Land Quality Management Ltd

For

Welwyn Hatfield Borough Council

REVIEW OF A DRAFT SUMMARY REPORT PRESENTING UPDATED ENVIRONMENTAL RISK ASSESSMENTS FOR THE PROPOSED BIRCHALL GARDEN SUBURB

LQM Report Number: **1359-5/1**

Issue Number: **1**

Status: **Final**

Date: **August 2019**

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1 INTRODUCTION

1.1 Examination of the WHBC draft Local Plan

(1) Welwyn Hatfield Borough Council (WHBC) have prepared a draft of its next Local Plan, which sets out proposals for relevant local planning policies and land allocations. If adopted this plan will provide the framework for development management within the WHBC area. The draft Local Plan currently includes the relevant land allocations for the Birchall Garden Suburb (BGS), indeed these allocations constitute an important element within the draft plan.

(2) All Local Plans in England are subject to an impartial and public examination by the Planning Inspectorate prior to being adopted by the relevant Local Authority. WHBC's draft plan is currently going through such an examination; a public examination hearing relating to the BGS was held in January 2018. During the examination process strong and concerted objections to the BGS were made by various parties on several grounds, including potential land contamination issues. Matters relating to the BGS are due to be considered further before the examination closes.

1.2 Terms of Reference

(3) Land Quality Management Ltd (LQM) were originally commissioned in December 2017 to provide WHBC with technical land contamination support in relation to the proposed inclusion of the BGS within the draft Local Plan. LQM have previously reviewed a number of documents with respect to the extent and nature of any land contamination issues associated with this proposed development.

(4) WHBC has asked LQM to review a draft report entitled "Birchall Garden Suburb – Land Quality Assessment", prepared by Royal HaskoningDHV (RHDHV) for Tarmac, Dated:14 June 2019, Status: 0.3/Draft, Reference: 9Y00741&BRP1805141446 (the '2019 Report') to ascertain whether any contamination issues may threaten the financial viability of the BGS or its progress through the ongoing examination. Conditions relating to contamination issues are likely to be needed in relation to any subsequent planning permission, but the current review is NOT intended to consider these issues in detail.

(5) It should be noted that LQM are not surveyors or valuers and therefore we can only comment on deliverability and financial viability from a technical perspective in relation to management of any land contamination issues.

1.3 Background

(6) Tarmac (formerly Lafarge Tarmac) are promoting a substantial extension to the south east of Welwyn Garden City, known as the Birchall Garden Suburb (BGS). WHBC's draft Local Plan

currently includes the relevant land allocations for the BGS, indeed these allocations constitute an important element within the draft plan.

(7) The BGS, as currently proposed by Tarmac, consists of three components:

- It is proposed that land to the north of the B195 Birchall Lane , known as 'Birchall Farm, would be a mixed use (primarily residential) development. The Birchall Farm site falls within the boundary of East Herts District Council (EHDC) and is allocated within their now adopted Local Plan. As the BGS falls across the common administrative boundary of EHDC and WHBC, the examination hearing held in January 2018 was a joint session involving both EHDC and WHBC. However, apart from any impacts it may have on the rest of the BGS, the Birchall Farm site is outside the scope of the current review;

- The land to the south of the B195 is within WHBC, and is the focus of the current review. This land comprises two areas:

    - The southern area is historically reported to be agricultural land. It is intended to allocate this area for "residential-led mixed use development" within the Local Plan and that this area will ultimately be developed for housing with provision for the necessary schools, shops *etc.* Within the current review, this is referred to as the 'Cole Green' site.

    - Between the Birchall Farm and Cole Green sites is the 'Former Mineral Workings' area. It is intended to allocate this area as 'urban open land' within the Local Plan, which would include limited access via footways and cycleways etc. It is understood that Tarmac's current BGS masterplan does not include the construction of any buildings in this area.

(8) The currently proposed site boundaries and parameter plan for the BGS are shown in Appendices 1 and 2 of the 2019 Report.

(9) It is understood that the Former Mineral Workings were operated by Tarmac's predecessor companies for aggregate extraction. Once these operations ceased, licenced waste disposal occurred to infill the excavated pits. Waste imports are understood to have ceased in the early 1980s. Since then Tarmac (and its predecessors) has implemented an environmental monitoring programme (groundwater, surface water and landfill gas), and installed a number of passive venting arrays to control landfill gas emissions and a fin drain to intercept leachate migrating in shallow groundwater.

1.4 Previous LQM reviews

(10) LQM have previously reviewed several reports, including RHDHV 2013, 2014a & 2014b, and a variety of additional information and data provided to WHBC by Tarmac prior to the Examination (Jan 2018). This review was reported in LQM 2018, and our conclusions included that :

- "*Notwithstanding the critiques of the information supplied by LT by LQM, Wardell Armstrong and WGCS, which highlight various deficiencies, uncertainties and potential inaccuracies in this information, the central question is whether there is any land contamination or stability reason that WHBC should* ***not*** *allocate the site for housing and urban open space within the Local Plan. As discussed above, although only preliminary works have been conducted to-date and significant uncertainty remains, the available information could be considered appropriate for the current stage of the planning cycle.";*
- *"The current evidence does not appear to suggest any substantial justification for the land not to be allocated within the Local Plan, notwithstanding the possibility that any development may ultimately be unviable/undeliverable."; and*
- *"The various limitations of the current work identified (e.g. by LQM, Wardell Armstrong and WGCS) would need to be addressed in any future investigation and assessments in support of any planning applications."*

(11) LQM were also previously engaged to review an earlier draft of the 2019 Report (Status: 0.2/Draft, Dated:14 March 2019).

1.5 The planning cycle

(12) Our review is also cognisant of the current stage in the planning cycle – which principally consists of i.) allocation in the Local Plan, ii.) submission of planning application(s), iii.) granting of planning permission(s) normally with conditions, and iv.) discharge of all conditions to the relevant permission(s).

(13) It should be noted that allocation within a Local Plan does not grant planning permission, merely allows compliant planning applications to be brought forward with a presumption in favour of being approved. Land contamination and stability issues would be a material consideration in determining such planning applications and the suitability and technical robustness of the risk assessments used to demonstrate that the proposed development would be, or would be made, 'safe' and 'suitable for use' would be subject to detailed scrutiny at that time and, if granted, subject to specific planning conditions in relation to these issues.

(14) It is understood that the 2019 Report has been submitted as part of Tarmac's evidence base to support the allocation of the BGS in the Local Plan, and has been reviewed as such.

(15) Land owners and developers tend to invest in preparatory works, such as land contamination and stability investigations, on an incremental basis taking account of factors such as investment risk and land value. Both these factors are influenced by the current status of a site within the planning system. For example, land will have a higher value and warrant more investment (e.g. ground

investigation) once allocated for development within the Local Plan and, again, once outline planning is granted. Consequently, the sufficiency of the available site investigation data and required detail of the risk assessments is dependent on the stage of the investigation/development. The currently available reports, including the 2019 Report, are therefore not intended to be the in-depth and comprehensive risk assessment reports we would expect to be submitted to support subsequent FULL planning application(s).

