallow soils above the saturated zone. Made ground is generally 0.6 m thick increasing to up to 1.5 m thick in the former gas governor area.

It is proposed that within this area the existing tarmac is left in situ, predominantly in the north and east of this area, as previous investigation works have recorded little in the way of contamination. This existing hardstand will then serve to accommodate the welfare compound and staff parking area. The area formerly accommodating the gas governor, (feature no. 19) within the central region of this area shall be reduced to surrounding ground level with the Made Ground being turned over and subject to assessment, sampling and testing. Below ground cast iron pipework and concrete foundations are known to be present in this area and will be removed as part of the groundworks. The existing roots and stumps of previously cleared vegetation in the south west of this area shall be removed during the Made Ground turnover. The existing concrete gasholder base (feature no. 15) will remain in place. Following the removal of any encountered contamination and processing of Made Ground, the area shall be generally levelled out and a 300 mm thickness of granular capping layer (Class 1B/6F2 or similar) placed on top of a geotextile layer to form a capping layer. This area will then be used to store and process hardstand materials generated from elsewhere on-site. The area may also be used to undertake stabilisation works, given its distance from sensitive human health receptors.

A summary of the works is outlined below:

- Remove vegetation stumps and roots for off-site disposal;
- Remove shingle/ hardcore surface for subsequent reuse where appropriate;
- Made Ground excavation and turnover with segregation of materials requiring treatment or unsuitable materials (initial excavation extent to be based on visual excavation inspection by Celtic engineer);
- Composite excavation extent verification sample collection for UKAS approved laboratory analysis and comparison to remedial criteria;
- Topographic survey completion of excavation extents and verification sample locations;
- Photographic record completion of excavation works for presentation in final verification report;
- Backfill area and level to surrounding ground levels (minus 300 mm capping layer);

- Cover levelled area with geotextile and a minimum of 300 mm of imported granular capping layer (Class 1B/6F2 or similar); and
- Undertake CBR tests.

### **5.3.2 Area 2 (Yellow Hatch) – Approximately 220 m<sup>2</sup>**

Area 2 represents a 5 m wide strip along the south west boundary of the site, adjacent to the neighbouring residential property. Due to the adjacent property being 1-2 m higher than the current site level and the depth of Made Ground extending to approximately 1 m, it is proposed to maintain a 2-3 m standoff, between the boundary and the excavation face, in order to maintain a safe 45 degree angle of repose. Sampling of the residual soils along the excavation face will be undertaken to assess the material left in place as a result of this standoff. Area 2 will be subject to excavation and turnover of Made Ground materials to a depth of approximately 1 m bgl with care undertaken not to undermine the site boundary. The Made Ground being turned over shall be subject to assessment, sampling and testing with contamination and unsuitable materials being segregated as appropriate. Materials being replaced and backfilled within this area will be subject to the more stringent criteria within Table 5, due to its proximity to the neighbouring residential property. The backfilled material will be covered with a 300 mm thickness of granular capping layer (Class 1B/6F2 or similar) placed on top of a geotextile layer to form a capping layer up to the existing ground level.

A summary of the works is outlined below:

- Remove vegetation stumps and roots for off-site disposal;
- Remove shingle/ hardcore surface for subsequent reuse, where appropriate;
- Excavation works to extend to a safe angle of repose along the southwestern boundary with additional verification sampling undertaken to assess materials along this boundary;
- Excavation of Area 2 to a depth of approximately 1 m bgl in Made Ground;
- Made Ground excavation and turnover with segregation of materials requiring treatment or unsuitable materials (initial excavation extent to be based on visual excavation inspection by Celtic engineer);
- Composite excavation extent verification sample collection for UKAS approved laboratory analysis and comparison to remedial criteria;
- Topographic survey completion of excavation extents and verification sample locations;
- Photographic record completion of excavation works for presentation in final verification report;
- Backfill area and level to surrounding ground levels (minus 300 mm capping layer);
- Cover levelled area with geotextile and a minimum of 300 mm of imported granular capping layer (Class 1B/6F2 or similar); and
- Undertake CBR tests.

### **5.3.3 Area 3 (Green Hatch) – Approximately 1,000 m<sup>2</sup>**

Area 3 has been identified as containing a shallow infilled gasholder base (feature no. 8) and sporadic contamination primarily in the top 1.2 m associated with Made Ground.

It is proposed that this area will be subject to excavation and turnover to approximately 1.2 m bgl, although any gross contamination identified deeper but above the saturated zone will also be subject to removal. Existing structures such as the gasholder base will be left in situ unless removal of any encountered structure is necessary to access contamination. Made Ground found to be contaminated will be segregated and subject to stabilisation treatment. Unsuitable materials will be segregated and subject to off-site disposal. Similarly to Area 2, verification sampling will be undertaken along the extent of excavation along the north western as the adjacent land is some 1-2 m higher than the site level.

On completion of turnover and verification, the area will be levelled, backfilled and completed with a minimum 300 mm layer of imported granular capping layer (Class 1B/6F2 or similar). Geotextile will provide segregation between the backfilled material and the 300 mm capping layer.

A summary of the works is outlined below:

- Remove vegetation stumps and roots for off-site disposal;
- Remove shingle/ hardcore surface for subsequent reuse, where appropriate;
- Excavation of Area 3 to a depth of approximately 1.2 m bgl in Made Ground (excavation extent initially based on visual excavation inspection by Celtic engineer);
- Additional localised excavations where gross contamination is identified deeper than 1.2 m bgl and above groundwater;
- Segregation of materials requiring treatment or unsuitable materials and transport to designated treatment or storage area;
- Composite excavation extent verification sample collection for UKAS approved laboratory analysis and comparison to remedial criteria;
- Topographic survey completion of excavation extents and verification sample locations;
- Photographic record completion of excavation extent for presentation in final verification report;
- Backfill area and level to surrounding ground levels (minus 300 mm capping layer);
- Cover levelled area with geotextile and a minimum of 300 mm of imported granular capping layer (Class 1B/6F2 or similar) aggregate; and
- Undertake CBR tests.

#### **5.3.4 Area 4 (Red Hatch) – Approximately 1,300 m<sup>2</sup>**

Area 4, representing the north east of the site, has been identified as having the most gasworks infrastructure and contamination within the shallow Made Ground and also deeper into the chalk. It is expected that the majority of the contamination will be consistent with the current investigative findings and may be expected throughout the Made Ground and into natural soils primarily up to approximately 2 m bgl.

It is proposed that this area will be subject to excavation and turnover to at least 1.2 m bgl and likely extending to at least 2 m or deeper in areas of gross contamination and where required to remove NAPL impact.

Existing structures may be left in situ but will be removed where necessary to access gross contamination that exceeds remedial criteria. Perched waters and NAPL impact will be removed to progress excavation works and verify excavation extents. Made Ground found to be contaminated will be segregated and subject to stabilisation treatment. Unsuitable materials will be segregated and subject to off-site disposal.

Similarly to Areas 2 & 3, verification sampling will be undertaken along the extent of excavations along the boundaries.

On completion of excavation, the area will be backfilled, compacted and completed with a minimum 300 mm layer of imported granular capping layer (Class 1B/6F2 or similar) aggregate to form the necessary capping layer. Geotextile will provide segregation between the compacted backfilled material and the capping layer.

A summary of the works is outlined below:

- Remove vegetation stumps and roots for off-site disposal;
- Remove shingle/hardcore surface for later re-use where appropriate;
- Excavation of Area 4 to a depth of at least 1.2 m bgl and, where locally required, extending to 2 m bgl or deeper (excavation extent initially based on visual excavation inspection by Celtic engineer);
- Segregation of materials requiring treatment and unsuitable materials and transport to designated treatment or storage area;
- Perched water recovery and treatment prior to discharge under consent;
- Composite excavation extent verification sample collection for UKAS approved laboratory analysis and comparison to remedial criteria;
- Topographic survey completion of excavation extents and verification sample locations;
- Photographic record completion of excavation extent for presentation in final verification report;
- Backfill area and level to surrounding ground levels (minus 300 mm capping layer);
- Cover levelled area with geotextile and a minimum of 300 mm of imported granular capping layer (Class 1B/6F2 or similar) aggregate; and
- Undertake CBR tests.

### **5.3.5 Estimated Volumes of Materials**

Based on the proposed remedial areas and anticipated depths of excavation, the volumes expected to be excavated, treated, re-used, imported and disposed off-site are presented within Table 9. These volumes will be subject to on-site survey and measurement during the remediation works and final volumes will be included within the verification report.

**Table 9 – Estimated Volumes of Materials**

| Source               | Estimated Volume (m <sup>3</sup> ) |
|----------------------|------------------------------------|
| Area 1 Excavation    | 1,000                              |
| Area 2 Excavation    | 200                                |
| Area 3 Excavation    | 1,300                              |
| Area 4 Excavation    | 2,400                              |
| Hardstand materials  | 250                                |
| S/S Treatment Volume | 1,600                              |
| Re-use on site       | 4,700                              |
| Disposal off-site    | 200                                |
| Capping Layer        | 1,100                              |

## **5.4 Proposed Remedial Works**

### **5.4.1 General**

In general, the works will involve the excavation, sentencing of materials for immediate re-use, treatment and re-use or unsuitable for re-use. The segregation, processing, sampling and testing of the materials will then follow, with a materials management and tracking system in place to record and verify material re-use. Materials deemed unsuitable for re-use will be appropriately segregated, stockpiled and subject to waste classification prior to off-site disposal. The proposed remediation areas are identified on drawing D1820/5045/A4, Appendix A and excavation areas shall be further divided into cells to ease the traceability. Nominal cells of 10 m x 10 m will be used or adjusted as appropriate to suit the area of excavation.

Cell excavation shall be turned into the adjoining cell in order to allow works to progress. The phasing of excavation shall be confirmed on a daily basis during the site briefing. In the event placed materials within a grid cell do not meet the specification following excavation then Celtic would return to the grid and re-excavate and or re-sample.

Any encountered NAPL and spent oxide contamination shall be taken for treatment via stabilisation if appropriate. Should materials be encountered that are not suitable for treatment then these would be subject to off-site disposal. All information related to this would be recorded within the site waste register and materials management plan respectively.

The proposed remedial works can be generally summarised as follows:

- Excavation and segregation for treatment of impacted made ground and grossly contaminated shallow alluvium and chalk where practicable containing mobile NAPL, within the north and east of the site;
- Treatment of site excavated contaminated soils using S/S techniques by the physical mixing of soils with additives as determined by the pilot trial and discussed below. The proposed works will create a monolith of treated material to be reused within excavations and where practicable from their original sources;

- Any NAPL encountered during excavation works to be removed either via the solid phase excavation works or using a combination of electric or diesel driven mechanical pumps and/or where practicable via top/bottom loading pumps installed within existing boreholes on-site;
- Excavation, turnover and compaction of all areas outside of those identified for specific remediation activities on a 10 m x 10 m grid such as to identify, segregate and treat any additional contamination encountered; and
- Verification sampling for chemical analysis on a 10 m x 10 m grid where Made Ground remains present (below the high tide groundwater level) and every 20 m<sup>2</sup> during gross contamination removal. Verification sampling of excavation extents along boundaries based on 1 sample per 10 m. Undertake CBR tests on a 20 m x 20 m grid basis.

The above works listed are described in detail below and a drawing illustrating the proposed remedial layout of treatment activities is included as drawing D1820/5045/A5 in Appendix A of this report.

#### 5.4.2 Stabilisation and Solidification (NAPL impacted soil)

On the basis of the remediation options appraisal, stabilisation and solidification (S/S) was identified as the most effective and appropriate technique to deploy at the site. This technique is one that Celtic have a long history in deployment of including on both historic National Grid sites and those for other landowners.

The aim of treatment by S/S will be to reduce the mobility of the contaminants of concern in order to mitigate potential risk to controlled waters. The design process prior to implementing the treatment at full scale is underway and comprises bench testing to determine the optimum additive mix. The monoliths produced at both bench and full scale will be tested in a tank leaching test in accordance with EN NEN 7375. Samples will be subject to the first four stages of the tank test (4 days) with chosen samples extended to the full 64-day duration. An assessment of sample durability and leaching characteristics will be made in accordance with EA NEN 7375 and the derived leaching rates compared to the site's remedial criteria.

Stabilisation treatability trials are being completed by Celtic and include trials with mixes of varying percentages of ordinary portland cement (OPC) and pulverised fuel ash (PFA). Based on the trial data, the proposed percentage of additives will comprise those included within Table 10:

**Table 10 – Stabilisation Additives**

| Soils to be Treated      | OPC (% W/W) | PFA (% W/W) |
|--------------------------|-------------|-------------|
| Made Ground and Alluvium | 4           | 8           |

The primary objectives of the S/S remediation technique as proposed are:

- To achieve environmental betterment by chemically and physically stabilising and reducing the mobility and leachability of contaminants within the Made Ground materials;
- To improve the strength of the Made Ground soil materials and form a lower permeability monolith; and
- To manage the moisture content of Made Ground soil materials as appropriate to ensure full curing of the treated materials.

## **Stabilisation**

Celtic propose to complete stabilisation of impacted soil materials via ex-situ stabilisation under deployment of an Environmental Permit (EPR/AP3195FG). Stabilisation would be completed on site within a designated treatment area within open top vessels such as (~12 yard) skips. Excavated materials requiring treatment will be transported (and tracked via the MMP system) to the designated area of site for stabilisation treatment.

Stabilisation will be undertaken using a combination of mechanical plant including ~21 tonne mechanical excavator with Allu mixing attachment, grout mixing plant with grout delivery pipework. Materials will be transported via (~9 tonne) dump trucks.

Materials deemed suitable for stabilisation (following mechanical segregation of non-treatable material such as wood, metal, plastic and oversize concrete/brick/masonry) shall be placed within the skips by mechanical excavator in advance of treatment. The use of skips will allow for a greater degree of containment and will assist with the wider management of potential environmental issues such as noise, dust and odour. Materials placed in the skips shall be recorded by volume and in advance of mixing in additives.

Additives (cement and PFA) shall be added at a volume percentage ratio of 4 % and 8 % respectively for cement and PFA. Water requirements to support the proposed mix and to take account of variations in material would be between 2.5 and 5 % (based on cement % addition). The additives shall be pre-mixed at the given values by an on-site batching plant. This mixing plant and the associated feedstocks of additives shall be located within a segregated and designated grout mixing area at ground level.

Celtic shall upon completion of stabilisation demonstrate that the treated material is durable via a combination of strength and leachability testing in line with the EA NEN 7375 test. Celtic have significant experience undertaking stabilisation projects and have an extensive database to compare against including many successfully remediated gasworks sites. The leachate testing will be undertaken to demonstrate that the remedial targets for leachate, as included within Table 6, have been met.

### **5.5 Unexpected Contamination**

The potential to encounter unexpected contamination at the site exists on the basis of the site having an historic gasworks use. However, based on the completed investigation works the risks of encountering non gasworks related contamination is considered low. In the event unexpected contamination is encountered then Celtic would stop works and bring to the attention of the Client's project team. In addition, unexpected contamination would be notified to the EA and local authority contaminated land representatives with a strategy for investigation, characterisation and mitigation. It is considered that except for significant notifiable or other asbestos materials additional contamination could be incorporated and or treated using stabilisation as the primary proposed remedial technique.

## **5.6 Groundwater Betterment**

The DQRA for controlled waters has concluded that groundwater remediation at the site is not a requirement per se to protect controlled waters. However, it is acknowledged that a groundwater treatment system will be required to facilitate remediation at the site, and it is therefore proposed that a groundwater treatment system is established to deal with NAPL, and incidental impacted perched water encountered during excavation works. Indeed, all encountered waters during excavation works will require removal and will be subject to passing through the on-site water treatment system to facilitate its proper disposal in-line with a consent to discharge with the sewerage undertaker.

Free phase NAPL is expected to be encountered in and around the former gasworks structures within Area 4, as was evident during investigation works. Where NAPL is encountered, there is likely to be very high concentrations of dissolved phase hydrocarbons which have the potential to impact perched and tidal groundwaters within the vicinity.

Diesel and/or electrical driven pumps will divert encountered groundwater, via above ground pipework, to a water treatment system which will be designed and commissioned by Celtic to deal with approximately 10 m<sup>3</sup> per hour. Celtic have a proven track record of designing and delivering bespoke water treatment systems, which will comply with the site's mobile treatment license under the associated deployment of Celtic's Environmental Permit.

The treatment system will comprise an upfront oil/water separator to initially capture any LNAPL and DNAPL. The water will then be transferred through sand filters and carbon vessels to remove suspended solids and dissolved phase contamination. A sampling point and holding tanks will be incorporated into the treatment system to allow regular sampling and testing of the treated water to assess the efficiency of the system and demonstrate compliance with the discharge consent. During commissioning of the treatment system, a closed loop test will be performed and several samples of treated water will be retrieved for laboratory chemical analysis and submitted to Southern Water to demonstrate compliance with agreed discharge criteria. A foul sewer chamber has been identified on the boundary of the site and discussion are being undertaken with Southern Water to agree the discharge point, sampling requirements and compliance criteria.

The treatment system will be sited on a purpose-built concrete pad, towards the southern part of Area 4, to the north of the SSE electrical substation. The treatment pad will incorporate a surrounding concrete block bund and include a sump. The bund will be designed to accommodate a minimum capacity of 110% of all water within the treatment vessels and an automated pump will be installed within the sump to deal with rainwater and any leaks/spills.

A discharge consent will be agreed with Southern Water and criteria established so that testing can be undertaken to demonstrate that it is achieved prior to disposal via the sewer consent.

## **5.7 Removal of Below Ground Structures**

Celtic will break out and remove below ground structures in order to access and remove gross contamination. The existing concrete gasholder bases identified as feature numbers 8 and 15 in the west and southern corners will not be removed, as they are founded on natural materials and no



evidence of gross contamination. Below ground structures remaining in-situ will be recorded using topographic survey techniques.

Above and below ground materials excavated and segregated for future re-use including concrete and hard materials shall be subject to additional processing, crushing and analytical testing in order to confirm suitability. If enough and suitable volumes of hard materials are generated on-site, a Permitted mobile crushing unit will be deployed under Process guidance Note 3/16(12) and notified to the local council. An approved operator will operate and maintain the plant, within the appropriate emission limits, monitoring and control techniques.

All materials reused shall be recorded as part of Celtic MMP with any non-suitable material sent for off-site disposal or recycling (re-bar etc). Any material disposed of off-site shall be recorded as per the site waste management plan respectively.

## **5.8 Asbestos Within Soils**

Historical investigations did not record the presence of asbestos fibres or products on-site, although the more recent investigation undertaken by Celtic did record the presence of asbestos within three of the 15 samples. Two of the samples (TP204 at 1m and TP206 at 1.2 m) recorded loose fibres of chrysotile, with one of those samples (TP204 at 1 m) also recording the presence of amosite fibres. The third sample (TP207 at 1.8 m) detected loose fibres of amosite and crocidolite and fibrous debris of amosite and chrysotile. This area on-site is associated with the presence of a below ground brick structure.

An asbestos risk assessment will be undertaken as part of the initial QHSE documentation preparation to determine if the works are deemed to be non-notifiable or notifiable. Currently, no licensable works have been identified. Should non-licensable asbestos products be encountered, the materials shall be collected and double bagged, by appropriately trained (CAT B) operatives in line with current disposal requirements and stored in a lockable skip. The skip shall be located within the quarantine area and appropriately signed to ensure no cross-waste contamination or disposal.

Asbestos reassurance air monitoring will be undertaken as described within Section 7.5.

All asbestos works shall be carried out in line with current legislation and industry best practice to include CAR2012, and recent CIRIA Asbestos Site guidance (SP168, C733) that Celtic were in support of and assisted development

## **5.9 Human Health Capping Layer**

Following remediation, all areas will be backfilled with site won verified materials and covered using 300 mm of granular capping layer (Class 1B/6F2 or similar), overlying a geotextile alert barrier. The aim will be to reinstate levels to pre-works (existing) ground levels. Areas to be covered will be levelled, however, it is not intended that site levels will be reduced to incorporate the cover layer. Backfilled materials and capping layer will be placed in appropriate layers and compacted to provide a minimum CBR value of 5% at top of capping. CBR tests will be carried out using a 450 mm plate at a frequency of 1 test per 400 m<sup>2</sup>. This will equate to 10 tests across site. The primary aim of the capping layer is to mitigate potential future risks to human health and nuisance exposure and the objectives are to:

- Reduce the potential for dust, vapour and odour emissions impacting on site neighbours;
- Prevent site workers and visitors from coming into direct dermal contact with residual soil contamination and mitigate ingestion and inhalation pathways; and
- Provide a surface which is suitable for the intended open storage end-use.

## **6.0 VERIFICATION PLAN**

### **6.1 Verification Test Plan**

#### **General**

In general, the aim of the verification test plan is to provide a regime of testing to demonstrate the following:

- that residual contaminants meet the remedial criteria and do not pose an unacceptable risk to human health or the wider environment;
- that materials have been appropriately treated and that remedial criteria have been achieved;
- that only appropriate materials have been imported to site; and
- that site originating materials are suitable for re-use.

Samples will be scheduled for the appropriate suite of analysis at UKAS accredited laboratories. Sample retrieval, handling, storage and record keeping will be undertaken in line with NGPH Core specification, Celtic standard operating procedures and will be subject to duplicate QA/QC assessment. Statistical methods may be used when comparing datasets and conformance to criteria.

#### **Excavation Extents**

Verification sampling of excavation extents will be undertaken on the following basis:

- Base of excavation where Made Ground remains below unsaturated zone (equivalent to high tide water table) at a frequency of 1 sample per 100 m<sup>2</sup>, generally equivalent to one sample per 10 m x 10 m grid or where gross contamination is present, at a frequency of one sample per 20 m<sup>2</sup>; and
- Boundary face of excavations (along south western boundary of residential property, north western boundary along Ford Road and north eastern boundary of Area 4) at a frequency of 1 sample per 10 linear metres of excavation face.

Samples will be sent for solid chemical analysis as per Table 12 and results compared against the remedial criteria in Table 6.

#### **Material Re-Use**

Verification sampling will be undertaken on material re-use at a frequency of one sample per 100 m<sup>3</sup>. Representative sampling will be undertaken in line with Celtic standard operating procedures, using sub-sampling methods and techniques such as cone and quartering.

Samples will be sent for solid chemical analysis as per Table 12 and results compared against the remedial criteria in Table 6.

## **S/S Treatment**

In order to demonstrate that the stabilised soils meet the remedial targets for the site, samples of treated soil will be recovered at a rate of 1 sample of 250 m<sup>3</sup> and allowed to cure for 28 days in moulds kept at ambient temperatures. Following curing, the samples will be subject to leachability tank testing in order to demonstrate the post-stabilisation immobilisation of the contaminants of concern. Testing will also be undertaken to demonstrate the strength and durability of the stabilised material.

Samples taken for validation purposes will be recovered from the treated material after blending with S/S additives, prior to any initial set or hardening occurring. Sufficient material will be collected and placed in moulds according to the methodology described below:

- Samples produced will be of uniform size, consistent with the testing requirements with duplicate samples being retrieved in case of damage;
- Material will be placed within moulds in layers, with hand pressure applied to ensure material extends into corners and edges of the moulds;
- The upper surface of the material will be smoothed, and the sample mould sealed;
- Samples will initially be kept in a designated safe and secure storage area and off the floor;
- Samples will then be transported to an appropriate testing facility as soon as is reasonably practicable, where they will be stored on shelving in a controlled environment for a minimum period of 28 days prior to testing; and
- Samples may be removed from their containers up to 7 days prior to testing to allow for sample preparation.

## **Capping Layer**

Samples will be recovered from site-won and imported materials used for the capping layer at a frequency of one sample per 100 m<sup>3</sup> with a minimum of three samples per off-site source. Samples are to be representative of the source tested and taken from a representative range of materials.

Samples will be sent for solid chemical analysis as per Table 12 and results compared against the remedial criteria in Table 6.

The capping layer will also be subject to on-site 450 mm plate CBR tests at a frequency of one test per 400 m<sup>2</sup>, with an aim to achieve a minimum CBR value of 5%.

## **Groundwater Quality**

Additional rounds of groundwater monitoring will be undertaken prior to the start of excavation works, during excavation works and following remediation works to ensure groundwater quality is stable and that concentrations present do not present an unacceptable risk to controlled waters. This may also provide additional data for review of the groundwater risk assessment if necessary. Samples will be sent for liquid chemical analysis as per Table 13 and results compared against the remedial criteria in Appendix C.

## Disposal to Foul Sewer

A discharge consent will be agreed with Southern Water with established criteria and sample testing frequency, so that data can be retrieved and shown to demonstrate that appropriate water quality is being achieved prior to disposal to the sewer.

## Summary of Testing Schedules

Table 11 provides a summary of the testing schedules described previously.

**Table 11 – Summary of Testing Schedules**

| Testing Location                                                                                                          | Testing Frequency                                                                                        | Testing Requirements                                                   |
|---------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Excavation extent – where natural material encountered                                                                    | Visual assessment with topographic and photographic evidence                                             | none                                                                   |
| Excavation extent – where Made Ground material remains (within saturated zone – below high tide level)                    | 1 per 100m <sup>2</sup>                                                                                  | Remedial Criteria (Table 6)                                            |
| Excavation extent – where gross contamination encountered                                                                 | 1 per 20 m <sup>2</sup>                                                                                  | Remedial Criteria (Table 6)                                            |
| Face of excavations along boundary with residential property, boundary along Ford Road and north east boundary of Area 4. | 1 per 10 linear metres of excavation                                                                     | Remedial Criteria (Table 6)                                            |
| Material Re-use                                                                                                           | 1 per 100 m <sup>3</sup>                                                                                 | Remedial Criteria (Table 6)                                            |
| S/S treated material                                                                                                      | 1 per 250 m <sup>3</sup>                                                                                 | EA NEN 7371 test and leachate to achieve Remedial Criteria (Table 6)   |
| Capping Layer                                                                                                             | 1 per 100 m <sup>3</sup>                                                                                 | Minimum 3 samples per source for standard solid suite (Table 12)       |
| Geotechnical Plate Bearing Test                                                                                           | 1 per 400 m <sup>2</sup>                                                                                 | >5% CBR value                                                          |
| Waste Materials                                                                                                           | Dependant on receiving facility requirements, typically one representative sample per 100 m <sup>3</sup> | Waste classification dependant on material type and substances present |
| Discharge water                                                                                                           | To be agreed with Southern Water                                                                         | To be agreed with Southern Water                                       |

Tables 12 and 13 provide summaries of the soil and groundwater testing suites to be scheduled. Differing analysis is likely to be required by Southern Water for discharge waters, which will be agreed with them in advance of treatment activities.

**Table 12 – Testing Suites Solids**

| Grouping           | Constituent COCs                                                                                                                                                                                                                                                  |
|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Phenols            | 2,4,5-Trichlorophenol; 2,4,6-Trichlorophenol; 2,4-Dichlorophenol; 2,4-Dimethylphenol; 2-Chlorophenol; 2-Methylphenol; 2-Nitrophenol; 4-Chloro-3-methylphenol; 4-Methylphenol; total phenols.                                                                      |
| Metals             | Arsenic, Boron, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Zinc.                                                                                                                                                                                 |
| PAHs               | Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Dibenz(a,h)anthracene, Benzo(ghi)perylene. |
| BTEX               | Benzene, Toluene, Ethylbenzene, p&m-xylene, o-xylene.                                                                                                                                                                                                             |
| Cyanide            | Free Cyanide, Complex Cyanide, Total Cyanide.                                                                                                                                                                                                                     |
| TPH                | Speciated Aliphatic and Aromatic Hydrocarbons.                                                                                                                                                                                                                    |
| General inorganics | pH, Electrical Conductivity, Total Sulphate (as SO <sub>4</sub> ), Sulphide, Total Chloride, Ammonium as NH <sub>4</sub> , Total Organic Carbon.                                                                                                                  |
| Asbestos           | Asbestos ID, Asbestos quantification (for positive ID).                                                                                                                                                                                                           |

**Table 13 – Testing Suites Groundwater**

| Grouping           | Constituent COCs                                                                                                                                                                                                                                                  |
|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Phenols            | Catechol, Resorcinol, Ethylphenol & dimethylphenol, Cresols, Naphthols, Isopropylphenol, Phenol, Trimethylphenols, Total Phenols.                                                                                                                                 |
| Metals             | Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Zinc.                                                                                                                                                                                        |
| PAHs               | Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Dibenz(a,h)anthracene, Benzo(ghi)perylene. |
| BTEX               | Benzene, Toluene, Ethylbenzene, p&m-xylene, o-xylene.                                                                                                                                                                                                             |
| Cyanide            | Free cyanide, complex cyanide, total cyanide.                                                                                                                                                                                                                     |
| TPH                | Speciated aliphatic and aromatic hydrocarbons.                                                                                                                                                                                                                    |
| General inorganics | pH, Electrical Conductivity, Sulphate (as SO <sub>4</sub> ), Sulphide, Chloride, Ammonium as NH <sub>4</sub> , Total Organic Carbon, Total Suspended Solids.                                                                                                      |

## 6.2 Record Keeping

Throughout the works extensive records will be maintained including (but not limited to) the following:

- A full and detailed description of the works completed;
- Site diaries (completed by the SM);
- All progress meeting minutes and key correspondence

- Records of local community liaison / letter drops etc.;
- Environmental monitoring records (including noise, dust, odour and surface/ground water monitoring)
- Completed 'Soil Treatment' log sheets;
- Details of unforeseen contamination encountered during the works and subsequent remedial actions;
- Materials / Waste import / export records (including full Duty of Care documentation);
- Groundwater quality monitoring data and laboratory analytical certificates;
- Relevant approvals from Arun District Council, the Environment Agency and utilities companies
- Records of water treatment / disposal to sewer (including meter readings and laboratory analysis certificates);
- Laboratory certificates for soil analysis (for environmental and geotechnical testing purposes);
- The extent and location of all soil / groundwater remediation works, including 'As Built' engineering plans showing the location of remedial excavations, location of validation sampling, backfilled soils, archaeological investigations, obstructions, boundary treatment cross sections etc.;
- Records of all soil treatment (including volumes and validation testing analytical results);
- Records of Groundwater and NAPL recovery including post betterment conditions and presence of remaining NAPL following demonstration of asymptotic conditions shall be provided. This shall include monitoring data at time of completion, thickness of remaining NAPL and a topographic record of well location to record distribution. This information shall be provided also on a monthly basis during NAPL betterment for Regulator review;
- A photographic record;
- A summary of environmental monitoring and complaints; and
- Full copies of key regulatory correspondence.

### **6.3 Verification Reporting**

A verification report will be prepared on completion of the remediation works. The report will contain details of all excavation works carried out, materials management aspects including details of the volumes of material excavated, treatment activities, disposal activities and material re-use on-site. Photographs of the works, environmental monitoring data and certificates of the laboratory verification testing for chemical and geotechnical properties of all soil material will also be included.

The verification report shall be completed in accordance with current regulatory guidance and best practice.

### **6.4 Post Works Monitoring**

There will be an ongoing requirement by NGPH to inspect and maintain the site's existing hardstand areas and capping layer based on their future use of the site. The retention of existing tarmac hardstanding at the site entrance and proposed compound area will readily allow and facilitate the ability for vehicles to enter and park in this area of the site. However, should vehicular access be required elsewhere on-site, inspection and maintenance will be required to ensure the resilience of the capping layer. The maintenance and inspection of the site boundary and access gates will also be required to ensure adequate security of the site.

## **7.0 PROPOSED MITIGATION MEASURES DURING WORKS**

Based on the proposed works which include mechanical excavation, breakout of hard materials, transport of materials on and off site, processing of materials, stabilisation, site re-profiling and groundwater recovery and treatment, the potential for odour, dust, noise and vibration exist. These risks have been identified as part of pre-works planning and will be subject to on-going monitoring throughout the works.

In order to address and manage the identified risks, it is proposed that the following mitigation and monitoring measures are employed during the works. The proposed methods below also reflect the monitoring and mitigation measures that will be presented and discussed with the Environment Agency as part of Celtic EA Permit deployment EA30379.

In compliance with Arun District Council's Construction Code of Practice, the proposed working hours will be restricted to Monday to Friday 08:00 – 18:00 hrs. In the unlikely event that Saturday working is required, this will be restricted to 08:00 – 13:00 hrs. No works will be undertaken on Sundays or Public Holidays.

### **7.1 Dust**

Dust levels will be visually assessed on an ongoing daily basis by all Celtic staff who shall be encouraged to manage and mitigate dust levels during their daily works and communicate any issues to the site manager.

Dust monitoring will be carried out at the 4 proposed environmental monitoring points, located at each corner of the site together with any additional monitoring locations based on actual working areas, which will be agreed at the daily activity briefing based on proposed works areas and activities. The monitoring will be undertaken twice a day using a portable handheld calibrated Dustmate instrument. The monitoring results will be fed back to the site manager so that mitigation measures can be deployed as necessary.

The action level for dust on the site is for total respirable dust (PM10) set at 250 µg /m<sup>3</sup> for a 15 min mean due to the sensitivity of offsite receptors (adjacent residential properties and gardens).

Dust mitigation measures will be undertaken pro-actively as part of the normal site operations and a management plan shall be in place as part of the Celtic site health and safety management plan. Should there be visible dust, or exceedance of the action level value for dust, then works will be stopped and the dust management measures re-assessed, adapted or upgraded. Further follow up monitoring shall be undertaken to confirm that the corrective actions have successfully managed dust levels.

Typical remedial actions to manage dust impacts that shall be deployed on site include:

- Traffic routes shall be sprayed with water to control potential dust generation. There will be a limit to all unnecessary traffic across the site and all haul routes shall be subject to routine and regular inspection.
- The speed limit for the site shall be limited to 5 mph in order to minimise the potential generation of debris/dust.



- Dust netting and fencing shall be erected in advance of works across areas of site on a phased basis to mitigate the potential for cross boundary migration.
- During periods of high winds (in the direction of key receptors) the works and activities with the potential to generate dust shall be suspended or amended until wind speeds reduce to acceptable levels and / or alternative working and control methods can be deployed.

Celtic propose to use a combination of fixed dust suppression systems in high dust risk activities areas such as break out and stabilisation with additional mobile suppression via dust cannons and rotary atomisers on site for deployment and relocation based on works progress and observed site conditions.

All monitoring data shall be recorded as per Celtic EA permit requirements.

## **7.2 Vapours and Gases**

A method statement detailing how odours and vapours will be minimised for remediation works during the handling of contaminated materials (including stabilisation and bulk excavations) will be available as part of Celtic's safety, health and environmental management plan.

Based on the known site contaminants and surrounding stakeholders, works will be progressed in a manner where practicable to minimise open excavations for extended periods, minimise contaminated material stockpile volumes and remove, where encountered, free NAPL and perched water within excavations with appropriate controlled on-site storage prior to off-site disposal. In addition, odour suppression equipment shall be made available which may include fixed boundary dispersal and mobile rotary atomiser systems to allow deployment and movement based on encountered conditions and contamination.

Mobile treatment plant for soils and waters will be under the strict control of Celtic and are unlikely to create significant emissions of vapours and gases during normal operations.

Monitoring of volatile organic carbons (VOCs) will be undertaken continuously during working hours for the duration of site works. Monitoring will be undertaken from the first day of site works before excavation and S/S treatment commence, in order to determine background levels. A Photo Ionisation Detection meter (PID meter) will be kept on-site for this purpose.

Celtic will be responsible for the environmental monitoring of VOCs in ambient air within Celtic work areas. Monitoring will be undertaken at a minimum of once per day, during working hours for the duration of site works. Monitoring will be undertaken prior to main works in order to determine baseline levels. A Photo Ionisation Detection meter (PID meter) will be kept on site for this purpose.

Monitoring will be carried out once a day for a duration of at least 15 minutes. Monitoring will be carried out with a PID meter calibrated to respond to an appropriate organic contaminant (e.g. benzene), to assess vapours quantitatively. The 15-minute average for each location and maximum concentration will be recorded, together with the time that the monitoring was carried out.

During periods where the intermittent monitoring is not being carried out, a PID meter will be located at a dust monitoring station or other location downwind of current works areas and set to log the average vapour concentration (time weighted average) at that location. Once again, the average

vapour concentration at that location and maximum concentration will be recorded, together with the time that the monitoring was carried out.

Celtic will be responsible for daily calibration of any PID meter used on site. The site Engineer will record all monitoring information in electronic format (table format) on a weekly basis.

The threshold levels for vapour monitoring set out in EH40/2005 (Health and Safety Executive Workplace Exposure Limits) and subsequent amendments will be observed during the works. However, in practice, a maximum limit for the time weighted average concentration of 1 ppm will be set for vapours. If ambient levels on site approach or exceed this concentration, works on-site and contingency measures deployed will be reviewed with the aim of mitigating vapour levels to below the threshold levels.

Celtic will also monitor personnel most at risk from odours/ vapours and gases whilst on site and will provide sufficient personal monitoring instruments to do this. Typically, this will include excavation operators, banksmen, operatives carrying out hand excavation works and plant operators carrying out bulk excavation in the contaminated areas/ removal of gasworks structures. For personal monitoring, PID meters will be placed on the operative and set to record the average vapour concentration (time weighted average). The average vapour concentration and maximum concentration will be recorded, together with the time that the monitoring was carried out.

These procedures will be reviewed during the work and potentially revised for activities deemed to be higher risk. All monitoring data shall be recorded as per Celtic EA permit requirements.

### 7.3 Odour

Odour monitoring (olfactory sniff test) will be undertaken daily at the edge of the works zone and at the most relevant site boundary to offsite receptors, dependent on work locations and weather conditions. The FIDOL factors will be recorded which are represented as follows:

|                               |                                                                                                                                                   |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>F</b> requency             | How often an individual is exposed to odour                                                                                                       |
| <b>I</b> ntensity             | The individual's perception of the strength of the odour                                                                                          |
| <b>D</b> uration              | The overall duration that individuals are exposed to an odour over time                                                                           |
| <b>O</b> odour unpleasantness | Odour unpleasantness describes the character of an odour as it relates to the 'hedonic tone', and will be measured on a standard none-point scale |
| <b>L</b> ocation              | The location of odour and nature of human activities on the vicinity of an odour source, including receptor characteristics                       |

Odour intensity will be measured and recorded on a 1-5 scale where:

- 1 – No odour;
- 2 – Faint odour;
- 3 – Distinct odour;
- 4 – Strong odour;
- 5 – Extremely strong odour.

The trigger criteria are as follows:

- **Action Levels** shall be set at 3 or above for intensity at which point odour reduction measures should be put in place. This includes covering of stockpiles, limiting area of open excavations and deodorising sprays.
- **Stop Work Levels** shall be set at 4 or above for intensity at which point works will cease until the odour problem can be rectified.

Remedial actions and mitigation measures shall be documented, and odour monitoring undertaken again to ensure that the remedial measures have achieved the appropriate level of improvement.

If monitored odours are considered to exceed the action levels, records of sensitivity of the location will also be made as follow:

|                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| High Sensitivity Receptor   | <p>Surrounding land use where:</p> <ul style="list-style-type: none"> <li>• Users can reasonably expect enjoyment of a high level of amenity; and</li> <li>• People would reasonably be expected to be present here continuously, or at least regularly for extended periods, as part of the normal pattern of use of the land</li> </ul> <p>Examples may include residential dwellings, hospitals, schools/education and tourist/cultural</p>                                                              |
| Medium Sensitivity Receptor | <p>Surrounding land use where:</p> <ul style="list-style-type: none"> <li>• Users would expect a reasonable level of amenity, but wouldn't reasonably expect to enjoy the same level of amenity as in their home; or</li> <li>• People wouldn't reasonably be expected to be present here continuously or regularly for extended periods as part of the normal pattern of use of the land</li> </ul> <p>Examples may include places of work, commercial/retail premises and playing/recreational fields</p> |
| Low Sensitivity Receptor    | <p>Surrounding land use where:</p> <ul style="list-style-type: none"> <li>• The enjoyment of amenity would not reasonably be expected; or</li> <li>• There is transient exposure, where the people would reasonably be expected to be present only for limited periods of time as part of the normal pattern of use of the land</li> </ul> <p>Examples may include industrial use, farms, footpaths and roads</p>                                                                                           |

The suggested descriptor for magnitude of odour effects is illustrated within Table 14. Where the overall effect is greater than 'slight adverse', the effect is likely to be considered significant.

**Table 14 – Suggested Descriptor for Magnitude of Odour Effects**

|                                  |            | Receptor Sensitivity |                     |                     |
|----------------------------------|------------|----------------------|---------------------|---------------------|
|                                  |            | Low                  | Medium              | High                |
| Relative Odour Exposure (Impact) | Very large | Moderate adverse     | Substantial adverse | Substantial adverse |
|                                  | Large      | Slight adverse       | Moderate adverse    | Substantial adverse |
|                                  | Medium     | Negligible           | Slight adverse      | Moderate adverse    |
|                                  | Small      | Negligible           | Negligible          | Slight adverse      |
|                                  | Negligible | Negligible           | Negligible          | Negligible          |

Appropriate PPE and RPE will be made available for use by workers if odours exceed action levels. PPE and RPE shall be assessed under separate works and requirements presented within the Celtic safety health and environment report.

Celtic will proactively deploy odour management measures in addition to the controls detailed above as part of works. These shall be set in advance in areas of known contamination and could be relocated based on nature of contamination and odour assessment. It is proposed that both fixed and mobile odour suppression units shall be used to include fixed fence line atomisers and mobile atomisers. Celtic would, based on an assessment of odours, also look to deploy odour neutralising and masking agents via both mobile and fixed atomiser systems.

#### 7.4 Monitoring/ Control of Noise and Vibration

Best practicable means of noise control will be applied during the remediation works to minimise noise (including vibration) at neighbouring residential properties and other sensitive receptors arising from the remediation activities.

Celtic shall complete works in accordance with a submitted Section 61 document and deploy mitigation measures as required. Mitigation and planning shall include the following:

- Restrict site working hours to 08:00 – 18:00 Monday to Friday and 08:00 – 13:00 Saturdays and not work public holidays;
- Celtic shall position treatment activities as far away from sensitive receptors as reasonably practicable;
- Celtic shall restrict the movement of plant and position haul routes away from the sensitive north west and south west site boundaries and minimise the works required in these areas;
- Celtic shall select plant and machinery in good working order and less than 3 years old and, where available, use quiet and low vibration equipment; and
- Vehicles and plant will be maintained in a good and effective working order and operated in a manner to minimise noise emissions.

Celtic shall review phasing and operations to limit the overlap and duration of highest noise and vibration level activities.

Noise monitoring shall be carried out by Celtic daily at the designated environmental monitoring points as per the works progression and phasing. These points shall be confirmed during the daily site briefings and confirmation of works areas. Noise monitoring shall be carried out using a calibrated and certified Decibel Noise Meter.

Baseline noise monitoring was undertaken by Celtic during the supplementary site investigation works in November 2020 as detailed in Table 15 and Celtic will endeavour not to exceed >10 dB of these average and maximum noise levels throughout the works.

**Table 15 – Baseline Noise Monitoring**

| Location | Date       | Time / Duration | L <sub>AEQ</sub> (dB) | Max (dB) | Min (dB) |
|----------|------------|-----------------|-----------------------|----------|----------|
| E        | 16/11/2020 | 09:48 - 10:03   | 56.3                  | 78.7     | 47.6     |
| N        | 16/11/2020 | 11:46 - 12:33   | 60.2                  | 76.2     | 48       |
| W        | 16/11/2020 | 10:30 - 11:23   | 66.1                  | 81.9     | 43.5     |
| S        | 16/11/2020 | 10:05 - 10:28   | 52.1                  | 74.1     | 43.5     |

If Celtic operations produce and record unacceptable noise and vibration levels then additional measures including further acoustic shielding/enclosures, works re-phasing and assessment of operational hours shall be completed.

All monitoring data shall be available and provided to the Client's team as part of both weekly and monthly reporting with additional information to support remedial measures in the event of a complaint or continued exceedance of action levels.

## **7.5 Asbestos Monitoring**

Based upon the ground investigation and laboratory testing undertaken at the site Celtic do not anticipate widespread or significant asbestos containing soils at site.

Background, reassurance, asbestos air monitoring shall be undertaken on a weekly basis during excavation works and cover operational areas and key identified receptors.

Asbestos assurance monitoring shall be completed by a specialist 3<sup>rd</sup> party sub-contractor with all results provided on day of testing to allow a proactive and immediate review and response based on any identified elevated concentrations.

The monitoring shall include occupational health monitoring of site staff, general works area monitoring and boundary monitoring targeting the most applicable potential receptors based on atmospheric conditions.

Specific asbestos air monitoring shall be undertaken in works areas and the site boundary in the event previously unidentified or asbestos materials of a different nature are recorded.

A watching brief for asbestos in soils shall be undertaken by environmental monitoring staff and all other staff during the works. An asbestos watching brief and discovery strategy shall be formulated, agreed and distributed to all identified stakeholders.

Any watching brief and associated further review of PPE and RPE shall be presented and updated as part of Celtic site-specific safety health and environmental report.

Asbestos monitoring data shall be presented as part of both the weekly and monthly report submissions and immediately should levels dictate an immediate suspension or change to works, working methodologies, controls, PPE or RPE.

It is noted that the controls detailed for dust mitigation will also serve to mitigate any potential asbestos generation based on the current data and current low risk level.

## **8.0 PERMIT AND LICENSING REQUIREMENTS**

Application for an Environment Agency Environmental Permit (former Mobile Treatment Licence) will be necessary as the proposed soil and ground / perched water treatment volumes are in excess of 1,000 m<sup>3</sup>. The required application and associated supporting information have been prepared and

submitted to the Environment Agency for review and acceptance prior to the commencement of any on-site activity.

Celtic submitted EA Permit application and confirmation of receipt and acceptance are presented in Appendix F of this report.

Works shall also be undertaken in line with the CL:aire Definition of Waste: Development Industry Code of Practice (DoWCoP) and associated Materials Management Plan (MMP) requirements and an application shall be made upon receipt of all supporting information. Works shall be completed in line with the submission and verification report provided upon completion of works as per the guidance requirements. Details of all on-site and off-site material movements will be recorded and completed in accordance with the Duty of Care regulations and MMP. Waste transfer/consignment notes and disposal certificates will be provided for each load of material removed from site so that an auditable trail of the dates, volumes and destination of material removed from site can be maintained.

In order to undertake dewatering works a discharge to sewer consent will be required from Southern Water. This application is required to be made no more than 6 weeks in advance of works and will require review and extension at 6 months.

Based on the current scope of works no abstraction consent is required for groundwater. This shall be reviewed considering any additional works that maybe added to the overall Celtic scope including any deeper excavation or additional requirements.

## **9.0 OUTLINE PROJECT PROGRAMME**

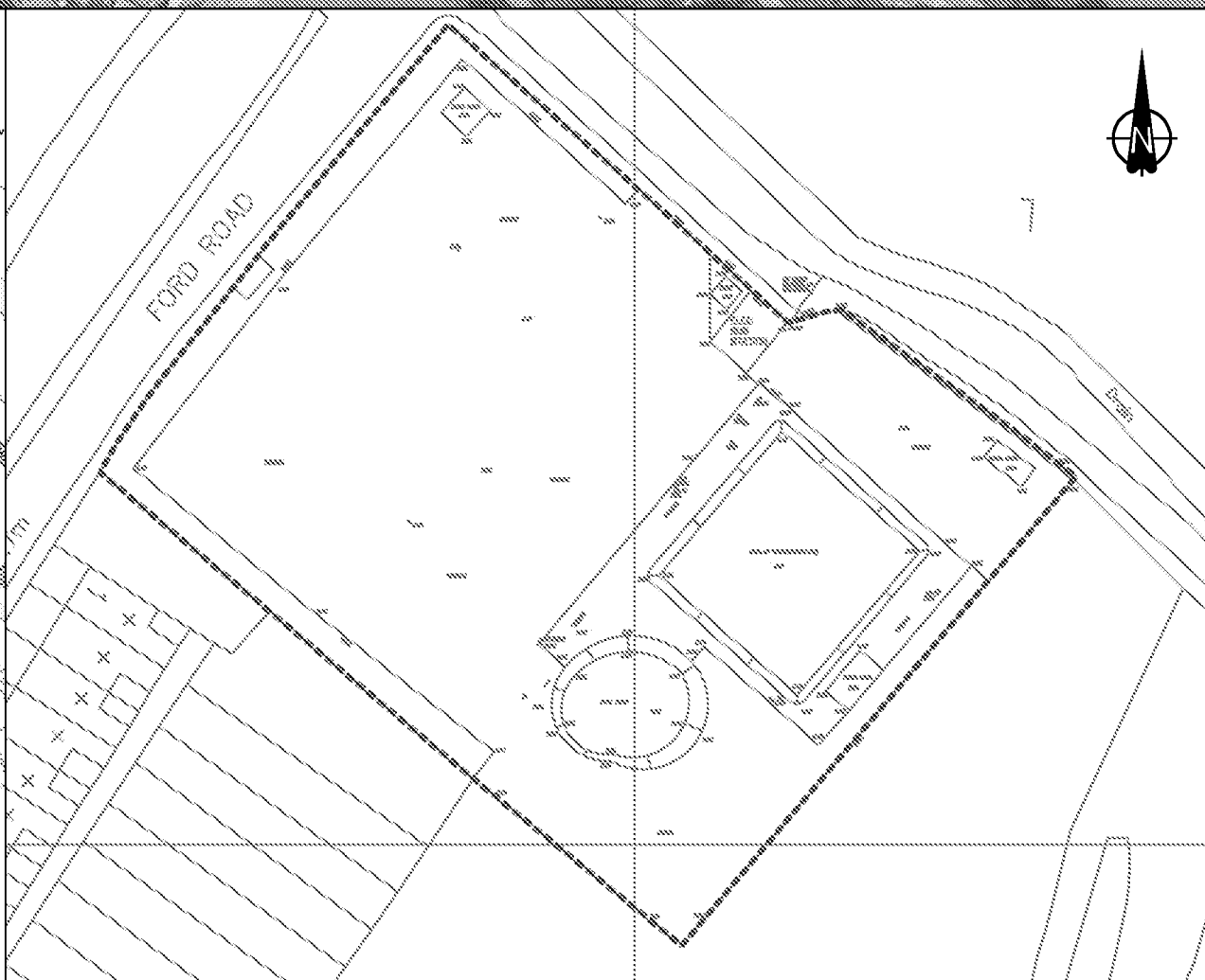
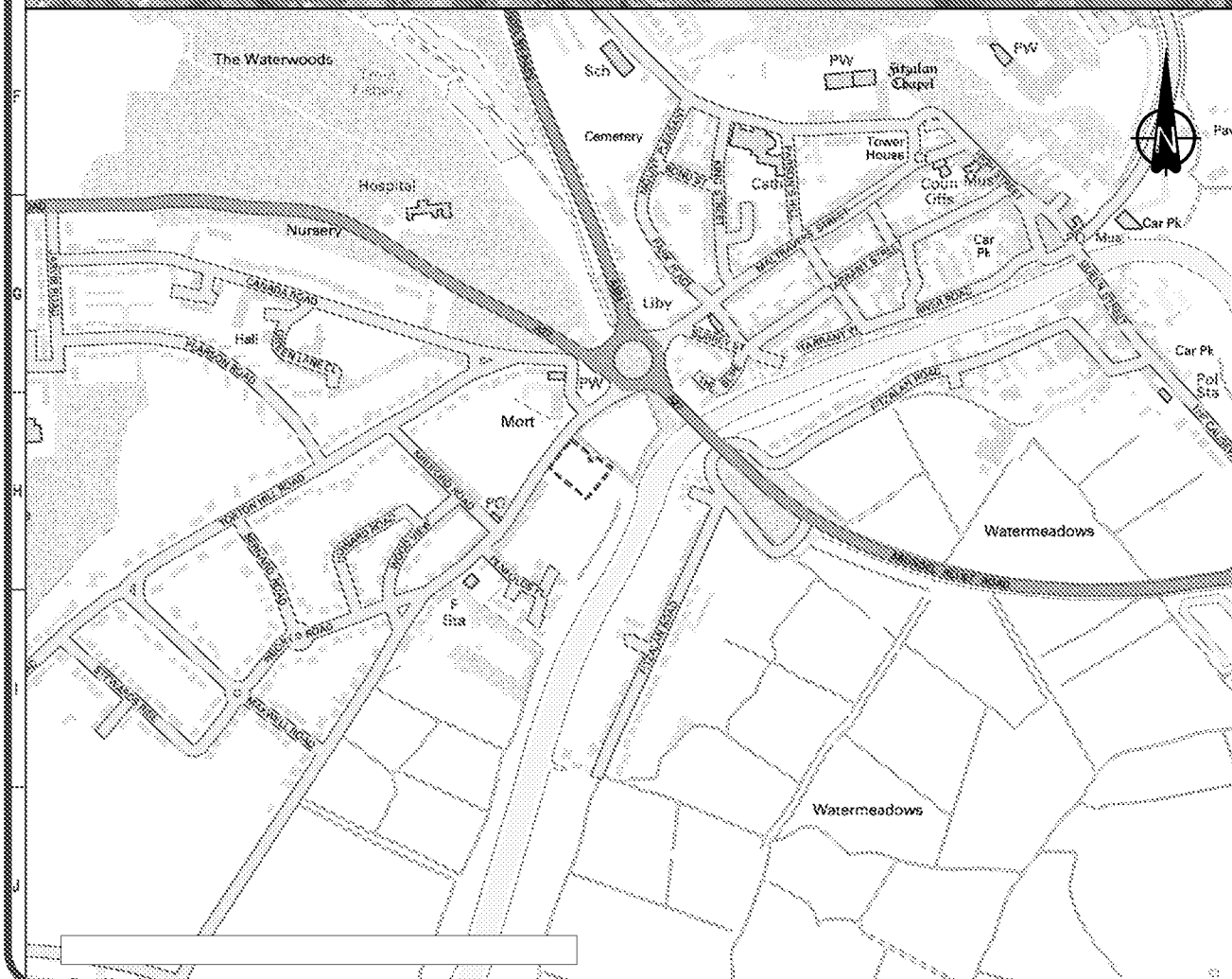
Celtics proposed outline programme of works is included in Appendix D of this report. This programme is subject to change with plant and machinery deployment subject to variation based on encountered ground conditions and identified contamination.

## **APPENDICIES**

|                   |                                                  |
|-------------------|--------------------------------------------------|
| <b>APPENDIX A</b> | <b>DRAWINGS</b>                                  |
| <b>APPENDIX B</b> | <b>HUMAN HEALTH RISK ASSESSMENT ADDENDA</b>      |
| <b>APPENDIX C</b> | <b>CONTROLLED WATERS RISK ASSESSMENT ADDENDA</b> |
| <b>APPENDIX D</b> | <b>OUTLINE PROGRAMME</b>                         |



## **APPENDIX A      DRAWINGS**



**Legend** E501308, N106749  
National Grid Property Holdings Ltd  
Site Boundary

0 First Issue 27/01/21  
REV COMMENT DATE

**Celtic enGlobe**  
Columbus House  
Village Way  
Cardiff  
CF15 7NE  
019 2036 8635  
Client

**nationalgrid**

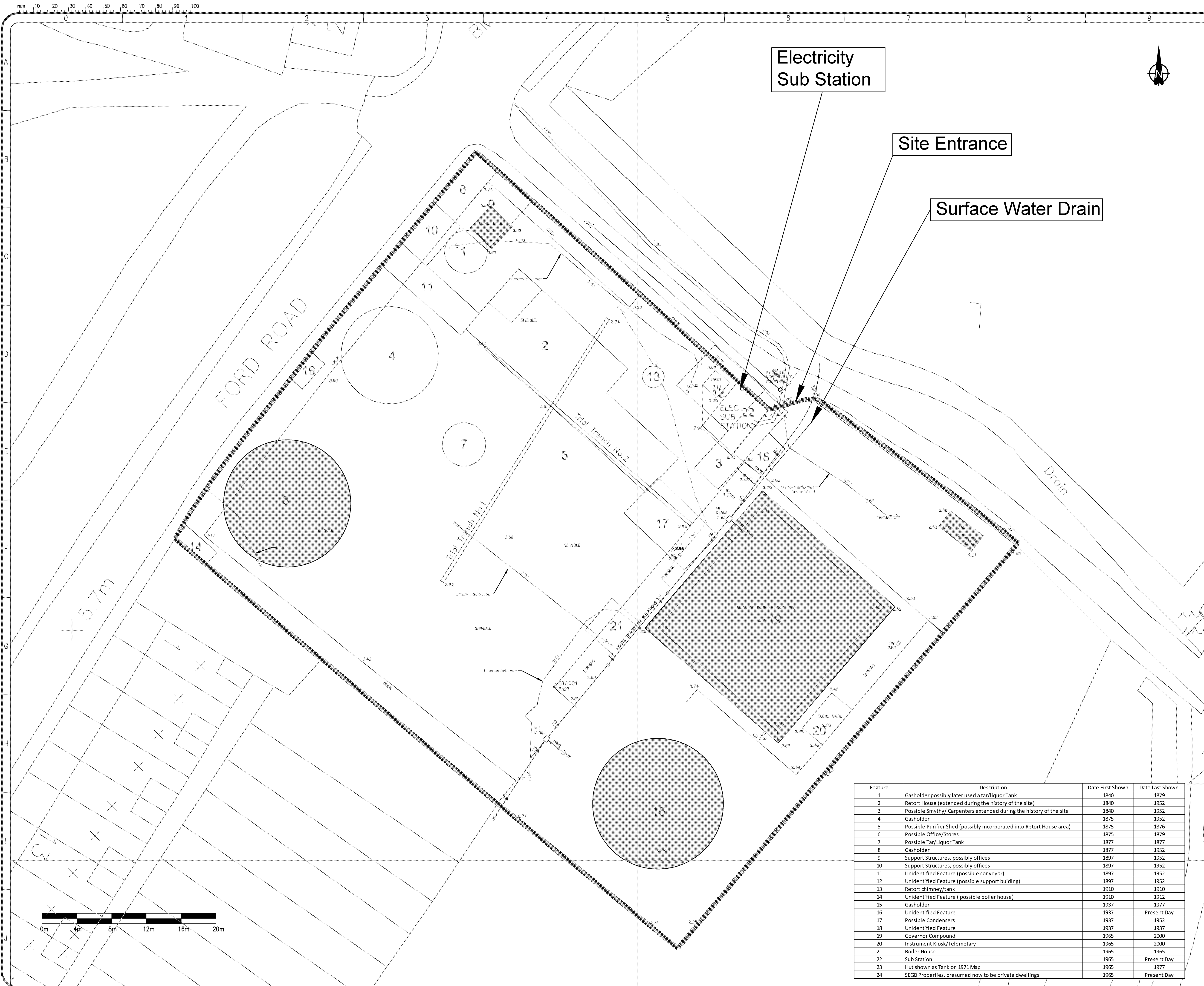
Project  
**Arundel Gas Works  
Ford Road, Arundel**

Title  
**Site Location and  
Surrounding Areas**

|                                |                         |                         |                         |                         |
|--------------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| Drawn by<br><b>GEP</b>         | Checked<br><b>SG</b>    | Date<br><b>27/01/20</b> | Authorised<br><b>MH</b> | Date<br><b>27/01/21</b> |
| Original Scale<br><b>N.T.S</b> | Date<br><b>27/01/21</b> | Rev<br><b>0</b>         | Paper<br><b>A3</b>      |                         |

Drawing Number  
**D1820/5045/A1**





Legend E501308, N106749

- \*\*\*\*\* National Grid Property Holdings Site Boundary
- ◇ Historical Features
- Proposed Celtic Compound

- LEGEND
- Foul Drainage
  - Surface Drainage
  - Combined Drainage
  - Electricity
  - Electricity High Voltage
  - Electricity Low Voltage
  - Gas
  - Ground Probing Radar
  - Water
  - Cable Television
  - Close Circuit Television
  - Communication
  - British Telecom
  - Compressed Air
  - Offset Fill-Line
  - Oil Pipe
  - Pipe
  - Ventilation
  - Fuel Line
  - Vapour Recovery
  - Gauge Line
  - Telemetry
  - Fibre Optics
  - Unknown
  - Fence
  - Edge of Canopy
  - Gully Run

0 First Issue 27/01/21  
REV COMMENT DATE

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Client nationalgrid

Project Arundel Gas Works  
Ford Road, Arundel

Title Historical Features

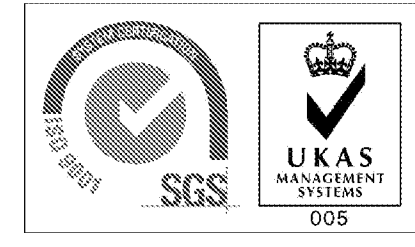
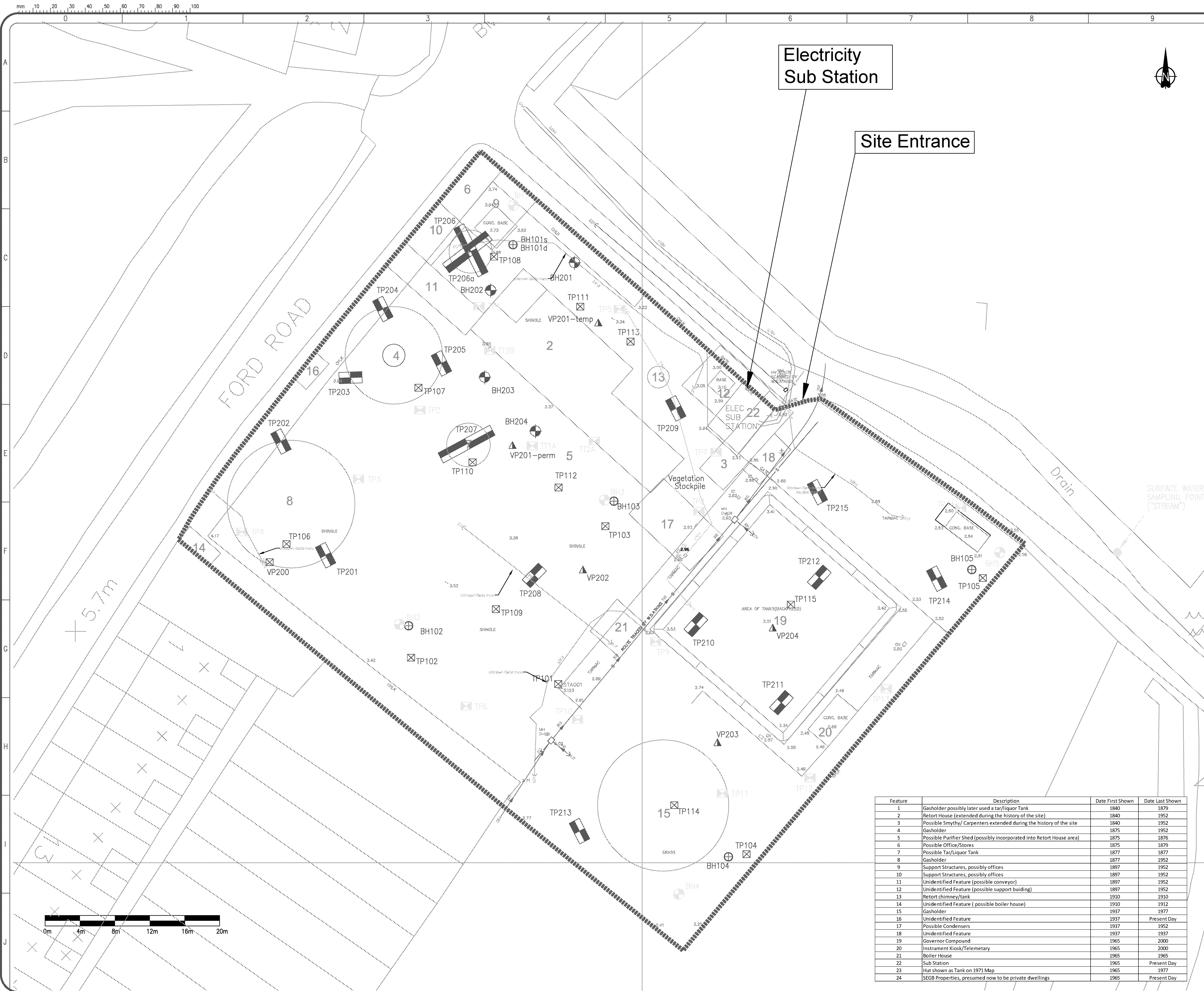
Drawn by GEP Checked SG Date 27/01/21 Authorised MH Date 27/01/21

Original Scale 1:200 Date 27/01/21 Rev 0 Paper A1

Drawing Number D1820/5045/A2

| Feature | Description                                                           | Date First Shown | Date Last Shown |
|---------|-----------------------------------------------------------------------|------------------|-----------------|
| 1       | Gasholder possibly later used a tar/liquor Tank                       | 1840             | 1879            |
| 2       | Retort House (extended during the history of the site)                | 1840             | 1952            |
| 3       | Possible Smythy/ Carpenters extended during the history of the site   | 1840             | 1952            |
| 4       | Gasholder                                                             | 1875             | 1952            |
| 5       | Possible Purifier Shed (possibly incorporated into Retort House area) | 1875             | 1876            |
| 6       | Possible Office/Stores                                                | 1875             | 1879            |
| 7       | Possible Tar/Liquor Tank                                              | 1877             | 1877            |
| 8       | Gasholder                                                             | 1877             | 1952            |
| 9       | Support Structures, possibly offices                                  | 1897             | 1952            |
| 10      | Support Structures, possibly offices                                  | 1897             | 1952            |
| 11      | Unidentified Feature (possible conveyor)                              | 1897             | 1952            |
| 12      | Unidentified Feature (possible support building)                      | 1897             | 1952            |
| 13      | Retort chimney/tank                                                   | 1910             | 1910            |
| 14      | Unidentified Feature ( possible boiler house)                         | 1910             | 1912            |
| 15      | Gasholder                                                             | 1937             | 1977            |
| 16      | Unidentified Feature                                                  | 1937             | Present Day     |
| 17      | Possible Condensers                                                   | 1937             | 1952            |
| 18      | Unidentified Feature                                                  | 1937             | 1937            |
| 19      | Governor Compound                                                     | 1965             | 2000            |
| 20      | Instrument Kiosk/Telemetry                                            | 1965             | 2000            |
| 21      | Boiler House                                                          | 1965             | 1965            |
| 22      | Sub Station                                                           | 1965             | Present Day     |
| 23      | Hut shown as Tank on 1971 Map                                         | 1965             | 1977            |
| 24      | SEGB Properties, presumed now to be private dwellings                 | 1965             | Present Day     |





- Legend** E501308, N106749
- \*\*\*\*\* National Grid Property Holdings Site Boundary
  - Celtic Trial Pits
  - Celtic Borehole Locations
  - 2000 Atkins Borehole Location
  - 2000 Atkins Trial Pit Location
  - 2000 Trial Trench Location
  - 2011 Atkins Borehole Location
  - 2011 Atkins Trial Pit Location
  - 2011 Vapour Well

- LEGEND**
- Foul Drainage
  - Surface Drainage
  - Combined Drainage
  - Electricity
  - Electricity High Voltage
  - Electricity Low Voltage
  - Gas
  - Ground Probing Radar
  - Water
  - Cable Television
  - Close Circuit Television
  - Communication
  - British Telecom
  - Compressed Air
  - Offset Fill-Line
  - Oil Pipe
  - Pipe
  - Ventilation
  - Fuel Line
  - Vapour Recovery
  - Gauge Line
  - Telemetry
  - Fire Optics
  - Unknown
  - Fence
  - Edge of Canopy
  - Gully Run

|     |             |          |
|-----|-------------|----------|
| 0   | First Issue | 27/01/21 |
| REV | COMMENT     | DATE     |

Columbus House  
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Client  
**nationalgrid**

Project  
Arundel Gas Works  
Ford Road, Arundel

Title  
Site Investigation Locations

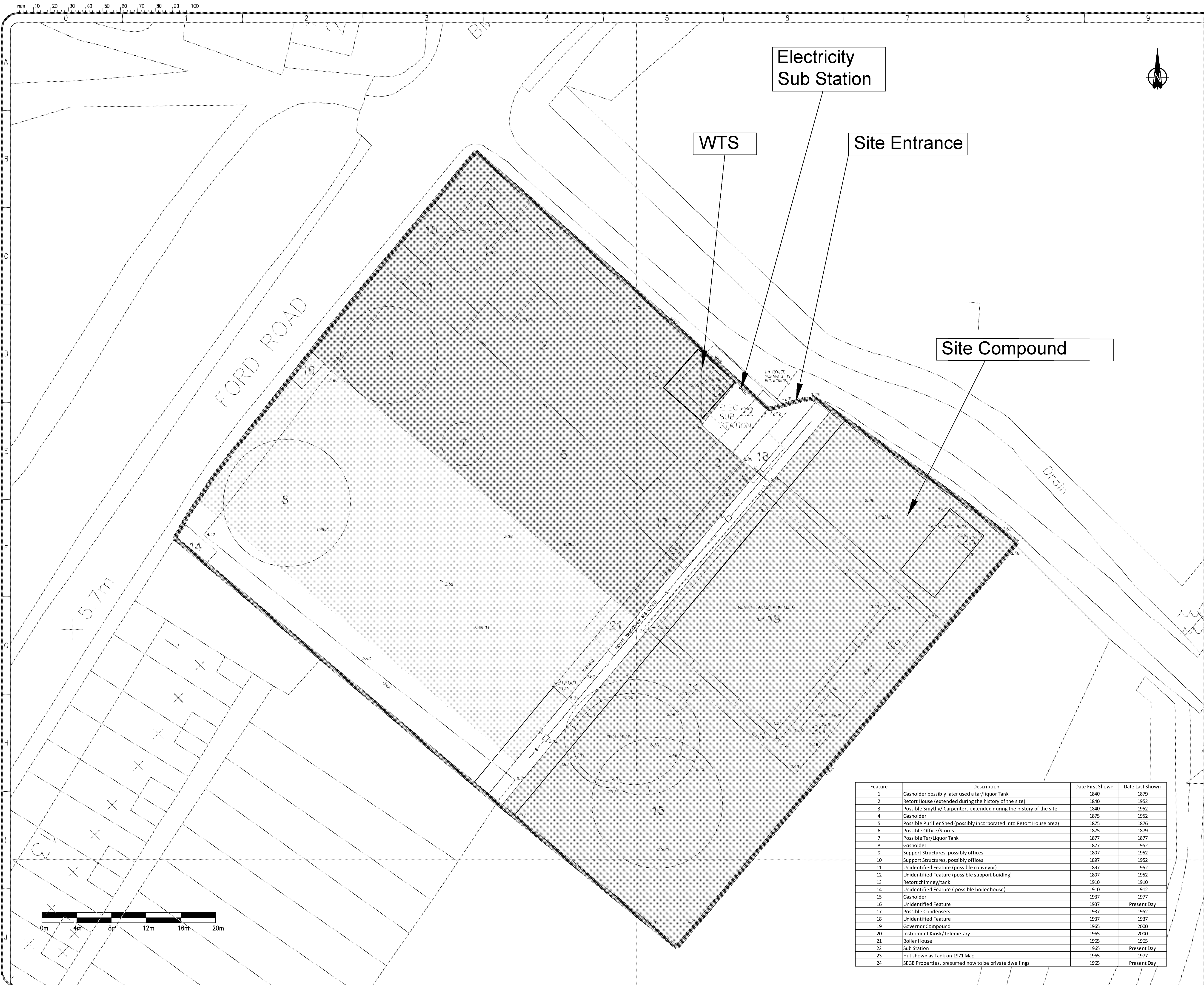
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| Drawn by | Checked | Date     | Authorised | Date     |
| CEP      | SG      | 27/01/21 | MH         | 27/01/21 |

|                |          |     |       |
|----------------|----------|-----|-------|
| Original Scale | Date     | Rev | Paper |
| 1:200          | 27/01/21 | 0   | A1    |

Drawing Number  
D1820/5045/A3

| Feature | Description                                                           | Date First Shown | Date Last Shown |
|---------|-----------------------------------------------------------------------|------------------|-----------------|
| 1       | Gasholder possibly later used as a tar/liquor Tank                    | 1840             | 1879            |
| 2       | Retort House (extended during the history of the site)                | 1840             | 1952            |
| 3       | Possible Smyth/ Carpenters extended during the history of the site    | 1840             | 1952            |
| 4       | Gasholder                                                             | 1875             | 1952            |
| 5       | Possible Purifier Shed (possibly incorporated into Retort House area) | 1875             | 1876            |
| 6       | Possible Office/Stores                                                | 1875             | 1879            |
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| 15      | Gasholder                                                             | 1937             | 1977            |
| 16      | Unidentified Feature                                                  | 1937             | Present Day     |
| 17      | Possible Condensers                                                   | 1937             | 1952            |
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| 19      | Governor Compound                                                     | 1965             | 2000            |
| 20      | Instrument Kiosk/Telemetry                                            | 1965             | 2000            |
| 21      | Boiler House                                                          | 1965             | 1965            |
| 22      | Sub Station                                                           | 1965             | Present Day     |
| 23      | Hut shown as Tank on 1971 Map                                         | 1965             | 1977            |
| 24      | SEG8 Properties, presumed now to be private dwellings                 | 1965             | Present Day     |





Legend

- National Grid Property Holdings Site Boundary
- Site Compound
- Water Treatment System
- Area 1
- Area 2
- Area 3
- Area 4
- Surface Water Easement
- Historical Locations

|     |                                |          |
|-----|--------------------------------|----------|
| 1   | Surface Water Easement Amended | 08/03/21 |
| 0   | First Issue                    | 27/01/21 |
| REV | COMMENT                        | DATE     |

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Client  
**nationalgrid**

Project  
Arundel Gas Works  
Ford Road, Arundel

Title  
Proposed Remediation  
Areas

|          |         |          |            |          |
|----------|---------|----------|------------|----------|
| Drawn by | Checked | Date     | Authorised | Date     |
| GEP      | SG      | 27/01/21 | MH         | 27/01/21 |

|                |          |     |       |
|----------------|----------|-----|-------|
| Original Scale | Date     | Rev | Paper |
| 1:200          | 27/01/21 | 1   | A1    |

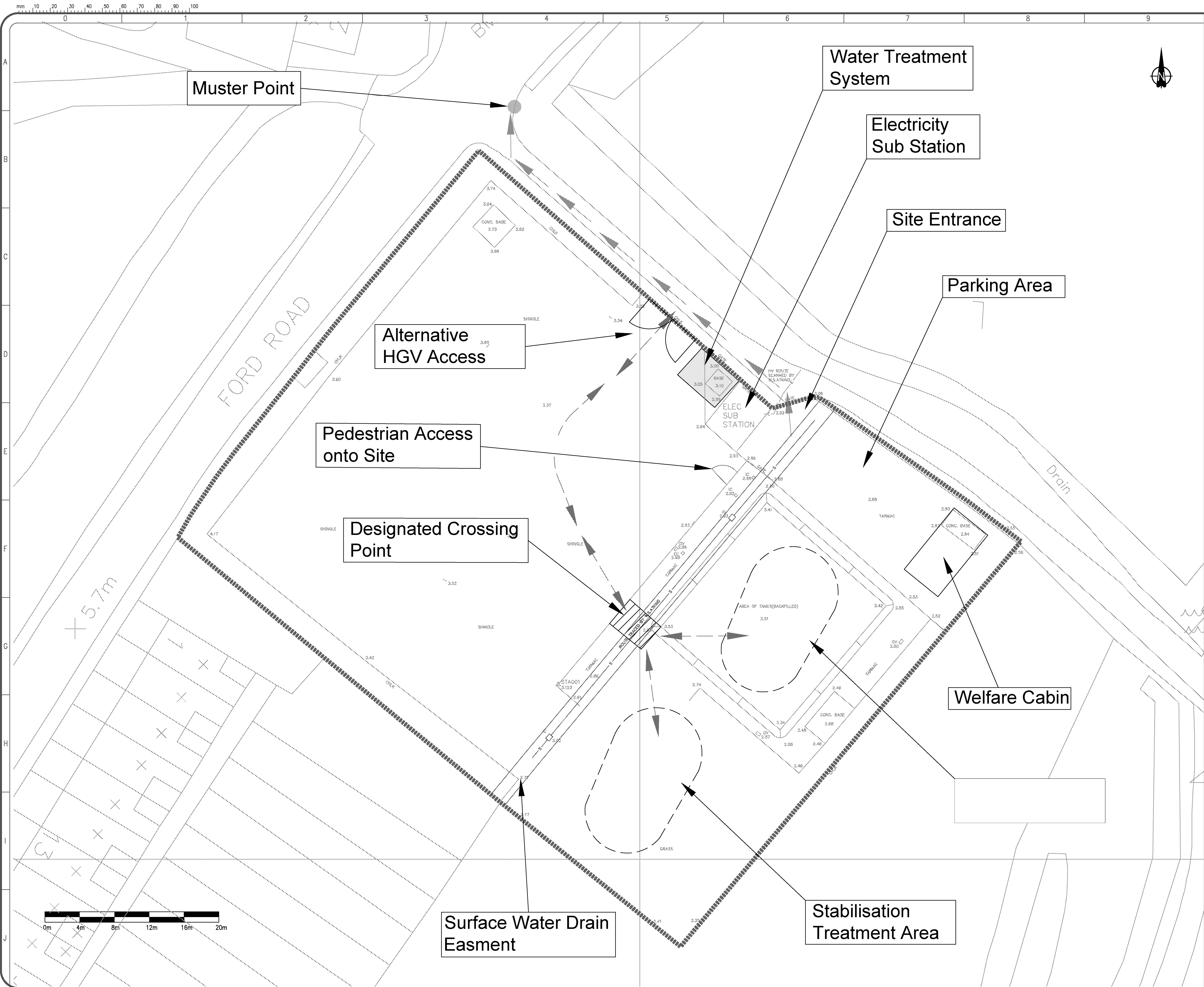
Drawing Number  
D1820/5045/A4

| Feature | Description                                                           | Date First Shown | Date Last Shown |
|---------|-----------------------------------------------------------------------|------------------|-----------------|
| 1       | Gasholder possibly later used as tar/liquor Tank                      | 1840             | 1879            |
| 2       | Retort House (extended during the history of the site)                | 1840             | 1952            |
| 3       | Possible Smythy/ Carpenters extended during the history of the site   | 1840             | 1952            |
| 4       | Gasholder                                                             | 1875             | 1952            |
| 5       | Possible Purifier Shed (possibly incorporated into Retort House area) | 1875             | 1876            |
| 6       | Possible Office/Stores                                                | 1875             | 1879            |
| 7       | Possible Tar/Liquor Tank                                              | 1877             | 1877            |
| 8       | Gasholder                                                             | 1877             | 1952            |
| 9       | Support Structures, possibly offices                                  | 1897             | 1952            |
| 10      | Support Structures, possibly offices                                  | 1897             | 1952            |
| 11      | Unidentified Feature (possible conveyor)                              | 1897             | 1952            |
| 12      | Unidentified Feature (possible support building)                      | 1897             | 1952            |
| 13      | Retort chimney/tank                                                   | 1910             | 1910            |
| 14      | Unidentified Feature ( possible boiler house)                         | 1910             | 1912            |
| 15      | Gasholder                                                             | 1937             | 1977            |
| 16      | Unidentified Feature                                                  | 1937             | Present Day     |
| 17      | Possible Condensers                                                   | 1937             | 1952            |
| 18      | Unidentified Feature                                                  | 1937             | 1937            |
| 19      | Governor Compound                                                     | 1965             | 2000            |
| 20      | Instrument Kiosk/Telemetry                                            | 1965             | 2000            |
| 21      | Boiler House                                                          | 1965             | 1965            |
| 22      | Sub Station                                                           | 1965             | Present Day     |
| 23      | Hut shown as Tank on 1971 Map                                         | 1965             | 1977            |
| 24      | SEGB Properties, presumed now to be private dwellings                 | 1965             | Present Day     |









- Legend
- \*\*\*\*\* National Grid Property Holdings Site Boundary
  - Celtic Site Compound
  - Muster Point
  - Egress Route
  - HGV Route
  - Surface Water Easment

|                                                                                                                                                                                    |                               |                  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|------------------|
| 1                                                                                                                                                                                  | Surface Water Easment Amended | 08/03/21         |
| 0                                                                                                                                                                                  | First Issue                   | 27/01/21         |
| REV                                                                                                                                                                                | COMMENT                       | DATE             |
| <div><div>Celtic enGlobe</div><div>Columbus House<br/>Village Way<br/>Cardiff<br/>CF15 7NE<br/>029 2036 8636</div><div>enquiries@celtic-ltd.com<br/>www.celtic-ltd.com</div></div> |                               |                  |
| Client<br>nationalgrid                                                                                                                                                             |                               |                  |
| Project<br>Arundel Gas Works<br>Ford Road, Arundel                                                                                                                                 |                               |                  |
| Title<br>Proposed Traffic<br>Management Plan                                                                                                                                       |                               |                  |
| Drawn by<br>CEP                                                                                                                                                                    | Checked<br>SG                 | Date<br>27/01/21 |
| Original Scale<br>1:200                                                                                                                                                            | Date<br>27/01/21              | Rev<br>1         |
| Drawing Number<br>D1820/5045/A6                                                                                                                                                    |                               | Paper<br>A1      |

**APPENDIX B      HUMAN HEALTH RISK ASSESSMENT ADDENDA**



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## APPENDICES

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## **1.0 GENERAL OUTLINE OF METHODOLOGY**

This technical appendix provides human health vapour inhalation risk modelling outputs to support the CELTIC remediation works and should be read in conjunction with the main text of the Remediation Implementation and Verification Plan (Celtic-RIP). The modelling outputs are utilised within the RIP to assist with the setting of relevant Site Assessment Criteria (SACs) for the remediation works.

The preliminary conceptual model in the Celtic-RIP main text identified relevant pollutant linkages for human health commercial on-site and residential off-site receptors associated with the inhalation of sufficiently volatile organic substances and recommended detailed human health assessment and associated CLEA modelling. A verified cover layer will be placed across the NGPH site and this is not a contamination source (see preliminary assessment in the main Celtic-RIP).

The detailed assessment has been undertaken within the 2009 DEFRA/Environment Agency (EA) SR3 CLEA (contaminated land exposure model) framework. The 2009 CLEA methodology has been amended to take into account relevant conceptual model updates outlined in documents associated with the 2015 LQM/CIEH Suitable for Use Levels (S4ULs), the 2014 DEFRA funded Category 4 Screening Levels (C4SL) and DEFRA CLEA model v1.071 with associated CLEA handbook Version 1.05. Additional guidance for VOC vapours/groundwater has been drawn from relevant current British Standards and other UK/worldwide guidance documents, including BS8485, BS8576, CIRIA C665/C682/C716/C735/C748, SoBRA-2017 groundwater GACs, the CIEH Ground Gas Handbook and USA technical references. The technical references are provided in Section 6.0.

The detailed assessment for the substances of concern, relevant pollutant linkages (RPLs) and critical receptor includes:

1. Substances of concern
2. Selection of health criteria values (HCV) and chemical parameters
3. Conceptual exposure model (CEM) that details the required pathway-specific exposure and fate & transport parameters
4. Modelling considerations for groundwater and vapour sources
5. CLEA modelling and pathway integration using an Excel CLEA-compliant spreadsheet model

The findings of the detailed assessment should only be used by competent persons for its intended purpose. It is beyond the scope of the assessment to present a detailed explanation of the underlying conceptual models, methodologies, supporting documents and their technical basis.

## 2.0 SUBSTANCES OF CONCERN

The substances of concern identified by the preliminary assessment are presented in Table 1. These are sufficiently volatile substances that are relevant to the active vapour inhalation pathways. The rationale for the choice of substances to be considered as sufficiently volatile is summarised in the Technical Notes in Appendix B1.

Benzene and toluene have their own aromatic C5-C7 & C7-C8 fractions (i.e. there are no other substances in these fractions) and modelling has not been duplicated for these two TPH fractions. Ethylbenzene, the xylene isomers and 16-PAHs will also be detected within the aromatic C8 to C12+ fractions, so it is important to ensure that potential 'double accounting' issues are considered when interpreting TPH/BTEX/PAH results.

**Table 1 - Detailed Assessment Human Health Substances of Concern**

| Potential Substances of Concern | Substances of Concern<br>Sufficiently Volatile<br>Calculate CLEA Outputs                                                            | Not Substances of Concern<br>Insufficiently Volatile, no RPLs<br>or below detection |
|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Risk banded TPH fractions       | Aliphatic C5-C16 fractions<br>Aromatic C8-C21 fractions<br>(see below)                                                              | <i>Non-Volatile</i><br>Aliphatic C16-C35 fractions<br>Aromatic C21-C35 fractions    |
| BTEX                            | BTEX<br><i>Benzene is solely aromatic C5-6<br/>Toluene is solely aromatic C7-8<br/>Ethylbenzene/ Xylenes also in Aromatic C8-10</i> | -                                                                                   |
| 16 PAHs                         | Naphthalene                                                                                                                         | Remaining PAHs                                                                      |
| Phenols                         | Modelled as Phenol                                                                                                                  | -                                                                                   |

### 3.0 HEALTH CRITERIA & CHEMICAL PARAMETERS

The UK published HCV used in the CLEA modelling are adult tolerable daily intakes (TDI) for threshold substances and index doses (ID) for non-threshold substances are drawn from the S4UL methodology (which also considers EA, EIC and C4SL resources).

The average adult mean daily intake (MDI) for the threshold health criteria are primarily drawn from the S4UL methodology (which also considers EA, EIC and C4SL resources). The exception is for the TPH fractions where more reasonable risk protective MDIs have been adopted in favour of the highly cautious (50% of the TDI) MDI values adopted by the S4UL approach. The adopted MDI for the TPH fractions are discussed and provided in Appendix B1.

The chemical-specific parameters required for the CLEA modelling are predominantly drawn from S4UL methodology, with additional parameters where required from EA-SR7, EA-TOX/SGV, EIC and C4SL resources.

Table 2 summarises the sources of the toxicological data, MDI and physiochemical parameters used in the CLEA modelling. The adopted parameters are presented in Appendix B2.

**Table 2 - Sources of Chemical Specific Parameters**

| Substances of Concern                                   | Toxicity Type    | HCV, MDI & Physiochemical Parameters                                                                            |
|---------------------------------------------------------|------------------|-----------------------------------------------------------------------------------------------------------------|
| Aliphatic C5-C16 fractions<br>Aromatic C8-C21 fractions | Threshold TDI    | S4UL/TPHCWG<br>See Appendix 1 for adopted MDI calculations as these are not based on 50% of TDI as used by S4UL |
| Benzene                                                 | Non-Threshold ID | S4UL/EA<br>Only substance in Aromatic C5-7 fraction                                                             |
| Toluene                                                 | Threshold TDI    | S4UL/EA<br>Only substance in Aromatic C7-C8 fraction                                                            |
| Ethylbenzene                                            | Threshold TDI    | S4UL/EA<br>Also in Aromatic C8-10                                                                               |
| Xylenes                                                 | Threshold TDI    |                                                                                                                 |
| Naphthalene                                             | Threshold TDI    | S4UL/EA<br>For soil-vapour, can also be considered via Aromatic C10-12 fraction                                 |
| Phenol                                                  | Threshold TDI    | S4UL/EA                                                                                                         |

## **4.0 CONCEPTUAL EXPOSURE MODEL**

### **4.1 Framework**

The baseline Conceptual Exposure Model (CEM) is drawn from the current S4UL conceptual approach, including default/baseline receptor & pathway assumptions and associated HCV, MDI and physiochemical parameters. The S4UL approach reflects the original CLEA guidance & conceptual exposure models detailed in SC050021 SR2, SR3, SR4 & SR7 and the associated original toxicological and soil guideline documents. The S4UL approach incorporates appropriate risk-protective amendments to the CLEA approach drawn from the 2014 C4SL methodology and provided in EA Excel CLEA Model v1.071 & associated Manual v1.05.

The S4UL methodology, which was published after the C4SL, continues the CLEA GAC/SGV approach based around 'tolerable'/'minimal' risk levels. This compares with the 'low level' of risk adopted by the C4SL methodology, which potentially provides a less cautious approach compared to the S4UL methodology. As such, the S4UL methodology only adopted C4SL changes to the CLEA-SR3 approach that were in keeping with the 'tolerable'/'minimal' risk ethos used in GAC/SGV calculation.

Justifications for the underlying S4UL conceptual approach are provided by the current S4UL documentation, which includes the main 2015 hard-copy publication, plus online FAQs and errata at [www.lqm.co.uk/publications/s4ul](http://www.lqm.co.uk/publications/s4ul). Detailed discussion of the S4UL/CLEA conceptual approach is beyond the scope of this technical appendix.

The CEM provides the modelling parameters, characterises the substances of concern, the critical receptor, the exposure scenario, ground conditions, source terms and averaging areas. To match the input requirements of the pathway algorithms, the CEM consists of the following elements:

- Critical Commercial Open Storage use receptor characteristics
- Critical Residential use receptor characteristics
- Relevant pollutant linkages (RPLs) for vapour inhalation
- Pathway exposure models and parameters
- Source terms & soil type properties
- Modelling considerations for groundwater and vapour sources
- Details of deviations from or amendments to the baseline S4UL approach

Any relevant amendments and/or deviations to the baseline S4UL conceptual approach are provided in the following sections, along with some commentary on the S4UL/C4SL conceptual approaches.

The additional pathway specific considerations for groundwater/soil-vapour sources with respect to the vapour inhalation pathways are also discussed in the following sections

The full set of modelling parameters are included in Appendix B2.

### **4.2 CLEA Modelling Software**

The modelling has been undertaken using a bespoke Excel spreadsheet model that is compliant with the S4UL/CLEA-SR methodologies/algorithms and provides outputs benchmarked to the soil S4UL GACs and the SoBRA Groundwater GACs (both of which were generated using the EA CLEA Excel-based model).

The bespoke CLEA model was developed by Peak Environmental Solutions Limited (PESL) and has been in use now for over a decade and has been benchmarked and updated over that time to keep in line with the UK good-practice approach to human health risk assessment. The bespoke model will be referred to as CLEA-PESL/2021 in this report.

A summary of the residential/commercial use benchmarking against selected published S4UL and SoBRA criteria is provided at the end of Appendix B2 and demonstrates a very good correlation with the EA model (minor discrepancies are due to the significant-figure rounding adopted by S4UL/SoBRA).

The CLEA-PESL/2021 model also implements the analytical solution to pathway integration and MDI contribution published in the Journal of Human and Ecological Risk Assessment by Dr Mengfang Chen. This analytical solution has been adopted in favour of the iterative 'goal-seek' solution used with in the EA-CLEA Model (which requires the EA CLEA model to be re-run after any changes parameter or model set up). Both these approaches seek to address a difficult mathematical problem provided by the CLEA '50% MDI intake rule' when integrating outputs from the oral and inhalation pathway (refer to CLEA-SR2 Section 3.6). Benchmarking/testing of the analytical solution used in CLEA-PESL/2021 with the EA CLEA model has shown excellent correlation, with only minor discrepancies (typically at the 3<sup>rd</sup>/4<sup>th</sup> significant figure), which are probably due to the iterative goal seek process rather than the analytical solution.

### 4.3 Critical Receptor Characteristics

The baseline exposure characteristics for the receptors are based on the standard S4UL exposures models. The S4UL baseline scenarios represent a CLEA-SR3/C4SL hybrid approach where selected changes to the CLEA-SR3 conceptual models have been adopted from the C4SL conceptual approach, (i.e. those that fit with the ethos of GAC/SGV calculation under the CLEA framework).

A principle change for vapour pathways under C4SL (and adopted by S4UL) was a revision of the CLEA-SR3 inhalation rates across all CLEA age classes. The C4SL/S4UL inhalation rates are based on 2011 mean USEPA values, which replaced the 2009-SR3 CLEA values (these were based on 2006 USEPA draft review values). The child daily inhalation rates went down (increasing model outputs) and the adult daily inhalation rates went up (decreasing modelling outputs).

In summary, the adopted critical receptors are as follows:

- Female Worker for on-site Commercial Open Storage Use
  - Female aged to 16 to 65: CLEA age class AC-17
  - Baseline S4UL parameters adopted
  - A site-specific commercial-use 9 hour/day working time adopted for Outdoor Working
  - *This replaces a standard general occupancy of 0.7 hour outside and 8.3 hours inside*
  - Generally comparable with the S4UL/CLEA standard commercial use
- Young Female Child for off-site Adjacent Residential Use
  - Female aged to 0 to 6: CLEA age classes AC 1 to 6
  - Baseline S4UL parameters adopted
  - Site specific two-storey terrace dwelling (see Section 4.5.1)
  - *This is in place of the CLEA-SR3 'Small Terrace' typically used for generic assessments*
  - Generally comparable with S4UL/CLEA standard residential use

The remainder of the baseline S4UL conceptual exposure models and receptor characteristics remain unchanged and have been adopted by the assessment. The adopted critical receptor characteristics are presented in the modelling results in Appendix B2.

#### 4.4 Relevant Pollutant Linkages

The identified RPLs associated with air vapour inhalation pathways and the adopted source media are summarised in Table 3. The pathway specific parameters are included in Appendix B2 and discussed as necessary in the following sections.

**Table 3 - Human Health RPLs**

| Source Media                                                                                                                        | Human Health RPLs         | General Source/Pathway Profile                                                                                                                                                                                                                   |
|-------------------------------------------------------------------------------------------------------------------------------------|---------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Commercial Open Storage Use                                                                                                         |                           |                                                                                                                                                                                                                                                  |
| Soils below Cover Layer (Soil)<br>Unsaturated Zone                                                                                  | Outdoor vapour inhalation | 1 m to 3 m thick unsaturated zone                                                                                                                                                                                                                |
| Groundwater (GW)                                                                                                                    |                           | Water Table at 1 m to 3 m bgl                                                                                                                                                                                                                    |
| Sources assumed to be under all the NGPH Land                                                                                       |                           |                                                                                                                                                                                                                                                  |
| Adjacent Residential Use                                                                                                            |                           |                                                                                                                                                                                                                                                  |
| Boundary Strip Only<br>Soils below Cover Layer (Soil-B & Soil-VapB)<br>Unsaturated Zone                                             | Indoor vapour inhalation  | Generally a minimum of ~7 m lateral migration distance to closest off-site building wall from NW site boundary. Unsaturated-zone soil and groundwater sources for off-site building receptors restricted to Boundary Strip along the NW boundary |
| Boundary Strip Only<br>Groundwater (GW-B)                                                                                           |                           |                                                                                                                                                                                                                                                  |
| Site Sources for Indoor Air pathway restricted to a 5m wide Boundary Strip along NW Boundary (See main text Celtic-RIP for details) |                           |                                                                                                                                                                                                                                                  |
| Soils below Cover Layer (Soil)<br>Unsaturated Zone                                                                                  | Outdoor vapour inhalation | 1 m to 3 m thick unsaturated zone                                                                                                                                                                                                                |
| Groundwater (GW)                                                                                                                    |                           | Water Table at 1 m to 3 m bgl                                                                                                                                                                                                                    |
| Sources assumed to be under all the NGPH Land                                                                                       |                           |                                                                                                                                                                                                                                                  |

The surface of the remediated site will comprise a robust verified cover layer (permeable hardstanding) and remnant areas of existing impermeable hardstanding. The bordering residential land includes the building cover, hardstandings (parking & hard landscaping) and soft garden & landscaping areas.

