APP/M1900/W/21/3278097
WITNESS STATEMENT

Groundwater contamination matters significant to The proposed quarrying activity at the Hatfield Aerodrome

By:	Dr Michael Rivett FGS (Director, GroundH_2O Plus Ltd)
Date:	15 October, 2021
Use:	Appeal **APP/M1900/W/21/3278097** (Nov. 2021) on rejection of proposed quarrying activity, Hatfield Aerodrome
Witness called by:	Ellenbrook Area Residents Association (EARA) and Smallford Residents Association (SRA)

Witness experience

Dr Michael Rivett is founding director of GroundH_2O Plus Ltd, a research oriented environmental consultancy established in 2016 that specialises in hydrogeological assessment and technical review of groundwater contamination issues of concern to contaminated land, nuclear, energy-development, water-industry, groundwater regulation and developing world sectors. Dr Rivett aims to support the advancement and application of groundwater contamination research in all settings. He has over 35 years' research-oriented experience in contaminant hydrogeology, nearly 20 years as a university academic. He is currently a University of Birmingham Honorary Senior Research Fellow in the School of Geography, Earth and Environmental Sciences. Dr Rivett has a significant track record of published research and project experience. He has over 100 publications that have received a total of 3660 citations per his Google Scholar metric and listing of publications accessed at the following link:

- https://scholar.google.com/citations?user=8H8pUbUAAAAJ&hl=en

Synopsis

This Witness Statement summarises the serious evidence relating to groundwater, in particular contamination risks, that give grounds to uphold the 24th Sept 2020 planning decision to reject the proposed quarrying activity at Hatfield Aerodrome.

The Statement provides the technical rationale to uphold the Rejection drawing together and extending the lines of evidence previously presented by myself. These include the supporting evidence in my report (18/03/2020) provided in response to the Hertfordshire CC Consultation on the Groundwater Management Plan (GWMP) (Final v5) and my 1-page Summary of Independent Expert (21/9/20) and my presentation delivered to the Development Control Committee (Herts CC) Meeting (24/9/20).

The groundwater bromate plume context is initially presented to provide rationale as to why the remediation of what is unprecedented contamination - Europe's largest known groundwater plume, is of utmost priority and should not be jeopardised.

The Statement core expounds on the significant groundwater-related bromate plume problems that will arise from the proposed Quarrying, especially the LMH unit. It provides technical reasons as to why the groundwater-related conditions requested by the Environment Agency will be inevitably breached. It highlights a significant range of groundwater flow and bromate transport processes that have been insufficiently considered by the Applicant, key uncertainties and groundwater monitoring shortfalls.

The final section draws together key conclusions and summarises significant groundwater – bromate plume related issues that remain poorly considered by the Applicant.

There is a very legitimate concern that granting permission for quarrying at this Site would set a dangerous precedent giving rise to much increased prospects of near-plume quarrying of the LMH gravels at other sites that can only multiply problems to the management and remediation of the bromate plume at large.

My concluding recommendation is to uphold original decision to reject the proposed quarrying activity based on the unacceptable contamination risks involved.

Contents

Note, all paragraphs in the Statement text have been numbered [1], [2], etc. for ease of reference.

1. Introduction to the groundwater bromate plume contexts

[1] At outset, it is important to outline the groundwater bromate plume contexts. These contexts provide rationale as to why the remediation of this unprecedented contamination is of utmost priority and should not be jeopardised. These contexts provide support to upholding the Rejection decision on the Applicant's quarrying proposal.

[2] Some of the commentary reflects my personal perspectives on these contexts that may be debated by others. Such debate is of course welcomed, especially from those with direct involvements.

[3] An Environment Agency map of the plume and approximate location of the proposed quarry and other points of interest are shown in Fig. 1. This figure later ones showing data and conceptualising the nuances of the bromate plume problem respectively aim to provide a frame of reference and schematic illustration of key points made.

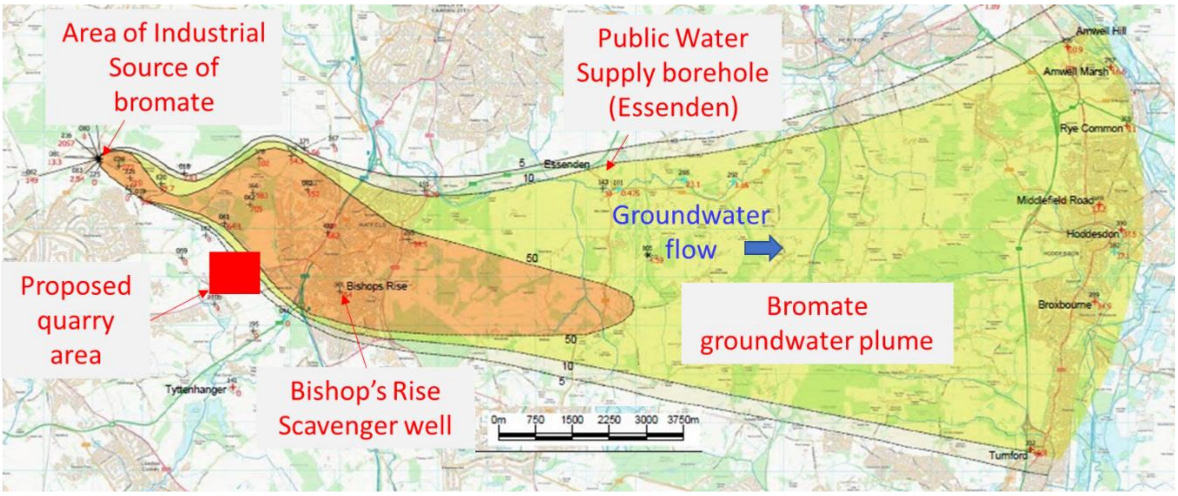

Fig. 1. Bromate plume and proposed quarry area vicinity and other features of interest. Licensed Public Water Supply (PWS) boreholes are indicated by the bold text names. The annotated plume – base map is reproduced from: Report F1, Part 2A of the EPA 1990 St Leonard's Court Decision Document Part 2 Environment Agency July 2019.

1.1. Europe's largest groundwater plume

[4] The rejected quarrying proposal at the Hatfield Aerodrome site occupies a large parcel of land immediately adjacent to, and it appears sometimes within (based on the Applicant's observed field data) what is currently Europe's largest known groundwater plume of contamination.

[5] The documented plume of dissolved-phase bromate in groundwater extends to over 20-km long. It has contaminated both the chalk aquifer used for public water supply (PWS) (and England's most important aquifer resource) and the overlying sand-&-gravel aquifer. The latter includes the Lower Mineral Horizon (LMH) 'gravels' proposed to be quarried.

[6] The plume is of unprecedented size, internationally rivalled only by relatively few similarly large plumes, for instance in the US. Often groundwater plumes are much shorter, hundreds of metres to several kilometres at most. In part because many contaminants will attenuate in the subsurface due to contaminant absorption to the aquifer rock, slowing the plume or, more usefully, contaminant being attenuated by (bio)degradation that destroys contaminant mass and usually lowers toxicity risks. Unfortunately, neither of these are significant for bromate.