2 SUMMARY OF THE 2019 REPORT

(16) Stated objectives of the 2019 Report are:

- "*To present the existing data presented in the [pre-existing] reports …, and additional studies in one comprehensive report*";
- "*To present a conceptual site model identifying potential pollutant linkages and potential mitigation measures";*
- *"To provide recommendations regarding further studies and appropriate timings, if deemed necessary"; and*
- *"To inform the allocation process and any subsequent outline planning application".*

(17) Consequently, the 2019 Report provides a synthesis of the previous reports (RHDHV 2013, 2014a & 2014b), the additional information and data provided to WHBC prior to the Examination (Jan 2018) and further studies, data and reports identified or conducted by Tarmac/RHDHV subsequent to the Examination. Based on this updated and extended body of information it then presents:

- A summary of the ground conditions encountered at the Cole Green and Former Mineral Workings sites, including geological cross-sections, sample location and other plans and Conceptual Site Models (CSMs) indicating potential contaminant linkages pre- and post-mitigation;
- Updates to the assessments presented in RHDHV 2014a & 2014b of the potential human health risks posed by:
    - Contaminants in soils (predominantly <1mbgl) to future residents/users at both the Cole Green and Former Mineral Workings sites;
    - Volatile contaminants in shallow groundwater (potentially resulting from landfill leachate migration) to future residents at the Cole Green site;
    - Contaminants in surface water (potentially resulting from landfill leachate migration) to future residents at the Cole Green site;
- Updates to the assessments presented in RHDHV 2014a & 2014b of the potential risks to controlled waters (*i.e.* ground and surface waters) posed by:

- Contaminants in soils (predominantly <1mbgl) to groundwater beneath both the Cole Green and Former Mineral Workings sites;
- Contaminants already present in shallow groundwater (potentially resulting from landfill leachate migration) at the Cole Green, Birchall Farm and Former Mineral Workings sites;
- Contaminants already present in surface water (potentially resulting from landfill leachate migration) principally at the Cole Green site.

- Updates to the assessments presented in RHDHV 2014a & 2014b of the potential risks posed by ground gases (most likely methane and carbon dioxide associated with landfill gas migration) at both the Cole Green and Former Mineral Workings sites.

(18) Based on these assessments, the 2019 Report acknowledges that a "*limited number of potential pollutant linkages that will need to be addressed through further investigation and assessment, and possibly remedial action*" have been identified. Although the report does not (and was not intended to) present a Remediation Strategy for the Site, it does indicate potential mitigation methods for these pollutant linkages[1]. However, it also states that while "…*the mitigation measures may evolve following further site characterisation and regulatory liaison, they demonstrate that mitigation measures can be employed to address the PL identified*". The potential pollutant linkages principally involve the migration of leachate and ground gas from the Former Mineral Workings and the 2019 Report proposes that these linkages can be broken, either solely or in combination with other measures, by the installation of an interceptor drain/vent trench along the western and southern boundary of the Former Mineral Workings.

(19) Overall, the 2019 Report concludes that "*the pollutant linkages identified can be mitigated via a range of engineering techniques commonly utilised during site redevelopment*", that "*the site conditions are unlikely to represent a significant constraint to redevelopment*" and that "*following implementation of remedial measures the Birchall Garden Suburb site will be suitable for the proposed end use*". The 2019 Report then recommends:

- Ongoing liaison with WHBC and the master planning team;
- Continuation of Tarmac's programme of monitoring ground gases (including further continuous/high frequency monitoring), ground and surface waters;

[1] The 2019 Report uses the term "pollutant linkages" but recent Statutory Guidance (Defra, 2012) Defra has adopted the term "contaminant linkage".

- Further continuous gas monitoring;
- Liaison with the Environment Agency during the preparation of any subsequent planning consultation process applications; and
- Following the granting of outline planning permission, additional works to feed into a full and updated strategy for the remediation required.

3 FINDINGS OF LQM'S REVIEW

3.1 Ground Conditions

(20) As stated previously (LQM 2018), given the current stage in the planning cycle (*i.e.* masterplanning and local plan development), a relatively large amount of site investigation and environmental monitoring data exists in relation to the ground conditions beneath the Cole Green site and, to a lesser extent, the Former Mineral Workings site. The limited data in relation to the materials beneath the Former Mineral Workings site is probably due to a reasonable desire not to disturb the wastes nor to facilitate the migration or gases, vapours and leachates etc. Based on the available evidence, the 2019 Report now includes several geological cross-sections within Appendix 23. Collectively, the evidence presented in the 2019 Report would appear to confirm that:

- It is unlikely that any substantial mineral extraction or wastes deposition occurred outside of the boundaries documented in the 2019 Report. However, a supplementary investigation (April 2019) in the southwest corner of the Cole Green site did identify anthropogenic materials to the north of the aggregate recycling centre (previously referred to as "Coopers Tip") and suggested that the Kesgrave Gravels were extracted during the excavation of a separate Borrow Pit during the construction of the A414;

- Imported wastes were not only used to backfill the Former Mineral Workings (ie landfill) but that the final landform is mounded (*i.e.* landraise) above the general levels of the Cole Green and Birchall Farm sites.

- Below any topsoil/madeground (including landfill wastes), are varying thicknesses of superficial deposits of the Lowestoft Formation, which appear to exist beneath the Site as alternating horizons of clay and sand. The shallow groundwater (Secondary(undifferentiated) aquifer) is assumed to flow within the permeable horizons (referred to elsewhere in the 2019 Report as the "upper granular"). The lower part of the Lowestoft Formation is marked by a layer of grey clay or diamicton (referred to elsewhere in the 2019 Report as "blue clay").

- Leachate breakouts have been documented in two locations, firstly adjacent to The Copse and secondly within Great Captains Wood (see Appendix 6 of the 2019 Report);

- The mineral workings appear to have removed the majority of the upper horizons of the Lowestoft Formation but left the diamicton wholly or mostly intact. Consequently, it seems likely that the diamicton forms a relatively low permeability layer at the base of the former workings/landfill.

- The diamicton is underlain by further superficial sand and gravel deposits of the Kesgrave Catchment Subgroup (referred to elsewhere in the 2019 Report as the "lower granular"). This is a Secondary A aquifer.

- The Kesgrave subgroup appears to be underlain by Chalk bedrock (Lewes Nodular Chalk Formation and Seaford Chalk Formation), which is a Principal Aquifer.

3.2 Human-health risk assessments

(21) The 2019 Report presents a Generic Quantitative Risk Assessment (GQRA) of potential soil contamination. The risk estimation involved screening contaminant concentrations against suitable UK generic assessment criteria (GACs), which are normally calculated to be precautionary and protective. Where contaminant concentrations exceed such GACs, the potential risks associated with that contaminant/location(s) may warrant further consideration.