The verified cover layer materials, combined with areas of impermeable hardstanding, are not contamination sources (see preliminary assessment in the main Celtic-RIP). This means that there will be no contamination sources at surface, so there will be no active soil ingestion, dermal contact, dust inhalation pathways or vapour inhalation pathways associated with these surface cover materials.

For human health, the primary source of VOC vapours are soil and groundwater sources. Any entrained residual/immobile NAPL sources (at the water table and within the unsaturated/saturated zones) are modelled as being part of the adopted soil/groundwater source terms.

For the outdoor inhalation RPLs (on/off-site receptors), the sources are assumed to be under all of the NGPH land. For the off-site residential building receptors to the northwest (i.e. the off-site indoor vapour inhalation RPL), the conceptual model considers lateral unsaturated zone VOC vapour migration (diffusion) from soil/groundwater sources within the northwestern 'Boundary Strip' (see the main Celtic-RIP text). A S4UL/CLEA/C4SL approach of considering a non-diminishing source has been adopted for the RPLs.

The terraced row of residential dwelling to the northwest along Ford Road are set back from the NGPH property boundary, with the eastern external wall of No 1 California Terrace ~7 m from the NGPH boundary.

The boundary strip represents a 5 m wide zone along the part of the northwestern boundary to ensure that off-site building vapour intrusion risks from VOC vapour sources within the NGPH land and close to NW boundary are considered by the assessment via lateral unsaturated zone vapour migration to the closest building. The use of the boundary strip approach is in keeping with our experience of soil VOC vapour assessment/investigation and discussions with respect to vertical/lateral 'screening distances' in CIRIA 682 and SoBRA-2017.

Given that the existing off-site residential receptors are lateral/up-gradient to overall groundwater flow, it is implausible for sources further into the site to pose a lateral or direct groundwater migration risk to the adjacent properties to the northwest. The groundwater risk assessment (see main Celtic-RIP) also indicates that tidal fluctuation effects on groundwater are unlikely to lead to significant groundwater flow across the NW boundary. The site investigation works to date also indicate that the main areas of contamination of potential concern are in the northeastern site area and not along the northwestern site margin.

There is also a single residential property to the north of Ford Road; this is not considered to be a plausible off-site building receptor with respect to lateral vapour migration from potential sources along the eastern part of the northern site boundary. This is in keeping with our experience of soil VOC vapour assessment/investigation and discussions with respect to the lateral 'screening distances' in CIRIA 682 and SoBRA-2017. It is also noted that: (i) the centre of the building footprint is ~25 m from the northwestern site boundary; (ii) the building is up-groundwater gradient of the site and; (iii) vapours would have to diffuse a distance of 25 m under the main road and then into the property, which is considered implausible.

For completeness, soil vapour modelling outputs have also been provided for the adjacent residential use to allow future comparison against any boundary soil vapour data should the need arise.

## **4.5 Pathway Specific Considerations**

### **4.5.1 Indoor Vapour Inhalation & Building Properties**

#### **On Site**

There will be no occupied permanent buildings on the NGPH land following remediation for an open storage use.

#### **Off-Site**

The adjacent residential terraced dwellings to the northwest have been modelled as follows:

- As a two-storey dwelling using the principles/parameters of the CLEA SR3 standard terrace dwellings (as adopted by the S4UL methodology).
- A site-specific modelled building footprint of 8.1 m by 4.6 m. Although the EA-CLEA model only allows square building footprints, CLEA-PESL/2021 allows modelling of square and rectangular building footprints.
- The footprint measurements are based on the smaller No 1 California Terrace, without the rear extension.



- The adopted building will be risk protective of the terrace row as smaller building footprints provide lower modelling outputs. Not considering the rear extension footprint for the modelled building will provide lower outputs.
- The modelled building provides a slightly larger footprint than the 5.3 m by 5.3 m CLEA-SR3 'Small Terrace' building typically used for generic assessments.
- The modelling assumes that the off-site buildings do not have vapour protection measures.
- The modelling assumes that the off-site buildings do not have basements. This will be risk protective as buildings modelled with basement provide higher outputs.
- The source is conservatively modelled as being underneath the building at a source separation depth equal to the minimum lateral migration distance of 7m. Lateral migration would be expected to provide more attenuation than an equivalent vertical source separation (e.g. Yao et al 2014).
- Baseline S4UL parameters are adopted for the remaining building properties.
- The adopted building properties are presented in Appendix B2.

Overall, the standard CLEA/S4UL modelling approach for vapour intrusion across a building foundation zone is considered sufficiently risk protective for the adjacent terraced properties, especially given the other modelling assumptions and the adoption of the boundary-strip approach in the Celtic-RIP. Further discussions of the CLEA approach to vapour intrusion across foundations are provided by CLEA SR3 Section 10.1.4 and SoBRA-2017.

The 7m source separation (lateral modelling distance) is considered risk protective. It would have been justified to have used the centre line of the dwelling and the centre line of the boundary strip (to give the average lateral migration distance from adopted boundary strip source to receptor); this would increase the average source separation to ~12 m, which would significantly increase modelling outputs.

### **Other Modelling Options**

The assessment uses a calculated soil-type dependant 'soil gas ingress rate' and the CLEA/S4UL indoor air 'correction factors' for TPH, BTEX and naphthalene for soil sources. This indoor air correction factors have not been applied to the groundwater and soil vapour modelling outputs; this will provide lower modelling outputs for groundwater/soil-vapour and is risk protective.

The 'No Void' reference in the CLEA-PESL/2021 modelling output sheets in Appendix 2 relates to an additional modelling option for the indoor air vapour pathway for residential use; if used, this option can assist in accounting for the effect of a ventilated void in a building foundation. The ventilated void option has not been used in this assessment; the 'No Void' check box in CLEA-PESL/2021 confirms that this modelling option is not enabled.

#### **4.5.2 Outdoor Vapour Inhalation**

The CLEA sub-surface model has been used for the outdoor air pathway, with the source modelled underneath all the NGPH land for both on and off-site receptors. Deviations for the baseline S4UL conceptual approach are detailed below.

Southampton has been adopted as the closest and most appropriate of the available CLEA SR3 cities for the outdoor air pathway. The default city in the S4UL approach is Newcastle, which will yield slightly lower modelling outputs.

A site-specific area of 0.5 hectares from the CLEA site area database has been adopted for the outdoor air pathway in line with the site area of ~0.44 hectares. This is lower than the S4UL baseline commercial use area of 2 hectares and much higher than the S4UL baseline residential use area of 0.01 hectares. Larger site areas will yield higher outdoor VOC vapour air concentrations from sub-surface soils.

Additional specific further technical modelling considerations in relation to the pathway are detailed in the Technical Notes in Appendix B1.

#### 4.5.3 Summary of Soil and Groundwater Profile

A conservative CLEA sandy loam soil (as adopted by S4UL/C4SL) with a low site wide SOM of 1% has been adopted for the modelling and is considered generally risk-protective and appropriate for the range of on/off-site soils. Off-site soils are only relevant for the indoor air RPL via lateral vapour migration from the NW site boundary-strip. The specific soil properties are presented in Appendix B2.

Note: of the published CLEA soil types, a CLEA 'sand soil' would provide the lowest 'worst-case' CLEA modelling outputs; the 'sandy loam' soil type provides the next lowest modelling outputs after the 'sand soil'. As such, the 'sandy loam' soil is considered to represent a balanced risk-protective modelling approach for a wide range of soils (as evidenced by adoption in the SGV/S4UL/C4SL approaches).

The modelled soil and groundwater source separation distances are summarised in Table 4

For the off-site receptor to the west, the conceptual model assumes that soil vapours from site sources have to the potential to migrate laterally via the unsaturated zone. The modelled distance is 7 m, which approximates to the shortest lateral distance from the site boundary to the closest building wall. The modelling algorithms then consider the additional thickness of building foundations.

**Table 4 - Summary of Modelling Source Separation Distances**

| Source Term                                                                                                                                         | On-site Commercial<br>Open Storage Use              | Off-site Residential Use                                                                                                                                       |                                                     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|
|                                                                                                                                                     | Outdoor Vapour                                      | Indoor Vapour                                                                                                                                                  | Outdoor Vapour                                      |
| Conceptual Approach                                                                                                                                 | Modelled Vertically<br>Source beneath all NGPH Land | Modelled Laterally<br>Sources modelled on NW<br>Boundary with Residential<br>Land<br>Building Receptor Offsite<br>'Boundary Strip' approach<br>discussed above | Modelled Vertically<br>Source beneath all NGPH Land |
| Soil & Soil Vapour<br>Source Separation                                                                                                             | 1 m                                                 | 7 m                                                                                                                                                            | 1 m                                                 |
| Groundwater<br>Source Separation                                                                                                                    | 1.5 m                                               | 7 m                                                                                                                                                            | 1.5 m                                               |
| Notes: The Cover Layer materials are not a contamination source; all depths relative to on-site final finished levels and off-site existing levels. |                                                     |                                                                                                                                                                |                                                     |

#### 4.5.4 Modelling of a Groundwater Source

The original USEPA documents used by CLEA-SR3 as the source for the vapour inhalation pathway algorithms (namely the USEPA document '*User's Guide for Evaluating Subsurface Vapour Intrusion*

into Buildings') also provide additional algorithms required for generating modelling outputs from a groundwater source of soil vapours.

The elements used in CLEA-PESL/2021 from the USEPA approach are the Van Genuchten water retention curve equation, the 'Deff' equation across a capillary zone and a Fick's Law based equation. A further equation is then used to estimate the vertical thickness of a soil-type dependant capillary zone/fringe of height Lcz above the water table. These long-standing (and extensively used) equations remain unchanged in the most recent 2017 J&E Version-6 document (see references).

The adopted additional algorithms add a lower permeability layer of height Lcz above the water table, so that modelled unsaturated zone soil profile becomes a two layer system. The current CLEA-SR3 equations for partitioning, unsaturated zone 'Deff' and buildings etc are then used for the remainder of the unsaturated zone thickness and vapour intrusion into the modelled building.

As the capillary zone will be of lower effective permeability for vapour diffusion due to increased pore-water content, consideration of the capillary zone raises model outputs. Ignoring the capillary zone effect would be conservative and provide lower modelling outputs.

For soil vapour modelling outputs for soil and groundwater sources at the same depth, the capillary fringe effect is ignored by CLEA-PESL/2021 to ensure the vapour modelling outputs are the same.

The groundwater element of CLEA-PESL/2021 (without the capillary zone) has been benchmarked to the SoBRA-2017 groundwater GACs (see Appendix B2).

#### **4.5.5 Modelling Sensitivity to Soil Parameters**

The following outlines the interdependence of the vapour inhalation model outputs on the soil parameters:

- Soil output as mg/kg: Dependent on foc & soil type
- Groundwater Output as mg/l: Independent of foc; dependant on soil type
- Soil Vapour Output as mg/m<sup>3</sup>: Independent of foc; dependant on soil type
- Csat Vapour Output as mg/m<sup>3</sup>: Independent of foc & soil type

#### **4.5.6 Saturation Limits**

Many of the CLEA algorithms depend on partitioning processes that are primarily based on linear chemical behaviour observed at low concentrations in soil and water. The CLEA methodology includes a number of checks to highlight boundary conditions when the simple linear relationships may not apply. These checks are then used to assist in the interpretation of the CLEA modelling outputs. The main checks are:

- Saturated aqueous concentrations
- Saturated vapour Concentration and associated soil concentration
- Presence of NAPL
- Saturated groundwater concentrations

The technical basis of the saturation limits are further discussed in Technical Notes in Appendix B1. The results of the saturated calculations are detailed in Appendix B2.

Concentrations exceeding the saturation limits may indicate the presence of non-aqueous phase liquid (NAPL) and this should be considered when assessing the CLEA model outputs. However, the saturation limits are theoretical and for contaminants that are strongly sorbed to soils (i.e. have high  $K_{oc}$ ) and/or a low aqueous solubility/vapour pressure, the exceedance of a saturation limits does not necessarily mean that NAPL is present.

## 5.0 CLEA MODELLING RESULTS

The CLEA modelling outputs (by-pathway and integrated values) are summarised in Table 5 to Table 7 and presented in Appendix B2. The values have been rounded as appropriate, with values in provided brackets where they are above theoretical saturation limits. The reporting protocols are detailed in Appendix B1 to ensure that the reported model outputs are credible.

**Table 5 - Soil Modelling Outputs in mg/kg**

| Substance              | Open Storage | Adjacent Residential Use |             |            |
|------------------------|--------------|--------------------------|-------------|------------|
|                        | Outdoor Air  | Indoor Air               | Outdoor Air | Combined   |
| Aliphatic TPH C5-C6    | (60,300)     | (710)                    | (41,300)    | (698)      |
| Aliphatic TPH C6-C8    | (>100,000)   | (1,730)                  | (>100,000)  | (1700)     |
| TPH Aliphatics C8-C10  | (38,200)     | (454)                    | (26,400)    | (447)      |
| TPH Aliphatics C10-C12 | (>100,000)   | (2,250)                  | (>100,000)  | (2210)     |
| TPH Aliphatics C12-C16 | (>100,000)   | (18,900)                 | (>100,000)  | (18500)    |
| TPH Aromatics C8-C10   | (63,900)     | 584                      | (34,000)    | 574        |
| TPH Aromatics C10-C12  | (>100,000)   | (3,180)                  | (>100,000)  | (3130)     |
| TPH Aromatics C12-C16  | (>100,000)   | (34,900)                 | (>100,000)  | (34300)    |
| TPH Aromatics C16-C21  | (>100,000)   | (>100,000)               | (>100,000)  | (>100,000) |
| Benzene (Aro C5-C7)    | 296          | 4.2                      | 246         | 4.1        |
| Toluene (Aro C7-C8)    | (>100,000)   | (10,200)                 | (>100,000)  | (10100)    |
| Ethylbenzene           | (68,700)     | (957)                    | (56,500)    | (941)      |
| Xylene Isomers         | (70,400)     | (910)                    | (53,700)    | (894)      |
| Naphthalene            | (22,700)     | (268)                    | (15,900)    | (264)      |
| Phenol                 | (381,000)    | 1,290                    | (>100,000)  | 1,290      |

**Table 6 - Groundwater Modelling Outputs in mg/l**

| Substance              | Open Storage | Adjacent Residential Use |             |          |
|------------------------|--------------|--------------------------|-------------|----------|
|                        | Outdoor Air  | Indoor Air               | Outdoor Air | Combined |
| Aliphatic TPH C5-C6    | (>10,000)    | 13.7                     | (>10,000)   | 13.7     |
| Aliphatic TPH C6-C8    | (>10,000)    | (10.6)                   | (>10,000)   | (10.6)   |
| TPH Aliphatics C8-C10  | (1,300)      | 0.41                     | (899)       | 0.41     |
| TPH Aliphatics C10-C12 | (837)        | (0.26)                   | (579)       | (0.26)   |
| TPH Aliphatics C12-C16 | (315)        | (0.10)                   | (218)       | (0.10)   |
| TPH Aromatics C8-C10   | (>10,000)    | 9.7                      | (>10,000)   | 9.7      |
| TPH Aromatics C10-C12  | (>10,000)    | (31)                     | (>10,000)   | (31)     |
| TPH Aromatics C12-C16  | (>10,000)    | (140)                    | (>10,000)   | (140)    |
| TPH Aromatics C16-C21  | (>10,000)    | (655)                    | (>10,000)   | (655)    |
| Benzene (Aro C5-C7)    | (2,350)      | 0.95                     | (1,950)     | 0.94     |
| Toluene (Aro C7-C8)    | (>10,000)    | (1,066)                  | (>10,000)   | (1,065)  |
| Ethylbenzene           | (>10,000)    | 52                       | (>10,000)   | 52       |
| Xylene Isomers         | (>10,000)    | 48                       | (>10,000)   | 48       |
| Naphthalene            | (>10,000)    | 7.5                      | (9,570)     | 7.5      |
| Phenol                 | (>10,000)    | 2,920                    | (>10,000)   | 2,910    |

**Table 7 - Soil Vapour Modelling Outputs in mg/m<sup>3</sup>**

| Substance              | Adjacent Residential Use |             |           |
|------------------------|--------------------------|-------------|-----------|
|                        | Indoor Air               | Outdoor Air | Combined  |
| Aliphatic TPH C5-C6    | >10,000                  | (>10,000)   | >10,000   |
| Aliphatic TPH C6-C8    | (>10,000)                | (>10,000)   | (>10,000) |
| TPH Aliphatics C8-C10  | >10,000                  | (>10,000)   | >10,000   |
| TPH Aliphatics C10-C12 | (>10,000)                | (>10,000)   | (>10,000) |
| TPH Aliphatics C12-C16 | (>10,000)                | (>10,000)   | (>10,000) |
| TPH Aromatics C8-C10   | 1,550                    | (>10,000)   | 1,528     |
| TPH Aromatics C10-C12  | 1,540                    | (>10,000)   | 1,520     |
| TPH Aromatics C12-C16  | (1,498)                  | (>10,000)   | (1,470)   |
| TPH Aromatics C16-C21  | (458)                    | (>10,000)   | (450)     |
| Benzene (Aro C5-C7)    | 71                       | (>10,000)   | 70        |
| Toluene (Aro C7-C8)    | (>10,000)                | (>10,000)   | (>10,000) |
| Ethylbenzene           | 4,600                    | (>10,000)   | 4,530     |
| Xylene Isomers         | 3,378                    | (>10,000)   | 3,320     |
| Naphthalene            | 44                       | (4,000)     | 43        |
| Phenol                 | 25                       | (612)       | 24        |

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## **APPENDIX B1**

### **CLEA TECHNICAL NOTES**

## **VOLATILITY AND TOXICITY SCREENING**

The USEPA screening mechanism for the identification of compounds likely to have sufficient volatility or toxicity to present a risk via vapour intrusion is described in the CIRIA C682 document and taken from the USEPA guidance, referenced in the main report. The screening accounts for likely volatility using Henry's law constant and likely toxicity using a modified health criteria value.

### **Sufficient Volatility Screening**

The first stage of the screening considers Henry's law constant. Other existing guidance documents, e.g. SNIFFER and USEPA (both referenced in the main report) indicate that if a compound has a dimensionless Henry's law constant of less than 0.0004 then it is considered to be a risk via vapour intrusion and emission pathways. The USEPA screening mechanism follows the same principle and recommends the use of properties appropriate for 10°C.

In addition to organic substances, chemical reactions involving cyanide may also form gases. However, the cyanide compounds typically found on brownfield sites are generally iron-complexed with a low potential to form gases. This means that the risk posed by cyanide gas is likely to be negligible and will not be considered by the risk assessment.

### **Sufficient Toxicity Screening**

Screening for sufficient toxicity requires information about the toxicity of the compound via inhalation exposure. The theoretical saturated soil vapour concentration of the pure compound is calculated and compared with a modified health criteria value based on inhalation exposure.

The theoretical saturated soil vapour concentration of the pure compound is calculated using the method detailed in SR3. The modified health criteria value is calculated by modifying the TDSI or ID (in  $\mu\text{g}/\text{kg}/\text{bw}/\text{day}$ ) to an acceptable air concentration (in  $\mu\text{g}/\text{m}^3$ ) and compared with the calculated vapour phase concentration.

If the calculated vapour phase concentration is less than the modified HCV then it is likely that the toxicity of the compound relating to the vapour intrusion and exposure pathway will not present a significant risk to human health. For compounds with a very low toxicological threshold for vapour inhalation or where a compound is close to failure then professional judgement and other lines of evidence may be used to inform the decision.

## **OUTDOOR VAPOUR INHALATION ALGORITHMS**

For outdoor air vapour inhalation, CLEA SR3/SR4 uses the concept of surface soils and subsurface soils. For surface soils, SR3/SR4 uses SR3 Equation 10.2; for sub-surface soils, SR4 recommends the use of SR4 equation 4.1. Where appropriate, the risk assessment has adopted SR3 Equation 10.2 for surface soils as recommended by SR3/SR4. The pathway actually uses an algorithm modelling source depth of 10 cm for all soils in the mixing zone as this is a necessary modelling anomaly due to the technical basis of the algorithm adopted by SR3.

The algorithm for shallow soils (SR3 Equation 10.2) also includes a time parameter that is used to estimate the average emission flux over the modelled exposure duration (with the emission flux decreasing exponentially over time). For default exposure durations for residential and commercial uses are six years and 49 years respectively.

For soil averaging areas not at surface, SR4 recommends the use of SR4 equation 4.1. There is no time parameter in SR4 equation 4.1. The groundwater calculations for the outdoor air pathway use SR4 equation 4.1. There is no time parameter in SR4 equation 4.1.

## **SATURATED AQUEOUS SOIL CONCENTRATIONS**

The SR3 document provides equations to calculate the theoretical soil concentration ( $C_{satw}$ ) where the resulting soil pore water concentration of a chemical may exceed the maximum aqueous solubility of the pure chemical in water at ambient temperature and pressure (SR3 Equation 5.11 & 5.12).

Where model output exceeds  $C_{satw}$  then uncertainty in the partitioning approach could affect the reliability of the model output assessment, e.g. leading to an overestimate via plant uptake and the inhalation of vapours.

## **SATURATED SOIL VAPOUR CONCENTRATIONS**

The saturated soil vapour concentrations have been calculated for each of the sufficiently volatile substances of concern using CLEA algorithms. The  $C_{sat}$  concentration is typically expressed as a vapour concentration ( $C_{sat-vap}$ ) in  $mg/m^3$ , but can also be expressed as a soil concentration in  $mg/kg$  ( $C_{satv}$ ). The algorithms to calculate  $C_{sat-vap}$  provide an upper limit vapour concentration in the soil pores; alternatively, this can be expressed as the lowest soil concentration capable of generating the upper bound vapour concentration. The  $C_{sat-vap}$  vapour concentration (in  $mg/m^3$ ) for a substance is the same irrespective of whether the source is soil, product or water (the  $C_{sat}$  concentration is soil-type dependant).

The  $C_{sat-vap}$  algorithms are based on the saturated vapour pressure (i.e. the source substances are assumed to be dissolved in water). Where values are not available in SR7 or LQM, the values have been corrected for ambient soil temperature by one of two methods detailed in a reference provided in SR7 (Property Estimation Methods for Chemicals, see references in main report). If the calculated vapour pressure at ambient soil temperature is above atmospheric pressure, then atmospheric pressure has been adopted as the vapour pressure at ambient soil temperature.

Vapour pressures for TPH fractions have been taken from TPHCWG documentation, with the conservative assumption that quoted values are for 10°C. This approach is consistent with LQM.

## **SATURATED GROUNDWATER CONCENTRATIONS**

Where groundwater output exceeds the theoretical solubility of a substance then uncertainty in the partitioning approach could affect the reliability of the model output assessment, e.g. leading to an overestimate via the inhalation of vapours.

## ADOPTED TPH INHALATION MDI

The MDIs for the TPH fractions provided by the S4UL methodology are based on the '50% rule' using the respective oral/inhalation TDIs. This is acknowledged in the 2015 S4UL main document to be a 'highly cautious' approach for deriving generic assessments that should be reviewed on site-specific basis.

If the 50% TDI rule for MDI calculation was adopted across the board for inhalation modelling, then it would provide an implied average annual concentration of  $\sim 24 \text{ mg/m}^3$  ( $24,000 \text{ ug/m}^3$ ) of TPH in background ambient air. This is clearly impossible for the UK.

For the site-specific risk assessment, a more nuanced (but still risk protective) approach has been adopted for the setting the TPH fraction inhalation MDIs. This is based on:

### Aliphatic fractions

- MDI at 5% of the inhalation TDI.
- 5% adopted as the aliphatic TDIs are relatively high compared with the aromatic TDI.
- For example: at 5% of the TDI for Ali C12-16:  $\text{MDI} = 5\% \text{ of } (0.29 \times 70) = \sim 1 \text{ mg/day}$ .
- The implied average annual background air concentration would be  $50 \text{ ug/m}^3$  [ $1000/20$ ], which although very unlikely in the UK, is suitably risk protective.
- At  $\text{MDI} = 10\% \text{ of TDI}$ , the implied average annual background air concentration would be  $100 \text{ ug/m}^3$ , which is clearly unfeasible for a single TPH fraction in the UK.
- Implied air concentrations for the fractions provided below
- *Calculations use the 'standard adult' weighing 70 kg and breathing  $20 \text{ m}^3/\text{day}$ .*

### Aromatic fractions

- MDI at 10% of the inhalation TDI.
- 10% adopted as the aromatic TDIs are relatively low compared with the aliphatic TDI.
- Note: the S4UL/EA published Benzene & Toluene MDI values adopted
- Implied air concentrations for the fractions provided below.

The MDI at 5% and 10% of the TDI is consistent with the TEX and PAH MDI-to-TDI ratios and provide a practical means to allow for a more reasonable risk-protective contribution to exposure from background intake.

This approach provides the following adult inhalation MDIs and implied annual average background air concentrations (in brackets):

|                          |             |                            |             |
|--------------------------|-------------|----------------------------|-------------|
| • MDI Aliphatic C5-6     | 18 mg/day   | ( $0.9 \text{ mg/m}^3$ )   | 5% TDI      |
| • MDI Aliphatic C6-8     | 18 mg/day   | ( $0.9 \text{ mg/m}^3$ )   | 5% TDI      |
| • MDI Aliphatic C8-C10:  | 1 mg/day    | ( $0.05 \text{ mg/m}^3$ )  | 5% TDI      |
| • MDI Aliphatic C10-C12: | 1 mg/day    | ( $0.05 \text{ mg/m}^3$ )  | 5% TDI      |
| • MDI Aliphatic C12-C16: | 1 mg/day    | ( $0.05 \text{ mg/m}^3$ )  | 5% TDI      |
| • MDI Aliphatic C12-C16: | 1 mg/day    | ( $0.05 \text{ mg/m}^3$ )  | 5% TDI      |
| • MDI Aliphatic C16-C35: | 7 mg/day    | ( $0.35 \text{ mg/m}^3$ )  | 5% TDI      |
| • MDI Aromatic C5-7      | 0.2 mg/day  | ( $0.01 \text{ mg/m}^3$ )  | Benzene MDI |
| • MDI Aromatic C7-8      | 0.52 mg/day | ( $0.026 \text{ mg/m}^3$ ) | Toluene MDI |

- MDI Aromatic C8-C10: 0.42 mg/day (0.021 mg/ m<sup>3</sup>) 10% TDI
- MDI Aromatic C10-C12 0.42 mg/day (0.021 mg/ m<sup>3</sup>) 10% TDI
- MDI Aromatic C12-C16: 0.42 mg/day (0.021 mg/ m<sup>3</sup>) 10% TDI
- MDI Aromatic C16-C21: 0.21 mg/day (0.011 mg/ m<sup>3</sup>) 10% TDI
- MDI Aromatic C21-C35: 0.21 mg/day (0.011 mg/ m<sup>3</sup>) 10% TDI

At these MDI values, the implied average annual ambient air concentrations summed across the TPH fractions provides a total of ~2,470 ug/m<sup>3</sup>. So even at 5%/10% of TDI, the adopted MDIs still provide a very high (but risk protective) implied annual average background air concentration of ~2.5 mg/m<sup>3</sup>.

The implied fraction average annual ambient air concentrations detailed above are also greater than the implied air concentrations based on the TPH fraction 'daily intake' values provided by Table 17.5 in the 2015 S4UL main document.

Note: for site-specific risk assessments, CLEA-SR2 recommends that the MDI should be considered negligible if no data or information is available on likely background exposure (SR2 Section 3.4.1), so the site-specific approach adopted for the TPH MDI is more risk protective than EA guidance.

## REPORTING PROTOCOL FOR OUTPUTS

To ensure that the reported outputs are credible, the following reporting protocols are recommended:

- If model outputs are  $>1,000,000 \text{ mg/kg}$  or  $>1,000,000 \text{ mg/l}$ , this would imply there would be  $>1 \text{ kg}$  of contaminant in  $1 \text{ kg}$  of soil or  $1 \text{ kg}$  of water. In this instance, the model output indicates “No Calculable Risk” as the model requires physically impossible source area concentrations to give rise to unacceptable risk via the CLEA approach (i.e. average daily exposure  $> \text{TDI/ID}$ ). Results will be reported as  $>100,000 \text{ mg/kg}$  or  $>10,000 \text{ mg/l}$ ;
- A similar approach will be adopted for soil vapour outputs, with outputs  $>10,000 \text{ mg/m}^3$  reported as  $>10,000 \text{ mg/m}^3$  (the mass of  $1 \text{ m}^3$  of air at sea level is  $\sim 1.25 \text{ kg}$ );
- If the soil, soil vapour or groundwater output for a substance of concern is greater than saturation limits for relevant pathways then modelling outputs in the main report will be presented in brackets. Exceedance of saturation limits should/can be an additional consideration in the selection of the SACs; and
- Outputs will be rounded to an appropriate number of significant figures (typically two or three).

## **APPENDIX B2**

### **CLEA MODELLING SHEETS**

[illegible]



**ACTIVE SOIL TYPE**

| Soil Properties                      | Units    | Soil Type Layer 1<br>Sandy Loam | Soil Type Layer 2<br>Sandy Loam |
|--------------------------------------|----------|---------------------------------|---------------------------------|
| Air-filled porosity                  | cm3/cm3  | 0.2                             | 0.2                             |
| Water-filled porosity                | cm3/cm3  | 0.33                            | 0.33                            |
| Total Porosity/Saturated Porosity    | cm3/cm3  | 0.53                            | 0.53                            |
| Residual soil water content          | cm3/cm3  | 0.12                            | 0.12                            |
| Saturated hydraulic conductivity     | cm/s     | 0.00356                         | 0.00356                         |
| van Genuchten shape parameter (m)    | unitless | 0.3201                          | 0.3201                          |
| Bulk density                         | g/cm3    | 1.21                            | 1.21                            |
| Mean Particle Diameter (D)           | m/s      | 0.03                            | 0.03                            |
| Threshold value of wind speed at 10m | unitless | 7.2                             | 7.2                             |
| Empirical function for dust model    | cm       | 1.22                            | 1.22                            |

|                                                   |          |           |               |
|---------------------------------------------------|----------|-----------|---------------|
| Arundel Onsite Commercial Open Storage            | Project  | 26 Jan 21 | Model Version |
| Adult Scenario S4UL (C4SL/SR3) Outdoor Commercial | R1320/20 |           | 901           |
| Female Worker AC17: Site Assessment Criteria      |          |           |               |

|        |       | Oral Pathways        |           |              |            |        | Inhalation Pathways |        |        |                   |          |            |              |              |         |          |         |         |                |          |  |
|--------|-------|----------------------|-----------|--------------|------------|--------|---------------------|--------|--------|-------------------|----------|------------|--------------|--------------|---------|----------|---------|---------|----------------|----------|--|
|        |       | Key Parameter Check  |           |              |            |        |                     |        |        |                   |          |            |              |              |         |          |         |         |                |          |  |
|        |       | Calculate GAC        |           |              |            |        |                     |        |        |                   |          |            |              |              |         |          |         |         |                |          |  |
|        |       | Calculate SSAC       |           |              |            |        |                     |        |        |                   |          |            |              |              |         |          |         |         |                |          |  |
| No     | Type  | COC                  | Ingestion | Veg Attached | Veg Direct | Dermal | Dust Inhalation     |        |        | Vapour Inhalation |          |            |              | Oral         | Inhal   |          |         |         |                |          |  |
|        |       |                      | SOIL-D    | SOIL-ID      | Veg-D      | DERM-I | DERM-O              | Dust-I | Dust-O | Vap In            | Out Surf | Out Sub    | MDI 50% Rule | MDI 50% Rule | Comb AC | Derm Via | Vol Ass | Use Vol | Calculated SAC | Baseline |  |
| COC-1  | TPH   | Aliphatic TPH C5-9   | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 60,270     | FALSE        | FALSE        | Yes     | Oral HCV | Y       | Yes     | 60,270         |          |  |
| COC-2  | TPH   | Aliphatic TPH C6-8   | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 147,100    | FALSE        | FALSE        | Yes     | Oral HCV | Y       | Yes     | 147,100        |          |  |
| COC-3  | TPH   | Aliphatic TPH C8-10  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 38,210     | TRUE         | FALSE        | Yes     | Oral HCV | Y       | Yes     | 38,210         |          |  |
| COC-4  | TPH   | Aliphatic TPH C10-12 | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 189,400    | TRUE         | FALSE        | Yes     | Oral HCV | Y       | Yes     | 189,400        |          |  |
| COC-5  | TPH   | Aliphatic TPH C12-16 | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 1,586,000  | TRUE         | FALSE        | Yes     | Oral HCV | Y       | Yes     | 1,586,000      |          |  |
| COC-6  | TPH   | Aromatic TPH C5-10   | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 63,890     | TRUE         | FALSE        | Yes     | Oral HCV | Y       | Yes     | 63,890         |          |  |
| COC-7  | TPH   | Aromatic TPH C10-12  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 348,000    | TRUE         | FALSE        | Yes     | Oral HCV | Y       | Yes     | 348,000        |          |  |
| COC-8  | TPH   | Aromatic TPH C12-16  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 3,808,000  | TRUE         | FALSE        | Yes     | Oral HCV | Y       | Yes     | 3,808,000.0    |          |  |
| COC-9  | BTEX  | Aromatic TPH C15-21  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 57,170,000 | TRUE         | FALSE        | Yes     | Oral HCV | Y       | Yes     | 57,170,000     |          |  |
| COC-10 | BTEX  | Benzene              | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 296        | FALSE        | FALSE        | Yes     | Oral HCV | Y       | Yes     | 296.0          |          |  |
| COC-11 | BTEX  | Toluene              | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 725,500    | FALSE        | FALSE        | Yes     | Oral HCV | Y       | Yes     | 725,500        |          |  |
| COC-12 | BTEX  | Ethylbenzene         | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 68,700     | FALSE        | FALSE        | Yes     | Oral HCV | Y       | Yes     | 68,700.000     |          |  |
| COC-13 | BTEX  | Xylene-p             | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 70,350     | FALSE        | FALSE        | Yes     | Oral HCV | Y       | Yes     | 70,350         |          |  |
| COC-14 | PAH   | Naphthalene          | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 22,650     | FALSE        | FALSE        | Yes     | Oral HCV | Y       | Yes     | 22,650         |          |  |
| COC-15 | OTHER | Phenol S4UL          | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | 380,900    | FALSE        | FALSE        | Yes     | Oral HCV | N       | No      | 380,900        |          |  |
| COC-16 | NONE  | n/a                  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | n/a        | n/a          | n/a          | n/a     | n/a      | n/a     | Yes     | n/a            |          |  |
| COC-17 | NONE  | n/a                  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | n/a        | n/a          | n/a          | n/a     | n/a      | n/a     | Yes     | n/a            |          |  |
| COC-18 | NONE  | n/a                  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | n/a        | n/a          | n/a          | n/a     | n/a      | n/a     | Yes     | n/a            |          |  |
| COC-19 | NONE  | n/a                  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | n/a        | n/a          | n/a          | n/a     | n/a      | n/a     | Yes     | n/a            |          |  |
| COC-20 | NONE  | n/a                  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | n/a        | n/a          | n/a          | n/a     | n/a      | n/a     | Yes     | n/a            |          |  |

|                |           |                   |             |            |              |
|----------------|-----------|-------------------|-------------|------------|--------------|
| Child Receptor | Soil Only | Global SOM        | 1.00%       | 0.00580    | Foc Equiv    |
|                |           | Soil Type Layer 1 | Sandy Loam  | Default    | Sandy Loam   |
|                |           | Soil Type Layer 2 | Sandy Loam  | Default    | Sandy Loam   |
|                |           | City              | Southampton | Default    | Newcastle    |
|                |           | Site Area Res     | 6.3         | Hectares   | Default 0.01 |
|                |           | H Res             | 0.8         | metres     | Default 0.8  |
|                |           | Site Area Com     | 6.5         | Hectares   | Default 2    |
|                |           | H Com             | 1.6         | metres     | Default 1.6  |
|                |           | Wind Type         | Urban       |            |              |
| Adult Receptor | Soil & GW | Dust Pathways     | Residential | Commercial |              |
|                |           | Loading Factor    | 50          | 100        |              |
|                |           | Default           | DF = 50     | DF = 100   |              |
|                |           | Fraction HCover   | 0.75        | 0.8        |              |
|                |           | Default           | DF = 0.75   | DF = 0.8   |              |

|                                     |                 |                              |             |
|-------------------------------------|-----------------|------------------------------|-------------|
| Indoor Air                          | Residential     | Commercial                   |             |
| Building                            | Arundel Terrace | 13 Post 1970 4 Storey Office |             |
| Building Qs                         | Site Specific   | Site Specific                |             |
| Foundation Void                     | No Void         | n/a                          |             |
| Use CF of >1                        | Y               | Y                            |             |
| Total Indoor                        | 700             | 300                          | DF = 50 cm  |
| Indoor Soil Source L1               | 700             | n/a                          |             |
| Indoor Soil Source L2               | 0               | n/a                          |             |
| Indoor GW Source                    | 700             | 300                          | DF = 100 cm |
| Depths Exclude Foundation Thickness |                 |                              |             |
| Outdoor Air Surface                 | AT=6            | 49                           | DF = 6 & 49 |
| Outdoor Air Subsurf                 | Residential     | Commercial                   |             |
| Outdoor Soil Source                 | 100             | 100                          | DF = 100 cm |
| Outdoor GW Source                   | 150             | 150                          | DF = 100 cm |

|                 |          |
|-----------------|----------|
| TPH Select      | Solvents |
| TPH > C8 Select | ODDs     |
| TPH All         | Metals   |
| PAH 16          |          |

Output Checked against CLEA UK 1.07

## ACTIVE ADULT RECEPTOR

| Adult Scenario                            | Receptor                  | AgeClass    |
|-------------------------------------------|---------------------------|-------------|
| <b>S4UL (C4SL/SR3) Outdoor Commercial</b> | <b>Female Worker AC17</b> | <b>AC17</b> |
| Gardener                                  | n/a                       |             |
| Direct soil & dust ingestion              | days/year                 | 230         |
| Consumption of homegrown produce          | days/year                 | n/a         |
| Skin contact - indoors                    | days/year                 | n/a         |
| Skin contact - outdoors                   | days/year                 | 230         |
| Inhalation of dusts & vapours - indoors   | days/year                 | n/a         |
| Inhalation of dusts & vapours - outdoors  | days/year                 | 230         |
| Occupany period - indoor                  | hours/day                 | n/a         |
| Occupany period - outdoor                 | hours/day                 | 9           |
| Averaging Time                            | Days                      | 17885       |
| Exposure Duration                         | years                     | 49          |
| Soil skin adherence factor - indoor       | mg/cm2/day                | 0.14        |
| Soil skin adherence factor - outdoor      | mg/cm2/day                | 0.14        |
| Direct soil & dust ingestion rate         | g/day                     | 0.05        |
| Body weight                               | kg                        | 70          |
| Body height                               | m                         | 1.6         |
| Inhalation rate                           | m3/day                    | 15.7        |
| Max exp skin factor - indoor              | m2/m2                     | 0.08        |
| Max exp skin factor - outdoor             | m2/m2                     | 0.08        |
| Max exposed skin area - indoor            | m2                        | 0.0476      |
| Max exposed area - outdoor                | m2                        | 0.0476      |
| Total skin area                           | m2                        | 1.7850      |
| HG Fraction - Green Veg                   | n/a                       | n/a         |
| HG Fraction - Root Veg                    | n/a                       | n/a         |
| HG Fraction - Tuber Veg                   | n/a                       | n/a         |
| HG Fraction - Herb Fruit                  | n/a                       | n/a         |
| HG Fraction - Shrub Fruit                 | n/a                       | n/a         |
| HG Fraction - Tree Fruit                  | n/a                       | n/a         |
| Green vegetables                          | g-FW/kg-bw/day            | n/a         |
| Root vegetables                           | g-FW/kg-bw/day            | n/a         |
| Tuber vegetables                          | g-FW/kg-bw/day            | n/a         |
| Herbaceous fruit                          | g-FW/kg-bw/day            | n/a         |
| Shrub fruit                               | g-FW/kg-bw/day            | n/a         |
| Tree fruit                                | g-FW/kg-bw/day            | n/a         |
| Oral MDI Correction Factor                | Unitless                  | 1           |
| Inhalation MDI Correction Factor          | Unitless                  | 1           |

Arundel Onsite Commercial Open Storage

S4UL (C4SL S4S) Outdoor Commercial - Adult Scenario - Female Worker AC17

RPL 11 Outdoor Air Inhalation - Subsurface Soil

Model Version

Outdoor Air Source Properties

Depth to subsurface contamination

Generic SR3 Receptor Height

Source Area

SR3 City Surrogate

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|----------------------------------------------|----------|-----------|---------------|
| Arundel: Adjacent Residential                | Project  | 26 Jan 21 | Model Version |
| Child Scenario S4UL (C4SL/SR2) Residential   | R1820/20 |           | 901           |
| Female Child AC1-6: Site Assessment Criteria |          |           |               |

|        |       | Oral Pathways        |           |              |            |        | Inhalation Pathways |        |        |                   |          |            |              |              |      |          |         |         |                |          |  |  |  |  |
|--------|-------|----------------------|-----------|--------------|------------|--------|---------------------|--------|--------|-------------------|----------|------------|--------------|--------------|------|----------|---------|---------|----------------|----------|--|--|--|--|
|        |       | Key Parameter Check  |           |              |            |        |                     |        |        |                   |          |            |              |              |      |          |         |         |                |          |  |  |  |  |
|        |       | Calculate GAC        |           |              |            |        |                     |        |        |                   |          |            |              |              |      |          |         |         |                |          |  |  |  |  |
|        |       | Calculate SSAC       |           |              |            |        |                     |        |        |                   |          |            |              |              |      |          |         |         |                |          |  |  |  |  |
| No     | Type  | COC                  | Ingestion | Veg Attached | Veg Direct | Dermal | Dust Inhalation     |        |        | Vapour Inhalation |          |            | Oral         | Inhal        | Comb | Derm Via | Vol Ass | Use Vol | Calculated SAC | Baseline |  |  |  |  |
|        |       |                      | SOIL-D    | SOIL-ID      | Veg-D      | DERM-I | DERM-O              | Dust-I | Dust-O | Vap In            | Out Surf | Out Sub    | MDI 50% Rule | MDI 50% Rule | AC   |          |         |         |                |          |  |  |  |  |
| COC-1  | TPH   | Aliphatic TPH C5-6   | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 710               | n/a      | 41,311     | FALSE        | FALSE        | Yes  | Oral HCV | Y       | Yes     | 698            |          |  |  |  |  |
| COC-2  | TPH   | Aliphatic TPH C6-8   | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 1,733             | n/a      | 100,800    | FALSE        | FALSE        | Yes  | Oral HCV | Y       | Yes     | 1,704          |          |  |  |  |  |
| COC-3  | TPH   | Aliphatic TPH C8-10  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 454               | n/a      | 26,440     | TRUE         | FALSE        | Yes  | Oral HCV | Y       | Yes     | 447            |          |  |  |  |  |
| COC-4  | TPH   | Aliphatic TPH C10-12 | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 2,252             | n/a      | 131,100    | TRUE         | FALSE        | Yes  | Oral HCV | Y       | Yes     | 2,214          |          |  |  |  |  |
| COC-5  | TPH   | Aliphatic TPH C12-16 | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 18,860            | n/a      | 1,097,000  | TRUE         | FALSE        | Yes  | Oral HCV | Y       | Yes     | 18,541         |          |  |  |  |  |
| COC-6  | TPH   | Aromatic TPH C5-10   | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 584               | n/a      | 33,990     | TRUE         | FALSE        | Yes  | Oral HCV | Y       | Yes     | 574            |          |  |  |  |  |
| COC-7  | TPH   | Aromatic TPH C10-12  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 3,183             | n/a      | 185,100    | TRUE         | FALSE        | Yes  | Oral HCV | Y       | Yes     | 3,129          |          |  |  |  |  |
| COC-8  | TPH   | Aromatic TPH C12-16  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 34,890            | n/a      | 2,026,000  | TRUE         | FALSE        | Yes  | Oral HCV | Y       | Yes     | 34,299.3       |          |  |  |  |  |
| COC-9  | BTEX  | Aromatic TPH C15-21  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 542,100           | n/a      | 30,410,000 | TRUE         | FALSE        | Yes  | Oral HCV | Y       | Yes     | 532,606        |          |  |  |  |  |
| COC-10 | BTEX  | Benzene              | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 4.2               | n/a      | 246        | FALSE        | FALSE        | Yes  | Oral HCV | Y       | Yes     | 4.1            |          |  |  |  |  |
| COC-11 | BTEX  | Toluene              | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 10,230            | n/a      | 601,500    | FALSE        | FALSE        | Yes  | Oral HCV | Y       | Yes     | 10,059         |          |  |  |  |  |
| COC-12 | BTEX  | Ethylbenzene         | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 957               | n/a      | 56,470     | FALSE        | FALSE        | Yes  | Oral HCV | Y       | Yes     | 940,762        |          |  |  |  |  |
| COC-13 | BTEX  | Xylene-p             | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 910               | n/a      | 53,690     | FALSE        | FALSE        | Yes  | Oral HCV | Y       | Yes     | 894            |          |  |  |  |  |
| COC-14 | PAH   | Naphthalene          | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 269               | n/a      | 15,860     | FALSE        | FALSE        | Yes  | Oral HCV | Y       | Yes     | 264            |          |  |  |  |  |
| COC-15 | OTHER | Phenol S4UL          | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | 1,294             | n/a      | 254,500    | FALSE        | FALSE        | Yes  | Oral HCV | N       | No      | 1,287          |          |  |  |  |  |
| COC-16 | NONE  | n/a                  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | n/a        | n/a          | n/a          | n/a  | n/a      | n/a     | Yes     | n/a            |          |  |  |  |  |
| COC-17 | NONE  | n/a                  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | n/a        | n/a          | n/a          | n/a  | n/a      | n/a     | Yes     | n/a            |          |  |  |  |  |
| COC-18 | NONE  | n/a                  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | n/a        | n/a          | n/a          | n/a  | n/a      | n/a     | Yes     | n/a            |          |  |  |  |  |
| COC-19 | NONE  | n/a                  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | n/a        | n/a          | n/a          | n/a  | n/a      | n/a     | Yes     | n/a            |          |  |  |  |  |
| COC-20 | NONE  | n/a                  | n/a       | n/a          | n/a        | n/a    | n/a                 | n/a    | n/a    | n/a               | n/a      | n/a        | n/a          | n/a          | n/a  | n/a      | n/a     | Yes     | n/a            |          |  |  |  |  |

|                  |             |                   |             |          |              |
|------------------|-------------|-------------------|-------------|----------|--------------|
| ☒ Child Receptor | ☒ Soil Only | Global SOM        | 1.00%       | 0.00580  | Foc Equiv    |
|                  |             | Soil Type Layer 1 | Sandy Loam  | Default  | Sandy Loam   |
| ☒ Adult Receptor | ☒ GW Only   | Soil Type Layer 2 | Sandy Loam  | Default  | Sandy Loam   |
|                  |             | City              | Southampton | Default  | Newcastle    |
|                  | ☒ Soil & GW | Site Area Res     | 0.3         | Hectares | Default 0.01 |
|                  |             | H Res             | 0.8         | metres   | Default 0.8  |
|                  |             | Site Area Com     | 0.5         | Hectares | Default 2    |
|                  |             | H Com             | 1.6         | metres   | Default 1.6  |
|                  |             | Wind Type         | Urban       |          |              |

|                 |             |            |
|-----------------|-------------|------------|
| Dust Pathways   | Residential | Commercial |
| Loading Factor  | 50          | 100        |
| Default         | DF = 50     | DF = 100   |
| Fraction HCover | 0.75        | 0.8        |
| Default         | DF = 0.75   | DF = 0.8   |

|                                     |                 |                              |             |
|-------------------------------------|-----------------|------------------------------|-------------|
| Indoor Air                          | Residential     | Commercial                   |             |
| Building                            | Arundel Terrace | 13 Post-1970 4 Storey Office |             |
| Building Qs                         | Site Specific   | Site Specific                |             |
| Foundation Void                     | No Void         | n/a                          |             |
| Use CF of >1                        | Y               | Y                            |             |
| Total Indoor                        | 700             | 300                          | DF = 50 cm  |
| Indoor Soil Source L1               | 700             | n/a                          |             |
| Indoor Soil Source L2               | 0               | n/a                          |             |
| Indoor GW Source                    | 700             | 300                          | DF = 100 cm |
| Depths Exclude Foundation Thickness |                 |                              |             |
| Outdoor Air Surface                 | AT=6            | 49                           | DF = 6 & 49 |
| Outdoor Air Subsurf                 | Residential     | Commercial                   |             |
| Outdoor Soil Source                 | 100             | 100                          | DF = 100 cm |
| Outdoor GW Source                   | 150             | 150                          | DF = 100 cm |

|                 |          |
|-----------------|----------|
| TPH Select      | Solvents |
| TPH > C8 Select | ODDs     |
| TPH All         | Metals   |
| PAH 16          |          |

Output Checked against CLEA UK 1.07

# ACTIVE CHILD RECEPTOR

| Child Scenario                           | Receptor           | AgeClass | AgeClass | AgeClass | AgeClass | AgeClass | AgeClass |
|------------------------------------------|--------------------|----------|----------|----------|----------|----------|----------|
| S4UL (C4SL/SR3) Residential              | Female Child AC1-6 | AC1      | AC2      | AC3      | AC4      | AC5      | AC6      |
| Gardener                                 | Average            |          |          |          |          |          |          |
| Direct soil & dust ingestion             | days/year          | 180      | 365      | 365      | 365      | 365      | 365      |
| Consumption of homegrown produce         | days/year          | 180      | 365      | 365      | 365      | 365      | 365      |
| Skin contact - indoors                   | days/year          | 180      | 365      | 365      | 365      | 365      | 365      |
| Skin contact - outdoors                  | days/year          | 170      | 170      | 170      | 170      | 170      | 170      |
| Inhalation of dusts & vapours - indoors  | days/year          | 365      | 365      | 365      | 365      | 365      | 365      |
| Inhalation of dusts & vapours - outdoors | days/year          | 365      | 365      | 365      | 365      | 365      | 365      |
| Occupany period - indoor                 | hours/day          | 23       | 23       | 23       | 23       | 19       | 19       |
| Occupany period - outdoor                | hours/day          | 1        | 1        | 1        | 1        | 1        | 1        |
| Averaging Time                           | Days               | 365      | 365      | 365      | 365      | 365      | 365      |
| Exposure Duration                        | years              | 1        | 1        | 1        | 1        | 1        | 1        |
| Soil skin adherence factor - indoor      | mg/cm2/day         | 0.06     | 0.06     | 0.06     | 0.06     | 0.06     | 0.06     |
| Soil skin adherence factor - outdoor     | mg/cm2/day         | 0.1      | 0.1      | 0.1      | 0.1      | 0.1      | 0.1      |
| Direct soil & dust ingestion rate        | g/day              | 0.1      | 0.1      | 0.1      | 0.1      | 0.1      | 0.1      |
| Body weight                              | kg                 | 5.6      | 9.8      | 12.7     | 15.1     | 16.9     | 19.7     |
| Body height                              | m                  | 0.7      | 0.8      | 0.9      | 0.9      | 1        | 1.1      |
| Inhalation rate                          | m3/day             | 5.4      | 8        | 8.9      | 10.1     | 10.1     | 10.1     |
| Max exp skin factor - indoor             | m2/m2              | 0.32     | 0.33     | 0.32     | 0.35     | 0.35     | 0.33     |
| Max exp skin factor - outdoor            | m2/m2              | 0.26     | 0.26     | 0.25     | 0.28     | 0.28     | 0.26     |
| Max exposed skin area - indoor           | m2                 | 0.0366   | 0.0533   | 0.0620   | 0.0742   | 0.0822   | 0.0873   |
| Max exposed area - outdoor               | m2                 | 0.0297   | 0.0420   | 0.0485   | 0.0593   | 0.0657   | 0.0688   |
| Total skin area                          | m2                 | 0.34     | 0.48     | 0.58     | 0.64     | 0.70     | 0.79     |
| HG Fraction - Green Veg                  | Average            | 0.05     | 0.05     | 0.05     | 0.05     | 0.05     | 0.05     |
| HG Fraction - Root Veg                   | Average            | 0.06     | 0.06     | 0.06     | 0.06     | 0.06     | 0.06     |
| HG Fraction - Tuber Veg                  | Average            | 0.02     | 0.02     | 0.02     | 0.02     | 0.02     | 0.02     |
| HG Fraction - Herb Fruit                 | Average            | 0.06     | 0.06     | 0.06     | 0.06     | 0.06     | 0.06     |
| HG Fraction - Shrub Fruit                | Average            | 0.09     | 0.09     | 0.09     | 0.09     | 0.09     | 0.09     |
| HG Fraction - Tree Fruit                 | Average            | 0.04     | 0.04     | 0.04     | 0.04     | 0.04     | 0.04     |
| Green vegetables                         | g-FW/kg-bw/day     | 7.12     | 6.85     | 6.85     | 6.85     | 3.74     | 3.74     |
| Root vegetables                          | g-FW/kg-bw/day     | 10.69    | 3.3      | 3.3      | 3.3      | 1.77     | 1.77     |
| Tuber vegetables                         | g-FW/kg-bw/day     | 16.03    | 5.46     | 5.46     | 5.46     | 3.38     | 3.38     |
| Herbaceous fruit                         | g-FW/kg-bw/day     | 1.83     | 3.96     | 3.96     | 3.96     | 1.85     | 1.85     |
| Shrub fruit                              | g-FW/kg-bw/day     | 2.23     | 0.54     | 0.54     | 0.54     | 0.16     | 0.16     |
| Tree fruit                               | g-FW/kg-bw/day     | 3.82     | 11.96    | 11.96    | 11.96    | 4.26     | 4.26     |
| Oral MDI Correction Factor               | Unitless           | 0.53     | 0.66     | 0.65     | 0.65     | 0.74     | 0.74     |
| Inhalation MDI Correction Factor         | Unitless           | 0.51     | 0.8      | 0.77     | 0.74     | 0.74     | 0.74     |
| Typical Body Weight for MDI Calcs        | kg                 | 5.6      | 9.8      | 12.7     | 15.1     | 16.9     | 19.7     |

| Figure  | Model | Model Version |
|---------|-------|---------------|
| FIG. 20 | 0     | 0.1           |
|         | 0     |               |

|                           |        |                     |
|---------------------------|--------|---------------------|
| Building ventilation rate | 2.66   | m <sup>3</sup> /day |
| Building volume           | 179    | m <sup>3</sup>      |
| Air changes per day       | 32     | changes/day         |
| Source area               | 37     | m <sup>2</sup>      |
| Source Thickness          | 1.5    | m                   |
| Source Volume             | 56     | m <sup>3</sup>      |
| Soil Mass                 | 67,927 | kg                  |

|          | Total        |
|----------|--------------|
| M Volume | Wald Ex Rate |
| 6080     | 972          |
| 5568     | -283         |
| 5568     | +228         |

|        |             |
|--------|-------------|
| COC-13 | Naphthalene |
| COC-14 | Naphthalene |
| COC-15 | Phenol      |
| COC-16 | n/a         |
| COC-17 | n/a         |
| COC-18 | n/a         |
| COC-19 | n/a         |
| COC-20 | n/a         |

**4.06 Conclusions**

| Harder Void       |                |  |  |
|-------------------|----------------|--|--|
| 15                | cm             |  |  |
| 10                | cm             |  |  |
| 77.5              | cm2            |  |  |
| 2                 | c 1.5m centres |  |  |
| 555               | cm2            |  |  |
| 77.5, Brick: 14.0 |                |  |  |

| Harder Void      |                |  |  |
|------------------|----------------|--|--|
| 15               | cm             |  |  |
| 10               | cm             |  |  |
| 77.5             | cm2            |  |  |
| 2                | c 1.5m centres |  |  |
| 555              | cm2            |  |  |
| 77.5 Brick: 14.0 |                |  |  |

| Harder Void      |                |  |  |
|------------------|----------------|--|--|
| 15               | cm             |  |  |
| 10               | cm             |  |  |
| 77.5             | cm2            |  |  |
| 2                | c 1.5m centres |  |  |
| 555              | cm2            |  |  |
| 77.5 Brick: 14.0 |                |  |  |

| Harder Void      |                |  |  |
|------------------|----------------|--|--|
| 15               | cm             |  |  |
| 10               | cm             |  |  |
| 77.5             | cm2            |  |  |
| 2                | c 1.5m centres |  |  |
| 555              | cm2            |  |  |
| 77.5 Brick: 14.0 |                |  |  |

| Site Name | Site Class | Dist (km) | Adj. Dist (km) |
|-----------|------------|-----------|----------------|
| 4750      | 48.02      | 27.5      | -              |
| 4760      | 117.19     | 67.2      | -              |
| 277       | 30.73      | 303.8     | -              |
| 277       | 152.33     | 1505.2    | -              |
| 277       | 1275.48    | 12,863.2  | -              |
| 57        | 30.51      | 1,888.8   | -              |
| 57        | 216.23     | 10,279.0  | -              |
| 29        | 2594.18    | 11,872.5  | -              |
| 1.3       | 0.28       | 582.2     | -              |
| 1,358     | 801.65     | 1,415.7   | -              |
| 57        | 84.70      | 2,495.2   | -              |
| 0.822     | 80.51      | 2,037.7   | -              |
| 0.8       | 18.16      | 25.07     | -              |
| 0.6       | 87.51      | 23,074.0  | -              |
| n/a       | n/a        | n/a       | -              |
| n/a       | n/a        | n/a       | -              |
| n/a       | n/a        | n/a       | -              |
| n/a       | n/a        | n/a       | -              |
| n/a       | n/a        | n/a       | -              |

[illegible][illegible][illegible][illegible]





March 2021

## CLEA-PESL/2021 MODEL SELECTED BENCHMARKING AGAINST S4UL in mg/kg

|                              | Residential With Plant Uptake |             | Commercial   |             |
|------------------------------|-------------------------------|-------------|--------------|-------------|
| Standard Metals & Inorganic  | PESL/2021                     | S4UL        | PESL/2021    | S4UL        |
| Arsenic                      | 36.5                          | 37          | 635          | 640         |
| Chromium III                 | 907                           | 910         | 8,563        | 8,600       |
| Chromium VI                  | 6.05                          | 6.0         | 32.8         | 33          |
| Copper                       | 2,414                         | 2,400       | 68,265 *     | 6,8000 *    |
| Inorganic Mercury            | 40.1                          | 40          | 1,117        | 1,100       |
| Nickel (Aug 2015)            | 126                           | 130         | 983          | 980         |
| Selenium                     | 254                           | 250         | 12,350       | 12,000      |
| Vanadium                     | 406                           | 410         | 9,026        | 9,000       |
| Zinc                         | 3,746                         | 3,700       | 732,658      | 730,000     |
| BTEX & Selected PAHs         | Model 1% SOM                  | S4UL 1% SOM | Model 1% SOM | S4UL 1% SOM |
| Benzene                      | 0.087                         | 0.087       | 26.6         | 27          |
| Toluene                      | 127                           | 130         | 869          | 869         |
| Ethylbenzene                 | 46.8                          | 47          | 518          | 518         |
| Xylene-p                     | 56.1                          | 56          | 478          | 478         |
| Naphthalene                  | 2.33                          | 2.3         | 192          | 190         |
| Benzo-a-pyrene               | 2.21                          | 2.2         | 35.2         | 35          |
| BaP Coal Tar                 | 0.79                          | 0.79        | 15.4         | 15          |
| Selected Other VOCs/Organics | Model 1% SOM                  | S4UL 1% SOM | Model 1% SOM | S4UL 1% SOM |
| PCE                          | 0.18                          | 0.18        | 18.6         | 19          |
| TCE                          | 0.016                         | 0.016       | 1.23         | 1.2         |
| VC                           | 0.00064                       | 0.00064     | 0.059        | 0.059       |
| Phenol                       | 117                           | 120         | 25,860       | (26,000)    |

The S4UL are rounded for publishing.

The CLEA-PESL /2021 outputs are very well correlated (to 3/4 significant figures) with the unrounded Agency CLEA model outputs.

\* = This S4UL needs to be checked with LQM as there are two different oral MDI values quoted in the S4UL document.

## CLEA-PESL/2021 MODEL SELECTED BENCHMARKING AGAINST SOBRA GW GACS in mg/l

|                              | Residential |         | Commercial |       |
|------------------------------|-------------|---------|------------|-------|
| BTEX & Selected PAHs         | PESL/2021   | SoBRA   | PESL/2021  | SoBRA |
| Benzene                      | 0.021       | 0.021   |            | 2.0   |
| Toluene                      | 22.6        | 23      |            | 2,100 |
| Ethylbenzene                 | 1.0         | 1.0     |            | 96    |
| Xylene-p                     | 0.99        | 0.99    |            | 8.6   |
| Naphthalene                  | 0.22        | 0.22    |            | 23.0  |
| Selected Other VOCs/Organics | PESL/2021   | SoBRA   | PESL/2021  | SoBRA |
| PCE                          | 0.034       | 0.034   |            | 4.6   |
| TCE                          | 0.0057      | 0.0057  |            | 0.53  |
| VC                           | 0.00062     | 0.00062 |            | 0.063 |

Note: The Indoor Air Correction Factors are taken to be 1.

## **APPENDIX C      CONTROLLED WATERS RISK ASSESSMENT ADDENDA**

# FORD ROAD ARUNDEL – CONTROLLED WATERS RISK ASSESSMENT

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## ADDENDA

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## **1 INTRODUCTION**

This report considers risk to controlled waters from residual impactation of potential contaminants at the former gas works site at Ford Road in Arundel and derives remedial targets for soils and groundwater that are designed to ensure that risks to controlled waters are acceptably low. The history of site usage has resulted in some impactation of the ground at the site with some potential contaminants, in particular hydrocarbons. The assessment has included numerical modelling of the groundwater system in the vicinity of the site. This modelling was undertaken to assist in development of the conceptual model with respect to the groundwater pathway and in order to allow predictions to be made as to the likely degree of dilution and attenuation of potential contaminants and their likely fate in the groundwater system. As such it assists in the quantification of the risks to controlled waters that may be associated with migration of any potential contaminants remaining on site and allows the development of defensible site-specific assessment criteria that are protective to controlled waters.

## **2 INITIAL CONCEPTUAL MODEL OF GROUNDWATER FLOW**

### **2.1 GROUND CONDITIONS**

A summary of ground conditions present on site and a description of the various phases of ground investigation are included in the main report. The present appendix is concerned with the potential migration and fate of dissolved contaminants within the groundwater system.

Various phases of ground investigation have been undertaken on site and recently Celtic have undertaken some additional investigation works, including installation of additional boreholes and wells and additional groundwater monitoring. Data gained during recent investigation have been used to build on the previous studies.

Below made ground, which is variable in thickness generally up to about 2.7 m, but at one location possibly up to 7.2 m deep, Raised Marine Deposits comprising typically very gravelly clay or gravel in a clay matrix generally have a thickness of between 0.7 to 5.1 m, although are locally absent. The Raised Marine Deposits in turn overlie 'solid' strata of Spetisbury Chalk Member, formerly known as the Upper Chalk. The Lambeth Group strata are expected to overlie the Upper Chalk a little way to the south of the site and are in turn overlain by London Clay further south.

Ground levels on site are typically in the range 2.5 to 3.7 mAOD. Figure C1 shows inferred contours of reported elevation of the base of made ground and Figure C2 shows inferred contours of the elevation of top of chalk. The reported depth of made ground at BH202 is unusually high (7.2 m) although the log does note 'possibly becoming natural below 4.5 m'. However, even 4.5 m depth would be somewhat anomalous. Nevertheless it can be inferred that the thickness of Raised Marine Deposits is relatively thin in the northern site area, where chalk levels are relatively high. This is consistent with the published geology, which shows the Raised Marine Deposits to become absent close to the site north western boundary.

Standing groundwater in the study area is typically at depths in the range 1 to 3 m but is heavily influenced by tidal fluctuations.

### **2.2 TOPOGRAPHIC SETTING AND SURFACE WATER FEATURES**

The site lies within a relatively flat area of land that follows the western bank of the River Arun. At its closest point the site is some 40 m from the River Arun bank. Ford Road forms the north western site boundary and the road and land to the west of the road are at a somewhat higher elevation and ground levels then rise steadily to the north west. Figure C3 shows the site's topographic setting with some topographic contours and surface water features highlighted for clarity.

The site is some six kilometres inland from the coast at Littlehampton but the Arun is tidal at this point, indeed the river is tidal for more than 20 km from the coast.

The usual water level range of the River Arun at Arundel Queen St Bridge, some 700 m upstream from the site, is between -0.28 and 2.50 mAOD. It has been between those levels

for 90% of the time since monitoring began. The typical recent level of the River Arun at Arundel Queen St Bridge over the past 12 months (to early January 2021) has been between -0.40 and 3.17 mAOD. It has been between these levels for at least 150 days in the past year. The highest level ever recorded at the River Arun at Arundel Queen St Bridge is 3.65 mAOD, reached on Friday 6th December 2013. (Source: [River Arun at Arundel Queen St Bridge :: the UK River Levels Website](#))

The low level plain along the west bank of the Arun is drained by a series of ditches. One of these, flowing south east, passes close to the site's north eastern boundary. Another, flowing south, originates between the site and the river and joins a network of other ditches to the south of the site. The ditch to the north may have originated as a natural stream as its course can be discerned from topographic contours to the north west of the site and it discharges to the Arun at about the closest point of the river to the site.

The ditches to the south are thought to be mainly artificial features. As high tide water levels can exceed ground level in some of the areas to the south of the site, there is a berm along the river bank.

Away from the river, a network of generally southerly flowing streams drain the land to the south and east of the site where Lambeth Group and London Clay strata overlie the chalk but further north, where the chalk outcrops or is present below head, there are few surface water features.

Surface water features in the vicinity of the site are illustrated in Figure C4a, selected topographic contours have been highlighted for clarity.

As part of the present study, water levels in some accessible features in the areas around the site, shown on Figure C4b, were surveyed on 01/12/2020, as follows:

| Feature | Easting  | Northing | Time  | Water Level (mAOD) | Time                 | Water Level (mAOD) |
|---------|----------|----------|-------|--------------------|----------------------|--------------------|
| 1       | 501369.4 | 106716.6 | 11:23 | 2.48               | 15:21                | 0.985              |
| 2       | 501297.1 | 106782.6 | 11:12 | 1.653              | Not tidally affected |                    |
| 3       | 501358.6 | 106730.7 | 11:17 | 1.495              | 15:18                | 1.058              |
| 4       | 501248.9 | 106502.4 | 11:28 | 0.885              | 15:28                | 0.84               |
| 5       | 501207.2 | 106325.2 | 11:35 | 2.613              | 15:35                | 0.752              |
| 6       | 501021.9 | 107359.8 | 12:40 | 2.205              | Not tidally affected |                    |
| 7       | 501139.3 | 107261.7 | 12:45 | 2.068              | Not tidally affected |                    |
| 8       | 501194.1 | 106354.6 | 11:33 | 0.702              | 15:33                | 0.779              |
| 9       | 500725.6 | 105795   | 12:06 | 1.183              | Not tidally affected |                    |
| 10      | 500022.2 | 107041.7 | 12:25 | 29.493             | Not tidally affected |                    |
| 11      | 500918.8 | 106297.5 | 11:45 | 1.099              | Not tidally affected |                    |
| 12      | 501138.2 | 106204.3 | 11:40 | 0.682              | 15:38                | 0.765              |

Figure C5 shows a plot of these data versus time.

### **2.3 ANTICIPATED PATTERN OF NEAR SURFACE GROUNDWATER FLOW**

Based on the site's topographic setting, the natural direction of near surface groundwater flow below the site could be expected to be generally to the east with discharge to the River Arun. Water level in the stream to the north is generally slightly higher than the average water level on the adjacent part of the site and is not tidally affected at Monitoring Point 2 and only slightly tidal downstream of the site prior to discharge to the Arun, Point 3, which is about half way from the site to the Arun, compared to the Arun (Point 1).

The drainage ditches to the south of the site are likely partly perched on the Raised Marine Deposits and likely isolated from the deeper chalk aquifer, although some do show some tidal fluctuation.

Groundwater originating from infiltration in the vicinity of the site would be expected therefore to migrate vertically downwards to the relatively permeable Chalk strata and then sub-horizontally within the saturated zone of the chalk aquifer to discharge. However, this picture is significantly complicated by the effect of tidal groundwater level fluctuations, as discussed later.

### **2.4 HYDROGEOLOGY AND POTENTIAL CONTROLLED WATERS RECEPTORS**

The natural superficial Raised Marine strata are classified as a Secondary Aquifer and the Chalk is a Principal Aquifer. The site does not lie within any groundwater source protection zones. The chalk aquifer is locally partly confined by the Raised Marine Deposits, which are generally clayey, but is unconfined to the west and north west of the site. Further south the Lambeth strata confine the chalk.

There are insufficient data to distinguish water levels in the chalk and marine deposits. However, it may be assumed that the two water bodies are in continuity although the likely lower conductivity of the marine deposits would complicate flow patterns, they become very thin or absent to the north west, in area of the apparent main residual potential contaminants source.

The area to the south east of the site, which is 'downstream' in terms anticipated direction of groundwater flow, is of limited width and given the proximity to the Arun and the tidal nature of the groundwater, it is not credible that it that the superficial or chalk aquifer in that area would be exploited in the future for potable use. Accordingly, as there is some evidence that historical impaction of the shallow aquifer has occurred, it is considered that the surface water features and in particular the River Arun are likely to represent the critical potential receptor with respect to controlled waters issues in relation to existing impaction.

The adjacent ditch to the north east has been discounted as a significant receptor or pathway for the following reasons:

Water levels are above average site groundwater water level except near the Arun, refer Figure C7 as water level is controlled by a sluice gate at discharge to the Arun. It follows that tidal level fluctuations are muted and much lower than fluctuations in boreholes on site, which confirm no direct connection to site groundwater levels, i.e. water level fluctuations in the ditch cannot be driving the groundwater level fluctuations on site.



Testing of surface water samples from the ditch show no measured levels of COC's above the limit of detection, ruling out the pathway possibility.

## **2.5 COMPLIANCE CRITERIA**

As the critical receptor is considered likely to be the surface water, the relevant compliance criteria are considered to be Environmental Quality Standards (EQS) for priority substances (and other pollutants) and Standards for Special Pollutants, where these have been published. Where these standards are in 'The Water Framework Directive (England and Wales) 2015, these have been adopted as the compliance criteria. Where these are not available or directly relevant, relevant UK Drinking Water Standards (DWS) will be adopted. Otherwise former surface water standards and DWS have been considered.

Based on surface water testing, the Arun would appear to be fresh water adjacent to the site although the stretch is technically classified as 'transitional waters' due to possible salt water incursions. There is ambiguity in the WFD standards as to whether to apply Inland Waters, Coastal Waters or Freshwater/Saltwater criteria to transitional water. However in that the river water in the Arun at Arundel cannot be classified as 'saltwater', the ecological status would be best protected by applying the 'freshwater standards', where given.

Based on this approach, the following compliance criteria have been adopted (all in mg/l).

| Substance             | Adopted Controlled Waters<br>Compliance Criterion for<br>Preliminary Screening | Comment                       |
|-----------------------|--------------------------------------------------------------------------------|-------------------------------|
|                       | (mg/l)                                                                         |                               |
| TPH Aliphatic C5-C6   | 0.01                                                                           | Former DWS (Sum of Fractions) |
| TPH Aliphatic C6-C8   | 0.01                                                                           | Former DWS (Sum of Fractions) |
| TPH Aliphatic C8-C10  | 0.01                                                                           | Former DWS (Sum of Fractions) |
| TPH Aliphatic C10-C12 | 0.01                                                                           | Former DWS (Sum of Fractions) |
| TPH Aliphatic C12-C16 | 0.01                                                                           | Former DWS (Sum of Fractions) |
| TPH Aliphatic C16-C21 | 0.01                                                                           | Former DWS (Sum of Fractions) |
| TPH Aliphatic C21-C34 | 0.01                                                                           | Former DWS (Sum of Fractions) |
| TPH Aliphatic C35-C44 | 0.01                                                                           | Former DWS (Sum of Fractions) |
| TPH Aromatic C8-C10   | 0.01                                                                           | Former DWS (Sum of Fractions) |
| TPH Aromatic C10-C12  | 0.01                                                                           | Former DWS (Sum of Fractions) |
| TPH Aromatic C12-C16  | 0.01                                                                           | Former DWS (Sum of Fractions) |
| TPH Aromatic C16-C21  | 0.01                                                                           | Former DWS (Sum of Fractions) |
| TPH Aromatic C21-C35  | 0.01                                                                           | Former DWS (Sum of Fractions) |
| TPH Aromatic C35-C44  | 0.01                                                                           | Former DWS (Sum of Fractions) |
| Benzene               | 0.01                                                                           | EQS                           |
| Toluene               | 0.074                                                                          | EQS                           |
| Ethylbenzene          | 0.02                                                                           | Former EQS                    |
| m-Xylene              | 0.03                                                                           | EQS                           |
| o-Xylene              | 0.03                                                                           | EQS                           |
| p-Xylene              | 0.03                                                                           | EQS                           |
| Benz[a]anthracene     | 0.002                                                                          | EQS Naphthalene               |
| Benzo[b]fluoranthene  | 0.00003                                                                        | EQS                           |
| Benzo[k]fluoranthene  | 0.00003                                                                        | EQS                           |
| Benzo[ghi]perylene    | 0.000002                                                                       | EQS                           |
| Benzo[a]pyrene        | 0.00000017                                                                     | EQS                           |
| Chrysene              | 0.002                                                                          | EQS Naphthalene               |
| Dibenz[ah]anthracene  | 0.002                                                                          | EQS Naphthalene               |
| Fluoranthene          | 0.0000063                                                                      | EQS                           |
| Indeno[123-cd]pyrene  | 0.000002                                                                       | EQS                           |
| Naphthalene           | 0.002                                                                          | EQS                           |
| Pyrene                | 0.002                                                                          | EQS Naphthalene               |
| Acenaphthalene        | 0.002                                                                          | EQS Naphthalene               |
| Acenaphthene          | 0.002                                                                          | EQS Naphthalene               |
| Fluorene              | 0.002                                                                          | EQS Naphthalene               |
| Phenanthrene          | 0.002                                                                          | EQS Naphthalene               |
| Anthracene            | 0.0001                                                                         | EQS                           |
| Arsenic               | 0.05                                                                           | EQS                           |
| Cadmium               | 0.00025                                                                        | EQS                           |
| Copper                | 0.028                                                                          | EQS                           |
| Chromium              | 0.02                                                                           | EQS                           |
| Lead                  | 0.0072                                                                         | EQS                           |
| Mercury               | 0.00005                                                                        | EQS                           |
| Nickel                | 0.02                                                                           | EQS                           |
| Selenium              | 0.01                                                                           | DWS                           |
| Zinc                  | 0.034                                                                          | EQS                           |

EQS = EQS, DWS = Drinking Water Standard, WHO = World Health Organisation

For TPH fractions, the adopted compliance criterion for preliminary screening is the former drinking water standard for all oils and hydrocarbons. As such arguably it should be divided between the various fractions. However, aliphatic and heavy aromatic fractions are of very low solubility and light aromatic TPH fractions (BTEX Compounds) are considered separately.

There is in fact reason to consider that for some TPH fractions, the adopted compliance criterion is likely to be conservative with respect to protection of controlled waters, where

the critical receptor is a surface water feature. The Massachusetts Department of Environmental Protection (MADEP) has published risk-based criteria that are protective of aquatic receptors (BATELLE,2007), see also SOBRA 2012. The approach used involved estimating the acute and chronic toxicity of hydrocarbon fractions to aquatic organisms based on equilibrium partitioning theory. Criteria in pore water and sediment were derived for eight groupings (fractions) of petroleum hydrocarbons based on similar toxicological and chemical properties, are set out in the following table:

| Hydrocarbon Fraction | Toxicity-based Water Criterion (mg/l) |
|----------------------|---------------------------------------|
| Aliphatics C5-C8     | 0.22                                  |
| Aliphatics C9-C12    | 0.0063                                |
| Aliphatics C13-C18   | *                                     |
| Aliphatics C19-C36   | *                                     |
| Aromatics C6-C8      | 1.2                                   |
| Aromatics C9-C12     | 0.046                                 |
| Aromatics C13-C15    | 0.0052                                |
| Aromatics C16-C24    | *                                     |

\*Note: These fractions are not likely to be toxic, toxicology-based pore water concentration exceeds mean aqueous solubility.

With regard to human toxicity, the World Health Organisation (2005) has developed the following guidelines for drinking water standards:

| Hydrocarbon Fraction | Toxicity-based Drinking Water Criterion (mg/l) |
|----------------------|------------------------------------------------|
| Aliphatics C5-C8     | 15                                             |
| Aliphatics C9-C16    | 0.3                                            |
| Aliphatics C17-C36   | *                                              |
| Aromatics C6-C8      | 0.01 (benzene) 0.7 (toluene)                   |
| Aromatics C9 - C16   | 0.1                                            |
| Aromatics C16-C35    | 0.09                                           |

Despite the above, the former DWS has been used in the derivation of remedial targets for the present study, which is considered conservative.

## 2.6 CONTAMINANTS OF CONCERN

Groundwater quality will be a very good indicator of the contaminating potential of soils associated with the groundwater system, particularly if the water table is shallow, as is the present case. This means that if concentrations of a substance in groundwater are at low levels, then it may be appropriate and reasonable to conclude that the substance in the soils associated with the groundwater system is unlikely to pose an unacceptable risk to controlled waters.

Based on the recent monitoring by Celtic, substances identified as being locally at apparently elevated concentrations in the groundwater are as follows:

- BTEX and other aromatic TPH fractions
- Aliphatic TPH Fractions heavier than C12
- Some PAH Compounds
- Nickel
- Ammonium
- Phenol

However, aliphatic fractions greater than C12 and aromatic fractions greater than C21 are unlikely to be significant with respect to controlled waters due to very low solubility.

### 3 MEASURED GROUND AND SURFACE WATER CONDITIONS ON SITE

#### 3.1 GROUNDWATER LEVELS

Figure C6 shows measured groundwater level for the various standpipes versus date of reading. Although the overall monitoring period spans some 20 years it is evident that tidal water level fluctuations are so great that unless the readings are related to the exact state of the tide, in most cases no sensible pattern of flow direction can be inferred. Accordingly, Figure C7 shows the same data for the period 01/12/20 and 02/12/20 with both surface water and groundwater levels. Also shown is the predicted fluctuation in the level of the River Arun immediately to the east of the site. This prediction was based on a sine curve through the reported high and low tide levels and times at Arundel (Queen Street Bridge) for this period slightly modified to comply with the actual measured levels, which were very slightly higher at peak, as measured at surface water monitoring point 1. A sine curve is the simplest cyclical form that approximates to tidal fluctuation and is considered to be a reasonable way of allowing a continuum function to fit published high and low tide levels.

As may be seen this plot rationalises the measured data. Times for high and low groundwater levels at the various standpipes lag behind the peaks and troughs for the surface water levels and generally the lag is greater with greater distance from the river.

Water level loggers were installed in four of the boreholes and monitored for the period 02/12/20 to 22/12/20. Figure C8 compares the measured water levels from the data logging with the manual readings, which overlap near the early stages of the data logging. The rapid changes in level highlight the difficulties in interpretation of any particular set of water level readings and confirm the lag in response inferred from the manual readings.

Figure C9 shows contours of the ratio of amplitude of groundwater level fluctuation in the boreholes to surface water level fluctuation. As may be expected this is greatest near the surface water but is still significant at the most distant part of the site.

Figure C10 shows the borehole water levels from the data logger monitoring versus time for the entire period monitored.

The rapid fluctuation in groundwater levels make estimation of the net groundwater flow difficult. Average water levels in the boreholes for the entire period of logging, some three weeks, show an average hydraulic gradient to the east of about 0.0025. However, as this is very low compared to gradients induced by tide, it is not considered that an accurate estimate of non-tidal flow and direction can be obtained from this methodology. It can, however, be concluded that such flow are very low compared to tidally induced flow volumes, this is illustrated later in the report.

As noted above, tidal water level fluctuations are so great that unless the readings are related to the exact state of the tide, no sensible pattern of flow direction can be inferred. An exception was on 15 July 2011 when all the available standpipes at that time were read within a period of 15 minutes near low tide. Figure C11 shows a contour plot of these data. This shows a flow direction to the south east with an average hydraulic gradient across the

site of about 0.017 straight towards the river, much higher than the estimated 'average' gradient of 0.0025 from the datalogging.

### **3.2 DISTRIBUTION OF CONTAMINANTS OF CONCERN IN GROUNDWATER**

Data are available from a recent monitoring round undertaken by Celtic as well as a monitoring round undertaken by Atkins in 2000 and two rounds in 2011. Addenda C1 to C4 include inferred contours of concentration of potential contaminants in groundwater for all contaminants of concern measured above the detection limit. A red contour is included to indicate the adopted compliance criterion where this has been exceeded.

The following paragraphs summarise the measured conditions:

| Substance Group | Recent Data                                                                                         | 2011 Round 2                                                                                       | 2011 Round 1                                                                                                    | 2000 Data                                                                                                                                                           |
|-----------------|-----------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PAH Compounds   | Some compounds elevated in northern site area. Most meet compliance by south eastern site boundary. | Some compounds elevated in northern site area. All meet compliance by south eastern site boundary. | Some compounds elevated in northern and western site area. Most meet compliance by south eastern site boundary. | naphthalene elevated in northern site area but meets compliance by south eastern site boundary. Benzo(a)pyrene elevated through most of site. No other exceedances. |
| BTEX Compounds  | Elevated in northern site are. Meet compliance by south eastern site boundary.                      | Elevated in northern site are. Meet compliance by south eastern site boundary.                     | Elevated in northern site are. Meet compliance by south eastern site boundary.                                  | Xylenes elevated in northern site are but meet compliance by south eastern site boundary. No other exceedances.                                                     |
| Aliphatic TPH   | C12 to C35 elevated in central site area. Meet compliance by south eastern site boundary.           | C16 to C35 elevated in northern/central site area. Meet compliance by south eastern site boundary. | No exceedances                                                                                                  | Total TPH exceeds compliance across site, not speciated.                                                                                                            |
| Aromatic TPH    | Elevated in northern site area. Meet compliance by south eastern site boundary.                     | Elevated in northern site are. Meet compliance by south eastern site boundary.                     | Elevated in northern and western site are. Meet compliance by south eastern site boundary.                      |                                                                                                                                                                     |
| Phenol          | Elevated in northern site are. Meets compliance by south eastern site boundary.                     | Elevated in northern site are. Meets compliance by south eastern site boundary.                    | Elevated in northern site are. Meets compliance by south eastern site boundary.                                 | No exceedances.                                                                                                                                                     |
| Metals          | All below compliance criteria, except nickel locally in northern site area.                         | All below compliance criteria, except nickel locally in northern site area.                        | All below compliance criteria, except arsenic and nickel locally in northern site area.                         | No exceedances.                                                                                                                                                     |
| Cyanide         | Meet compliance throughout site.                                                                    | Free cyanide elevated in northern site area and slightly elevated at south eastern site boundary.  | Free cyanide elevated in eastern site area                                                                      | No exceedances.                                                                                                                                                     |
| Chloride        | Highest in northern site area.                                                                      | Highest in northern site area.                                                                     | Highest in northern site area.                                                                                  | Highest in northern site area.                                                                                                                                      |
| Ammonium        | Elevated across north eastern site area. Highest in northern site area.                             | Elevated across north eastern site area. Highest in northern site area.                            | Elevated across north eastern site area. Highest in northern site area.                                         | Elevated across north eastern site area.                                                                                                                            |

Elevated = Above Compliance Criterion.

In summary the major impacts measured in water samples are restricted to the northern site area. TPH impactation currently meets compliance by south eastern site boundary.

A review of the reported TPH conditions shows the highest concentrations of aliphatic fractions and heavy aromatics are at reported concentrations well above solubility, as follows:

| TPH Fraction          | Solubility | Maximum Measured Concentration<br>Recent Data (mg/l) | Maximum Measured Concentration<br>2011 Round 2 (mg/l) |
|-----------------------|------------|------------------------------------------------------|-------------------------------------------------------|
| TPH Aliphatic C12-C16 | 0.00076    | 3.1                                                  | -                                                     |
| TPH Aliphatic C16-C21 | 2.5E-06    | 7.8                                                  | 0.17                                                  |
| TPH Aliphatic C21-C35 | 2.5E-06    | 3.2                                                  | 0.12                                                  |
| TPH Aromatic C8-C10   | 65         | 1.2                                                  | 1.7                                                   |
| TPH Aromatic C10-C12  | 25         | 3.2                                                  | 0.35                                                  |
| TPH Aromatic C12-C16  | 5.8        | 4                                                    | 4.6                                                   |
| TPH Aromatic C16-C21  | 0.65       | 2.5                                                  | 4.1                                                   |
| TPH Aromatic C21-C35  | 0.0066     | 1                                                    | 0.3                                                   |

(Shading denotes concentration exceeds solubility. Solubility based on Gustafson et al 1997)

This suggests that some NAPL has been incorporated into the water samples from these locations and that the measured TPH conditions, even for fractions that did not exceed solubility, and indeed all organics, should not therefore be taken to represent a true measurement of the dissolved phase concentration. Even if no measurable NAPL has been detected it is not unusual for some NAPL to be smeared in the soil as an emulsion in the zone of fluctuating groundwater level. The very sharp gradients in contours of measured impaction levels between some nearby boreholes for organics, is also unlikely to be present in the true dissolved phase and supports this interpretation. By comparison concentration gradients for inorganics are generally much flatter.



## **4 DEVELOPMENT OF EXTENDED CONCEPTUAL MODEL**

### **4.1 GENERAL**

The volumes and patterns of groundwater flow beneath the site and between the site areas and the discharge points are important to the assessment of risks associated with the groundwater pathway. Although estimates of flow volumes may be made based on hydraulic gradient and estimated hydraulic conductivity of the site subsoils, the latter parameter in particular cannot be measured directly, is difficult to estimate and may be expected to vary quite significantly on a local level, as is evidenced by the wide range of material types recorded on the borehole logs, particularly within the materials present above the chalk. On the present site the situation is significantly complicated by the fact that tidal influence on groundwater flow is dominant and temporary hydraulic gradients induced by the tide significantly exceed average gradients.

### **4.2 TIDAL INFLUENCE ON GROUNDWATER**

#### **4.2.1 BACKGROUND AND APPROACH ADOPTED**

Based on previous work and as has been found on the present site, the peak ground water level lags some time after peak tide level, the amplitude of fluctuation is generally some fraction of tidal amplitude and the mean groundwater level at any point is offset by an approximately constant amount above mean tidal water level. Generally the amplitude reduces, the lag time increases and the offset increases with increasing distance from the tidal water body. The magnitude of these effects is influenced by the aquifer hydraulic parameters. Indeed if sufficient data are available it is possible to estimate aquifer characteristics from observed response to tidal water level fluctuations (Ferris 1951).

It is clear that for the present site that local groundwater conditions are dominated by the tide. It follows that the tide induced flows will significantly exceed flow from wider catchment and catchment modelling, as may be useful for many sites, is of limited value in defining flow conditions. An average hydraulic gradient has been estimated and this will be partly due to catchment flow but even the local average gradient in the tidal zone can be increased by the effect of tidal pumping. This occurs because most materials, particularly in unconfined conditions, show lower hydraulic conductivity when pore pressures are lower, particularly if they become negative. As the tide level drops, the aquifer will have relatively high pore pressures whereas as the tide rises, pore pressures in the adjacent aquifer will generally be relatively low. The result is that greater flow out occurs as the tide drops than flows in as it rises, inducing an increased net flow towards the tidal body.

The chalk aquifer is unconfined in some areas of the site but may be partially confined in others. However, as the confining attributes of the Marine Deposits are discontinuous an unconfined conceptual model is considered more appropriate. The direction of average groundwater flow is not considered to have been definitively determined except that there is an easterly component. A south easterly flow direction is inferred from the conceptual model of the catchment and has been shown to be the case during low tide, when discharge to the Arun would be highest.

In order to develop the conceptual model of general groundwater flow conditions, a vertical section numerical model of flow within the site area has been developed.

#### **4.2.2 MODELLING SOFTWARE**

Numerical modelling undertaken as part of the present study has made use of the SEEP/W program developed by Geo-Slope International Ltd. This was chosen as it allows rapid parametric studies to be undertaken and the implications of various assumptions to be graphically displayed. The program is based on the well-established finite element method for continuum analysis. Although similar analysis may be undertaken using finite difference based methods, the finite element approach offers some advantages, in particular the method is less sensitive to such factors as node spacing as conditions are not assumed to be linear within elements. In this process the study area is divided into a number of elements. If required, potential patterns of contaminant transport may be mapped on the results of the SEEP/W analysis with the use of a companion program CTRAN/W.

#### **4.2.3 SIMULATION OF TIDAL GROUNDWATER FLOW**

The finite element mesh used for the vertical cross section analysis is shown in Figure C12. The top of the right-hand boundary represents the tidal River Arun. The left hand boundary was chosen to be sufficiently far from the river to have negligible influence on local site conditions.

The tidal variations were accommodated by applying a variable head with time boundary condition to the river boundary. A tidal range for 01/12/20 was adopted, refer Figure C7, which was intermediate between Spring and Neap tides, was simulated. The left hand boundary was assigned a constant head value such that the predicted average hydraulic gradient on site was reasonably consistent with the measured value, to accommodate the groundwater flow originating as infiltration in the wider catchment, although at this site the catchment flow is small compared to tidal induced flow. Although the aquifer is expected to be some 250 m thick in this area, the lower portions of chalk aquifers invariably show very low conductivity (BGS, 1997) and a 50 m thickness was modelled. The chalk and Raised Marine deposits constitute a locally partially confined aquifer but the chalk is unconfined to the west and storativity would be expected to derive partly from the fluctuating water table and partly from elastic compression. Within the vertical section model, aquifer storativity is accommodated by specifying a relationship between water filled porosity and water pressure. For initial evaluation saturated porosity of 0.35 was adopted and the relationship between water content and pore pressure was based on literature data for materials of similar characteristics to those present on site, although site conditions are quite variable so the model represents a significant simplification. However, previous experience has shown that storativity influences the lag between tidal changes and groundwater levels more than the absolute magnitude of pore pressure fluctuation.

The saturated conductivity of the aquifer, which dominates tidal response, was treated parametrically.

Figure C13 shows the predicted relationship between tidal fluctuation and groundwater head at three different distances from the tidal water body and for three values of assumed aquifer conductivity. It is evident from this figure that for the range of water level

fluctuations measured on site, the implied hydraulic conductivity is very high, likely in the range 0.01 to 0.001 m/s. Figure C14 shows the predicted tidal water head fluctuation, expressed as a ratio of the tidal water fluctuation, versus distance from the river. Also shown are the site measured amplitudes. For those data it is necessary to adopt an equivalent distance from the river. The closest point of the site to the river, south eastern corner, is some 35 m from the river, but the lower stretch of the drainage ditch to the north east is also slightly tidal, although the section nearest to the site shows no fluctuation, refer Figure C7, points 2 and 3, point 2 being adjacent to the site and point 3 in the ditch between the site and the river. For illustration, values of 25 m and 35 m equivalent distance to the river have been included. The implied equivalent hydraulic conductivity is of the order of 0.008 m/s.

This value of hydraulic conductivity is significantly higher than would be expected for the Raised Marine deposits, which are generally clayey, and it may be assumed that the major tidal water flows occur in the chalk. Indeed the inferred hydraulic conductivity is also very high for intact chalk, being a typical value for clean sand or gravel (Freeze and Cherry, 1979) but chalk conductivities are generally highest near discharge points and the ongoing tidal fluctuations are likely to have enhanced fissure flow. This effect is similar to the very high values of hydraulic conductivity found in chalk within the zone of seasonal water table fluctuation (eg Foster and Milton, 1974).

Figure C15 shows the predicted vertical and horizontal hydraulic gradient fluctuations for a location near the south eastern site boundary that would be associated with the magnitude of water level fluctuations measured on site for the tidal fluctuation level modelled in Figure C13. As may be seen, these are large compared to the estimated 'average' hydraulic gradient (0.0025), which confirms that groundwater flow conditions at the site are dominated by the tidal effect. During Spring tides, even more extreme gradients may be expected.

#### **4.3 EXTENDED CONCEPTUAL MODEL**

Based on the above discussion of site conditions and modelling, the conceptual model of groundwater flow conditions and potential pollution linkages at the site is summarised as follows:

There is a source area of un-dissolved residual impaction within the near surface saturated and unsaturated soils in the northern site area. This is likely to be persistent as likely present in material of low hydraulic conductivity. Measured groundwater concentrations of organic substances in samples from wells are influenced by the presence of un-dissolved phase in the soils and are unlikely to be representative of true dissolved phase groundwater concentrations.

High effective conductivity of the underlying chalk, probably dominated by fissure flow, is leading the large fluctuations in groundwater heads across the site due to tidal water level changes in the adjacent surface water that can be reasonably simulated by a simplified numerical model.

Groundwater originating as surface infiltration in the site area is likely flowing vertically downwards through the near surface unsaturated and saturated soils or relatively low conductivity until discharge to flow in the chalk, probably dominated by fissure flow.

The very high level of response of groundwater head to tidal fluctuations confirms a direct connection between the surface water and the chalk aquifer. This implies that the Raised Marine Deposits in the immediate vicinity of the river are either of very high conductivity, or absent.

Very high dilution would occur within the aquifer prior to discharge to the river due to a combination of dilution and dispersion due to average groundwater flow and due to tidal flow. The net result is very high gradients in measured concentrations of organic substances with distance, i.e. very high apparent attenuation with horizontal distance, which is largely due to real dilution due to tidal groundwater movements but accentuated by the likely presence of NAPL.