[7] The bromate plume in this case is so large as the lack of attenuating mechanisms is compounded by a combination of factors:

i) Both the chalk via its fissure/fracture network and permeable gravels each offer fast pathways for groundwater plume migration; very high velocities may exist in chalk with 'karst' (large fissures etc.) features.

ii) Bromate, per above, is not appreciably attenuated in the subsurface and essentially moves at the groundwater velocity. The main, partial attenuation, slowing mechanism is bromate diffusion into the microporous chalk rock matrix adjacent to the chalk fissures, or diffusion into clay 'aquitard' layers such as the 'interburden' clay layer (or clay 'barrier') between the Lower and Upper Mineral Horizons (UMH) that is subject to proposed excavation and replacement during the Applicant's quarrying.

iii) The spread of the plume has been exacerbated, effectively 'pulled', by several public water supply (PWS) borehole abstractions. These for instance contribute to the plume's fan-shape appearance at its leading edge in the distant east and the pull of the plume southwards towards the Bishop's Rise (BR) scavenging well (Fig. 1).

iv) It appears the chemical source / 'soakaway' discharge of bromate causing groundwater contamination was inadequately controlled (regulated) during the former industrial site operations and caused on-going groundwater contamination for many years from around 1955 to the early 1980s, apparently unnoticed, or at least its significance unappreciated. Considerable bromate mass is anticipated in the subsurface due to this long release duration.

v) Based on the continued observation of persistent bromate plume concentrations, the legacy source of bromate not remediated (cleaned up) near the original industrial release area remaining in the underlying subsurface must still contain significant bromate mass. So much mass that it is still able to continually input bromate contamination into the wider groundwater environment, i.e., it acts as a ‘continuous source’ of contamination ‘feeding’ and sustaining the large bromate plume downstream.

[8] It is probable that the bromate plume may have reached a quasi-‘steadystate’ condition if it no longer appears to be growing larger, but has reached and remains at a similar size. In this condition the plume mass inputs to the plume are balanced by its mass outputs that include the BR abstracted bromate mass, any mass abstracted by other wells, plume mass discharge to surface waters, and mass lost to dilution beyond the defined plume boundary below detectable concentrations. It is important to realise that a plume at steadystate size still has considerable bromate flowing through it at high velocities through the chalk fractures – permeable gravels conveying bromate from the source input area to the various plume output locations. Bromate is hence continually passing adjacent to, and sometimes through the Applicant’s quarry site (see later Figs. 2 and 3).

[9] Whilst estimates of how long the groundwater bromate plume problem will last are subject to considerable uncertainty, plume lifetime estimates of 200 years (predicted by a UCL PhD study) for the bromate plume to remain above regulatory limits have been modelled (Fitzpatrick, 2010). Agreeing with Fitzpatrick, the ‘double-porosity’ (dual porosity) nature of the chalk comprising a micro-porous rock matrix in addition to fracture (cracks) porosity is fundamentally important. It allows diffusion of groundwater bromate travelling through the factures and diffusive accumulation of bromate into the adjacent micro-porous chalk matrix. The bromate contaminated chalk microporous matrix may then provide a relatively immobile ‘secondary source’ of bromate that will significantly extend the duration of elevated bromate concentrations and bromate plume lifetimes (Section 1.2). From the simple consideration that reverse diffusion is a much slower process than forward invading diffusion, coupled with an original bromate release date of 1955, parts of the chalk matrix will have experienced (forward) diffusion inputs for over 70 years now. Where reverse diffusion of contamination is yet to start (likely much of the plume), this reversal must take much longer than 70 years and hence the above estimate of 200 years for plume longevity is not unreasonable.

[10] This scale of groundwater contamination is unprecedented in the UK, and wider. Clearly the remediation of a plume of this scale cannot be jeopardised. It cannot be put at risk by other activities such as the proposed quarrying that may interfere with, or be reasonably anticipated to interfere with groundwater flows and bromate plume behaviour and remediation

endeavours. In my opinion this should include proposals that may require an intensity of field monitoring or modelling works to try to prove otherwise due to their inherent uncertainties. In the sense, that it is not worth 'taking the chance'.

1.2. A bromate plume problem - exacerbated

[11] Controversially, has the bromate plume problem been exacerbated by previous regulatory failings? And if so, is this relevant to the planned quarrying activity? I would answer 'yes' to both questions.

[12] Protecting our groundwater resource is a primary responsibility of the Environment Agency (EA). The responsibility has many facets and the EA do an admiral job at national and local scales - many, many case examples and initiatives are evident. In my opinion though, the bromate plume remains large and a persistent and difficult problem due to regulatory failings historically to secure much better remediation of the plume in a timely manner.

[13] In the absence of access to ground beneath the original bromate spill area due to the residential area since developed (and questioning too if remedial works at that development should/could have been better implemented), it would have then reasonably been expected that the regulator responsible for groundwater protection, the EA, should have better protected the downstream groundwater resource from continued bromate input. In my opinion, forcing the responsible party to undertake a source-zone containment-based remediation as soon as possible after plume discovery in 2000.

[14] Adopting, for instance, a pump-and-treat (P-&-T) scheme using pumping borehole(s) installed at the near-source, narrow-neck of the plume (Fig. 1) to essentially cut off, and contain the continued impact of the bromate source to the groundwater down gradient. Containing or remediating contaminant source zones is widely recognised as a primary EA response to contaminated sites to protect wider groundwater resources, but this has not transpired in this case.

[15] The failure to achieve timely (early 2000s) source zone containment is very expensive. It has led to the large-scale plume being needlessly further fed with bromate for nigh on two decades. It has meant a continued very large-scale plume has had to be contended with further down gradient, including in the area subject to the proposed quarrying.

[16] It is reasonable to conceptualise a bromate plume problem existing now that is exacerbated. The above shortfalls in remediation have allowed:

i) The bromate plume to essentially remain at its large > 20 km size and of similar widths (subject to PWS well pumping changes) feeding the mobile plume migration in the permeable chalk fissures/fractures and permeable gravels and enabling a large, quasi-steadystate plume to abide.

ii) Additional bromate mass to needlessly spread and still continuously accumulate in the large, around 20-km long downstream aquifer system.

[17] In particular, this has allowed significant further bromate contaminant mass to continuously diffuse into the porous low permeability chalk matrix and clay layers downstream (including around the planned quarrying area) over a further two decades driven by the high bromate fissure groundwater concentrations persisting from the failure to cut-off the plume near its source. Diffused bromate accumulates in the chalk matrix rock or fine-grained clays each having a water filled porosity of around 40% which can store a significant, near immobile (as low permeability to groundwater flow), mass of bromate that may serve as a 'secondary source' of bromate later on. Essentially wherever the bromate plume has been allowed to migrate, there remains a 'memory footprint' of its passage in the form of diffused bromate present as dissolved-phase concentrations in the near-immobile pore waters of the low permeability chalk matrix or low permeability clays where it has passed by in the adjacent permeable gravels/sands or chalk fractures. The longer the timeframes of plume passage, the greater the accumulation of diffused mass footprint in the matrix/clays. Hence my concern on the failure to achieve source zone control via pump-and-treat.

[18] Such diffused bromate mass accumulation, perhaps sounds benign, but is critically important as it will ultimately control the longevity of the bromate plume problem in that once bromate concentrations eventually begin to decline in the chalk fissures/fractures (as the source of contamination is hopefully contained or removed), bromate concentration gradients will reverse and 'reverse diffusion, of the 'secondary source' bromate footprint mass in the chalk/clay matrix will occur. This process will perpetuate the groundwater plume, effectively now feeding, groundwater bromate concentrations in the adjacent flowing fissure groundwater. The modelling of Fitzpatrick (2010) yielding bromate plume longevity estimates of 200 years incorporates the above processes and confirms the great significance of forward and reverse diffusion to the bromate plume problem persistence.