(22) RHDHV have adopted GACs from a number of authoritative sources, including:

- LQM/CIEH Suitable 4 Use Levels (S4ULs) (Nathanail et al., 2015)

- CL:AIRE/EIC Generic Assessment Criteria (CL:AIRE et al., 2010)

- Defra Category 4 Screening Levels (C4SLs) (Defra, 2014)

(23) In general, where no such assessment criteria have been published (*e.g.* for some semivolatile organic compounds (SVOCs) and pesticides) the "*laboratory limit of detection has been utilised as a benchmark*" by RHDHV.

(24) In most cases, the GQRA was initially based on the maximum contaminant concentration (*i.e.* cautious approach) observed at each site; statistical approaches (*e.g.* mean or UCL95 concentrations) were only implemented for contaminants for which the maximum concentration exceeded GAC.

3.2.1 Cole Green

(25) The GAC adopted are likely to be appropriate and protective for the proposed "residential-led mixed use development". There is less certainty regarding the protection provided by using laboratory limits of detection as screening criteria. Although this is common industry practice in many cases it has little scientific basis. The assessment was conducted with respect to both the near surface (<1mbgl) and deeper (>1mbgl) soils.

(26) It is likely that post-development most human exposure will be limited to the soils within the upper metre, consequently RHDHV collected the majority of data within this depth range. Dependant on the contaminant, the risk estimation for the surface soils considered data from between 7 and 46

samples (plus 2 to 11 additional samples analysed during the 2019 Supplementary Investigation). With respect to the deeper soils, the risk estimation only considered data from between 12 and 24 samples per contaminant (plus 1 to 6 additional samples analysed during the 2019 Supplementary Investigation).

(27) Exceedances of the GACs were noted in the shallow soils; these were considered further as part of the risk evaluation. A limited number of exceedances were reported in the deeper soils, but these do not seem to have been considered further.

(28) The risk evaluation for the shallow soils generally concludes that the exceedances (referred to as 'potential contaminants of concern' or PCOC) are "*unlikely to represent an unacceptable risk to human health or a major constraint to redevelopment of the site*". However, it also acknowledges the need for mitigation measures (not necessarily remediation) in relation to the presence of asbestos in the shallow soils.

3.2.2 Former Mineral Workings

(29) The GAC adopted are likely to be appropriate for the proposed "*urban open land*" land use. The assessment again differentiated between surface (<1mbgl) and deeper (>1mbgl) soils. Dependant on the contaminant, the GQRA for the surface soils considered data from between 10 and 69 samples. With respect to the deeper soils, the GQRA generally considered data from between 6[2] and 7 samples.

(30) Exceedances, principally of LoDs for several SVOCs, were noted in both the shallow and deeper soils and risk evaluations are presented for both depths.

(31) The PCOCs in shallow soils included asbestos and a variety of phenols and other VOCs/SVOCs. Polychlorinated biphenyls (PCBs) were identified above the LoD in 2 locations. RHDHV identified that, in general, PCOCs were associated with the presence of various anthropogenic materials (ash, brick etc.) in the relevant samples, which we assume represents the presence of landfill wastes. The risk evaluation for the deeper soils is less detailed but involves similar substances. Both risk evaluations generally conclude that these PCOCs are "*unlikely to represent an unacceptable risk to human health or a major constraint to redevelopment of the site*".

3.2.3 Risks from vapours released from groundwater at the Cole Green and Former Mineral Workings

(32) The 2019 Report also evaluates the a risk from vapours released from groundwater at Cole Green (Appendix 28) and the Former Mineral Workings (Appendix 31), by screening groundwater concentrations against GAC derived by SoBRA (2017). However, GAC are only available for some

[2] an exception was the single sample tested for hexavalent chromium

contaminants (*i.e.* the more volatile). For Cole Green, dependant on contaminant, the assessment considers between 19 and 45 samples (15 locations over 3 rounds of monitoring). For the Former Mineral Workings, the assessment considers 6 samples (a single round at 6 locations). LQM have assumed that all samples represent the shallow aquifer within the upper Lowestoft Formation. Given the assessment below and the geology, LQM would agree that it is unnecessary to consider potential vapour risks from the deeper aquifers.

(33) The limit of detection for vinyl chloride was not low enough to enable a valid assessment to be undertaken (ie GAC<LoD). In general, the risk evaluation suggests that:

- Hydrocarbons within the groundwater at the Former Mineral Workings would pose potential vapour inhalation risks within any buildings constructed on this site;
- The levels of volatile contaminants at the Cole Green site are not sufficient to pose a vapour risk within the residential homes (or other buildings) proposed for this site.

(34) As there are currently no proposals to construct any buildings at the Former Mineral Workings, there is almost certainly no vapour inhalation risk associated at this site and so should not prevent WHBC allocating the site within the Local Plan.

(35) LQM would tend to agree that at this stage in the planning cycle, the available groundwater data at Cole Green is adequate and that it suggests that the underlying groundwater is unlikely to pose any unacceptable risks to residents via vapour inhalation and so should not prevent WHBC allocating the site within the Local Plan.

3.2.4 Risks associated with surface waters at Cole Green

(36) The 2019 Report evaluates the potential risks to future residents from contact with surface water courses and leachate breakouts at the Cole Green and Birchall Farm sites[3]. Dependant on contaminant, the assessment considers between 3 and 15 samples (representing up to 5 locations at Cole Green over 3 rounds of monitoring plus, a single round of monitoring from 2 locations at Birchall Farm).

(37) No published assessment criteria exist for the potential risks posed by contact with contaminated surface waters. RHDHV have conducted a GQRA by comparing contaminant concentrations in surface water samples with Drinking Water Standards (DWS) or, if there is no suitable DWS, with Environmental Quality Standards (EQS). LQM would generally concur that this is

[3] It should also be noted that any risks at the Birchall Farm site are outside LQM's remit

likely to lead to a conservative assessment as DWS would be protective of not only contact with but also consumption of significant quantities of such surface waters.

(38) The risk evaluation states that concentrations of several metals (including arsenic, boron, nickel and selenium) and hydrocarbons (including polyaromatic hydrocarbons (PAHs)) exceeded the DWS/EQS in at least one sample at Cole Green. Significant variation in concentrations was reported between locations and between monitoring rounds but the highest concentrations were generally reported in CGSW01, which represents the leachate breakout adjacent to The Copse. RHDHV conclude that due to the cautious approach the risks are unlikely to be unacceptable but mitigation is recommended to "*address the odour nuisance and any potential residual risk*". A number of options are proposed but in Section 9 of the 2019 Report it is proposed that an interceptor drain be installed.