In addition to tidal effects, the site's location near a major groundwater discharge feature, the River Arun, and over a deep aquifer will mean that there will be a significant upward gradient in the deeper aquifer towards the river which will lead to increased dilution close to the river.

#### **4.4 IMPLICATIONS FOR DERIVATION OF REMEDIAL TARGETS**

##### **4.4.1 GENERAL**

The Environment Agency's Remedial Targets Methodology, Hydrogeological risk assessment for land contamination, can be used to simulate conditions in the site area. However, using the terminology of that methodology, the Level 3 Attenuation Factor should include an additional attenuation factor due to dilution and dispersion with respect to tidal effects as well as dilution due to the upward flow from the deeper aquifer. Previous experience has shown this factor to be large where the tide is giving rise to significant groundwater head fluctuations.

##### **4.4.2 ESTIMATION OF ADDITIONAL ATTENUATION**

###### **4.4.2.1 TIDAL GROUNDWATER FLOW**

As water from the river enters the ground during rising tidal conditions it will lead to a dilution of any dissolved phase contaminants. This can lead to much lower concentrations at discharge than would otherwise be the case (Yim and Mohsen 1992, Atasie-Ashtiani et al, 2002).

The volume of groundwater flow into the aquifer during each tidal cycle can be estimated from the numerical model, which can be used directly to estimate dilution'

###### **4.4.2.2 DISPERSION**

Detailed analysis of the effect of tide has shown that the tidal fluctuations in water level are associated with a forward and backward as well as vertical motion of the groundwater, i.e. a

looped flow path that moves laterally towards discharge. Figure C16 shows the results of a simple 'particle tracking' analysis that shows predicted flow paths associated with purely advective flow for a location near the 'upstream' north western site boundary. This oscillation must be associated with an increased vertical dispersion of potential dissolved phase contaminants, which would lead to a further attenuation in concentration.

#### 4.4.2.3 UPWARD GROUNDWATER FLOW

The upward flow effect is illustrated by predicted flow lines for 'steady state' conditions from the numerical model in Figure C17. Flow from the upper 20 m of the aquifer could be expected to converge on the riverside downstream of the site. This will lead to an increased dilution prior to discharge than would occur due to purely horizontal flow.

#### 4.4.2.4 APPROACH ADOPTED

A simplified approach has been adopted for the present study. The increased dispersion has not been explicitly calculated but it has been assumed that due to increased dispersion and upward flow near the river a volume of groundwater corresponding to the steady state flow within the top 20 m of the aquifer will dilute the impacted groundwater prior to discharge.

An estimate of the additional Dilution Factor (DFt) may be made as follows:

$$DFt = (Qt + Qh + Qmz)/Qmz$$

Where:

Qt = Daily flow of water into aquifer and out of aquifer due to tide per m width

Qh = Steady state average volume of groundwater flow towards the tidal body within the top 20 m of the aquifer per m width

Qmz = Flow volume in 'Level 2' mixing zone per m width, i.e. the assumed volume of groundwater impacted by the source.

The average hydraulic gradient below the site has been taken as 0.0025 to calculate Qh and Qmz. The values of Qt, Qh and Qmz will depend upon the assumed hydraulic conductivity of the Chalk aquifer and a parametric analysis has therefore been undertaken, as follows:

| Assumed Conductivity (m/s) | Qt (m3/d)<br>From Numerical Model | Qh (m3/d) | Qmz (m3/d) | Additional Dilution Factor (DFt) |
|----------------------------|-----------------------------------|-----------|------------|----------------------------------|
| 0.01                       | 233                               | 43        | 3.4        | 82                               |
| 0.001                      | 45                                | 4.3       | 0.35       | 141                              |
| 0.0001                     | 7.4                               | 0.43      | 0.046      | 171                              |

As may be anticipated the tidal effect is the dominant process.

As discussed above, the tidal analysis suggests that the average conductivity of the aquifer near the site is of the order of 0.01 m/s and accordingly the derived remedial targets from RTM analysis may therefore be increased by a factor of 82 times if some allowance is made for potential dilution and dispersion within the ground prior to discharge resulting from tidal

fluctuations in the groundwater table and upward gradient of the groundwater as the groundwater approaches discharge.

## **5 DEVELOPMENT OF REMEDIAL TARGETS FOR POTENTIAL CONTAMINANTS**

### **5.1 GENERAL**

The Environment Agency's Remedial Targets Methodology, Hydrogeological risk assessment for land contamination, was used to simulate conditions in the site area. The associated Remedial Targets Worksheet, Release 3.2 is rather awkward for use with multiple potential contaminants and an in-house spreadsheet was used for parametric studies. This uses the same algorithms as Remedial Targets Worksheet, Release 3.2 and has been validated against the Remedial Targets Worksheet, Release 3.2. All input data are included in the output sheets to allow check analysis using RTM Release 3.2, if necessary.

For the present site, consideration has also been given to the potential additional Level 3 dispersion and dilution that may be expected to occur within the ground prior to discharge as a result of tidal oscillations of groundwater level and upward gradient within the chalk aquifer, as discussed above.

### **5.2 COMPLIANCE CRITERIA AND SOLUBILITY**

The relevant compliance criteria with respect to the surface water have been summarised above. Dilution within the surface water system will be ignored, which is conservative.

Some higher level TPH fractions have very low aqueous solubility. Where the aqueous solubility is less than the adopted compliance criterion, more detailed analysis of potential fate and transport is not strictly warranted but these compounds have been included in the RTM analysis for completeness.

Within the RTM methodology, unless background concentrations are high, remedial targets are directly proportional to the adopted compliance criterion so that it is not necessary to repeat analysis if the effect of varying compliance criterion is to be studied.

### **5.3 LEVEL 1 PARAMETERS**

The Level 1 analysis compares estimated pore water concentration to the compliance criteria. The additional parameters required for this assessment are as follows:

| Physiochemical Parameters            | Principal Source of Parameter Adopted                     |
|--------------------------------------|-----------------------------------------------------------|
| <b>Organics</b>                      |                                                           |
| Henry's Constant                     | EA 2008 (SR7 Report)/LQM 2009/EIC                         |
| Organic Carbon Partition Coefficient | EA 2008 (SR7 Report)/LQM 2009/EIC                         |
| <b>Inorganics</b>                    |                                                           |
| Soil Water Partition Coefficient     | Lijzen et al 2001 (RIVM Report 711701 023)                |
| <b>Soil Properties</b>               |                                                           |
| Air and Water Filled Porosity        | Typical Values for Soil Types-CLEA 'Sandy Loam            |
| Bulk Density                         | Typical Values for Soil Types-CLEA 'Sandy Loam            |
| Fraction of Organic Carbon           | 0.0175 - Average for near surface soils, refer Figure C18 |

Values of Koc for the various compounds and fractions have been based on EA Report SR7 (2008) and, for TPH fractions, LQM (2009). The latter are based primarily on TPHCWG recommendations (Gustafson et al 1997).

## 5.4 LEVEL 2 PARAMETERS

### 5.4.1 GENERAL

The Level 2 analysis considers attenuation in the vadose zone below the source and subsequent dilution that would occur within the aquifer below the site. The attenuation is characterised by an attenuation factor (AFU2) and the dilution by a dilution factor (DF2). The overall reduction factor in concentration at Level 2 would be computed as AFU2 x DF2. If the depth to groundwater is not great, it is conservative but usual to ignore Level 2 attenuation, i.e. to assume AFU2 = 1.0, which has been done in the present case.

If attenuation in the unsaturated zone is ignored, no additional physiochemical parameters are needed for this assessment. Site parameters required are the infiltration rate, geometry of 'source' and the volume of flow within the aquifer mixing zone. The latter is usually computed from the hydraulic gradient, the hydraulic conductivity and the thickness of the mixing zone.

For horizontal groundwater flow, the mixing zone is usually calculated based on the method included in the EA RTM, which follows USEPA guidance. However, as the River Arun is a major groundwater discharge feature a significant upward component of groundwater flow would be anticipated, the effective volume of groundwater flow leading to dilution prior to discharge will be significantly greater and this has been accommodated in the Level 3 Attenuation Assessment, as discussed above.



An average hydraulic gradient of 0.0025 has been assumed, a reasonable average value based on numerical modelling and the site groundwater level contouring.

With regard to Level 2 analysis, only the length of the source in the direction parallel to the groundwater flow is required with regard to source geometry. As discussed above, impactation of the aquifer is limited to a local area in the north of the site where elevated concentrations of potential contaminants has been measured. Indeed these appear to be influenced by local presence of some NAPL in the unsaturated zone. Accordingly, a source area of plan dimensions of 15 m by 15 m was considered.

Details of the proposed site usage were not available at the time of preparation of the present report and a non-hard cover usage was assumed with an estimate annual infiltration of 40 % of annual average precipitation (747 mm, <https://en.climate-data.org>).

## **5.5 LEVEL 3 PARAMETERS**

### **5.5.1 GENERAL**

The Level 3 analysis considers attenuation within the aquifer as the plume moves away from the source area. The additional parameters necessary for this analysis are the longitudinal and lateral dispersivities, the half life degradation rate and the partition coefficient (Kd) of the substances in the aquifer. For organics the fraction of organic carbon (foc) is needed to compute Kd. This would be expected to be relatively high for the shallow portion of the aquifer. A value of foc = 0.0001 was adopted for RTM modelling, which is considered a reasonable low bound for the shallow section of the aquifer.

Longitudinal and lateral dispersivities were set 10% and 1 % respectively of the path length to discharge.

The chalk would be expected to have a low effective porosity due to fissure flow, and a value of 0.1 was adopted.

### **5.5.2 DEGRADATION PARAMETERS**

It is conservative in RTM analysis to ignore degradation. However, it is found that some degradation of organic compounds invariably occurs in the groundwater system and to ignore this effect is in most cases extremely conservative.

Adopted degradation rates are based primarily on EA P2 228 (2002). The data presented in EA P2 228 for shallow sand and gravel aquifers are considered relevant to the present case as the near surface groundwater is unconfined. Generally, where a range of typical field values has been given, the upper limit has been adopted. These data are relevant to field conditions, i.e. not the 'dissolved phase only' option in the EA RTM Spreadsheet. As pointed out by Alvarez and Illman (2006), Wiedemeier et al (1999) and ASTM (1998), if it is assumed that degradation occurs only in the dissolved phase, then the degradation rate derived from field conditions should be multiplied by the retardation factor. If this is done, derived remedial targets are in fact the same for either option. It is generally found that for TPH compounds, rates of degradation in the field reduce with increasing molecule size. For TPH

fractions where no guidance is given in EA P2 228, approximate half lives have been estimated based on the guidance given in EA P2 228 for BTEX and scaling half lives based on the general relationship between half life and molecule size proposed in New Zealand Guidance.

The adopted values for preliminary analysis are summarised in the table below:

| Substance             | Half Life (days) | Source                                                                   |
|-----------------------|------------------|--------------------------------------------------------------------------|
| Benzene               | 350              | Upper Limit EA Report P2-228/TR                                          |
| Toluene               | 200              | Upper Limit EA Report P2-228/TR                                          |
| Ethylbenzene          | 200              | Upper Limit EA Report P2-228/TR                                          |
| m-Xylene              | 200              | Upper Limit EA Report P2-228/TR                                          |
| o-Xylene              | 200              | Upper Limit EA Report P2-228/TR                                          |
| p-Xylene              | 200              | Upper Limit EA Report P2-228/TR                                          |
| TPH Aliphatic C8-C10  | 700              | Upper Limit for BTEX EA Report P2-228/TR scaled according to NZ Practice |
| TPH Aliphatic C10-C12 | 1750             | As TPH C8-C10 scaled according to NZ Practice                            |
| TPH Aromatic C8-C10   | 700              | As TPH C8-C10 scaled according to NZ Practice                            |
| TPH Aromatic C10-C12  | 1750             | As TPH C8-C10 scaled according to NZ Practice                            |
| TPH Aromatic C12-C16  | 2450             | As TPH C8-C10 scaled according to NZ Practice                            |
| TPH Aromatic C16-C21  | 3500             | As TPH C8-C10 scaled according to NZ Practice                            |

## 5.6 DERIVED REMEDIAL TARGETS

RTM spreadsheets are included in Addendum 5, which also includes all input values.

Derived remedial targets for soils, pore water (leachate) and groundwater with respect to controlled waters are summarised in the following table. These should be used within the overall assessment in conjunction with pragmatic considerations and human health issues to develop appropriate overall remedial targets. Note that some of the derived targets exceed the likely solubility of some compounds and some derived soil targets exceed residual saturation levels. In such cases, the relevant substances may be assumed to be insufficiently leachable to pose any risk to controlled water. These factors should be considered in the overall assessment.

Remedial targets have been derived for an assumed distance to compliance of 90 m, which is the approximate distance from the source area in the north of the site to the downstream site boundary. No dilution in the receiving water (river) ('Level 4') has been considered, which in the present is very conservative.

**Arundel**
**Case:**
**1 15 by 15 m Source Zone**

| Substance                  | RTM Remedial Target Concentrations |                    |                     |
|----------------------------|------------------------------------|--------------------|---------------------|
|                            | Level 3 Soil                       | Level 3 Pore Water | Level 3 Groundwater |
|                            | (mg/kg)                            | (mg/l)             | (mg/l)              |
| Benzene                    | 2,900                              | ES(2,000)          | 7                   |
| Toluene                    | 57,000                             | ES(>10,000)        | 53                  |
| Ethylbenzene               | 33,000                             | ES(4,000)          | 14                  |
| m-Xylene                   | 53,000                             | ES(6,000)          | 21                  |
| o-Xylene                   | 47,000                             | ES(6,000)          | 21                  |
| p-Xylene                   | 49,000                             | ES(6,000)          | 21                  |
| Benzo[a]anthracene         | >100,000                           | ES(440)            | ES(1.6)             |
| Benzo[b]fluoranthene       | 13,000                             | ES(6.9)            | ES(0.025)           |
| Benzo[k]fluoranthene       | 19,000                             | ES(7.4)            | ES(0.026)           |
| Benzo[ghi]perylene         | 5,400                              | ES(0.74)           | ES(0.0026)          |
| Benzo[a]pyrene             | 92                                 | ES(0.041)          | 0.00015             |
| Chrysene                   | >100,000                           | ES(430)            | ES(1.5)             |
| Dibenz[ah]anthracene       | >100,000                           | ES(520)            | ES(1.9)             |
| Fluoranthene               | 400                                | ES(1.3)            | 0.0045              |
| Indeno[123-cd]pyrene       | 680                                | ES(0.45)           | ES(0.0016)          |
| Naphthalene                | 4,600                              | ES(400)            | 1.4                 |
| Pyrene                     | >100,000                           | ES(400)            | ES(1.4)             |
| Acenaphthalene             | 17,000                             | ES(390)            | 1.4                 |
| Acenaphthene               | 55,000                             | ES(400)            | 1.4                 |
| Fluorene                   | 88,000                             | ES(400)            | 1.4                 |
| Phenanthrene               | >100,000                           | ES(410)            | ES(1.4)             |
| Anthracene                 | 11,000                             | ES(21)             | ES(0.073)           |
| Phenol                     | 1,200                              | 1,600              | 5.5                 |
| TPH Aliphatic C8-C10       | >100,000                           | ES(2,500)          | ES(9.1)             |
| TPH Aliphatic C10-C12      | >100,000                           | ES(4,300)          | ES(15)              |
| TPH Aliphatic C12-C16      | >100,000                           | ES(>10,000)        | ES(8,300)           |
| TPH Aliphatic C16-C21      | >100,000                           | ES(>10,000)        | ES(>10,000)         |
| TPH Aliphatic C21-C34      | >100,000                           | ES(>10,000)        | ES(>10,000)         |
| TPH Aliphatic C35-C44      | >100,000                           | ES(>10,000)        | ES(>10,000)         |
| TPH Aromatic C8-C10        | 56,000                             | ES(2,000)          | 7.1                 |
| TPH Aromatic C10-C12       | 87,000                             | ES(2,000)          | 7                   |
| TPH Aromatic C12-C16       | >100,000                           | ES(2,000)          | ES(7)               |
| TPH Aromatic C16-C21       | >100,000                           | ES(2,000)          | ES(7.1)             |
| TPH Aromatic C21-C35       | >100,000                           | ES(2,400)          | ES(8.6)             |
| TPH Aromatic C35-C44       | >100,000                           | ES(2,400)          | ES(8.6)             |
| Arsenic                    | >100,000                           | 9,800              | 35                  |
| Cadmium                    | >100,000                           | 49                 | 0.17                |
| Copper                     | >100,000                           | 5,500              | 19                  |
| Chromium                   | >100,000                           | 3,900              | 14                  |
| Lead                       | >100,000                           | 1,400              | 5                   |
| Inorganic Mercury          | 73,000                             | 9.8                | 0.035               |
| Nickel                     | >100,000                           | 3,900              | 14                  |
| Selenium                   | 98,000                             | 2,000              | 7                   |
| Zinc                       | >100,000                           | 6,600              | 24                  |
| Hexavalent Chromium        | 12,000                             | 660                | 2.4                 |
| Trivalent Chromium         | >100,000                           | 920                | 3.3                 |
| Easily Liberatable Cyanide | 250                                | 200                | 0.71                |
| Total Cyanide              | >100,000                           | >10,000            | >10,000             |

Values Include an Additional Dilution Factor for Tide of 82

ES = Target Exceeds Solubility

Only measured groundwater concentrations for benzene fluoranthene and naphthalene slightly exceed the remedial targets and fluoranthene and naphthalene only in one of the four monitoring rounds available.

## 6 SITE-SPECIFIC ATTENUATION DATA

The present study has shown that extremely high levels of dilution would be expected to occur within the chalk aquifer downstream of the source zone and prior to discharge to the River Arun due primarily to tidal dilution but also by an expected upward gradient from the deeper chalk aquifer. The evidence for this includes the following:

- Numerical modelling has shown that locally the chalk must have very high average conductivity in order to explain the large fluctuations in groundwater head at the site during tidal cycles. It follows that large volumes of water must enter and leave the aquifer during each tide cycle.
- Contouring of measured concentration of potential contaminants in groundwater show rapid attenuation with almost all meeting compliance prior to the downstream south eastern site boundary.
- Available monitoring of surface water adjacent to the site has shown no detectable impaction.

It follows that analysis to determine 'Level 3' attenuation based on conventional Remedial Targets Methodology does not adequately model the site conditions. This is illustrated further in Figure C19 where the site attenuation based on measured data is plotted against distance from the peak measured concentration. This plot was developed from the contoured concentrations of benzene and naphthalene from the recent monitoring (Addendum C1) with attenuation factor being defined as the peak concentration divided by the concentration at distance from the peak. Also shown is the predicted attenuation using conventional RTM analysis and no allowance for the additional dilution factors. Indeed, even if the adopted additional dilution factor for analysis (82 times) is considered, measured attenuation rates greatly exceed predicted values, confirming that all substances could be expected to meet compliance prior to discharge to the Arun.

As tidal dilution dominates the calculation of remedial targets and available data show that actual levels of attenuation significant exceed computed rates, there is little point in undertaking detailed sensitivity analysis of all RTM parameters. For example, the net attenuation at level 3 for conservative compounds (no degradation) is only 8.48. The total attenuation for benzene, including degradation, is 8.57, so clearly analysis is not sensitive to degradation for mobile compounds. The additional dilution due to tide is in excess of 80 times. So varying parameters associated with Level 3 analysis, other than tidal effects, is clearly not significant. The main parameter controlling the degree of tidal dilution, average conductivity, has been treated parametrically and a sensible lower bound adopted such that more detailed sensitivity analysis is of little value.

## **7 IMPLICATIONS FOR REMEDIAL OPTIONS**

The present analysis and available data have shown that, largely due to very high tidal induced groundwater flows, levels of potential contaminants present in the northern site area can be expected to meet compliance prior to discharge to the River Arum and that groundwater remediation per se would offer little benefit. In addition the high tidal induced groundwater flows would likely make available groundwater remediation technologies ineffective.

There is some evidence of a residual source, or sources of non aqueous phase organic potential contaminants in the northern site area. Consideration could be given to removing or reducing these potential sources.

## 8 SUMMARY CONCLUSIONS

There is a source area of un-dissolved residual impaction within the near surface saturated and unsaturated soils in the northern site area. This is likely to be persistent as it is present in material of low hydraulic conductivity. Measured groundwater concentrations of organic substances in samples from wells are influenced by the presence of un-dissolved phase in the soils and are unlikely to be representative of true dissolved phase groundwater concentrations.

High effective conductivity of the underlying chalk, probably dominated by fissure flow, is leading the large fluctuations in groundwater heads across the site due to tidal water level changes in the adjacent surface water that can be reasonably simulated by a simplified numerical model.

Groundwater originating as surface infiltration in the site area is likely flowing vertically downwards through the near surface unsaturated and saturated soils or relatively low conductivity until discharge to flow in the chalk, probably dominated by fissure flow.

Very high dilution is occurring within the aquifer prior to discharge to the river due to a combination of dilution and dispersion due to average groundwater flow and due to tidal flow. The net result is very high gradients in measured concentrations of organic substances with distance, i.e. very high apparent attenuation with horizontal distance, which is largely due to real dilution due to tidal and upward groundwater movements but accentuated by the likely presence of NAPL that is leading to apparent concentrations near the source that likely exceed the true dissolved phase concentration.

Dissolved phase concentrations of potential contaminants in the groundwater may be assumed to meet compliance before discharge to the tidal water body and groundwater remediation per se would offer little benefit. The high groundwater flows induced by the tidal fluctuations would, in any case, make available remedial options ineffective.

Consideration could be given to reducing near surface potential contaminant sources in the northern site area.

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Data Maximum Value = 3.2 (mAOD) Data Minimum Value = -3.61 (mAOD)

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Date: Jan 2021

Scale: NTS

Title: Inferred Contours of Base of Made Ground Elevation

Client: NGPH

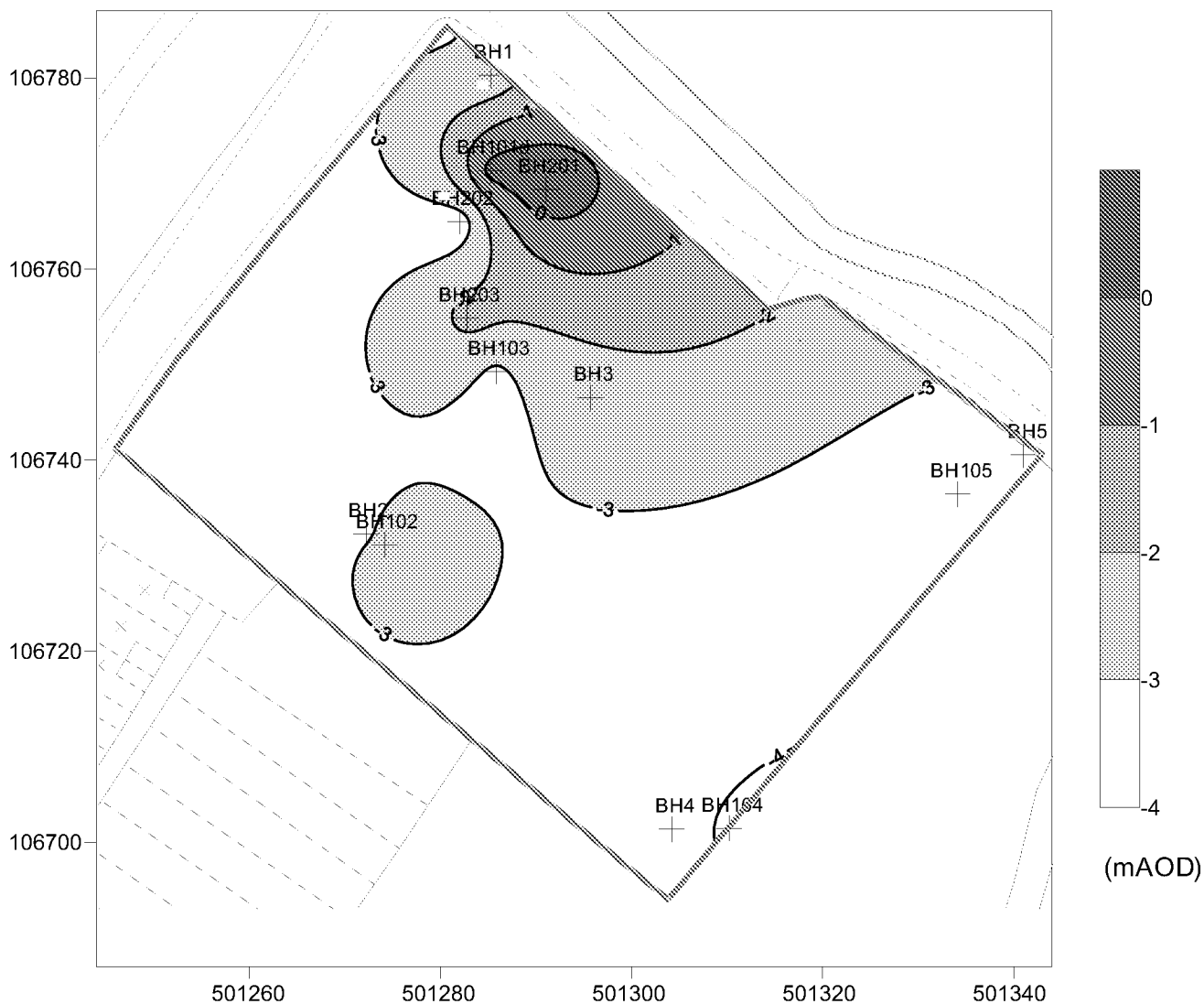
Project: Name: Ford Road, Arundel

Contract No.: C1820

Figure No: C1







Data Maximum Value = 0.72 (mAOD) Data Minimum Value = -4.22 (mAOD)

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Date: Jan 2021

Scale: NTS

Title: Inferred Contours of Top of Chalk Elevation

Client: NGPH

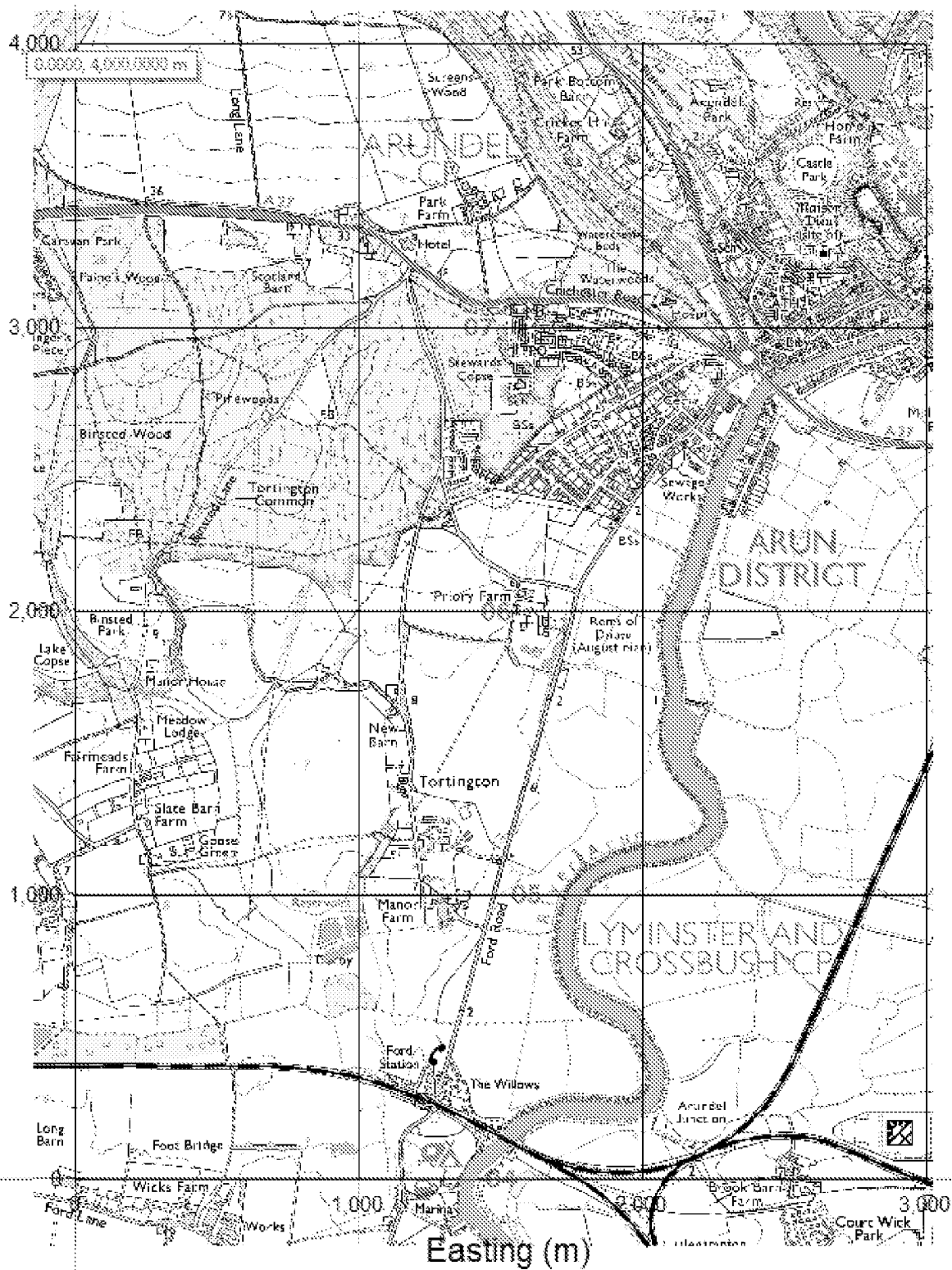
Project: Name: Ford Road, Arundel

Contract No.: C1820

Figure No: C2



North (m)



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Date: Jan 2021

Scale: NTS

Title: Site Topographic Setting

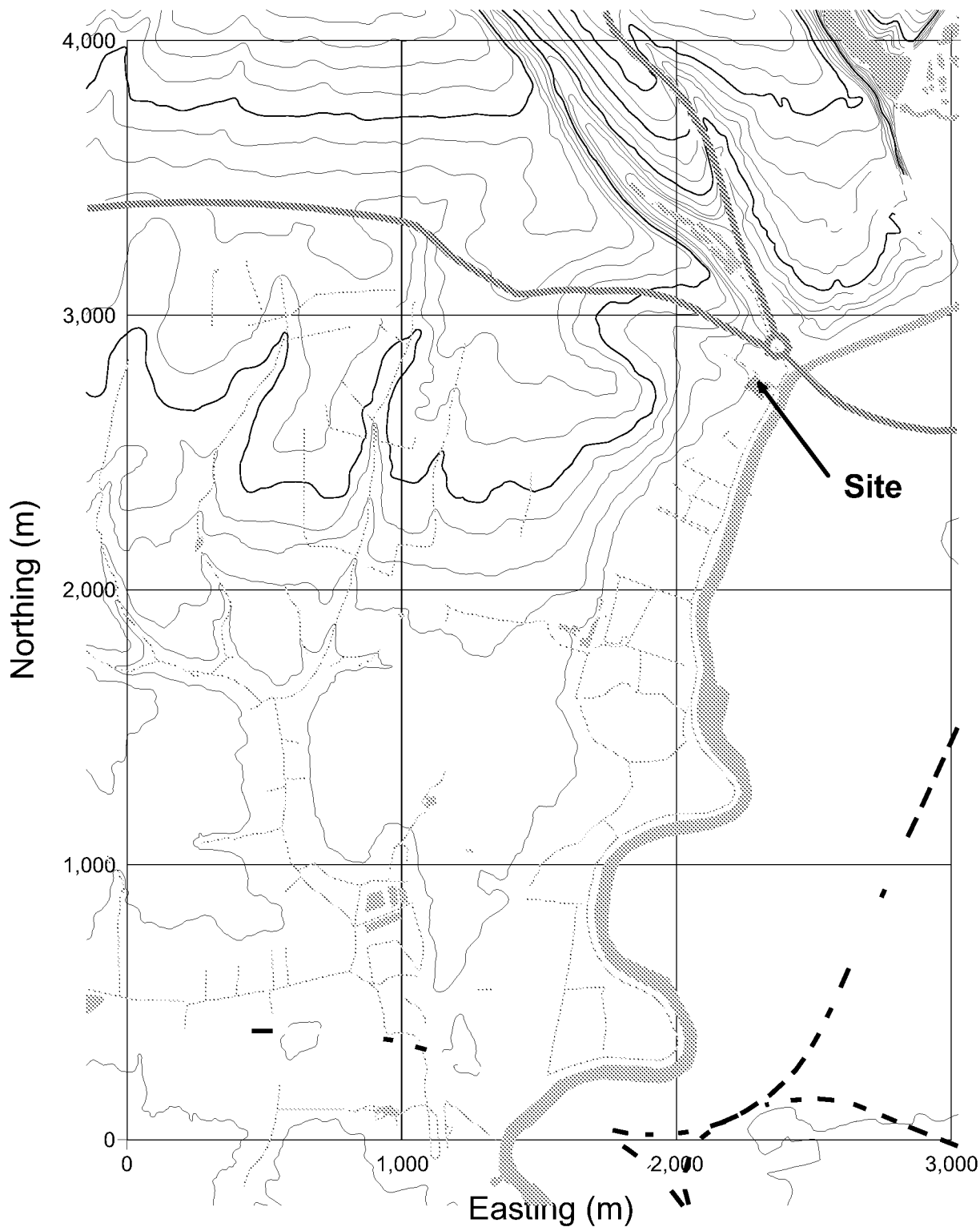
Client: NGPH

Project: Name: Ford Road, Arundel

Contract No.: C1820

Figure No: C3





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Date: Jan 2021

Scale: NTS

Title: Surface Water Features in Vicinity of Site

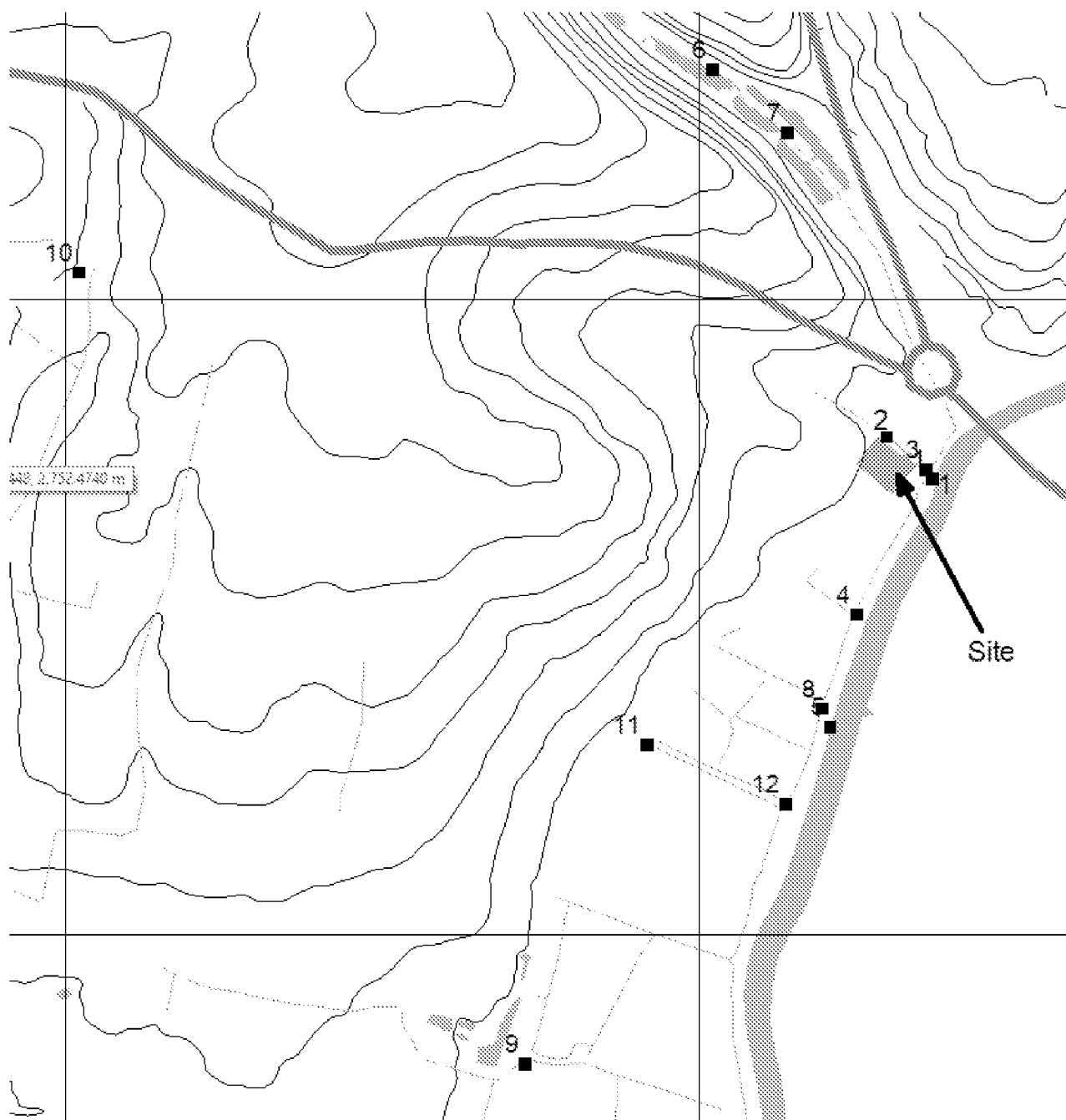
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Project: Name: Ford Road, Arundel

Contract No.: C1820

Figure No: C4a





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Date: Jan 2021

Scale: NTS

Title: Surface Survey Points

Client: NGPH

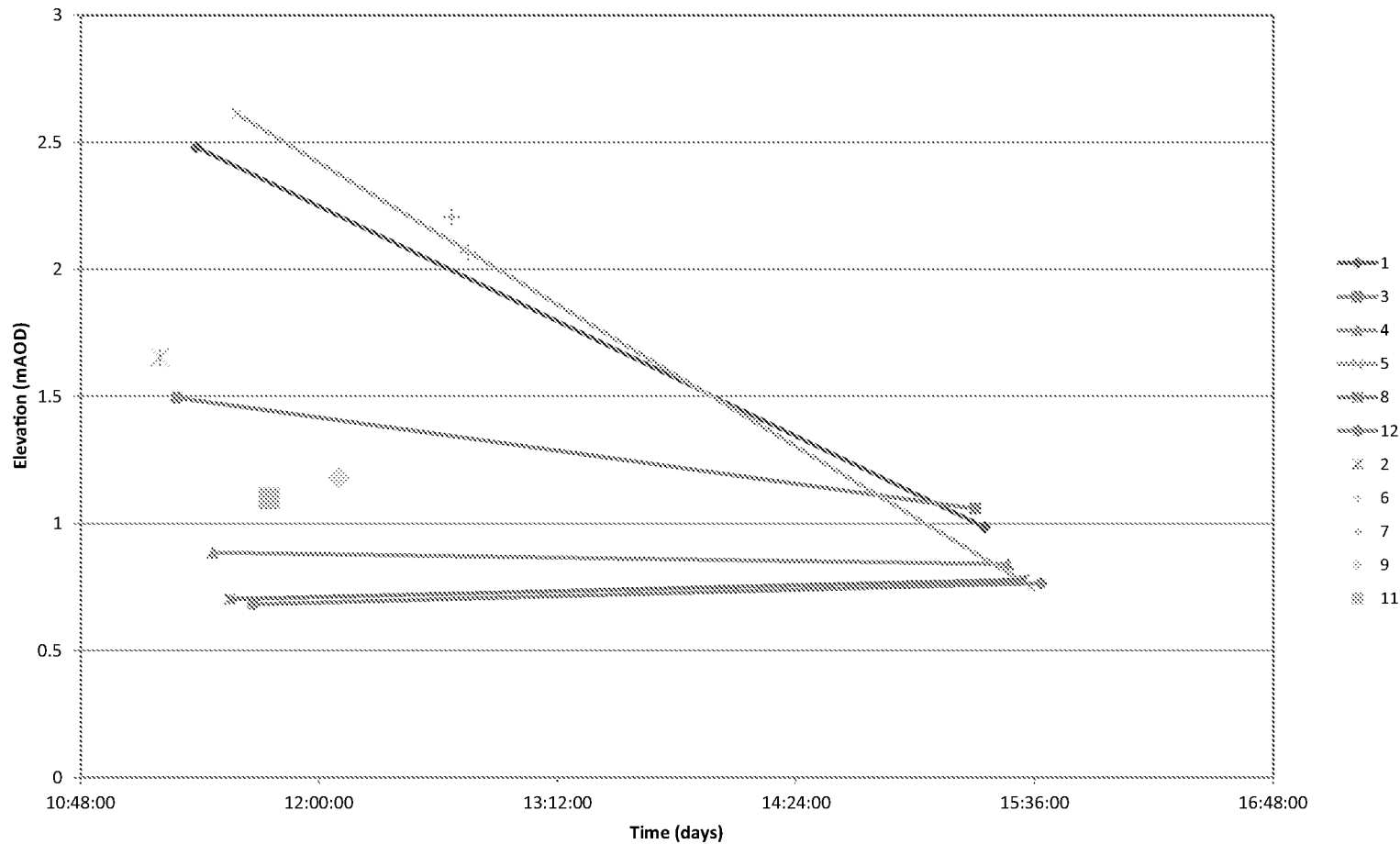
Project: Name: Ford Road, Arundel

Contract No.: C1820

Figure No: C4b



Surface Water Levels vs Time on 01/12/2020



CELTIC Technologies Ltd  
Columbus House  
Greenmeadow Springs  
Tongwynlais  
Cardiff CF15 7NE

TEL. (029) 2036 8636  
Fax. (029) 2036 8637

Client: National Grid

Project: Name: Ford Road, Arundel

Contract No. C1820

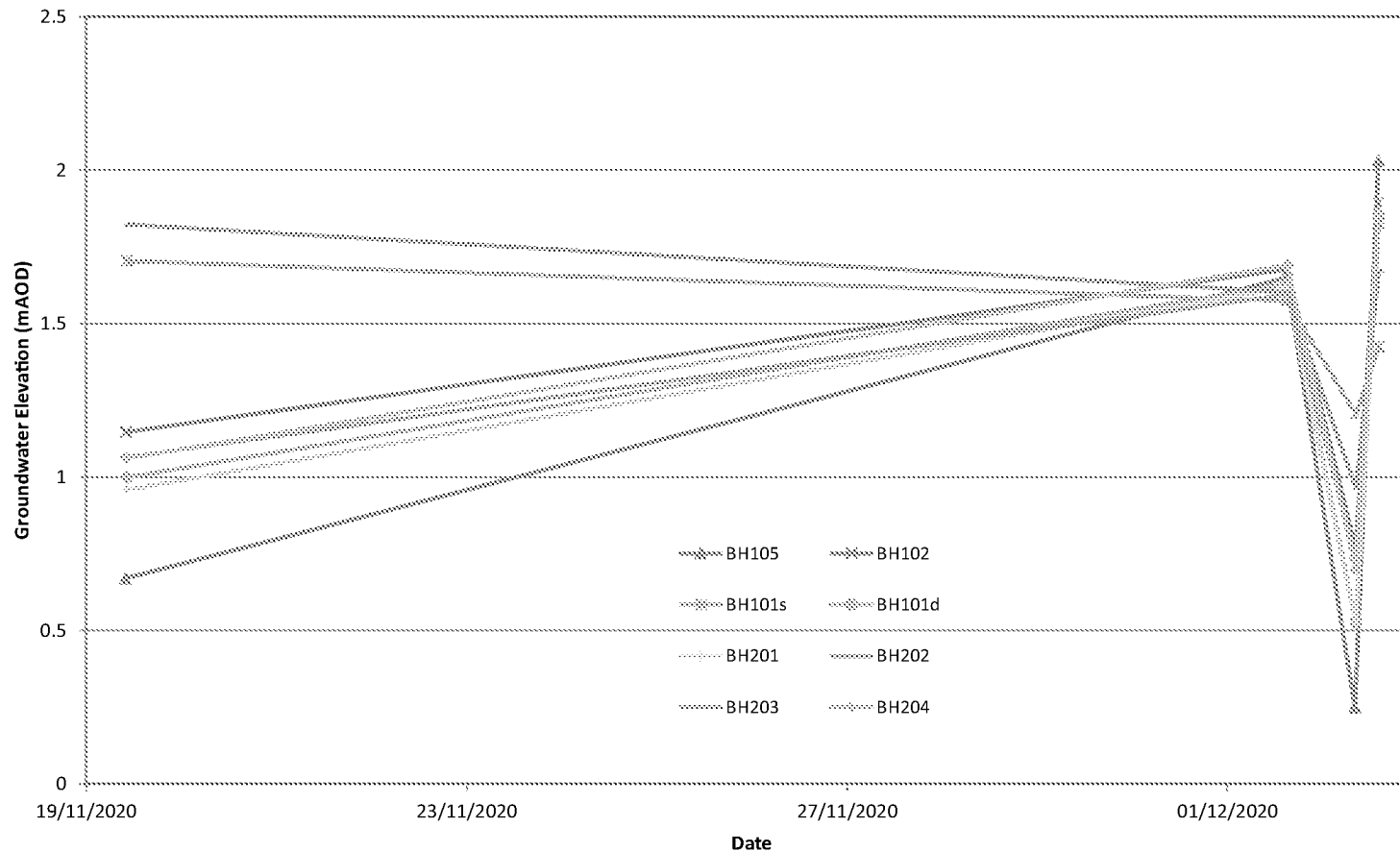
Title: Measured Surface Water Levels  
vs Time

Figure No: C5

Scale: NTS

Date Drawn: January 2021

## Standpipe Water Levels vs Time



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Client: National Grid

Project: Brackley

Contract No. C1820

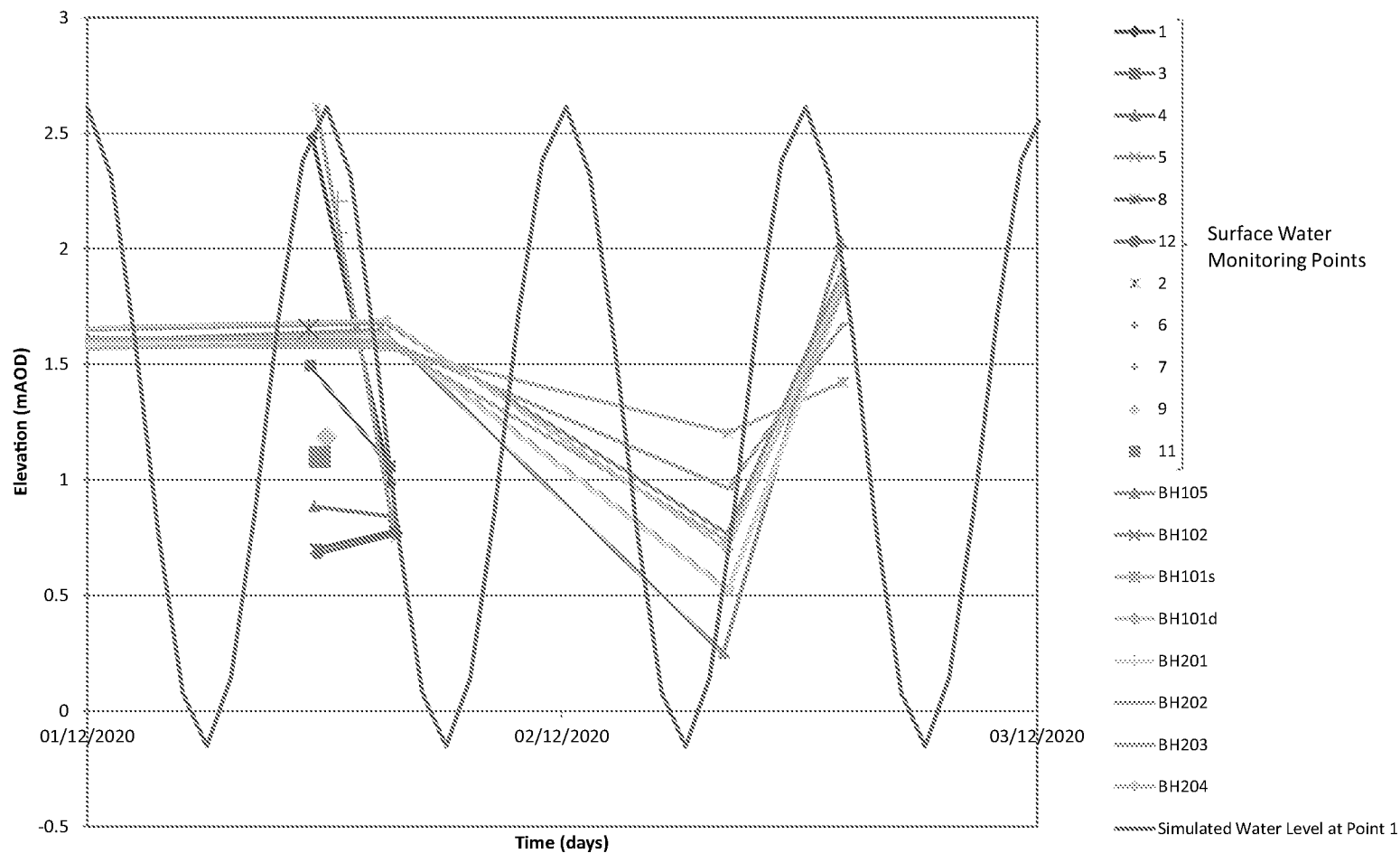
Title: Ford Road, Arundel

Figure No: C6

Scale: NTS

Date Drawn: January 2021

# Surface Water and Standpipe Water Levels vs Time



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Cardiff CF15 7NE

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Client: National Grid

Project: Ford Road, Arundel

Contract No. C1820

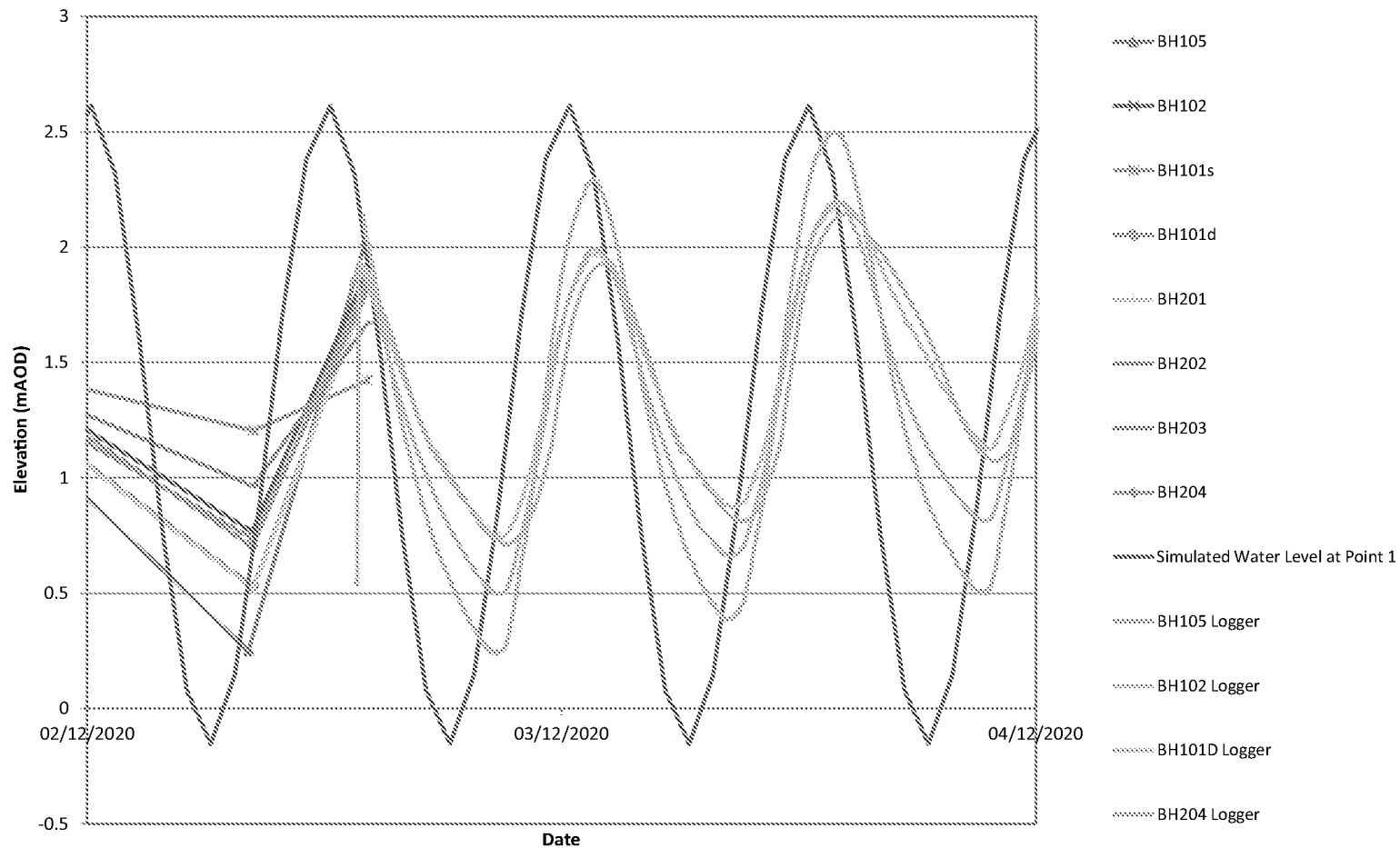
Title: Surface and Groundwater Levels  
Compared

Figure No: C7

Scale: NTS

Date Drawn: January 2021

## Surface Water and Standpipe Water Levels vs Time



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Cardiff CF15 7NE

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Client: National Grid

Project: Ford Road, Arundel

Contract No. C1820

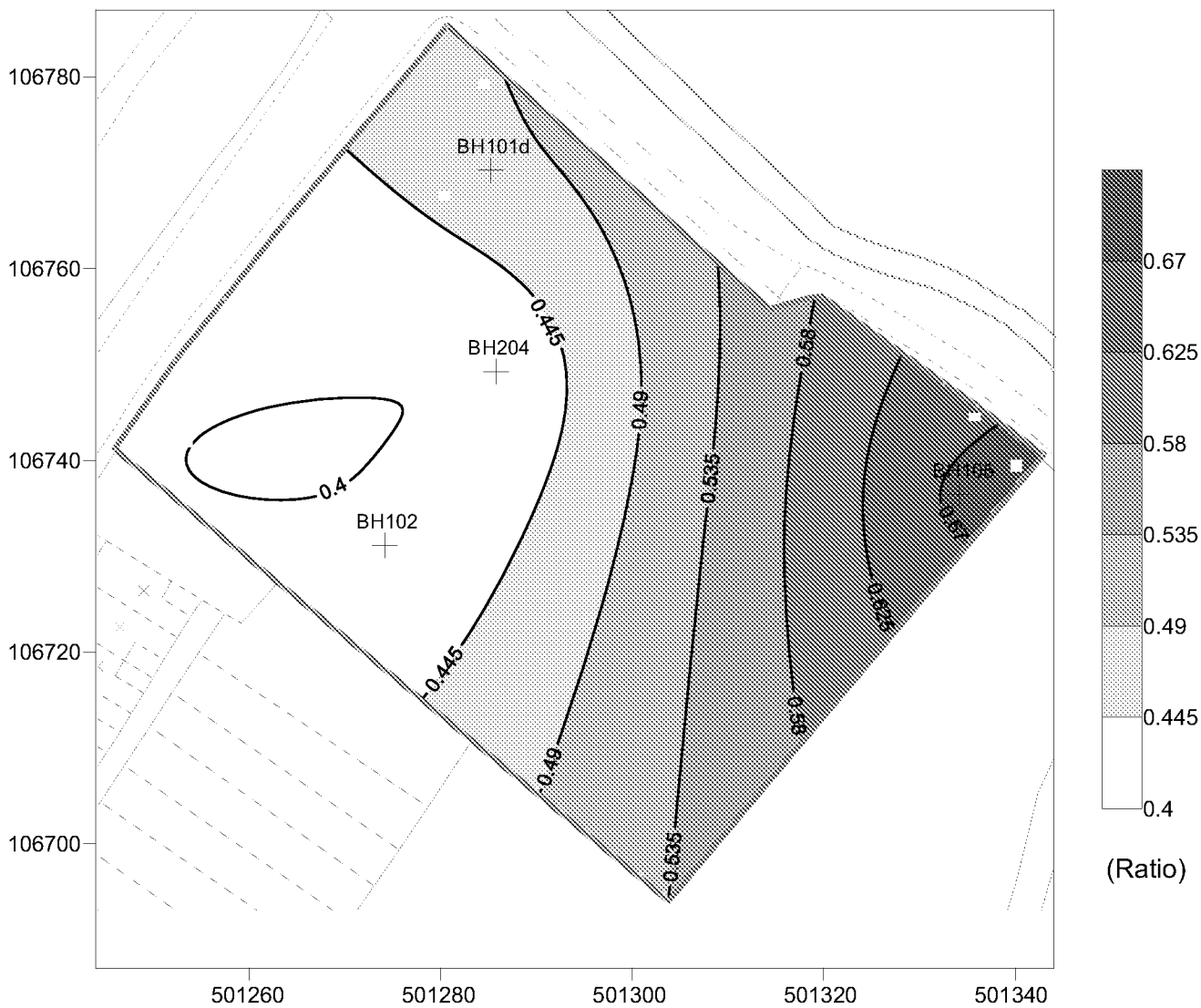
Title: Manual and Data Logger Water  
Levels Compared

Figure No: C8

Scale: NTS

Date Drawn: January 2021





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Date: Jan 2021

Scale: NTS

Title: Contours of Ratio of Amplitudes of Groundwater Level Fluctuation to Surface Water Fluctuation

Client: NGPH

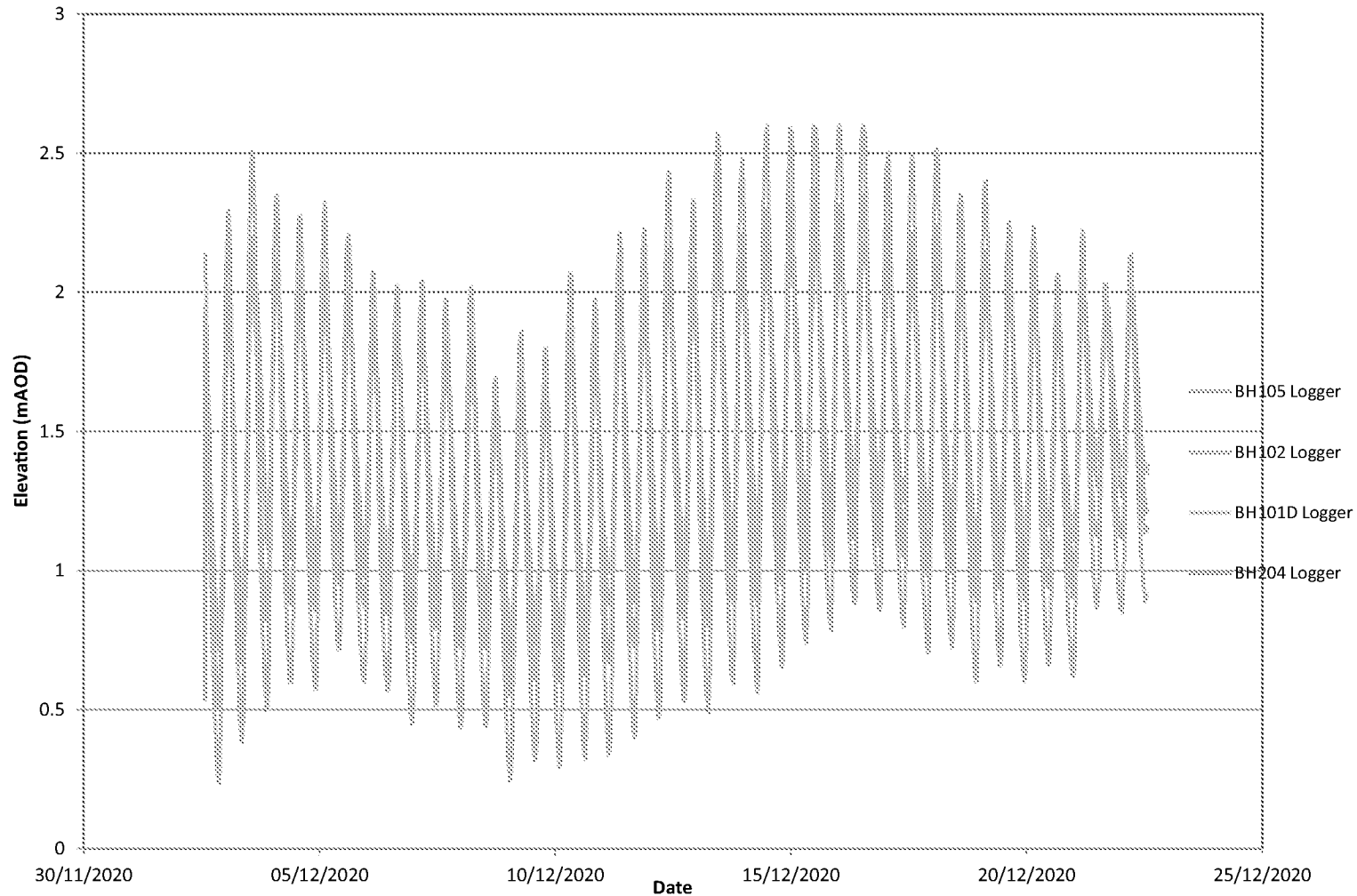
Project: Name: Ford Road, Arundel

Contract No.: C1820

Figure No: C9



# Datalog Standpipe Water Levels vs Time



CELTIC Technologies Ltd  
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Greenmeadow Springs  
Tongwynlais  
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Client: National Grid

Project: Ford Road, Arundel

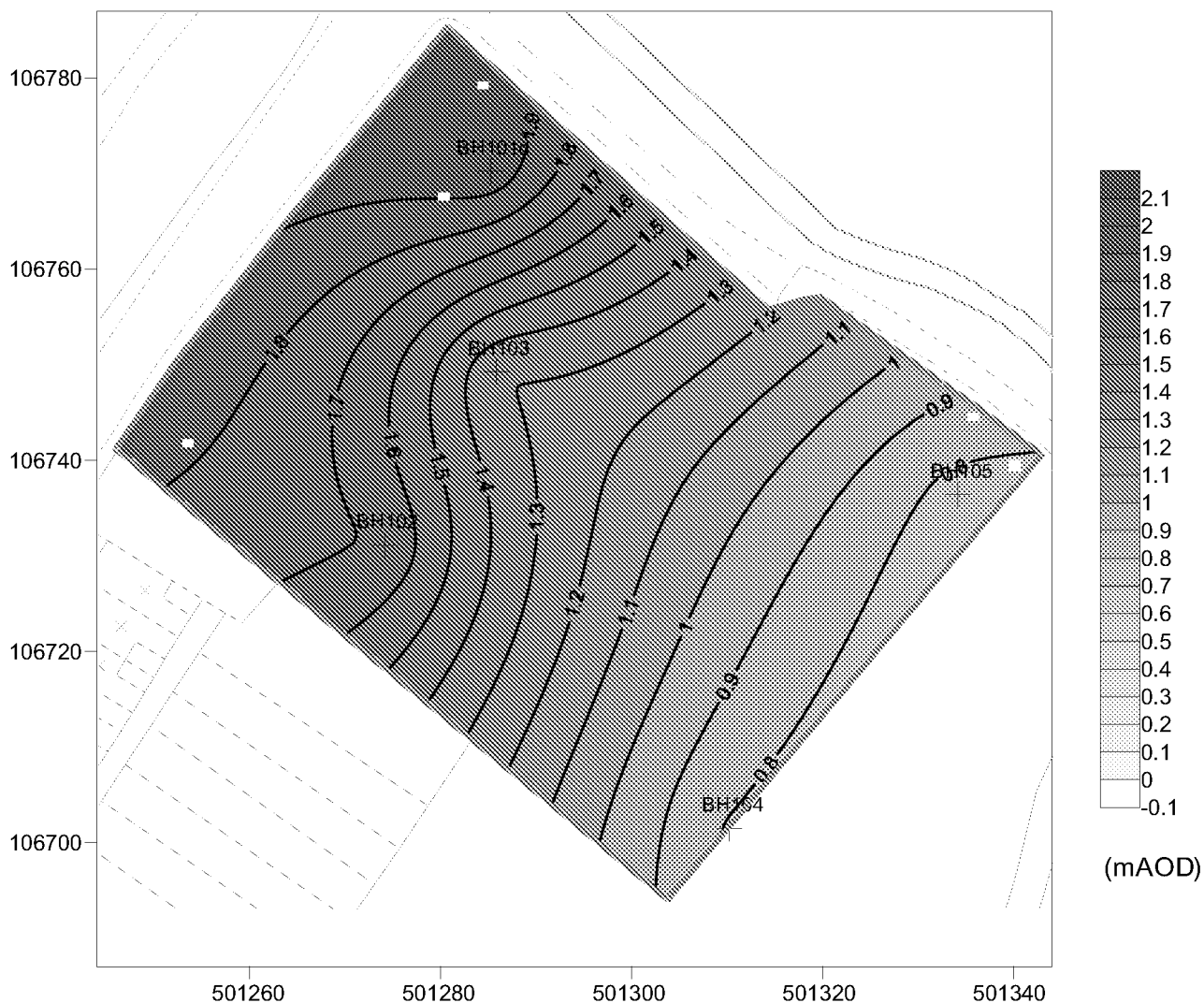
Contract No. C1820

Title: Water Level Fluctuations during  
Logged Period

Figure No: C10

Scale: NTS

Date Drawn: January 2021



Data Maximum Value = 1.975 (mAOD) Data Minimum Value = 0.76 (mAOD)

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Date: Jan 2021

Scale: NTS

Title: Contours of 15 July 2011 15 Minute Groundwater Level Readings

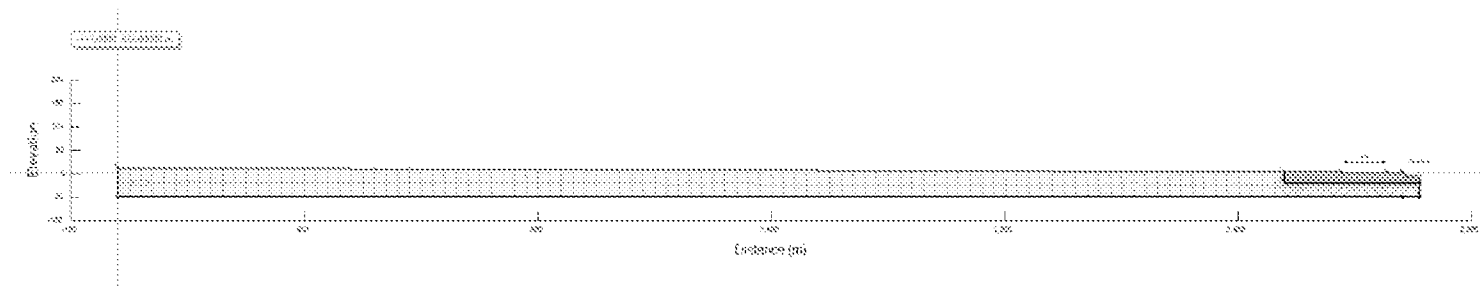
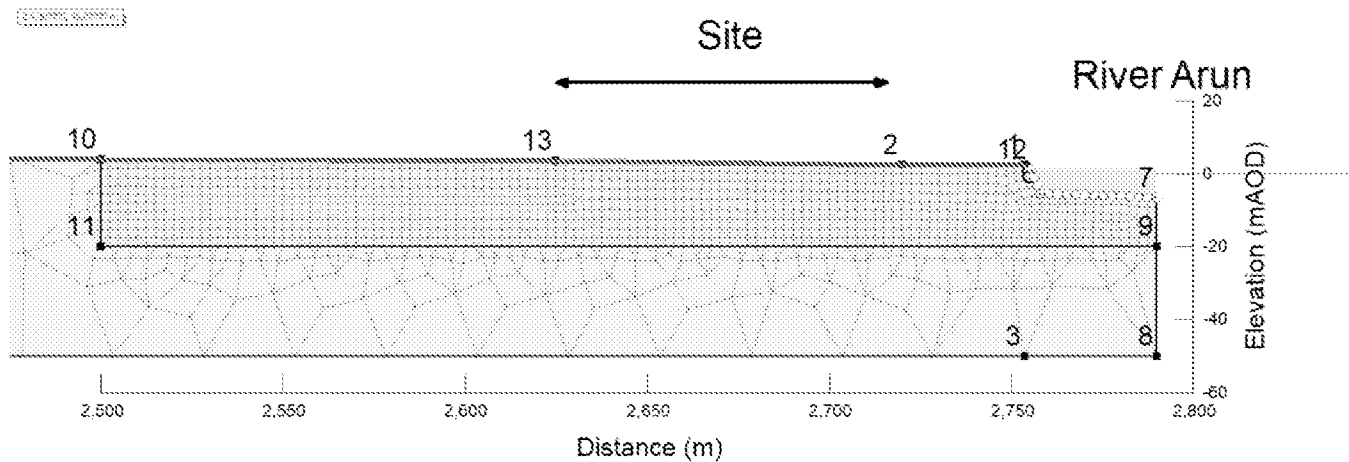
Client: NGPH

Project: Name: Ford Road, Arundel

Contract No.: C1820

Figure No: C11





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Project: Ford Road, Arundel

Contract No. C1820

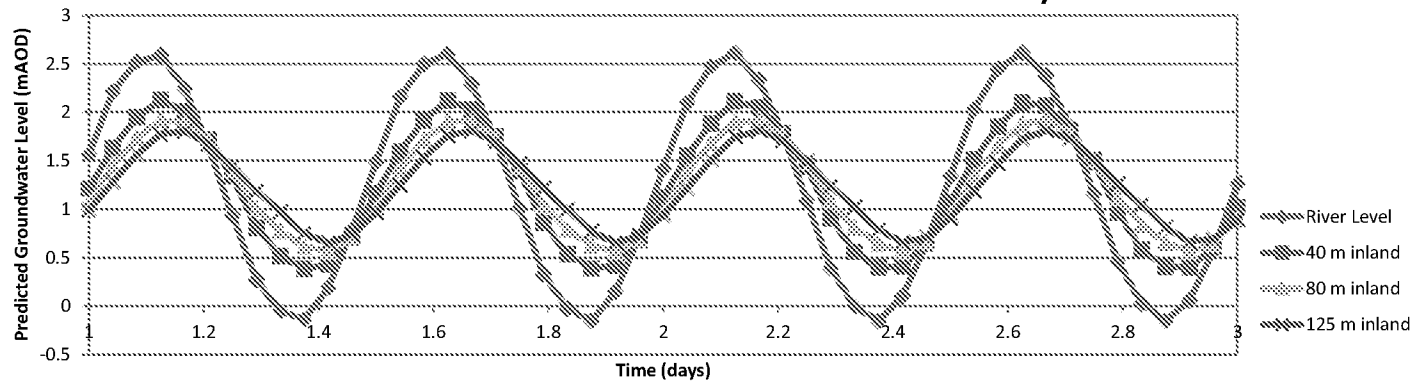
Title: Finite Element Mesh Used for  
Tidal Simulations

Figure No: C12

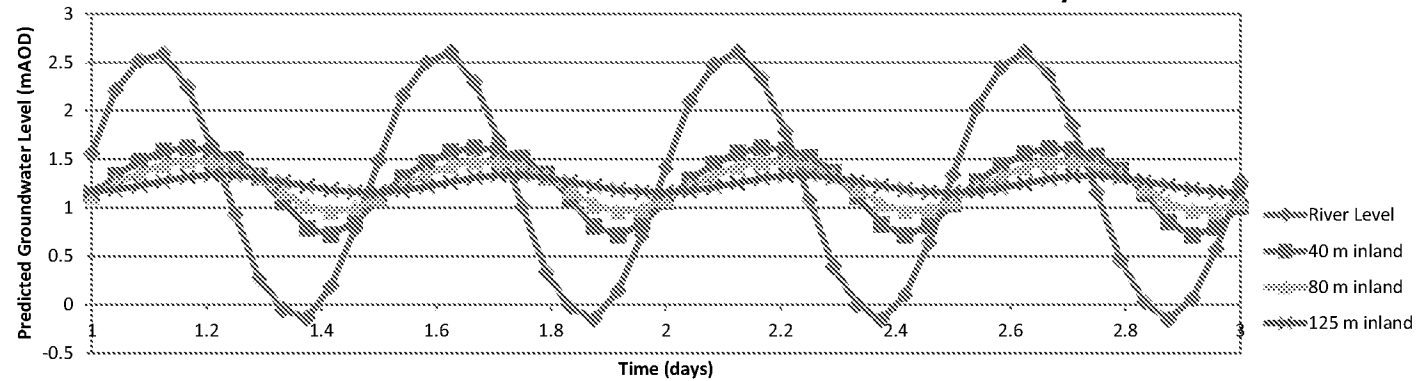
Scale: NTS

Date Drawn: January 2021

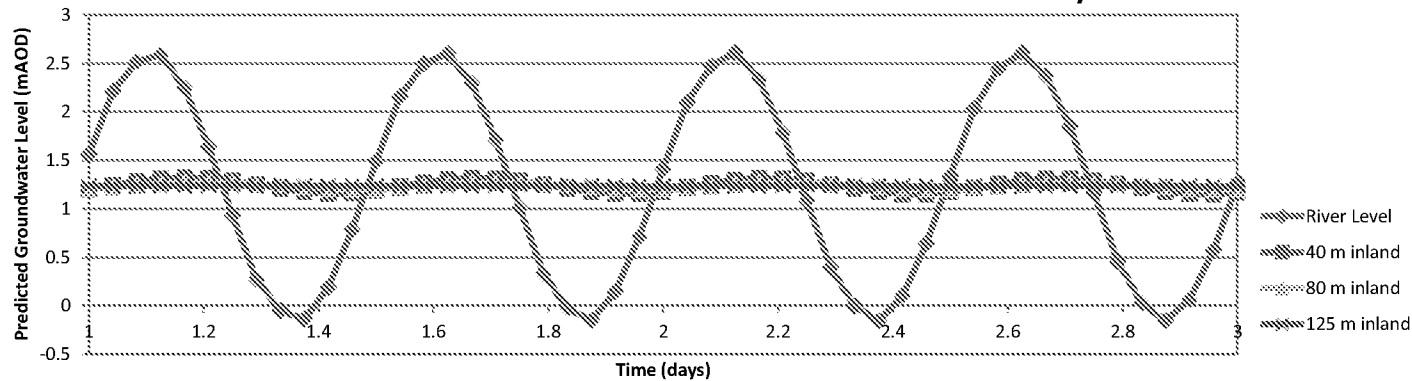
**Predicted Groundwater Fluctuations  $ksat = 0.01 \text{ m/s}$**



**Predicted Groundwater Fluctuations  $ksat = 0.001 \text{ m/s}$**



**Predicted Groundwater Fluctuations  $ksat = 0.0001 \text{ m/s}$**



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Project: Ford Road, Arundel

Contract No. C1820

Title: Predicted Groundwater Head  
Fluctuations due to Tide

Figure No: C13

Scale: NTS

Date Drawn: January 2021



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Client: National Grid

Project: Ford Road, Arundel

Contract No. C1820

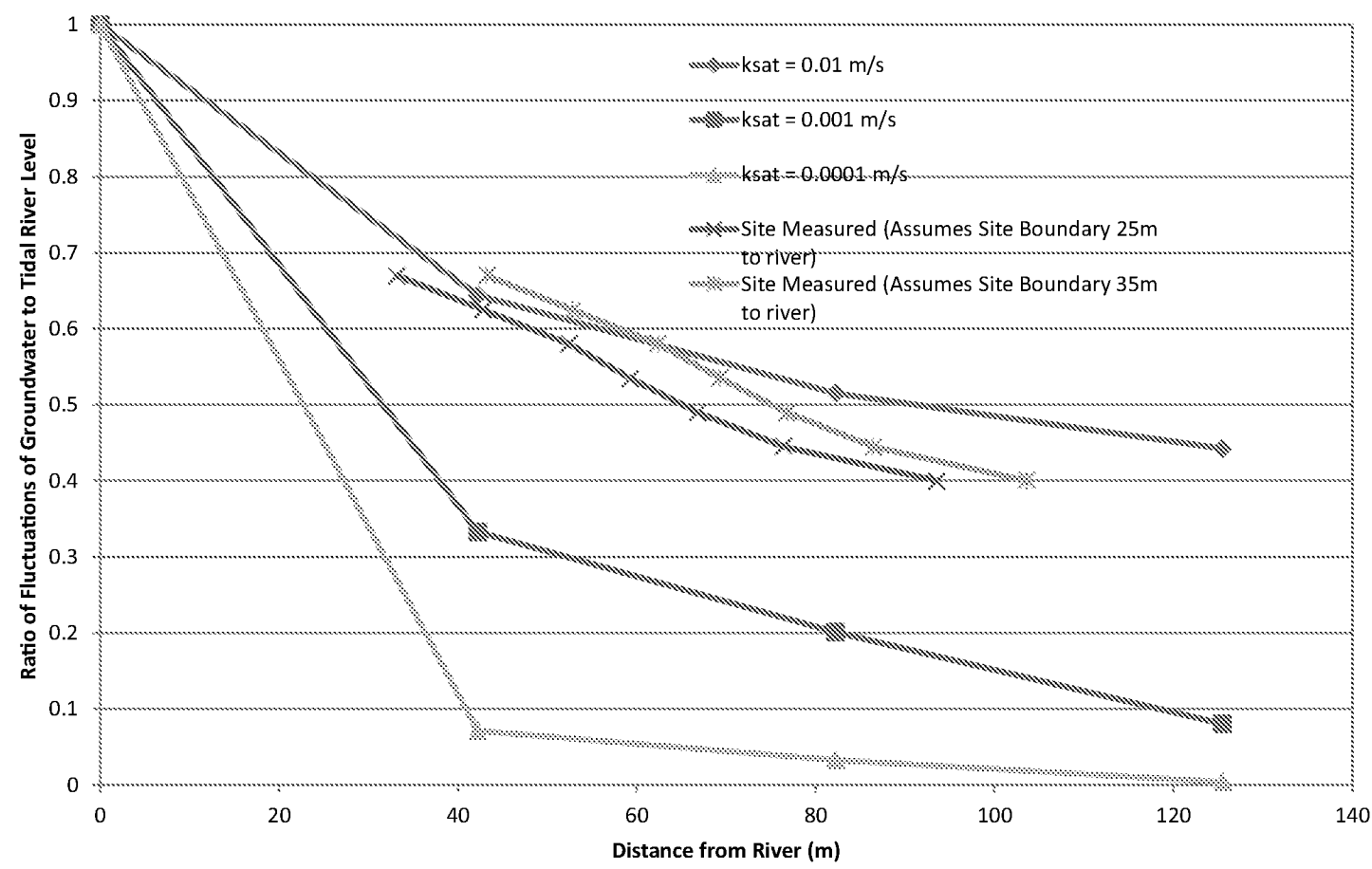
Title: Ratio of Predicted Groundwater  
Level Fluctuation to Tidal Level  
Fluctuation vs Distance from River

Figure No: C14

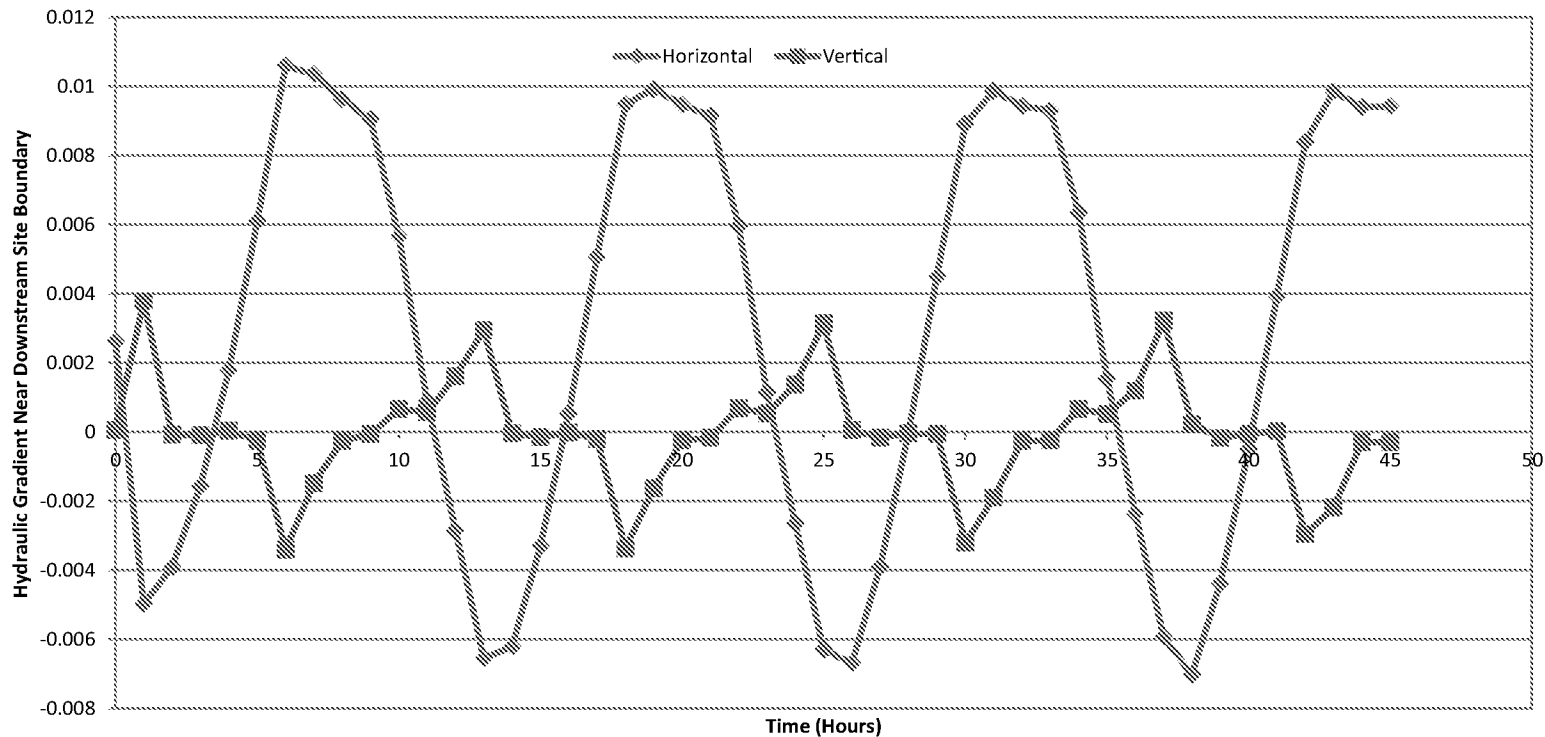
Scale: NTS

Date Drawn: January 2021

Ratio of Predicted Groundwater Level Fluctuation to Tidal Level Fluctuation vs Distance from River



## Hydraulic Gradient vs Time



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Project: Ford Road, Arundel

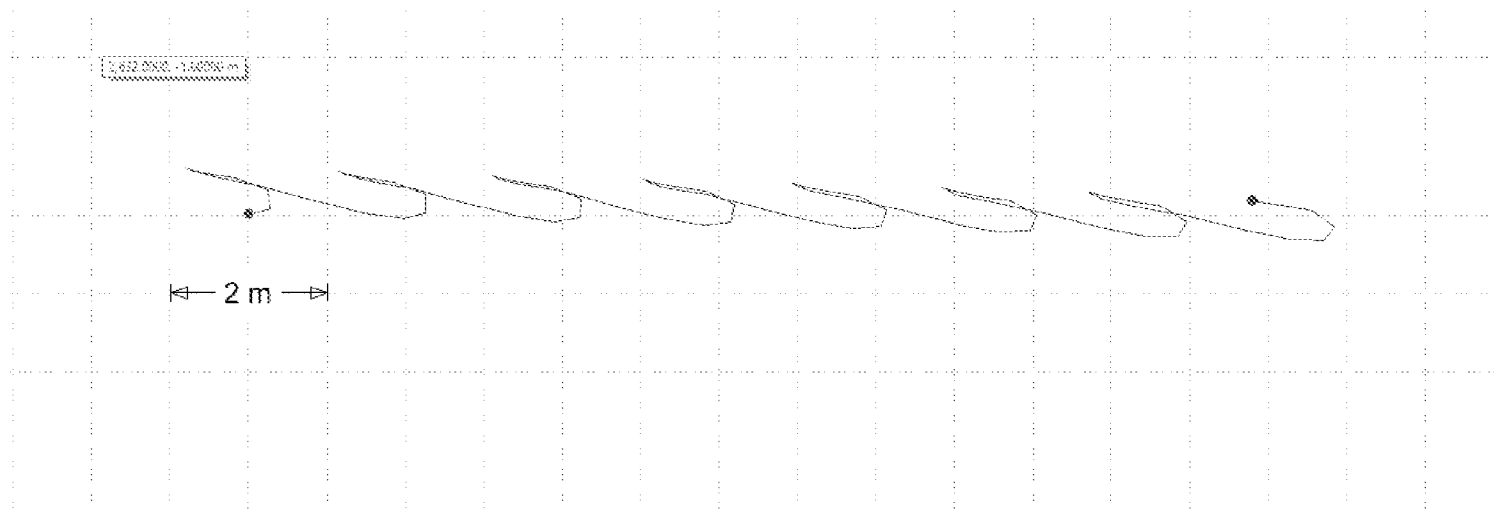
Contract No. C1820

Title: Predicted Hydraulic Gradient  
Fluctuations

Figure No: C15

Scale: NTS

Date Drawn: January 2021



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Project: Ford Road, Arundel

Contract No. C1820

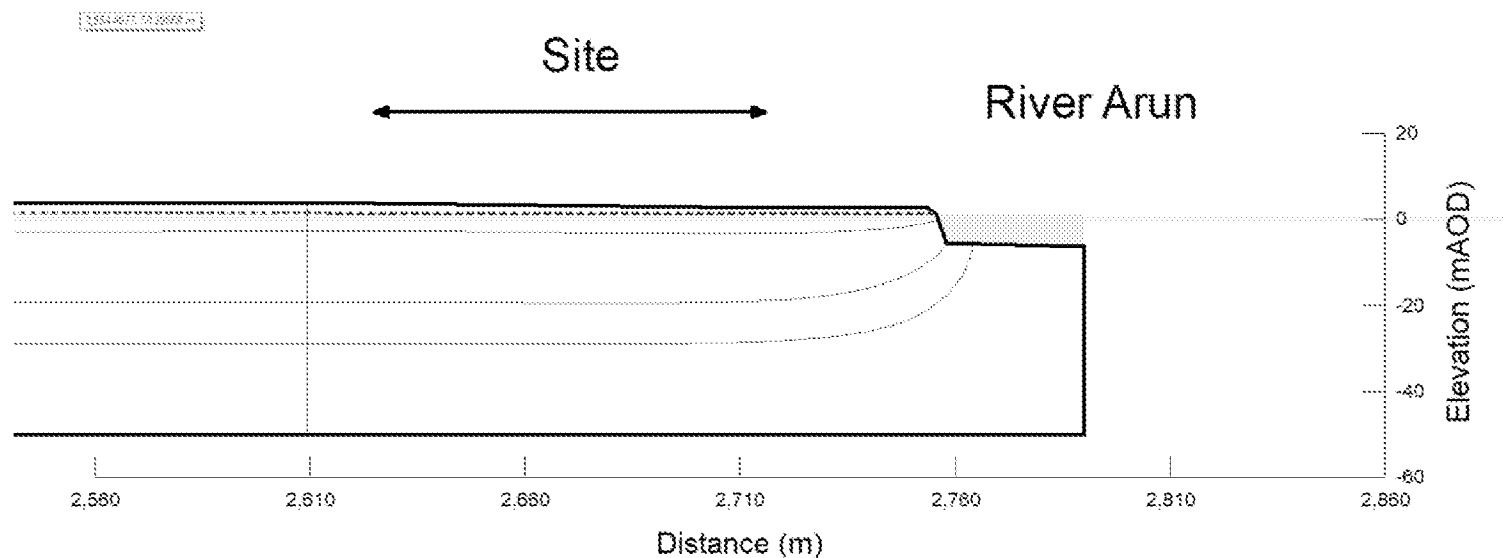
Title: Particle Tracking Analysis

Figure No: C16

Scale: NTS

Date Drawn: January 2021





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Client: National Grid

Project: Ford Road, Arundel

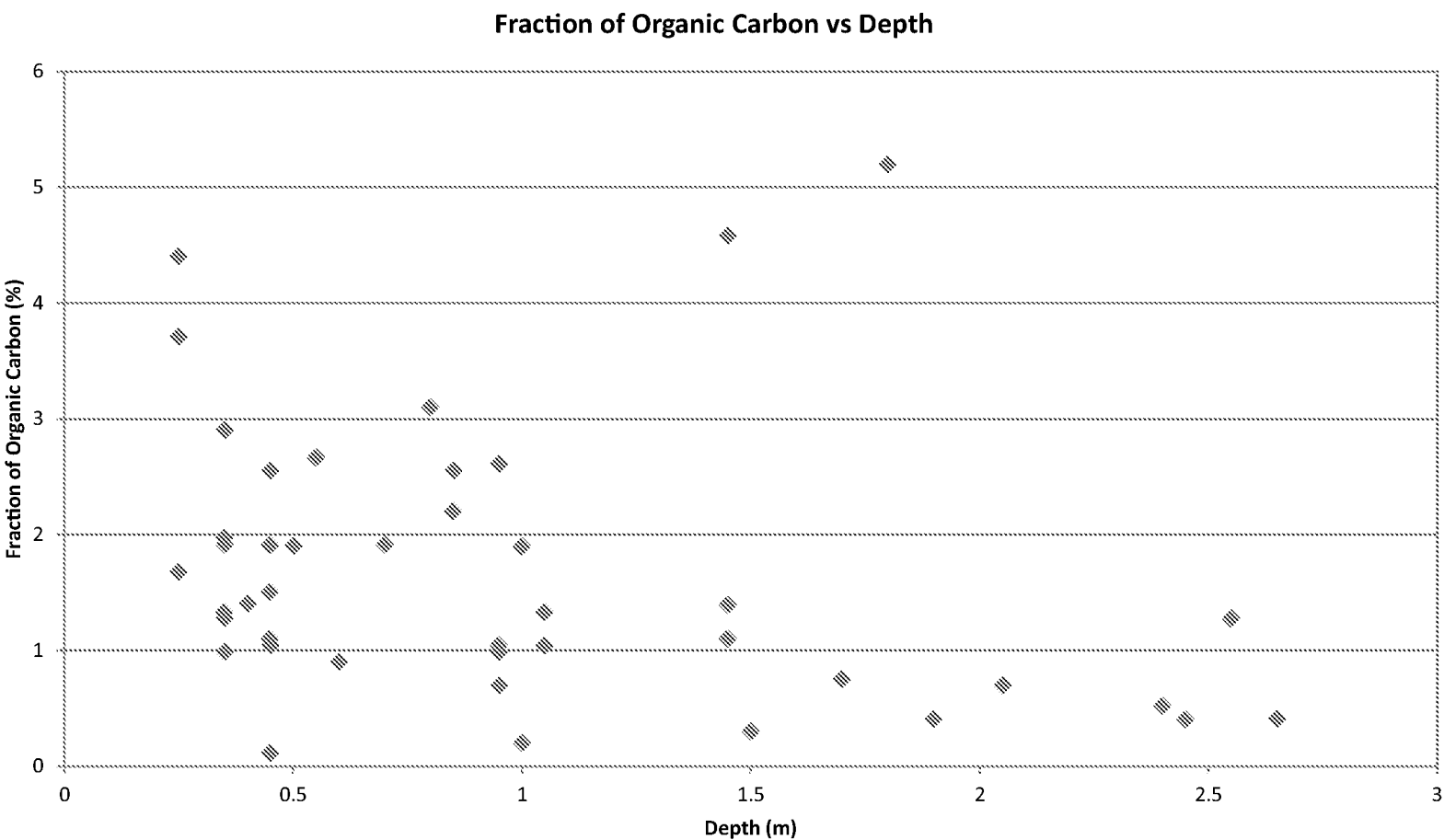
Contract No. C1820

Title: Predicted Flow Lines with  
No Tidal Fluctuation

Figure No: C17

Scale: NTS

Date Drawn: January 2021



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Client: National Grid

Project: Ford Road, Arundel

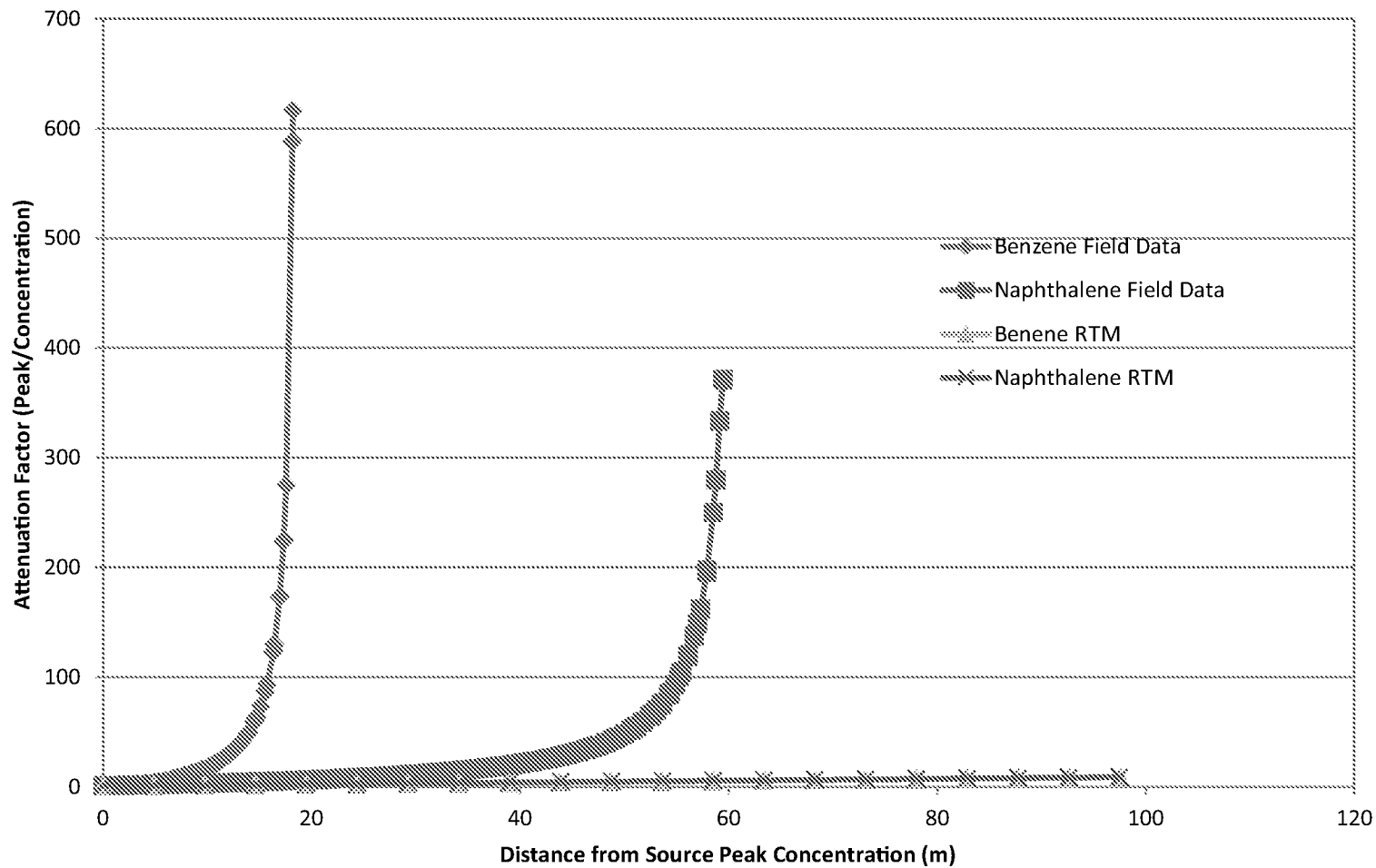
Contract No. C1820

Title: Total Organic Carbon vs Depth

Figure No: C18

Scale: NTS

Date Drawn: January 2021



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Client: National Grid

Project: Ford Road, Arundel

Contract No. C1820

Title: Comparison of Field Measured  
Attenuation Rates and RTM Prediction  
with No Tidal Dilution