[19] The around two decades of failure to intercept the bromate plume near its source means the diffusion-based 'tailing' of the bromate problem has been needlessly and significantly added to throughout the downstream plume area. [I note that the same diffusion – reverse diffusion mechanism occurring closer to the original bromate source spill area (driven by even

higher concentration gradients) may be largely responsible for the continued persistence of the bromate source inputs observed, essentially occurring as 'secondary source' inputs after the primary source inputs (bromate effluent discharge to ground) have long since abated.]

[20] Hence in agreement with others, the bromate plume problem is likely to be very long lived. This is relevant to the planned quarrying as the evidence here is that the bromate plume problems are very likely to persist far beyond the planned lifetime of the quarry in its vicinity. I would not anticipate that a source zone containment remediation intervention now at the industrial bromate source area (which would still take several years to implement) would make as much difference to the risks posed as may be hoped for due to the diffused mass of bromate resident in the downstream aquifer system that would be gradually re-released over time by reverse diffusion.

[21] Regardless though of their format (Bishops Rise scavenging well or additions), groundwater plume remediation activities are going to be required for the 'long haul' and should not be put at risk, even low risk, of being compromised by other development activities on or close to the bromate plume. This is a complex groundwater contamination problem to manage – the double-porosity nature of the chalk poses a significant challenge. The proposed quarrying will not have a positive influence on plume remediation, but rather aggravate and add to the remediation challenge for the reasons outlined further below.

1.3. Plume management: undue water company onus compounded by quarrying

[22] It is important to appreciate that the current bromate plume remediation approach, the Bishop's Rise (BR) scavenging abstraction operated By Affinity Water (AW) is critically important to providing protection of PWS wells in the vicinity. However, it will not have appreciably foreshortened the longevity of the bromate plume problem in my opinion.

[23] Local community expectations of some that the BR abstraction over its operational period to date will have made a significant difference to bromate plume concentrations and problem longevity are unfortunately misplaced in my opinion. As this was not a design outcome of the BR scheme as I understand that scheme.

[24] The BR scheme 'scavenging well' is nevertheless critically important as it draws the bromate plume away from and protects important local PWS borehole abstractions (notably Essendon) and may lower somewhat bromate mass migrating further downstream. But it will not fully prevent

the bromate plume from migrating further downstream from BR, will make little difference to plume concentrations between BR and the bromate industrial source, will not effectively contain the bromate source impacts, and not appreciably foreshorten the longevity of bromate plume problem.

[25] The regulatory failing to gain bromate source zone containment outlined, in my opinion continues to put water supply companies (utilities), especially Affinity Water more locally and Thames Water at remote distances, in a continued onerous position to deliver safe water supplies to the public from the chalk groundwater resource downstream that might otherwise have been reduced. Whist the water companies admirably continue to achieve this protection and deliver safe water to their customers, they are in my opinion somewhat unfairly landed in a groundwater bromate plume management role (e.g. Bishop's Rise scavenging abstraction) by the EA failure to secure a more appropriate, near-source, remediation scheme.

[26] The water companies hence deserve every support in achieving this 'cascaded role' in my opinion. This support should include the rejection of planning applications that may otherwise if granted effectively cause water companies to enter into detailed separate legal agreements with the Applicant (exterior to the Planning system) to try to protect their Public Water Supply interests as has proven the case here. The undue onus on the water companies cascaded from the failure to secure source zone containment remediation by the EA is being further and unreasonably compounded by the proposed quarrying activity and onus to safeguard the remediation scheme from further complications arising from that activity.

[27] The very fact that Affinity Water have seen the need to secure separate legal agreements with the Applicant (exterior to the Planning system) raises some concerns, in that:

i) The presumption, I speculate controversially, is that the planning system and conditions enforcement is perhaps seen as insufficient to fully protect water company interests.

ii) The inference, I speculate, but borne out by AW's original intent to object to the proposed quarrying, is that the quarrying operations unless very tightly controlled to AW's satisfaction do pose risk to the effectiveness of the BR scavenging scheme.

iii) I imagine and speculate that any separate legal agreement reached between AW and the quarry applicant will need to be highly detailed which may raise questions as to its workability in practice – at least it would require significant efforts and commitment on both sides, and it appears far from ideal 'self-policing'.

iv) The lack of availability of the Applicant – AW legal agreement to the communities, local authorities, EA and professional experts means that its effectiveness to deliver adequate protection of public water supplies remains beyond scrutiny and has to be taken on trust. This lack of transparency is clearly of concern, to professionals such as myself who could technically review its probably effectiveness, uncertainties and possible deficiencies. But, especially concerning to local communities on the receiving end of an agreement's effectiveness. Hence the details of the key area of groundwater control have become opaque and beyond scrutiny.

v) My impression is that the BR scavenging well scheme operates on a delicate 'knife edge', carefully balancing the optimal abstraction rates of the scavenging well to capture the plume sufficiently adjusting for the prevailing climate – hydrogeological influences to achieve protection of other PWS wells. In my opinion, this delicate operation should not be compounded by the added burden to AW of keeping vigilance on a quarry operator and their adherence to an agreement reached and the effectiveness of the agreement in achieving its aspirations.

vi) What if the legal agreement is breached – Are the consequences irretrievable or not? – Can they be ameliorated? The lack of transparency renders these and similar questions unanswered and concerning.

[28] Whist AW having a legal agreement with the Applicant may/should theoretically perhaps allay concerns as it presumably provides relevant control etc.; in practice, local communities and other stakeholders may not see it quite this way for the above reasons. There is also no opportunity for the technical community (beyond AW and the Applicant's team) to assess the risks posed to bromate plume management to evaluate the adequacy of the controls agreed.

2. Groundwater-related issues with the Proposed Quarrying Activity

[29] The remainder of the Statement, in line with my presented material to the September 2020 Development Control Committee, focuses on the bromate plume groundwater-related issues (problems) of the proposed quarrying activity and the anticipated breaching of groundwater-related Conditions included at the request of the Environment Agency (EA).

[30] There is a very legitimate concerns that these conditions will not, or cannot be met by the proposed development and will inevitably be breached. Relevant to addressing these conditions, there appears several technical groundwater-related problems that overlooked or inadequately considered in the Developers Quarrying proposal.

[31] These problem areas are outlined below, integrated appropriately to my discussion of anticipated breaching of the Conditions set. This material largely draws from but also extends some arguments from my previously presented materials noted in the Synopsis.

[32] The scope of my Statement is limited to groundwater issues connected with the bromate plume contamination. It does not include, for instance, flooding concerns that may be expected to be influenced by groundwater flows/changes to some extent (and are beyond my main area of expertise).

2.1. Excavation of LMH Gravels poses the most significant risk

[33] The most significant groundwater-related risks of the Proposal stem from the Applicant's wide-scale excavation of the lower mineral horizon (LMH) gravels located below the protective interburden boulder clay layer that is removed. This unit protects the immediate underlying Chalk aquifer groundwater resource and indeed is the only low permeability geological unit present that offers significant protection. The proposed interburden clay excavation jeopardises:

i) protection of Chalk groundwater resource, the sole public drinking water supply to most in Herts;

ii) optimal remediation of the >20 km bromate groundwater plume, Europe's largest and expected to last upwards of 200 years without direct intervention (Fitzpatrick, 2010).

[34] The proposed quarrying fails to recognise the importance of the LMH gravel aquifer to wider safeguard of public water supplies and bromate plume management. Of key concern and not adequately recognised in the Quarry Proposal (nor I contest adequately recognised by the EA in the workability of their proposed groundwater-related Conditions) is the fundamental fact that:

i) The proposed 4 million tonnes quarry backfill will have a much lower permeability to groundwater flow than the removed sand-&-gravel and hence this permanent backfill will inevitably and permanently reduce total capacity of the site and wider LMH gravels to store and slow down the bromate plume. This will cause increased bromate contamination risks to downstream public water supply wells (e.g. Essendon) and prove a detriment to overall plume remediation.