3.2.5 LQM conclusions

(39) Based on our review of the 2019 Report, LQM conclude that:

- the available soil sampling at both Cole Green and the Former Mineral Workings is sufficient for this stage in the planning cycle;

- as might be expected, a greater range of contaminants are present at the Former Mineral Workings and that they are generally present more widely and at higher concentrations than at Cole Green. However, the proposed land use for this area (*i.e.* urban open land) also provides less potential for human exposure than the residential development at Cole Green;

- the analysis presented by RHDHV suggests that adequate mitigation of any contamination at both Cole Green and the Former Mineral Workings is likely to be achievable using standard techniques. If adequately designed and implemented, such mitigation should ensure development is safe and suitable for the future end use.

  However, the elevated levels of several contaminants (including asbestos, lead and PCB) and anthropogenic materials subsequently identified in surface soils (<1.0mbgl)) in one corner of the Cole Green site during the Supplementary Investigation (April 2019), suggests that additional soil contamination issues may well be identified following the further investigations that is likely to be required to gain planning approval, or discovered during earthworks associated with subsequent remediation and redevelopment activities. Consideration of such soil contamination (with the exception of asbestos) is currently absent from the pollutant linkages presented in the 2019 Report (Table 9-1). If identified, such contamination may require additional remediation activities and WHBC should clarify with Tarmac that these additional costs would not impact on the overall financial viability of the BGS.

- Any potential risks from asbestos are likely to be such that they can be adequately mitigated but are likely to result in public concern. Consequently, full details of the management approach to be adopted with respect to asbestos should accompany any subsequent planning application.

- the installation of a suitably designed interceptor drain should result in an improvement in surface water quality, including leachate breakouts, such that unacceptable risks to residents are unlikely.

(40) If the proposed mitigations do not threaten financial viability, LQM believe that the soil contamination issues identified are such that they can be adequately dealt with via conditions to any subsequent planning application(s). Consequently, these issues should not prevent WHBC allocating the BGS within the Local Plan.

3.3 Controlled waters risk assessment

(41) The 2019 Report presents several groundwater contour plots based on the available groundwater depth data (mAOD) for the Secondary (undifferentiated) aquifer within the Lowestoft Formation in Appendix 25. RHDHV interpret these as indicating "a groundwater flow predominantly to the south". Predicted groundwater flows within the Secondary A (Kesgrave Subgroup) and Principal (Chalk) aquifers were not presented, presumably due to the lack of data with respect to these water bodies.

(42) The 2019 Report states that "*There is also likely to be some continuity between groundwater in the upper reaches of the Lowestoft Formation and the eastern arm of the Hatfield Hyde Brook; and between the Kesgrave Gravels and the River Lea, therefore these surface waters are considered to be receptors, as are the other on-site surface waters*". Consequently, in the absence of any local abstraction of potable water from the shallow aquifer, RHDHV adopted a hierarchy of GACs relevant to the protection of surface water quality, primarily surface water EQS, where available. If no EQS was available, DWS were adopted and where no suitable standard was available the LoD was utilised.

(43) Based on the above, the 2019 Report presents a GQRA of:

- The potential risks to surface water quality from soil leaching (based on measured soil concentrations/leachability) at the Cole Green and Former Mineral Workings sites;

- The potential risks to surface water quality from groundwater contamination (based on measured groundwater concentrations) at the Cole Green, Former Mineral Workings and Birchall farm[4] sites; and

- The potential risks to surface water quality (based on measured surface water concentrations)

3.3.1 Assessment of soil leaching – Cole Green

(44) Dependant on contaminant, the GQRA considered data from between 2 and 17 shallow soil samples. Exceedances were noted for several metals (between 1 and 16 samples), petroleum hydrocarbons (up to 2 samples), and some PAH congeners (up to 15 samples). LQM understand that no relevant additional data was generated during the 2019 Supplementary Investigation.

(45) The risk evaluation states that in general there was little correlation at given boreholes between soil leachate and groundwater concentrations. Overall, RHDHV found the shallow soils "*not to represent an unacceptable risk to groundwater or a constraint to redevelopment of the site for the proposed end uses*" but highlight that the groundwater quality has also been assessed directly.

3.3.2 Assessment of soil leaching – Former Mineral Workings

(46) Dependant on contaminant, the GQRA considered data from between 6 and 12 shallow soil samples, but not from the underlying wastes. Exceedances were noted for several metals (between 1 and 11 samples), phenol (2 samples), petroleum hydrocarbons (up to 4 samples), and some PAH congeners (up to 6 samples). It was noted that the mean leachable copper, nickel and zinc concentrations were an order of magnitude above the EQS.

(47) The risk evaluation states that in general there was little correlation at given boreholes between soil leachate and groundwater concentrations. RHDHV found the shallow soils "*not to represent an unacceptable risk to groundwater or a constraint to redevelopment of the site for the proposed end uses*". However, they acknowledge that the assessment does not include samples of the landfilled wastes but highlight that the groundwater quality has also been assessed directly.

3.3.3 Assessment of groundwater concentrations – Cole Green and Former Mineral Workings

(48) At Cole Green, dependant on contaminant, the GQRA considered data from between 13 and 45 groundwater samples (15 locations over 3 rounds of monitoring). Exceedances were noted for ammoniacal nitrogen (26 samples), several metals (up to 39 samples), petroleum hydrocarbons (up to 2 samples), and some PAH congeners (up to 15 samples).

[4] It should also be noted that any risks at the Birchall Farm site are outside LQM's remit as the land is in EHDC

(49) At the Former Mineral Workings, dependant on contaminant, the GQRA considered data from between 2 and 6 groundwater samples (a single round at 6 locations), including samples within the waste deposits. Exceedances were noted for ammoniacal nitrogen (6 samples), several metals (up to 6 samples), Phenol (up to 3 samples), petroleum hydrocarbons (up to 6 samples), and some PAH congeners (up to 6 samples).

(50) RHDHV acknowledge that PCOC have been identified in the Secondary (undifferentiated) aquifer but "*this is unlikely to represent a receptor, but is important as a potential pathway allowing the migration of PCOC to other sensitive receptors*". Overall they conclude that "*Whilst the Former Mineral Workings appears to be having some impact on groundwater quality, it is unlikely to be affecting the wider groundwater resource*". However, they go on to state "*Further groundwater risk assessment may be required following detailed liaison with the Environment Agency to canvass their opinion and agree the scope of any further assessment*" and that "*mitigation measures will be required as part of the proposed development to manage leachate migration*". The 2019 Report suggest the installation of an interceptor drain to manage such leachate migration.

3.3.4 Assessment of surface water concentrations - Cole Green and Former Mineral Workings

(51) Dependant on contaminant, the GQRA considered between 3 and 15 samples (representing up to 5 locations at Cole Green over 3 rounds of monitoring plus, a single round of monitoring from 2 locations at Birchall Farm[5]). Exceedances were noted for several metals (up to 15 samples), petroleum hydrocarbons (up to 2 samples), and some PAH congeners (up to 15 samples)[6].