Figure No: C19

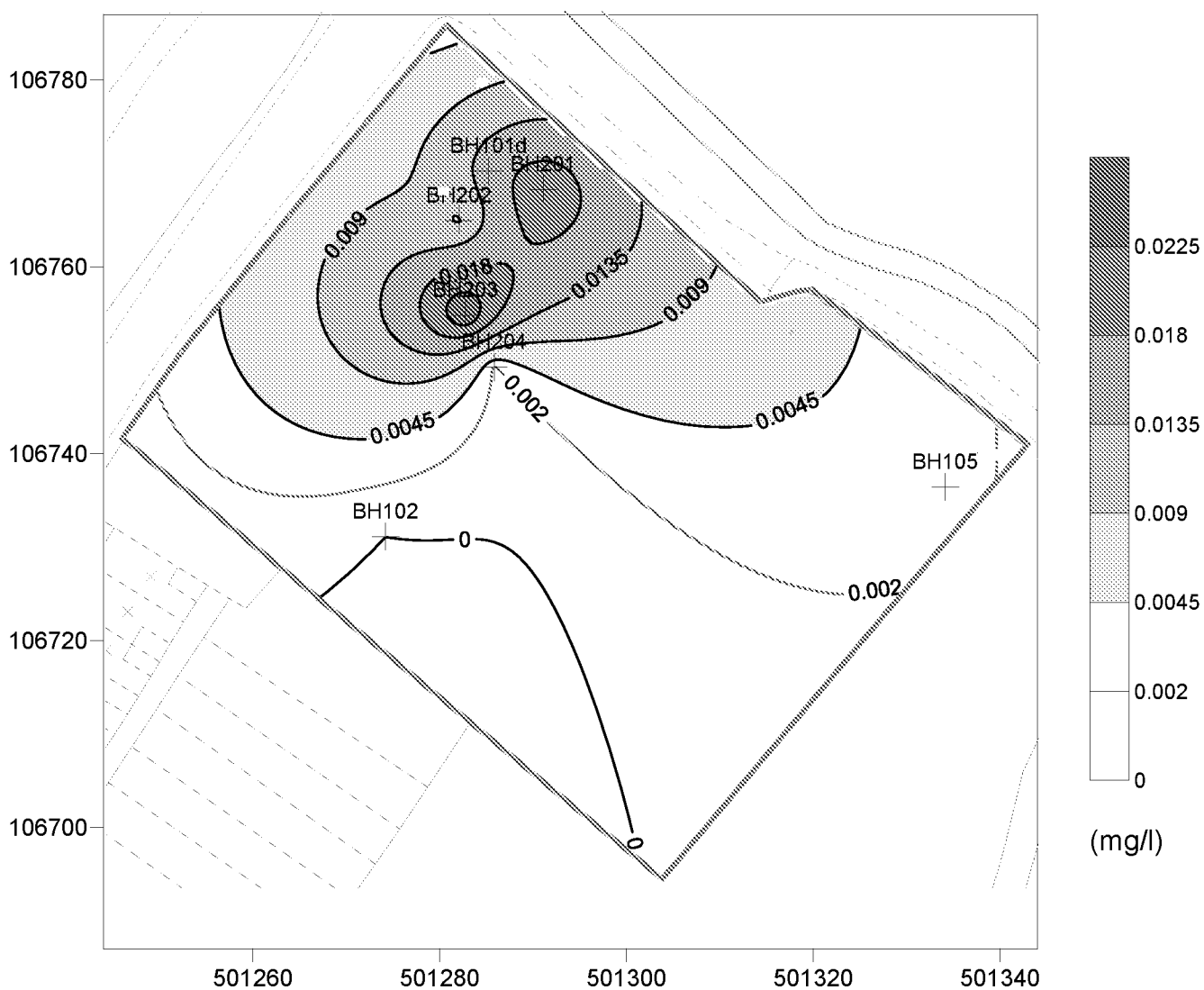
Scale: NTS

Date Drawn: January 2021

**Addendum C1**  
**Contours of Measured Concentrations of Substances**  
**In Recent Groundwater Data**

## Ford Road, Arundel

Inferred Contours of Acenaphthene Groundwater Concentration 02/12/2020

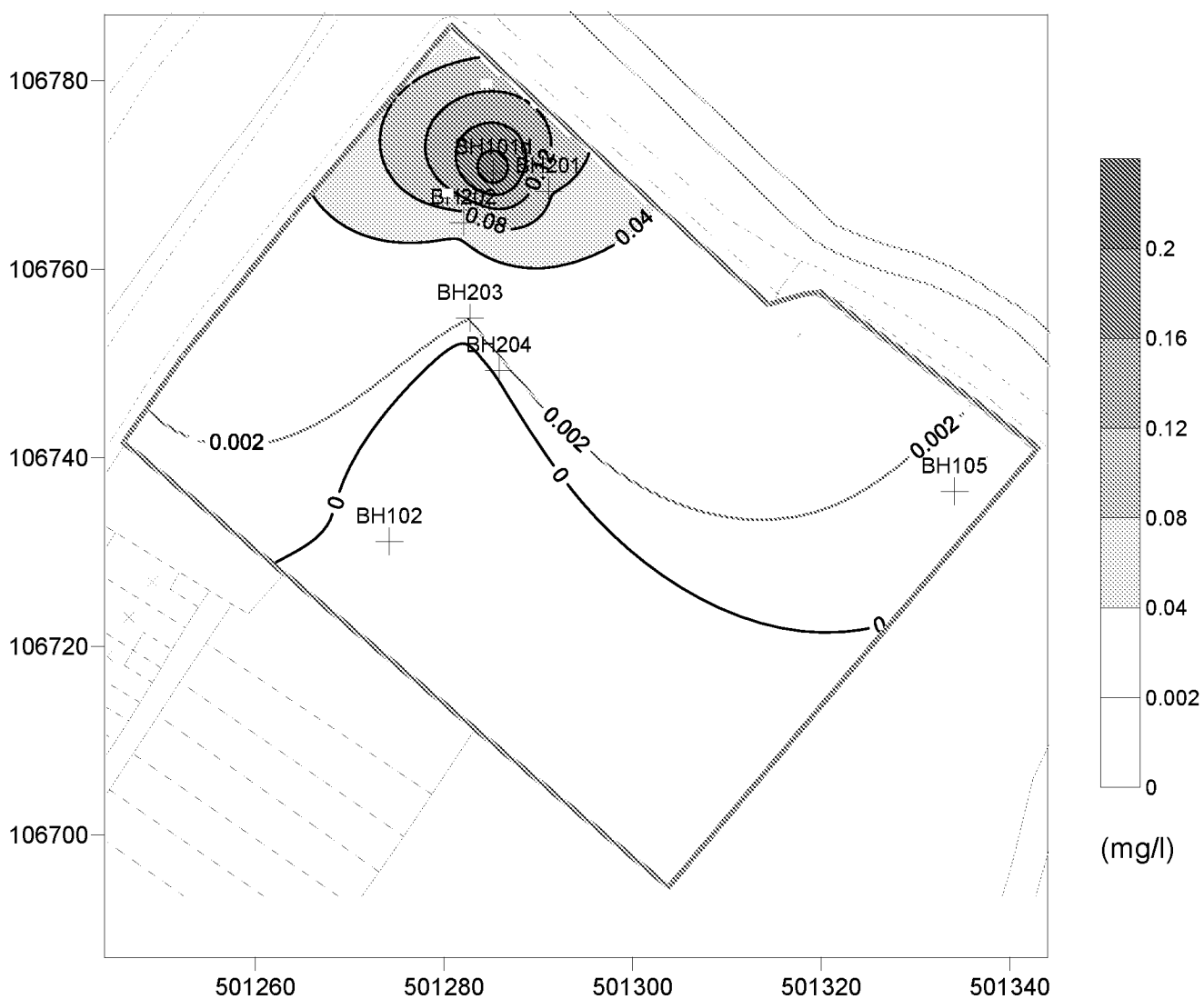


Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.0266 (mg/l)

## Ford Road, Arundel

Inferred Contours of Acenaphthylene Groundwater Concentration 02/12/2020

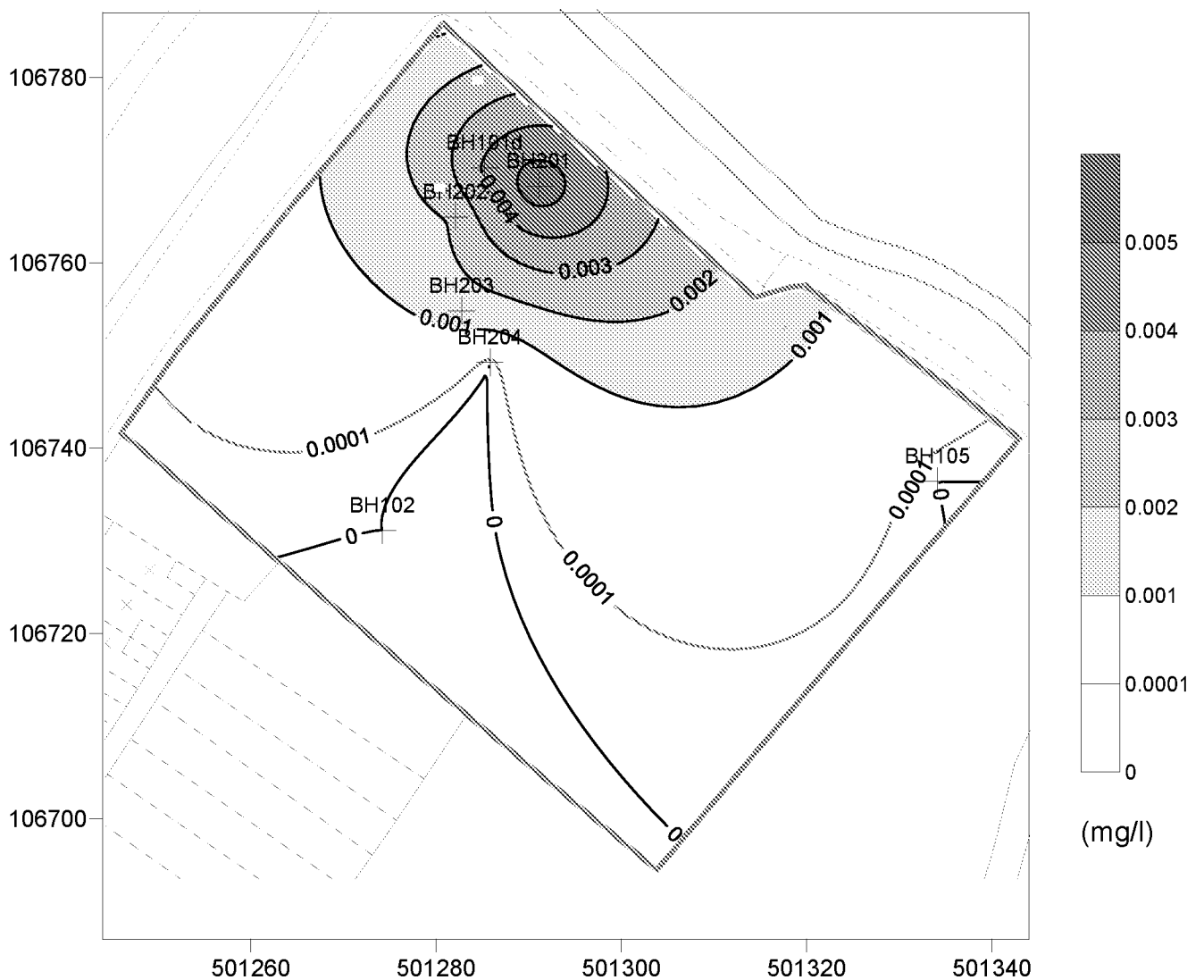


Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.237 (mg/l)

## Ford Road, Arundel

Inferred Contours of Anthracene Groundwater Concentration 02/12/2020



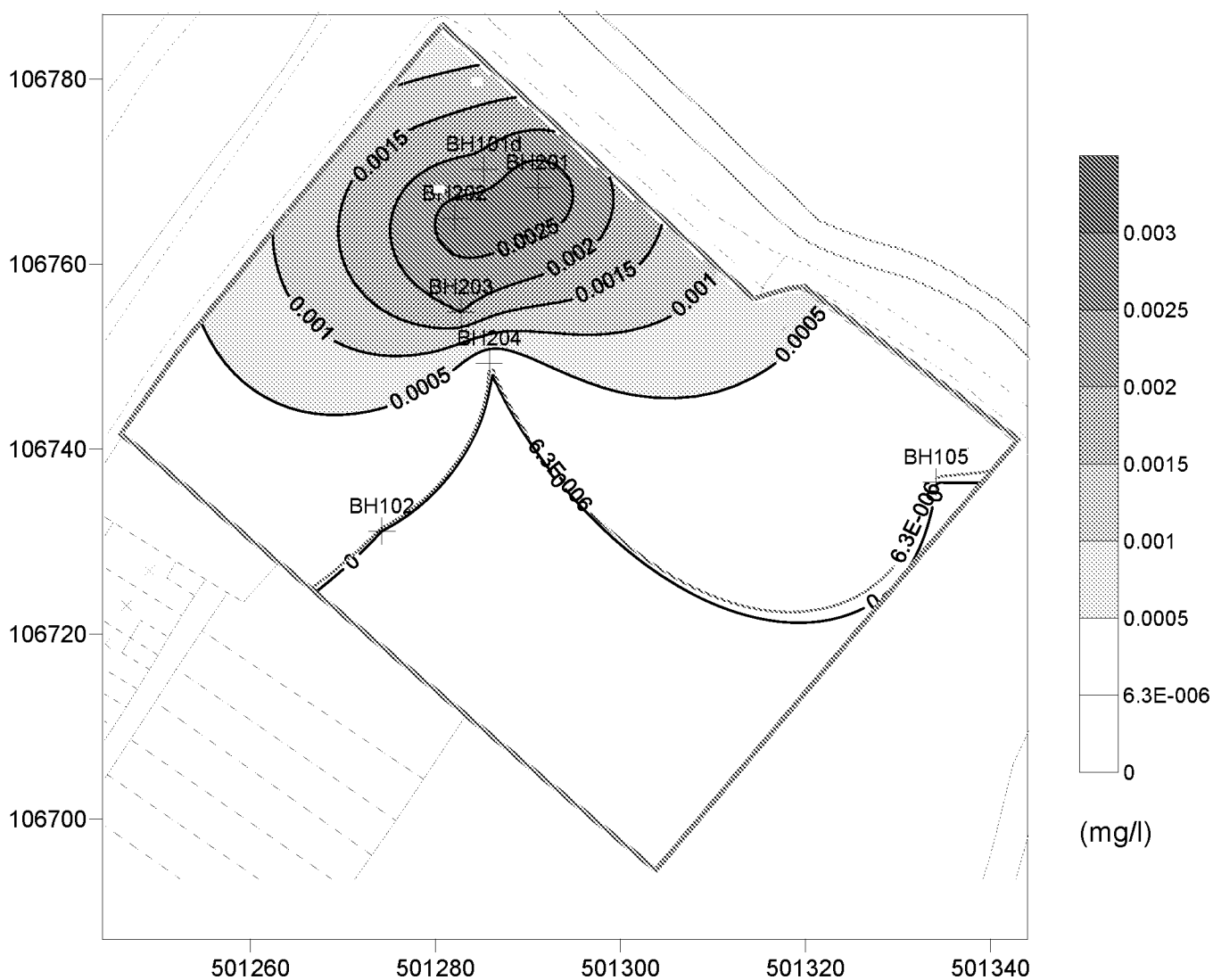
Compliance Criterion = 0.0001 (mg/l)

Data Maximum Value = 0.00571 (mg/l)

(mg/l)

## Ford Road, Arundel

Inferred Contours of Fluoranthene Groundwater Concentration 02/12/2020



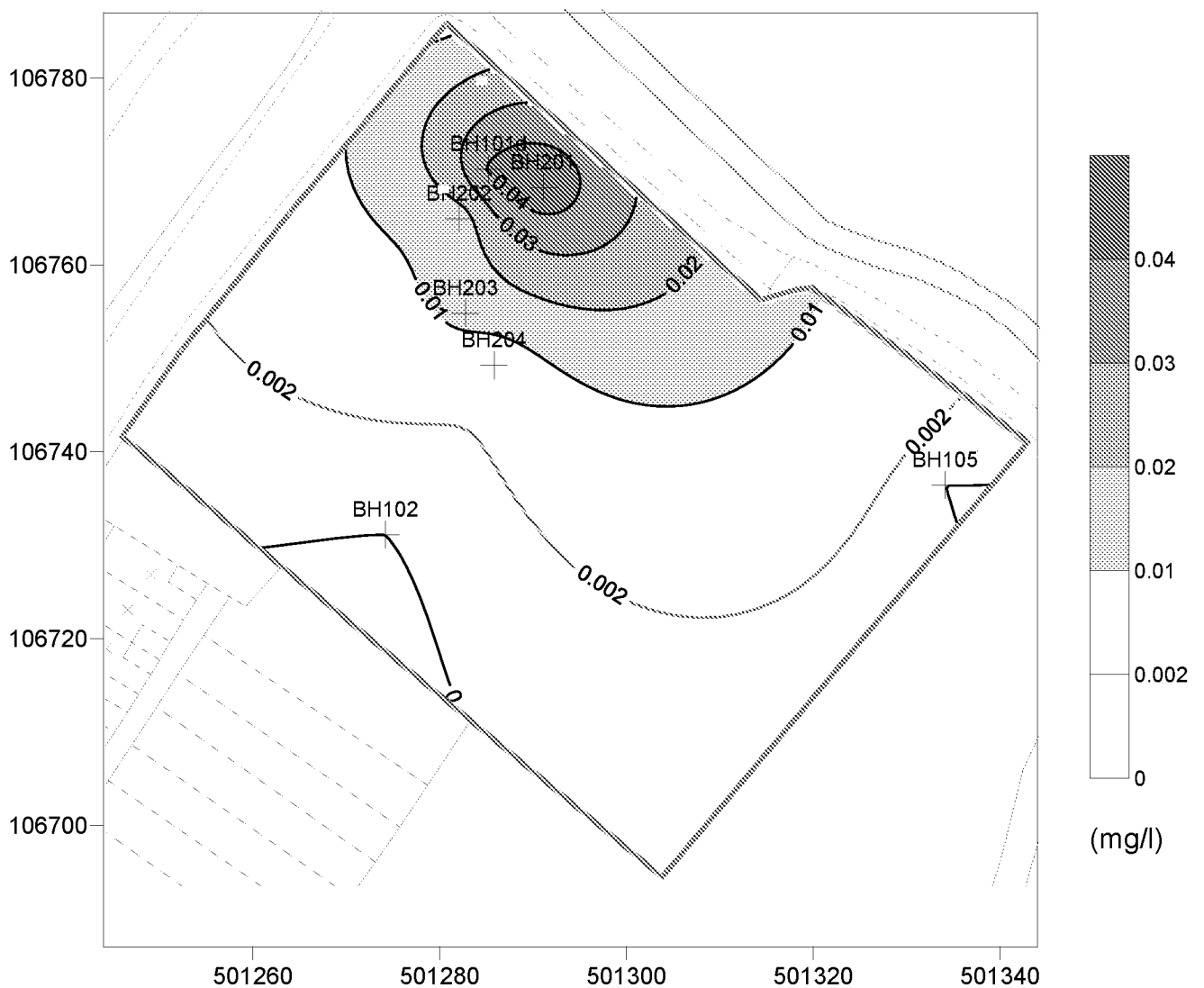
Compliance Criterion = 0.0000063 (mg/l)

Data Maximum Value = 0.003 (mg/l)



## Ford Road, Arundel

Inferred Contours of Fluorene Groundwater Concentration 02/12/2020

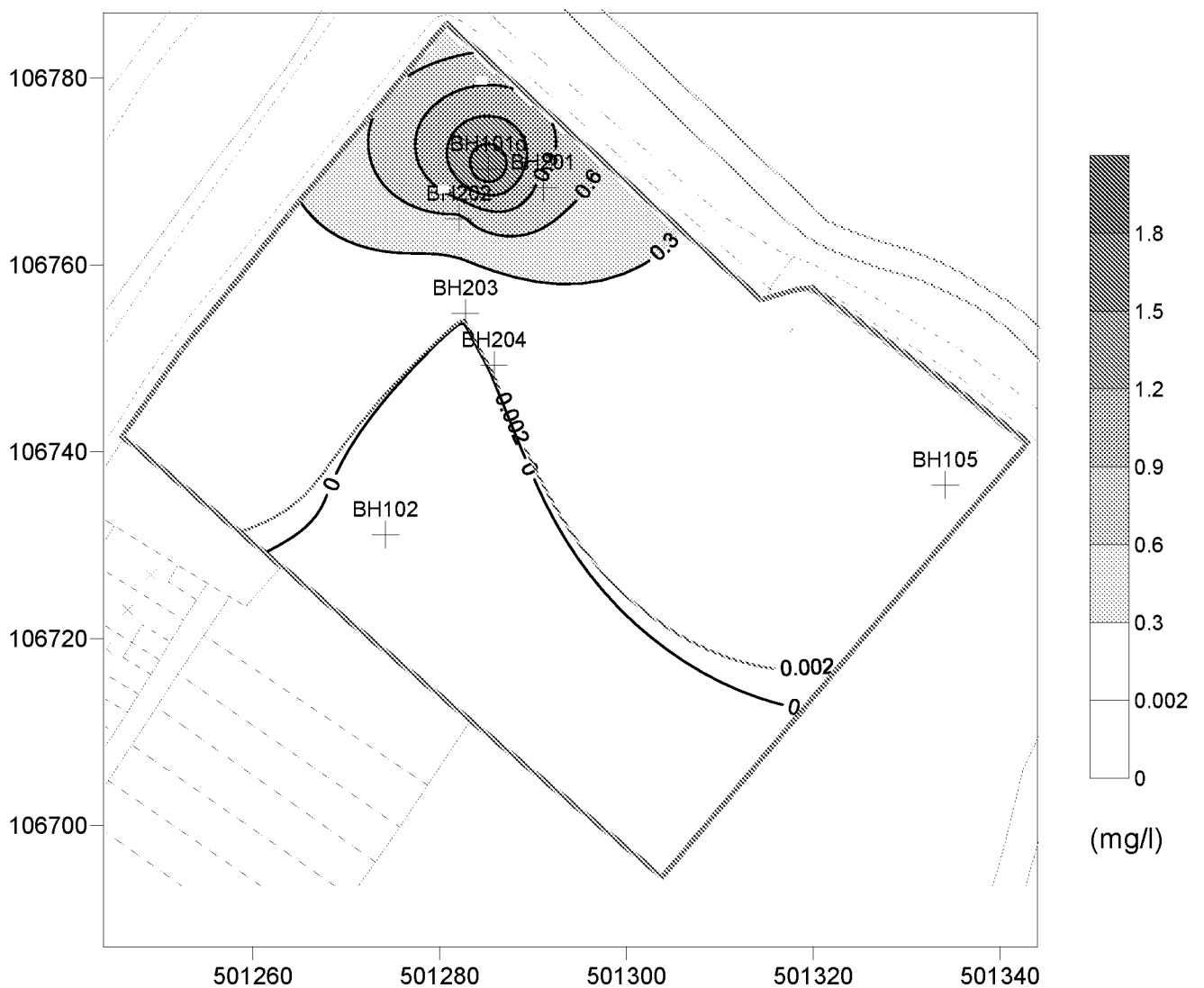


Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.0478 (mg/l)

## Ford Road, Arundel

Inferred Contours of Naphthalene Groundwater Concentration 02/12/2020

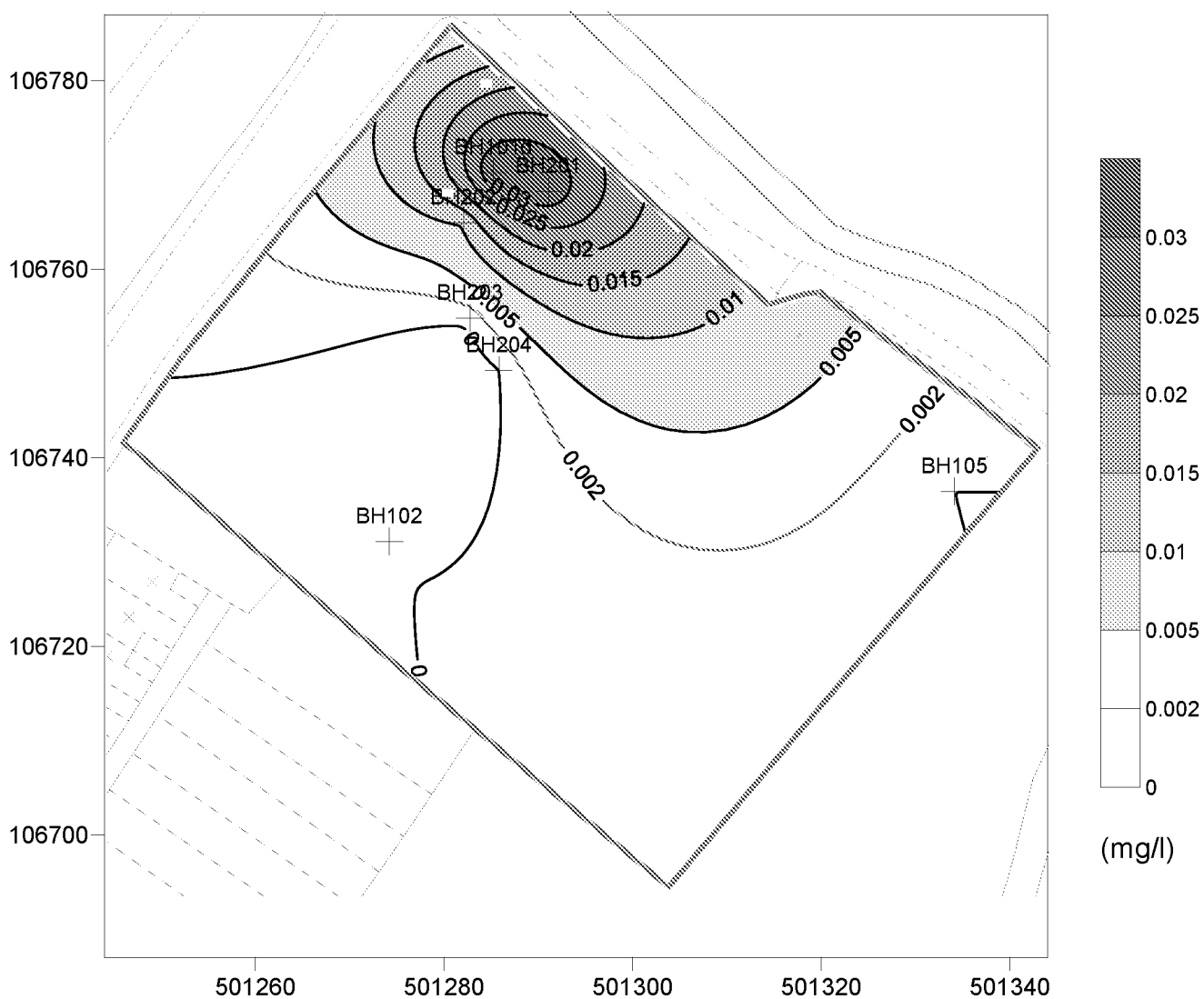


Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 1.81 (mg/l)

## Ford Road, Arundel

Inferred Contours of Phenanthrene Groundwater Concentration 02/12/2020

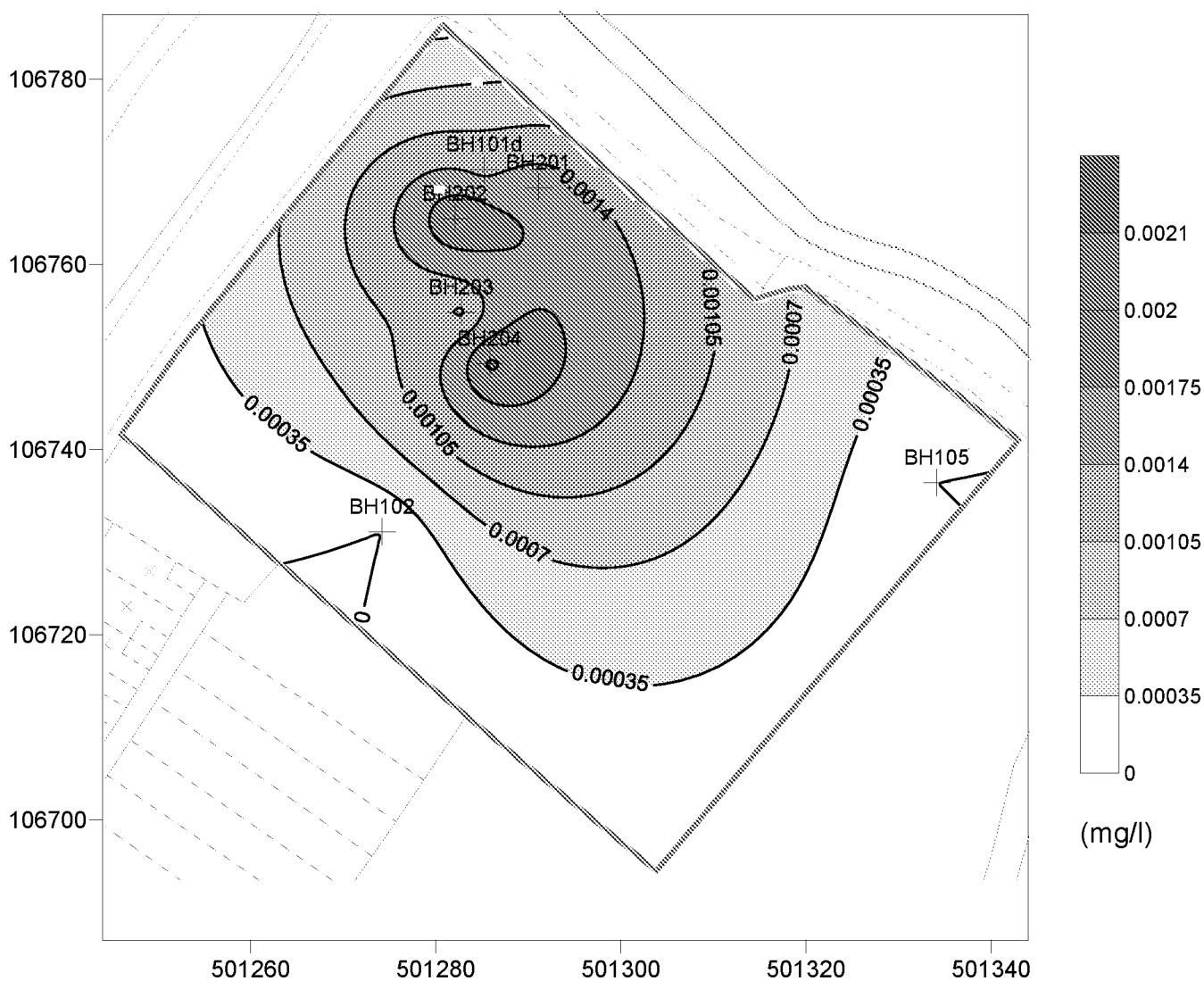


Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.0344 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Pyrene Groundwater Concentration 02/12/2020



Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.00216 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Benzene Groundwater Concentration 02/12/2020



Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 12.9 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Ethylbenzene Groundwater Concentration 02/12/2020



Compliance Criterion = 0.02 (mg/l)

Data Maximum Value = 0.0772 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Toluene Groundwater Concentration 02/12/2020

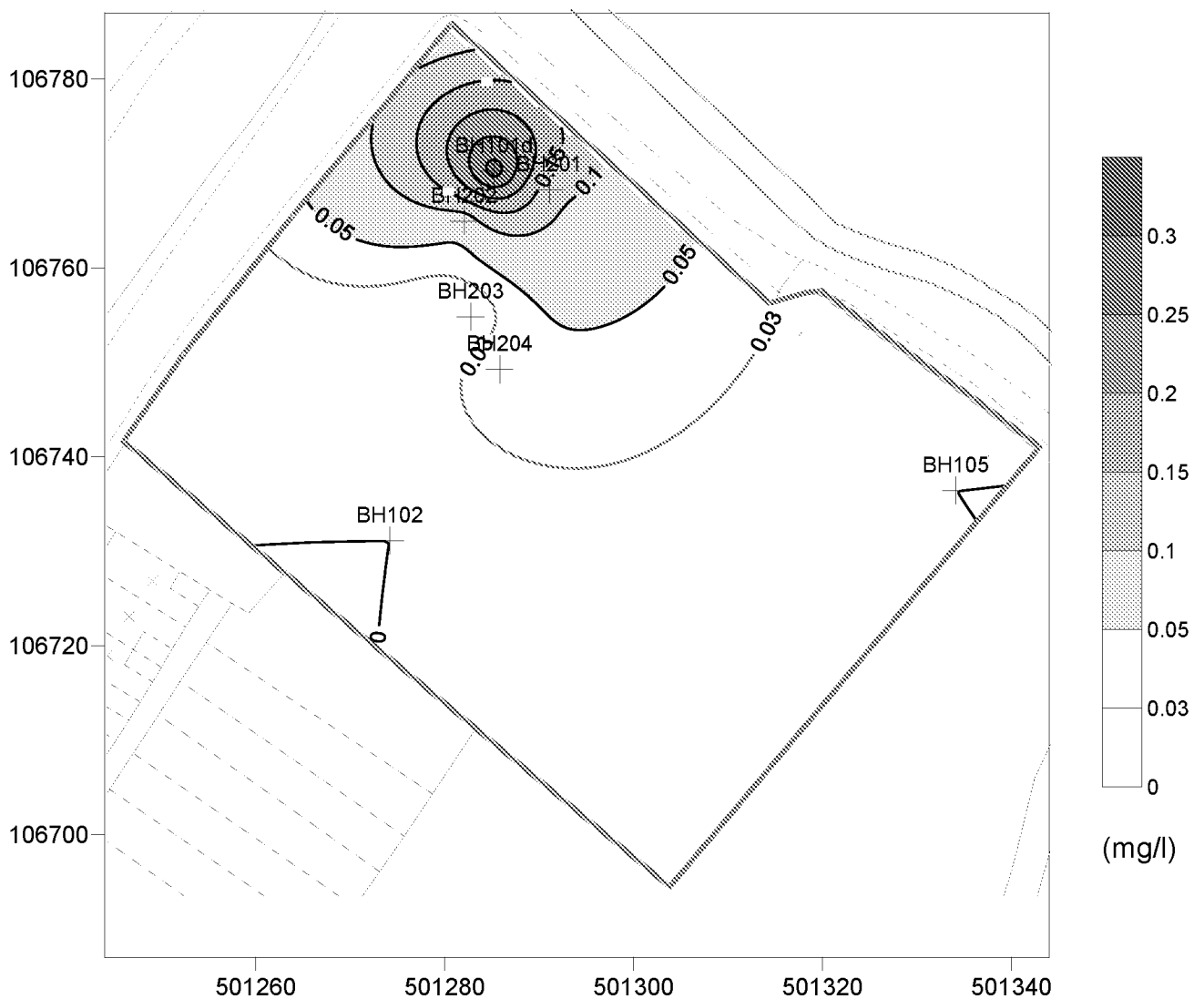


Compliance Criterion = 0.074 (mg/l)

Data Maximum Value = 4.95 (mg/l)

## Ford Road, Arundel

Inferred Contours of o-xylene Groundwater Concentration 02/12/2020



Compliance Criterion = 0.03 (mg/l)

Data Maximum Value = 0.328 (mg/l)



## Ford Road, Arundel

Inferred Contours of p & m-xylene Groundwater Concentration 02/12/2020



## Ford Road, Arundel

Inferred Contours of TPH-CWG - Aromatic C5 - C7 Groundwater Concentration 02/12/2



Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 13 (mg/l)

## Ford Road, Arundel

Inferred Contours of TPH-CWG - Aromatic C7 - C8 Groundwater Concentration 02/12/2

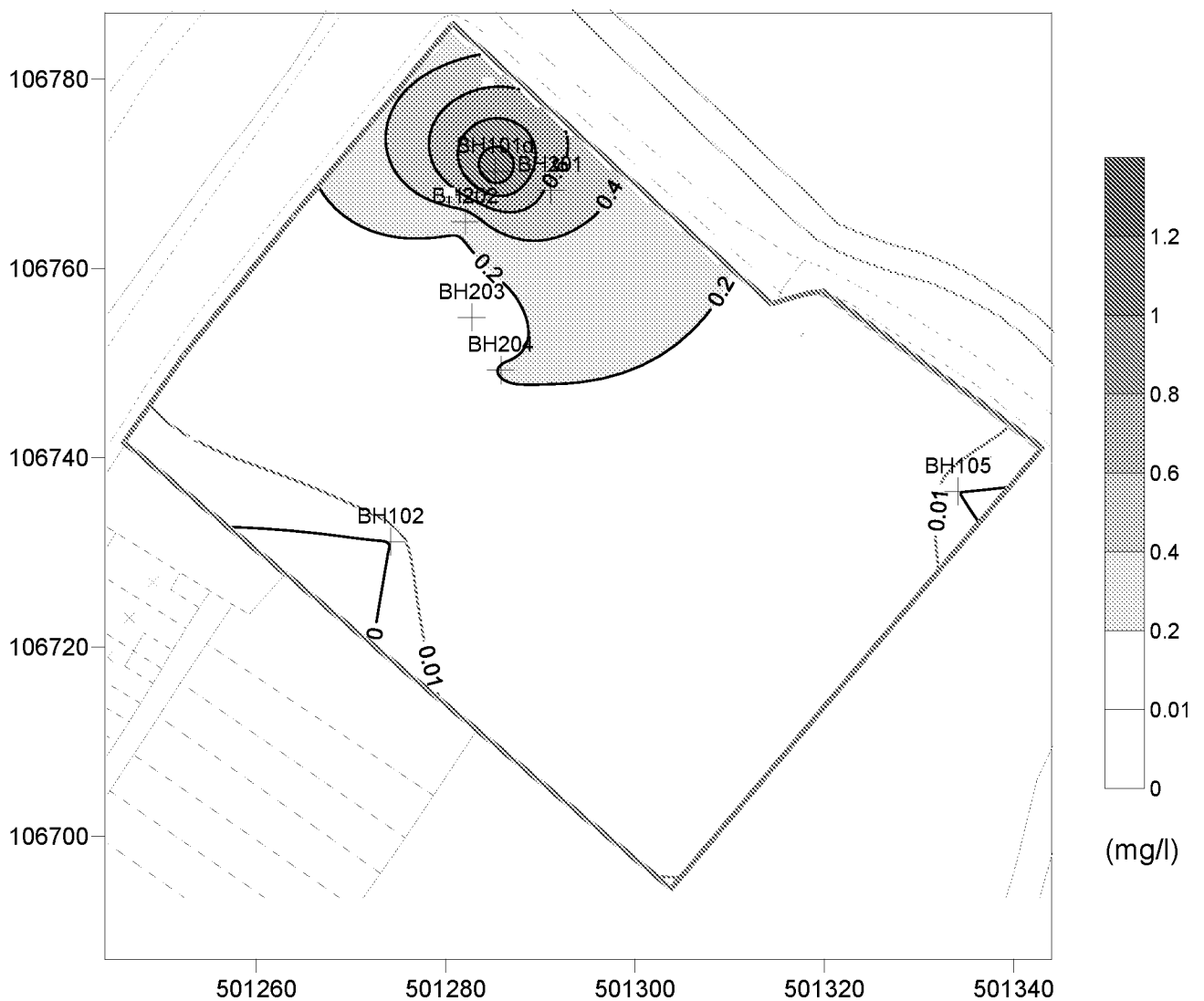


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 5 (mg/l)

## Ford Road, Arundel

Inferred Contours of TPH-CWG - Aromatic C8 - C10 Groundwater Concentration 02/12/

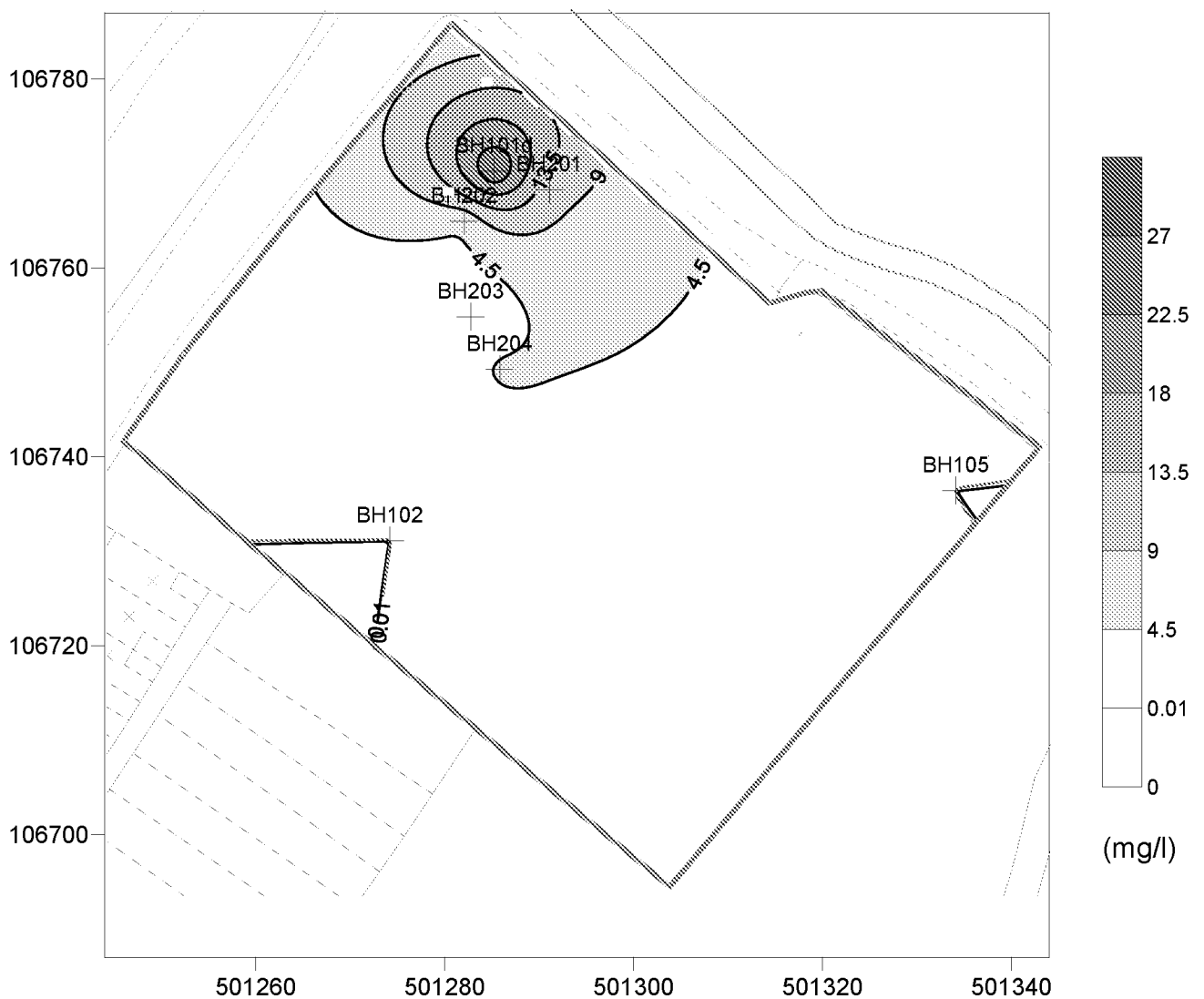


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 1.2 (mg/l)

## Ford Road, Arundel

Inferred Contours of TPH-CWG - Aromatic (C5 - C35) Groundwater Concentration 02/1/

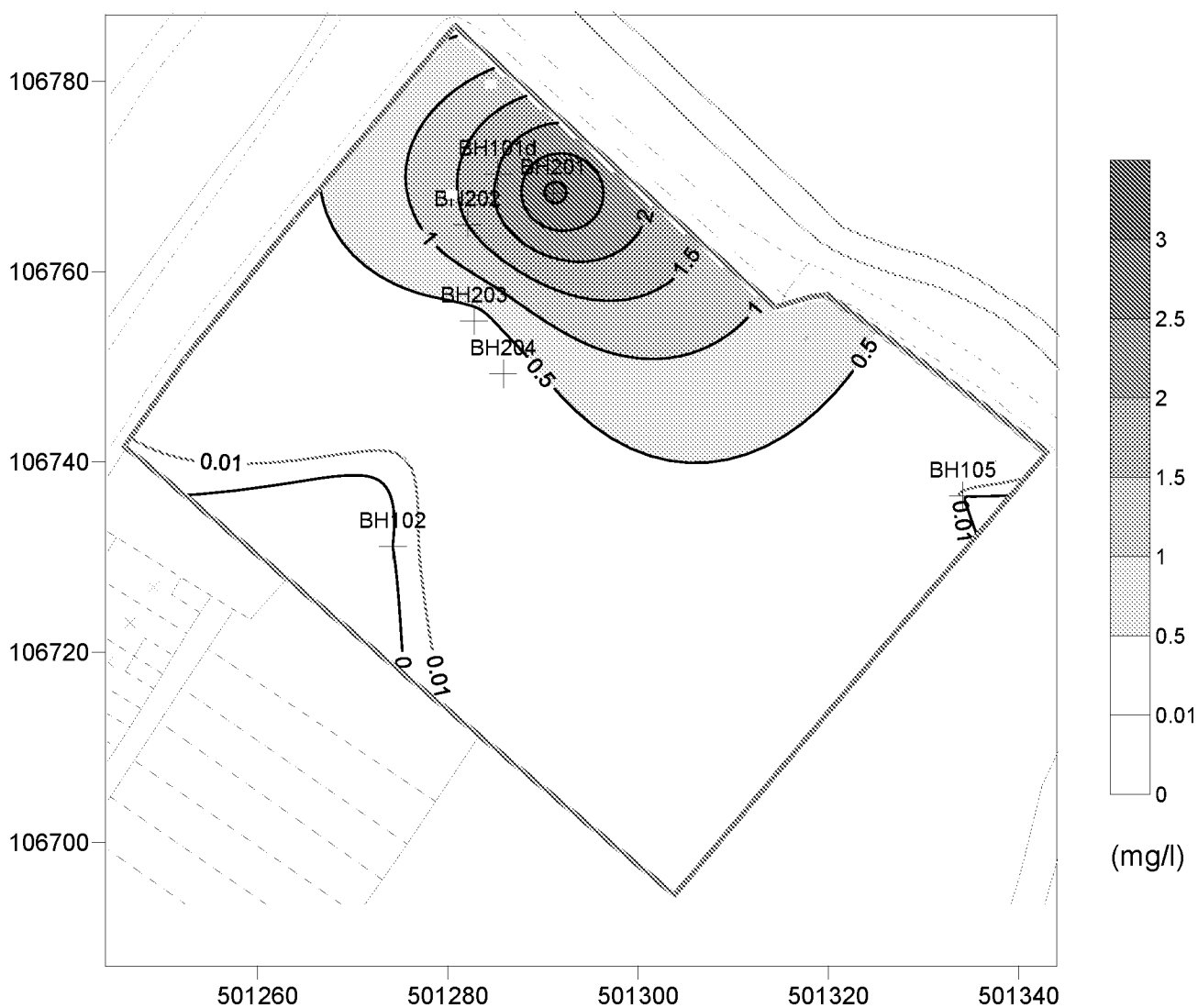


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 27 (mg/l)

## Ford Road, Arundel

### Inferred Contours of TPH-CWG - Aromatic C10 - C12 Groundwater Concentration 02/12

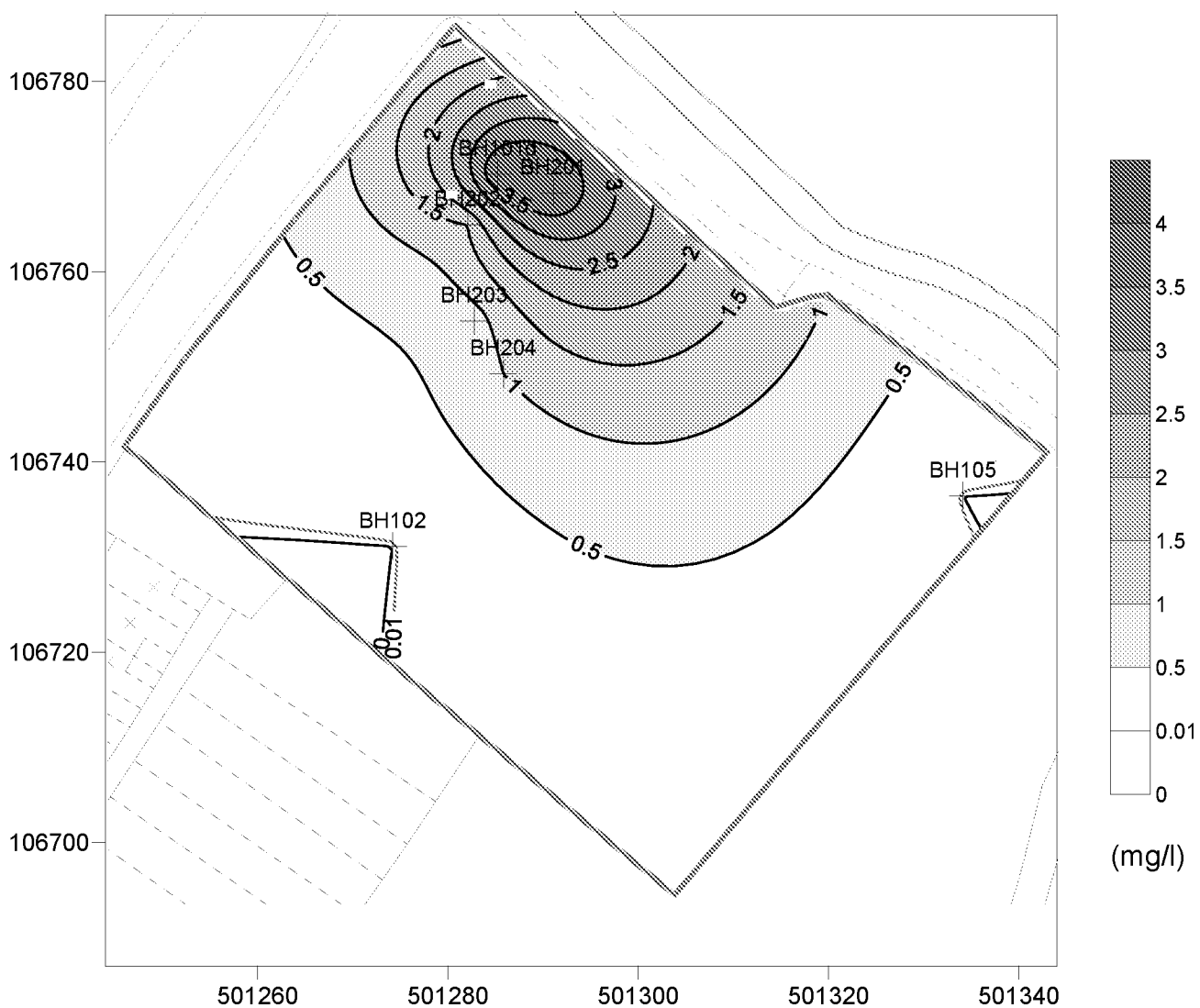


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 3.2 (mg/l)

## Ford Road, Arundel

Inferred Contours of TPH-CWG - Aromatic C12 - C16 Groundwater Concentration 02/12

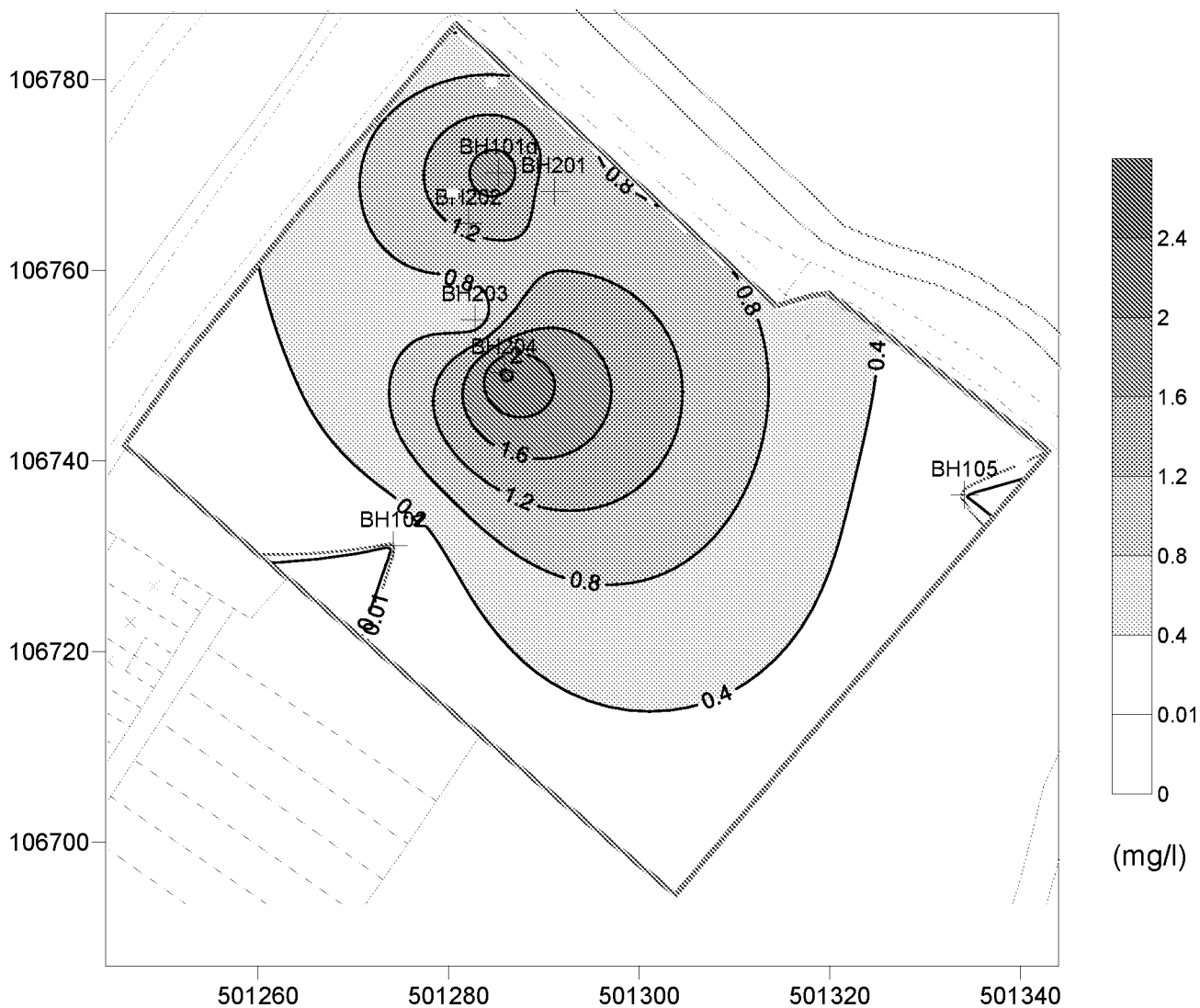


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 4 (mg/l)

## Ford Road, Arundel

Inferred Contours of TPH-CWG - Aromatic C16 - C21 Groundwater Concentration 02/12



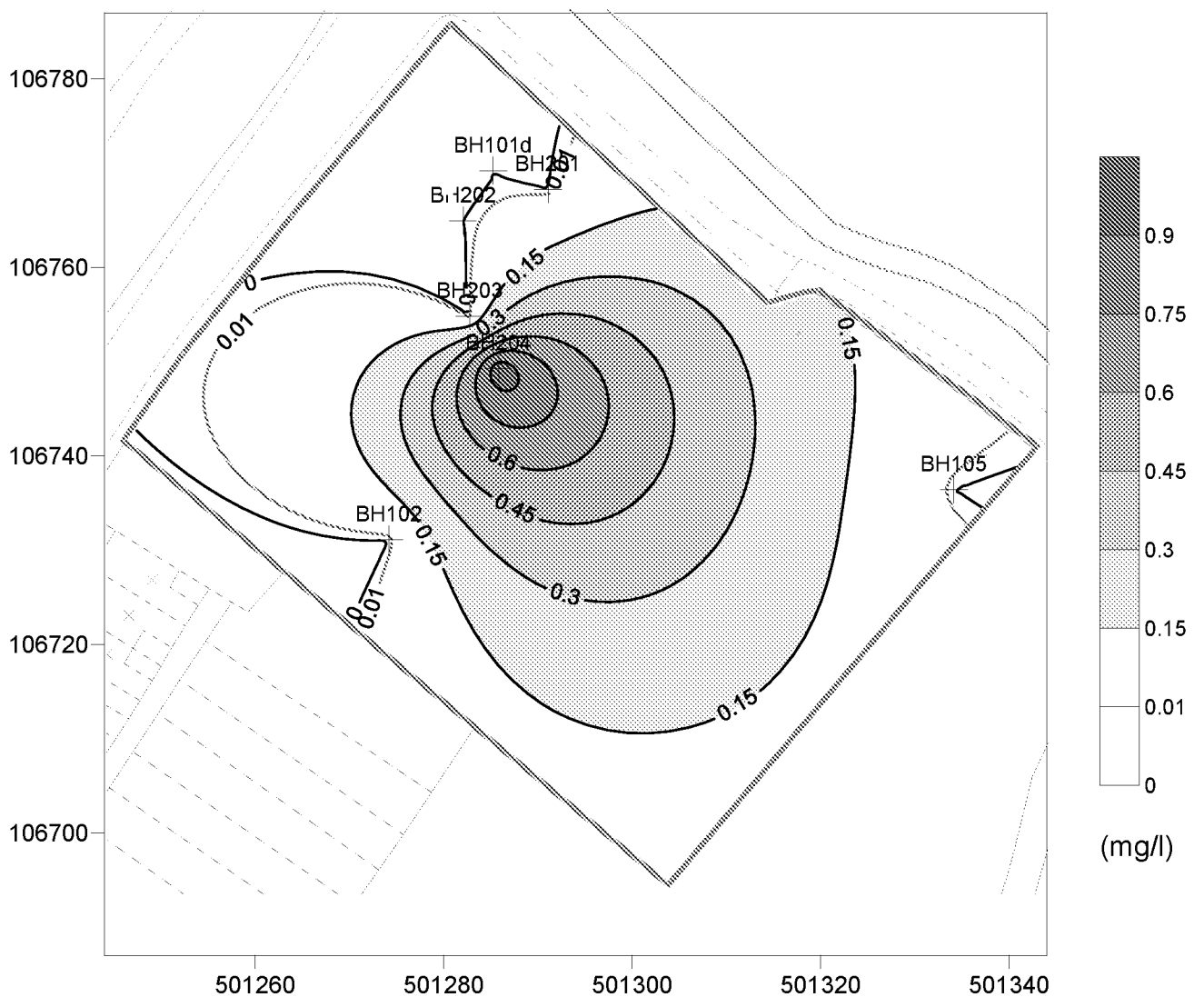
Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 2.5 (mg/l)



## Ford Road, Arundel

Inferred Contours of TPH-CWG - Aromatic C21 - C35 Groundwater Concentration 02/12

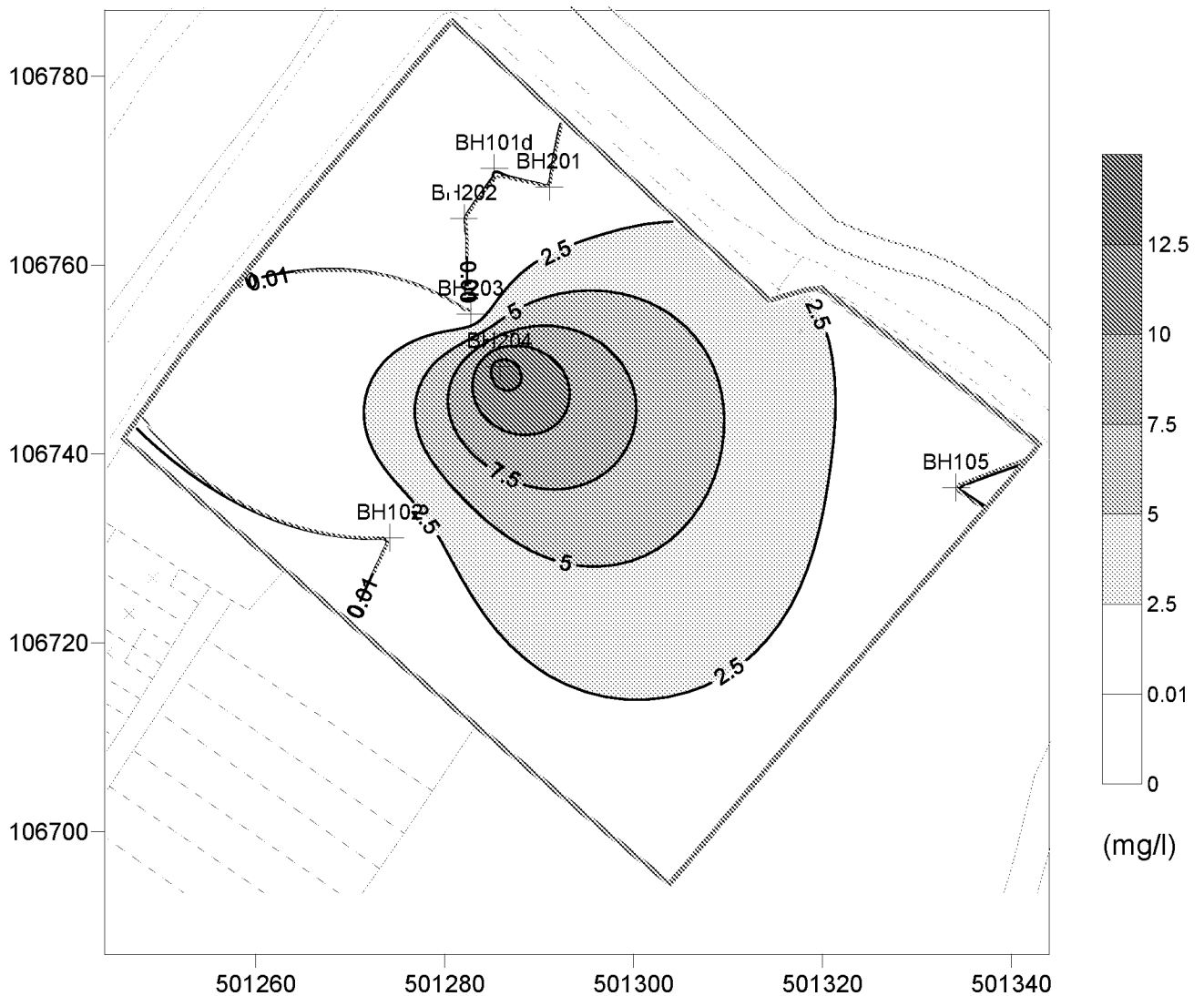


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 1 (mg/l)

## Ford Road, Arundel

Inferred Contours of TPH-CWG - Aliphatic (C5 - C35) Groundwater Concentration 02/12

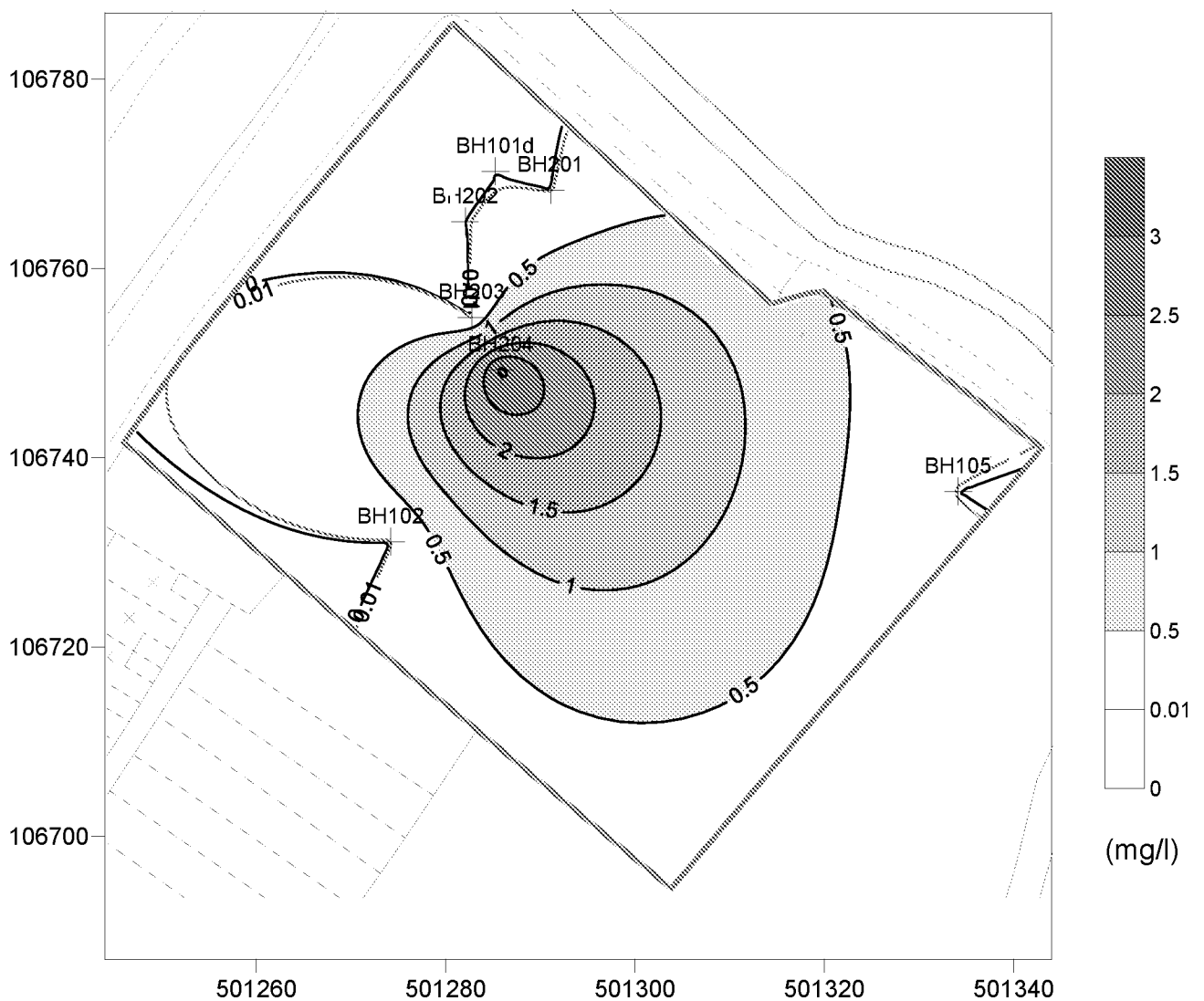


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 14 (mg/l)

## Ford Road, Arundel

### Inferred Contours of TPH-CWG - Aliphatic C12 - C16 Groundwater Concentration 02/12

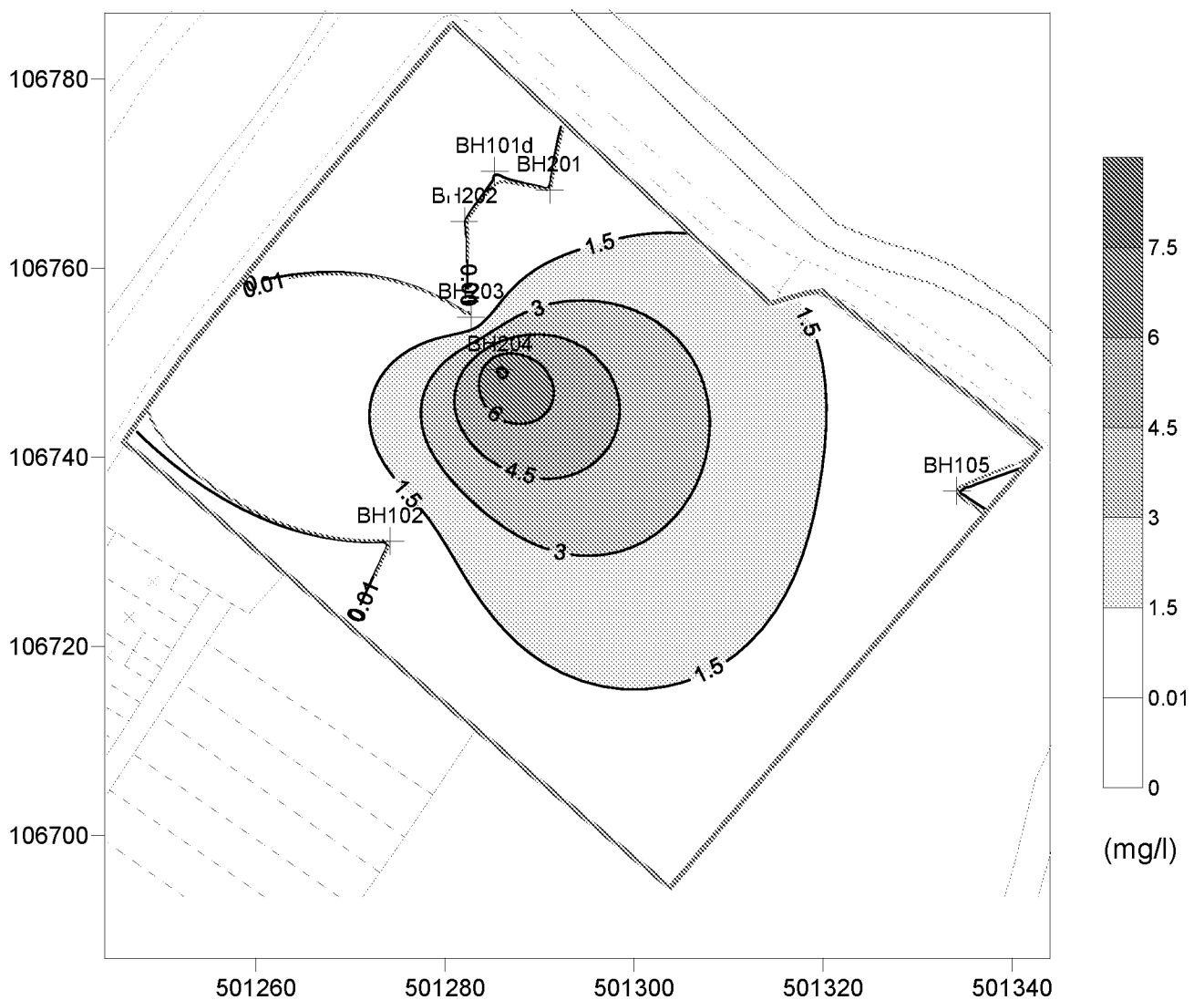


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 3.1 (mg/l)

## Ford Road, Arundel

### Inferred Contours of TPH-CWG - Aliphatic C16 - C21 Groundwater Concentration 02/12

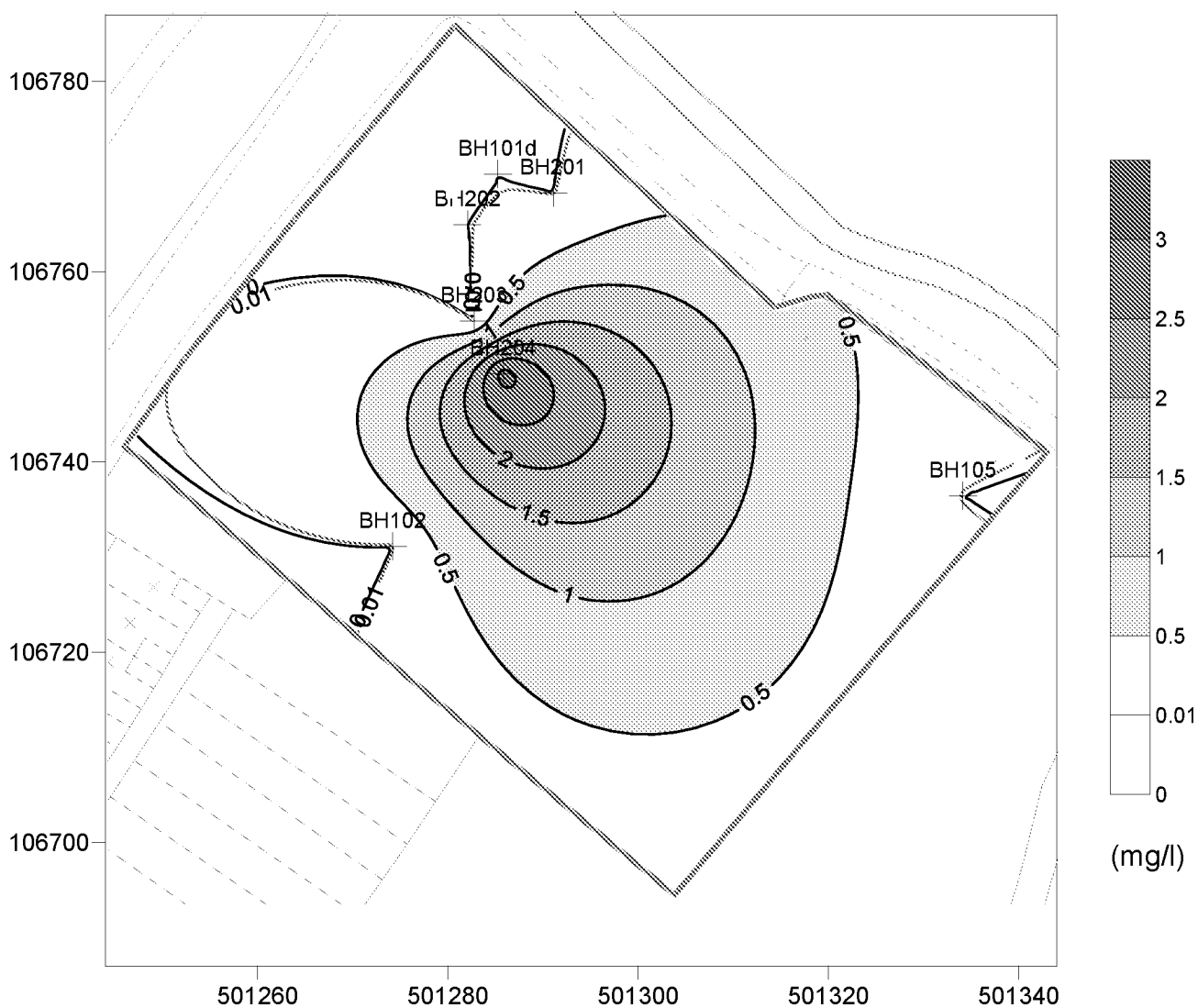


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 7.8 (mg/l)

## Ford Road, Arundel

### Inferred Contours of TPH-CWG - Aliphatic C21 - C35 Groundwater Concentration 02/12

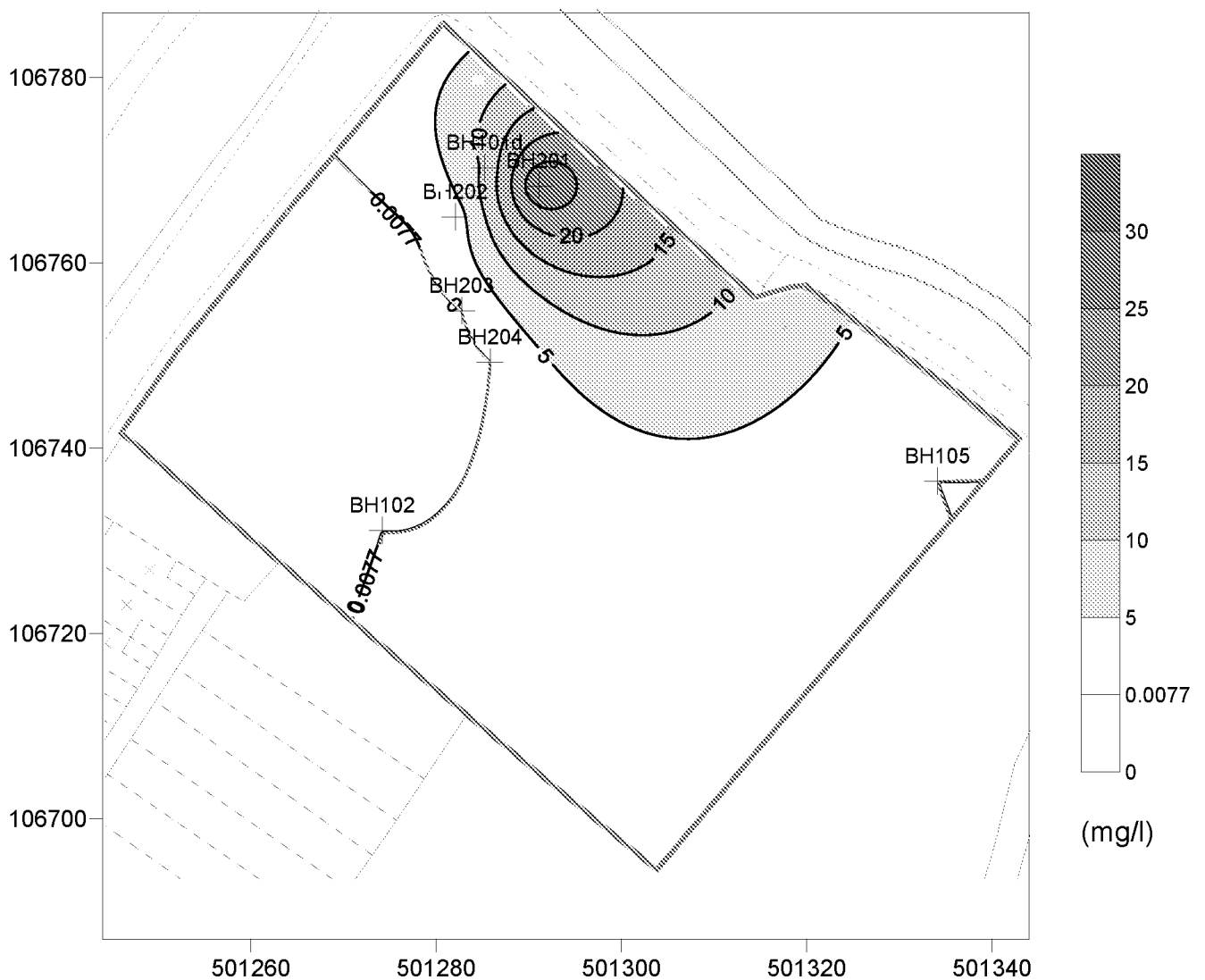


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 3.2 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Phenol Groundwater Concentration 02/12/2020

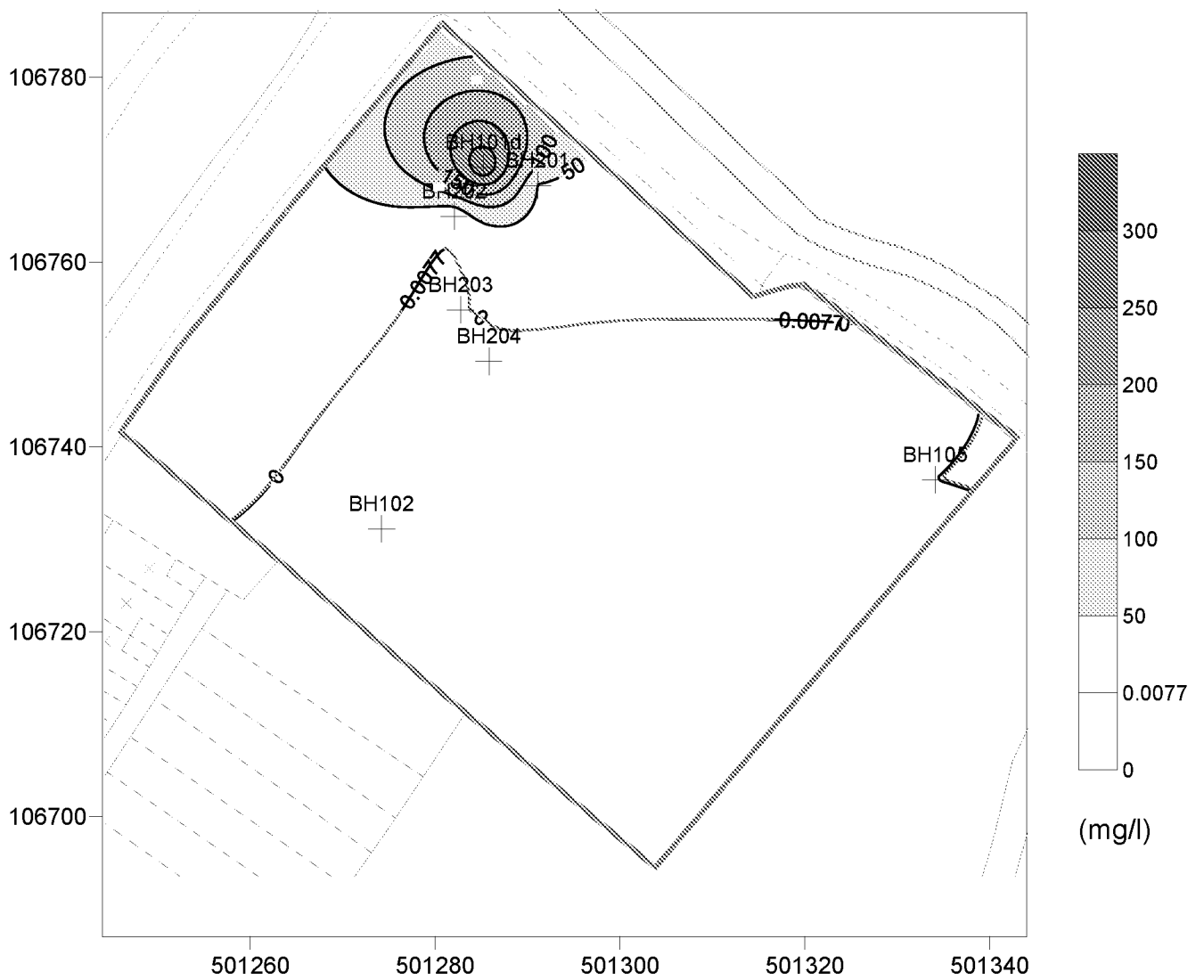


Compliance Criterion = 0.0077 (mg/l)

Data Maximum Value = 30 (mg/l)

## Ford Road, Arundel

Inferred Contours of Total Phenols (HPLC) Groundwater Concentration 02/12/2020

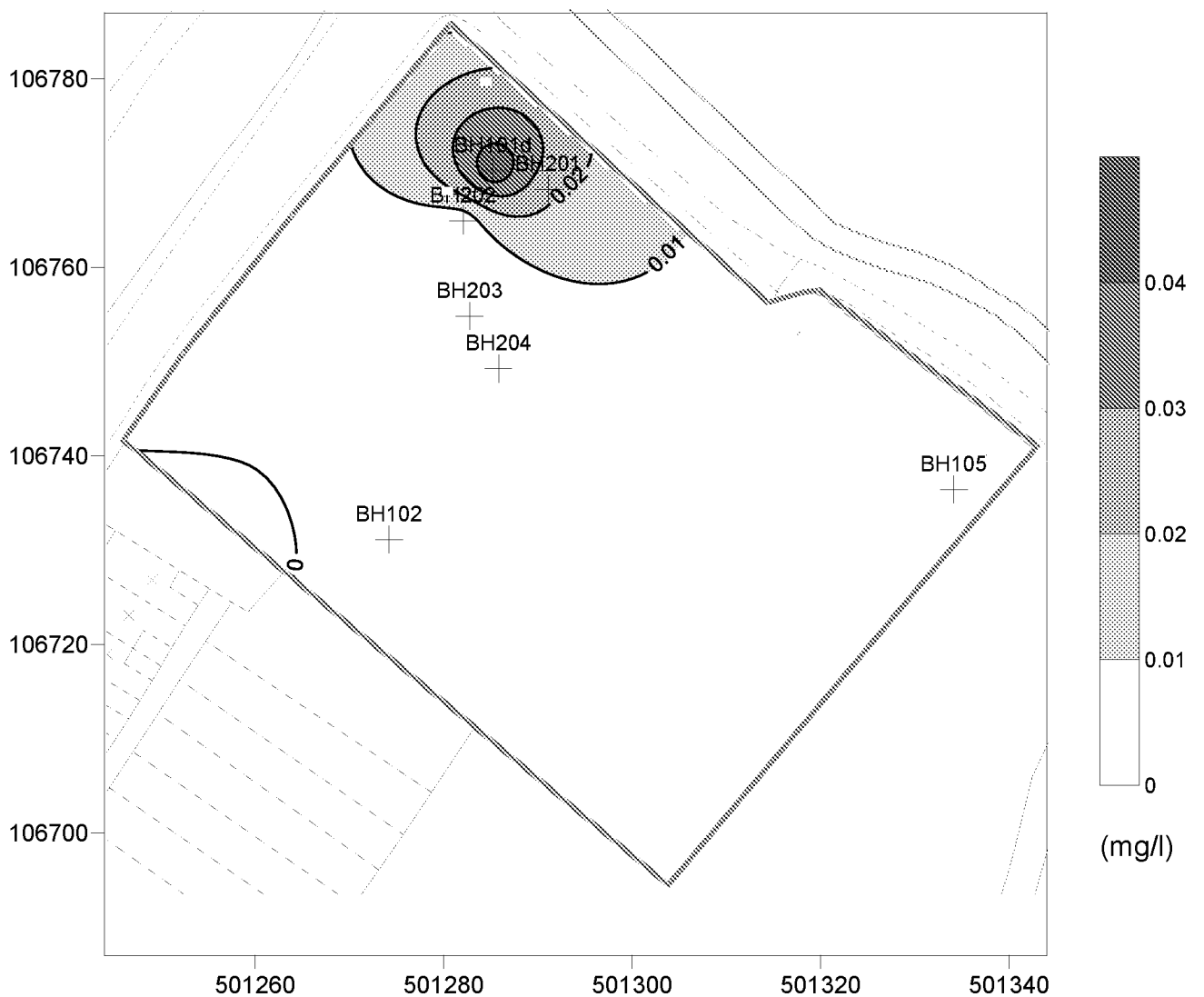


Compliance Criterion = 0.0077 (mg/l)

Data Maximum Value = 300 (mg/l)

## Ford Road, Arundel

Inferred Contours of Arsenic (dissolved) Groundwater Concentration 02/12/2020



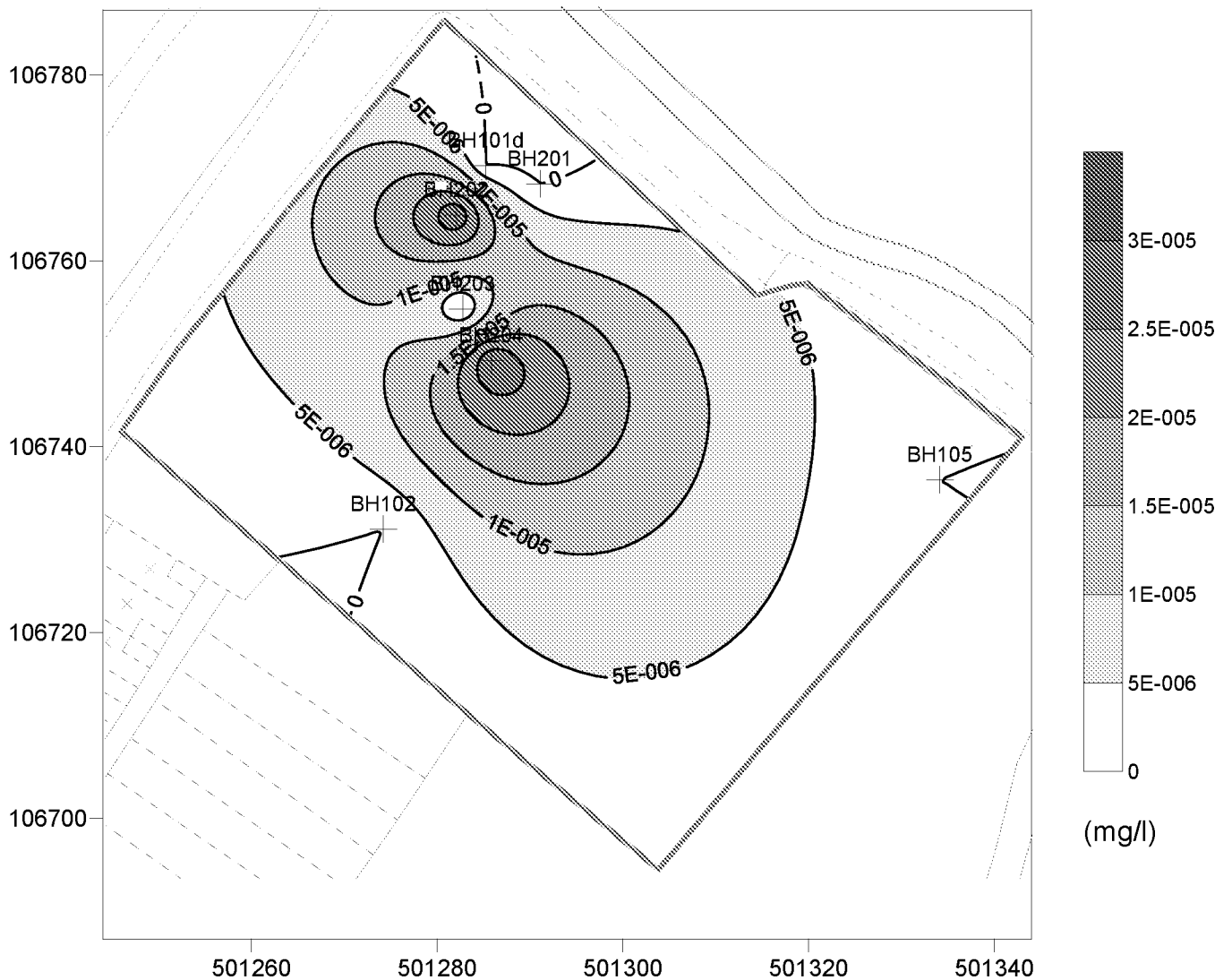
Compliance Criterion = 0.05 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.049 (mg/l)



## Ford Road, Arundel

Inferred Contours of Cadmium (dissolved) Groundwater Concentration 02/12/2020

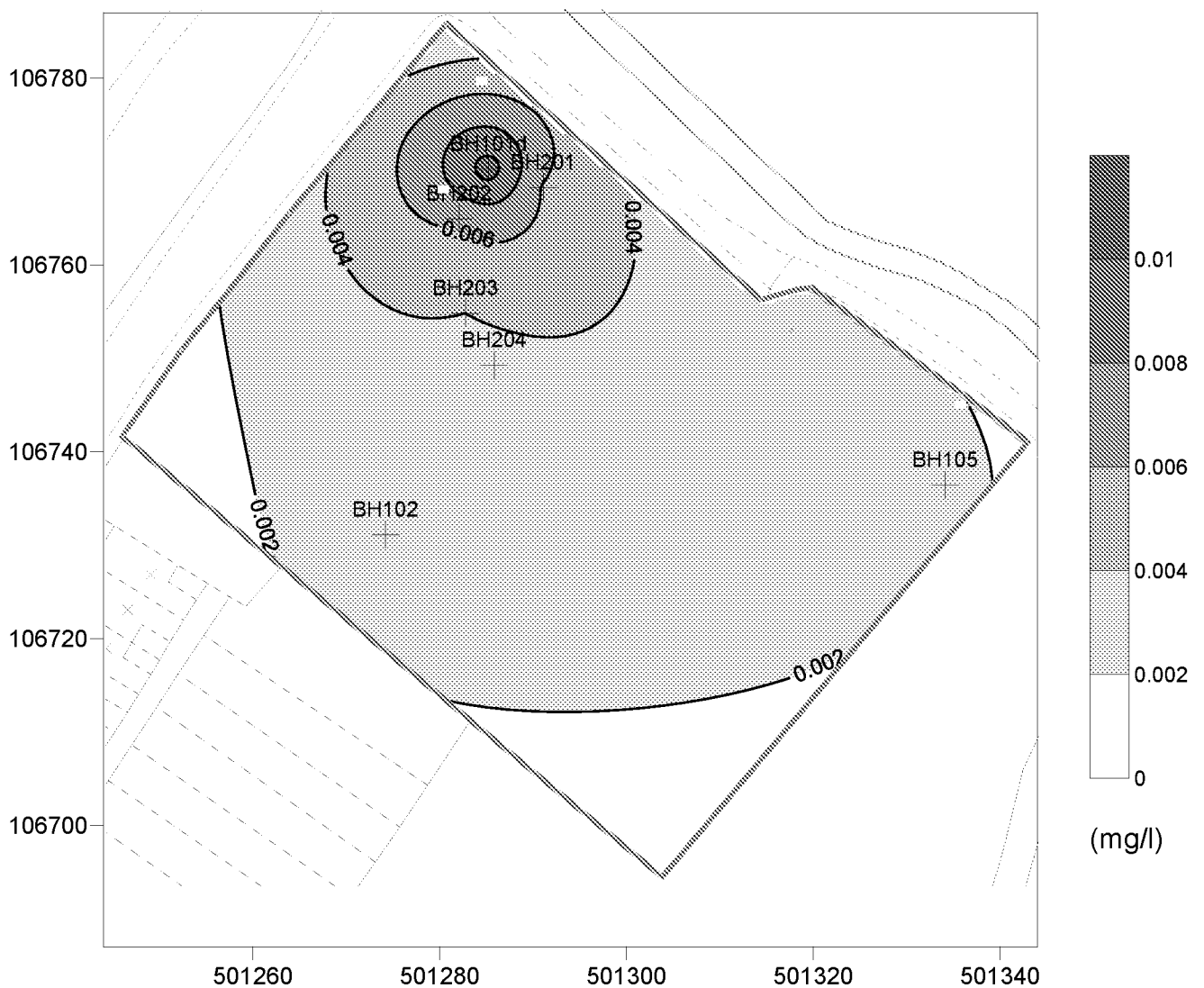


Compliance Criterion = 0.00025 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.00003 (mg/l)