[35] The Environment Agency has proposed three groundwater monitoring-based 'EA Conditions' that in my opinion will not be met, or are unlikely to be met, due to the LMH gravel extraction. The critical failures are outlined further below.

[36] It is very evident, from both the Quarry Applicant's and EA's wider plume monitoring well data available that parts of the LMH gravels aquifer is significantly contaminated by bromate. However, it should be recognised that to date the investigation, assessment, and research on migration of the bromate plume by the wider community (the EA, AW, researchers) has very largely focused on its behaviour in the chalk aquifer and not the overlying sand-&-gravel aquifer (LMH aquifer) system.

[37] Bromate distributions in the LMH at large are poorly understood compared to the chalk plume for which data are usually shown on maps such as those in Fig. 2 presented later. Likewise, the migration behaviour of bromate in the LMH groundwater and its relationship to bromate plume fate in the underlying chalk is poorly understood. Much uncertainty exists over the control of the LMH sands-&-gravels on bromate migration in the underlying chalk aquifer system, the groundwater flow and plume interplay exchange between these two aquifers and ultimately the influence of the gravels LMH aquifer on risks posed to PWS abstractions in the chalk, including the Bishop's Rise scavenging well.

[38] Advancement of LMH quarrying in the plume near-vicinity is not prudent with such a dearth of understanding. It would be highly imprudent to effectively remove 4 million tonnes (roughly 4 million cubic metres (m^3)) of the LMH material replacing it with low permeability material without first understanding the role and significance of the gravels to the bromate plume behaviour and risks posed to bromate plume migration and its remedial management.

[39] In my opinion, the role of the LMH gravels in this context is far from sufficiently understood at present to warrant their excavation over such a wide area immediately adjacent to and sometimes within the bromate plume.

2.2. EA Condition I - "No mineral is extracted from within the existing plume of bromate and bromide groundwater pollution"

[40] Regarding 'EA Condition I', "*No mineral is extracted from within the existing plume of bromate and bromide groundwater pollution*", bromate groundwater contamination in the LMH/chalk at or near the Quarry Site is significantly controlled by pumping rates of the Bishop's Rise scavenging well. Concentration variations at/near the Quarry Site will be additionally induced by anticipated secondary influences of rainfall variability and changes in aquifer natural recharge, i.e., replenishment of groundwater at the water table by infiltrating water.

[41] It is recognised here that various renditions of the wider scale plume and Quarry Site location proposed show this location to be variously within

or just beyond the plume boundary (Fig. 2). It should be recognised in such figures that plume contours drawn may relate to real plume changes with time, but also will depend on monitoring well data included in each rendition that may vary. Plume contouring will also be somewhat uncertain, especially in areas of sparse monitoring well density.

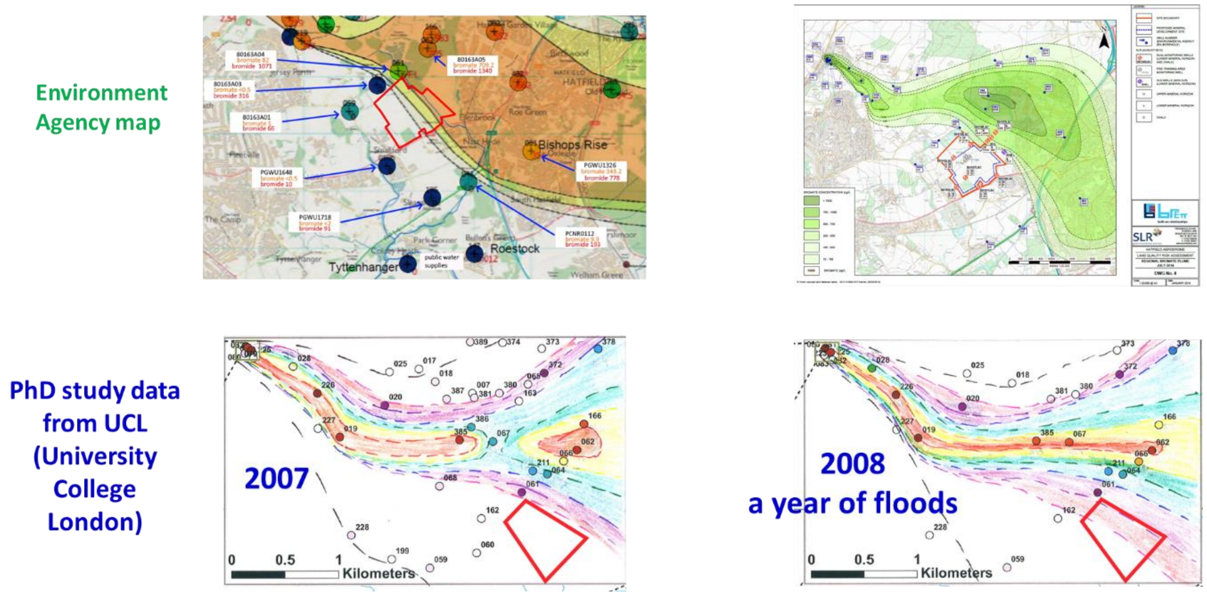

Fig. 2. Various renditions of the bromate groundwater plume showing the quarry site just within or just beyond the proposed quarry site boundary (approx. red outline).

[42] Further, the plume is clearly 3-D in reality rather than 2-D as plotted in Fig. 2. The 3-D variability of the plume at its high concentration gradient marginal edge close to the quarry site is likely to be very significant. However, this is currently poorly known with for example little, if any data (such as multilevel sampler depth profiles) available to establish the bromate concentration heterogeneity in the vertical and discrete elevation layers where the plume edge is likely most extensive towards the Site.

[43] The bromate plume is likely to be dynamically responsive to changes in rainfall seasonally and over longer time periods which may lead to changes in local concentrations and plume shape. Effects of rainfall are possibly seen in Fig. 2 with the 2008 wet year plume depicted within the Site and not in 2007. In general, wetter years have witnessed higher bromate plume concentrations regionally and at the BR abstraction that may be attributed to greater contaminant source zone leaching inputs, including secondary source zone inputs.

[44] The future influence of climate change (a priority EA concern generally https://www.gov.uk/government/news/adapt-or-die-says-environment-agency) is likely significant on source zone leaching inputs and lead to changes in the plume shape and concentration distributions. Increased intensity rainfall events in particular may lead to significant flow regime

changes and promote ‘pulsed’ lateral plume excursions towards and into the Quarry Site that would be greatly exacerbated (promoted) by the Applicant’s groundwater abstraction. The influence of climate change requires greater consideration by the Applicant on some of the flow regime – plume migration processes nuance they have currently overlooked outlined further below.

[45] Higher-end BR Scavenging well pumping rates as necessary of 4 up to 8 megalitres per day may be expected to cause greater ‘drag’ of the bromate plume down into the Site area LMH gravels and underlying chalk, thereby breaching EA Condition I. Deciphering whether increased bromate concentrations on or near site (for instance in 2019 data) are due to increased pumping, or changes in rainfall need to be better understood through detailed examination of the field data (that currently appears lacking) and augmented by modelling works so that these controls can be understood and these dynamics predicted. The Applicant has failed to explain why low concentrations of bromate have been sporadically seen on site (see later Fig. 3) and also why bromide (also included in Condition I) is showing anomalous concentrations elevated compared to plume fringe ratios in the wider plume. The Applicant is proposing quarry activity in the LMH gravels for which they at present do not understand adequately (or at all) what has caused the bromate concentrations observed and needs to do so.