(52) RHDHV conclude that "*Metals and a range of PAH have been detected in the surface waters at concentrations exceeding the EQS/LOD*" and that "*The PCOC are similar to those detected in the groundwater samples and are probably present as a result of leachate emanating from the Former Mineral Workings and migration in shallow groundwater*". Thus, RHDHV state that "*mitigation measures will be required to manage leachate migration and improve the baseline conditions*".

3.3.5 LQM Conclusions

(53) Based on our review of the 2019 Report, LQM conclude that:

- While limited, the available leachability data is reasonable for this stage in the planning cycle and that, based on the data presented, it seem likely that contamination within the shallow soils at Cole Green and the Former Mineral Workings is unlikely to pose unacceptable risks to controlled waters;

[5] It should also be noted that any risks at the Birchall Farm site are outside LQM's remit

[6] 8 samples also exceed the LoD for ammoniacal nitrogen, but this is not documented in Table 7-6.

- Although the groundwater risks posed by the deeper buried wastes within the Former Mineral Workings may be considerable, we appreciate the difficulties and the rationale behind the decision not to disturb these materials in order to collect representative samples for testing. However, this places considerable importance on i.) developing a sound characterisation of the groundwater regime in and around the Former Mineral Workings, and ii.) robust groundwater risk assessments being presented at the planning application stage;

- The available groundwater data at Cole Green is sufficient for this stage in the planning cycle. While limited, the available groundwater data at the Former Mineral Workings is reasonable for this stage in the planning cycle, particularly given the proposed mitigation measures in relation to leachate.;

- Although we have a number of reservations regarding the characterisation of the flow regime in the Secondary (undifferentiated) aquifer, based on the data presented in the 2019 Report, LQM would tend to agree that the installation, verification and maintenance of a suitably-designed interceptor drain should mitigate the potential risks relating to the migration of leachate within the Secondary (undifferentiated) aquifer. However, the required location and extent of such a drain can only be determined once there is a robust understanding of the flow regime in and around the Former Mineral Workings;

- Only very limited data has been collected in relation to the deeper aquifers, and no assessment of the risks to them is presented in the 2019 Report. It is still possible that these aquifers are being impacted by landfill leachate and that additional remediation is required to protect them. However, it should be noted that any such requirement would probably be independent of whether or not the land is allocated within the local plan and is a matter for the Environment Agency;

- The available surface water data is reasonable for this stage in the planning cycle;

- The surface water data suggests that leachate is potentially impacting on-site surface waters. We agree that, if properly designed, installed, verified and maintained, the mitigation measures proposed should facilitate an improvement in local surface water quality, but this necessitates a robust understanding of the flow regime in and around the Former Mineral Workings.

(54) If the proposed mitigations do not threaten financial viability, LQM believe that the issues relating to controlled waters at the BGS are such that they can be adequately dealt with via conditions to any subsequent planning application(s). The Environment Agency should be invited to comment on any such application(s) with respect to the need for further site investigation, risk assessment and

mitigation relating to controlled waters. Consequently, these issues should not prevent WHBC allocating the BGS within the Local Plan.

3.4 Ground gas risk assessment

(55) The 2019 Report presents a Generic Quantitative Risk Assessment (GQRA) of the potential ground gas (*i.e.* methane and carbon dioxide) risks relating to the BGS. RHDHV believe the main risks relate to the migration of landfill gas from the Former Mineral Workings within the permeable horizons of the Lowestoft Formation. An array of passive vents installed to ensure protection of the properties on Holwell Hyde Lane has previously been installed by Tarmac (and its predecessors). No other gas control measures are in place.

(56) The assessment is based on both intermittent spot monitoring and high frequency (also called continuous) monitoring. RHDHV have adopted an assessment based on BS8485 (BSI, 2015) and/or C665 (Wilson et al., 2007) that involves deriving a representative Gas Screening Values (GSV), based partly on calculated Hazardous Gas Flow Rates. The GSV for methane and carbon dioxide are then compared to threshold values to assign the relevant Characteristic Situation that dictates the required level of remediation; CS1 indicates a very low gas risk up to CS6 indicating a very high gas risk.

(57) RHDHV acknowledge that this approach has limitations with respect to the risk assessment of landfill gas migration, but suggest that this would be taken into account at a later stage in the planning process, to ensure "*appropriate mitigation measures are adopted*".

3.4.1 Cole Green and Birchall Farm[7]

(58) The report states that 24 boreholes were installed at Cole Green (monitored on 4 occasions) and 5 boreholes at Birchall Farm (monitored on 2 occasions).

(59) RHDHV report that :

- Methane concentrations were generally <0.1% except in one borehole close to the Former Mineral Workings during low atmospheric pressure;
- Carbon dioxide concentrations fluctuated (0.1-11%) but were generally low during high atmospheric pressure;
- Oxygen ranged between 9 and 22%;
- Carbon monoxide was generally not detected but could be up to 11%;

[7] It should also be noted that any risks at the Birchall Farm site are outside LQM's remit

- Hydrogen sulphide was generally not detected but could be up to 3%;
- Flow rates were typically 0.1 L/hr (Max 9.1 L/hr).

(60) Three rounds of monitoring data allowed RHDHV to classify Cole Green as CS1 but a higher flow rate and CO2 (close to the Former Mineral Workings) during the fourth monitoring round reached the threshold for CS2.

(61) In addition, following the 2019 Supplementary Investigation a single round of monitoring was conducted at 7 boreholes in the southwest of the Cole Green site located in areas of suspected made ground. Based on this single round of monitoring, and in isolation, RHDHV again generally assigned CS1, but upgraded this to CS2 based on elevated methane concentrations (12.8%) in one of the boreholes (methane was not detected in the other 6 boreholes).

3.4.2 Former Mineral Workings

(62) The 2019 Report summarises Tarmac monitoring data (2011-13) but the raw data is not presented. RHDHV state that, in general, this data does not include flow rates and so Hazardous Gas Flow Rates cannot be calculated. Some of the data reportedly relates to monitoring in the vicinity of the civic amenity site located off Hatfield Road, but the remaining data relates to the gas vents near Holwell Hyde Lane. The latter seems to suggest that high gas concentrations are present within the landfill (up to 58.5% methane, 32.4% carbon dioxide) but that this is dissipated by the vents such that closer to the residential properties (location 01-03) methane was generally not detected (a maximum of 0.6% was recorded).

(63) In Appendices 38 and 39, additional data (including flow data) is presented for a further 9 gas wells (monitored on 1 occasion). Most data relates to the northwest of the Former Mineral Workings in the vicinity of the passive vents, and so it is uncertain if these wells are truly representative of conditions across the Former Mineral Workings as a whole. These wells generally have elevated gas concentrations (up to 62.5% methane, 35.4% carbon dioxide) but limited gas flow (max 0.3l/hr). Based on this data, RHDHV assign CS2, taking account of the high methane concentrations involved.