## Ford Road, Arundel

Inferred Contours of Chromium (dissolved) Groundwater Concentration 02/12/2020

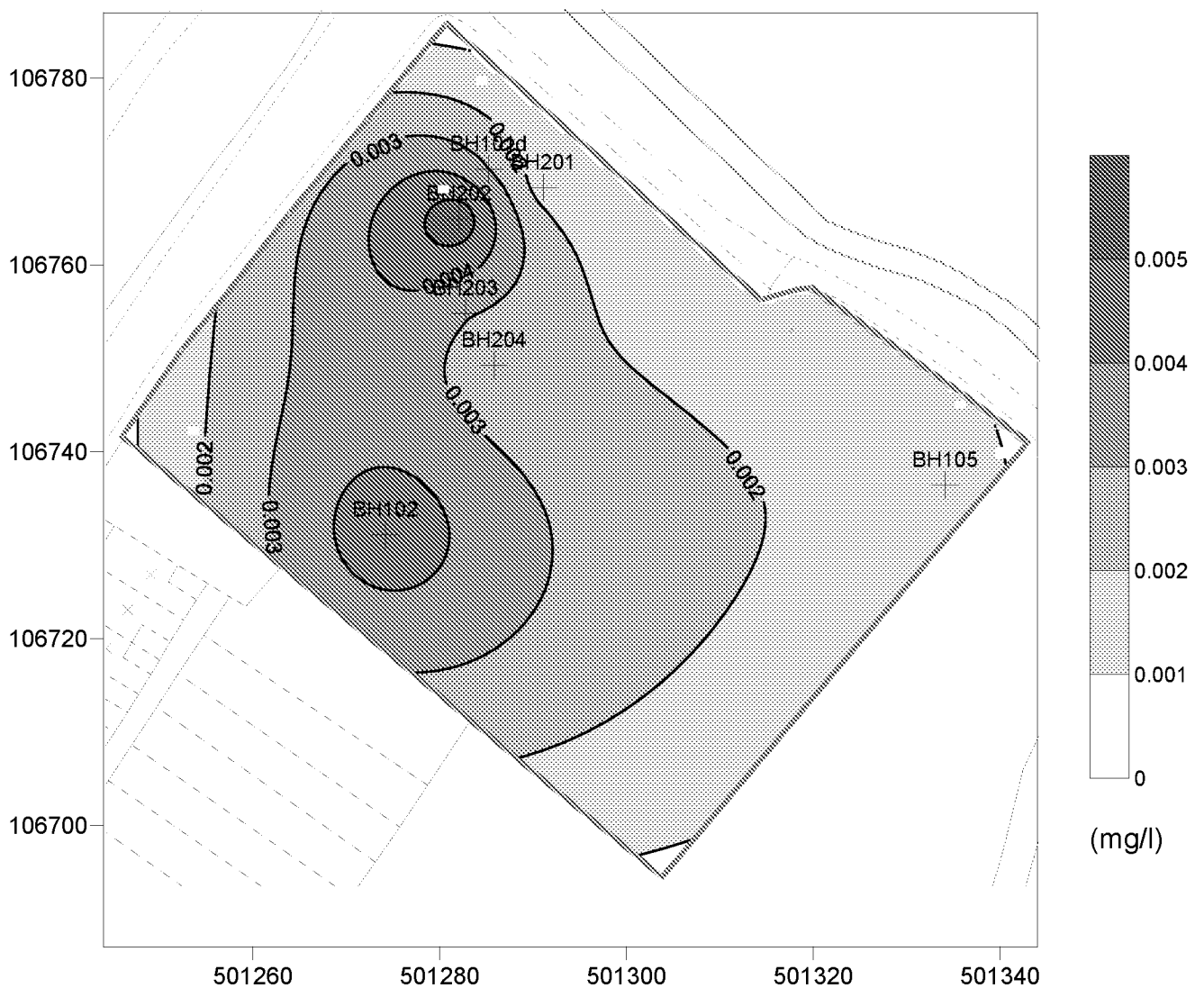


Compliance Criterion = 0.02 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.011 (mg/l)

## Ford Road, Arundel

Inferred Contours of Copper (dissolved) Groundwater Concentration 02/12/2020

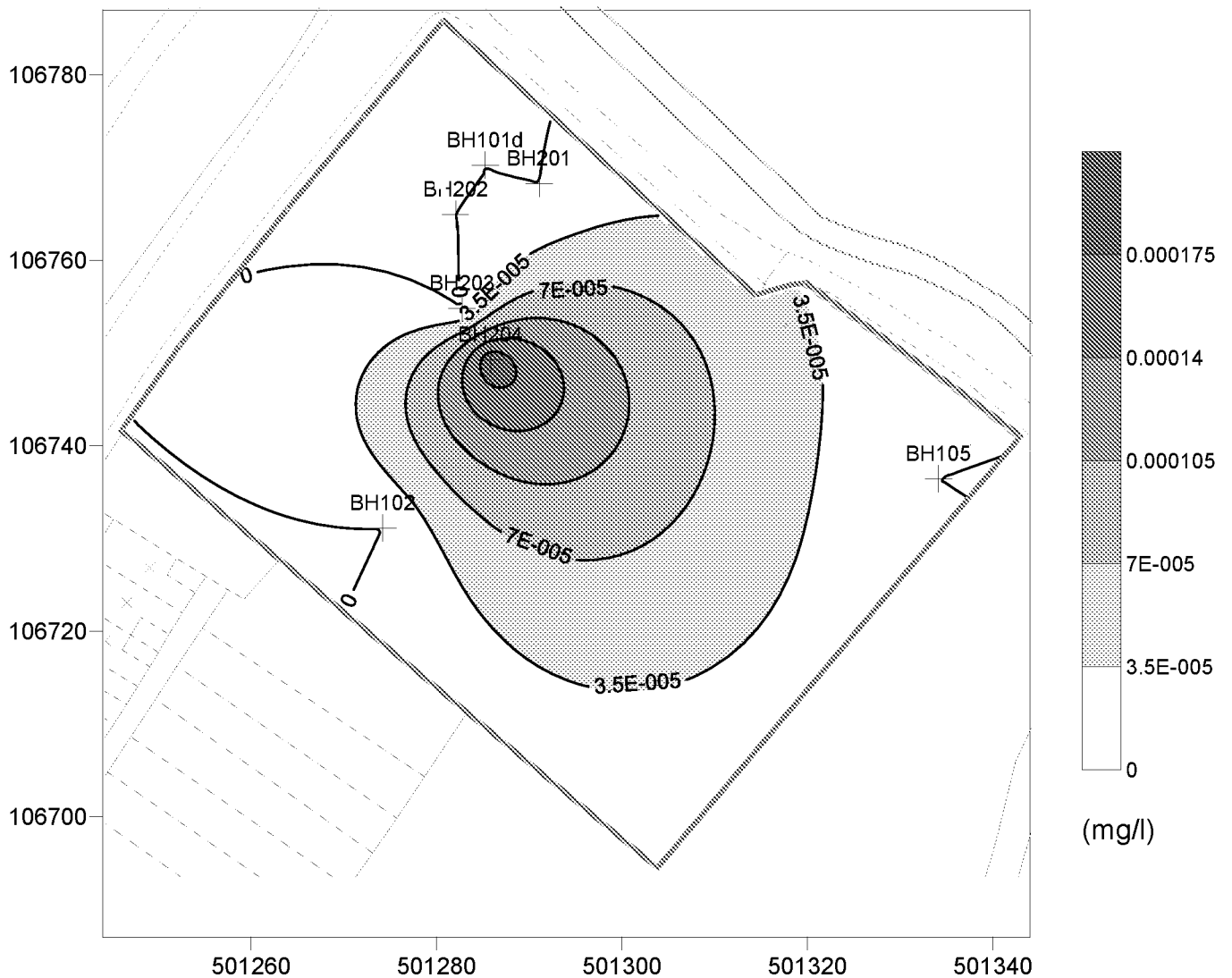


Compliance Criterion = 0.028 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.0058 (mg/l)

## Ford Road, Arundel

Inferred Contours of Lead (dissolved) Groundwater Concentration 02/12/2020

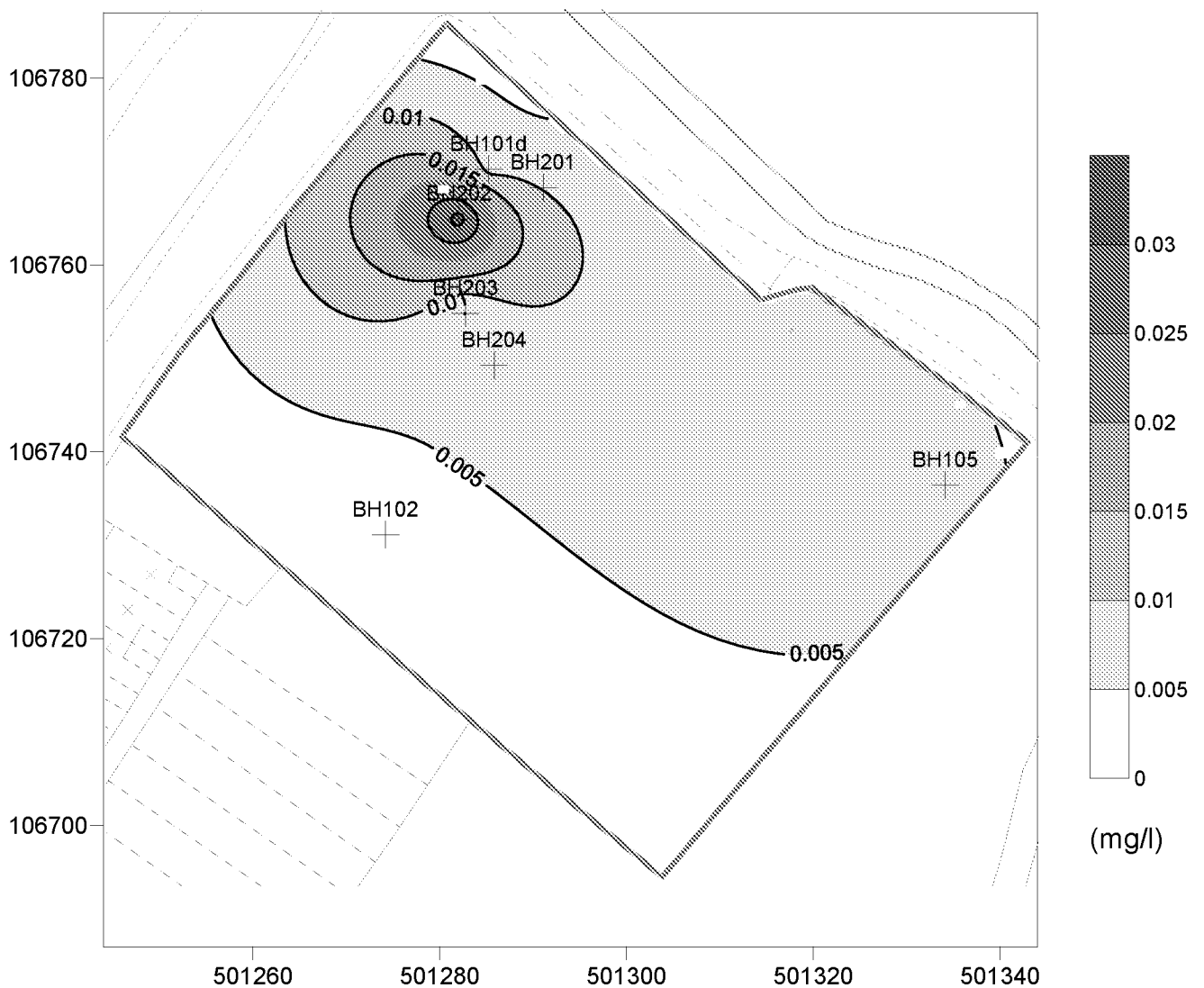


Compliance Criterion = 0.0072 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.0002 (mg/l)

## Ford Road, Arundel

Inferred Contours of Nickel (dissolved) Groundwater Concentration 02/12/2020

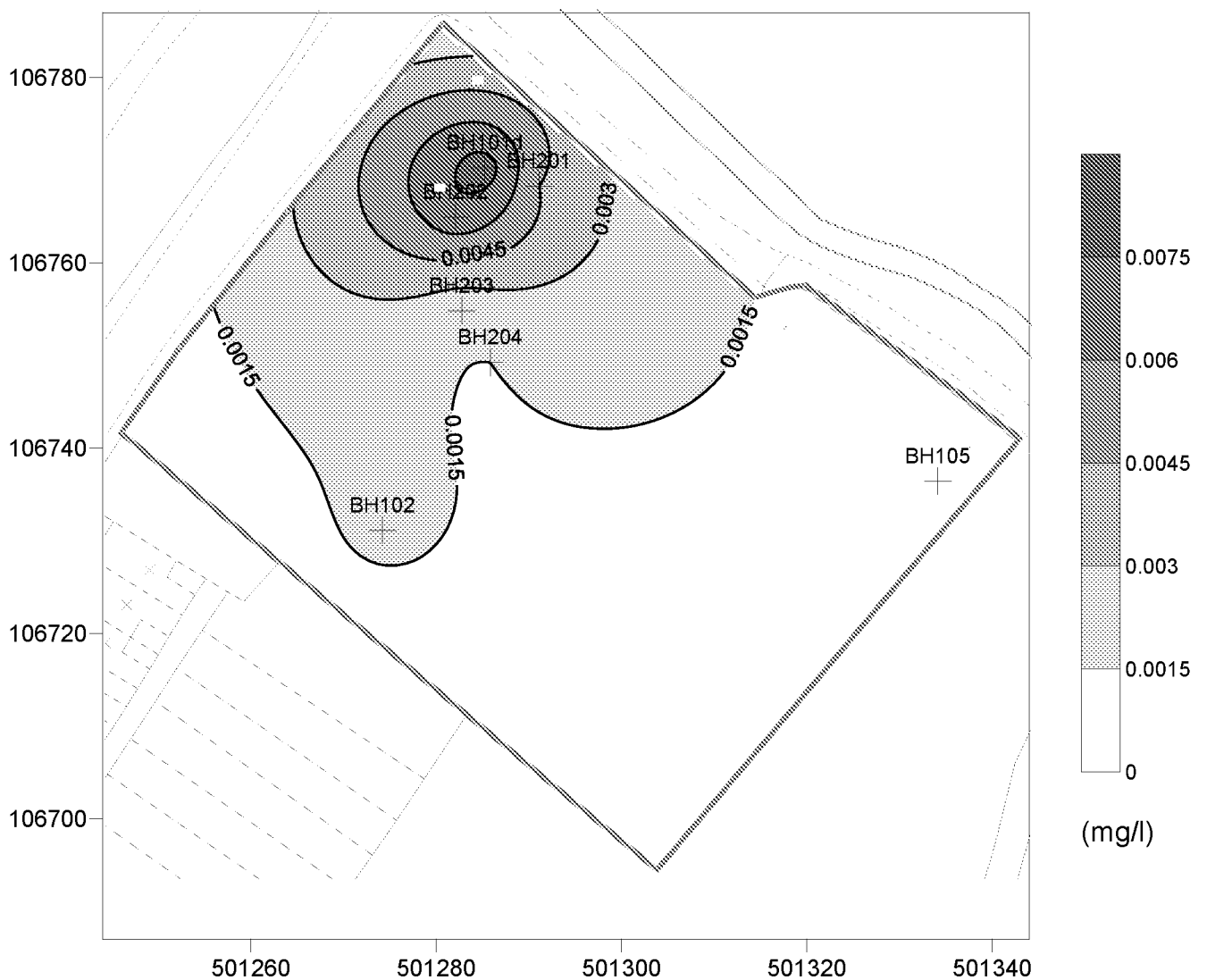


Compliance Criterion = 0.02 (mg/l)

Data Maximum Value = 0.032 (mg/l)

## Ford Road, Arundel

Inferred Contours of Selenium (dissolved) Groundwater Concentration 02/12/2020

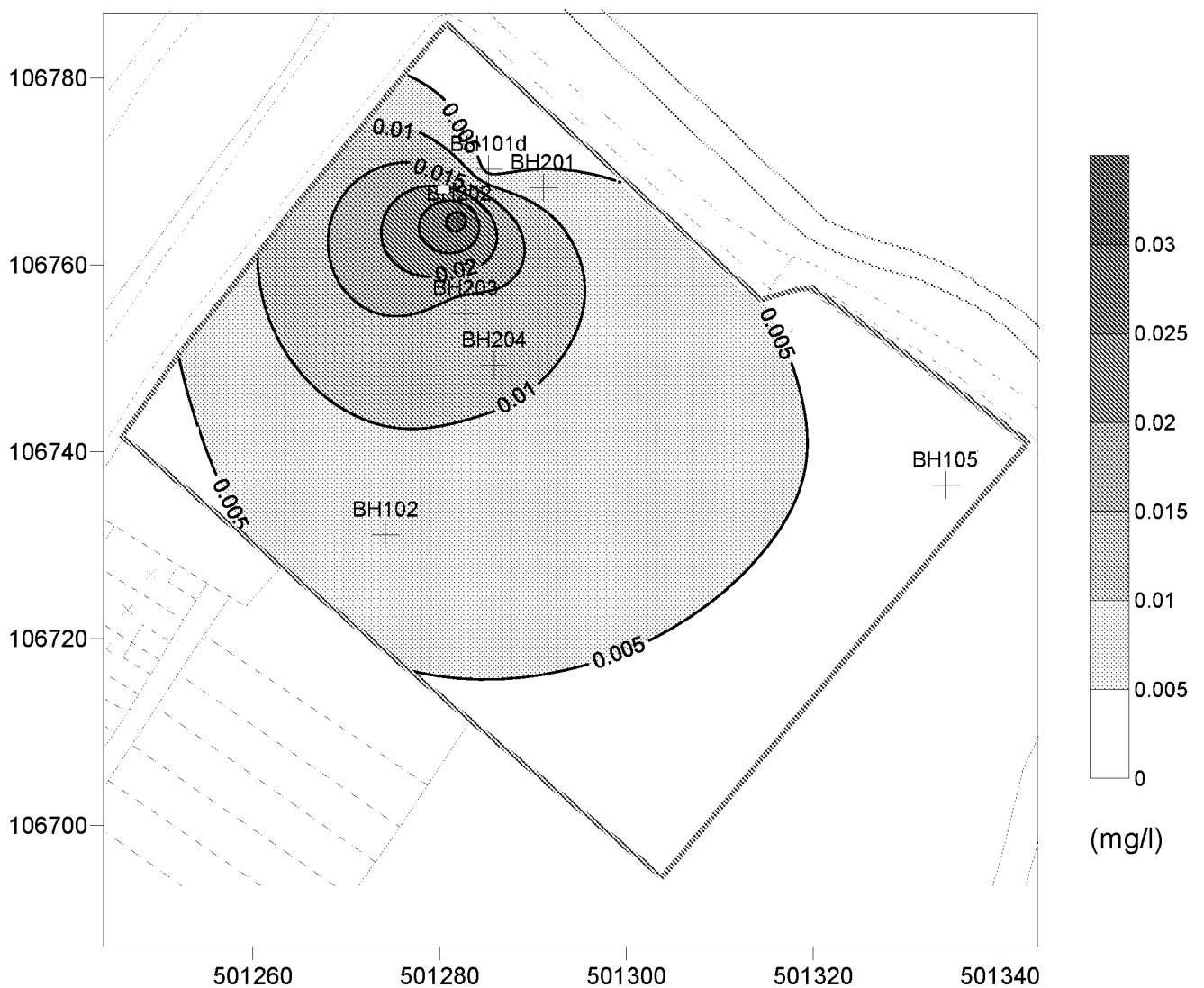


Compliance Criterion = 0.01 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.0083 (mg/l)

## Ford Road, Arundel

Inferred Contours of Zinc (dissolved) Groundwater Concentration 02/12/2020

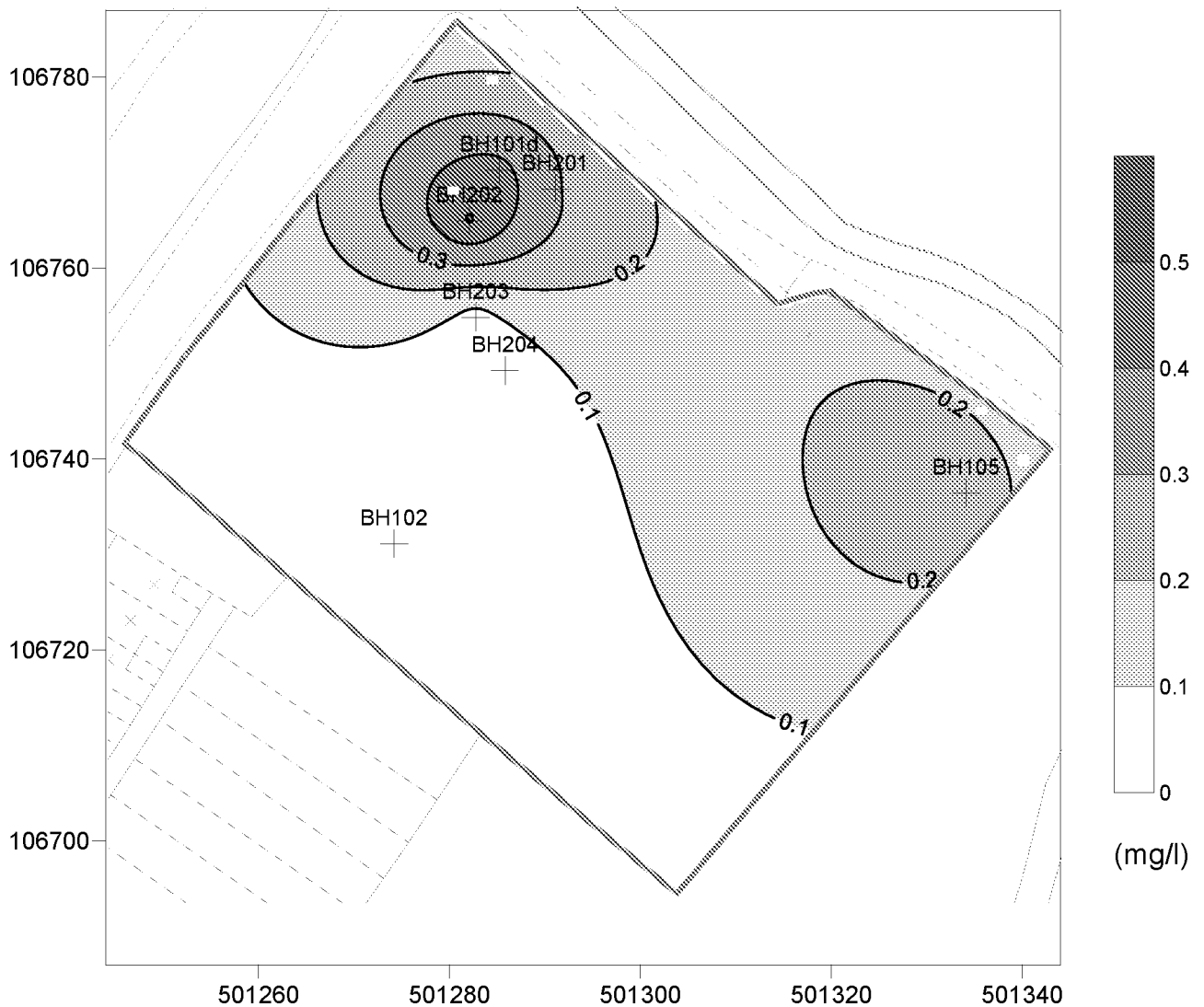


Compliance Criterion = 0.034 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.033 (mg/l)

## Ford Road, Arundel

Inferred Contours of Complex Cyanide Groundwater Concentration 02/12/2020



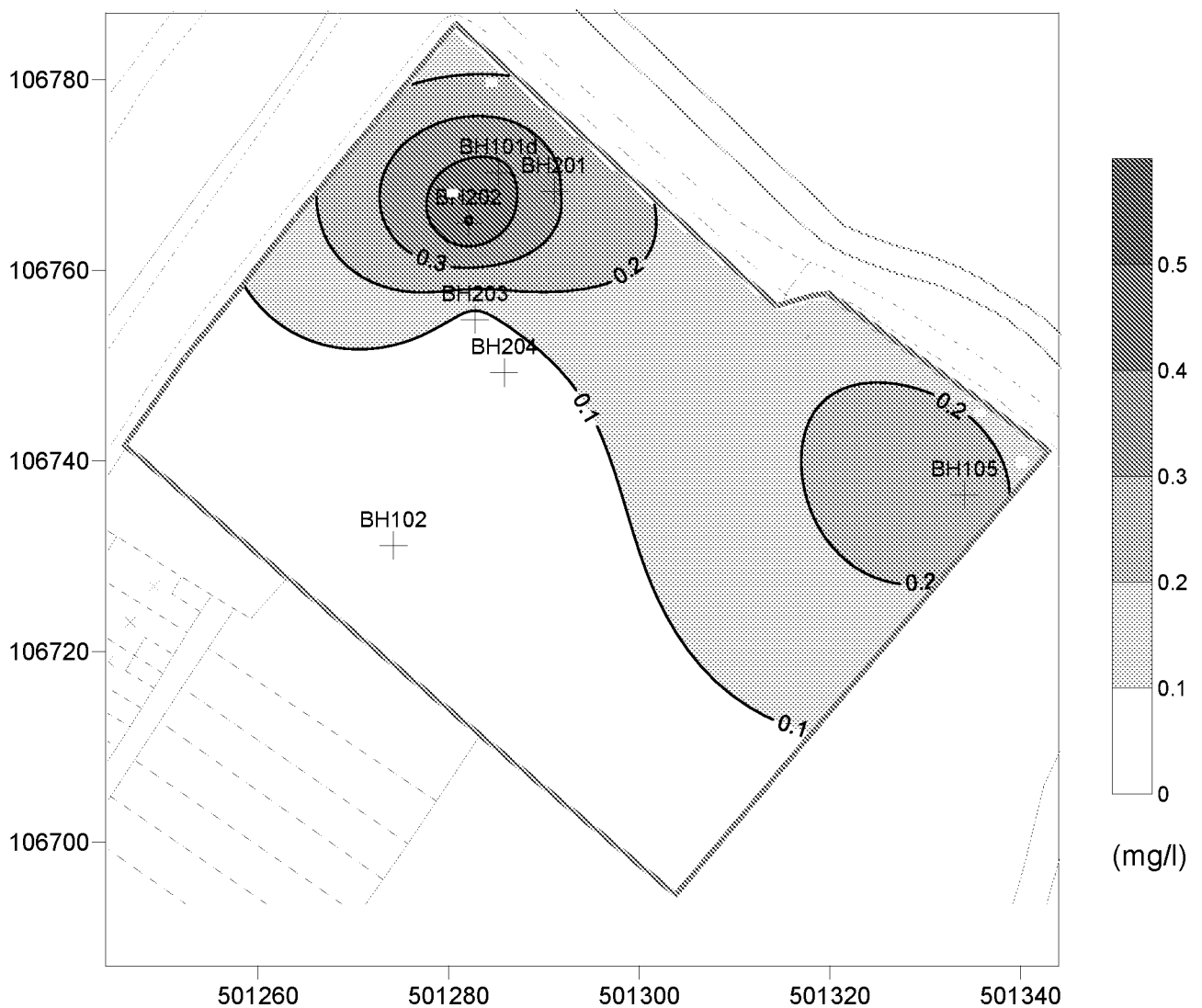
Compliance Criterion = 14 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.51 (mg/l)



## Ford Road, Arundel

### Inferred Contours of Total Cyanide Groundwater Concentration 02/12/2020

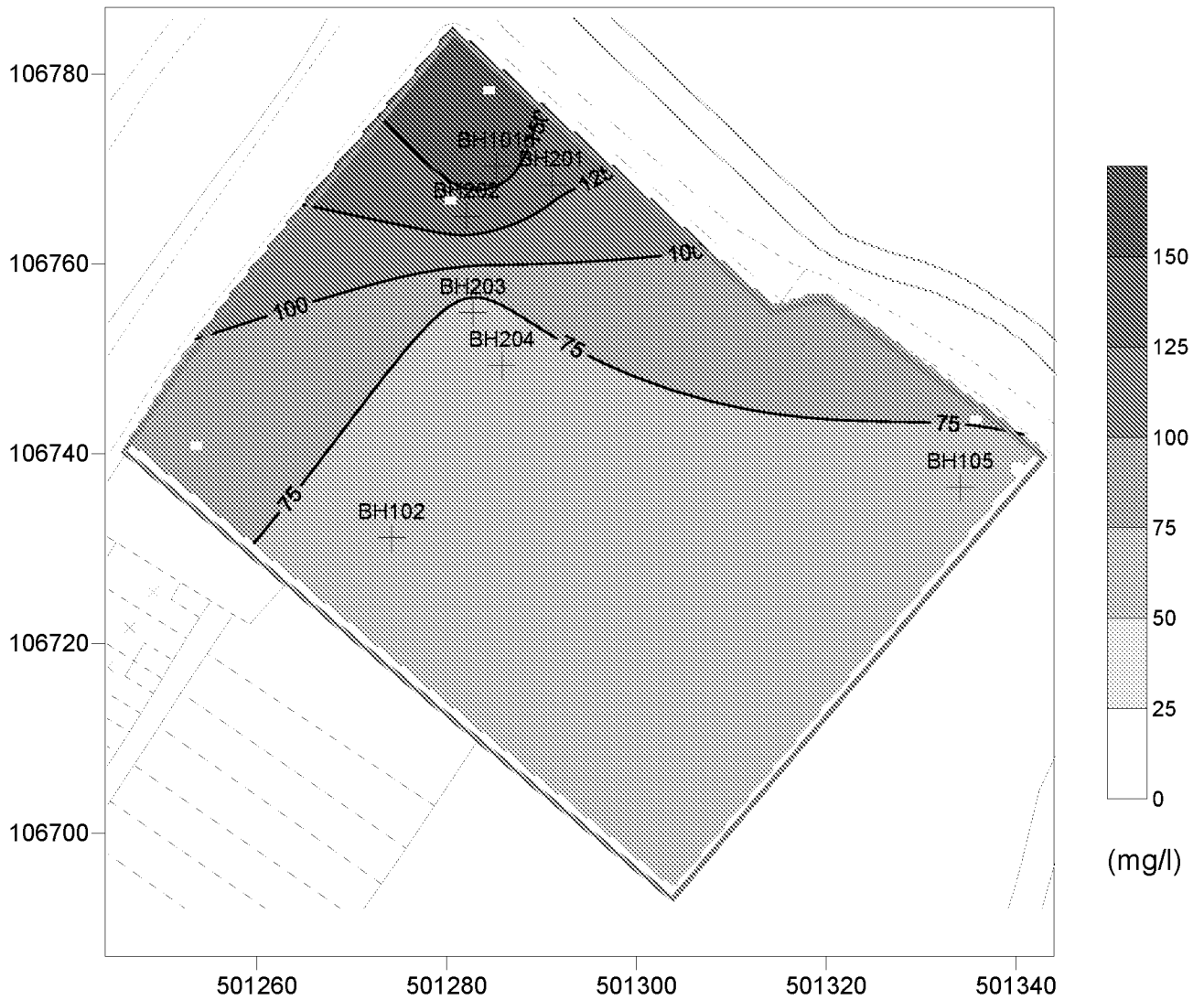


Compliance Criterion = 14 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.51 (mg/l)

## Ford Road, Arundel

Inferred Contours of Chloride Groundwater Concentration 02/12/2020

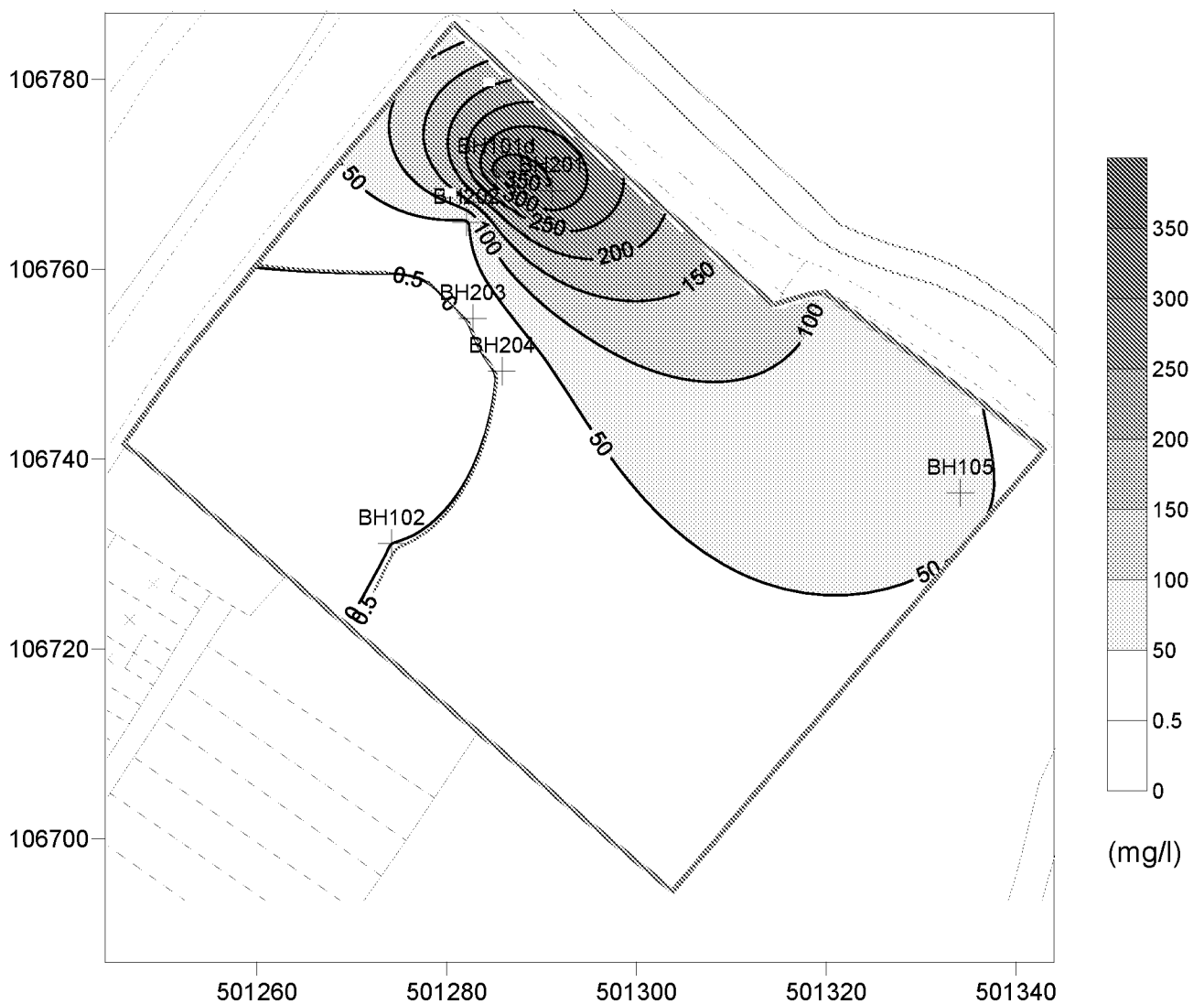


Compliance Criterion = 250 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 160 (mg/l)

## Ford Road, Arundel

Inferred Contours of Ammonium as NH4 Groundwater Concentration 02/12/2020



Compliance Criterion = 0.5 (mg/l)

Data Maximum Value = 370 (mg/l)

(mg/l)

## Ford Road, Arundel

Inferred Contours of Iron (dissolved) Groundwater Concentration 02/12/2020



Data Maximum Value = 0.59 (mg/l)

## Ford Road, Arundel

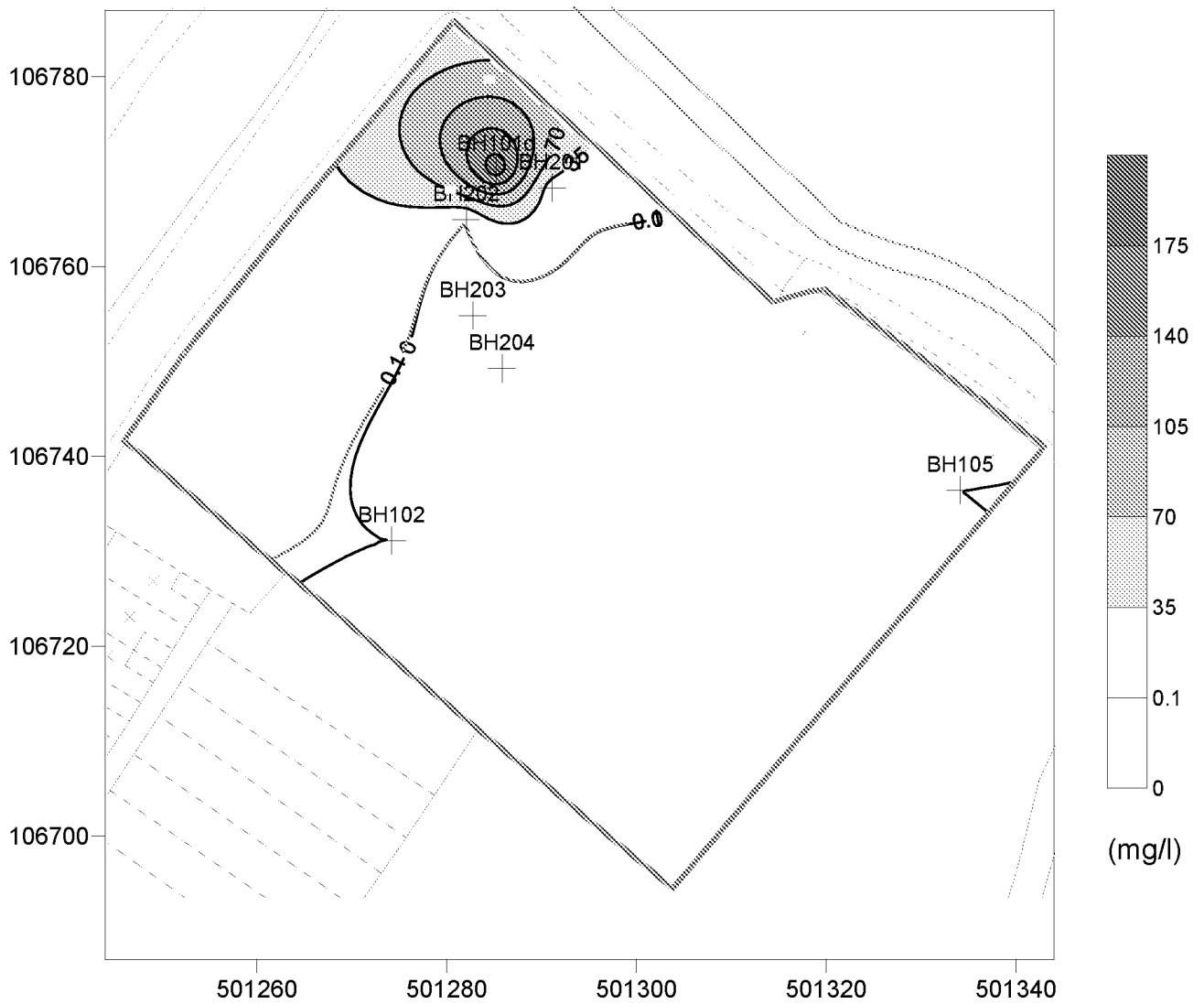
Inferred Contours of Ethylphenol & Dimethylphenol Groundwater Concentration 02/12/2



Data Maximum Value = 87 (mg/l)

## Ford Road, Arundel

Inferred Contours of Cresols Groundwater Concentration 02/12/2020

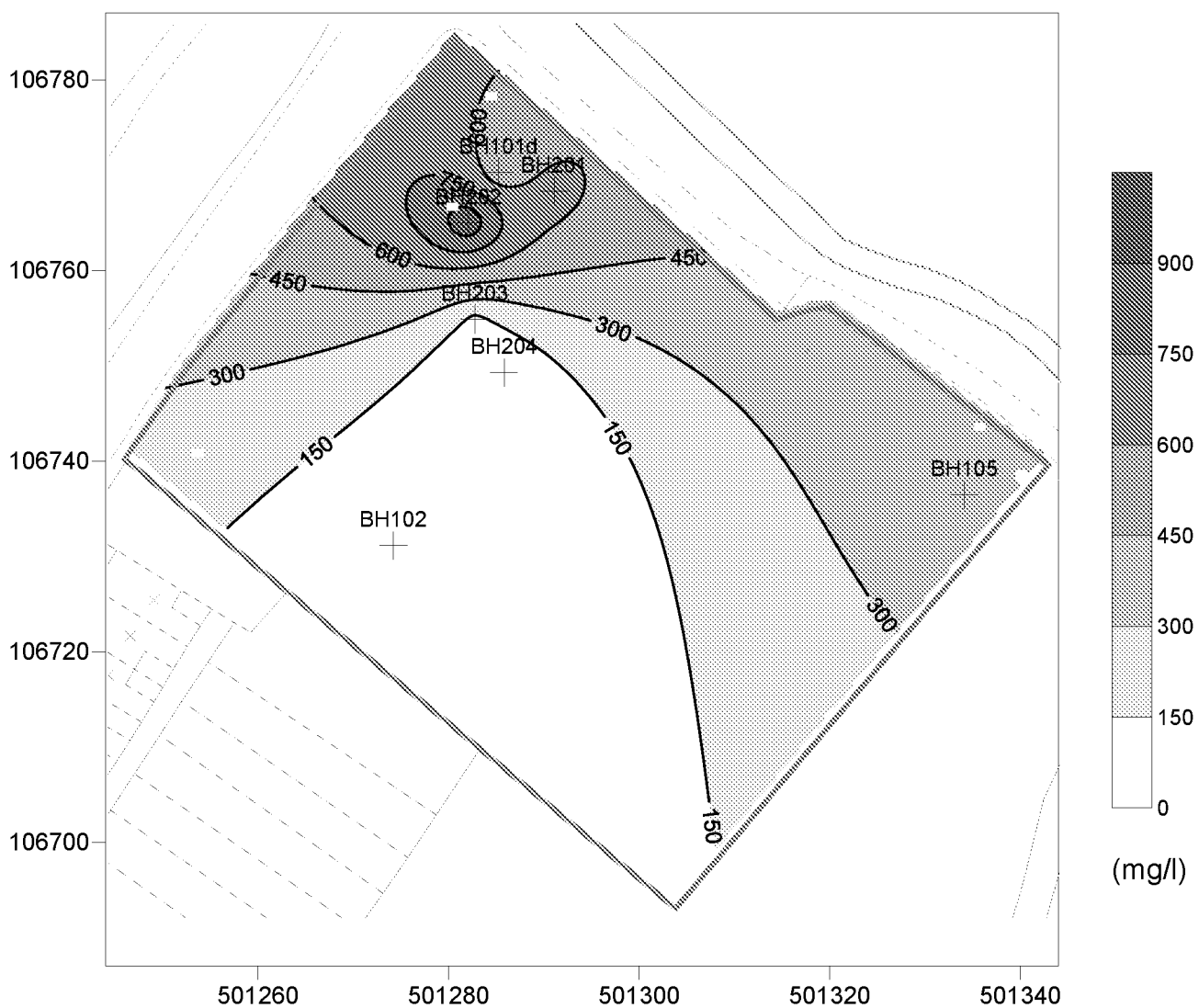


Compliance Criterion = 0.1 (mg/l)

Data Maximum Value = 200 (mg/l)

## Ford Road, Arundel

Inferred Contours of Sulphate as SO<sub>4</sub> Groundwater Concentration 02/12/2020



Data Maximum Value = 1020 (mg/l)

## Ford Road, Arundel

Inferred Contours of Total EPA-16 PAHs Groundwater Concentration 02/12/2020

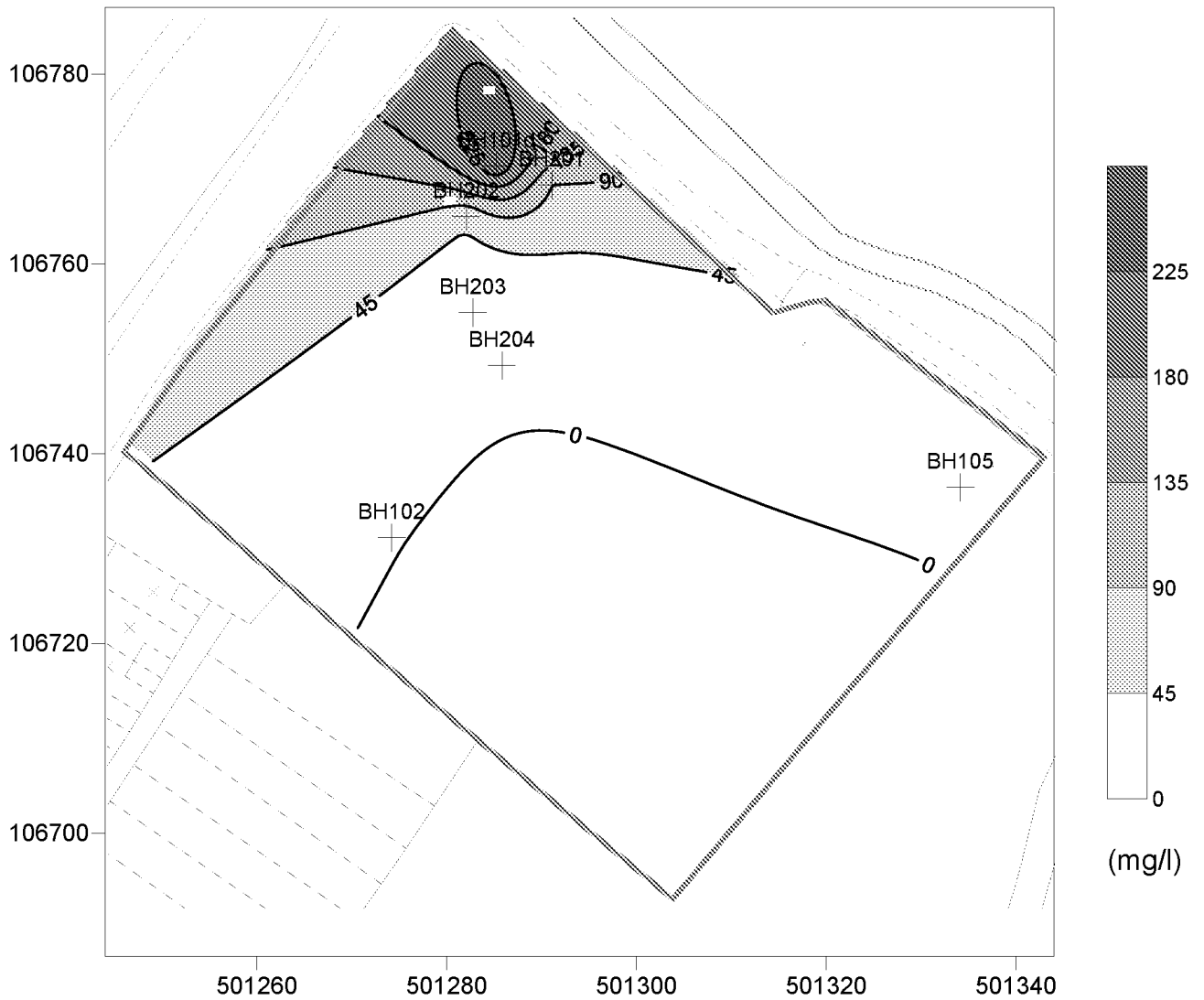


Data Maximum Value = 2.15 (mg/l)



## Ford Road, Arundel

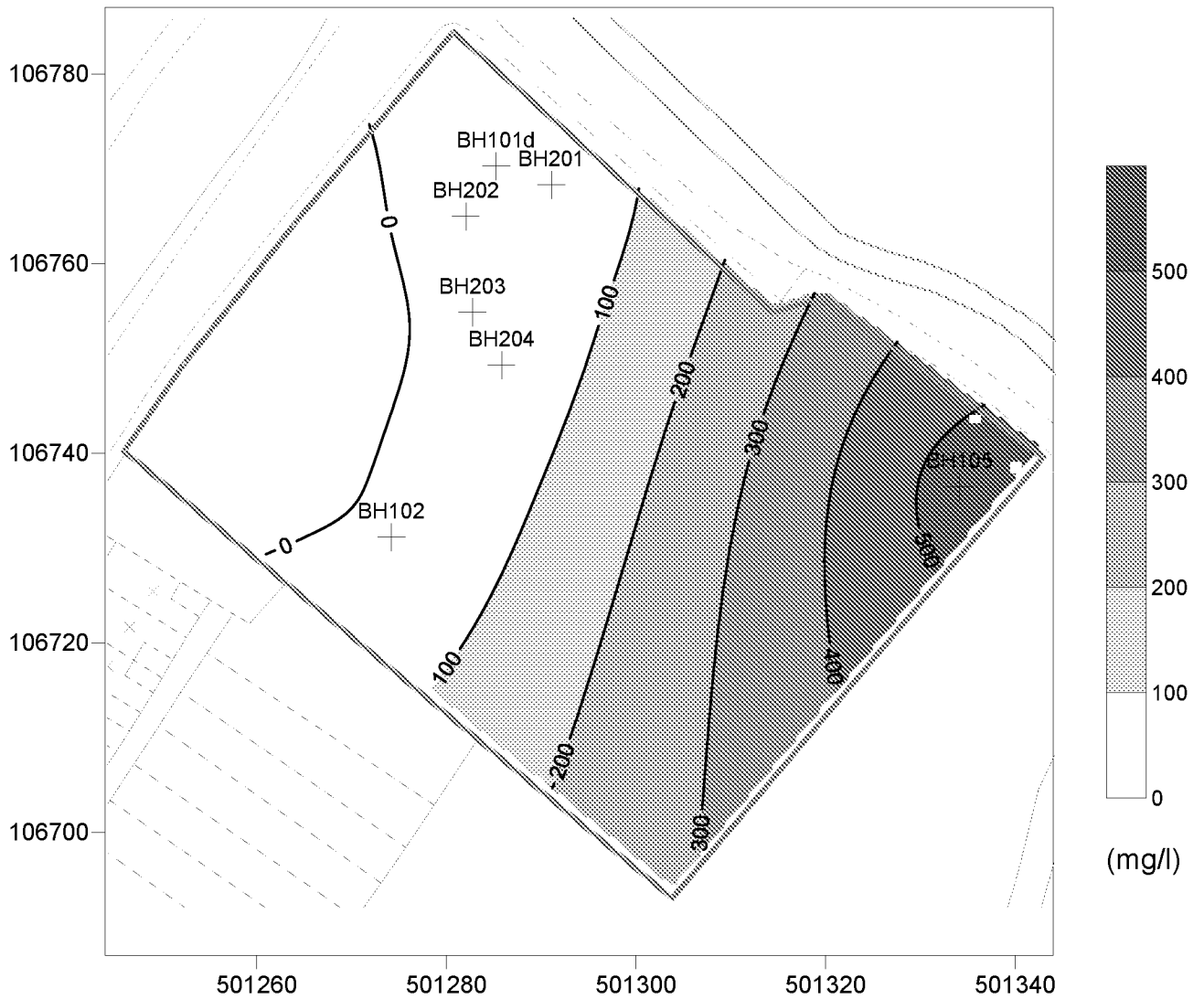
Inferred Contours of Total Organic Carbon (TOC) Groundwater Concentration 02/12/20:



Data Maximum Value = 263 (mg/l)

## Ford Road, Arundel

Inferred Contours of Total Suspended Solids Groundwater Concentration 02/12/2020



Data Maximum Value = 550 (mg/l)

**Addendum C2**  
**Contours of Measured Concentrations of Substances**  
**In Groundwater 2011 Round 1 Data**

## Ford Road, Arundel

### Inferred Contours of Acenaphthene in Groundwater 7/7/11

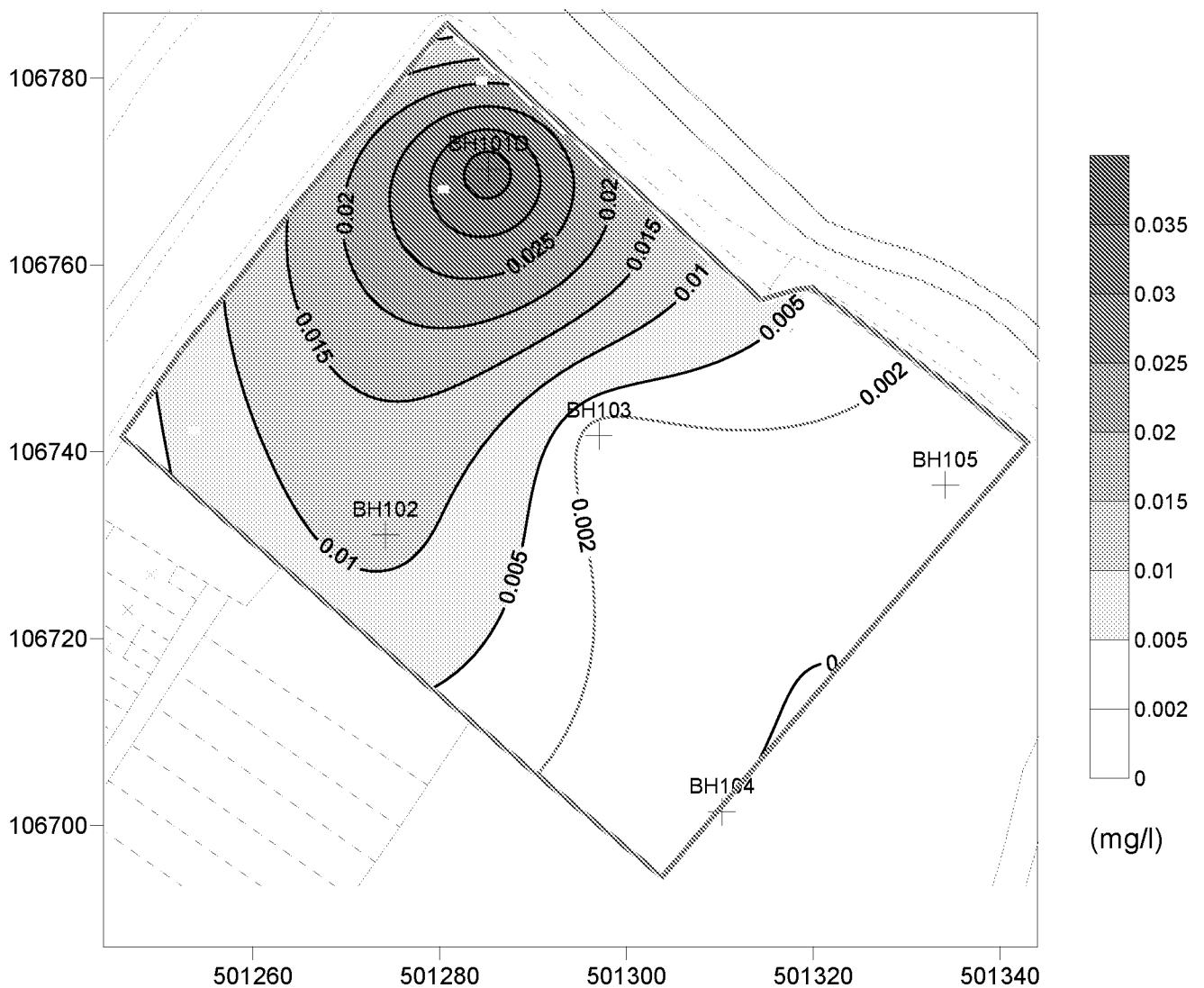


Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.018 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Acenaphthylene in Groundwater 7/7/11



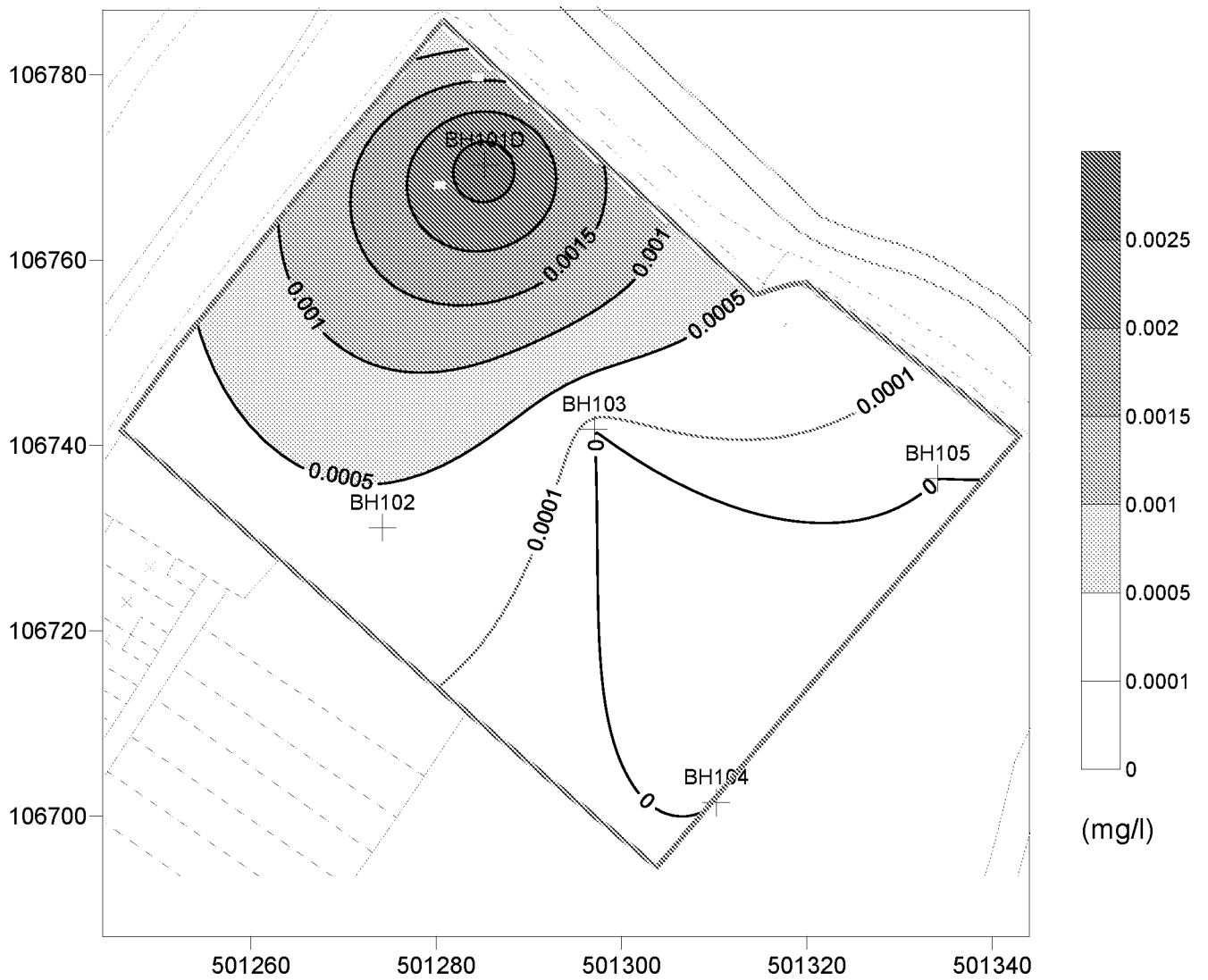
Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.039 (mg/l)

(mg/l)

## Ford Road, Arundel

### Inferred Contours of Anthracene in Groundwater 7/7/11

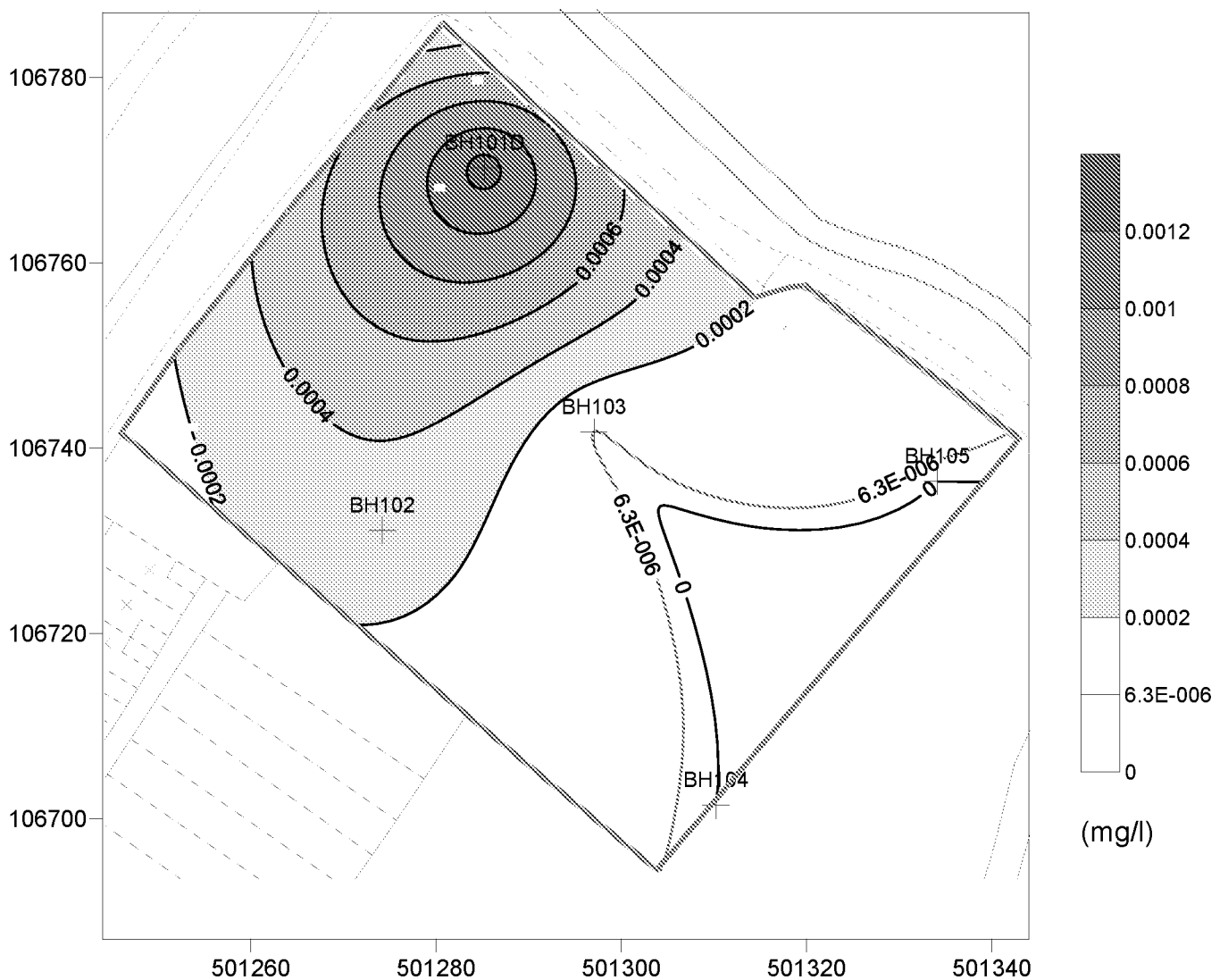


Compliance Criterion = 0.0001 (mg/l)

Data Maximum Value = 0.0029 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Fluoranthene in Groundwater 7/7/11

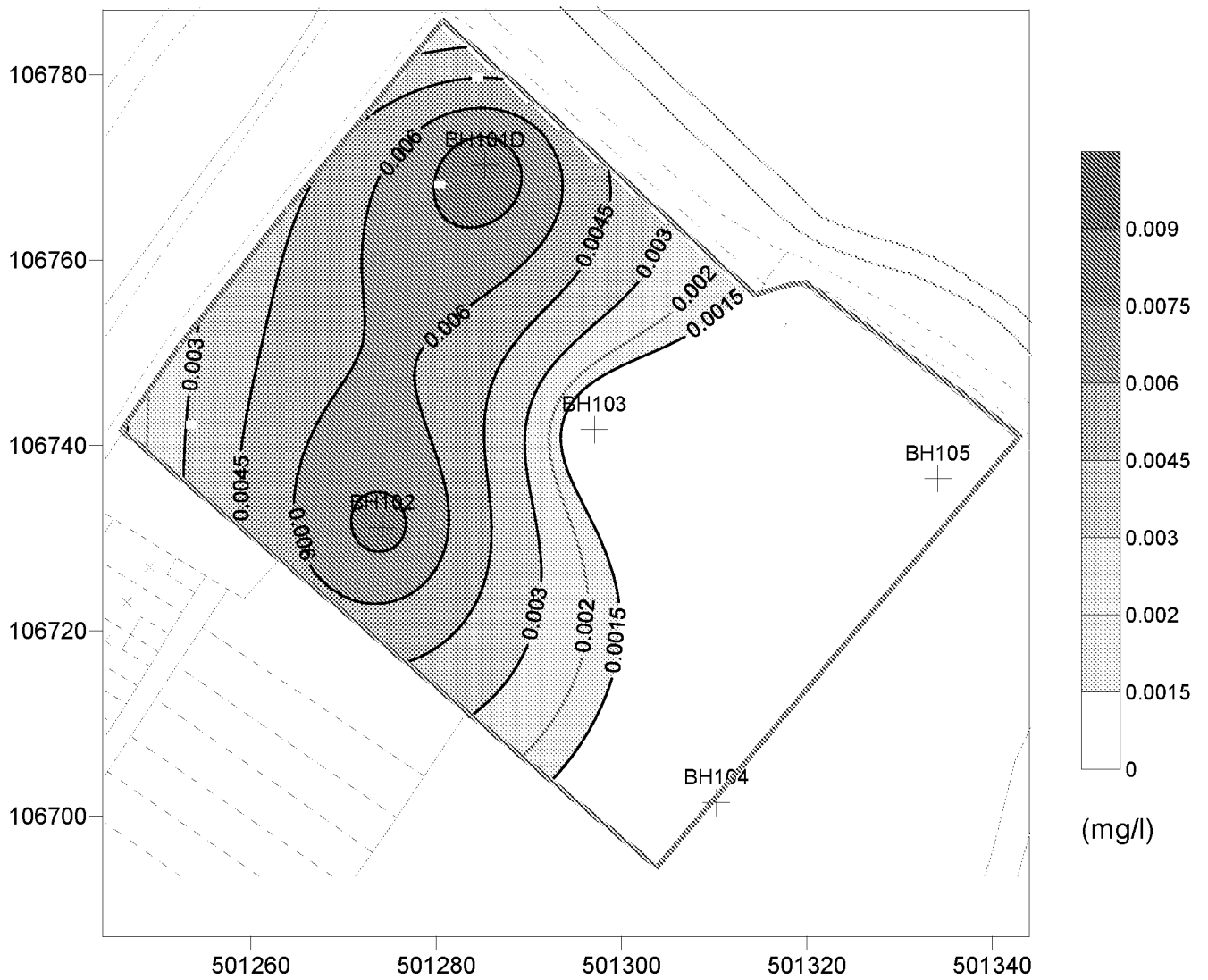


Compliance Criterion = 0.0000063 (mg/l)

Data Maximum Value = 0.0013 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Fluorene in Groundwater 7/7/11



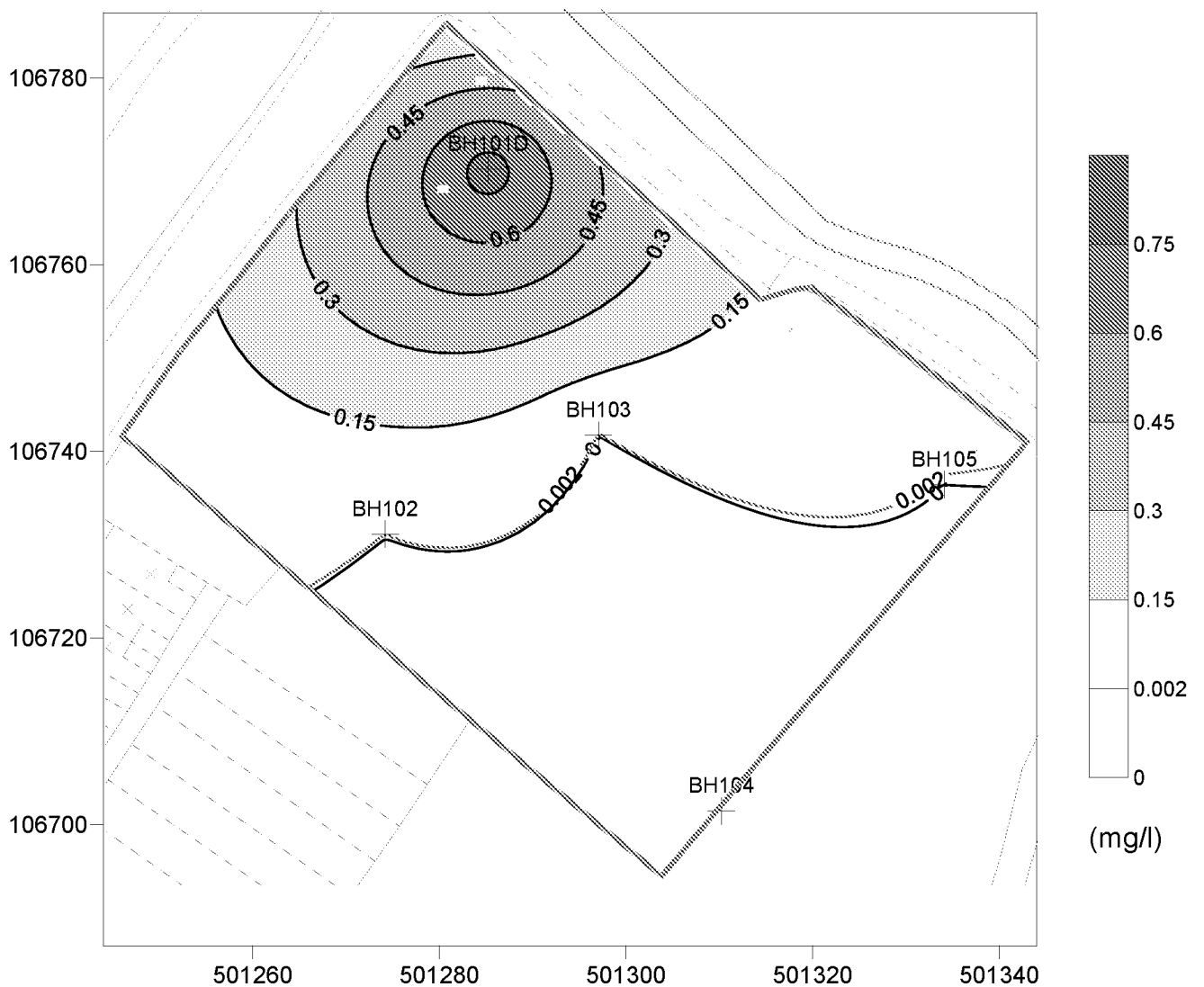
Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.009 (mg/l)



## Ford Road, Arundel

### Inferred Contours of Naphthalene in Groundwater 7/7/11

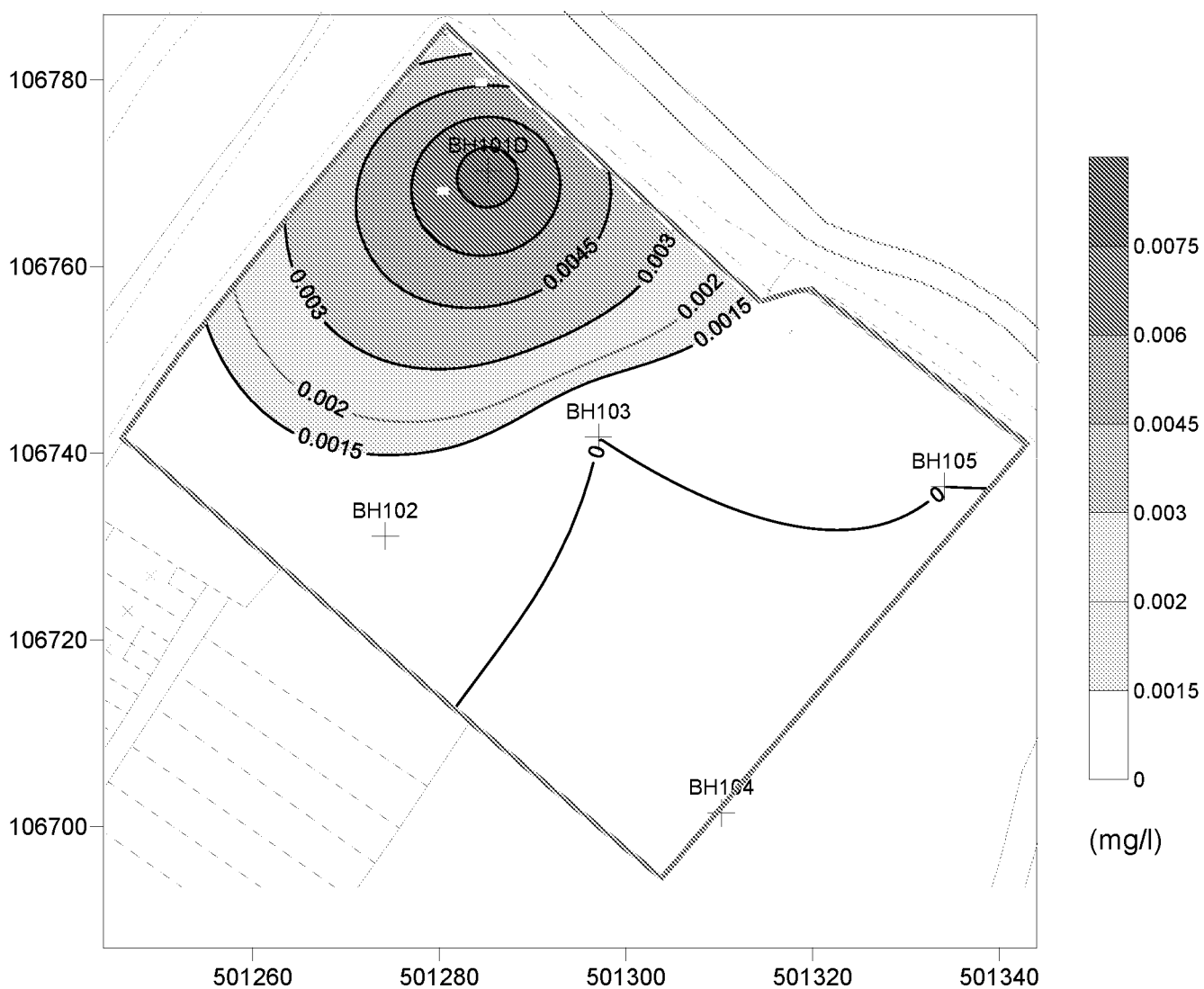


Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.83 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Phenanthrene in Groundwater 7/7/11

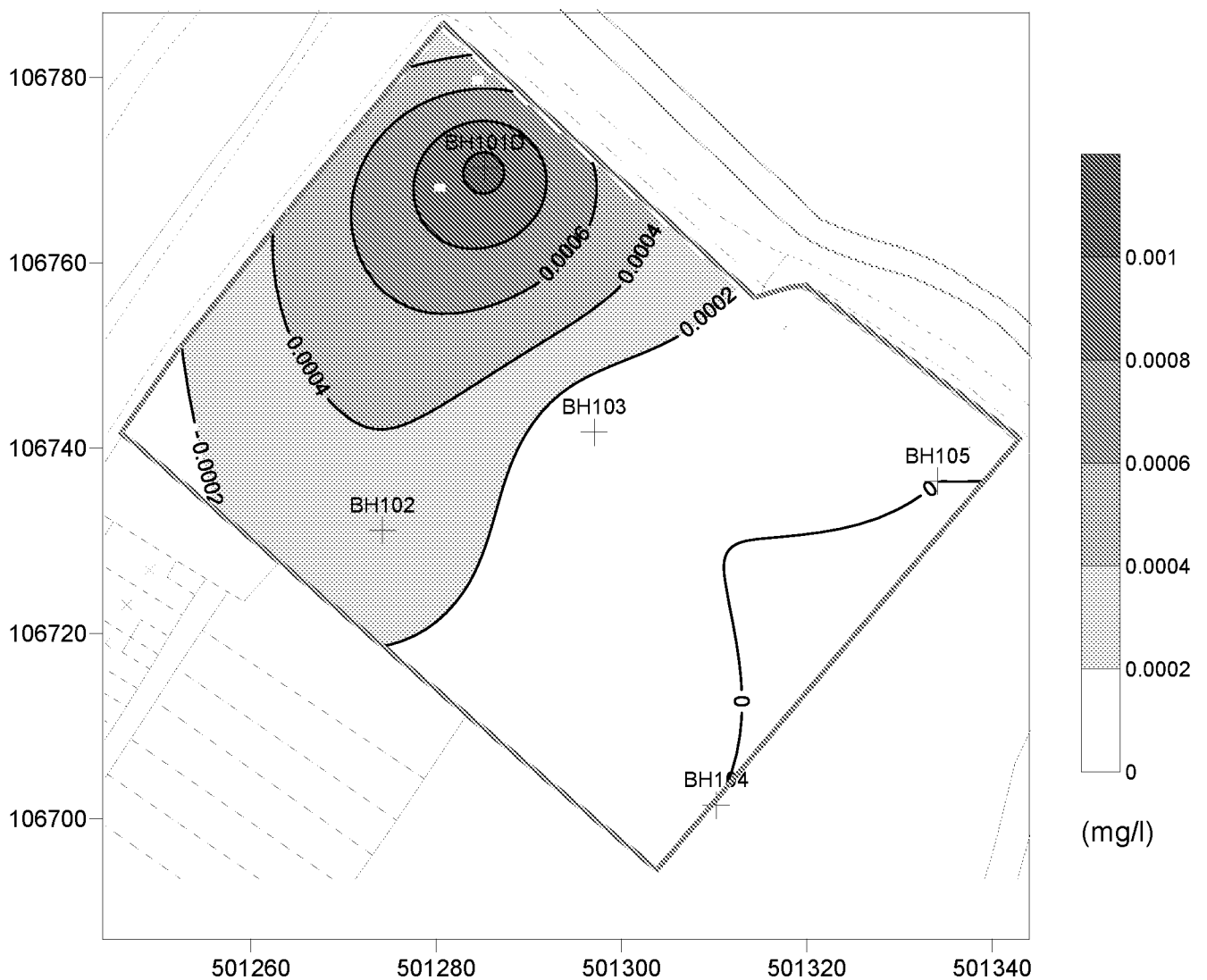


Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.0087 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Pyrene in Groundwater 7/7/11

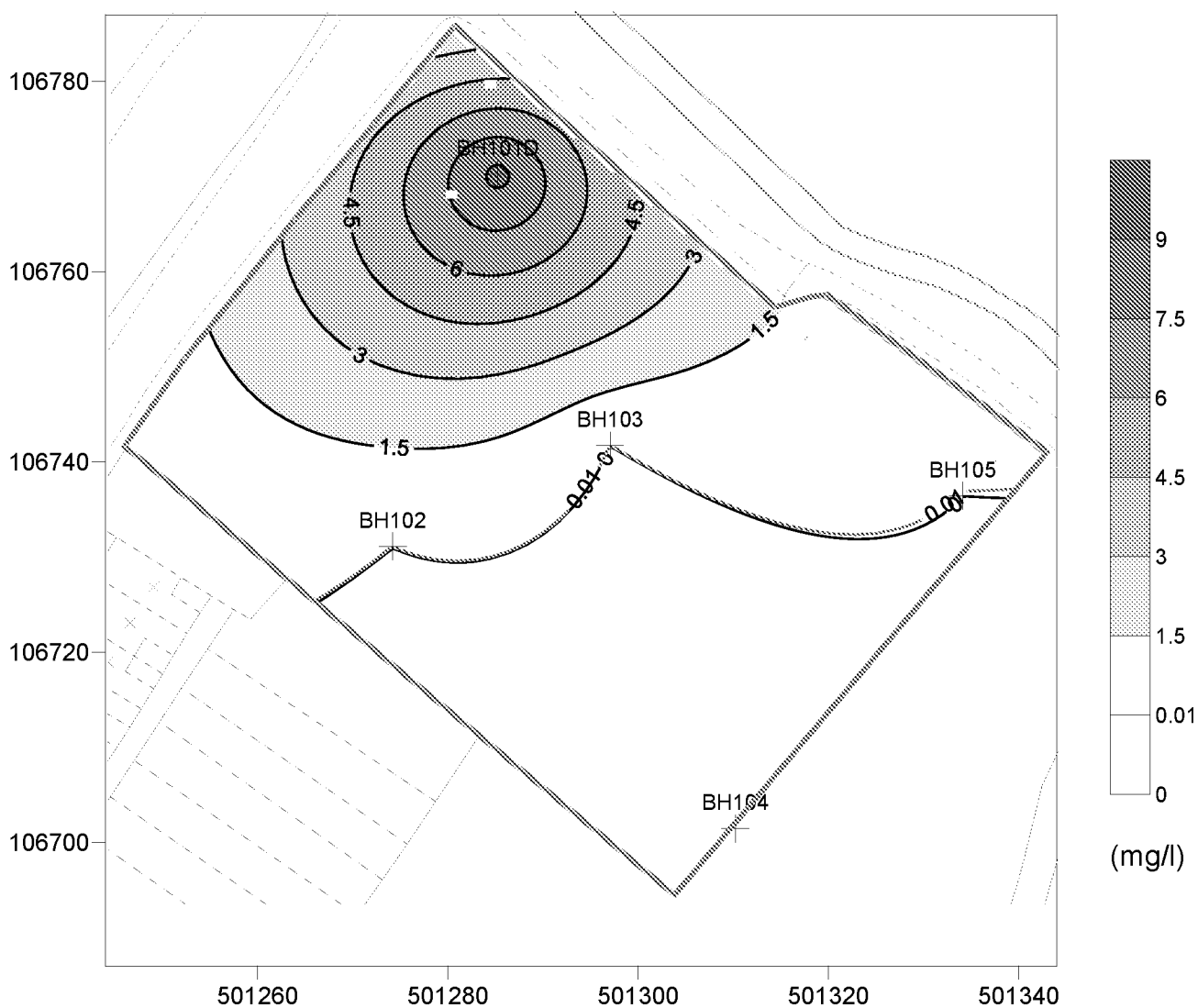


Compliance Criterion = 0.002 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.0011 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Benzene in Groundwater 7/7/11

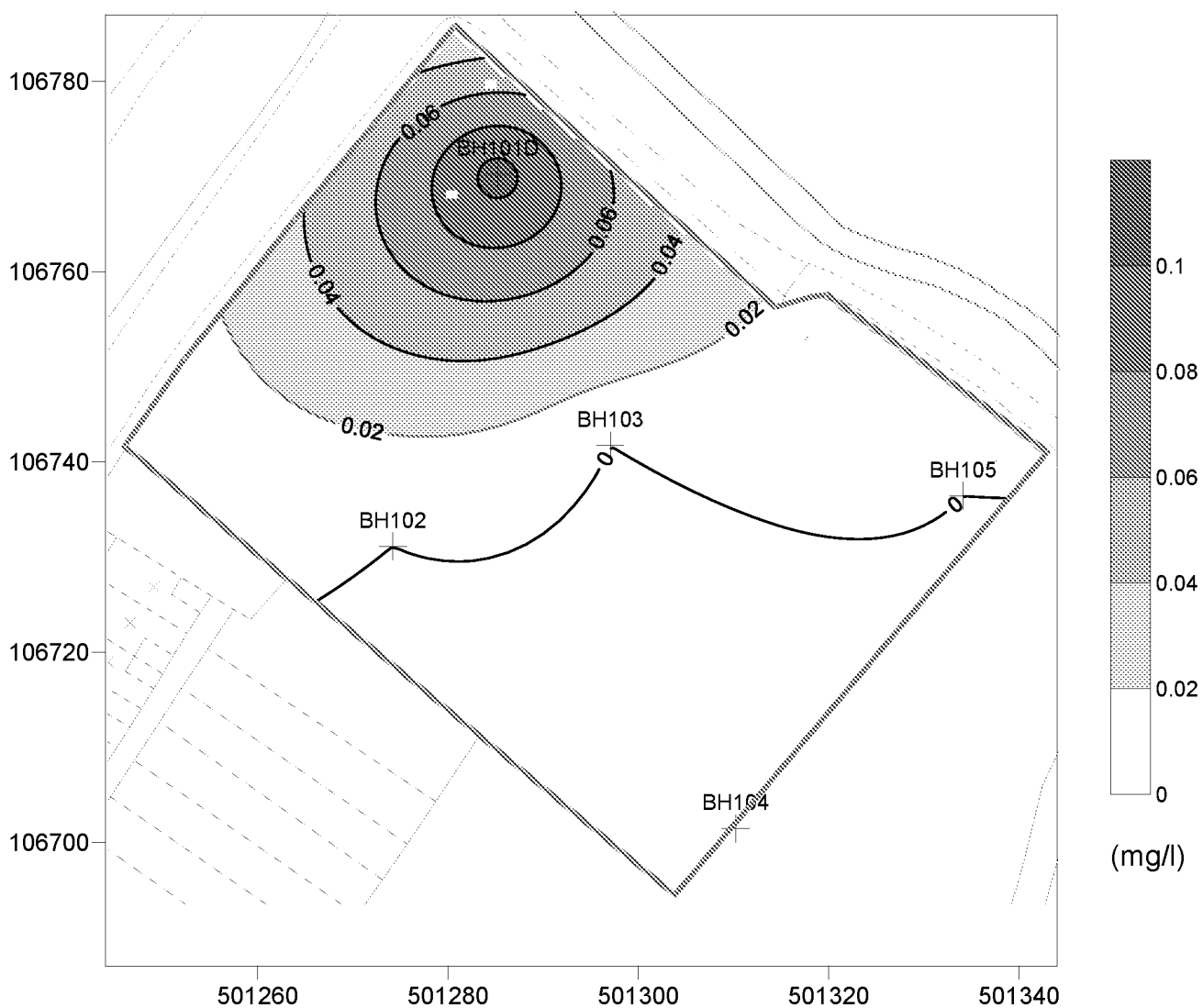


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 9.5 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Ethylbenzene in Groundwater 7/7/11

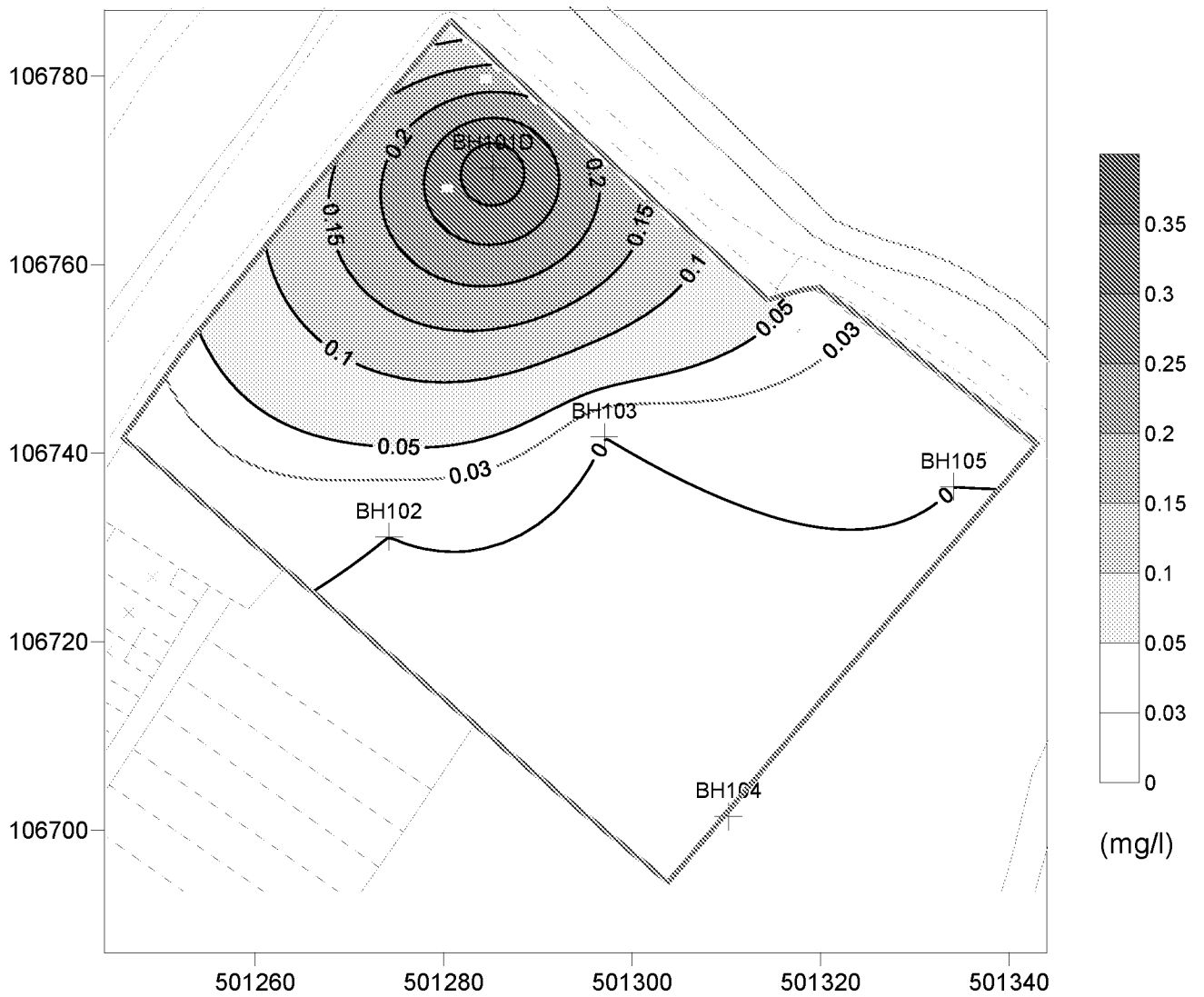


Compliance Criterion = 0.02 (mg/l)

Data Maximum Value = 0.11 (mg/l)

## Ford Road, Arundel

### Inferred Contours of o-xylene in Groundwater 7/7/11

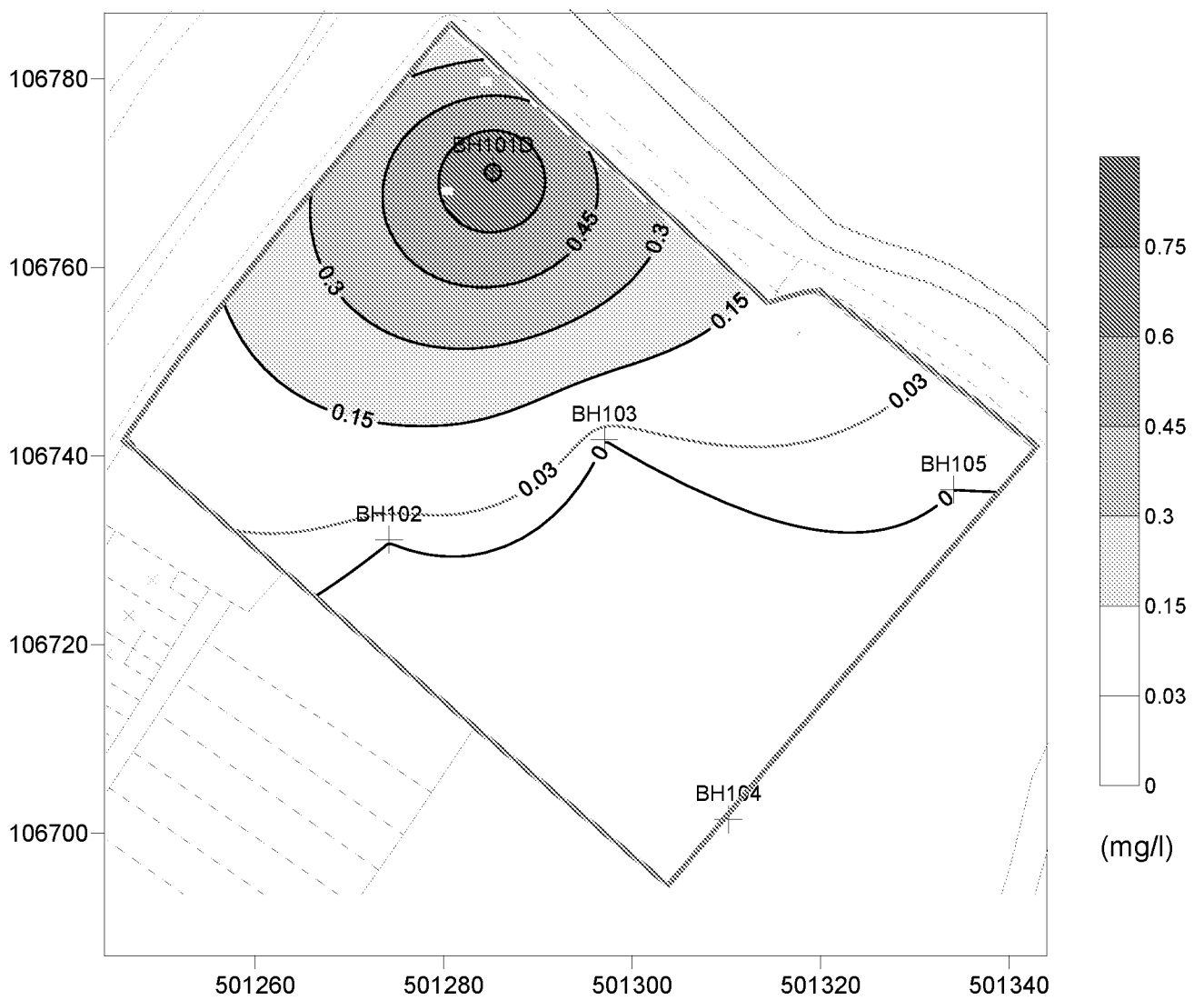


Compliance Criterion = 0.03 (mg/l)