[46] Turning more closely to the local data, Fig. 3 plots the Applicant’s groundwater bromate monitoring data. Virtually all of the monitoring wells shown that variously monitor the chalk, LMH gravels and UMH gravels have exceeded the 2 µg/L bromate ‘limit’ at some point in time (the orange-circled wells). Of most concern is the clear occurrence of bromate concentrations specifically monitored in the LMH gravel aquifer monitoring wells; the maximum bromate concentrations over the period 2013-19 for the LMH gravels monitoring being noted in the Fig. 3 yellow-highlighted labels.

[47] The Fig. 3 LMH data clearly show observations of low, but significant groundwater bromate concentrations observed in monitoring wells in the LMH gravels just within the Site perimeter. With very high bromate to over 500 µg/L bromate nearby to the immediate north-east of the site. The on-site contamination observations appear at odds with Applicant / EA statements/plots that bromate is not present in the LMH gravels on site.

[48] The Fig. 3 evidence combined with further temporal data that it is recognised may show below detection limit bromate too at Site perimeter wells (not shown here) is that bromate-contaminated groundwater may be sometimes transiently encountered in the site monitoring wells.

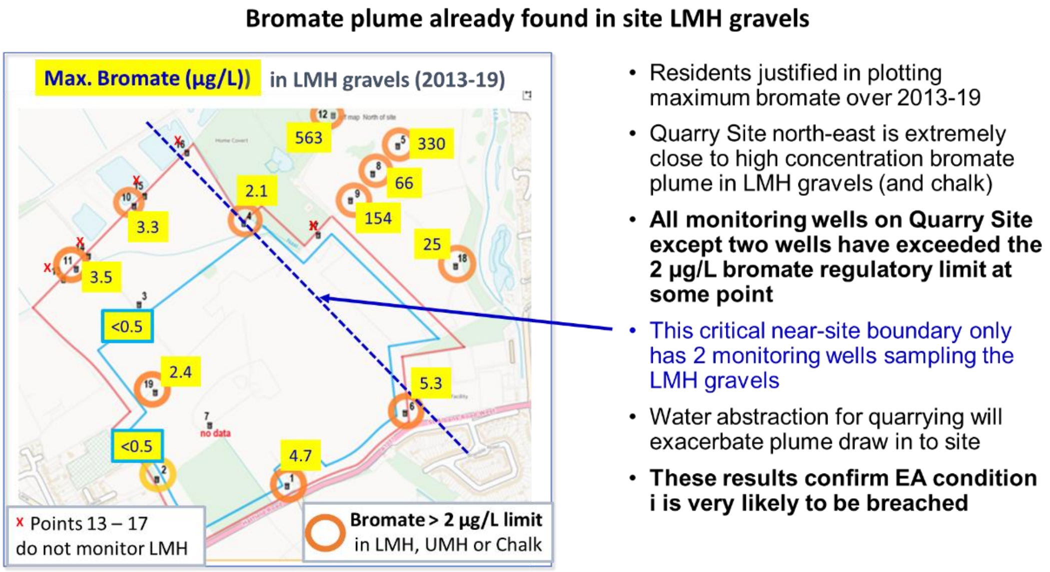

Fig. 3. Plot of maximum bromate plume concentrations observed in the LMH gravel aquifer monitoring wells over the period 2013-19 (slide from my Sept. 2020 DCC Meeting Presentation). A significant, around 800 m length gap, in the on-Site monitoring network is also illustrated by the arrowed very sparsely monitored blue-dashed line transect along the NE site boundary close to the very high-concentration bromate plume.

[49] In my opinion, transient entry of bromate could be expected into the Site as the high-concentration lateral plume edge moving predominantly south-eastwards towards BR may be subject to some lateral movement normal to that principal flow direction. This is due to weak plume transverse dispersion mixing causing some plume lateral spreading, but also some expected transients in the groundwater flow field arising from variability in the BR pumping rates and spatial variability in groundwater recharge. The high-concentration bromate plume edge may effectively laterally 'pulse' into the north-eastern / eastern site area (a boundary along the site edge that I note below is unfortunately sparsely monitored). The pulsing and lateral plume motion into Site would be further induced by the Applicant's proposed abstraction of groundwater from the LMH gravels. The Applicant has not made adequate efforts to understand such processes controlling the bromate concentrations on or near Site and is hence naïve how these concentrations may be best controlled and monitored (noting the point further below on inadequacies of their plume monitoring to date).

[50] It is possible that the lower bromate concentrations in some of the recent monitoring could be attributed to lower scavenging well pumping rates in recent years (due to operational issues). If so, bromate may be expected to gradually increase on/near the Quarry Site with resumption of higher scavenging pumping rates. Hence, part of the viability of meeting EA Condition I is not controlled by the Site developer, but by the scavenging

well operator and their remediation objectives. Noting Essendon public water supplies may see increased bromate within days if scavenging well rates are set too low – a delicate knife-edge 'balancing act'.

[51] I would also note that the Applicant indicates daily abstraction rates that are large and significant and potentially greater than the BR operational abstraction rates, or at least a significant percentage of these rates. Such rates are of concern. The Applicant provides amazingly little detail to make a realistic assessment of their expected influence and bromate plume draw in to the Quarry Site. There is no indication by the Applicant of rates beyond daily abstraction rates, e.g., weekly, monthly, annual or an estimate of total volumes of groundwater expected to be extracted are not indicated at all (and I suspect they cannot easily estimate some of these). There is no numerical modelling of the influence of the proposed abstraction influence by the Applicant. It would be reasonable to have expected such modelling works to underpin such large abstraction volumes with justified and agreed model set up (conceptualisation and of formation units modelled) and agreed parameter values selected for modelling (hydraulic conductivities, recharge etc.). This is a volume of works that should have been undertaken in advance of quarrying to avoid the actual abstraction activity undertaken being an 'experiment'.

[52] I hold concerns that there may be as yet unfound 'footprints' of bromate existing at the Site already present from the previous excursions of the bromate plume into the quarry Site area. This would include historically when BR was pumped at higher rates and used for Public Water Supply where it is more probable that the bromate plume (Fig. 2) would have been more likely to have been pulled down through the Site area. Secondary source zone plume memory footprints of bromate may exist diffused into the low permeability units, notably in the underside of the interburden clay that may have become bromate contaminated from contact with, and diffusion from, the bromate flowing past in the LMH gravels below. Some of the interburden clays proposed for excavation may hence well be contaminated from their memory of historic bromate plume exposure. This prospect appears not to have been considered by the Applicant and is concerning.

[53] Taken together, the above lines of evidence strongly suggest that the bromate plume is 'too close for comfort', has transiently been already observed within the site (Fig. 3) and hence EA Condition I is very likely to be breached during Site operations. The Applicant has failed to provide any flow and contaminant transport modelling works to underpin their proposal allowing some quantitative evaluation of the abstraction rates proposed and their influence and uncertainties. These should be reasonably expected to underpin assessment of the Application. The quantitative numerical prediction of the impacts of the quarrying by the Applicant lack entirely and should be reasonably expected.

2.3. Concern over monitoring well inadequate coverage of the key Site boundary

[54] As alluded to, a great surprise to myself in reviewing the Site groundwater monitoring well data is the sparse monitoring well coverage within the key LMH aquifer along the north-east boundary of the site closest to the highest concentrations of bromate close to site (Fig.3). Considering the relatively long temporal duration of monitoring conducted, my anticipation is that the Applicant would have wanted (or EA required) a much more robust demonstration of the lack of potential for bromate plume entry across this key Site boundary.