3.4.3 High frequency monitoring

(64) According to RHDHV, high frequency monitoring has been conducted during differing periods at:

(65) 4 locations "*within the former mineral workings*", but according to Appendix 40 none are in the center of the former landfill and one (RBH01) is inside the Cole Green site;

(66) 9 locations "*located around the periphery of the former mineral workings*"; according to Appendix 40 these represent 5 locations on the western boundary along Holwell Hyde Lane (protected by the gas vent system), 1 location on the southern boundary of the Former Mineral Workings, 1 location within the Birchall Farm site and 2 locations within the Cole Green site.

(67) Average concentrations of all landfill gas components were considerably higher in all boreholes "*within the former mineral workings*" than those on the periphery, with the exception of RBH01. No risk evaluation for the high frequency data appears to be presented within the 2019 Report, but within Section 8.10 RHDHV appear to assign CS4 to these 4 boreholes based on typical Hazardous Gas Flow Rates calculated from high frequency data. Similarly, in Section 8.10 RHDHV seem to conclude that Hazardous Gas Flow Rates for methane in the boreholes on the periphery (which RHDHV now seem to refer to as the Cole Green Site) typically represent CS2 but levels of carbon dioxide above 5% require this to be raised to CS3.

3.4.4 Risk evaluation

(68) Overall, RHDHV conclude the Former Mineral Working site is typically CS4 and that there is evidence for landfill gas migration onto the Cole Green site but that "*high gas concentrations were not observed throughout the monitoring period within the Cole Green site*". Cole Green is assigned CS3 based on the elevated carbon dioxide encountered near the Former Mineral Workings.

(69) Overall RHDHV state "*Based on the data collected to date there appears to be an active pollutant linkage where ground gas generated within the Former Mineral Workings is able to migrate via more permeable horizons associated with the upper reaches of the Lowestoft Formation and could therefore represent a potential unacceptable risk to human health without mitigation, although unlikely to represent a significant constraint to redevelopment of the site*". To address this linkage, within Section 9 of the report RHDHV are reported as having proposed the "*installation of a vent trench along western and southern boundary … to sever the gas migration pathway*".

3.4.5 LQM conclusions

(70) Based on our review of the 2019 Report, LQM conclude that:

- the available gas monitoring data (including high frequency monitoring) at Cole Green and the Former Mineral Workings is sufficient for this stage in the planning cycle;
- the available monitoring suggests that gas risks at the BGS are mainly driven by migration of landfill gas generated within the Former Mineral Workings. This migration is most likely to be along porous horizons within the Lowestoft Formation (Although this has not been fully demonstrated with reference to the available data); and

- migration of gases away from the Former Mineral Workings could be suitably mitigated by the installation, verification and maintenance of a suitably-designed vent system.

(71) If the proposed mitigations do not threaten financial viability, LQM believe that the gas risks identified are such that they can be adequately dealt with via conditions to any subsequent planning application(s). Consequently, these issues should not prevent WHBC allocating the BGS within the Local Plan.

4 LQM'S OVERALL CONCLUSIONS

(72) Detailed Site investigation, robust risk assessments and fully documented remediation proposals are not a prerequisite for allocation within the local plan. At this preliminary stage in the planning cycle, LQM consider the amount and quality of the data and risk assessments presented in the 2019 Report to be reasonable. More detailed evidence and assessment will undoubtedly be required to fulfil conditions to any subsequent planning application(s)

(73) The 2019 Report presents a Conceptual Site Model of the principal land contamination risks that appears to be supported by the available data, and identifies a number of pollutant linkages that require mitigation. RHDHV have suggested remediation measures that are likely to provide adequate mitigation of these risks, including those involving ground gas and leachate migration. LQM understand that Tarmac do not feel that the costs associated with the design, installation, verification and maintenance of these remediation measures threaten the financial viability of the BGS.

(74) The central question for this review is whether there is any land contamination or stability reason that WHBC should **not** allocate the BGS for housing and urban open space within the Local Plan. Although potential risks relating to land contamination issues have been identified, and others may subsequently be identified, these issues are such that they can be adequately dealt with via conditions to any subsequent planning application(s). Therefore, based on our review of the 2019 Report, safe and suitable development should be achievable and there seems to be no substantial justification for the land not to be allocated within the Local Plan.

(75) Notwithstanding the above, LQM have identified a number of uncertainties etc. within the data and risk assessments presented within the 2019 Report. These are outlined in Annex 1 and would need to be considered during the submission of any future planning application(s) and may require conditions to be applied to any subsequent planning approval. It should also be noted that, although there are significant uncertainties relating to potential impacts on the deeper underlying (Secondary A and Principal) aquifers, these do not preclude the allocation of the BGS. Impacts to these aquifers are potentially already occurring and are independent of the proposed BGS development, indeed the BGS potentially facilitates the assessment and, if necessary, mitigation of any such impacts. In any event, any such impacts are the responsibility of the landowner and would be regulated by the Environment Agency.

5 REFERENCES

5.1 Site-specific reports

LQM (2018), "Review Of Information Relating To The Proposed Inclusion Of The Birchall Garden Suburb Within The Draft Local Plan (Issue 2)", Report Number: 1359-1/1, Dated: April 2019.

RHDHV (2013), "Land Quality Preliminary Investigation & Outline Management Study – Land South of Birchall Road, Cole Green", Royal HaskoningDHV, Dated:30/1/13, Ref: 9Y0074

RHDHV (2014a), "Cole Green Former Mineral Workings: Soil Survey and Generic Quantitative Risk Assessment", Royal HaskoningDHV, Dated:6/10/14, Ref: 9Y0074

RHDHV (2014b), "Cole Green Site Characterisation and Generic Quantitative Risk Assessment", Royal HaskoningDHV, Dated:6/10/14, Ref: 9Y0074

5.2 Other references

BSI. (**2015**). BS 8485:2015 Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings. British Standards Institution: London, UK.

CL:AIRE, EIC, & AGS. (**2010**). Soil Generic Assessment Criteria for Human Health Risk Assessment. CL:AIRE: London, UK. Accessed from http://www.claire.co.uk/index.php?option=com_content&view=article&id=306&Itemid=91

Defra. (**2012**). Contaminated Land Statutory Guidance - Environmental Protection Act 1990 Part 2A. Department for Environment, Food, and Rural Affairs (London, UK). Accessed from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223705/pb13735cont-land-guidance.pdf

Defra. (**2014**). SP1010: Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination – Policy Companion Document. December 2014. Department for Environment Food and Rural Affairs (London, UK). Accessed from http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=18341

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Nathanail CP, McCaffrey C, Gillett AG, Ogden RC, & Nathanail JF. (**2015**). The LQM/CIEH S4ULs for Human Health Risk Assessment. Land Quality Press, a Division of Land Quality Management Ltd: Nottinghamshire, UK.

SoBRA. (**2017**). Development of Generic Assessment Criteria for assessing vapour risks to human health from volatile contaminants in groundwater (Version 1). Society of Brownfield Risk Assessment: Bristol, UK.