Data Maximum Value = 0.35 (mg/l)

## Ford Road, Arundel

### Inferred Contours of p & m-xylene in Groundwater 7/7/11

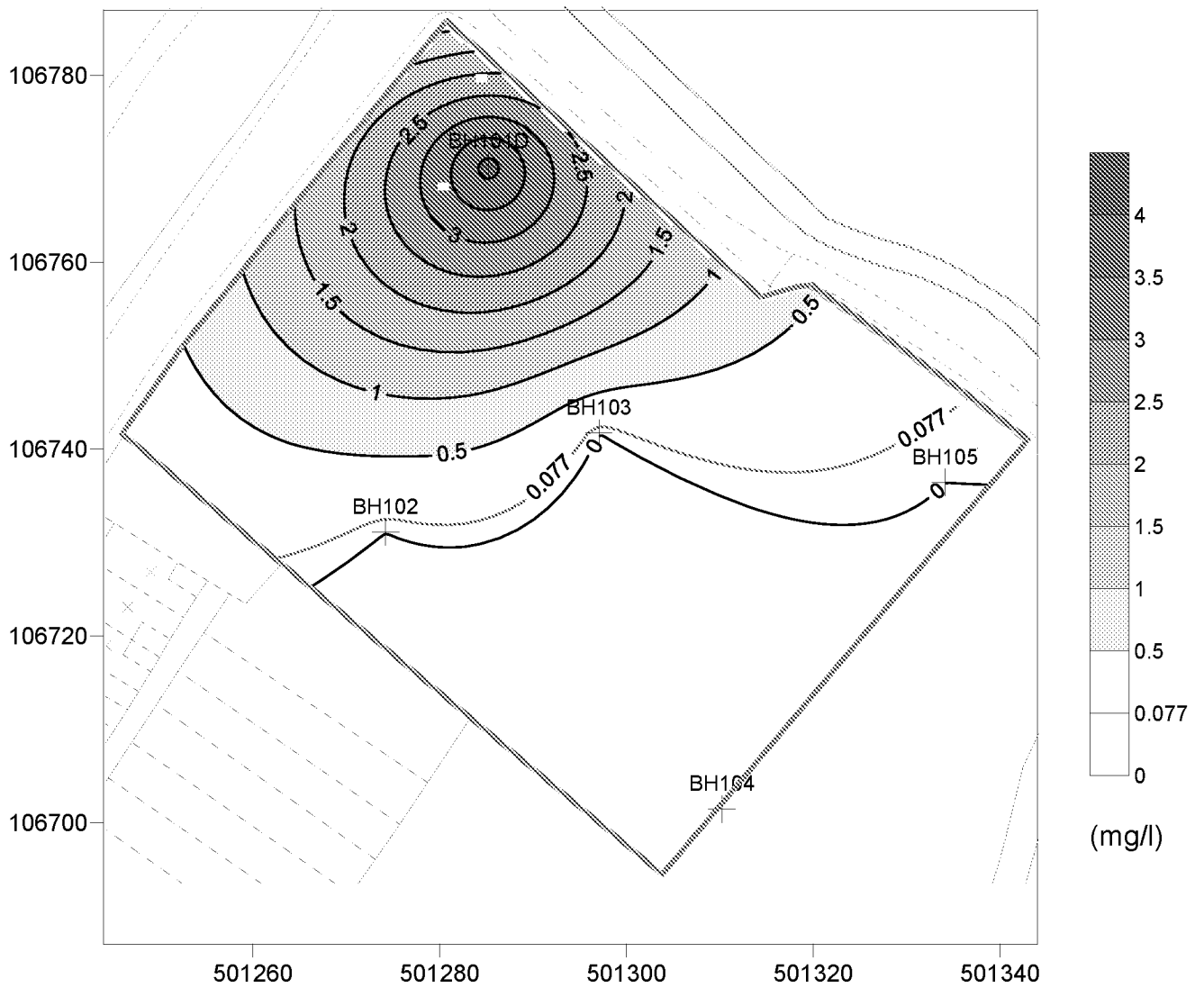


Compliance Criterion = 0.03 (mg/l)

Data Maximum Value = 0.78 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Toluene in Groundwater 7/7/11



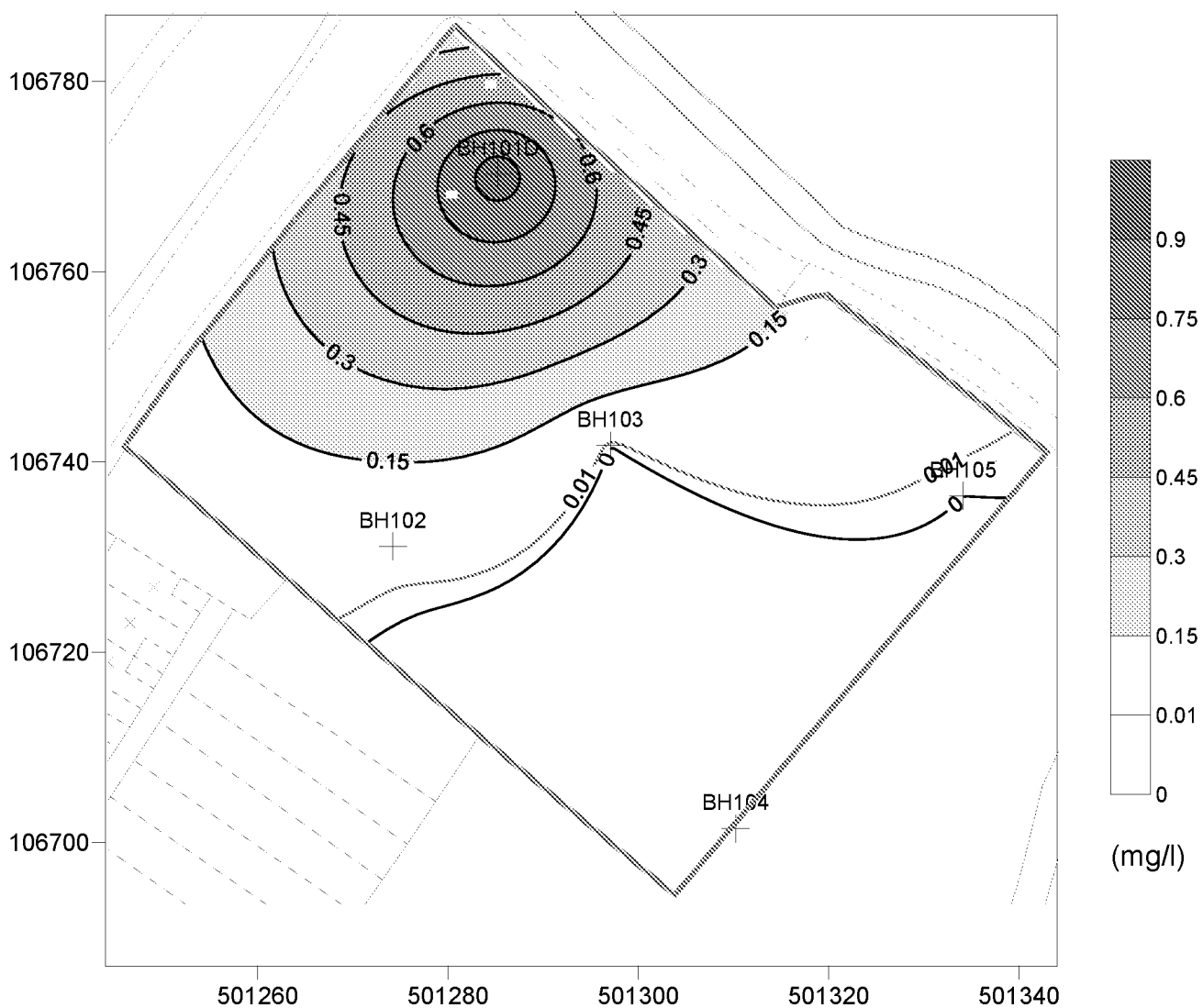
Compliance Criterion = 0.077 (mg/l)

Data Maximum Value = 4.2 (mg/l)



## Ford Road, Arundel

### Inferred Contours of TPH7 - Aromatic C10 - C12 in Groundwater 7/7/11

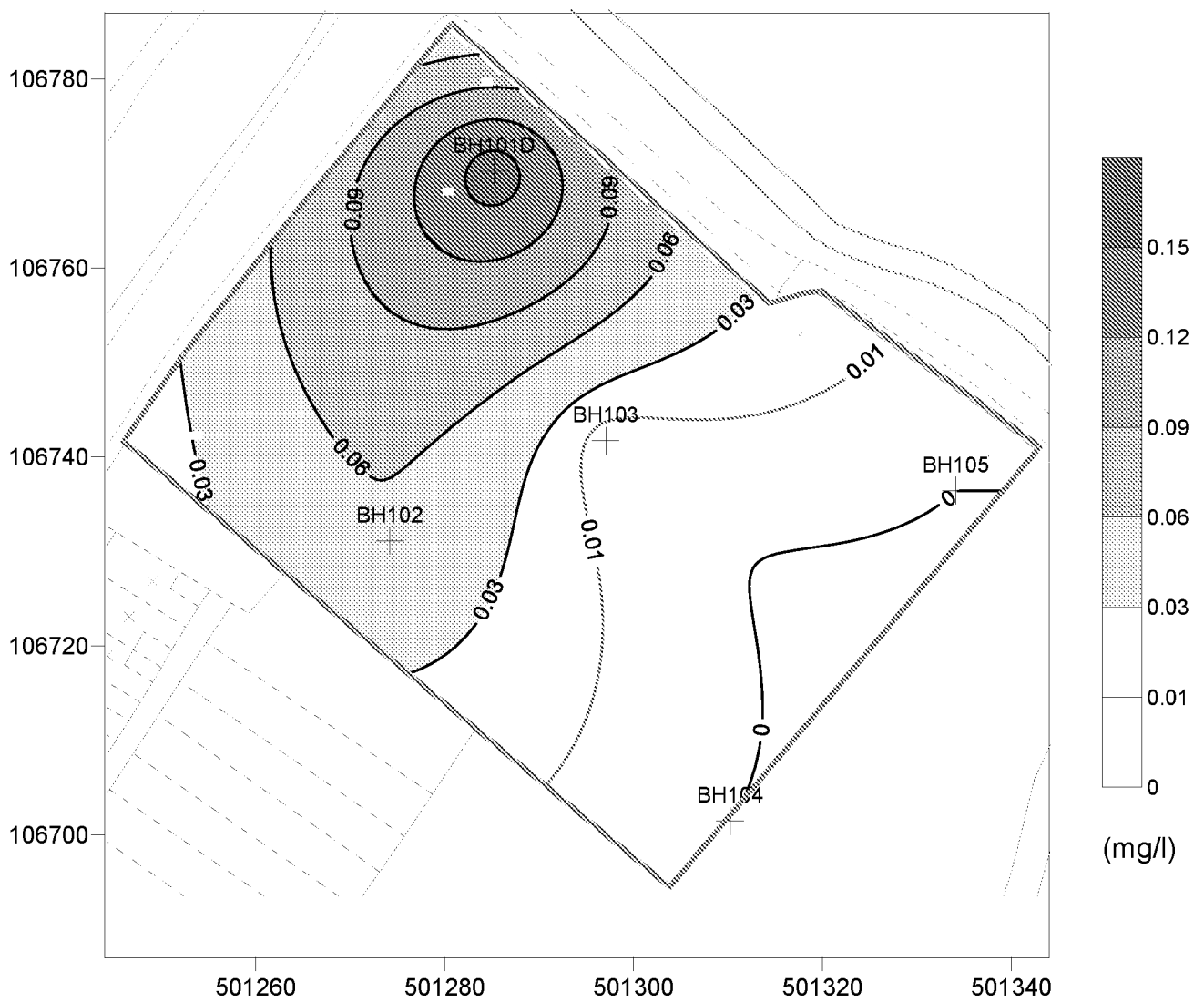


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 1 (mg/l)

## Ford Road, Arundel

### Inferred Contours of TPH7 - Aromatic C12 - C16 in Groundwater 7/7/11



Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 0.17 (mg/l)

## Ford Road, Arundel

### Inferred Contours of TPH7 - Aromatic C16 - C21 in Groundwater 7/7/11



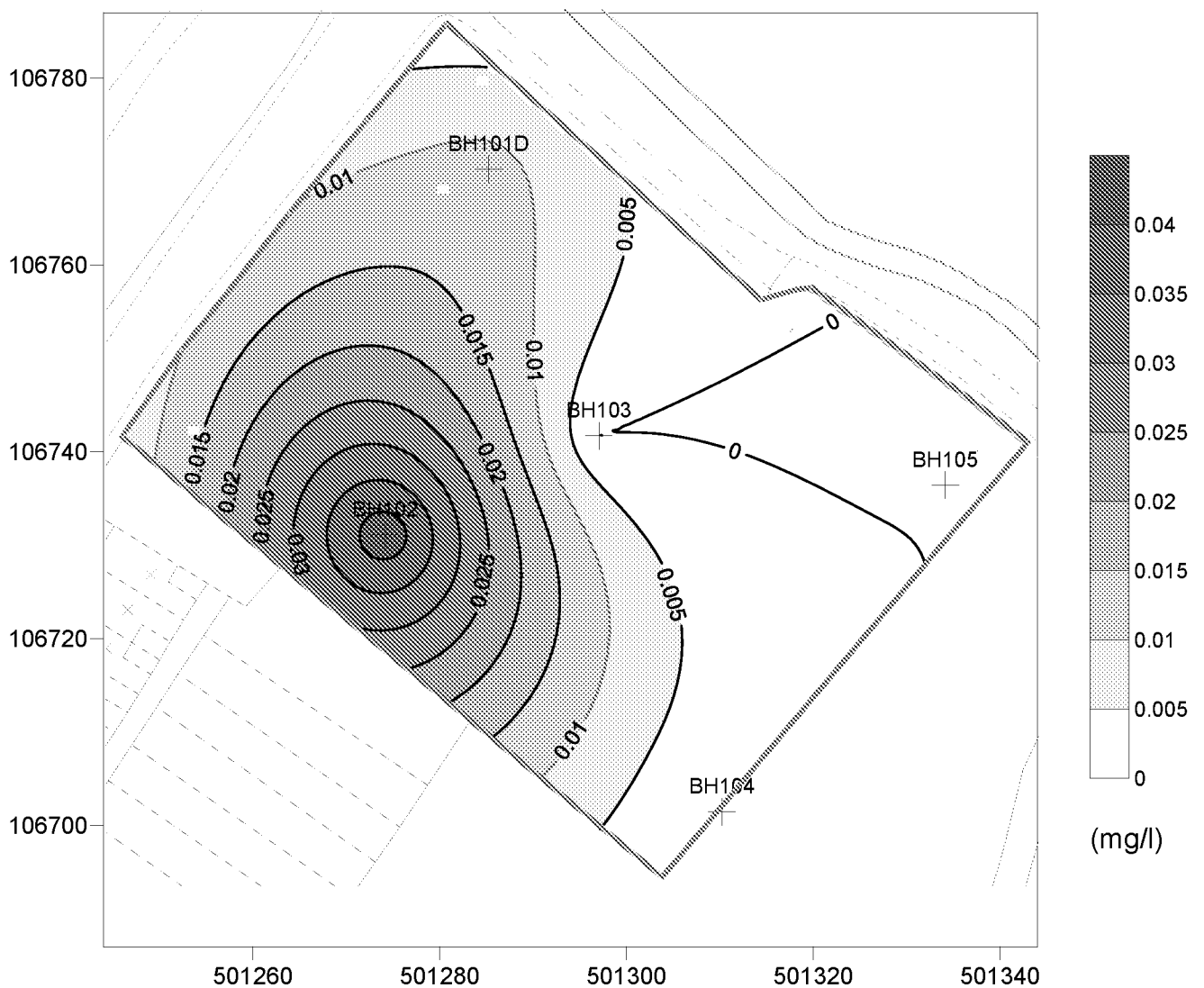
Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 0.095 (mg/l)

(mg/l)

## Ford Road, Arundel

Inferred Contours of TPH7 - Aromatic C21 - C35 in Groundwater 7/7/11



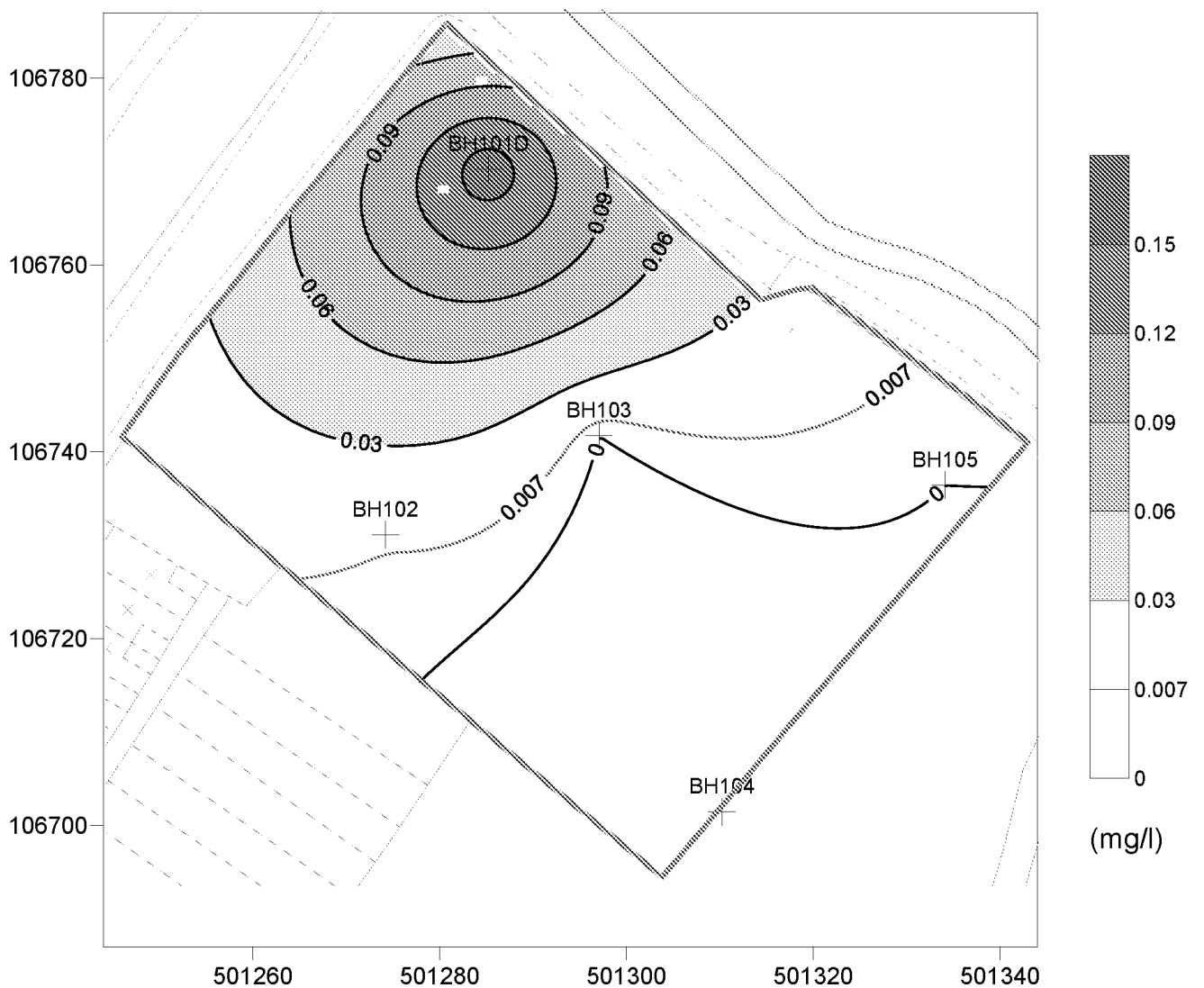
Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 0.044 (mg/l)

(mg/l)

## Ford Road, Arundel

### Inferred Contours of Phenol in Groundwater 7/7/11

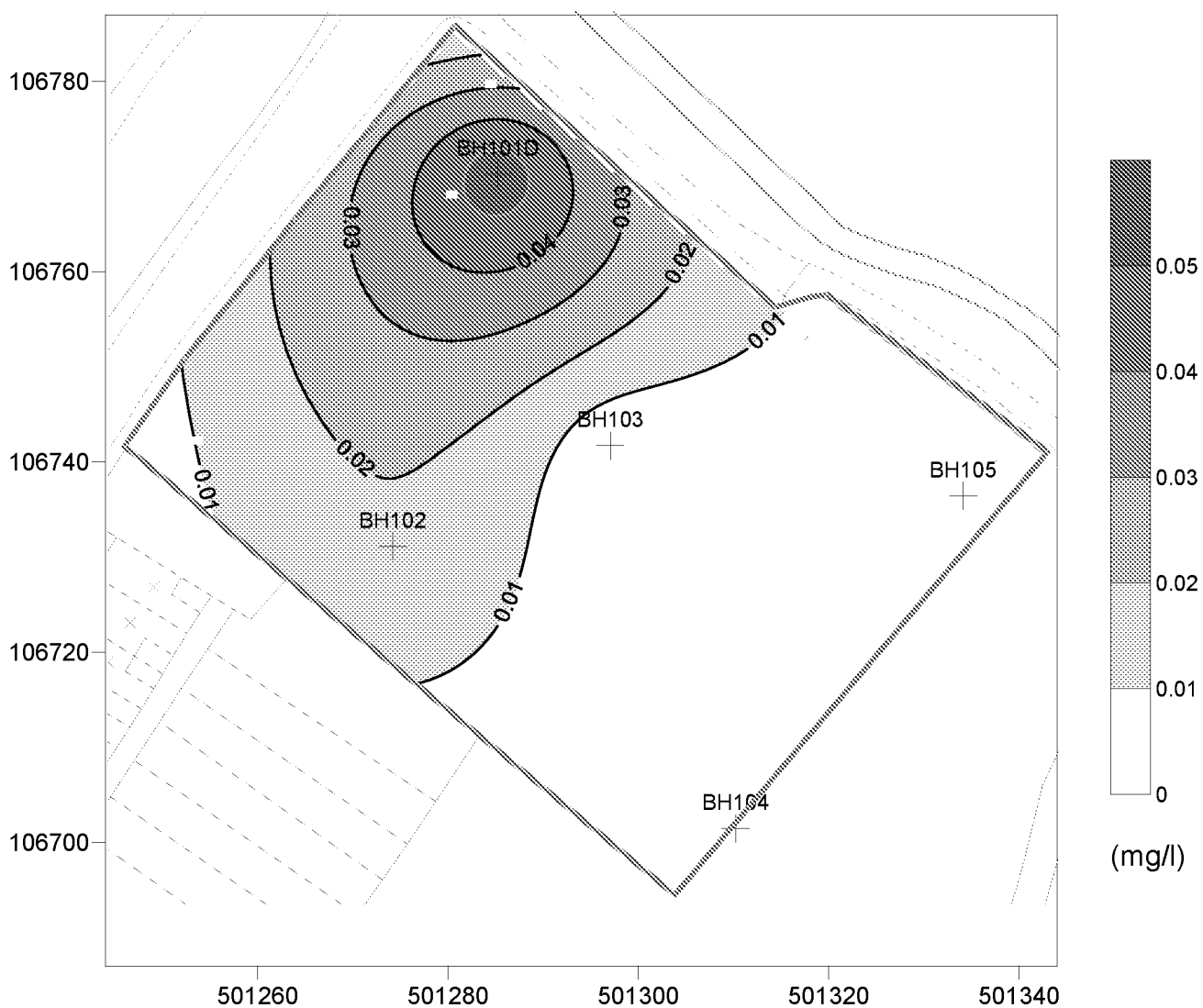


Compliance Criterion = 0.007 (mg/l)

Data Maximum Value = 0.17 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Arsenic (dissolved) in Groundwater 7/7/11

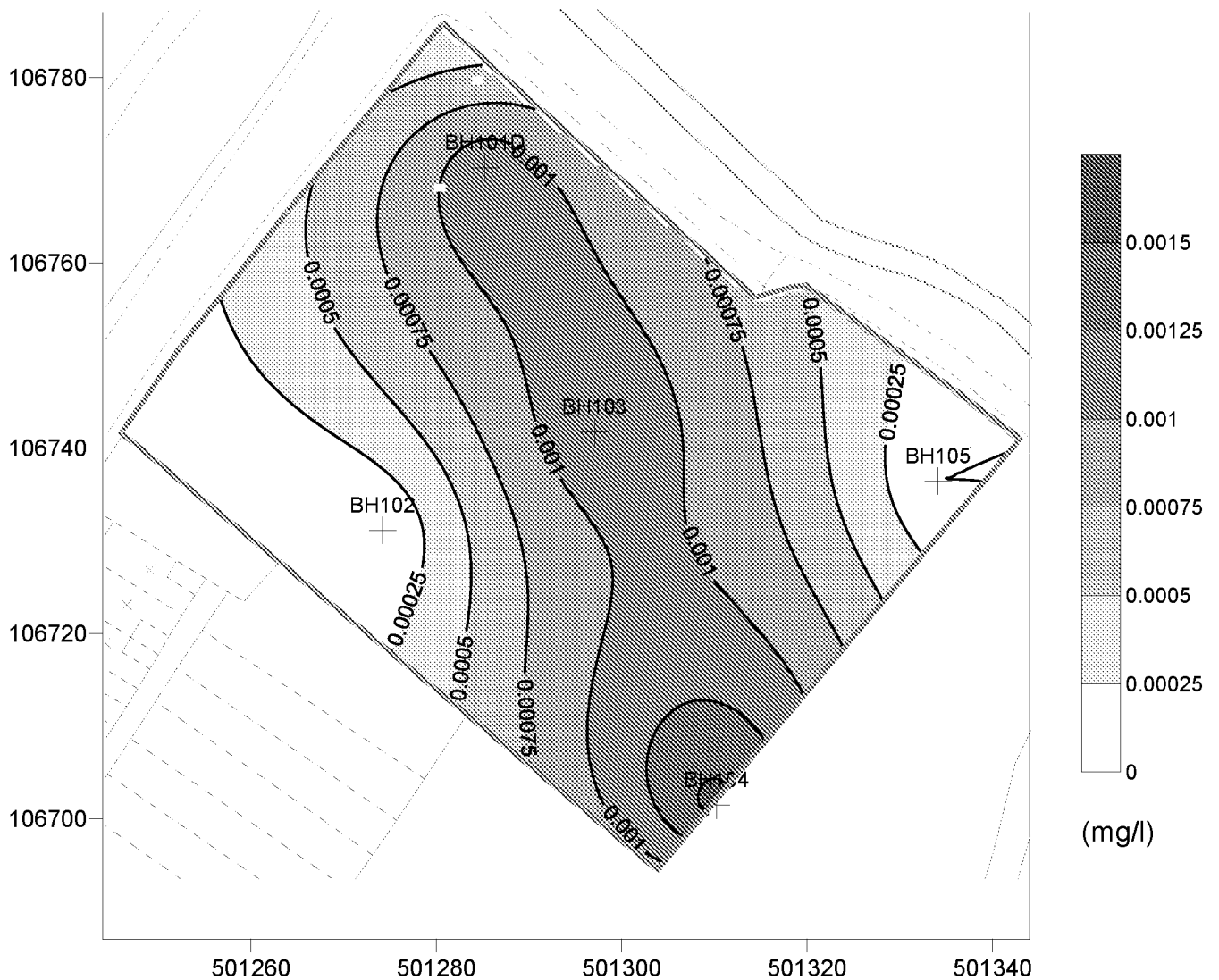


Compliance Criterion = 0.05 (mg/l)

Data Maximum Value = 0.058 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Copper (dissolved) in Groundwater 7/7/11

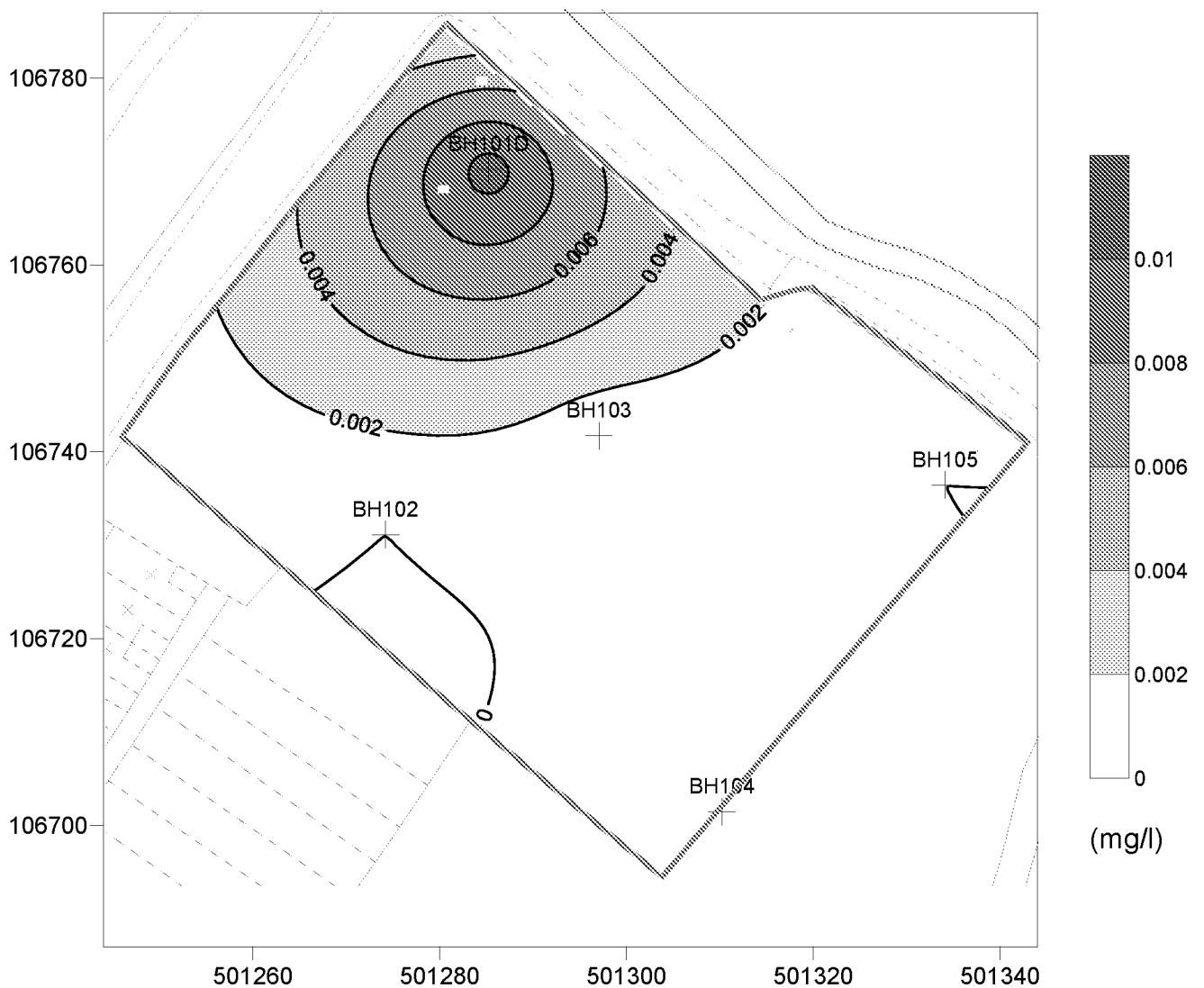


Compliance Criterion = 0.028 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.0016 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Chromium (dissolved) in Groundwater 7/7/11



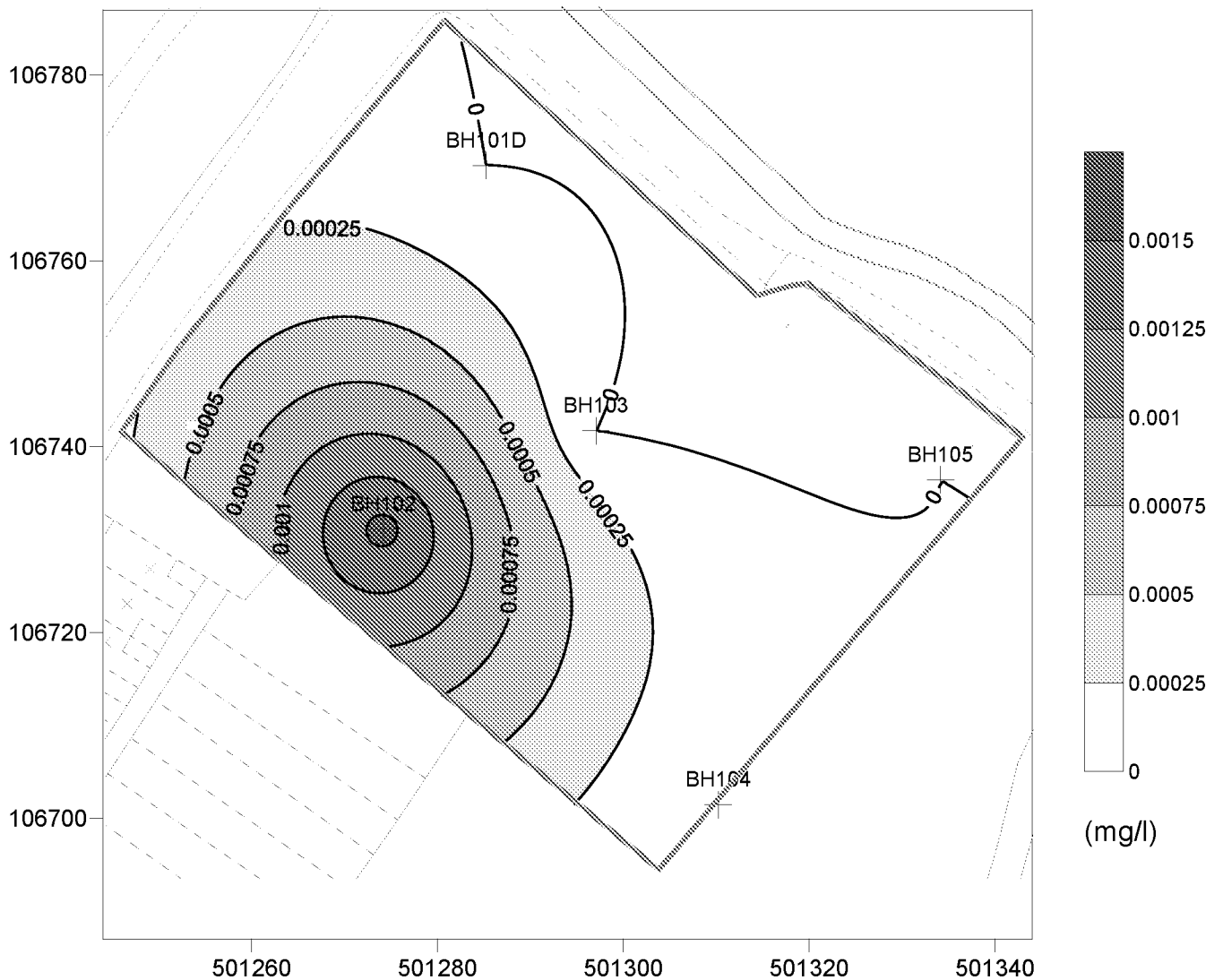
Compliance Criterion = 0.02 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.011 (mg/l)



## Ford Road, Arundel

### Inferred Contours of Lead (dissolved) in Groundwater 7/7/11

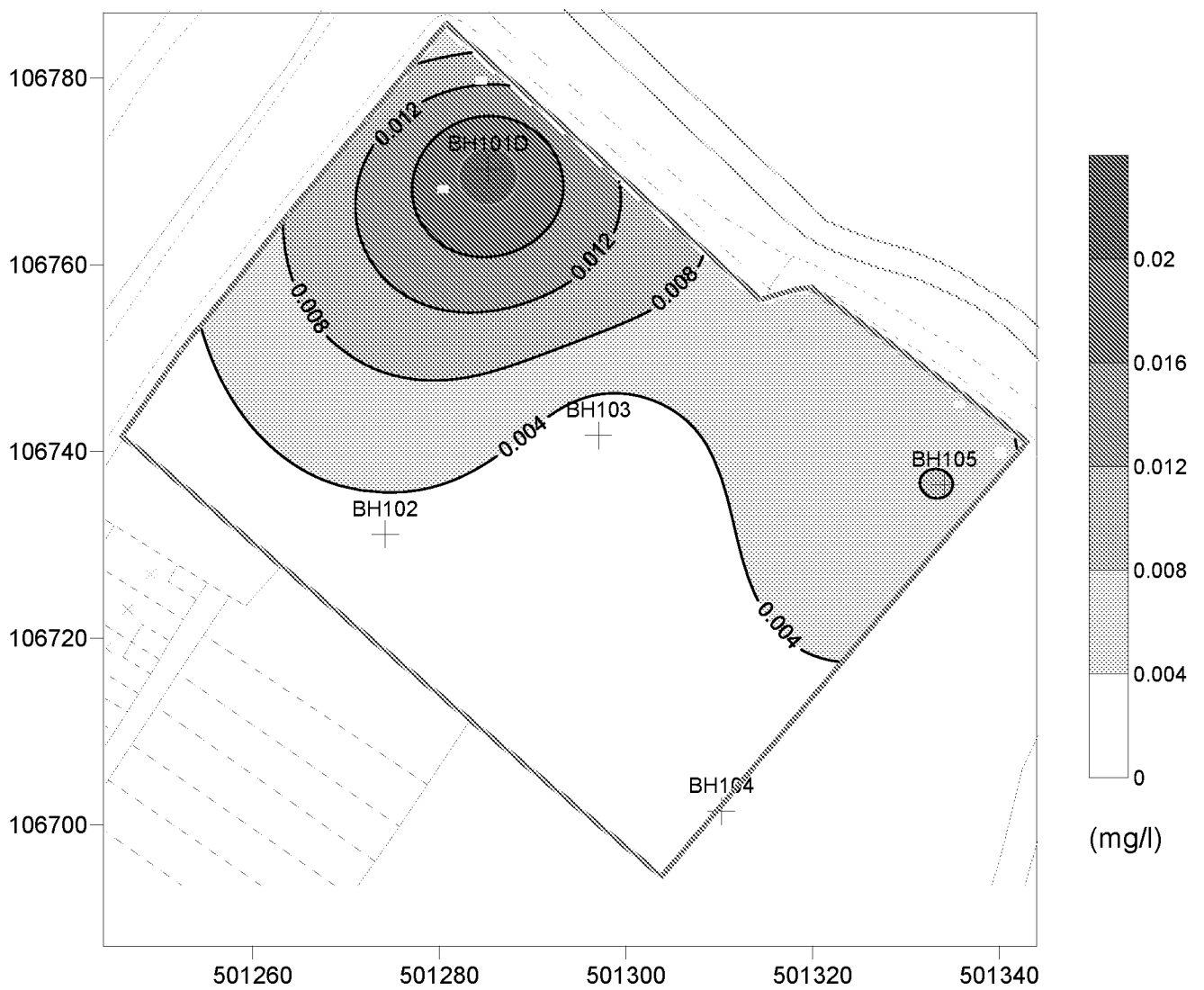


Compliance Criterion = 0.0072 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.0016 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Nickel (dissolved) in Groundwater 7/7/11

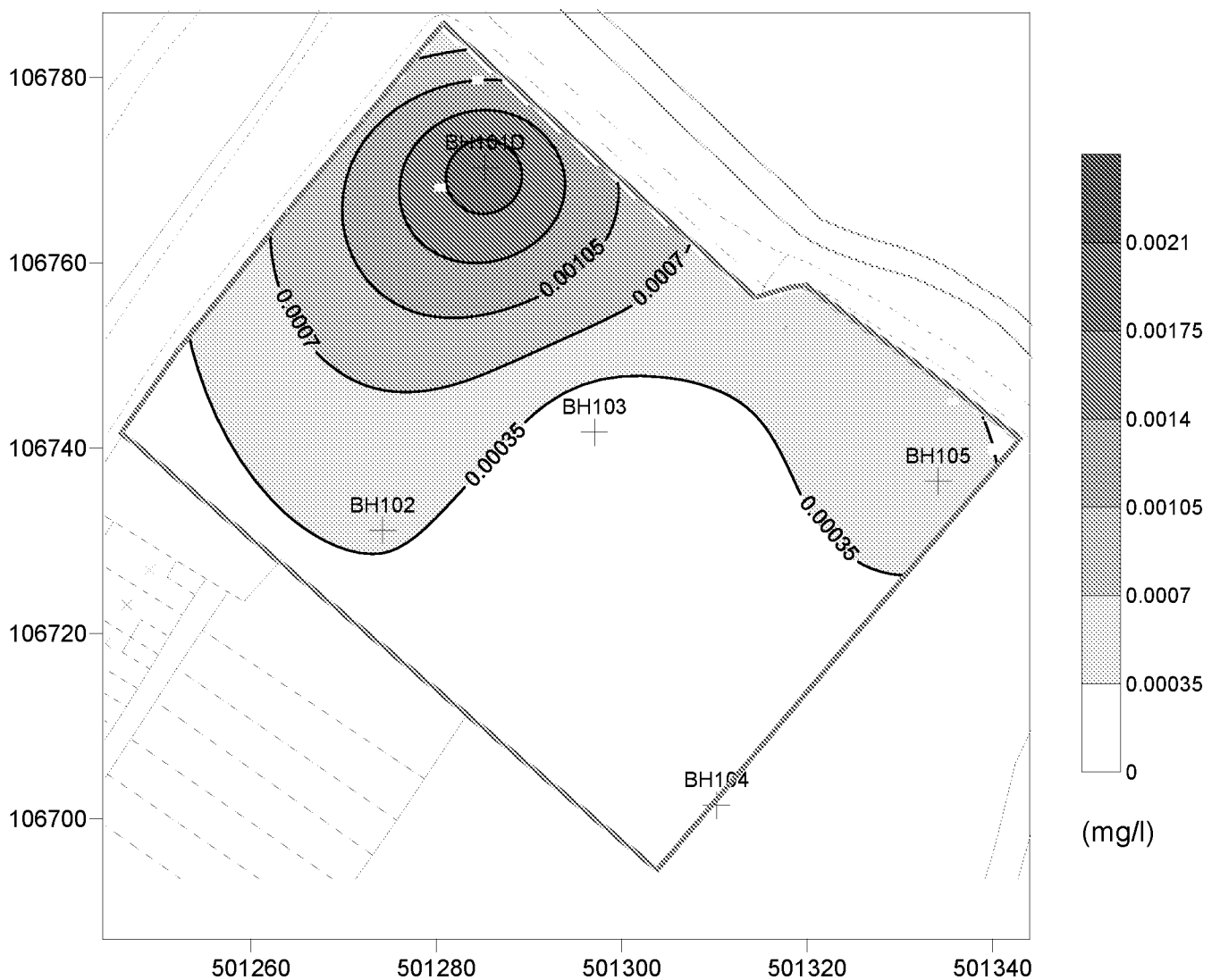


Compliance Criterion = 0.02 (mg/l)

Data Maximum Value = 0.023 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Zinc (dissolved) in Groundwater 7/7/11

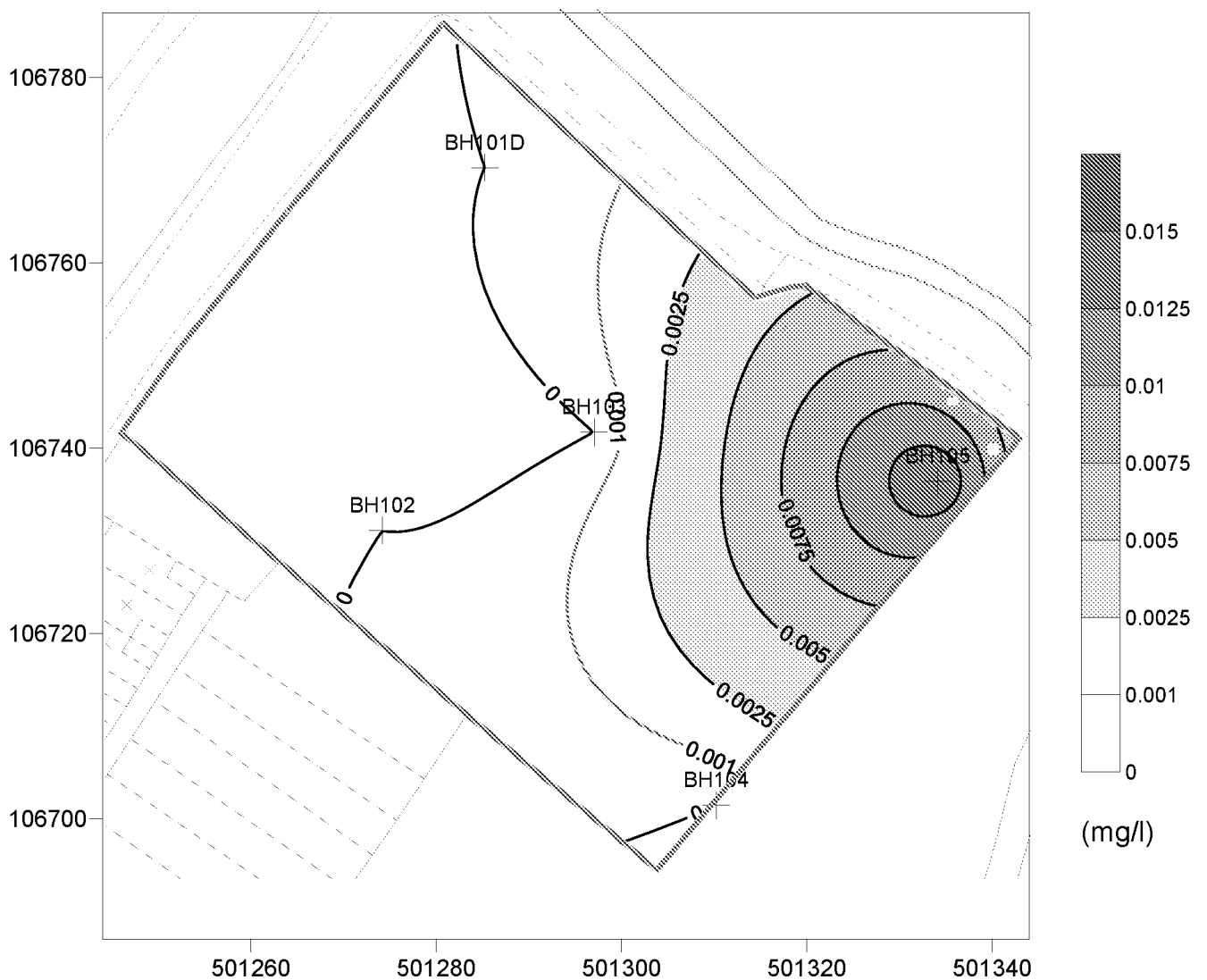


Compliance Criterion = 0.034 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.0021 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Free Cyanide in Groundwater 7/7/11

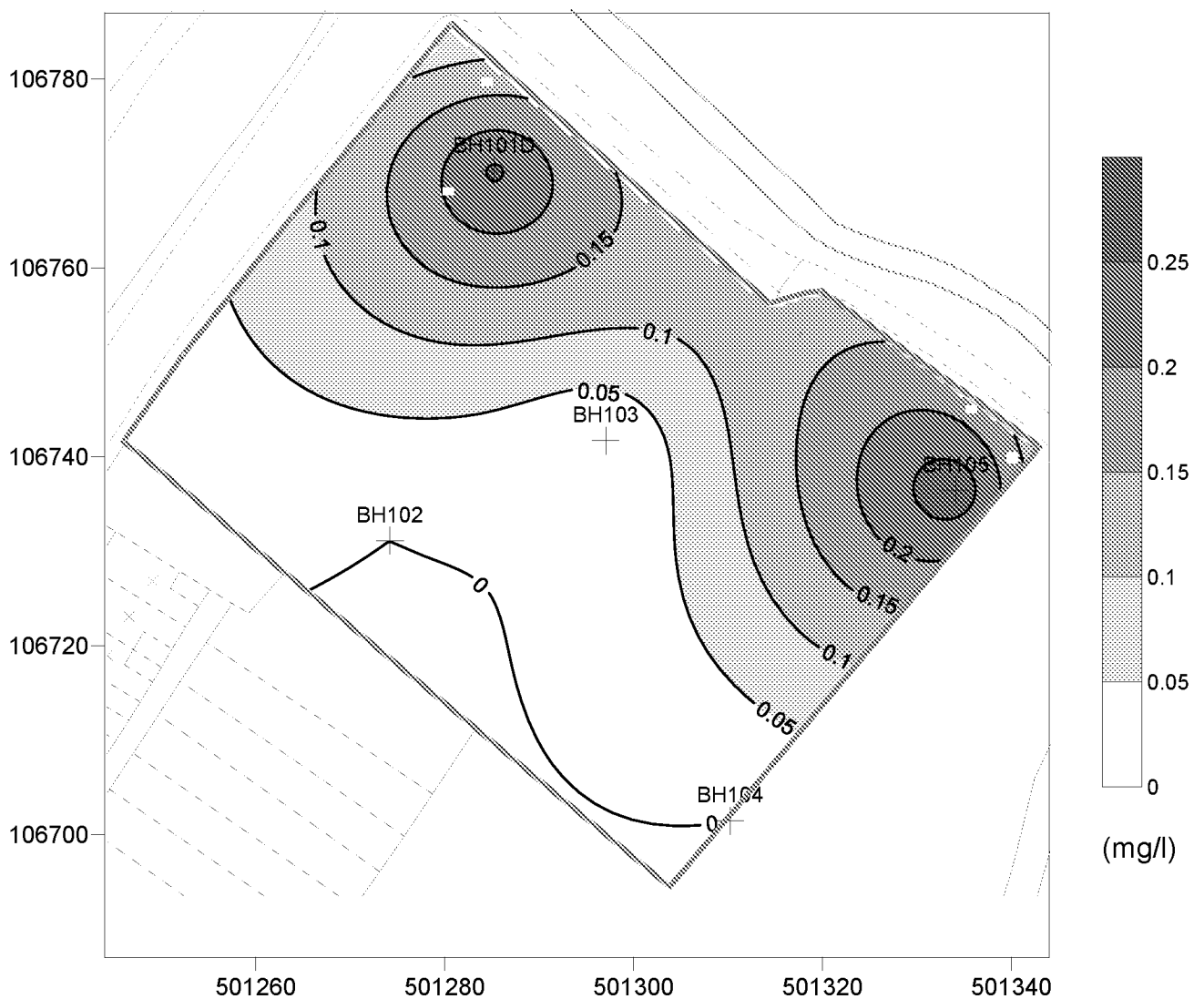


Compliance Criterion = 0.001 (mg/l)

Data Maximum Value = 0.015 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Complex Cyanide in Groundwater 7/7/11

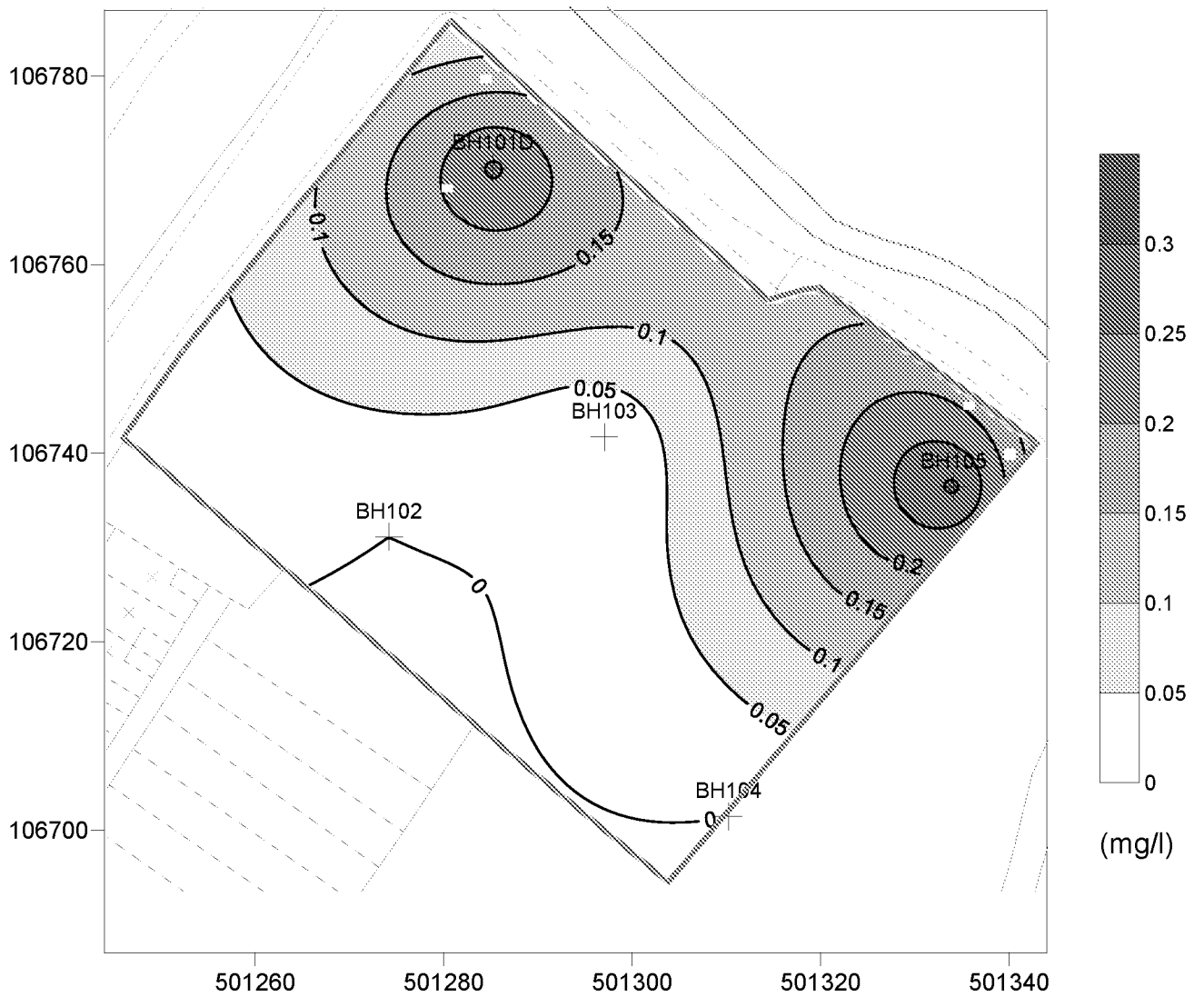


Compliance Criterion = 14 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.29 (mg/l)

## Ford Road, Arundel

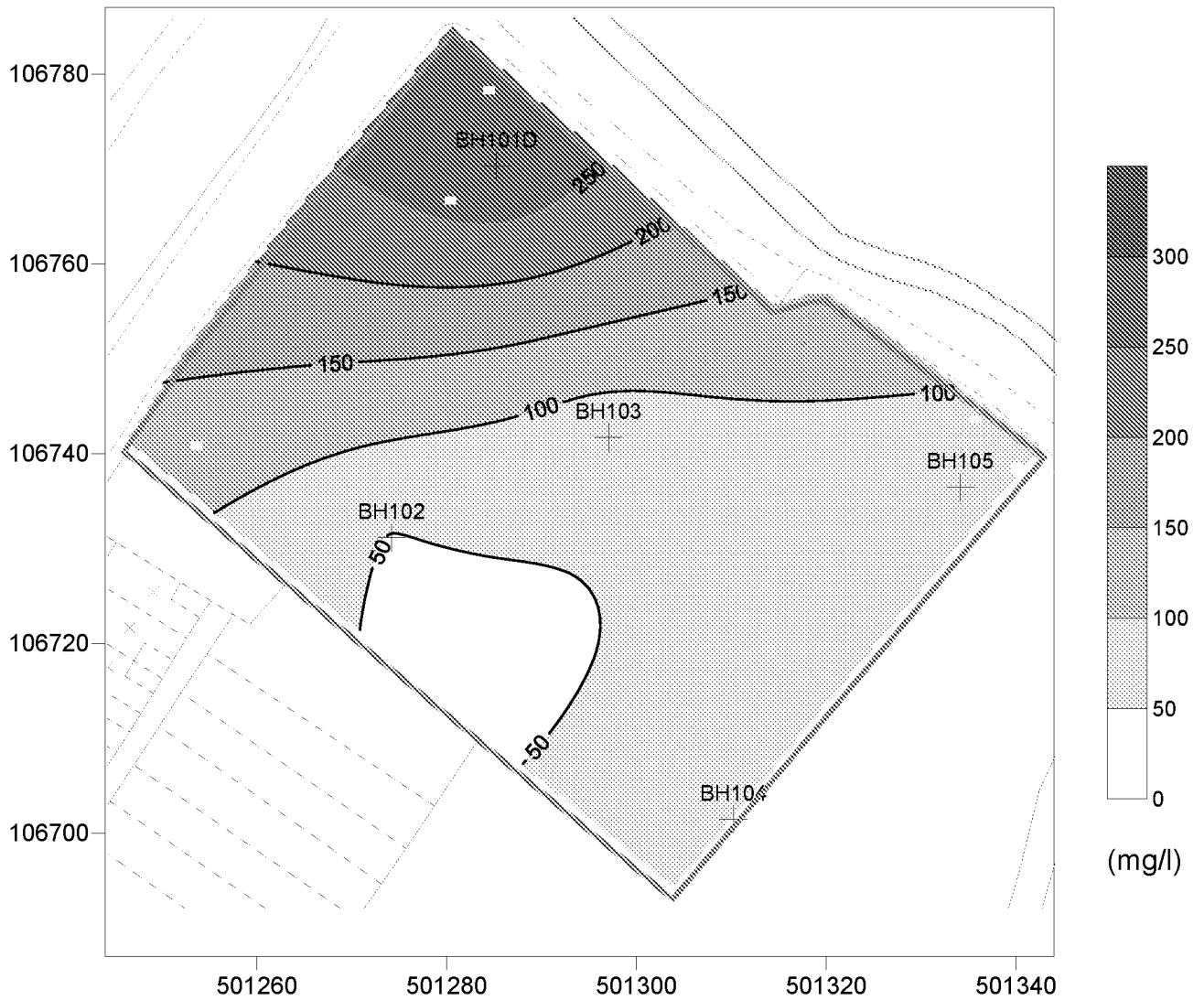
### Inferred Contours of Total Cyanide in Groundwater 7/7/11



Data Maximum Value = 0.31 (mg/l) Data Minimum Value = 0 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Chloride in Groundwater 7/7/11

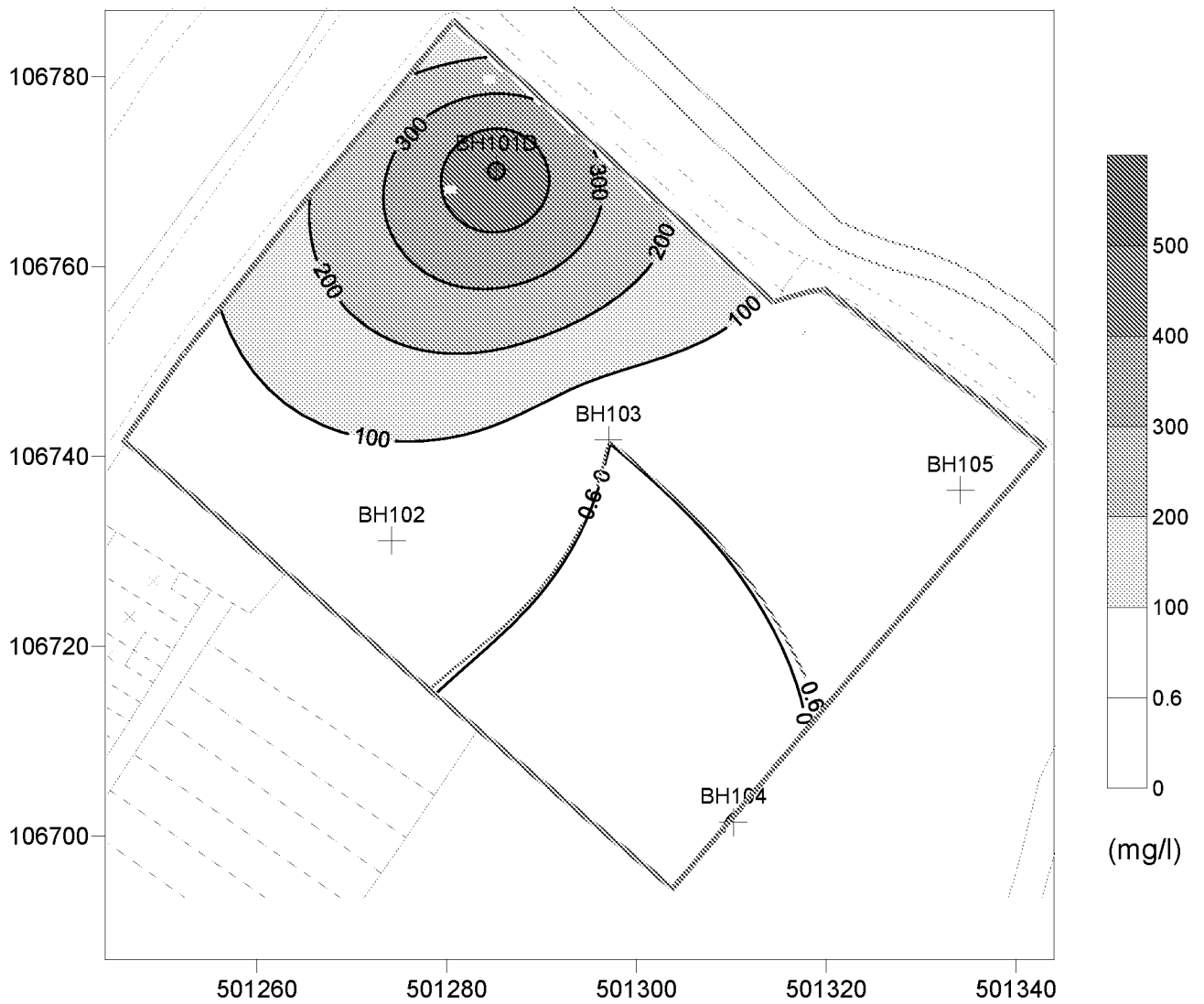


Compliance Criterion = 250 (mg/l)

Data Maximum Value = 300 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Ammonium as NH<sub>4</sub> in Groundwater 7/7/11



Compliance Criterion = 0.6 (mg/l)

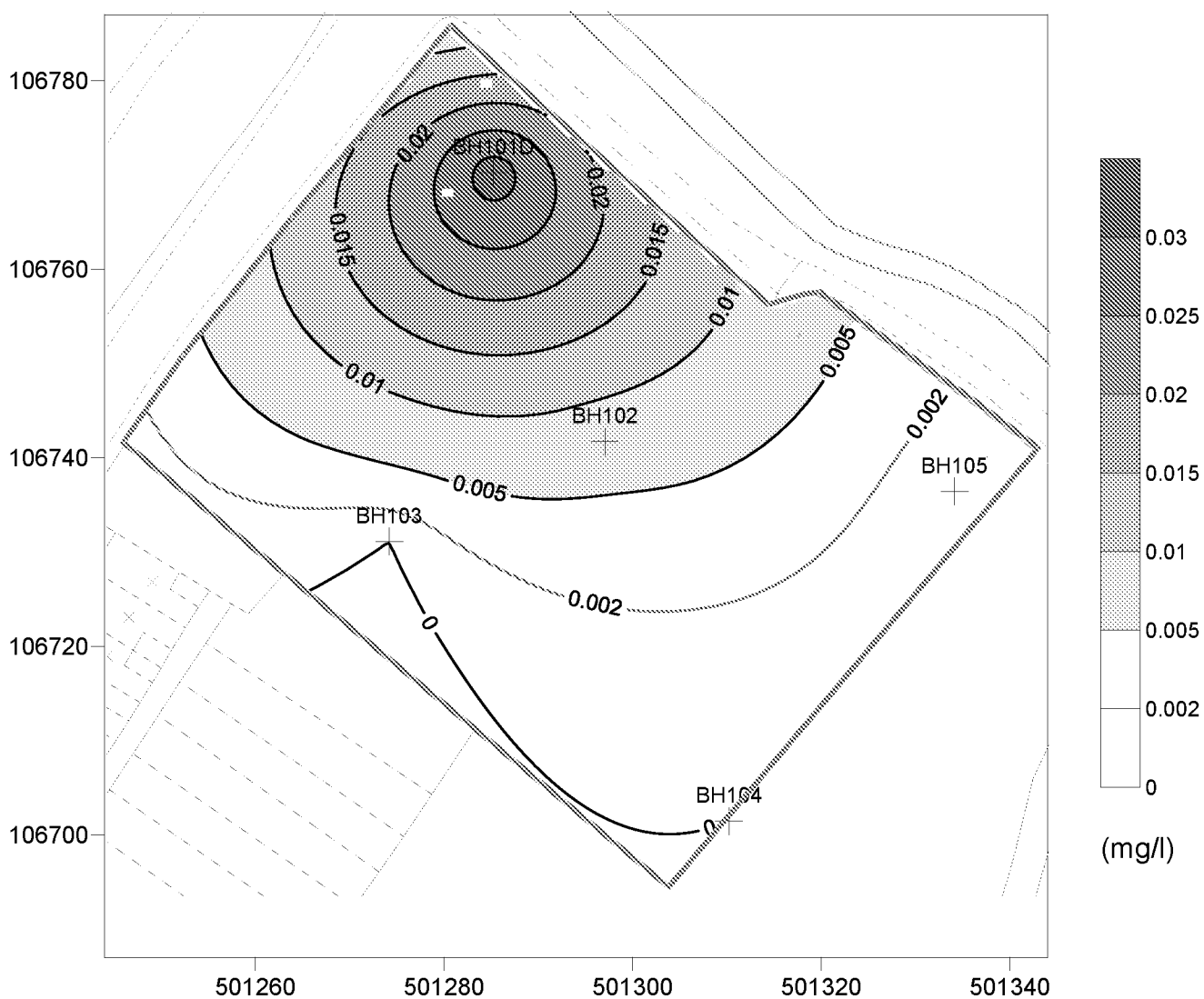
Data Maximum Value = 520 (mg/l)



**Addendum C3**  
**Contours of Measured Concentrations of Substances**  
**In Groundwater 2011 Round 2 Data**

## Ford Road, Arundel

Inferred Contours of Acenaphthene in Groundwater 15/07/2011

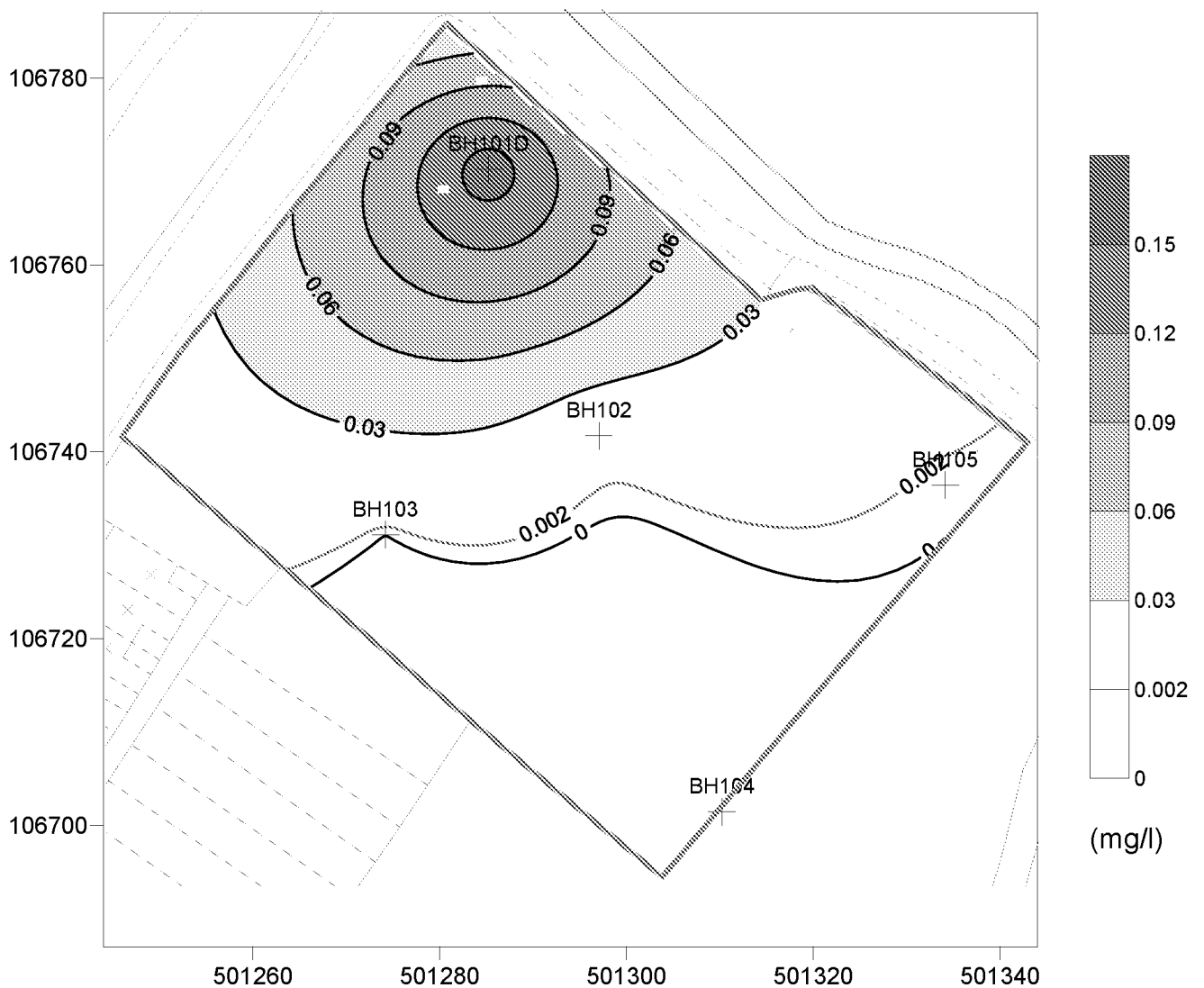


Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.033 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Acenaphthylene in Groundwater 15/07/2011

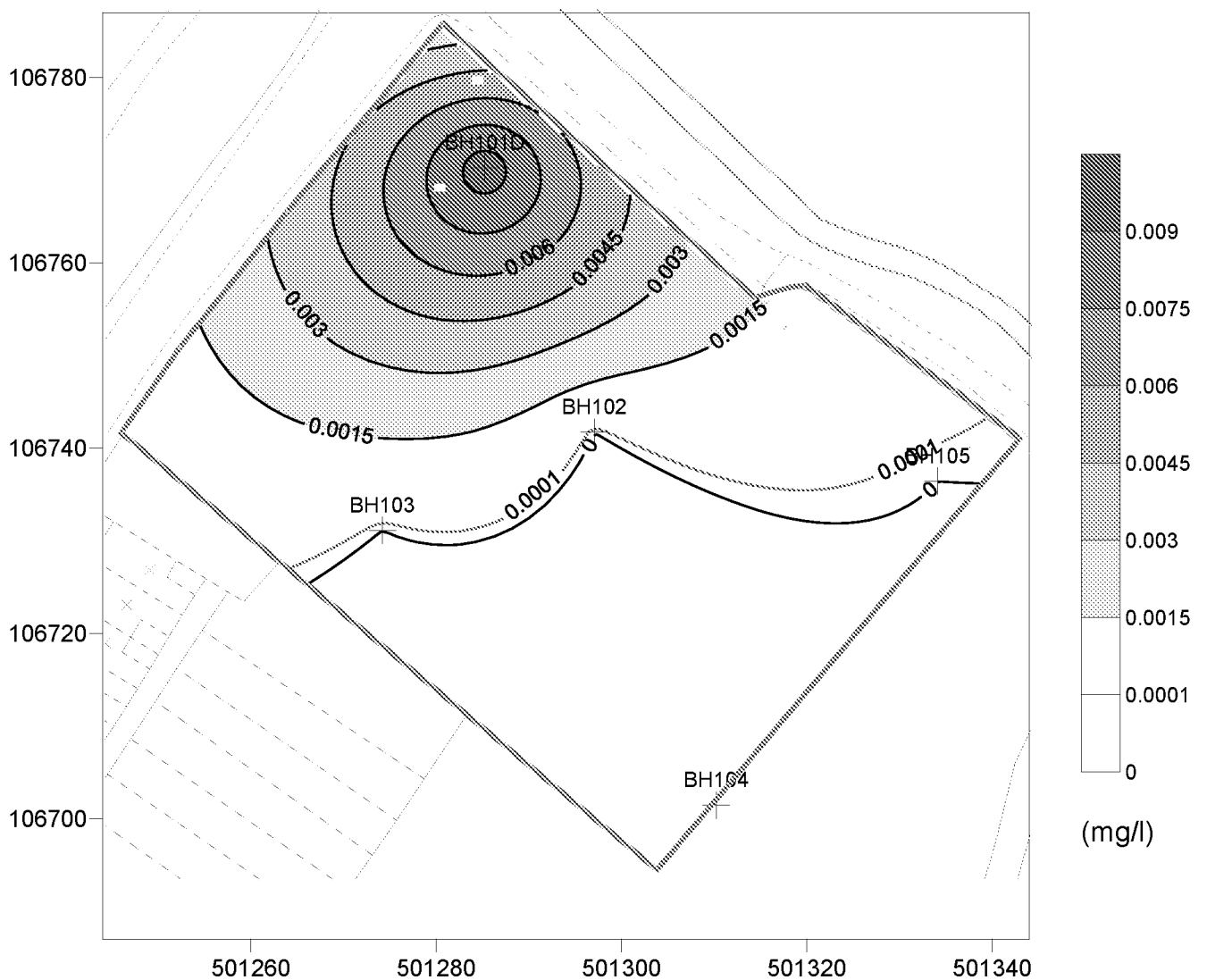


Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.17 (mg/l)

## Ford Road, Arundel

Inferred Contours of Anthracene in Groundwater 15/07/2011

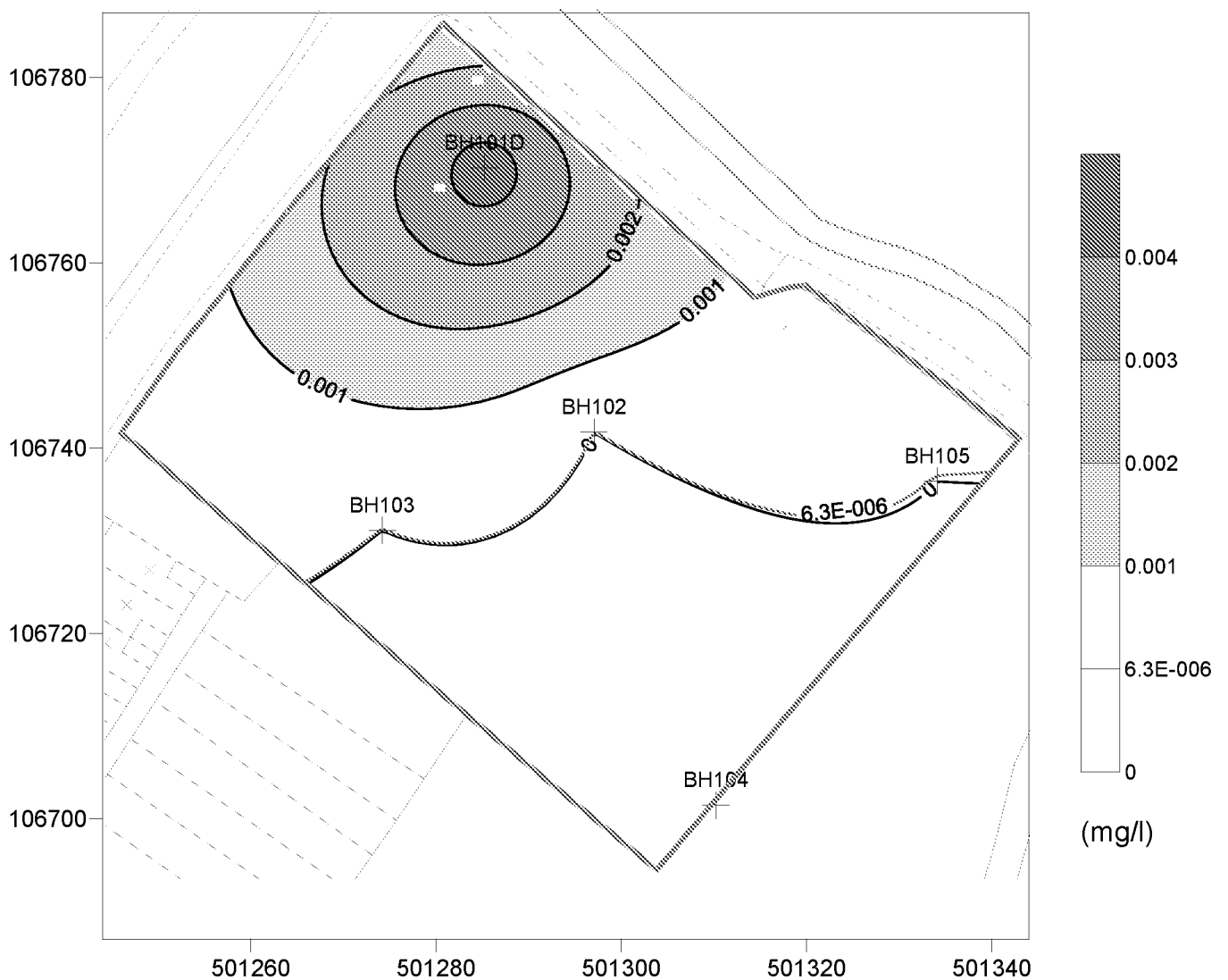


Compliance Criterion = 0.0001 (mg/l)

Data Maximum Value = 0.01 (mg/l)

## Ford Road, Arundel

Inferred Contours of Fluoranthene in Groundwater 15/07/2011



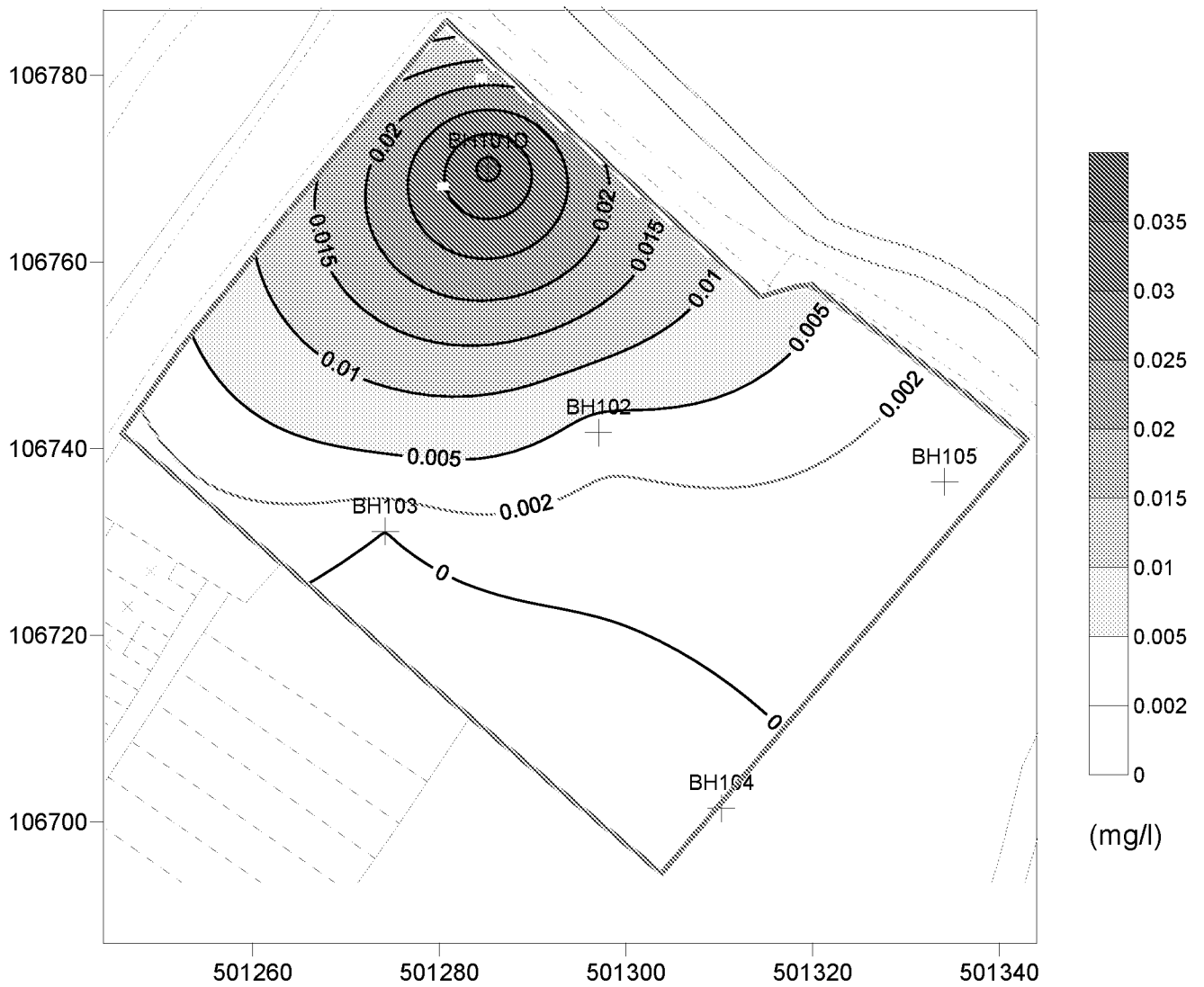
Compliance Criterion = 0.0000063 (mg/l)

Data Maximum Value = 0.0047 (mg/l)

(mg/l)

## Ford Road, Arundel

Inferred Contours of Fluorene in Groundwater 15/07/2011

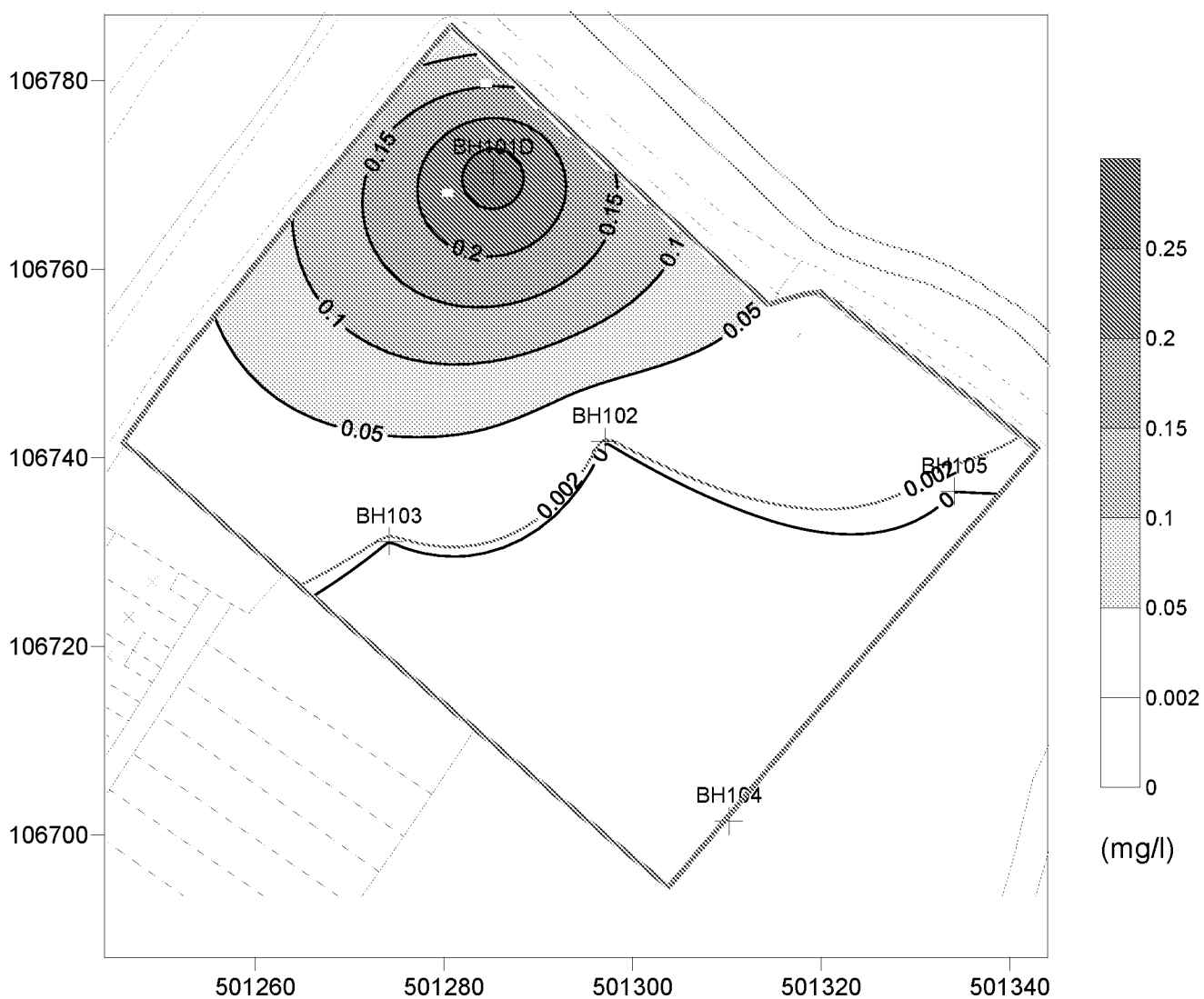


Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.037 (mg/l)

## Ford Road, Arundel

Inferred Contours of Naphthalene in Groundwater 15/07/2011

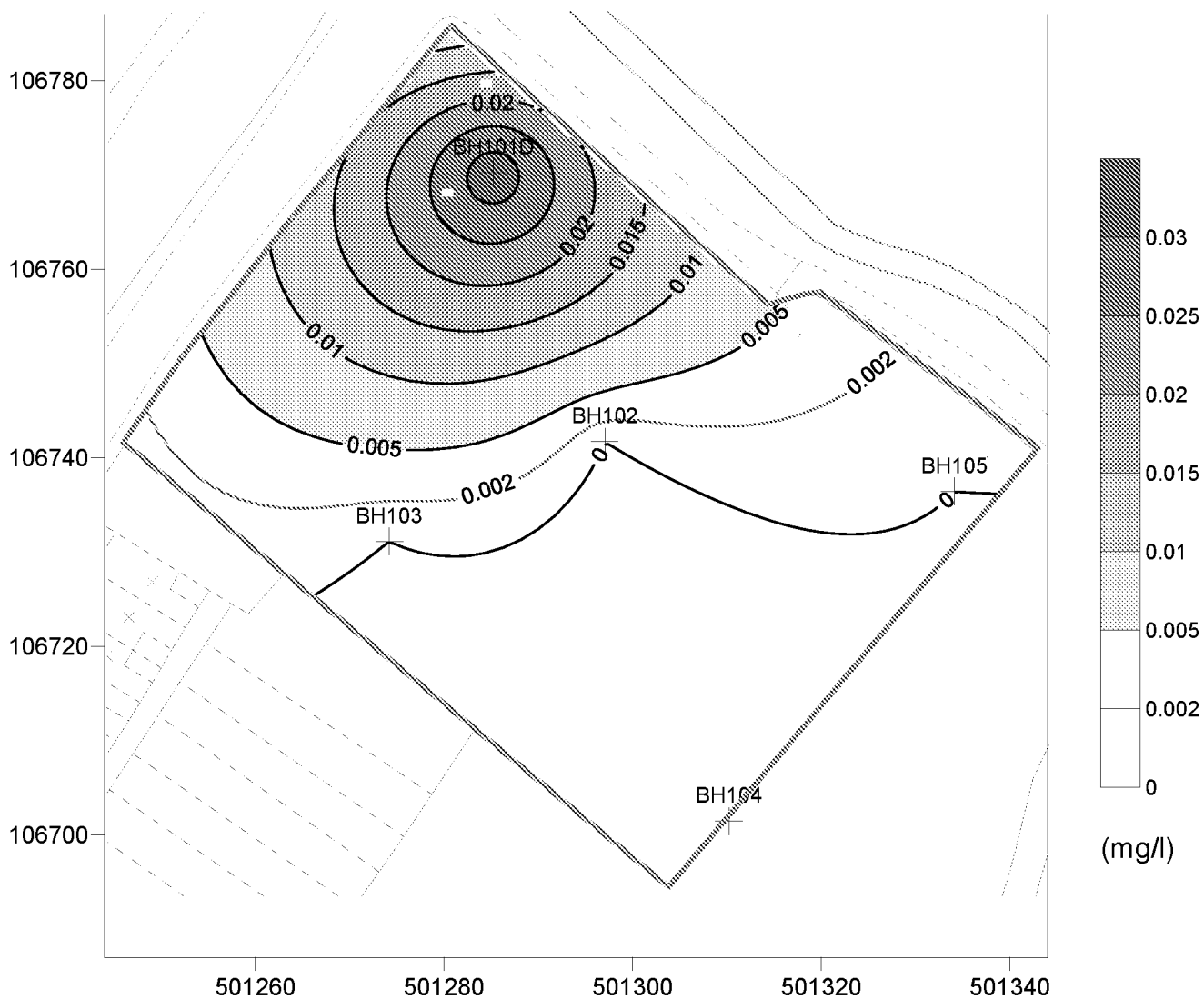


Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.29 (mg/l)

## Ford Road, Arundel

Inferred Contours of Phenanthrene in Groundwater 15/07/2011



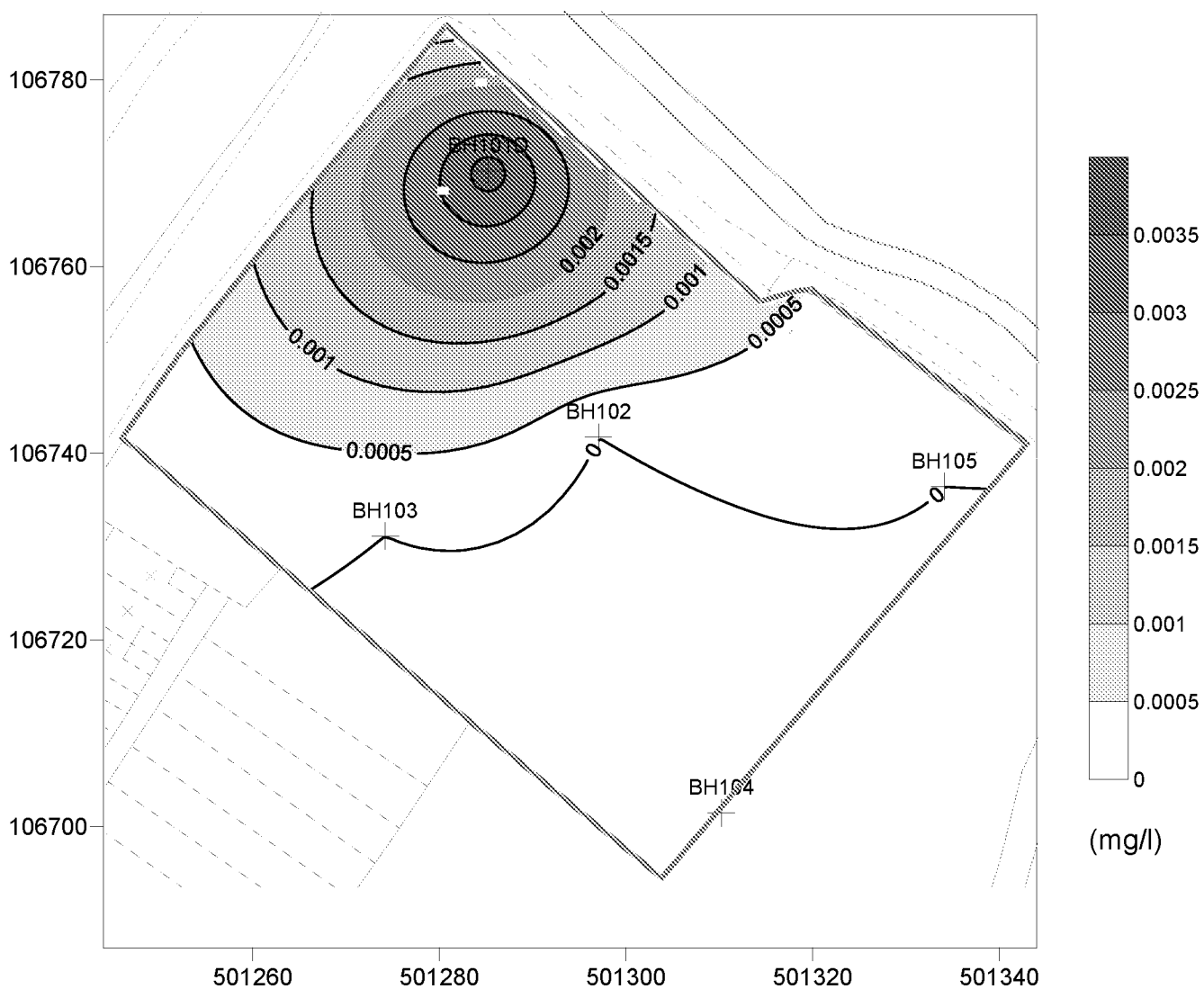
Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.034 (mg/l)