[55] The dashed-blue line added to Fig. 3 shows this critical near-site boundary transect only has 2 monitoring wells sampling the LMH gravels, the critical unit to monitor to assess Site risks pertinent to the quarrying of the LMH gravels. The two monitoring wells on the dashed line that monitor the LMH are a staggering 800 m apart, recognising the other two wells on this transect line (denoted by x) do not monitor the LMH.

[56] In my opinion this is woefully inadequate monitoring that has failed to prove if bromate was substantially entering the site along much of the most likely point of entry into the Site over the last 7 years and provides little confidence in making decisions going forward.

[57] It is unclear why this key boundary was not more intensively monitored to underpin the Application and provide evidence to underpin the likelihood of fulfilling EA Condition I. It would be very remiss to leave detailed monitoring of this boundary to be only undertaken during active Quarry Site operations and prove problems at that late stage.

[58] Moreover, groundwater monitoring of the most likely Site boundaries for bromate plume entry would require intensive monitoring of the LMH gravels, both spatially and temporally. The numbers of wells proposed for the entire site appear insufficient to allow this needed focused effort. It would be all too easy for the plume to slip between a sparse monitoring well network unnoticed. Also, monitoring well positioning requires careful design with respect to the location of the point(s) of abstraction; wells could be located in flow divide areas and be of little use without careful thought. Per above, the monitoring to date does not give a good foundation for future monitoring design along the critical north-east boundary. It begs the question as to can, or whether, future planned monitoring will be sufficiently robust to document risks arising, both in space and time. The fact that the EA has sanctioned the existing inadequate monitoring gives cause for concern that planned future monitoring would also be inadequate, but find regulatory approval. This is most concerning.

2.4. EA Condition II - "any activities close to the plume must not change the existing hydrogeological flow regime"

[59] Regarding EA Condition ii, "*any activities close to the plume must not change the existing hydrogeological flow regime*". In my opinion this, black-and-white, "must not" condition will be permanently breached during and moreover, permanently following, Site quarrying development.

[60] A permanent breaching will inevitably occur by the proposed replacement of excavated permeable sand-&-gravel aquifer LMH formation and the consequent permanent insertion within the former Site LMH aquifer unit of 4 million tonnes of low permeability 'clay' backfill across the site or other finer-grained material that will inevitably be of much lower permeability (by orders of magnitude) to groundwater flow than the sand-&-gravel materials removed by quarrying. The inevitable change in the "existing hydrogeological flow regime" is conceptualised in Fig. 4 depicting the flows in the LMH aquifer unit before and after Quarry backfill.

[61] Focusing initially on the before Quarrying current scenario, Fig. 4a plots groundwater hydraulic head (water level) contours for the LMH aquifer unit that have been directly traced from the Applicant's contoured maps based on their collected LMH groundwater level data. Directions of groundwater flow (arrows added in Fig. 4a) will be perpendicular to the groundwater head contours. LMH head contours on site are clearly arcuate about the Bishop's Rise (BR) abstraction confirming groundwater flow directions are convergent on the Bishop's Rise abstraction. Hence, the Applicant's own data supports BR's 'cone of depression' due to its abstraction is sufficiently extensive for the well to abstract groundwater in the LMH gravels currently flowing across the Quarry Site. This is clearly important evidence confirming the influence of the BR abstraction on existing Site flows in the LMH gravels.

[62] Groundwater flows in the LMH gravels on site are hence currently being influenced by the BR abstraction, indeed being drawn towards that abstraction point and highly likely to be a component of the groundwater abstracted by BR. This would be enabled by the good hydraulic connection (groundwater flow) between the LMH gavels and the upper Chalk with increased drawdown closer to the BR abstraction permitting increased vertical groundwater flows from the gravels down into the chalk (further increased by increased abstraction rates).

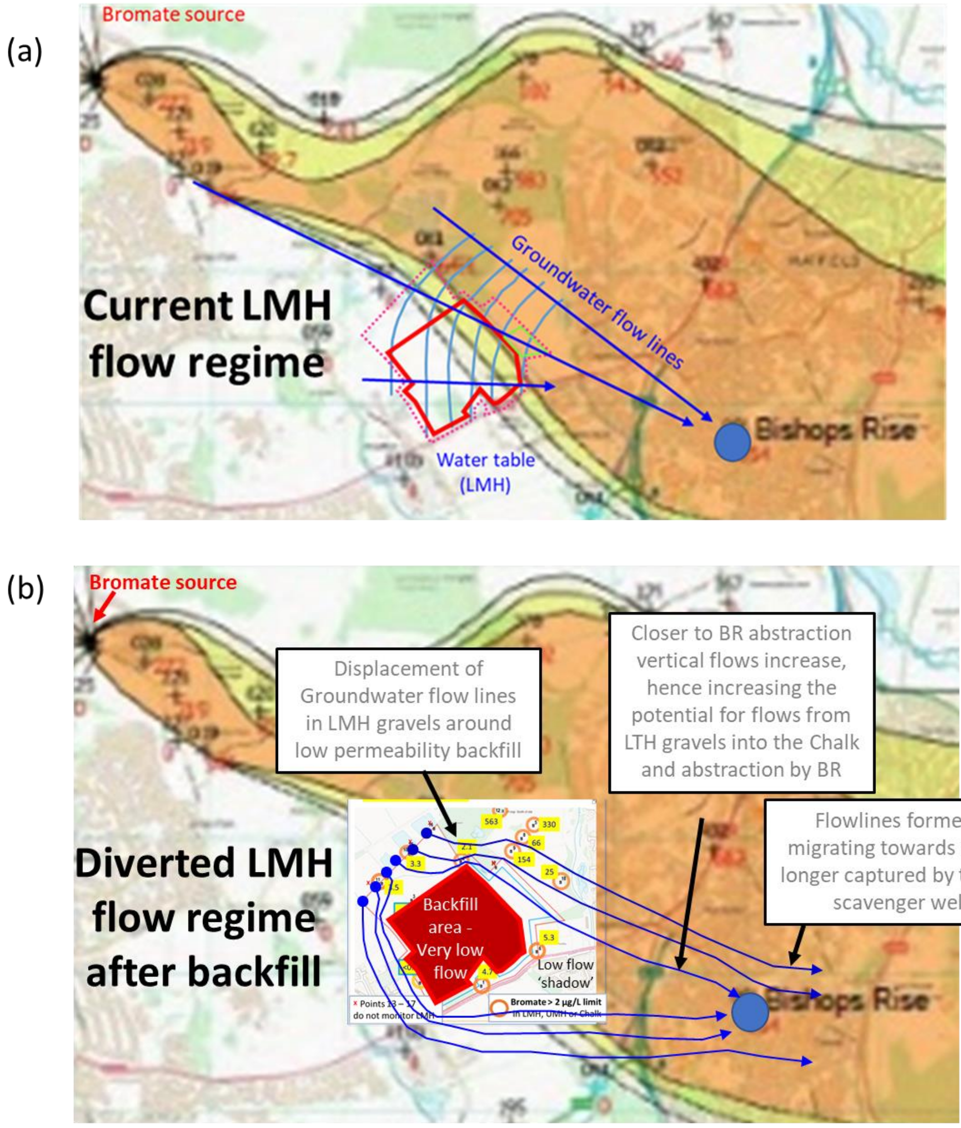

Fig. 4. Conceptualisation of permanent change in the existing hydrogeological flow regime expected between (a) current LMH flow regime (head contours drawn from Applicant's LMH water table head data) and (b) diversion of LMH flows around the backfilled LMH Quarry Site due to the low permeability backfill 'island' installed significantly reducing groundwater flow across the site. To note that flow lines to be captured need to leak down into the chalk aquifer from the LMH gravels – a possibility that increases with approach to BR. To note flowlines in (b) are schematic (illustrative), but those in (a) are actual expected based on observations. Also, the conceptualisation is shown in 2D, but flow deflection will be 3D, including possible downflow into the Chalk.