Wilson SA, Oliver S, Mallett H, Hutchings H, & Card GB. (**2007**). C665 - Assessing risks posed by hazardous ground gases to buildings. CIRIA: London, UK.

ANNEX 1: OUTSTANDING ISSUES THAT SHOULD BE ADDRESSED DURING THE SUBSEQUENT DEVELOPMENT MANAGEMENT PROCESS

Uncertainties relating to the human-health risk assessment

(76) The current human-health risk assessments are based solely on screening the currently available contaminant concentrations against GAC. Where GAC have been exceeded, the risk evaluations do not present any DQRA or substantive additional lines of evidence to demonstrate that the potential risks are not unacceptable. For example, although potential sources have been suggested in some cases, the spatial distribution of, and correlations between, the exceedances have not been examined to support these suggestions.

(77) We also note that RHDHV have derived several assessment criteria (*e.g.* for carbazole and complex cyanide). Full justification of such criteria, including all input parameters (*e.g.* toxicological thresholds), should be provided to WHBC if these criteria are used to support a subsequent planning application.

(78) RHDHV suggest that some or all of the asbestos-containing soils at the Cole Green site could be "encapsulated beneath highway infrastructure/landscape/noise bunding ". While this may be suitable and appropriate, it would depend on a robust risk assessment demonstrating its suitability for such uses. LQM are also aware of several sites where the waste implications of using such materials, particularly in noise bunds, has not been adequately addressed. Given the recent changes in HMRC guidance in relation to disposals not made at landfills, this potentially poses a significant liability to developers.

Former Mineral Workings

(79) The appropriateness of the 'public open space (park)' landuse (POS_{park}) with respect to the Former Mineral Workings may be overly cautious in some areas but insufficiently stringent in others. This land use assumes regular picnicing by small children and includes the resulting direct ingestion of soil but excludes the possibility of soil trackback. LQM understand that the proposed "*urban open land*" development may be such that picnicing *etc*. is discouraged across most of the Site; and hence exposures may be lower than predicted by the POS_{park} land use. In contrast, it is possible (even likely) that the open land may be used for other unofficial uses (*e.g.* informal BMX tracks etc.) in which case exposures may possibly be higher than predicted by the POS_{park} land use.

(80) The risk assessment for this area needs to be kept under review as the plans for the redevelopment of the Former Mineral Workings mature, this includes considerations of the proposed

layout, landform and landscaping (incl. planting) and also the future maintenance arrangements for this site.

(81) As the POS_{park} land use also excludes the possibility of trackback, the potential risks posed by some priority contaminants at the proposed residential areas of Cole Green adjacent to the Former Mineral Workings should be reviewed to ensure that the possible trackback of soil and/or windblown dust/and vapours etc. does not impact the safe development of these properties.

(82) However, LQM acknowledge that RHDHV are already aware "*that as the masterplan evolves it may be necessary to review the risk assessment to ensure they are adequate for the proposed end use. This may mean further risk assessment to assess a specific end use in a specific area of the site*".[8]

Risks from vapours released from groundwater at the Cole Green and Former Mineral Workings

(83) There are uncertainties relating to the assessment of vapours arising from the shallow groundwater. However, as long as the remediation strategy includes the installation, maintenance and verification of interceptor drain(s) intended to prevent any migration of groundwater from the Former Mineral Workings onto the Cole Green site, this pathway will effectively be broken and should not require further assessment.

Risks associated with surface waters at Cole Green

(84) Any subsequent planning application should clarify the risk evaluation on which this assessment is based. However, as long as the remediation strategy includes the installation, maintenance and verification of a suitably-designed interceptor drain(s) intended to prevent any migration of groundwater/leachate onto the Cole Green site (including the eastern arm of the Hatfield Hyde Brook), this pathway will effectively have been broken and should not require further assessment.

Uncertainties relating to the Controlled waters risk assessment – Secondary (undifferentiated) Aquifer (Lowestoft Formation)

Groundwater flow regime

(85) Within the report, RHDHV acknowledge that further risk assessment maybe required and this should be discussed with the EA to agree scope. LQM would concur with this statement but would stress that the flow regime within the Secondary (undifferentiated) aquifer is a critical assumption within the subsequent risk assessments (for vapours, ground and surface water) and the design of the proposed interceptor drain. Consequently, it will be necessary for the flow regime to be fully and

[8] Email from Darren Banner-Perry to Sue Tiley (14 June 2019) entitled "BGS Revised Consolidated Report"

rigorously characterised and documented, preferably using a 'lines of evidence' approach, prior to the granting of outline planning permission.

(86) LQM have several concerns regarding the current characterisation of the flow regime. Appendix 25 of the 2019 Report presents 2 x 3 sets of groundwater contours for the shallow aquifer. Contours are presented either including or excluding data within the landfill (presumably on the basis that groundwater within the landfill may not be in continuity with the surrounding aquifer (*e.g.* it may be perched water) and its inclusion would impact the predicted contours). In each case, contours are presented for the minimum, maximum and average reduced groundwater levels over up to 3 rounds of monitoring spanning ~6-9 months.

(87) However, LQM do not believe:

- that the use of minimum, maximum and average data across monitoring rounds is scientifically valid. For example, such an approach would mask any temporal trends (*e.g.* seasonal variations within the flow regime) and produce unrepresentative results. Furthermore, although RHDHV acknowledge that there appear to be anomalous low groundwater levels in the vicinity of the existing fin drain, there are other anomalies in the contours that have not been commented on.

- that the contours presented in Appendix 25 are a true reflection of the flow regime as they are biased by the weight of data at Cole Green to the south of the Former Mineral Workings and that this raises substantial doubt about RHDHV's conclusion that the contours indicate "*a groundwater flow predominantly to the south*". The contours presented in Appendix 25 could also be interpreted as demonstrating a radial flow in several directions potentially driven by the raised landform of the landfill/land raise. Indeed the leachate breakout within Great Captains Wood would suggest that this is the case as such a breakout would not be possible if the flow was entirely southerly.

(88) Finally, the interpolation approach, including all input parameters, can have a significant impact on the predicted contours. Although LQM have been informed that the contours in Appendix 25 were generated using kringing[8], full details of how any contours have been derived should be documented in any subsequent risk assessment, and the sensitivity to the interpolation approach investigated.

Ammoniacal nitrogen

(89) The current risk assessments concentrate on metals and organic contaminants. However, ammoniacal nitrogen (*i.e.* the sum of ammonium and ammonia) is a significant and highly soluble component of landfill leachate (as is chloride). Laboratory analysis and water quality standards for

ammoniacal nitrogen, ammonium and ammonia can be reported in a variety of units. It is possible to interconvert the various measurement units based on stoichiometry and, if necessary, to estimate the ammonium:ammonia partitioning based on an assumed pH.