## Ford Road, Arundel

### Inferred Contours of Pyrene in Groundwater 15/07/2011

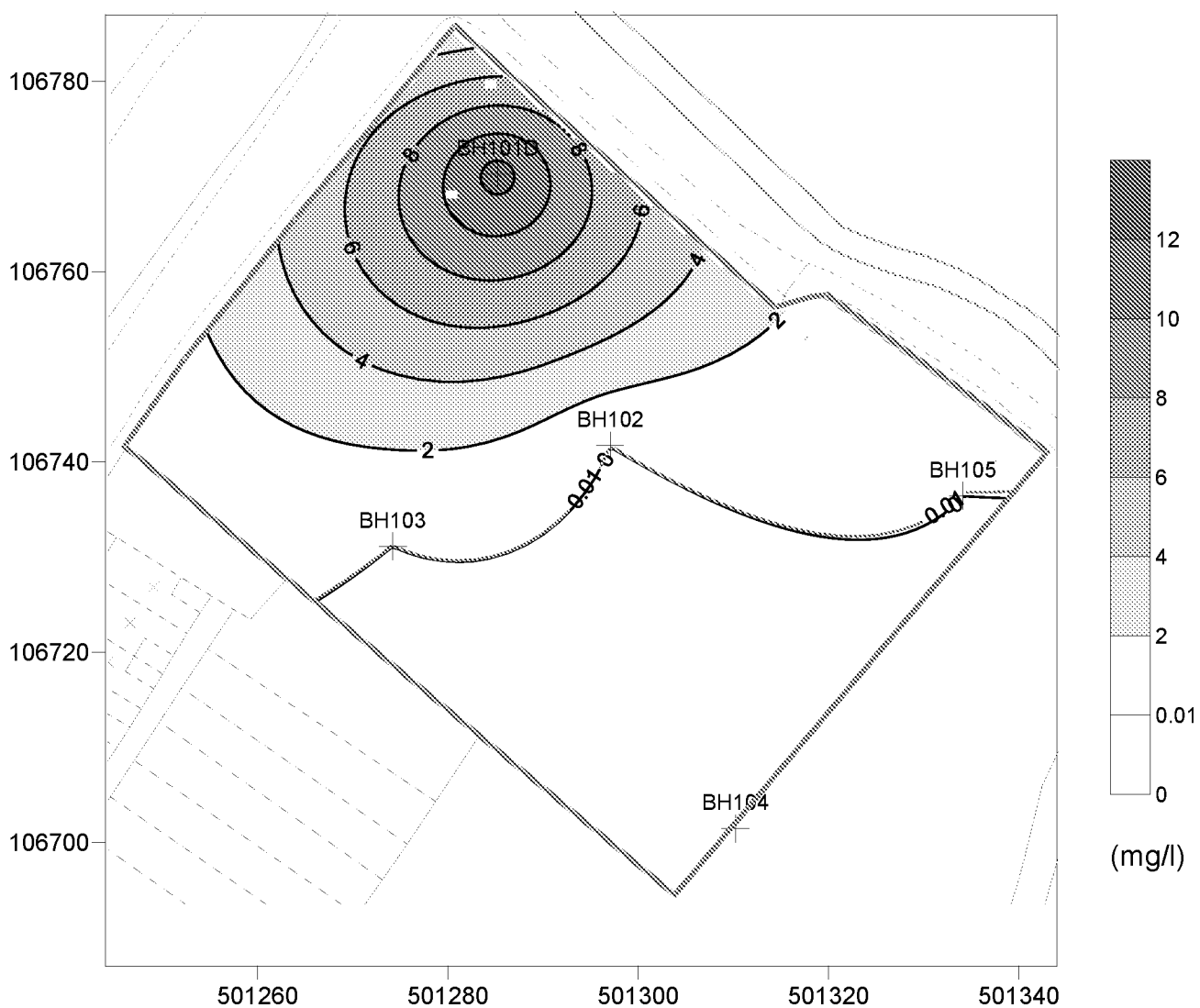


Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.0038 (mg/l)

## Ford Road, Arundel

Inferred Contours of Benzene in Groundwater 15/07/2011

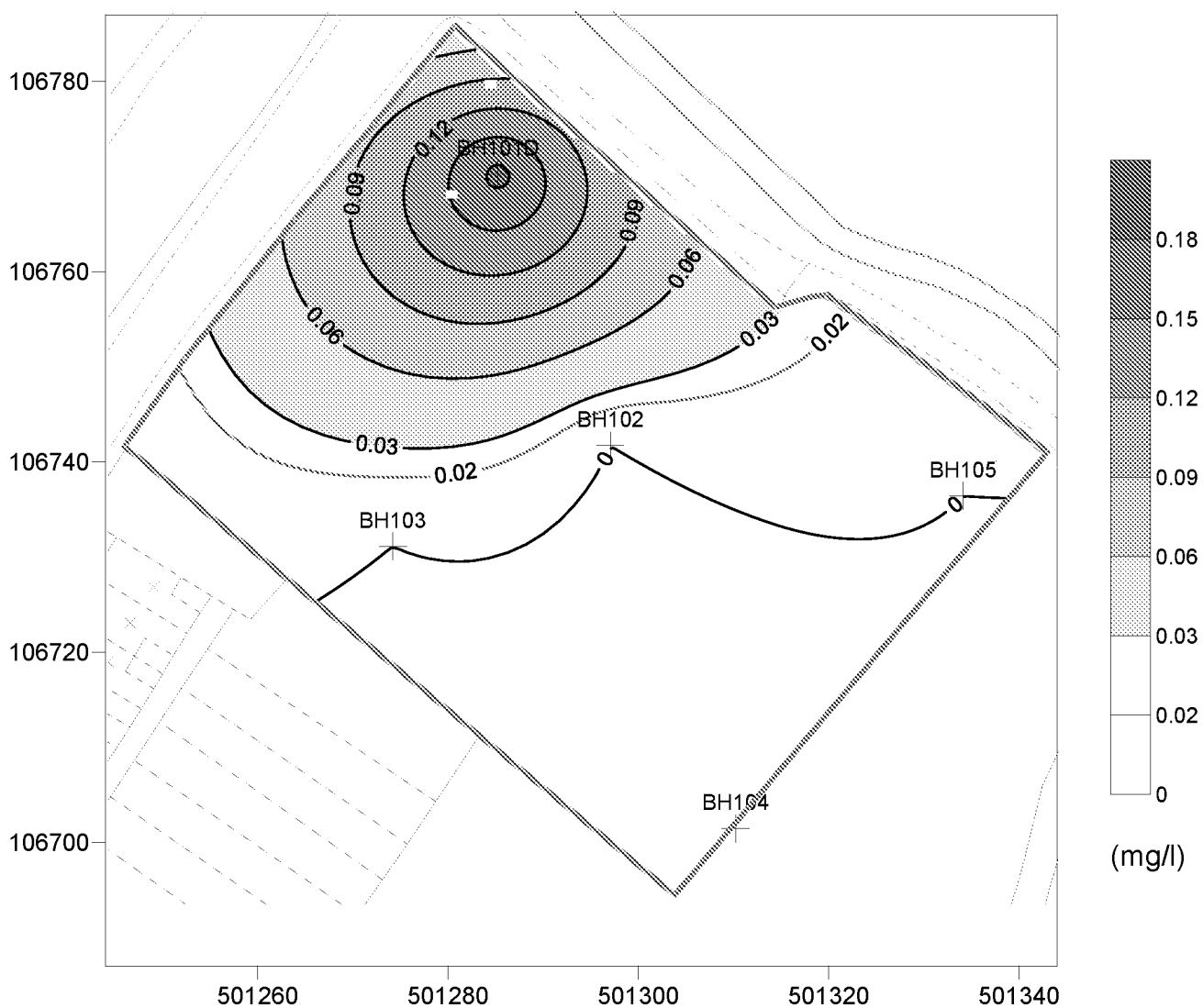


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 13 (mg/l)

## Ford Road, Arundel

Inferred Contours of Ethylbenzene in Groundwater 15/07/2011

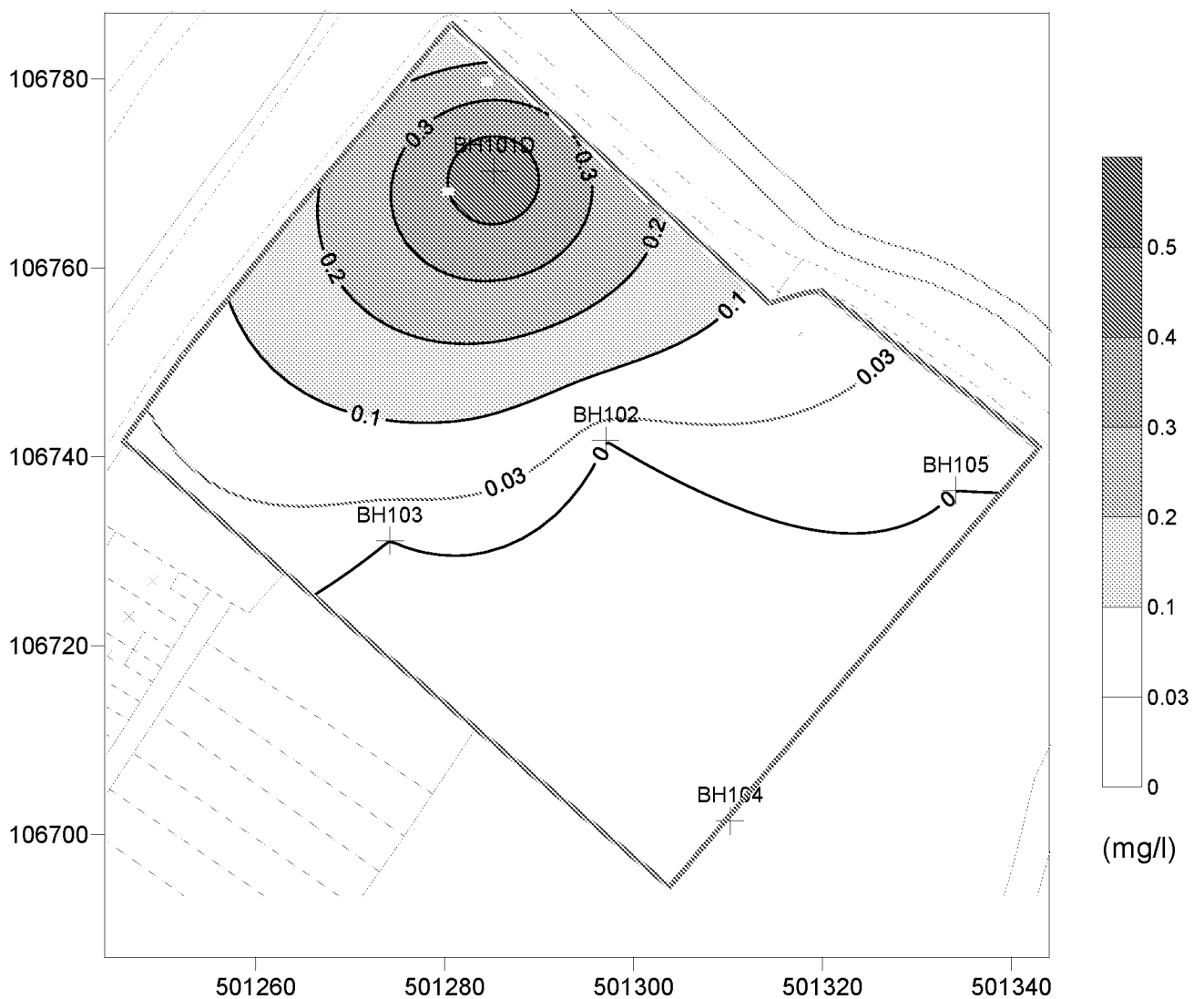


Compliance Criterion = 0.02 (mg/l)

Data Maximum Value = 0.19 (mg/l)

## Ford Road, Arundel

Inferred Contours of o-xylene in Groundwater 15/07/2011



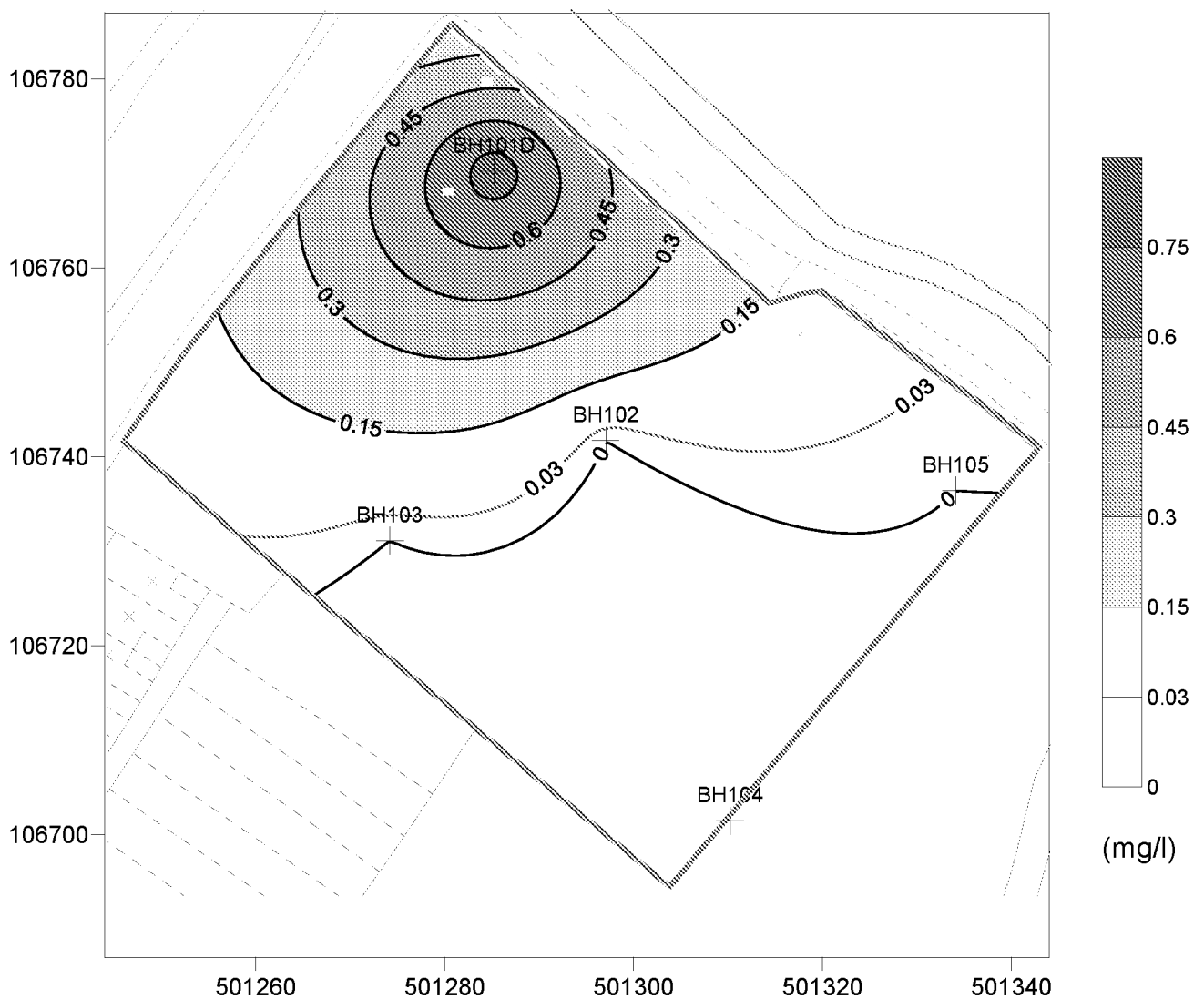
Compliance Criterion = 0.03 (mg/l)

Data Maximum Value = 0.5 (mg/l)

(mg/l)

## Ford Road, Arundel

Inferred Contours of p & m-xylene in Groundwater 15/07/2011

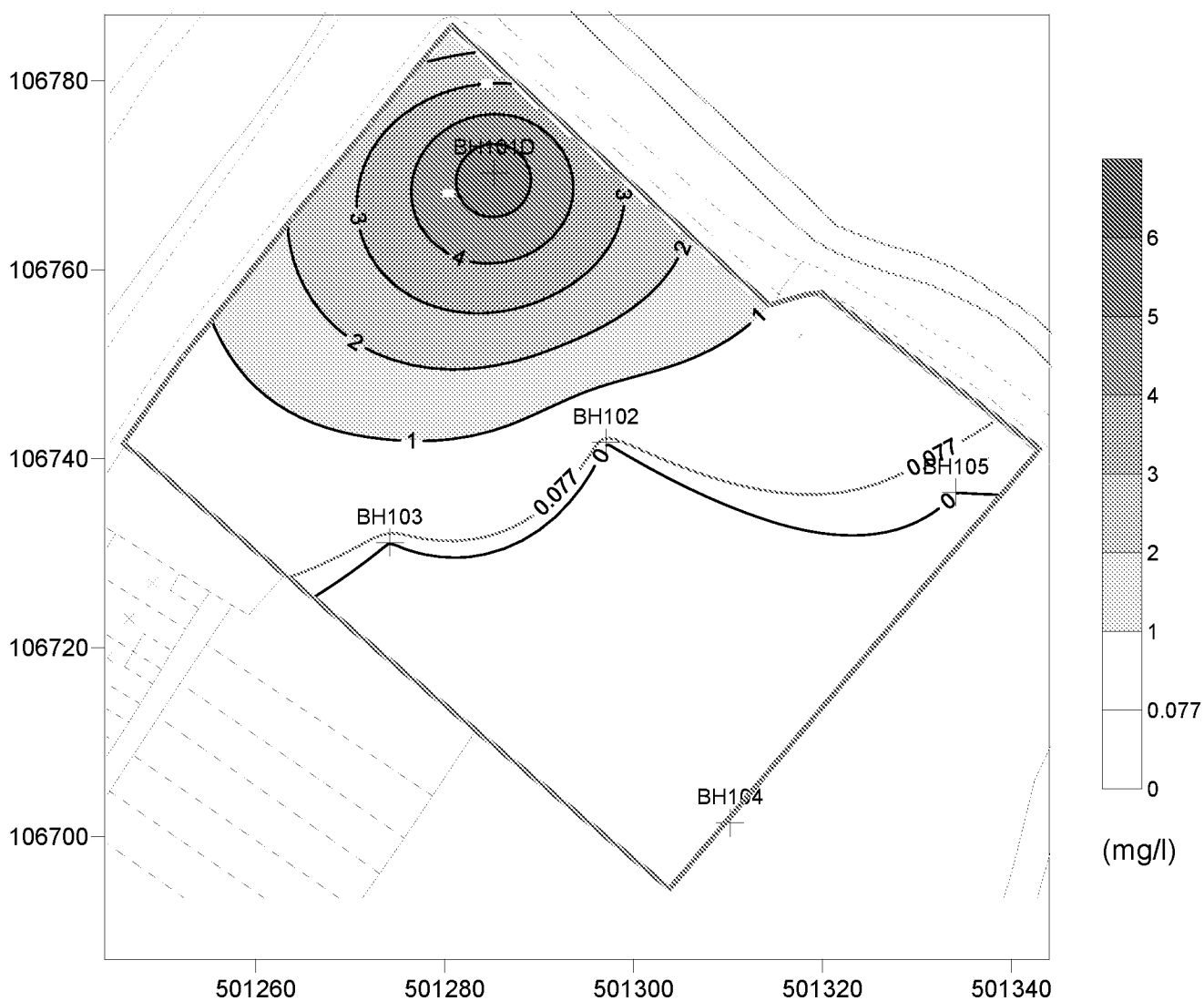


Compliance Criterion = 0.03 (mg/l)

Data Maximum Value = 0.84 (mg/l)

## Ford Road, Arundel

Inferred Contours of Toluene in Groundwater 15/07/2011

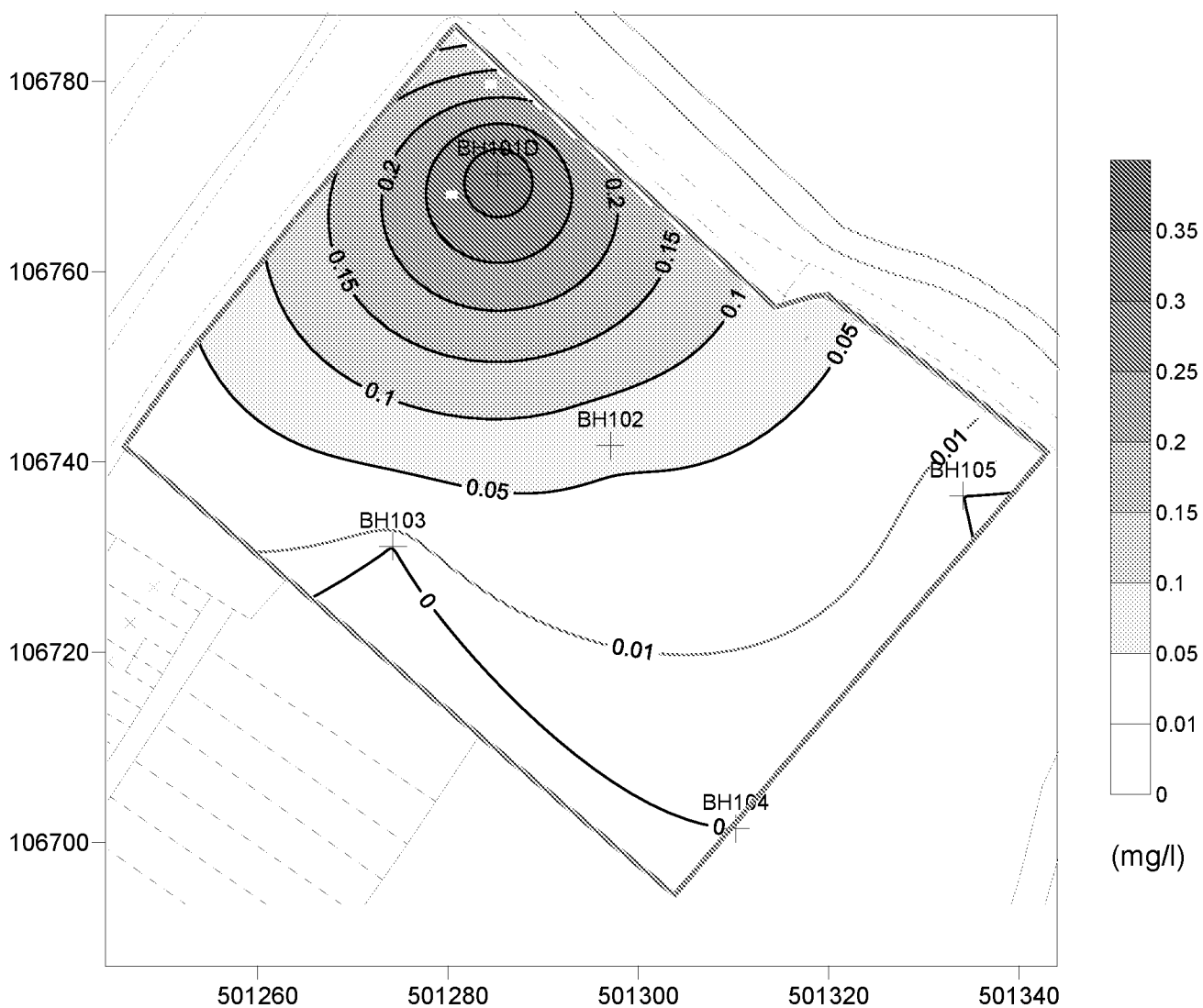


Compliance Criterion = 0.077 (mg/l)

Data Maximum Value = 6 (mg/l)

## Ford Road, Arundel

Inferred Contours of TPH7 - Aromatic C10 - C12 in Groundwater 15/07/2011

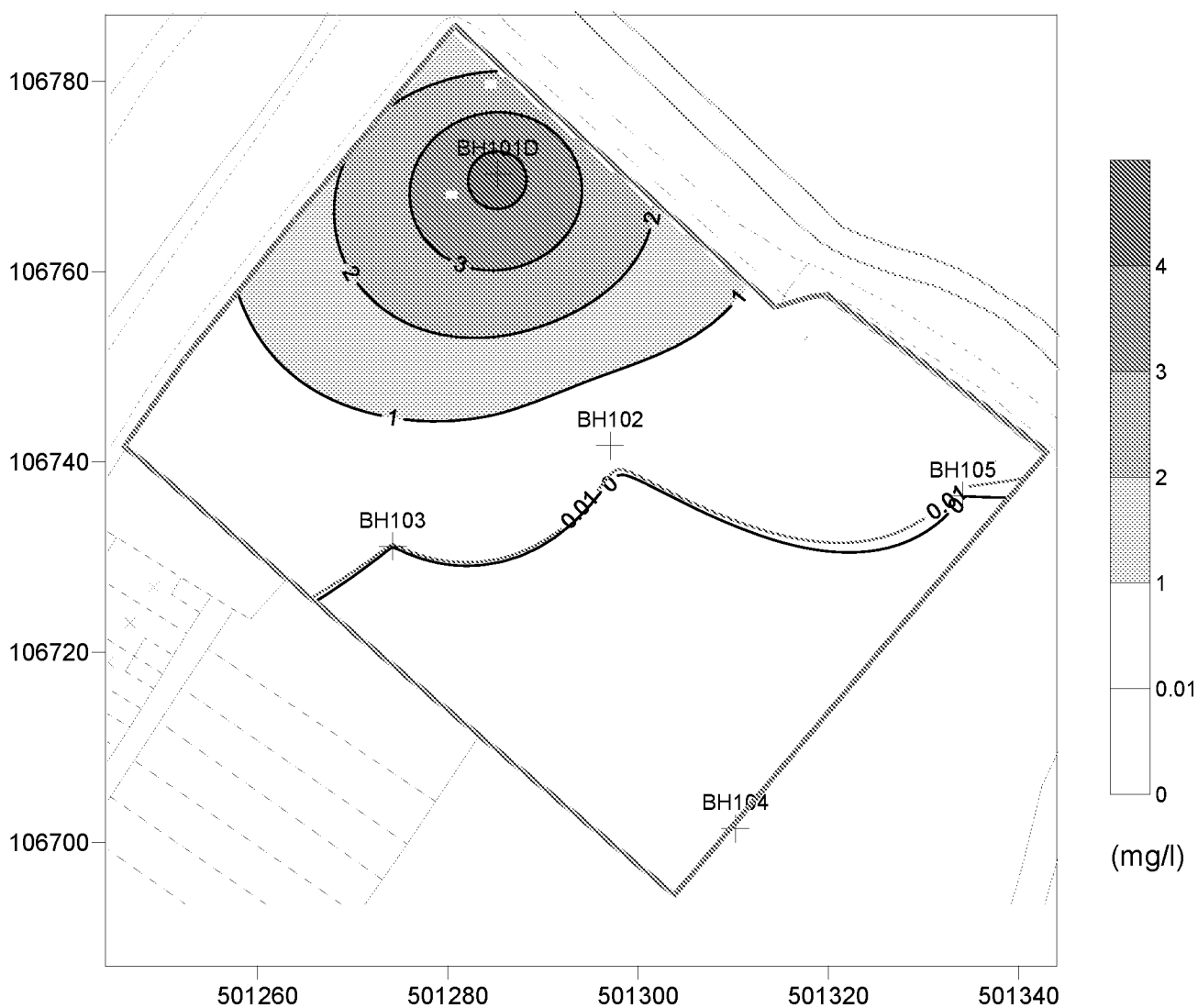


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 0.35 (mg/l)

## Ford Road, Arundel

Inferred Contours of TPH7 - Aromatic C12 - C16 in Groundwater 15/07/2011



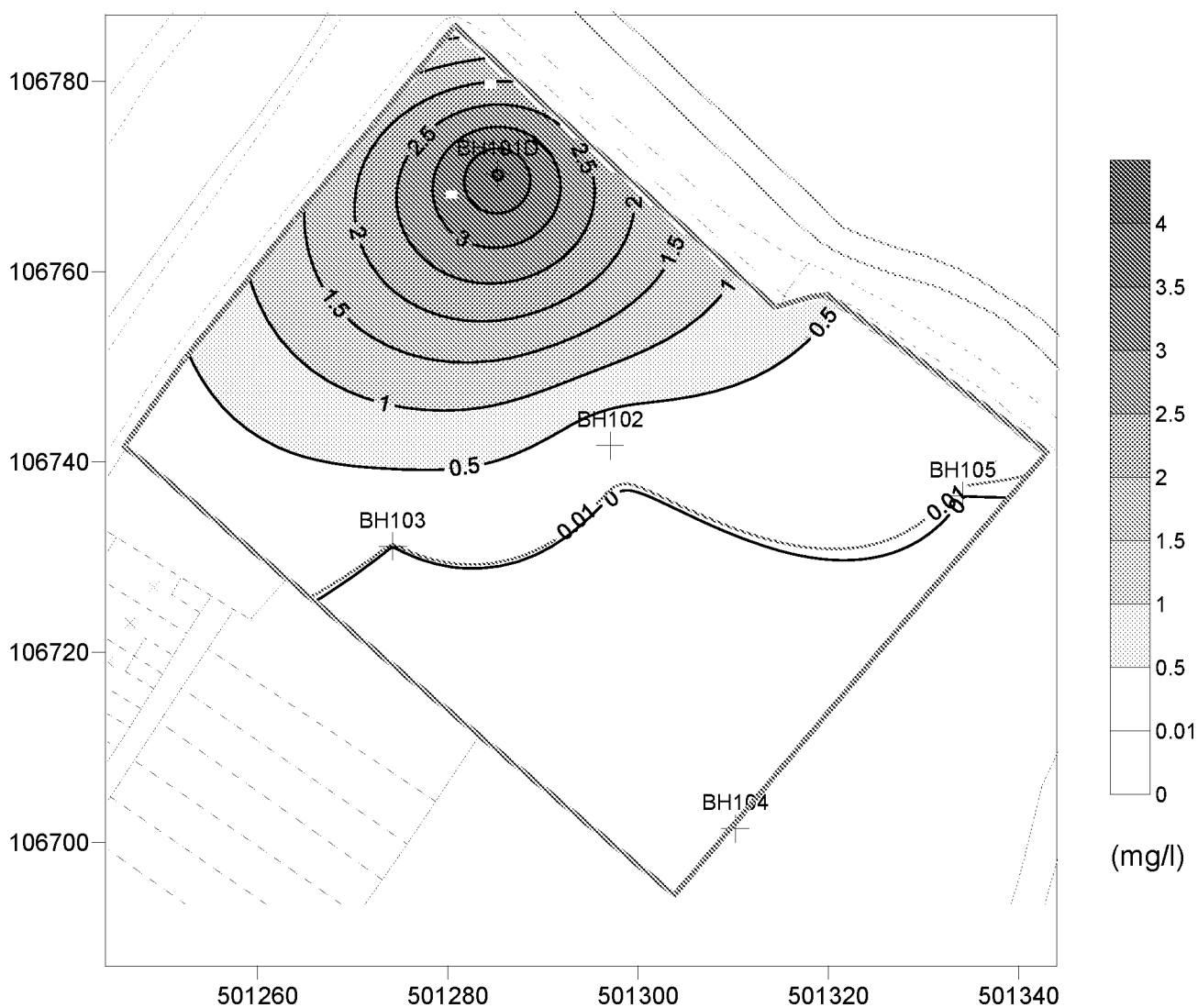
Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 4.6 (mg/l)



## Ford Road, Arundel

Inferred Contours of TPH7 - Aromatic C16 - C21 in Groundwater 15/07/2011

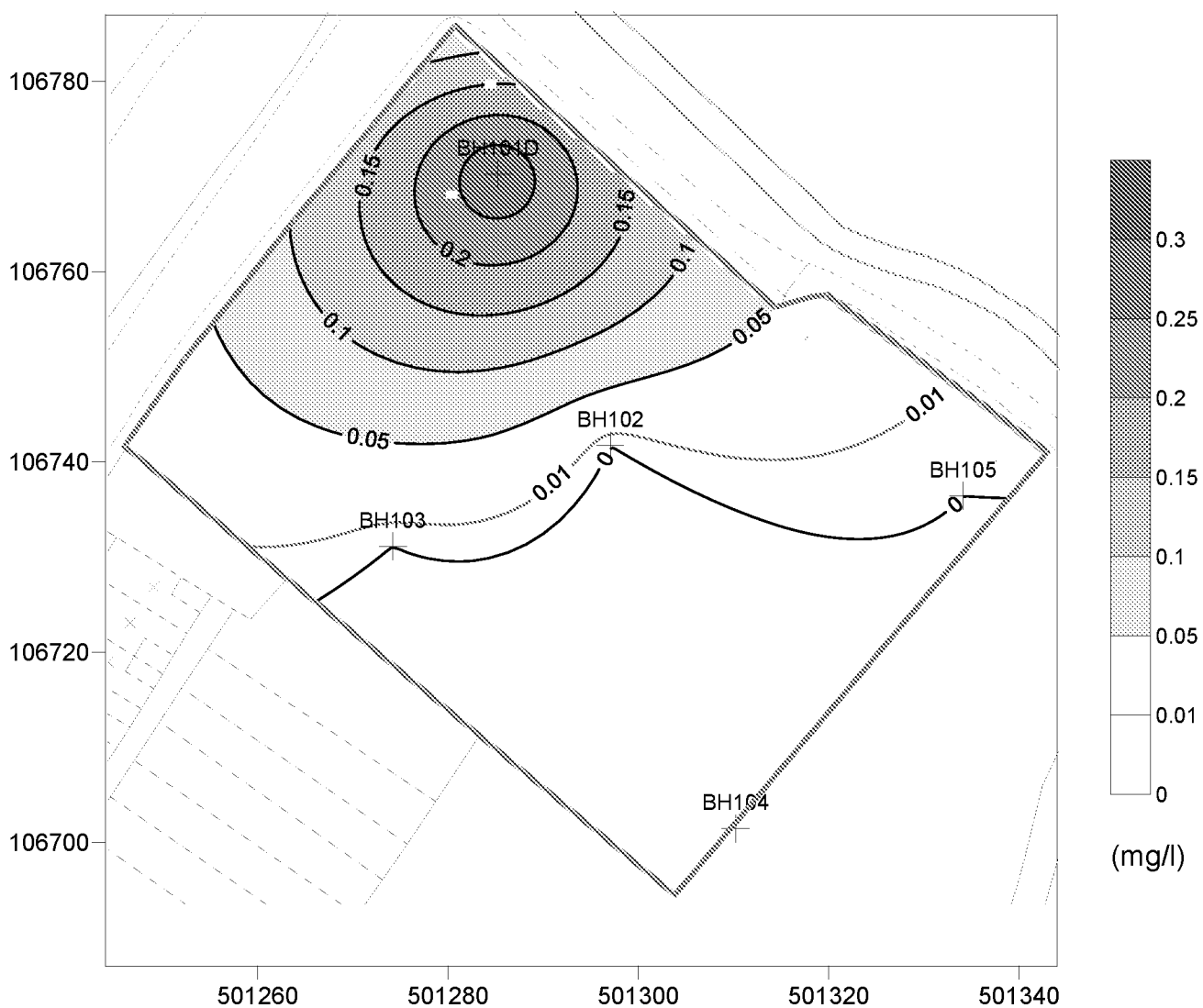


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 4.1 (mg/l)

## Ford Road, Arundel

Inferred Contours of TPH7 - Aromatic C21 - C35 in Groundwater 15/07/2011

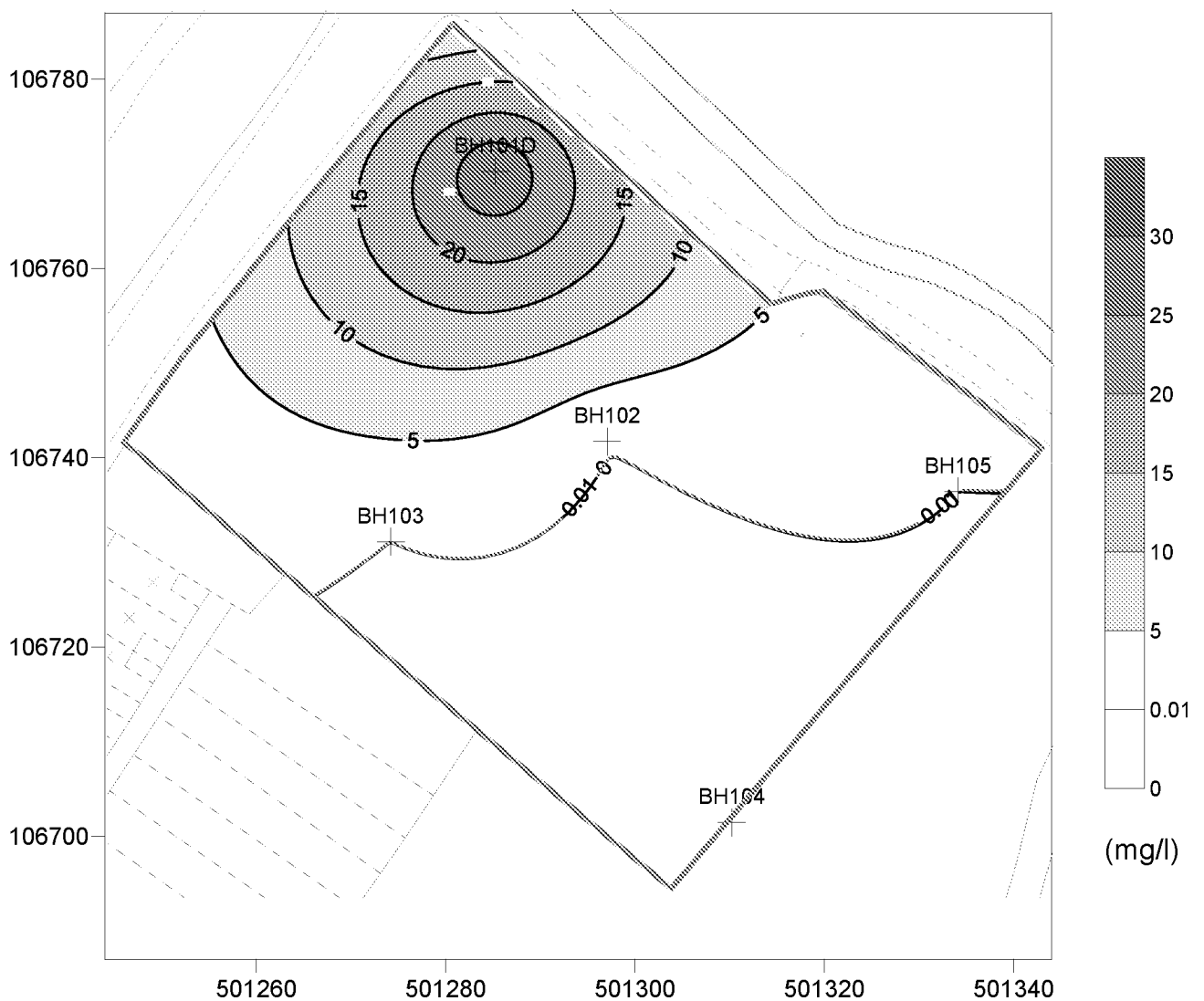


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 0.3 (mg/l)

**Ford Road, Arundel**

Inferred Contours of TPH7 - Aromatic (C5 - C35) in Groundwater 15/07/2011

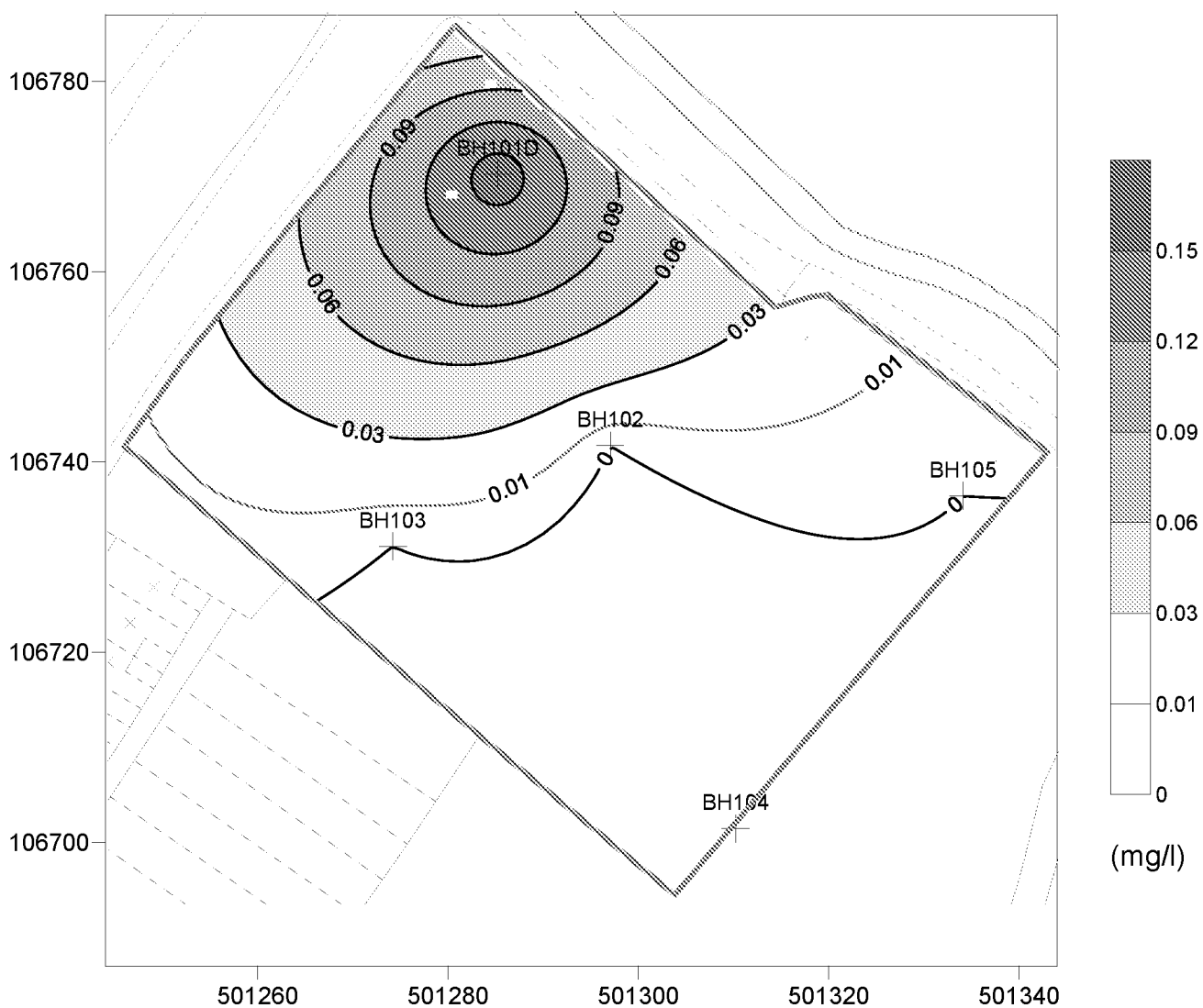


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 30 (mg/l)

## Ford Road, Arundel

Inferred Contours of TPH7 - Aliphatic C16 - C21 in Groundwater 15/07/2011

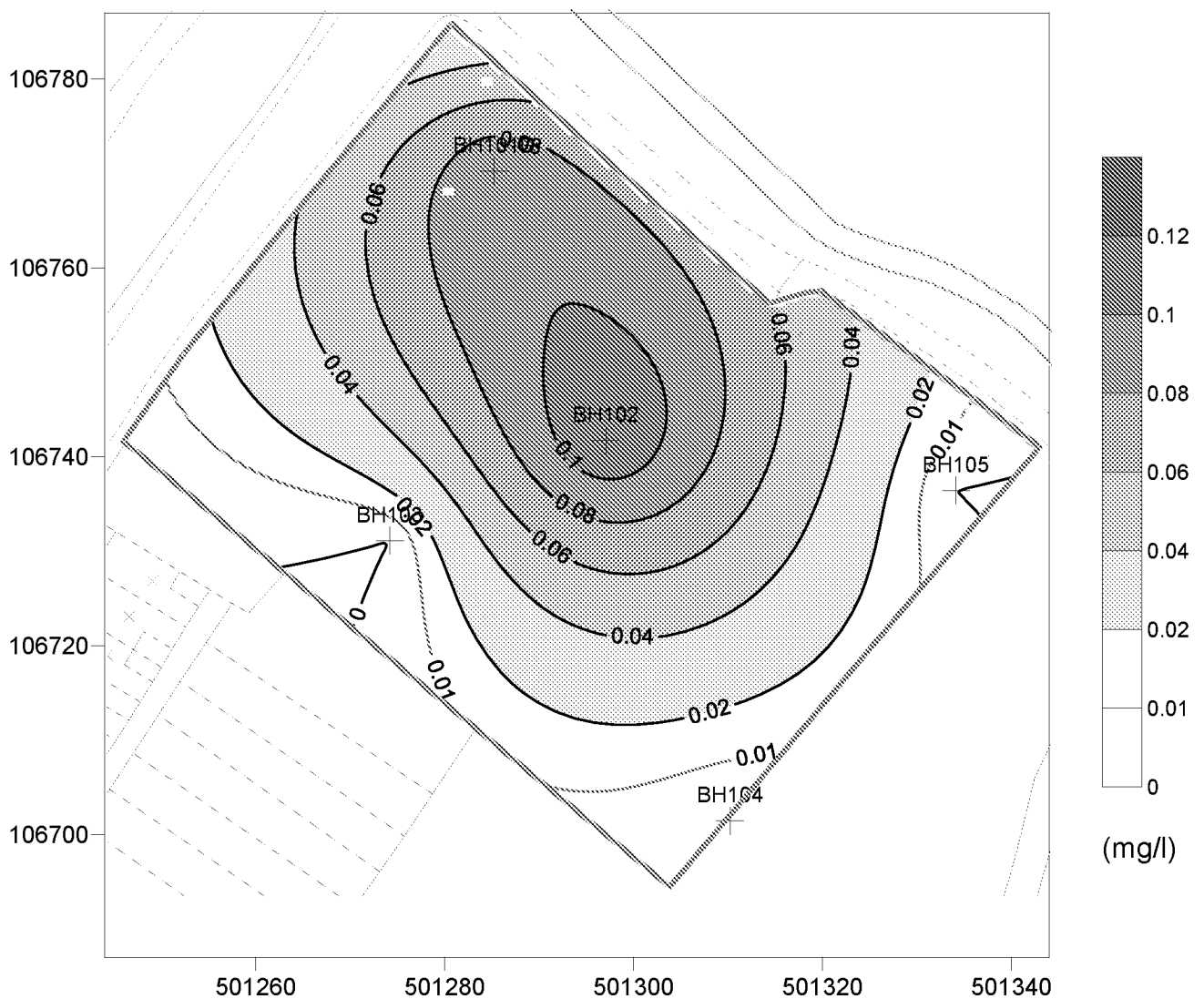


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 0.17 (mg/l)

## Ford Road, Arundel

Inferred Contours of TPH7 - Aliphatic C21 - C35 in Groundwater 15/07/2011

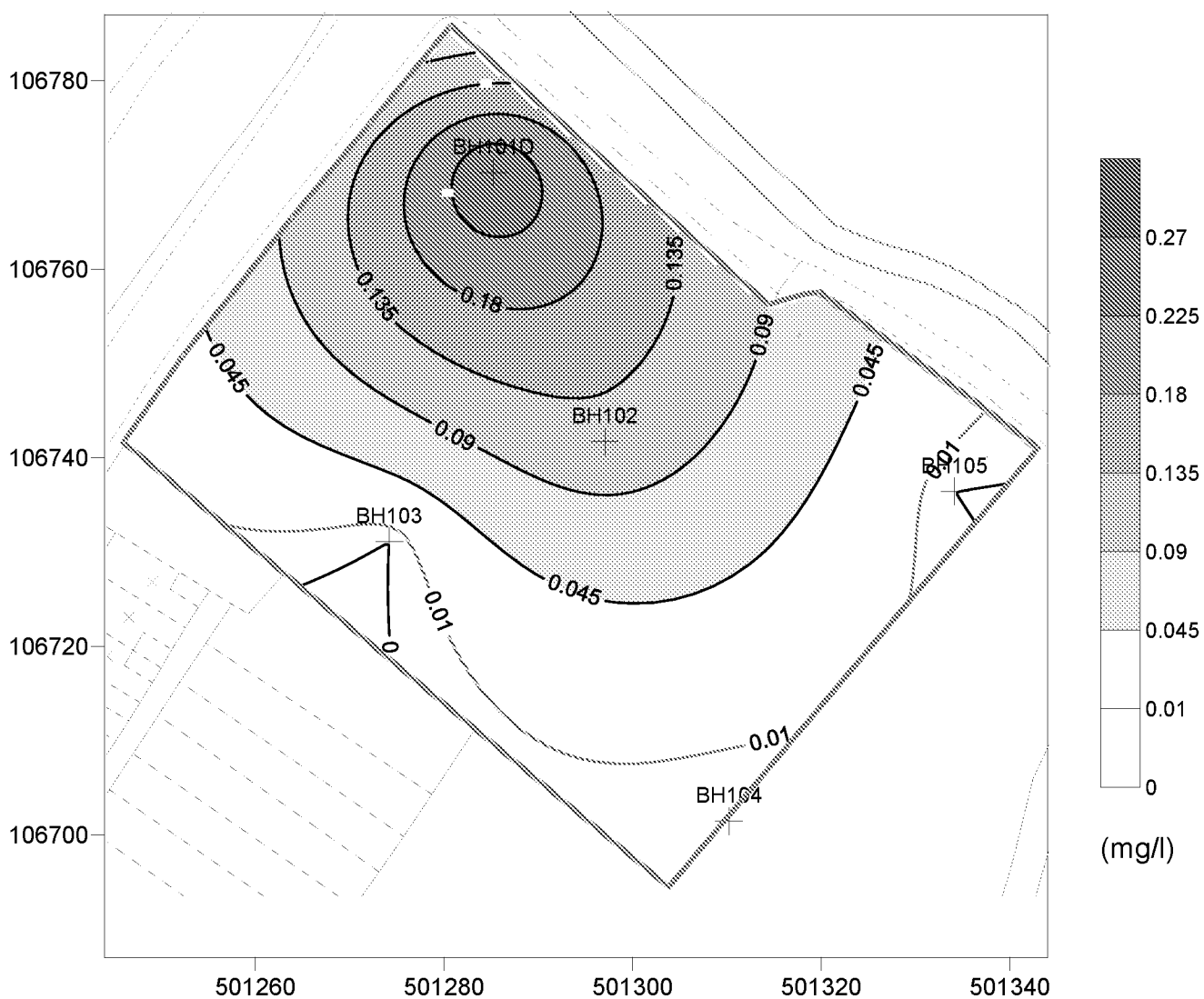


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 0.12 (mg/l)

## Ford Road, Arundel

Inferred Contours of TPH7 - Aliphatic (C5 - C35) in Groundwater 15/07/2011

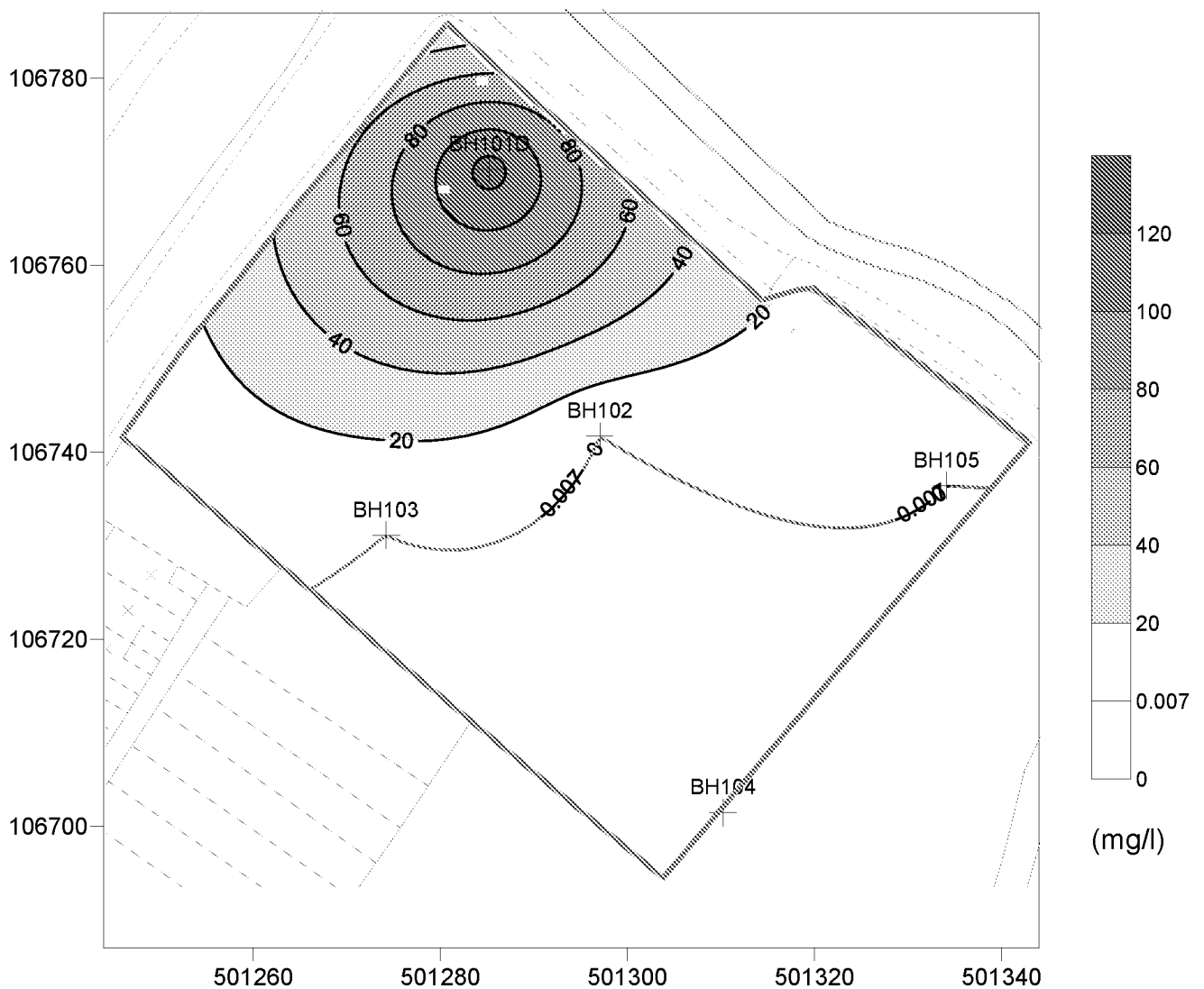


Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 0.27 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Phenol in Groundwater 15/07/2011

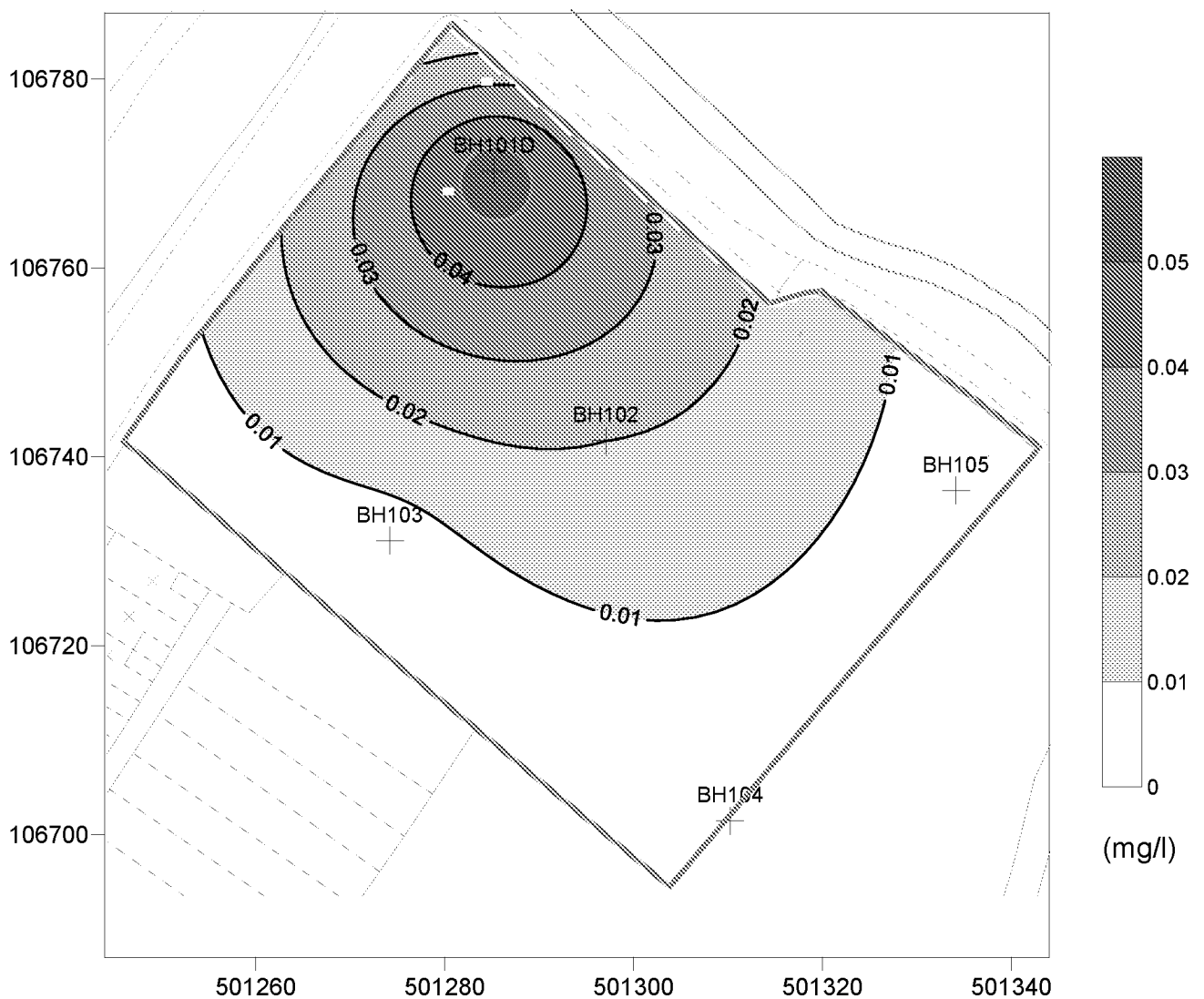


Compliance Criterion = 0.007 (mg/l)

Data Maximum Value = 130 (mg/l)

## Ford Road, Arundel

Inferred Contours of Arsenic (dissolved) in Groundwater 15/07/2011



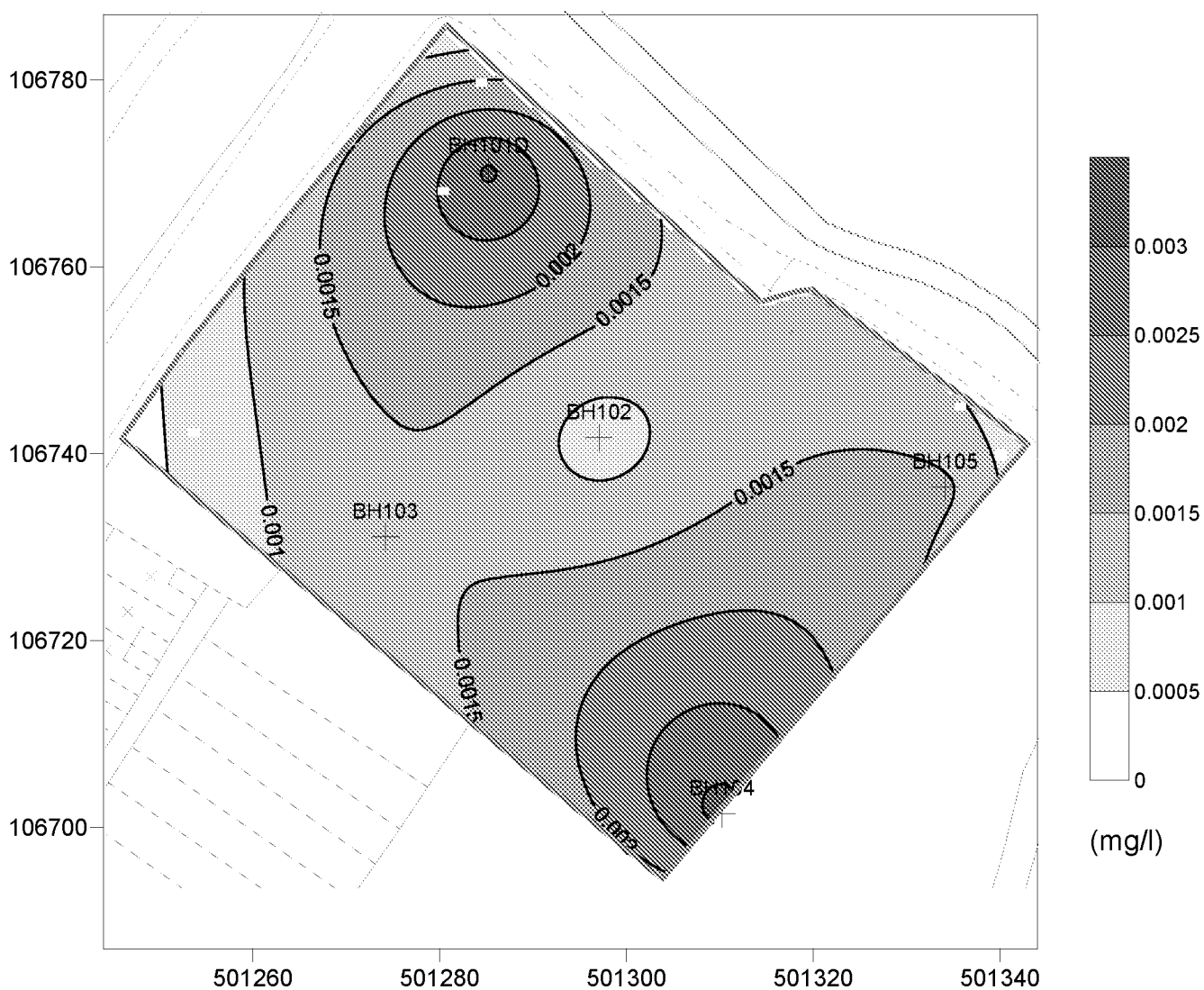
Compliance Criterion = 0.05 (mg/l)

Data Maximum Value = 0.058 (mg/l)



## Ford Road, Arundel

Inferred Contours of Copper (dissolved) in Groundwater 15/07/2011

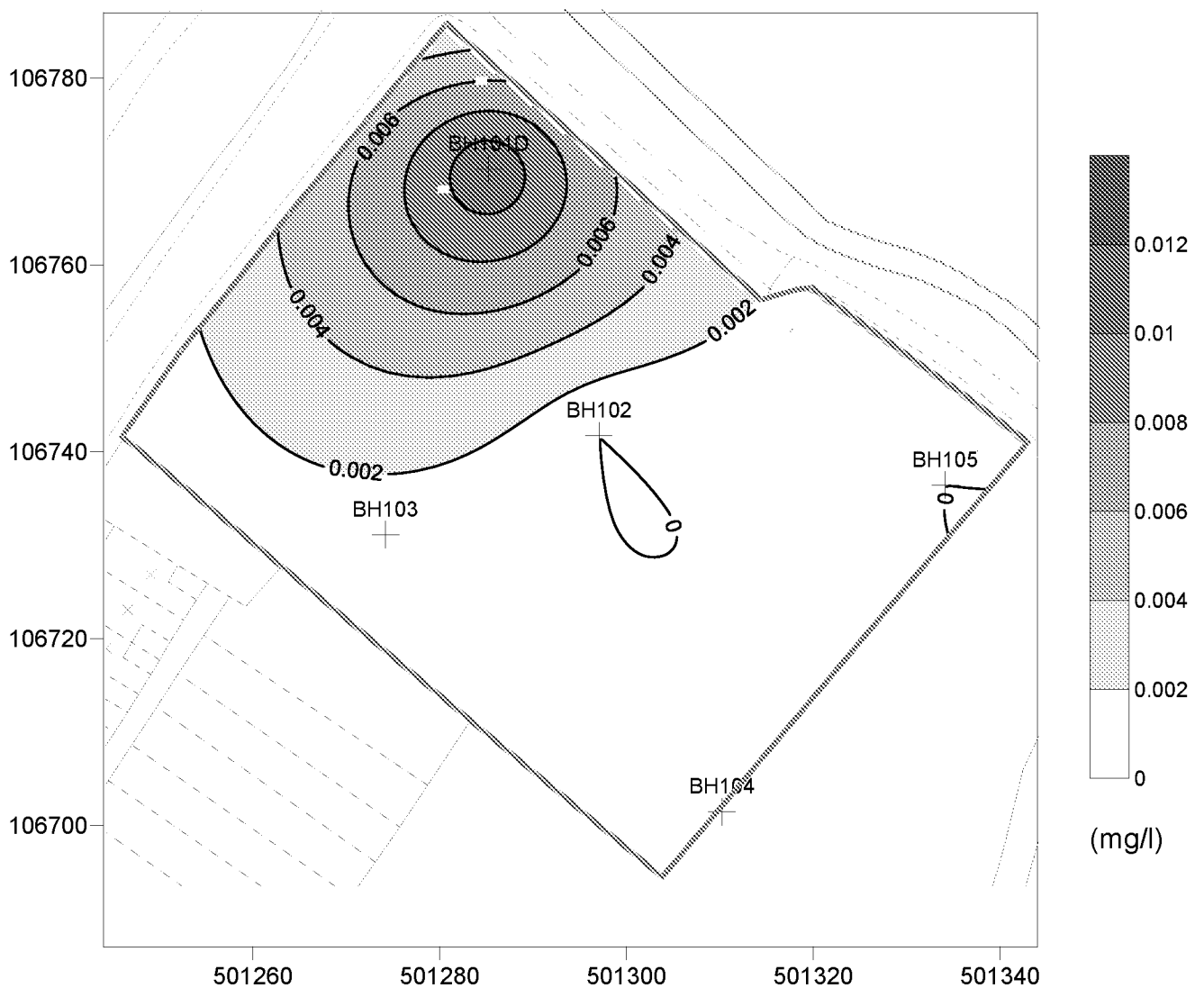


Compliance Criterion = 0.028 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.0032 (mg/l)

## Ford Road, Arundel

Inferred Contours of Chromium (dissolved) in Groundwater 15/07/2011

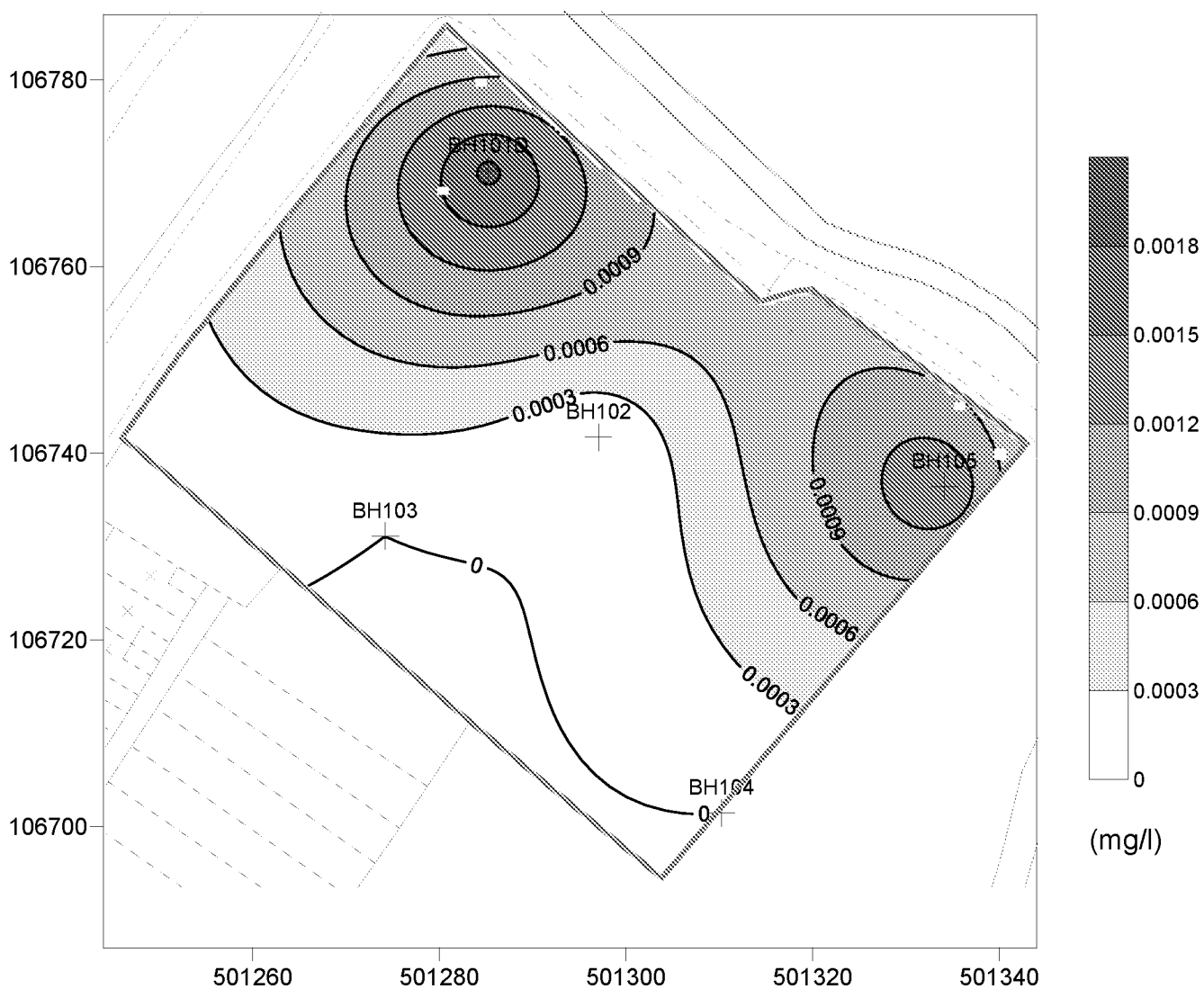


Compliance Criterion = 0.02 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.012 (mg/l)

## Ford Road, Arundel

Inferred Contours of Lead (dissolved) in Groundwater 15/07/2011

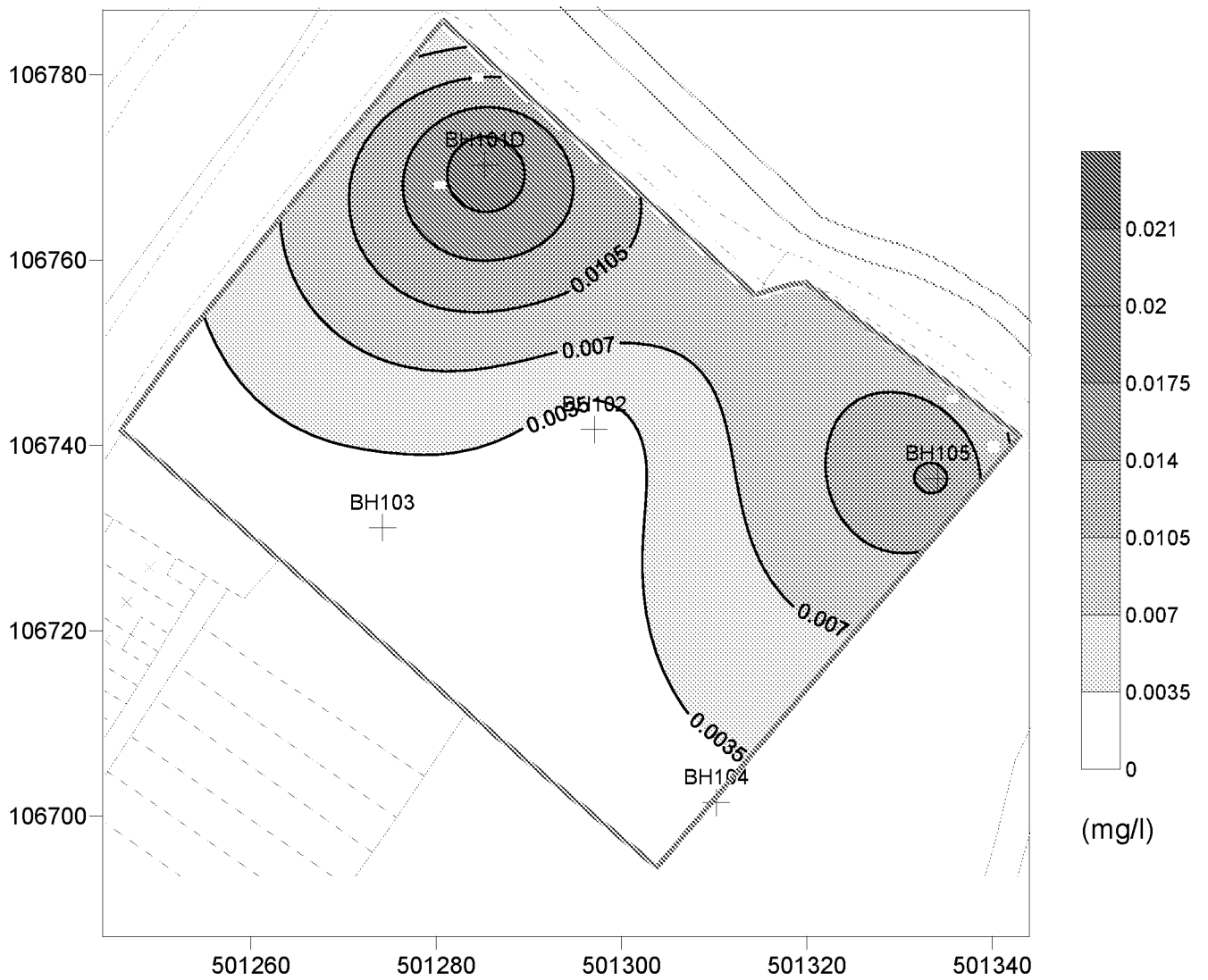


Compliance Criterion = 0.0072 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.0019 (mg/l)

## Ford Road, Arundel

Inferred Contours of Nickel (dissolved) in Groundwater 15/07/2011

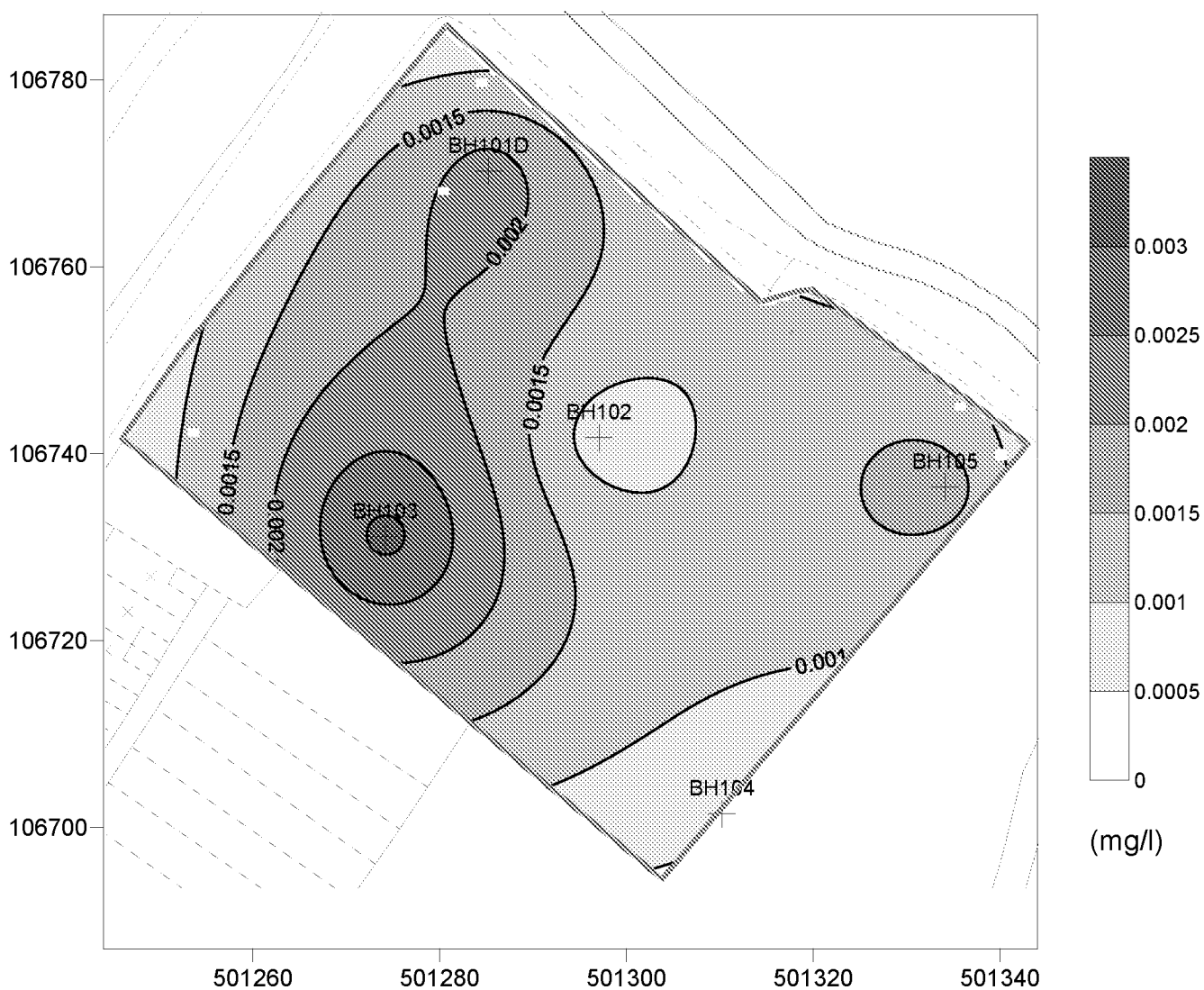


Compliance Criterion = 0.02 (mg/l)

Data Maximum Value = 0.021 (mg/l)

## Ford Road, Arundel

Inferred Contours of Zinc (dissolved) in Groundwater 15/07/2011

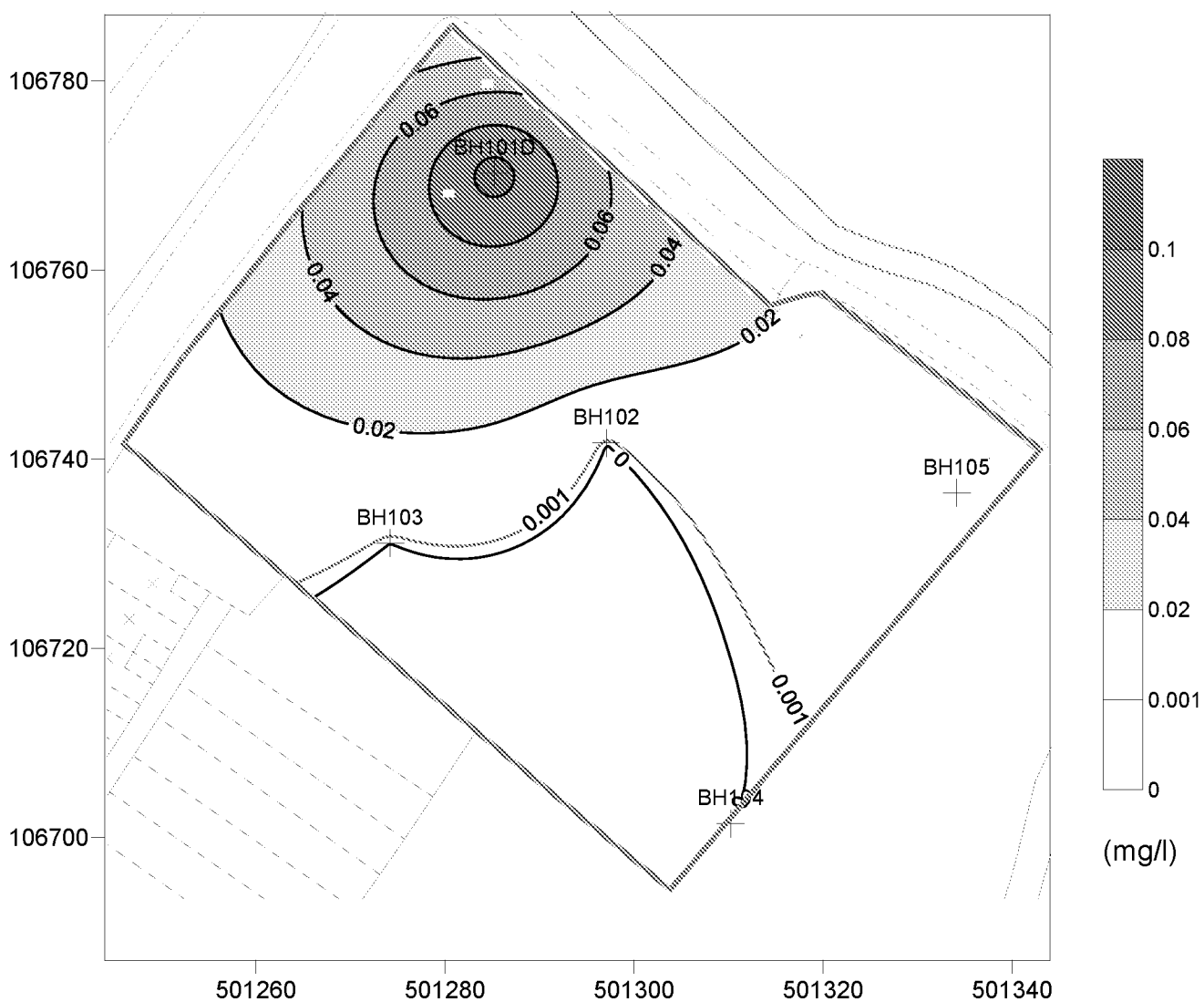


Compliance Criterion = 0.034 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.0032 (mg/l)

## Ford Road, Arundel

Inferred Contours of Free Cyanide in Groundwater 15/07/2011

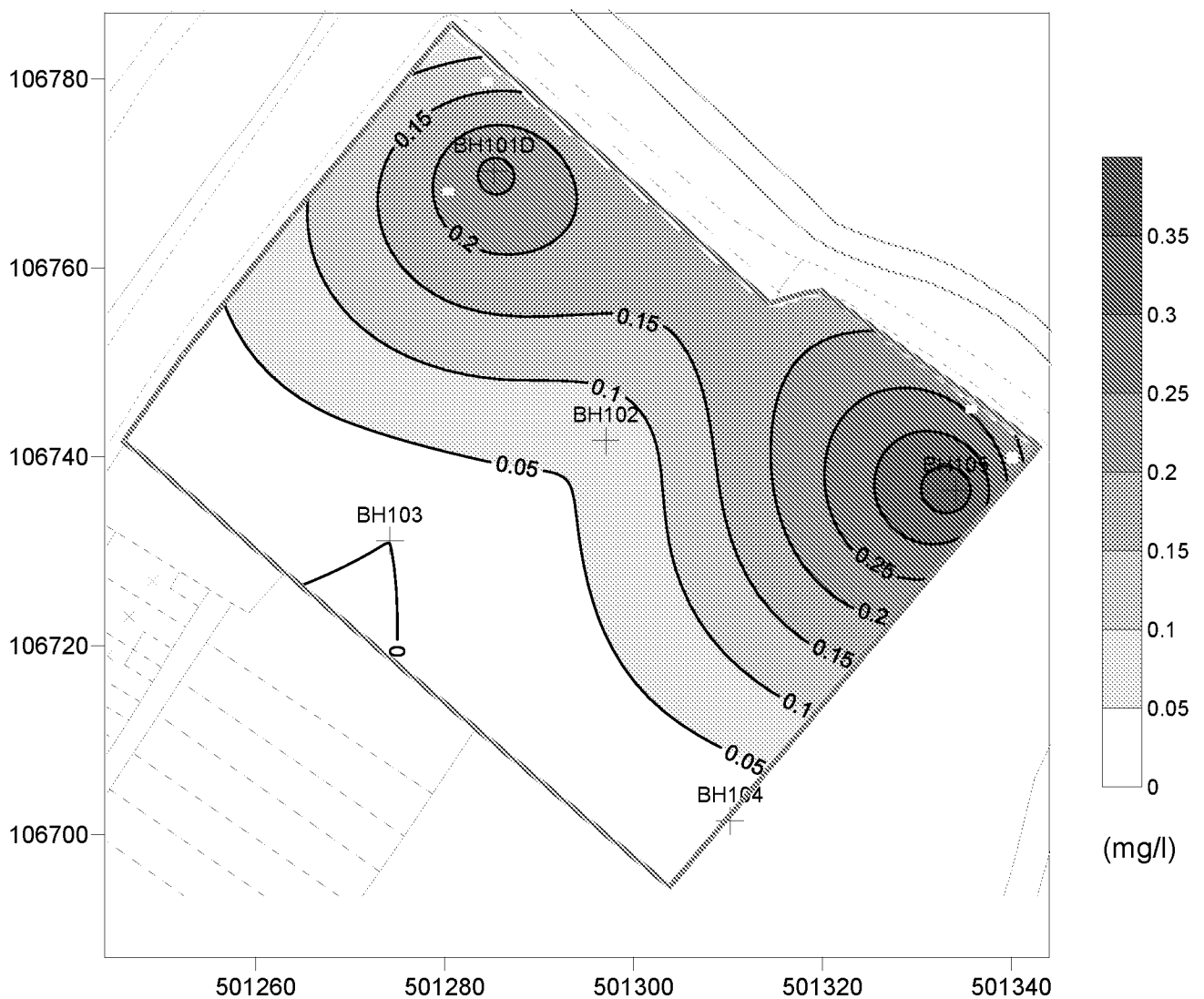


Compliance Criterion = 0.001 (mg/l)

Data Maximum Value = 0.11 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Complex Cyanide in Groundwater 15/07/2011

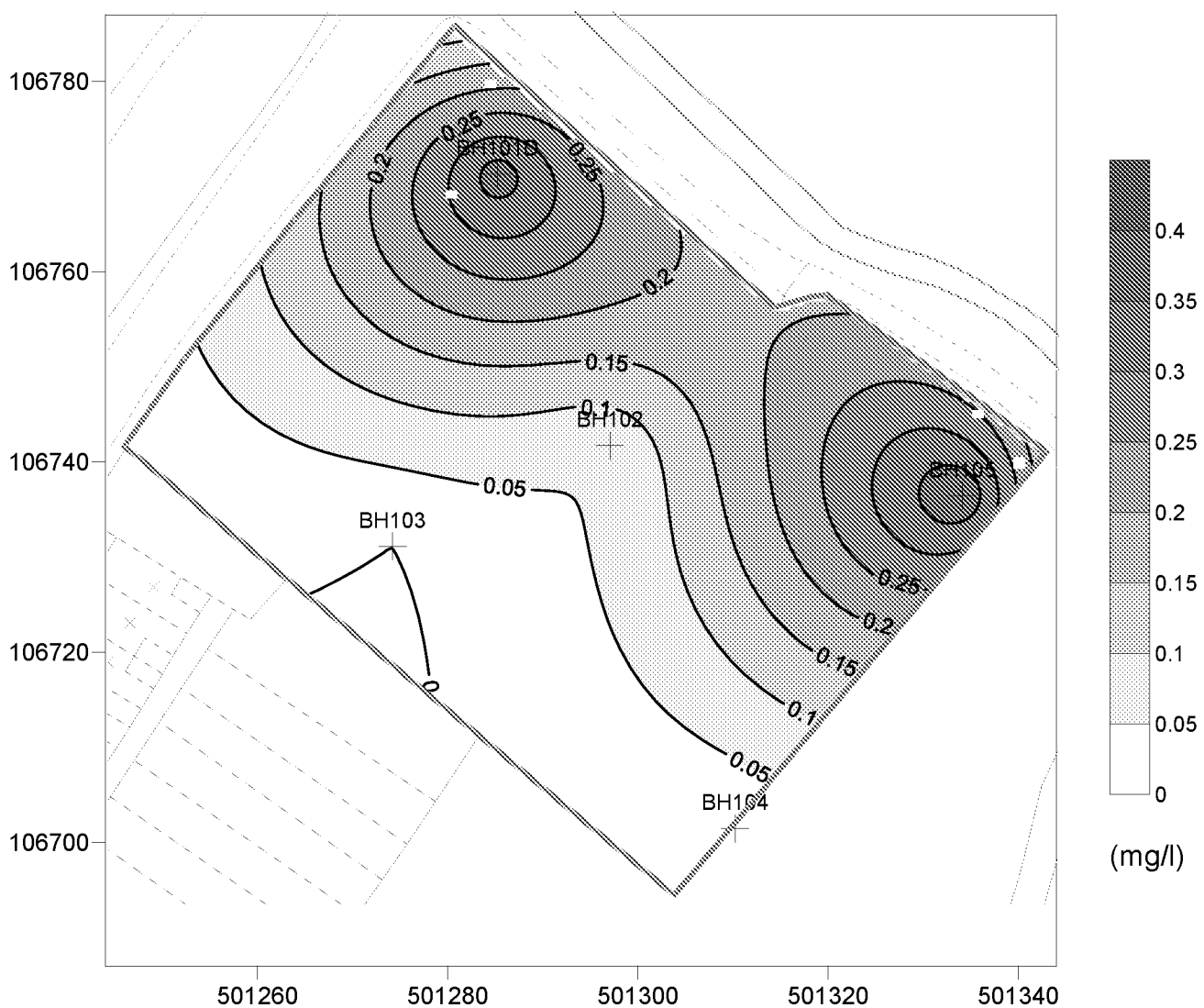


Compliance Criterion = 14 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.39 (mg/l)

## Ford Road, Arundel

Inferred Contours of Total Cyanide in Groundwater 15/07/2011

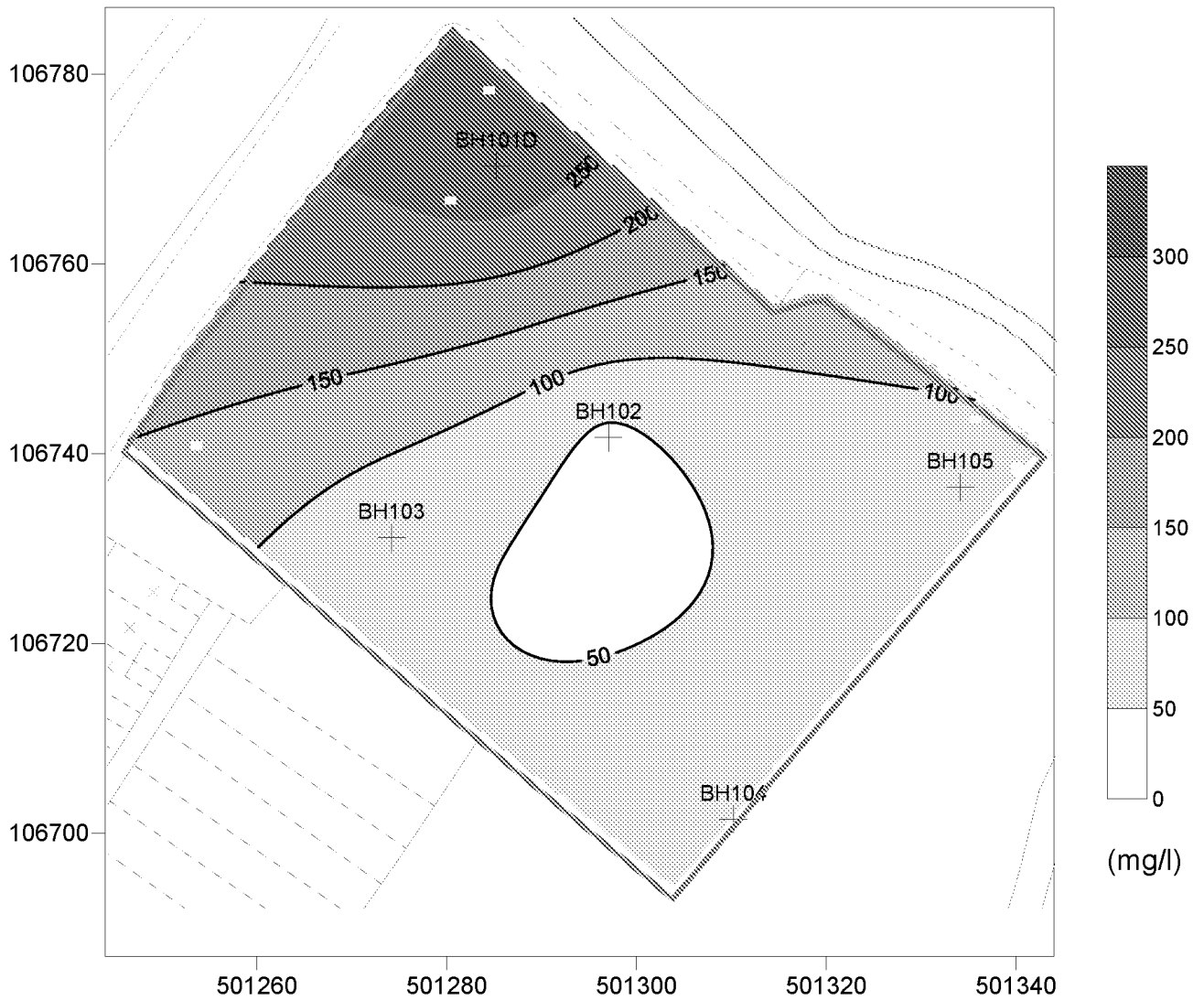


Data Maximum Value = 0.4 (mg/l) Data Minimum Value = 0 (mg/l)



## Ford Road, Arundel

Inferred Contours of Chloride in Groundwater 15/07/2011

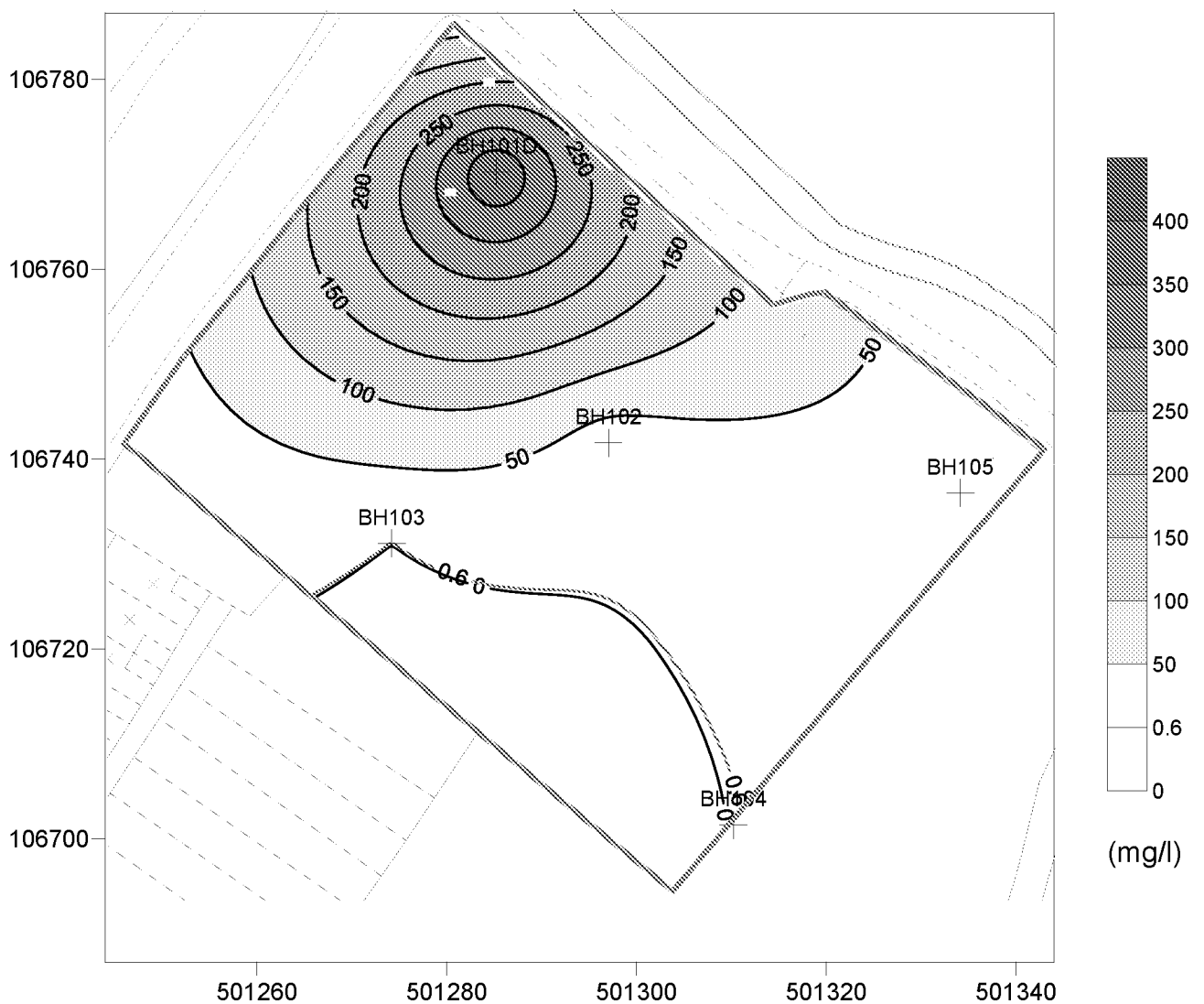


Compliance Criterion = 250 (mg/l)