[63] In relation to the above, I would contend that the following statements made by the EA at the Sept. 2020 DCC Meeting were misleading and failed to convey the full picture of the significance of BR abstraction of the bromate plume in the LMH gravels and also correctness on its relative depth

appearing to overlook the BR site ground elevation is 25 m higher that of the quarry site. The EA comments: "*the vast majority of the high concentration of bromate and the transport of bromate actually occurs at quite a greater depth than the base of the quarry the actual Bishops Rise abstraction abstracts from a depth greater than 68 metres below the ground*" and the "*base of the quarry I believe is 16 metres below ground level*". This point is taken up by EARA in their response to the EA following the DCC Meeting (EARA document 043).

[64] Fig. 4b conceptually illustrates the considerable and permanent change in the existing LMH hydrogeological flow regime that may be caused by the permanent backfill site-wide of quarried LMH gravels with lower permeability geological materials (clays, finer grained deposits etc.). Groundwater flows within the remaining LMH aquifer will be largely deflected around, rather than pass through the backfilled Quarry Site. Some of these deflected groundwater flowlines, previously passing through, or near the Quarry Site, and previously vertically draining from the LMH gravels into the Chalk and possibly then abstracted by the BR scavenging well may conceivably no longer be captured by the well due to their laterally deflected flowpaths in the LMH gravels, i.e., they are displaced beyond reach of the BR abstraction.

[65] Overall, the excavation of a significant ~4 million cubic metres volume of permeable LMH aquifer material and replacement with inevitably much less permeable backfill material causing deflection of previous groundwater flowlines focused towards the BR abstraction will constitute a permanent change in the existing hydrogeological flow regime thus inevitably contravening EA Condition II. The Condition cannot be met.

[66] The only way this could be avoided is to not quarry the LMH gravels and thereby, in short, avoid replacing a perfectly good aquifer unit with what largely amounts to a low permeability aquitard 'island' set within the wider LMH gravels remaining beyond the Site.

2.5. EA Condition III - "any activities close to the plume must not interfere with the remediation of the bromate and bromide pollution"

[67] The knock-on consequence of failure to meet EA Condition II, is failure to meet EA Condition III - "*any activities close to the plume must not interfere with the remediation of the bromate and bromide pollution*".

[68] The low permeability 'island' of backfill installed within the LMH void post quarrying results in groundwater flow predominantly pushed around that island. Such flow will effectively displace, 'push' parts of the nearby bromate plume in the surrounding LMH gravel aquifer away from the Quarry Site, pushing to the north-east as conceptualised in Fig. 5. Critically, displaced plume in the LMH gravels that may have formerly vertically drained down into the chalk and was abstracted BR could now be effectively

pushed beyond the reach of the BR abstraction and no longer be captured by the scavenging well (Fig. 5). Remediation is inevitably interfered with.

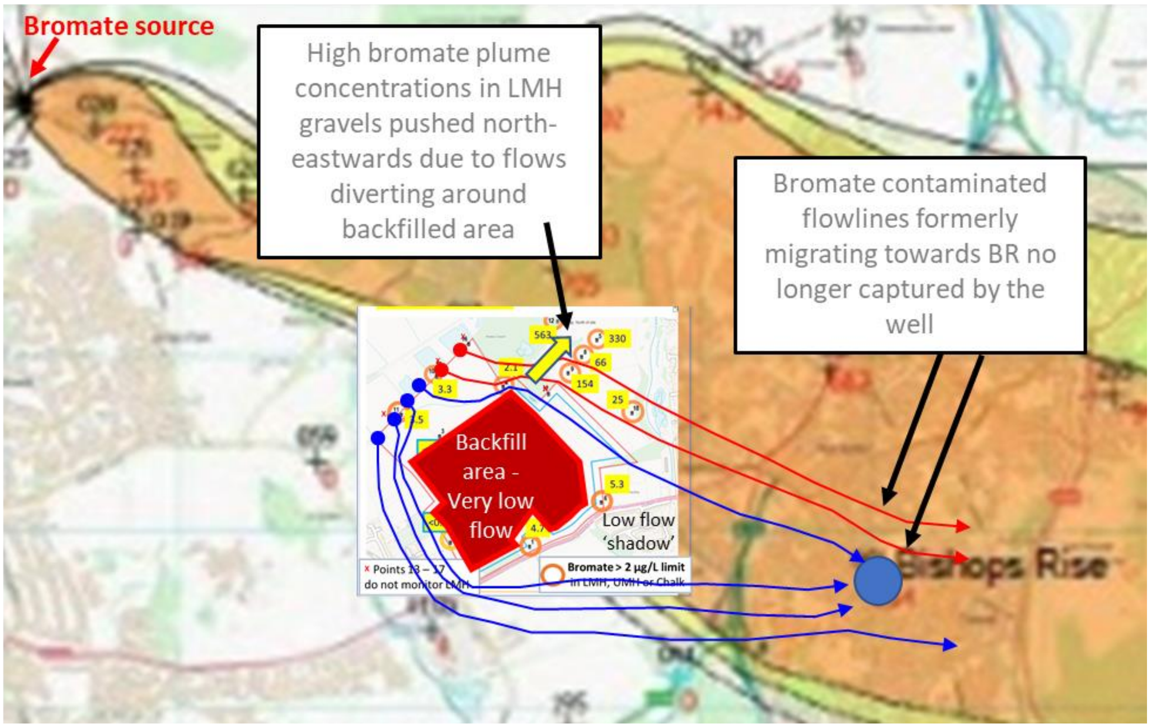

Fig. 5. Conceptualisation of groundwater flow in the LMH gravels around the quarry backfill low permeability 'island' illustrating that some of the contaminated particle pathlines (red lines) formerly captured by BR are no longer captured by the BR abstraction and pose increased risks to other public water supplies. To note flowlines shown are schematic and illustrative of the concept.

[69] Such a failure would lead to a permanent breaching of EA Condition III - "*any activities close to the plume must not interfere with the remediation of the bromate and bromide pollution*". Such interference would dictated that the BR abstraction would need to be pumped at a higher rate, continually, to attempt to capture the groundwater – bromate contamination laterally displaced by the low permeability backfill.

[70] Such a failure to capture possible components of the bromate plume previously captured will lead to an increased risk of displaced bromate plume migrating to downstream public water supply wells (eg Essendon, Broxbourne) (Fig. 1).

[71] Flow diversions would be greatest in wet years with high water tables and when bromate concentrations are typically found to be highest in the plume generally from increased contaminant source area leaching, thus heightening risks further. It would hence be important that such transient

events are appropriately monitored in time – monthly rather than quarterly sampling of monitoring wells would be required at minimum to discern such influences recognising too there may often be lag times involved between rainfall events and expression of concentration increases in wells making their connection to rainfall sometimes challenging to prove.

[72] To note, that the flow lines drawn in Fig 4b and Fig 5 are schematic and illustrative of the groundwater flow and plume displacement concepts outlined. Accurate predictions would require numerical groundwater flow and transport modelling works. These works would have inherent uncertainties and would require validation by field observational data.