(90) In the absence of an EQS for ammoniacal nitrogen, RHDHV have adopted the LoD (0.2 mg/l as NH_3) as the relevant assessment criterion within their controlled waters assessments. However, the Water Framework Directive total ammonia as nitrogen (mg/l) is a key determinant of surface water quality status with anything above 1.1-2.5 being rated 'Poor'. Groundwater samples collected at Cole Green have reported between <0.2 and 244 mg/l as NH_3 and those at the Former Mineral Workings between 43.3 and 262 mg/l as NH_3. Concentrations in surface water samples varied between <0.2 to 118 mg/l as NH_3. Given the link between ammoniacal nitrogen and landfill leachate, its known aquatic toxicity and its importance with respect to surface water quality, the assessments presented by RHDHV seem cursory. The Environment Agency should be consulted in relation to an appropriate assessment strategy in relation to any subsequent planning application(s).

(91) Furthermore, ammoniacal nitrogen and/or chloride concentrations could be used as indicative markers for leachate to reduce uncertainty with respect to the groundwater/leachate flow regime within the Secondary (undifferentiated) aquifer and provide additional lines of evidence to support the CSM.

Uncertainties relating to the Controlled waters risk assessment – Secondary A Aquifer (Kesgrave Gravels)

(92) The 2019 Report acknowledges that only limited data has been collected in relation to Kesgrave Gravels/Secondary A Aquifer. The Kesgrave Gravels were encountered in 5 boreholes at the Cole Green site; groundwater monitoring wells were installed in four of these, but groundwater was subsequently encountered in only two of these wells (CGBH03 and CGBH04). It is unclear how many boreholes have proved the Kesgrave Gravels at the Former Mineral Workings, but it is believed that no monitoring wells have been installed within this stratum. Consequently, there is currently very limited empirical data regarding the depth to the Secondary A Aquifer beneath the BGS or of any existing impact, or otherwise, on the water quality within it.

(93) The report states that, based on what data is available, "*it appears that the sand and gravels associated with the upper reaches of the Lowestoft Formation were generally removed, leaving the stiff grey clay (Diamicton) in situ, which separates groundwater associated with the Secondary Undifferentiated Aquifer and waste deposits from the Secondary A Aquifer and Principal Aquifer located beneath. The clay would be expected to significantly retard the vertical migration of PCOC*". However, the report also concedes that "*There is also some evidence that the Secondary A Aquifer has been impacted by inorganic and organic PCOC at concentrations exceeding the EQS. The presence of*

these PCOC may be as a result of migration through interconnected permeable horizons or infiltration where the clay thins at the perimeter".

(94) No robust risk assessment in relation to such impacts on the Secondary A aquifer is presented with the 2019 Report. As RHDHV acknowledge, the need and remit for any such assessment should be ascertained during discussion with the Environment Agency.

Uncertainties relating to the Controlled waters risk assessment – Principal Aquifer (Chalk)

(95) The 2019 Report acknowledges that only limited data has been collected in relation to Chalk/Principal Aquifer. The Chalk was encountered in 2 boreholes at the Cole Green site, but a groundwater monitoring well was only installed in one of these. No groundwater was encountered during the intrusive investigation or during subsequent monitoring rounds. It is unclear how many boreholes have proved the Chalk at the Former Mineral Workings, but it is believed that no monitoring wells have been installed within the Chalk. Consequently, there is currently no empirical data regarding the depth of the principal aquifer beneath the BGS or of any existing impact, or otherwise, on the water quality within it.

(96) The 2019 report states that, based on the available data, the Chalk is "*slightly sandy, slightly gravelly silt which is likely to exhibit a lower permeability than the gravels associated with the Secondary A Aquifer and retard, to some degree*," downward migration. This is a poor description of the Chalk, which is more usually described in terms of weathering grades (Lord et al., 2002). The description appears to come from a single cable percussive borehole (CGBH06) where the Chalk is described as "*recovered as …*" (*i.e.* degraded during drilling). Whilst a layer of weathered putty chalk is sometimes present at the top of the chalk, one borehole with poor recovery is insufficient evidence from which to draw this conclusion. Consequently, there is still uncertainty regarding continuity between the Secondary A and Principal aquifers. If landfill-related contamination has, or does in the future, enter the Secondary A Aquifer, this may pose risks to the underlying Principal Aquifer.

(97) No robust assessment of this scenario in presented with the 2019 Report. As RHDHV acknowledge, the need and remit for any such assessment should be ascertained during discussion with the Environment Agency.

Uncertainties relating to the ground gas risk assessment

(98) Ground gases can potentially pose an acute risk of death from asphyxiation or explosion. As a consequence, a robust investigation and assessment of the potential risk is likely to be a critical factor in determining any future planning application(s). Furthermore, a robust gas Conceptual Site Model (gCSM) is a prerequisite for such an assessment and critical to the design of an effective venting system as proposed within the 2019 Report

(99) It seems likely that the principal driver of gas risks relate to the generation of landfill gas within the wastes in the Former Mineral Workings. However, there remains some weaknesses in the current gCSM and gas risk assessment:

- In particular, the possibility for landfill gas to migrate in a dissolved phase within the shallow groundwater in the Lowestoft Formation is not currently included within the gCSM. Consequently, the relevant testing has not been conducted;

- We note that, although a location plan is provided for the continuous monitoring locations, no such plan(s) appears to be provided for the spot monitoring data in Appendices 10, 38 and 39. Furthermore, the location of some of the gas monitoring locations (including continuous monitoring) relative to the vent system in the northwest of the landfill is unclear. Consequently, it is possible that some of the data from the Former Mineral Workings is not representative of gas generation within the wastes, as might be assumed;

- The GSVs selected by RHDHV, while likely to be cautious, result from a mechanistic and erroneous application of BS8485 (BSI, 2015) and if they were selected with due consideration of the reliability of the underlying monitoring data this is not documented. This is particularly true for the assessment of the spot monitoring data. For example:

    - All the current monitoring data was obtained from combined gas/groundwater wells. Although commonly used in the past, such combined wells are not regarded as current good practice, particularly at high risk sites, as such wells can result in erroneous data;

    - Is there sufficient spatial and temporal coverage within the data set, including periods of falling atmospheric pressure? Although RHDHV do state the atmospheric pressure associated with most monitoring, it is now known that it is more informative to know the trend in pressure (rising or falling) rather than historical requirements for monitoring during low pressure events. RHDHV do not generally discuss pressure trends.

    - The construction of each well and whether it targets one or more strata and the potential influence of groundwater flooding are important considerations and may mean that some data should be excluded from consideration when selecting a GSV;

    - Do peak or steady state flows provide the best insight into the overall gas regime and potential risks?

- The high frequency monitoring data contains several anomalies that challenge the current gCSM but these have not been identified and addressed by RHDHV. For example, why is the flow rate in CLGBH03 (Holwell Hyde Lane) 10x-100x higher than in all other wells? Why are the methane concentrations in RBH01 ~50x lower than in any other well within Former Mineral Workings? High frequency data also provides greater opportunity for robust analysis of the gas regime (*e.g.* time duration curves); such analysis has not so for been reported.