Data Maximum Value = 300 (mg/l)

## Ford Road, Arundel

Inferred Contours of Ammonium as NH<sub>4</sub> in Groundwater 15/07/2011



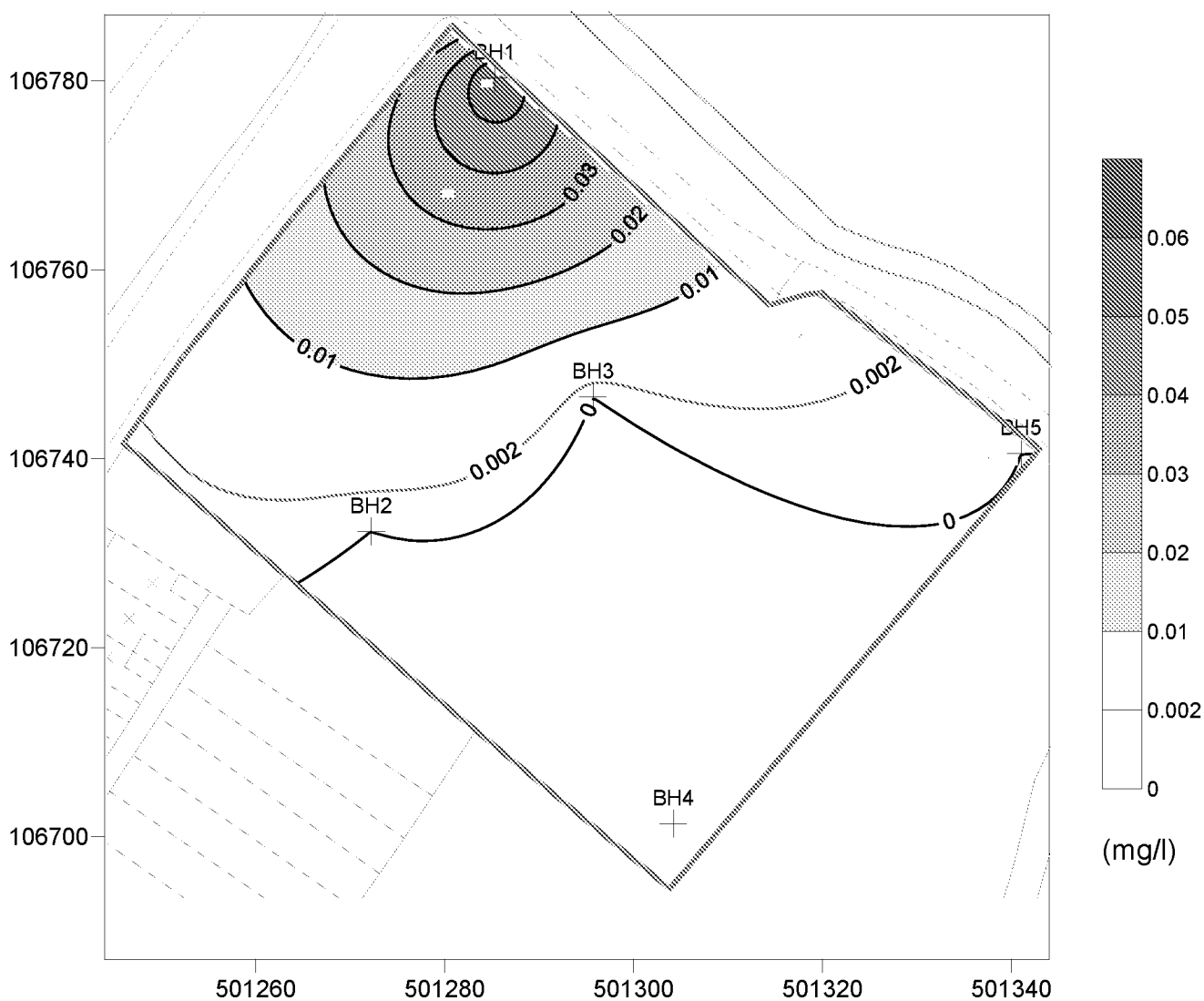
Compliance Criterion = 0.6 (mg/l)

Data Maximum Value = 400 (mg/l)

**Addendum C4**  
**Contours of Measured Concentrations of Substances**  
**In Groundwater 2000 Data**

## Ford Road, Arundel

### Inferred Contours of Naphthalene in Groundwater 6/6/00

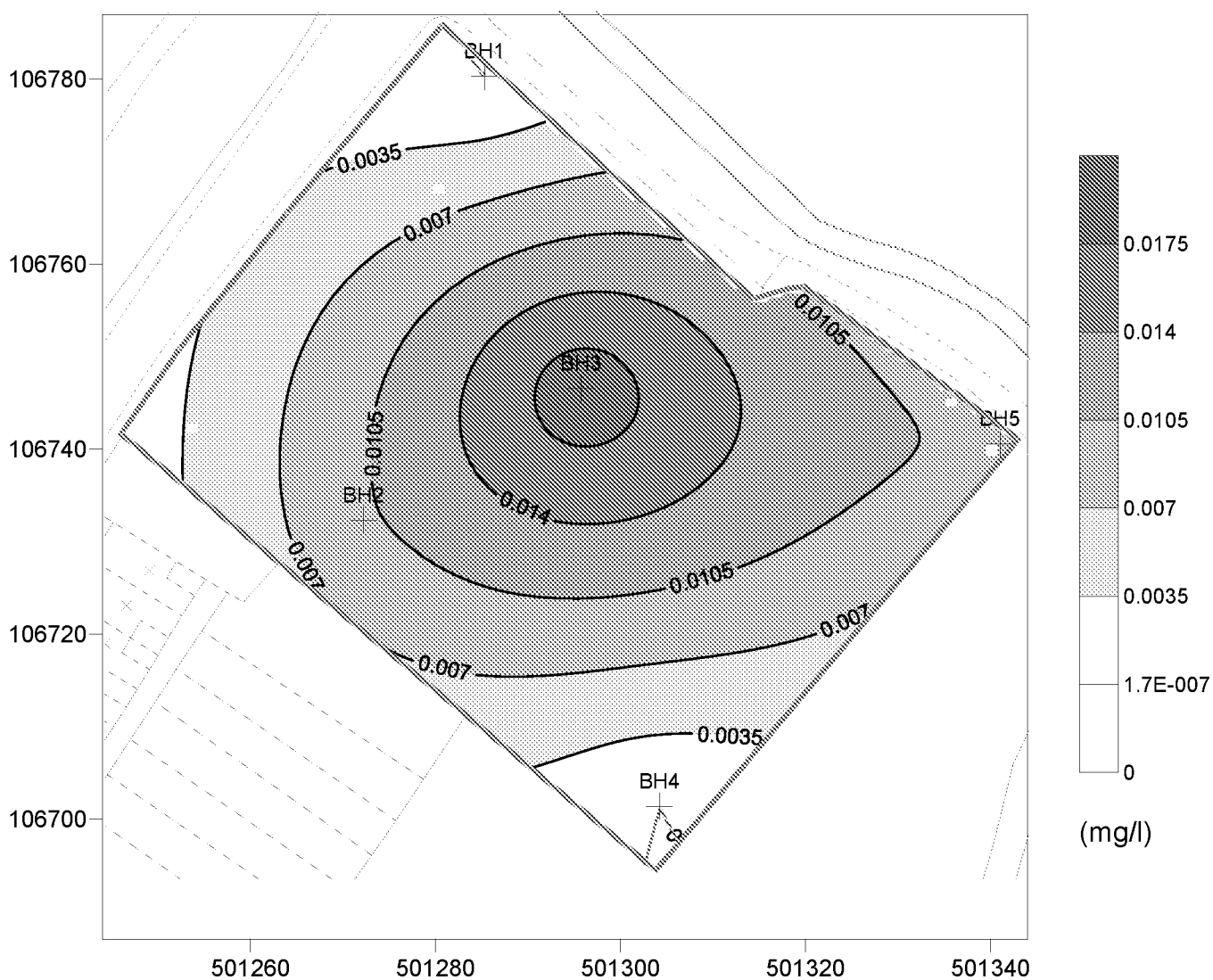


Compliance Criterion = 0.002 (mg/l)

Data Maximum Value = 0.06 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Benzo(a)Pyrene in Groundwater 6/6/00

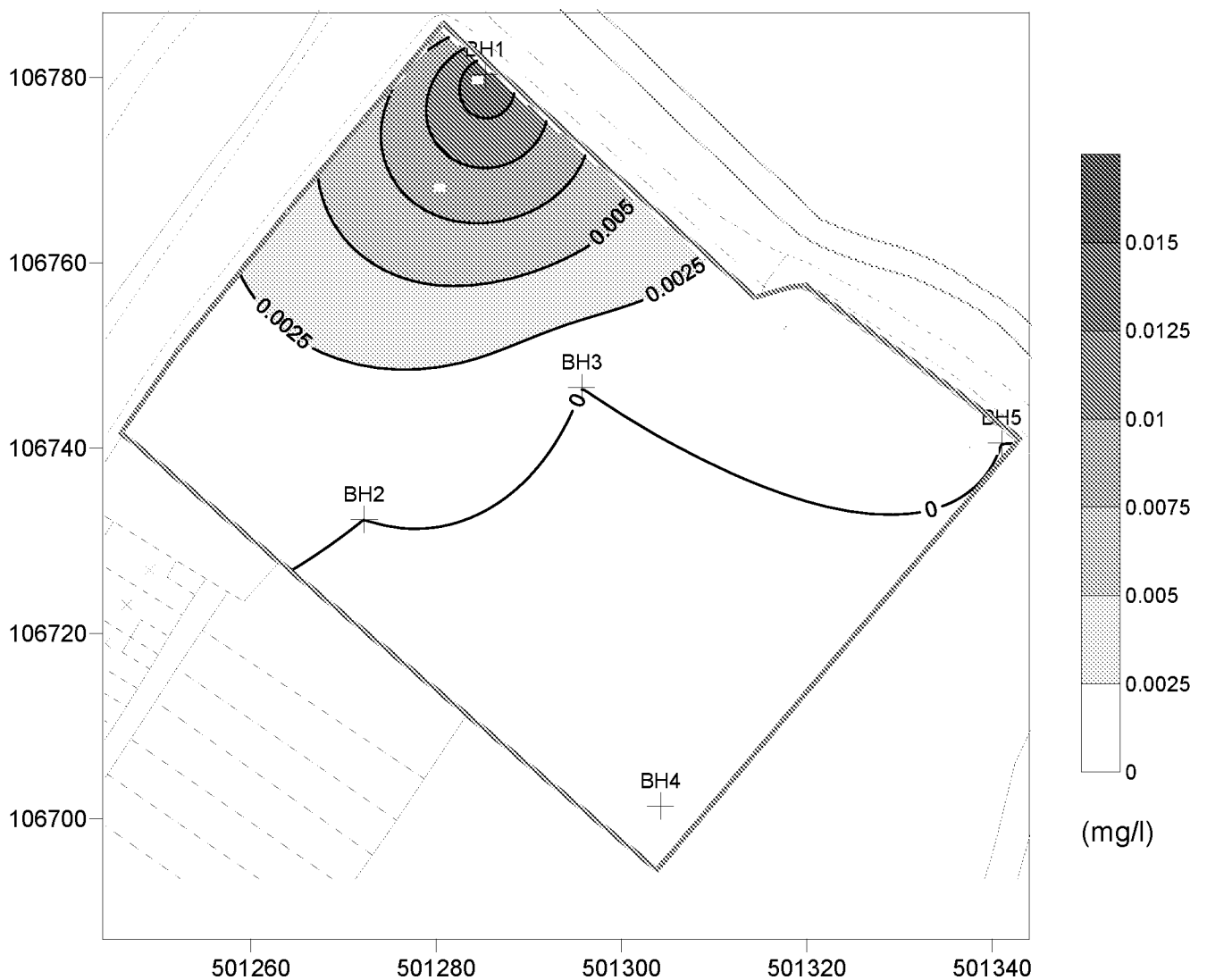


Compliance Criterion = 0.00000017 (mg/l)

Data Maximum Value = 0.02 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Ethyl Benzene in Groundwater 6/6/00

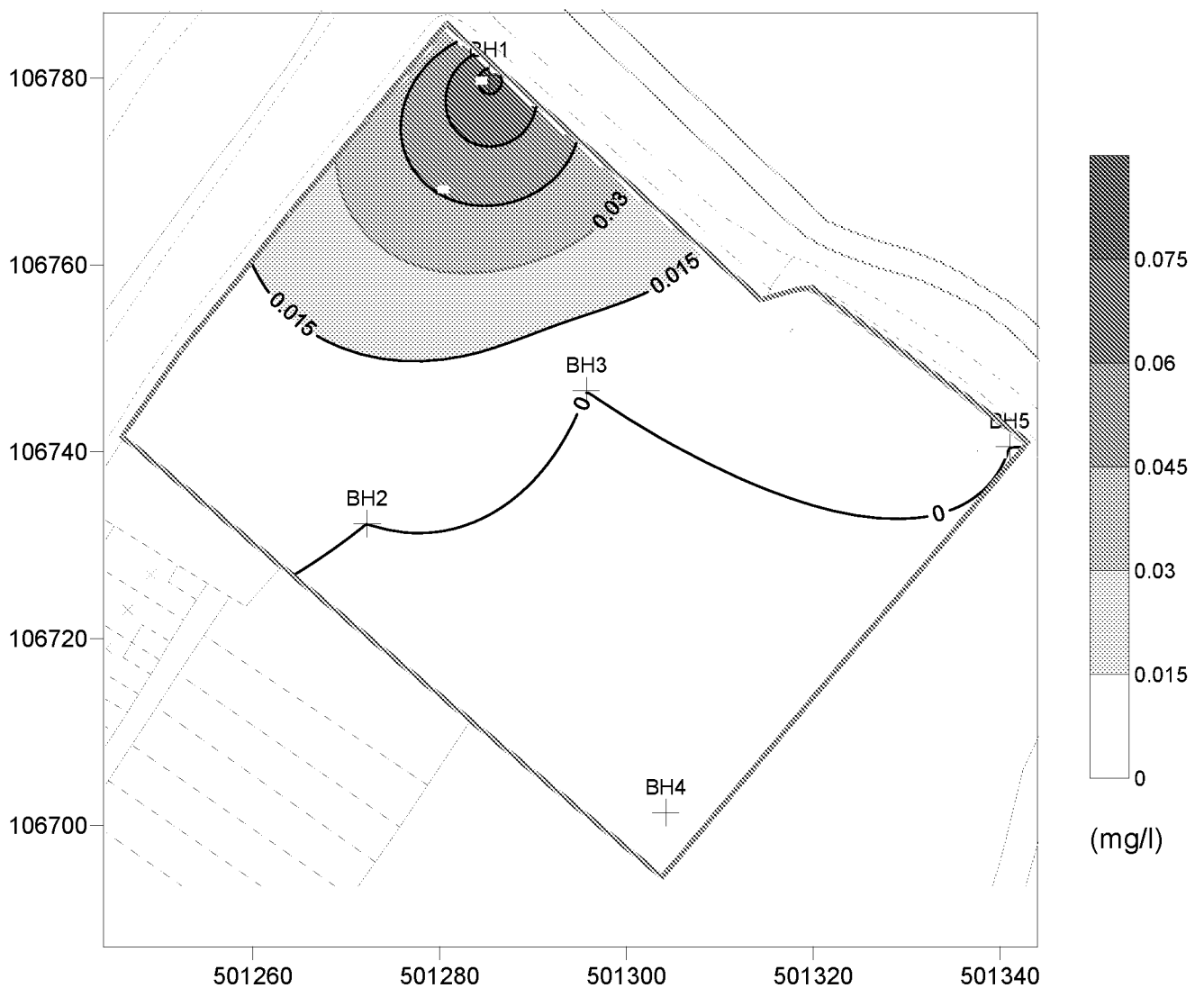


Compliance Criterion = 0.02 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.015 (mg/l)

## Ford Road, Arundel

### Inferred Contours of Xylenes in Groundwater 6/6/00

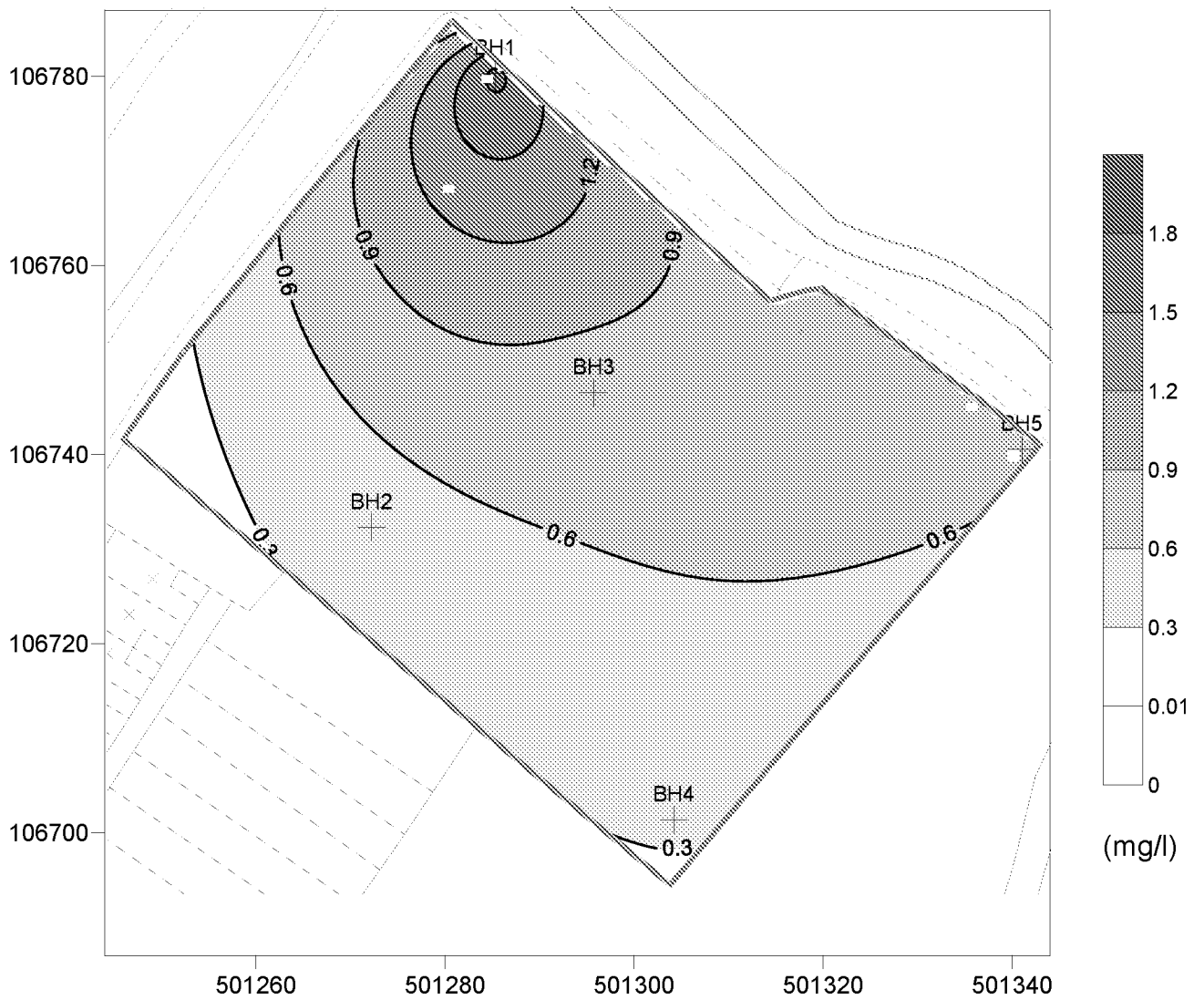


Compliance Criterion = 0.03 (mg/l)

Data Maximum Value = 0.081 (mg/l)

## Ford Road, Arundel

### Inferred Contours of TPH GC in Groundwater 6/6/00



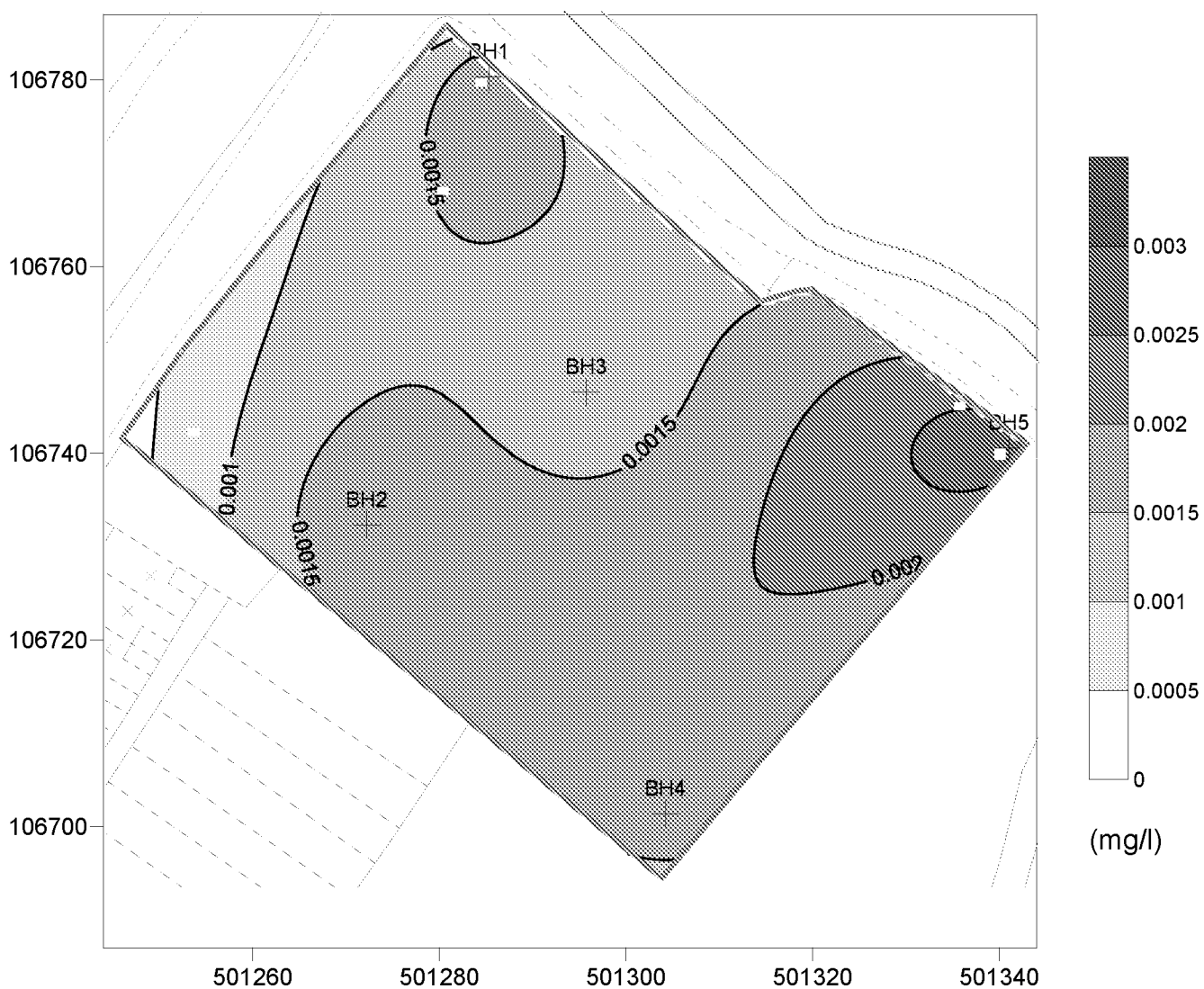
Compliance Criterion = 0.01 (mg/l)

Data Maximum Value = 1.9 (mg/l)



## Ford Road, Arundel

Inferred Contours of Selenium as Se (Dissolved) in Groundwater 6/6/00

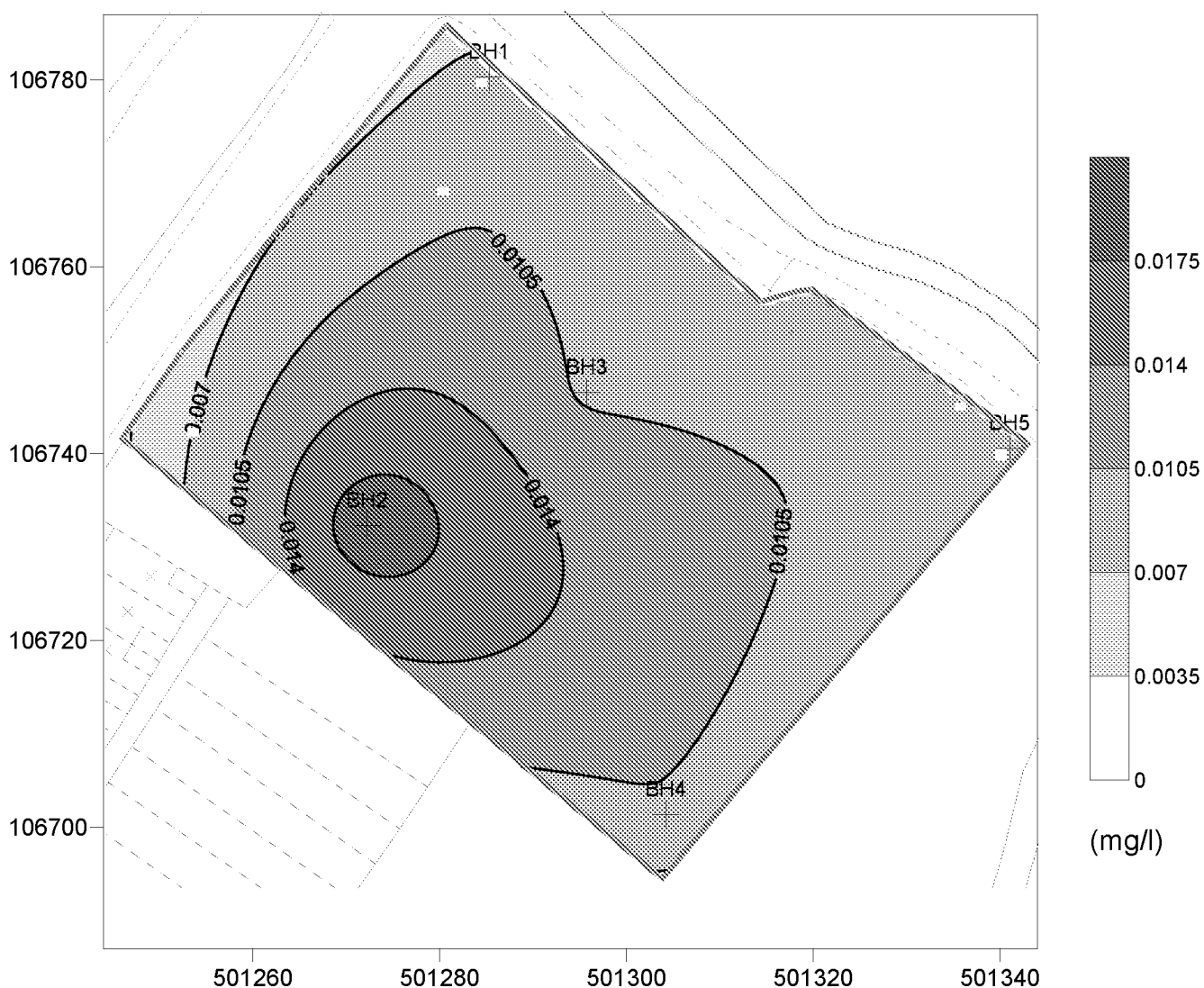


Compliance Criterion = 0.01 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.003 (mg/l)

## Ford Road, Arundel

Inferred Contours of Zinc as Zn (Dissolved) in Groundwater 6/6/00

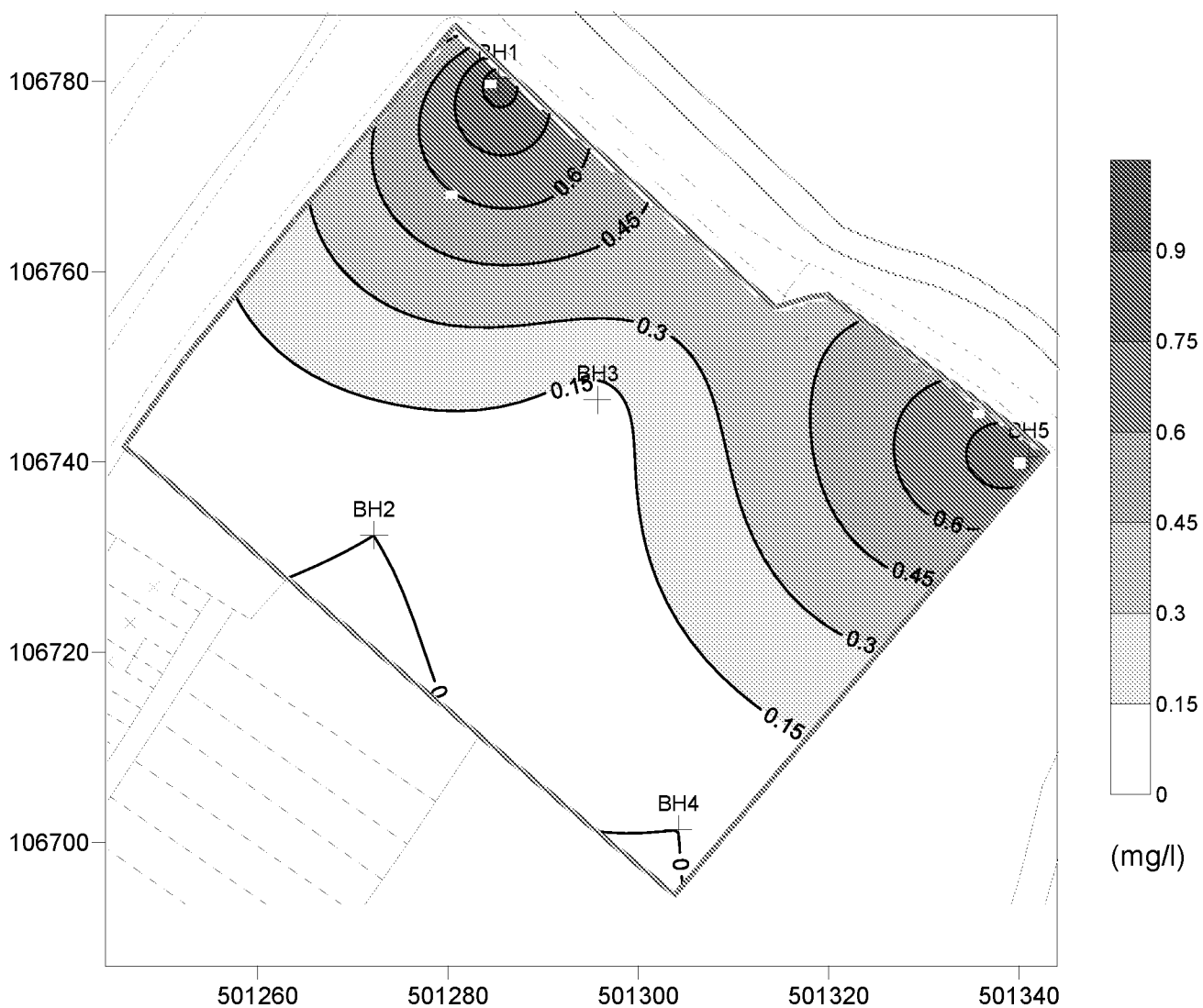


Compliance Criterion = 0.034 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 0.02 (mg/l)

## Ford Road, Arundel

Inferred Contours of Complex Cyanide as CN in Groundwater 6/6/00

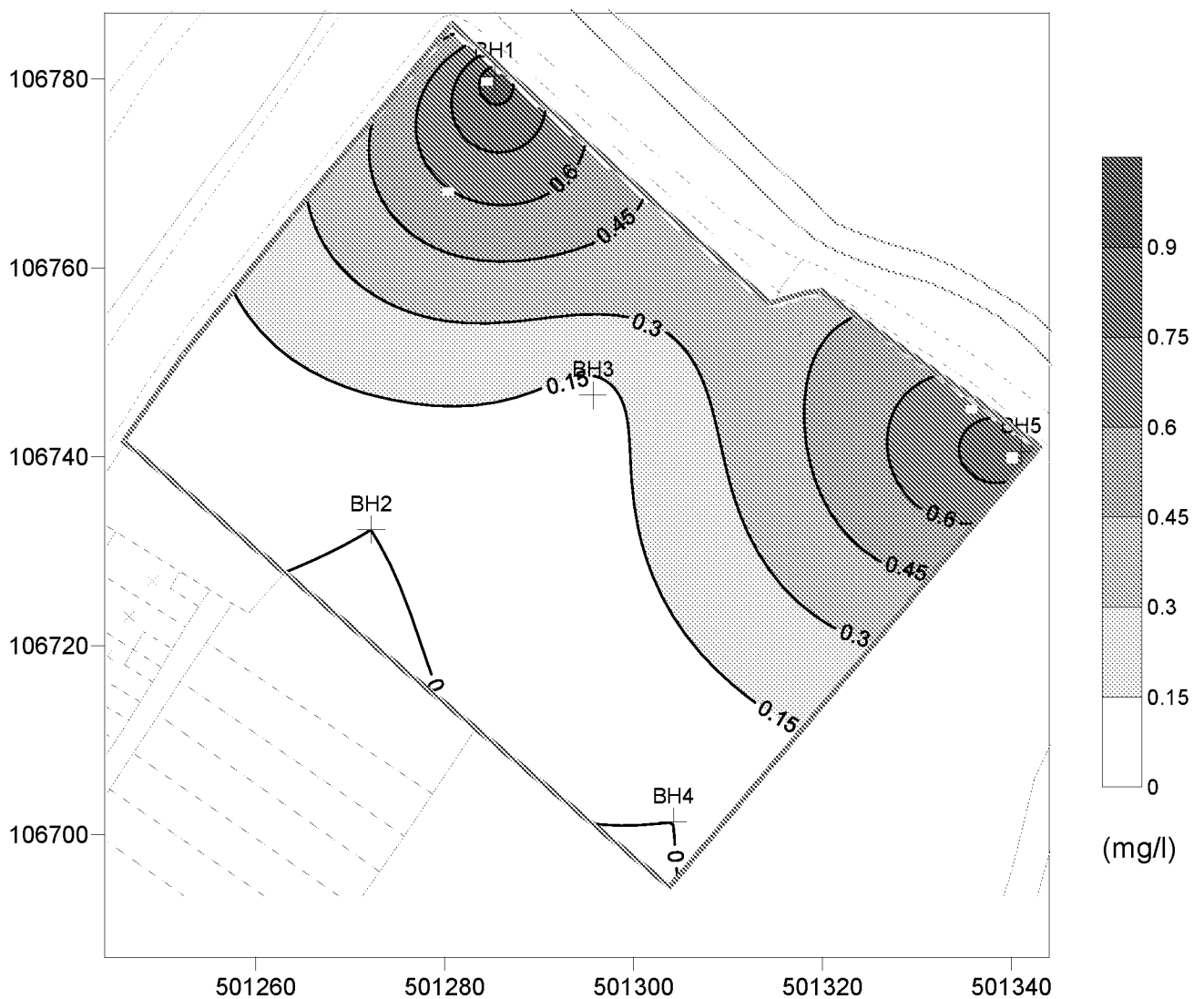


Compliance Criterion = 14 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 1 (mg/l)

## Ford Road, Arundel

Inferred Contours of Cyanide (Total) as CN in Groundwater 6/6/00



Compliance Criterion = 14 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 1 (mg/l)

## Ford Road, Arundel

Inferred Contours of Chloride as Cl in Groundwater 6/6/00

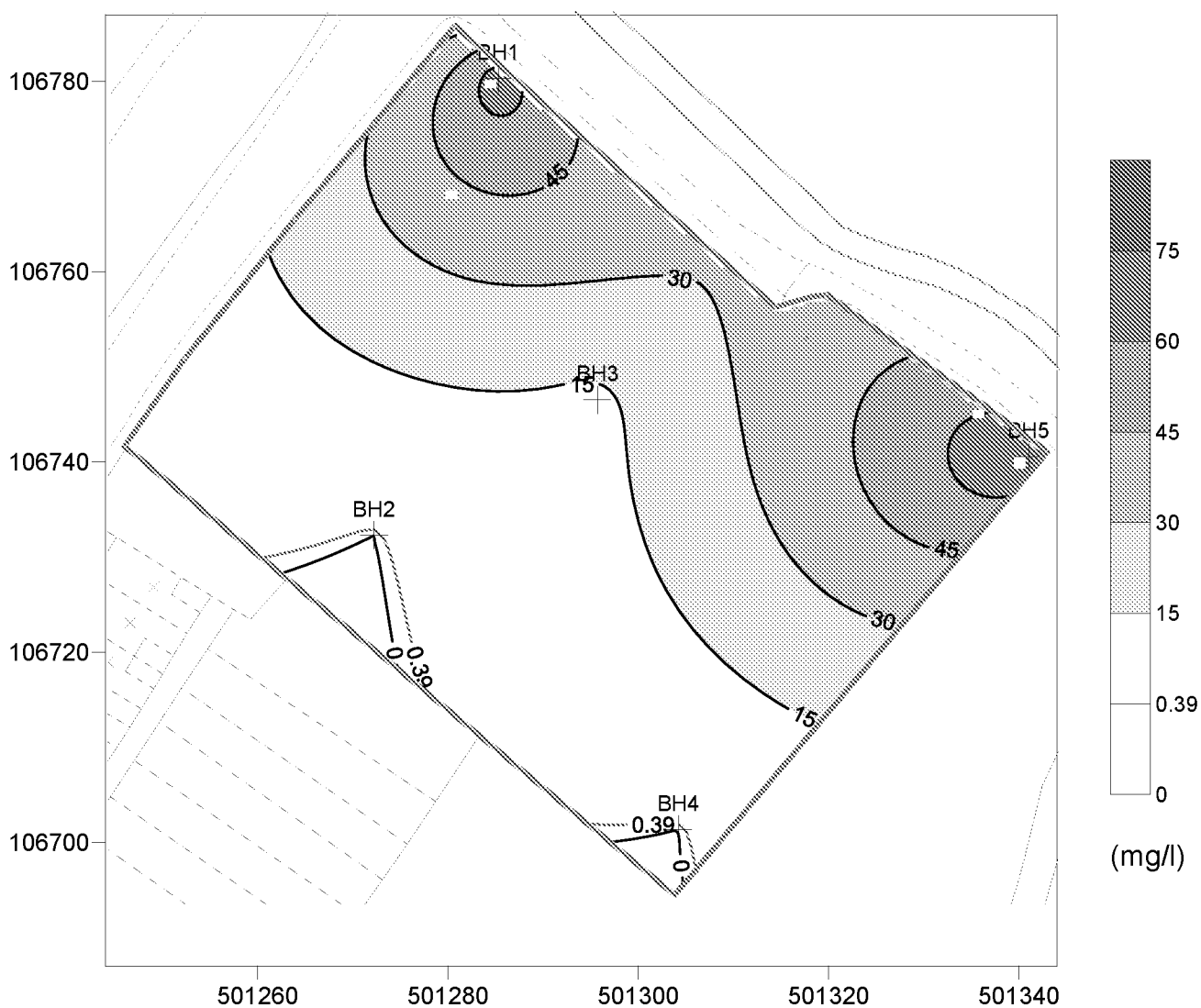


Compliance Criterion = 250 (mg/l) : Compliance Criterion Exceeds Data Maximum Value

Data Maximum Value = 111 (mg/l)

## Ford Road, Arundel

Inferred Contours of Ammoniacal Nitrogen as N in Groundwater 6/6/00



Compliance Criterion = 0.39 (mg/l)

Data Maximum Value = 75.5 (mg/l)

**Addendum C5**  
**RTM Parameter Summary Table and Worksheets**

|               |                   |       |                          |
|---------------|-------------------|-------|--------------------------|
| Site Name:    | Arundel           | Case: | 1 15 by 15 m Source Zone |
| Site Address: | Ford Road Arundel |       |                          |
| Completed by: | JAS               |       |                          |
| Date:         | 13/01/2021        |       |                          |

Number of Substances = 48

|                            |           | Compliance Criteria |                    |                    | Site Measured Concentrations |                    |  | Physiochemical Properties        |                    |                                        |             |                                 |                      |         |
|----------------------------|-----------|---------------------|--------------------|--------------------|------------------------------|--------------------|--|----------------------------------|--------------------|----------------------------------------|-------------|---------------------------------|----------------------|---------|
|                            |           |                     |                    |                    |                              |                    |  |                                  |                    |                                        |             |                                 |                      |         |
| Substance                  | Type      | DWS                 | EQS                | Comment            | Measured Soil                | Measured GW        |  | Kaw (H)                          | Water solubility   | Koc                                    | Kow         | Kd                              | Reference            |         |
|                            |           | mg L <sup>-1</sup>  | mg L <sup>-1</sup> |                    | mg kg <sup>-1</sup>          | mg L <sup>-1</sup> |  | cm <sup>3</sup> cm <sup>-3</sup> | mg L <sup>-1</sup> | Log (cm <sup>3</sup> g <sup>-1</sup> ) | Log (ratio) | cm <sup>3</sup> g <sup>-1</sup> |                      |         |
| Benzene                    | organic   |                     | 1.00E-02           | Former EQS         |                              |                    |  | 1.16E-01                         | 1.78E+03           | 1.83E+00                               | 2.13E+00    |                                 | SR7                  |         |
| Toluene                    | organic   |                     | 7.40E-02           |                    |                              |                    |  | 1.15E-01                         | 5.90E+02           | 2.31E+00                               | 2.73E+00    |                                 | SR7                  |         |
| Ethylbenzene               | organic   |                     | 2.00E-02           |                    |                              |                    |  | 1.39E-01                         | 1.80E+02           | 2.65E+00                               | 3.15E+00    |                                 | SR7                  |         |
| m-Xylene                   | organic   |                     | 3.00E-02           |                    |                              |                    |  | 1.12E-01                         | 2.00E+02           | 2.69E+00                               | 3.20E+00    |                                 | SR7                  |         |
| o-Xylene                   | organic   |                     | 3.00E-02           |                    |                              |                    |  | 9.20E-02                         | 1.73E+02           | 2.63E+00                               | 3.12E+00    |                                 | SR7                  |         |
| p-Xylene                   | organic   |                     | 3.00E-02           |                    |                              |                    |  | 1.07E-01                         | 2.00E+02           | 2.65E+00                               | 3.15E+00    |                                 | SR7                  |         |
| Benzo[a]anthracene         | organic   |                     | 2.00E-03           | EQS Naphthalene    |                              |                    |  | 3.16E-05                         | 3.80E-03           | 4.89E+00                               | 5.91E+00    |                                 | SR7                  |         |
| Benzo[b]fluoranthene       | organic   |                     | 3.00E-05           | EQS Naphthalene    |                              |                    |  | 2.05E-06                         | 2.00E-03           | 5.02E+00                               | 6.08E+00    |                                 | SR7                  |         |
| Benzo[k]fluoranthene       | organic   |                     | 3.00E-05           |                    |                              |                    |  | 1.74E-06                         | 8.00E-04           | 5.17E+00                               | 6.26E+00    |                                 | SR7                  |         |
| Benzo[ghi]perylene         | organic   |                     | 2.00E-06           |                    |                              |                    |  | 2.36E-06                         | 2.64E-04           | 5.62E+00                               | 6.81E+00    |                                 | SR7                  |         |
| Benzo[a]pyrene             | organic   |                     | 1.70E-07           |                    |                              |                    |  | 1.76E-06                         | 3.80E-03           | 5.11E+00                               | 6.18E+00    |                                 | SR7                  |         |
| Chrysene                   | organic   |                     | 2.00E-03           |                    |                              |                    |  | 3.18E-06                         | 2.00E-03           | 4.74E+00                               | 5.73E+00    |                                 | SR7                  |         |
| Dibenz[ah]anthracene       | organic   |                     | 2.00E-03           |                    |                              |                    |  | 5.40E-06                         | 6.00E-04           | 5.27E+00                               | 6.38E+00    |                                 | SR7                  |         |
| Fluoranthene               | organic   |                     | 6.30E-06           |                    |                              |                    |  | 6.29E-05                         | 2.30E-01           | 4.26E+00                               | 5.13E+00    |                                 | SR7                  |         |
| Indeno[123-cd]pyrene       | organic   |                     | 2.00E-06           |                    |                              |                    |  | 2.05E-06                         | 2.00E-04           | 4.94E+00                               | 5.97E+00    |                                 | SR7                  |         |
| Naphthalene                | organic   |                     | 2.00E-03           |                    |                              |                    |  | 6.62E-03                         | 1.90E+01           | 2.81E+00                               | 3.34E+00    |                                 | SR7                  |         |
| Pyrene                     | organic   |                     | 2.00E-03           |                    |                              |                    |  | 5.64E-05                         | 1.30E-01           | 4.21E+00                               | 5.08E+00    |                                 | SR7                  |         |
| Acenaphthalene             | organic   |                     | 2.00E-03           |                    |                              |                    |  | 3.40E-03                         | 1.61E+01           | 3.40E+00                               | 4.00E+00    |                                 | TR1                  |         |
| Acenaphthene               | organic   |                     | 2.00E-03           |                    |                              |                    |  | 4.90E-03                         | 3.80E+00           | 3.90E+00                               | 3.90E+00    |                                 | TR1                  |         |
| Fluorene                   | organic   |                     | 2.00E-03           |                    |                              |                    |  | 3.20E-03                         | 1.90E+00           | 4.10E+00                               | 4.20E+00    |                                 | TR1                  |         |
| Phenanthrene               | organic   |                     | 2.00E-03           |                    |                              |                    |  | 1.30E-03                         | 1.10E+00           | 4.40E+00                               | 4.60E+00    |                                 | TR1                  |         |
| Anthracene                 | organic   |                     | 1.00E-04           |                    |                              |                    |  | 1.60E-03                         | 4.50E-02           | 4.50E+00                               | 4.50E+00    |                                 | TR1                  |         |
| Phenol                     | organic   |                     | 7.70E-03           |                    |                              |                    |  |                                  | 8.35E-06           | 8.41E+04                               | 1.46E+00    | 1.48E+00                        |                      | SR7/LQM |
| TPH Aliphatic C8-C10       | organic   |                     | 1.00E-02           |                    |                              |                    |  |                                  | 4.15E+01           | 4.30E-01                               | 4.50E+00    | 5.20E+00                        |                      | LQM     |
| TPH Aliphatic C10-C12      | organic   |                     | 1.00E-02           |                    |                              |                    |  |                                  | 6.44E+01           | 3.40E-02                               | 5.40E+00    | 6.30E+00                        |                      | LQM     |
| TPH Aliphatic C12-C16      | organic   |                     | 1.00E-02           |                    |                              |                    |  | 1.71E+02                         | 7.60E-04           | 6.70E+00                               | 7.90E+00    |                                 | LQM                  |         |
| TPH Aliphatic C16-C21      | organic   |                     | 1.00E-02           |                    |                              |                    |  | 1.07E+03                         | 2.50E-06           | 8.80E+00                               | 1.04E+01    |                                 | LQM                  |         |
| TPH Aliphatic C21-C34      | organic   |                     | 1.00E-02           |                    |                              |                    |  | 1.07E+03                         | 2.50E-06           | 8.80E+00                               | 1.04E+01    |                                 | LQM                  |         |
| TPH Aliphatic C35-C44      | organic   |                     | 1.00E-02           |                    |                              |                    |  | 1.07E+03                         | 2.50E-06           | 8.80E+00                               | 1.04E+01    |                                 | LQM                  |         |
| TPH Aromatic C8-C10        | organic   |                     | 1.00E-02           |                    |                              |                    |  | 2.53E-01                         | 6.50E+01           | 3.20E+00                               | 3.70E+00    |                                 | LQM                  |         |
| TPH Aromatic C10-C12       | organic   |                     | 1.00E-02           |                    |                              |                    |  | 7.22E-02                         | 2.50E+01           | 3.40E+00                               | 3.90E+00    |                                 | LQM                  |         |
| TPH Aromatic C12-C16       | organic   |                     | 1.00E-02           |                    |                              |                    |  | 1.26E-02                         | 5.80E+00           | 3.70E+00                               | 4.30E+00    |                                 | LQM                  |         |
| TPH Aromatic C16-C21       | organic   |                     | 1.00E-02           |                    |                              |                    |  | 6.95E-04                         | 6.50E-01           | 4.20E+00                               | 4.90E+00    |                                 | LQM                  |         |
| TPH Aromatic C21-C35       | organic   |                     | 1.00E-02           |                    |                              |                    |  | 2.48E-05                         | 6.60E-03           | 5.10E+00                               | 6.00E+00    |                                 | LQM                  |         |
| TPH Aromatic C35-C44       | organic   |                     | 1.00E-02           |                    |                              |                    |  | 2.48E-05                         | 6.60E-03           | 5.10E+00                               | 6.00E+00    |                                 | LQM                  |         |
| Arsenic                    | inorganic |                     | 5.00E-02           | DWS                |                              |                    |  |                                  |                    | 1.25E+06                               |             |                                 | 1.80E+03             | RIVM    |
| Cadmium                    | inorganic |                     | 2.50E-04           |                    |                              |                    |  |                                  |                    | 1.62E+06                               |             |                                 | 2.56E+03             | RIVM    |
| Copper                     | inorganic |                     | 2.80E-02           |                    |                              |                    |  |                                  | 1.38E+06           |                                        |             | 2.12E+03                        | RIVM                 |         |
| Chromium                   | inorganic |                     | 2.00E-02           |                    |                              |                    |  |                                  | 5.85E+05           |                                        |             | 4.80E+03                        | RIVM                 |         |
| Lead                       | inorganic |                     | 7.20E-03           |                    |                              |                    |  |                                  |                    |                                        |             | 3.60E+04                        | RIVM                 |         |
| Inorganic Mercury          | inorganic |                     | 5.00E-05           |                    |                              |                    |  |                                  | 7.40E+04           |                                        |             | 7.50E+03                        | RIVM                 |         |
| Nickel                     | inorganic |                     | 2.00E-02           |                    |                              |                    |  |                                  | 2.50E+06           |                                        |             | 2.00E+03                        | RIVM                 |         |
| Selenium                   | inorganic |                     | 1.00E-02           |                    |                              |                    |  |                                  | 2.17E+06           |                                        |             | 5.00E+01                        | EA SGV Report        |         |
| Zinc                       | inorganic |                     | 3.40E-02           |                    |                              |                    |  | 4.32E+06                         |                    |                                        | 2.60E+03    | RIVM                            |                      |         |
| Hexavalent Chromium        | inorganic |                     | 3.40E-03           | Note Marine 0.0006 |                              |                    |  |                                  | 2.30E+06           |                                        |             | 1.80E+01                        | LQM                  |         |
| Trivalent Chromium         | inorganic |                     | 4.70E-03           |                    |                              |                    |  |                                  | 5.85E+05           |                                        |             | 4.80E+03                        | LQM                  |         |
| Easily Liberatable Cyanide | inorganic |                     | 1.00E-03           | Derived DWS        |                              |                    |  |                                  |                    |                                        |             | 1.00E+00                        | Arbitrary Low Number |         |
| Total Cyanide              | inorganic |                     | 1.40E+01           |                    |                              |                    |  |                                  |                    |                                        |             |                                 | 9.90E+00             | USEPA   |



Remedial Targets Worksheet

|           |         |      |                          |  |  |
|-----------|---------|------|--------------------------|--|--|
| Site Name | Arundel | Case | 1 15 by 15 m Source Zone |  |  |
|-----------|---------|------|--------------------------|--|--|

Level 1 - Soil

| Soil Parameters                      |                 |          |                   | Source of parameter value |  |
|--------------------------------------|-----------------|----------|-------------------|---------------------------|--|
| Total Porosity                       | n               | 0.53     | fraction          | CLEA Sandy Loam           |  |
| Fraction of organic carbon (in soil) | f <sub>oc</sub> | 1.75E-02 | fraction          | Reasonable Site Average   |  |
| Water filled soil porosity           | θ <sub>w</sub>  | 0.33     | fraction          | CLEA Sandy Loam           |  |
| Air filled soil porosity             | θ <sub>a</sub>  | 0.2      | fraction          | CLEA Sandy Loam           |  |
| Bulk density of soil zone material   | ρ               | 1.21     | g/cm <sup>3</sup> | CLEA Sandy Loam           |  |

 = Target Exceeds Solubility

| Level 1 Remedial Targets   |                                 |              |          |                   |                                                                                      |                                   |     |                                    |     |
|----------------------------|---------------------------------|--------------|----------|-------------------|--------------------------------------------------------------------------------------|-----------------------------------|-----|------------------------------------|-----|
| Substance                  | Kd                              | Soil (mg/kg) |          | Pore Water (mg/l) |                                                                                      | Soil Level Exceeds Level 1 Target |     | Water Level Exceeds Level 1 Target |     |
|                            |                                 | DWS          | EQS      | DWS               | EQS                                                                                  | DWS                               | EQS | DWS                                | EQS |
|                            | dm <sup>3</sup> g <sup>-1</sup> |              |          |                   |                                                                                      |                                   |     |                                    |     |
| Benzene                    | 1.18E+00                        |              | 1.48E-02 |                   | 1.00E-02                                                                             |                                   |     |                                    |     |
| Toluene                    | 3.57E+00                        |              | 2.86E-01 |                   | 7.40E-02                                                                             |                                   |     |                                    |     |
| Ethylbenzene               | 7.82E+00                        |              | 1.62E-01 |                   | 2.00E-02                                                                             |                                   |     |                                    |     |
| m-Xylene                   | 8.57E+00                        |              | 2.66E-01 |                   | 3.00E-02                                                                             |                                   |     |                                    |     |
| o-Xylene                   | 7.47E+00                        |              | 2.33E-01 |                   | 3.00E-02                                                                             |                                   |     |                                    |     |
| p-Xylene                   | 7.82E+00                        |              | 2.43E-01 |                   | 3.00E-02                                                                             |                                   |     |                                    |     |
| Benzo[a]anthracene         | 1.36E+03                        |              | 2.72E+00 |                   | 2.00E-03                                                                             |                                   |     |                                    |     |
| Benzo[b]fluoranthene       | 1.83E+03                        |              | 5.50E-02 |                   | 3.00E-05                                                                             |                                   |     |                                    |     |
| Benzo[k]fluoranthene       | 2.59E+03                        |              | 7.77E-02 |                   | 3.00E-05                                                                             |                                   |     |                                    |     |
| Benzo[ghi]perylene         | 7.30E+03                        |              | 1.46E-02 |                   | 2.00E-06                                                                             |                                   |     |                                    |     |
| Benzo[a]pyrene             | 2.25E+03                        |              | 3.83E-04 |                   | 1.70E-07                                                                             |                                   |     |                                    |     |
| Chrysene                   | 9.62E+02                        |              | 1.92E+00 |                   | 2.00E-03                                                                             |                                   |     |                                    |     |
| Dibenz[ah]anthracene       | 3.26E+03                        |              | 6.52E+00 |                   |  |                                   |     |                                    |     |
| Fluoranthene               | 3.18E+02                        |              | 2.01E-03 |                   | 6.30E-06                                                                             |                                   |     |                                    |     |
| Indeno[123-cd]pyrene       | 1.52E+03                        |              | 3.05E-03 |                   | 2.00E-06                                                                             |                                   |     |                                    |     |
| Naphthalene                | 1.13E+01                        |              | 2.31E-02 |                   | 2.00E-03                                                                             |                                   |     |                                    |     |
| Pyrene                     | 2.84E+02                        |              | 5.68E-01 |                   | 2.00E-03                                                                             |                                   |     |                                    |     |
| Acenaphthalene             | 4.40E+01                        |              | 8.85E-02 |                   | 2.00E-03                                                                             |                                   |     |                                    |     |
| Acenaphthene               | 1.39E+02                        |              | 2.79E-01 |                   | 2.00E-03                                                                             |                                   |     |                                    |     |
| Fluorene                   | 2.20E+02                        |              | 4.41E-01 |                   | 2.00E-03                                                                             |                                   |     |                                    |     |
| Phenanthrene               | 4.40E+02                        |              | 8.80E-01 |                   | 2.00E-03                                                                             |                                   |     |                                    |     |
| Anthracene                 | 5.53E+02                        |              | 5.54E-02 |                   | 1.00E-04                                                                             |                                   |     |                                    |     |
| Phenol                     | 5.05E-01                        |              | 5.99E-03 |                   | 7.70E-03                                                                             |                                   |     |                                    |     |
| TPH Aliphatic C8-C10       | 5.53E+02                        |              | 5.61E+00 |                   | 1.00E-02                                                                             |                                   |     |                                    |     |
| TPH Aliphatic C10-C12      | 4.40E+03                        |              | 4.41E+01 |                   | 1.00E-02                                                                             |                                   |     |                                    |     |
| TPH Aliphatic C12-C16      | 8.77E+04                        |              | 8.77E+02 |                   |  |                                   |     |                                    |     |
| TPH Aliphatic C16-C21      | 1.10E+07                        |              | 1.10E+05 |                   |  |                                   |     |                                    |     |
| TPH Aliphatic C21-C34      | 1.10E+07                        |              | 1.10E+05 |                   |  |                                   |     |                                    |     |
| TPH Aliphatic C35-C44      | 1.10E+07                        |              | 1.10E+05 |                   |  |                                   |     |                                    |     |
| TPH Aromatic C8-C10        | 2.77E+01                        |              | 2.81E-01 |                   | 1.00E-02                                                                             |                                   |     |                                    |     |
| TPH Aromatic C10-C12       | 4.40E+01                        |              | 4.42E-01 |                   | 1.00E-02                                                                             |                                   |     |                                    |     |
| TPH Aromatic C12-C16       | 8.77E+01                        |              | 8.80E-01 |                   | 1.00E-02                                                                             |                                   |     |                                    |     |
| TPH Aromatic C16-C21       | 2.77E+02                        |              | 2.78E+00 |                   | 1.00E-02                                                                             |                                   |     |                                    |     |
| TPH Aromatic C21-C35       | 2.20E+03                        |              | 2.20E+01 |                   |  |                                   |     |                                    |     |
| TPH Aromatic C35-C44       | 2.20E+03                        |              | 2.20E+01 |                   |  |                                   |     |                                    |     |
| Arsenic                    | 1.80E+03                        |              | 9.00E+01 |                   | 5.00E-02                                                                             |                                   |     |                                    |     |
| Cadmium                    | 2.56E+03                        |              | 6.40E-01 |                   | 2.50E-04                                                                             |                                   |     |                                    |     |
| Copper                     | 2.12E+03                        |              | 5.94E+01 |                   | 2.80E-02                                                                             |                                   |     |                                    |     |
| Chromium                   | 4.80E+03                        |              | 9.60E+01 |                   | 2.00E-02                                                                             |                                   |     |                                    |     |
| Lead                       | 3.60E+04                        |              | 2.59E+02 |                   | 7.20E-03                                                                             |                                   |     |                                    |     |
| Inorganic Mercury          | 7.50E+03                        |              | 3.75E-01 |                   | 5.00E-05                                                                             |                                   |     |                                    |     |
| Nickel                     | 2.00E+03                        |              | 4.00E+01 |                   | 2.00E-02                                                                             |                                   |     |                                    |     |
| Selenium                   | 5.00E+01                        |              | 5.03E-01 |                   | 1.00E-02                                                                             |                                   |     |                                    |     |
| Zinc                       | 2.60E+03                        |              | 8.84E+01 |                   | 3.40E-02                                                                             |                                   |     |                                    |     |
| Hexavalent Chromium        | 1.80E+01                        |              | 6.21E-02 |                   | 3.40E-03                                                                             |                                   |     |                                    |     |
| Trivalent Chromium         | 4.80E+03                        |              | 2.26E+01 |                   | 4.70E-03                                                                             |                                   |     |                                    |     |
| Easily Liberatable Cyanide | 1.00E+00                        |              | 1.27E-03 |                   | 1.00E-03                                                                             |                                   |     |                                    |     |
| Total Cyanide              | 9.90E+00                        |              | 1.42E+02 |                   | 1.40E+01                                                                             |                                   |     |                                    |     |

Remedial Targets Worksheet

|            |         |       |                          |
|------------|---------|-------|--------------------------|
| Site Name: | Arundel | Case: | 1 15 by 15 m Source Zone |
|------------|---------|-------|--------------------------|

Level 2 - Soil (Afu = 1)

| Site Parameters                        |          |          |     | Source of parameter value |                 |             |  |
|----------------------------------------|----------|----------|-----|---------------------------|-----------------|-------------|--|
| Infiltration:                          | 8.20E-04 | m/d      | Inf | 300 mm/year               | Calculated:     |             |  |
| Saturated aquifer thickness:           | 50       | m        | da  | See Text Discussion       | Transmissivity: | 43200       |  |
| Mixing Zone thickness:                 | 1.59E+00 | m        | Mz  | Calculated                | DF (Cu = 0):    | 2.81E+02    |  |
| Hydraulic Gradient:                    | 2.50E-03 | fraction | I   | See Text Discussion       | Q = k.i.Mz:     | 3.441192999 |  |
| Hydraulic conductivity of aquifer:     | 8.64E+02 | m/d      | K   | See Text Discussion       | L.inf:          | 1.23E-02    |  |
| Length of source in direction of flow: | 15       | m        | L   | Site Dimension            |                 |             |  |

 = Target Exceeds Solubility

| Level 2 Remedial Targets   |            |                 |          |              |          |                   |          |                                   |     |                                    |     |
|----------------------------|------------|-----------------|----------|--------------|----------|-------------------|----------|-----------------------------------|-----|------------------------------------|-----|
| Substance                  | Background | Dilution Factor |          | Soil (mg/kg) |          | Pore Water (mg/l) |          | Soil Level Exceeds Level 2 Target |     | Water Level Exceeds Level 2 Target |     |
|                            | Cu         | DWS             | EQS      | DWS          | EQS      | DWS               | EQS      | DWS                               | EQS | DWS                                | EQS |
| Benzene                    | 0          |                 | 2.81E+02 |              | 4.14E+00 |                   | 2.81E+00 |                                   |     |                                    |     |
| Toluene                    | 0          |                 | 2.81E+02 |              | 8.03E+01 |                   | 2.08E+01 |                                   |     |                                    |     |
| Ethylbenzene               | 0          |                 | 2.81E+02 |              | 4.56E+01 |                   | 5.62E+00 |                                   |     |                                    |     |
| m-Xylene                   | 0          |                 | 2.81E+02 |              | 7.46E+01 |                   | 8.42E+00 |                                   |     |                                    |     |
| o-Xylene                   | 0          |                 | 2.81E+02 |              | 6.53E+01 |                   | 8.42E+00 |                                   |     |                                    |     |
| p-Xylene                   | 0          |                 | 2.81E+02 |              | 6.83E+01 |                   | 8.42E+00 |                                   |     |                                    |     |
| Benzo[a]anthracene         | 0          |                 | 2.81E+02 |              | 7.63E+02 |                   | 5.62E-01 |                                   |     |                                    |     |
| Benzo[b]fluoranthene       | 0          |                 | 2.81E+02 |              | 1.54E+01 |                   | 5.62E-03 |                                   |     |                                    |     |
| Benzo[k]fluoranthene       | 0          |                 | 2.81E+02 |              | 2.18E+01 |                   | 5.62E-03 |                                   |     |                                    |     |
| Benzo[ghi]perylene         | 0          |                 | 2.81E+02 |              | 4.10E+00 |                   | 5.62E-04 |                                   |     |                                    |     |
| Benzo[a]pyrene             | 0          |                 | 2.81E+02 |              | 1.08E-01 |                   | 4.77E-05 |                                   |     |                                    |     |
| Chrysene                   | 0          |                 | 2.81E+02 |              | 5.40E+02 |                   | 5.62E-01 |                                   |     |                                    |     |
| Dibenz[ah]anthracene       | 0          |                 | 2.81E+02 |              | 1.83E+03 |                   | 5.62E-01 |                                   |     |                                    |     |
| Fluoranthene               | 0          |                 | 2.81E+02 |              | 5.64E-01 |                   | 1.77E-03 |                                   |     |                                    |     |
| Indeno[123-cd]pyrene       | 0          |                 | 2.81E+02 |              | 8.56E-01 |                   | 5.62E-04 |                                   |     |                                    |     |
| Naphthalene                | 0          |                 | 2.81E+02 |              | 6.50E+00 |                   | 5.62E-01 |                                   |     |                                    |     |
| Pyrene                     | 0          |                 | 2.81E+02 |              | 1.60E+02 |                   | 5.62E-01 |                                   |     |                                    |     |
| Acenaphthalene             | 0          |                 | 2.81E+02 |              | 2.48E+01 |                   | 5.62E-01 |                                   |     |                                    |     |
| Acenaphthene               | 0          |                 | 2.81E+02 |              | 7.82E+01 |                   | 5.62E-01 |                                   |     |                                    |     |
| Fluorene                   | 0          |                 | 2.81E+02 |              | 1.24E+02 |                   | 5.62E-01 |                                   |     |                                    |     |
| Phenanthrene               | 0          |                 | 2.81E+02 |              | 2.47E+02 |                   | 5.62E-01 |                                   |     |                                    |     |
| Anthracene                 | 0          |                 | 2.81E+02 |              | 1.55E+01 |                   | 2.81E-02 |                                   |     |                                    |     |
| Phenol                     | 0          |                 | 2.81E+02 |              | 1.68E+00 |                   | 2.16E+00 |                                   |     |                                    |     |
| TPH Aliphatic C8-C10       | 0          |                 | 2.81E+02 |              | 1.57E+03 |                   | 2.81E+00 |                                   |     |                                    |     |
| TPH Aliphatic C10-C12      | 0          |                 | 2.81E+02 |              | 1.24E+04 |                   | 2.81E+00 |                                   |     |                                    |     |
| TPH Aliphatic C12-C16      | 0          |                 | 2.81E+02 |              | 2.46E+05 |                   | 2.81E+00 |                                   |     |                                    |     |
| TPH Aliphatic C16-C21      | 0          |                 | 2.81E+02 |              | 3.10E+07 |                   | 2.81E+00 |                                   |     |                                    |     |
| TPH Aliphatic C21-C34      | 0          |                 | 2.81E+02 |              | 3.10E+07 |                   | 2.81E+00 |                                   |     |                                    |     |
| TPH Aliphatic C35-C44      | 0          |                 | 2.81E+02 |              | 3.10E+07 |                   | 2.81E+00 |                                   |     |                                    |     |
| TPH Aromatic C8-C10        | 0          |                 | 2.81E+02 |              | 7.88E+01 |                   | 2.81E+00 |                                   |     |                                    |     |
| TPH Aromatic C10-C12       | 0          |                 | 2.81E+02 |              | 1.24E+02 |                   | 2.81E+00 |                                   |     |                                    |     |
| TPH Aromatic C12-C16       | 0          |                 | 2.81E+02 |              | 2.47E+02 |                   | 2.81E+00 |                                   |     |                                    |     |
| TPH Aromatic C16-C21       | 0          |                 | 2.81E+02 |              | 7.80E+02 |                   | 2.81E+00 |                                   |     |                                    |     |
| TPH Aromatic C21-C35       | 0          |                 | 2.81E+02 |              | 6.19E+03 |                   | 2.81E+00 |                                   |     |                                    |     |
| TPH Aromatic C35-C44       | 0          |                 | 2.81E+02 |              | 6.19E+03 |                   | 2.81E+00 |                                   |     |                                    |     |
| Arsenic                    | 0          |                 | 2.81E+02 |              | 2.53E+04 |                   | 1.40E+01 |                                   |     |                                    |     |
| Cadmium                    | 0          |                 | 2.81E+02 |              | 1.80E+02 |                   | 7.02E-02 |                                   |     |                                    |     |
| Copper                     | 0          |                 | 2.81E+02 |              | 1.67E+04 |                   | 7.86E+00 |                                   |     |                                    |     |
| Chromium                   | 0          |                 | 2.81E+02 |              | 2.70E+04 |                   | 5.62E+00 |                                   |     |                                    |     |
| Lead                       | 0          |                 | 2.81E+02 |              | 7.28E+04 |                   | 2.02E+00 |                                   |     |                                    |     |
| Inorganic Mercury          | 0          |                 | 2.81E+02 |              | 1.05E+02 |                   | 1.40E-02 |                                   |     |                                    |     |
| Nickel                     | 0          |                 | 2.81E+02 |              | 1.12E+04 |                   | 5.62E+00 |                                   |     |                                    |     |
| Selenium                   | 0          |                 | 2.81E+02 |              | 1.41E+02 |                   | 2.81E+00 |                                   |     |                                    |     |
| Zinc                       | 0          |                 | 2.81E+02 |              | 2.48E+04 |                   | 9.55E+00 |                                   |     |                                    |     |
| Hexavalent Chromium        | 0          |                 | 2.81E+02 |              | 1.74E+01 |                   | 9.55E-01 |                                   |     |                                    |     |
| Trivalent Chromium         | 0          |                 | 2.81E+02 |              | 6.33E+03 |                   | 1.32E+00 |                                   |     |                                    |     |
| Easily Liberatable Cyanide | 0          |                 | 2.81E+02 |              | 3.57E-01 |                   | 2.81E-01 |                                   |     |                                    |     |
| Total Cyanide              | 0          |                 | 2.81E+02 |              | 4.00E+04 |                   | 3.93E+03 |                                   |     |                                    |     |

Remedial Targets Worksheet

|            |         |       |                          |
|------------|---------|-------|--------------------------|
| Site Name: | Arundel | Case: | 1 15 by 15 m Source Zone |
|------------|---------|-------|--------------------------|

Level 3 - Soil - Domenico Steady State Equation

| Site Parameters                                    |        |                   |    | Source of parameter value |                                                |             |  |
|----------------------------------------------------|--------|-------------------|----|---------------------------|------------------------------------------------|-------------|--|
| Bulk density of aquifer materials:                 | 1.9    | g/cm <sup>3</sup> | ρ  | See Text Discussion       | Calculated or from Level 2:                    |             |  |
| Effective porosity of aquifer:                     | 0.1    | fraction          | n  | "                         | Hydraulic Gradient:                            | 2.51E-03    |  |
| Distance to compliance point from source boundary: | 90     | m                 | "  | "                         | Hydraulic Conductivity:                        | 864         |  |
| Width of plume at source:                          | 15     | m                 | Sz | "                         | Mz = Sy                                        | 1.593144907 |  |
| Fraction of organic carbon in aquifer:             | 0.0001 |                   |    | "                         | Length of source                               | 15          |  |
|                                                    | 9.75   |                   | ax | "                         | Distance from centre of source to compliance x | 97.5        |  |
|                                                    | 0.975  |                   | az | "                         |                                                |             |  |
|                                                    | 0.0975 |                   | ay | "                         |                                                |             |  |

= Target Exceeds Solubility

| Level 3 Remedial Targets   |                   |          |                                   |          |           |           |          |          |          |              |          |                   |          |
|----------------------------|-------------------|----------|-----------------------------------|----------|-----------|-----------|----------|----------|----------|--------------|----------|-------------------|----------|
| Substance                  | Kd                | Rf       | Apply Decay                       | u        | Half Life |           | λ        | ced/co   | AF       | Soil (mg/kg) |          | Pore Water (mg/l) |          |
|                            | g/cm <sup>3</sup> | fraction | 1 =<br>Dissolved<br>Phase<br>Only | m/d      | days      | Reference | 1/d      | fraction | fraction | DWS          | EQS      | DWS               | EQS      |
| Benzene                    | 6.76E-03          | 1.13E+00 |                                   | 1.92E+01 | 350       | P2-228    | 1.98E-03 | 1.17E-01 | 8.57E+00 |              | 3.55E+01 |                   | 2.41E+01 |
| Toluene                    | 2.04E-02          | 1.39E+00 |                                   | 1.56E+01 | 200       | P2-228    | 3.47E-03 | 1.15E-01 | 8.67E+00 |              | 6.96E+02 |                   | 1.80E+02 |
| Ethylbenzene               | 4.47E-02          | 1.85E+00 |                                   | 1.17E+01 | 200       | P2-228    | 3.47E-03 | 1.15E-01 | 8.73E+00 |              | 3.98E+02 |                   | 4.90E+01 |
| m-Xylene                   | 4.90E-02          | 1.93E+00 |                                   | 1.12E+01 | 200       | P2-228    | 3.47E-03 | 1.14E-01 | 8.74E+00 |              | 6.52E+02 |                   | 7.36E+01 |
| o-Xylene                   | 4.27E-02          | 1.81E+00 |                                   | 1.20E+01 | 200       | P2-228    | 3.47E-03 | 1.15E-01 | 8.72E+00 |              | 5.70E+02 |                   | 7.35E+01 |
| p-Xylene                   | 4.47E-02          | 1.85E+00 |                                   | 1.17E+01 | 200       | P2-228    | 3.47E-03 | 1.15E-01 | 8.73E+00 |              | 5.96E+02 |                   | 7.35E+01 |
| Benzo[a]anthracene         | 7.76E+00          | 1.48E+02 |                                   | 1.46E-01 | 3650      | See Text  | 1.90E-04 | 1.04E-01 | 9.61E+00 |              | 7.33E+03 |                   | 5.40E+00 |
| Benzo[b]fluoranthene       | 1.05E+01          | 2.00E+02 |                                   | 1.08E-01 | 3650      | See Text  | 1.90E-04 | 9.97E-02 | 1.00E+01 |              | 1.55E+02 |                   | 8.45E-02 |
| Benzo[k]fluoranthene       | 1.48E+01          | 2.82E+02 |                                   | 7.69E-02 | 3650      | See Text  | 1.90E-04 | 9.32E-02 | 1.07E+01 |              | 2.34E+02 |                   | 9.04E-02 |
| Benzo[ghi]perylene         | 4.17E+01          | 7.93E+02 |                                   | 2.73E-02 | 3650      | See Text  | 1.90E-04 | 6.24E-02 | 1.60E+01 |              | 6.57E+01 |                   | 9.00E-03 |
| Benzo[a]pyrene             | 1.29E+01          | 2.46E+02 |                                   | 8.82E-02 | 3650      | See Text  | 1.90E-04 | 9.60E-02 | 1.04E+01 |              | 1.12E+00 |                   | 4.97E-04 |
| Chrysene                   | 5.50E+00          | 1.05E+02 |                                   | 2.06E-01 | 3650      | See Text  | 1.90E-04 | 1.08E-01 | 9.27E+00 |              | 5.01E+03 |                   | 5.21E+00 |
| Dibenz[ah]anthracene       | 1.86E+01          | 3.55E+02 |                                   | 6.11E-02 | 3650      | See Text  | 1.90E-04 | 8.78E-02 | 1.14E+01 |              | 2.08E+04 |                   | 6.39E+00 |
| Fluoranthene               | 1.82E+00          | 3.56E+01 |                                   | 6.09E-01 | 3650      | See Text  | 1.90E-04 | 1.14E-01 | 8.74E+00 |              | 4.93E+00 |                   | 1.55E-02 |
| Indeno[123-cd]pyrene       | 8.71E+00          | 1.66E+02 |                                   | 1.30E-01 | 3650      | See Text  | 1.90E-04 | 1.02E-01 | 9.76E+00 |              | 8.35E+00 |                   | 5.48E-03 |
| Naphthalene                | 6.46E-02          | 2.23E+00 |                                   | 9.73E+00 | 300       | P2-228    | 2.31E-03 | 1.15E-01 | 8.68E+00 |              | 5.64E+01 |                   | 4.87E+00 |
| Pyrene                     | 1.62E+00          | 3.18E+01 |                                   | 6.81E-01 | 3650      | See Text  | 1.90E-04 | 1.15E-01 | 8.71E+00 |              | 1.39E+03 |                   | 4.69E+00 |
| Acenaphthalene             | 2.51E-01          | 5.77E+00 |                                   | 3.76E+00 | 3650      | See Text  | 1.90E-04 | 1.17E-01 | 8.52E+00 |              | 2.12E+02 |                   | 4.79E+00 |
| Acenaphthene               | 7.94E-01          | 1.61E+01 |                                   | 1.35E+00 | 3.65E+03  | See Text  | 1.90E-04 | 1.16E-01 | 8.60E+00 |              | 6.72E+02 |                   | 4.63E+00 |
| Fluorene                   | 1.26E+00          | 2.49E+01 |                                   | 8.70E-01 | 3.65E+03  | See Text  | 1.90E-04 | 1.15E-01 | 8.66E+00 |              | 1.07E+03 |                   | 4.66E+00 |
| Phenanthrene               | 2.51E+00          | 4.87E+01 |                                   | 4.45E-01 | 3.65E+03  | See Text  | 1.90E-04 | 1.13E-01 | 8.84E+00 |              | 2.18E+03 |                   | 4.96E+00 |
| Anthracene                 | 3.16E+00          | 6.11E+01 |                                   | 3.55E-01 | 3.65E+03  | See Text  | 1.90E-04 | 1.12E-01 | 8.93E+00 |              | 1.39E+02 |                   | 2.51E-01 |
| Phenol                     | 2.88E-03          | 1.05E+00 |                                   | 2.06E+01 | 1.00E+02  | P2-228    | 6.93E-03 | 1.14E-01 | 8.76E+00 |              | 1.47E+01 |                   | 1.89E+01 |
| TPH Aliphatic C8-C10       | 3.16E+00          | 6.11E+01 |                                   | 3.55E-01 | 7.00E+02  | See Text  | 9.90E-04 | 9.05E-02 | 1.11E+01 |              | 1.74E+04 |                   | 3.10E+01 |
| TPH Aliphatic C10-C12      | 2.51E+01          | 4.78E+02 |                                   | 4.53E-02 | 1.75E+03  | See Text  | 3.96E-04 | 5.35E-02 | 1.87E+01 |              | 2.31E+05 |                   | 5.24E+01 |
| TPH Aliphatic C12-C16      | 5.01E+02          | 9.52E+03 |                                   | 2.28E-03 | 2.45E+03  | See Text  | 2.83E-04 | 9.82E-05 | 1.02E+04 |              | 2.51E+09 |                   | 2.96E+04 |
| TPH Aliphatic C16-C21      | 6.31E+04          | 1.20E+06 |                                   | 1.81E-05 | 3.50E+03  | See Text  | 1.98E-04 | 2.05E-44 | 4.88E+43 |              | 1.51E+51 |                   | 1.37E+44 |
| TPH Aliphatic C21-C34      | 6.31E+04          | 1.20E+06 |                                   | 1.81E-05 | 3.50E+03  | See Text  | 1.98E-04 | 2.05E-44 | 4.88E+43 |              | 1.51E+51 |                   | 1.37E+44 |
| TPH Aliphatic C35-C44      | 6.31E+04          | 1.20E+06 |                                   | 1.81E-05 | 3.50E+03  | See Text  | 1.98E-04 | 2.05E-44 | 4.88E+43 |              | 1.51E+51 |                   | 1.37E+44 |
| TPH Aromatic C8-C10        | 1.58E-01          | 4.01E+00 |                                   | 5.40E+00 | 7.00E+02  | See Text  | 9.90E-04 | 1.16E-01 | 8.63E+00 |              | 6.80E+02 |                   | 2.42E+01 |
| TPH Aromatic C10-C12       | 2.51E-01          | 5.77E+00 |                                   | 3.76E+00 | 1.75E+03  | See Text  | 3.96E-04 | 1.17E-01 | 8.57E+00 |              | 1.06E+03 |                   | 2.41E+01 |
| TPH Aromatic C12-C16       | 5.01E-01          | 1.05E+01 |                                   | 2.06E+00 | 2.45E+03  | See Text  | 2.83E-04 | 1.16E-01 | 8.59E+00 |              | 2.12E+03 |                   | 2.41E+01 |
| TPH Aromatic C16-C21       | 1.58E+00          | 3.11E+01 |                                   | 6.97E-01 | 3.50E+03  | See Text  | 1.98E-04 | 1.15E-01 | 8.72E+00 |              | 6.80E+03 |                   | 2.45E+01 |
| TPH Aromatic C21-C35       | 1.26E+01          | 2.40E+02 |                                   | 9.02E-02 | 3.50E+03  | See Text  | 1.98E-04 | 9.56E-02 | 1.05E+01 |              | 6.47E+04 |                   | 2.94E+01 |
| TPH Aromatic C35-C44       | 1.26E+01          | 2.40E+02 |                                   | 9.02E-02 | 3500      | See Text  | 1.98E-04 | 9.56E-02 | 1.05E+01 |              | 6.47E+04 |                   | 2.94E+01 |
| Arsenic                    | 1.80E+03          | 3.42E+04 |                                   | 6.34E-04 | 9.00E+09  |           | 7.70E-11 | 1.18E-01 | 8.48E+00 |              | 2.14E+05 |                   | 1.19E+02 |
| Cadmium                    | 2.56E+03          | 4.86E+04 |                                   | 4.46E-04 | 9.00E+09  |           | 7.70E-11 | 1.18E-01 | 8.48E+00 |              | 1.52E+03 |                   | 5.95E-01 |
| Copper                     | 2.12E+03          | 4.03E+04 |                                   | 5.38E-04 | 9.00E+09  |           | 7.70E-11 | 1.18E-01 | 8.48E+00 |              | 1.41E+05 |                   | 6.67E+01 |
| Chromium                   | 4.80E+03          | 9.12E+04 |                                   | 2.38E-04 | 9.00E+09  |           | 7.70E-11 | 1.18E-01 | 8.48E+00 |              | 2.29E+05 |                   | 4.76E+01 |
| Lead                       | 3.60E+04          | 6.84E+05 |                                   | 3.17E-05 | 9.00E+09  |           | 7.70E-11 | 1.18E-01 | 8.48E+00 |              | 6.17E+05 |                   | 1.71E+01 |
| Inorganic Mercury          | 7.50E+03          | 1.43E+05 |                                   | 1.52E-04 | 9.00E+09  |           | 7.70E-11 | 1.18E-01 | 8.48E+00 |              | 8.93E+02 |                   | 1.19E-01 |
| Nickel                     | 2.00E+03          | 3.80E+04 |                                   | 5.70E-04 | 9.00E+09  |           | 7.70E-11 | 1.18E-01 | 8.48E+00 |              | 9.53E+04 |                   | 4.76E+01 |
| Selenium                   | 5.00E+01          | 9.51E+02 |                                   | 2.28E-02 | 9.00E+09  |           | 7.70E-11 | 1.18E-01 | 8.48E+00 |              | 1.20E+03 |                   | 2.38E+01 |
| Zinc                       | 2.60E+03          | 4.94E+04 |                                   | 4.39E-04 | 9.00E+09  |           | 7.70E-11 | 1.18E-01 | 8.48E+00 |              | 2.11E+05 |                   | 8.10E+01 |
| Hexavalent Chromium        | 1.80E+01          | 3.43E+02 |                                   | 6.32E-02 | 9.00E+09  |           | 7.70E-11 | 1.18E-01 | 8.48E+00 |              | 1.48E+02 |                   | 8.10E+00 |
| Trivalent Chromium         | 4.80E+03          | 9.12E+04 |                                   | 2.38E-04 | 9.00E+09  |           | 7.70E-11 | 1.18E-01 | 8.48E+00 |              | 5.37E+04 |                   | 1.12E+01 |
| Easily Liberatable Cyanide | 1.00E+00          | 2.00E+01 |                                   | 1.08E+00 | 3500      | See Text  | 1.98E-04 | 1.16E-01 | 8.63E+00 |              | 3.08E+00 |                   | 2.42E+00 |
| Total Cyanide              | 9.90E+00          | 1.89E+02 |                                   | 1.15E-01 | 3500      | See Text  | 1.98E-04 | 9.99E-02 | 1.00E+01 |              | 4.00E+05 |                   | 3.93E+04 |

Remedial Targets Worksheet

|            |         |       |                          |
|------------|---------|-------|--------------------------|
| Site Name: | Arundel | Case: | 1 15 by 15 m Source Zone |
|------------|---------|-------|--------------------------|

Level 3 - Groundwater - Domenico Steady State Equation

|                     |
|---------------------|
| Site Parameters     |
| As Per Soil Level 3 |

= Remedial Target Exceeds Solubility

| Substance                  | Measured GW        | Level 3 Remedial Targets |          |                                    |     |
|----------------------------|--------------------|--------------------------|----------|------------------------------------|-----|
|                            |                    | Groundwater (mg/l)       |          | Water Level Exceeds Level 3 Target |     |
|                            | mg L <sup>-1</sup> | DWS                      | EQS      | DWS                                | EQS |
| Benzene                    |                    |                          | 8.57E-02 |                                    |     |
| Toluene                    |                    |                          | 6.41E-01 |                                    |     |
| Ethylbenzene               |                    |                          | 1.75E-01 |                                    |     |
| m-Xylene                   |                    |                          | 2.62E-01 |                                    |     |
| o-Xylene                   |                    |                          | 2.62E-01 |                                    |     |
| p-Xylene                   |                    |                          | 2.62E-01 |                                    |     |
| Benzo[a]anthracene         |                    |                          | 1.92E-02 |                                    |     |
| Benzo[b]fluoranthene       |                    |                          | 3.01E-04 |                                    |     |
| Benzo[k]fluoranthene       |                    |                          | 3.22E-04 |                                    |     |
| Benzo[ghi]perylene         |                    |                          | 3.21E-05 |                                    |     |
| Benzo[a]pyrene             |                    |                          | 1.77E-06 |                                    |     |
| Chrysene                   |                    |                          | 1.85E-02 |                                    |     |
| Dibenz[ah]anthracene       |                    |                          | 2.28E-02 |                                    |     |
| Fluoranthene               |                    |                          | 5.51E-05 |                                    |     |
| Indeno[123-cd]pyrene       |                    |                          | 1.95E-05 |                                    |     |
| Naphthalene                |                    |                          | 1.74E-02 |                                    |     |
| Pyrene                     |                    |                          | 1.74E-02 |                                    |     |
| Acenaphthalene             |                    |                          | 1.70E-02 |                                    |     |
| Acenaphthene               |                    |                          | 1.72E-02 |                                    |     |
| Fluorene                   |                    |                          | 1.73E-02 |                                    |     |
| Phenanthrene               |                    |                          | 1.77E-02 |                                    |     |
| Anthracene                 |                    |                          | 8.93E-04 |                                    |     |
| Phenol                     |                    |                          | 6.75E-02 |                                    |     |
| TPH Aliphatic C8-C10       |                    |                          | 1.11E-01 |                                    |     |
| TPH Aliphatic C10-C12      |                    |                          | 1.67E-01 |                                    |     |
| TPH Aliphatic C12-C16      |                    |                          | 1.02E+02 |                                    |     |
| TPH Aliphatic C16-C21      |                    |                          | 4.66E+41 |                                    |     |
| TPH Aliphatic C21-C34      |                    |                          | 4.68E+41 |                                    |     |
| TPH Aliphatic C35-C44      |                    |                          | 4.66E+41 |                                    |     |
| TPH Aromatic C8-C10        |                    |                          | 8.63E-02 |                                    |     |
| TPH Aromatic C10-C12       |                    |                          | 8.57E-02 |                                    |     |
| TPH Aromatic C12-C16       |                    |                          | 8.59E-02 |                                    |     |
| TPH Aromatic C16-C21       |                    |                          | 8.72E-02 |                                    |     |
| TPH Aromatic C21-C35       |                    |                          | 1.05E-01 |                                    |     |
| TPH Aromatic C35-C44       |                    |                          | 1.05E-01 |                                    |     |
| Arsenic                    |                    |                          | 4.24E-01 |                                    |     |
| Cadmium                    |                    |                          | 2.12E-03 |                                    |     |
| Copper                     |                    |                          | 2.37E-01 |                                    |     |
| Chromium                   |                    |                          | 1.70E-01 |                                    |     |
| Lead                       |                    |                          | 6.11E-02 |                                    |     |
| Inorganic Mercury          |                    |                          | 4.24E-04 |                                    |     |
| Nickel                     |                    |                          | 1.70E-01 |                                    |     |
| Selenium                   |                    |                          | 8.48E-02 |                                    |     |
| Zinc                       |                    |                          | 2.88E-01 |                                    |     |
| Hexavalent Chromium        |                    |                          | 2.88E-02 |                                    |     |
| Trivalent Chromium         |                    |                          | 3.99E-02 |                                    |     |
| Easily Liberatable Cyanide |                    |                          | 8.63E-03 |                                    |     |
| Total Cyanide              |                    |                          | 1.40E+02 |                                    |     |

Arundel

Case: 1 15 by 15 m Source Zone

| Substance                  | RTM Remedial Target Concentrations |                    |                     |
|----------------------------|------------------------------------|--------------------|---------------------|
|                            | Level 3 Soil                       | Level 3 Pore Water | Level 3 Groundwater |
|                            | (mg/kg)                            | (mg/l)             | (mg/l)              |
| Benzene                    | 2,900                              | ES(2,000)          | 7                   |
| Toluene                    | 57,000                             | ES(>10,000)        | 53                  |
| Ethylbenzene               | 33,000                             | ES(4,000)          | 14                  |
| m-Xylene                   | 53,000                             | ES(6,000)          | 21                  |
| o-Xylene                   | 47,000                             | ES(6,000)          | 21                  |
| p-Xylene                   | 49,000                             | ES(6,000)          | 21                  |
| Benzo[a]anthracene         | >100,000                           | ES(440)            | ES(1.6)             |
| Benzo[b]fluoranthene       | 13,000                             | ES(6.9)            | ES(0.025)           |
| Benzo[k]fluoranthene       | 19,000                             | ES(7.4)            | ES(0.026)           |
| Benzo[ghi]perylene         | 5,400                              | ES(0.74)           | ES(0.0026)          |
| Benzo[a]pyrene             | 92                                 | ES(0.041)          | 0.00015             |
| Chrysene                   | >100,000                           | ES(430)            | ES(1.5)             |
| Dibenz[ah]anthracene       | >100,000                           | ES(520)            | ES(1.9)             |
| Fluoranthene               | 400                                | ES(1.3)            | 0.0045              |
| Indeno[123-cd]pyrene       | 680                                | ES(0.45)           | ES(0.0016)          |
| Naphthalene                | 4,600                              | ES(400)            | 1.4                 |
| Pyrene                     | >100,000                           | ES(400)            | ES(1.4)             |
| Acenaphthalene             | 17,000                             | ES(390)            | 1.4                 |
| Acenaphthene               | 55,000                             | ES(400)            | 1.4                 |
| Fluorene                   | 88,000                             | ES(400)            | 1.4                 |
| Phenanthrene               | >100,000                           | ES(410)            | ES(1.4)             |
| Anthracene                 | 11,000                             | ES(21)             | ES(0.073)           |
| Phenol                     | 1,200                              | 1,600              | 5.5                 |
| TPH Aliphatic C8-C10       | >100,000                           | ES(2,500)          | ES(9.1)             |
| TPH Aliphatic C10-C12      | >100,000                           | ES(4,300)          | ES(15)              |
| TPH Aliphatic C12-C16      | >100,000                           | ES(>10,000)        | ES(8,300)           |
| TPH Aliphatic C16-C21      | >100,000                           | ES(>10,000)        | ES(>10,000)         |
| TPH Aliphatic C21-C34      | >100,000                           | ES(>10,000)        | ES(>10,000)         |
| TPH Aliphatic C35-C44      | >100,000                           | ES(>10,000)        | ES(>10,000)         |
| TPH Aromatic C8-C10        | 56,000                             | ES(2,000)          | 7.1                 |
| TPH Aromatic C10-C12       | 87,000                             | ES(2,000)          | 7                   |
| TPH Aromatic C12-C16       | >100,000                           | ES(2,000)          | ES(7)               |
| TPH Aromatic C16-C21       | >100,000                           | ES(2,000)          | ES(7.1)             |
| TPH Aromatic C21-C35       | >100,000                           | ES(2,400)          | ES(8.6)             |
| TPH Aromatic C35-C44       | >100,000                           | ES(2,400)          | ES(8.6)             |
| Arsenic                    | >100,000                           | 9,800              | 35                  |
| Cadmium                    | >100,000                           | 49                 | 0.17                |
| Copper                     | >100,000                           | 5,500              | 19                  |
| Chromium                   | >100,000                           | 3,900              | 14                  |
| Lead                       | >100,000                           | 1,400              | 5                   |
| Inorganic Mercury          | 73,000                             | 9.8                | 0.035               |
| Nickel                     | >100,000                           | 3,900              | 14                  |
| Selenium                   | 98,000                             | 2,000              | 7                   |
| Zinc                       | >100,000                           | 6,600              | 24                  |
| Hexavalent Chromium        | 12,000                             | 660                | 2.4                 |
| Trivalent Chromium         | >100,000                           | 920                | 3.3                 |
| Easily Liberatable Cyanide | 250                                | 200                | 0.71                |
| Total Cyanide              | >100,000                           | >10,000            | >10,000             |

Values Include an Additional Dilution Factor for Tide of 82

ES = Target Exceeds Solubility

## **APPENDIX D    OUTLINE PROGRAMME**