[73] Such modelling work has not been undertaken by the Applicant. Their claim was that flow diversions due to low permeability backfill would be a temporary rather than permanent phenomenon. I fail to see the technical basis for this position that appears very misleading.

[74] Returning to the influence of the Applicant's own proposed high-volume abstraction of groundwater on bromate plume remediation. It should be pointed out that even if the bromate plume was not pulled on to Site and detected in on-Site monitoring wells, there would still be some inevitable pull of the high-concentration plume core towards the Site. This pull of the plume will inevitably lead to higher Bromate plume concentrations migrating into areas that currently have low or non-detect concentrations of bromate.

[75] Even if groundwater abstraction by the Applicant was later suspended after operation, the lateral excursion of the higher concentration bromate plume towards site caused by the abstraction will inevitably lead to an increased 'footprint' of bromate of diffused mass in the chalk matrix and low permeability deposits (clay layers, interburden etc) in the area into which the plume was pulled by the Applicants abstraction. The Applicant's abstraction will inevitably hence cause a widened plume footprint of semi-permanent, secondary source bromate mass that will slowly re-diffuse over time. The Applicant's abstraction will hence inevitably lead to an aggravated remediation condition by laterally extending the secondary bromate source zone area. Hence it does not need the bromate plume to be pulled on to the Quarry site for the remediation to be interfered with, the remediation will be aggravated and made more onerous by the simple expansion of the plume towards the Site which will inevitably occur.

2.6. Overlooked significance of the LMH gravels to provide 'dynamic buffer storage' of the bromate plume and reduce PWS risks

[76] A key overlooked technical aspect by the Applicant (and it also appears the EA) is the possible significance of the LMH gravels to provide important 'dynamic buffer storage' of the bromate plume. This storage may help to reduce bromate migration velocities overall and thereby reduce risks to

PWS boreholes. Conceptually the dynamic buffer storage is outlined in Fig. 6 and the concept outlined in the text below.

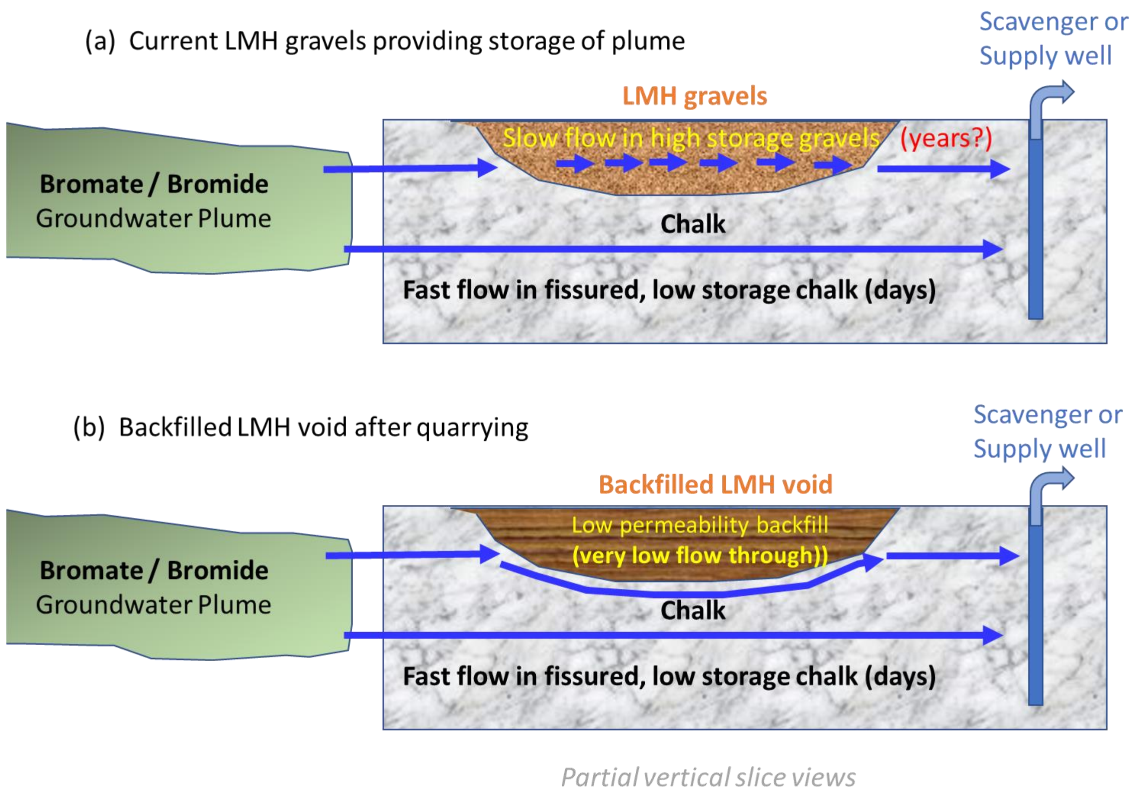

Fig. 6. Conceptual model illustrating (a) the capacity of the LMH gravels to provide 'dynamic buffer storage' of the bromate plume; and (b) loss of this storage capacity due to backfill of the quarried LMH gravels with low permeability clays/materials.

[77] A 'dynamic buffer storage' of the bromate plume arises as there is significant capacity of the LMH gravels to store and considerably slow down the bromate plume, removing it from the mobile chalk groundwater. The (temporary) residence of the bromate plume in the heterogeneous gravels provides a dynamic buffering opportunity, buffering the plume impact on PWS abstractions screened in the chalk. The gravels essentially act as a 'slow lane' to drop in to from the 'fast lane' chalk 'motorway'. Its significance remains a key unknown and the removal of this capacity to help attenuate bromate plume impacts is entirely overlooked by the Applicant.

[78] Roughly, the LMH gravel have an accessible pore-space of about 20% that may store mobile groundwater. This is around an order of magnitude greater than the chalk where the mobile groundwater may largely be assumed to occupy fracture/fissure space, around 2% of the rock volume. Hence a 5 m thickness of LMH gravels may offer a dynamic storage equivalent to a 50 m thickness of fractured chalk based on the above percentages. This simple calculation would suggest that the dynamic

storage offered by the gravels is significant and should not be overlooked and definitely not permanently reduced as will occur from the low permeability backfill proposed by the Applicant.

[79] The very presence of bromate in the LMH gravels at high concentrations adjacent to the site confirms the bromate plume is accessing the significant dynamic storage capacity of the LMH gravels. As illustrated in Fig. 6a, the gravels will provide buffer storage of the plume and considerably slow down the bromate plume progress, removing it from the mobile chalk groundwater where velocities in the fractures can be considerably higher.

[80] Removal of the LMH by quarrying with re-insertion of low permeability backfill, significantly reduces the potential for dynamic plume storage with limited plume flow through the backfill material as shown in Fig. 6b. The slowing mechanism and buffer storage of the LMH gravels has been lost due to the backfill. A plume previously migrating through a gravel subsequently backfilled would largely have to remain in the chalk migrating at high velocities (Fig. 6b).

[81] Even if the backfilled LMH gravel area did not contain a bromate plume, but the plume was nearby, the loss of backfilled LMH gravel volume causing lateral diversion of clean groundwater previously across site into the adjacent plume will lead to reduced capacity for the bromate plume to access the LMH buffer storage. The ability of gravels to store and buffer plume concentrations will still be permanently lost by the backfill nearby.

[82] It is really important to note that such buffer storage of some of the bromate plume may be expected to lead to a slowing of that plume, help reduce the dynamic variability of bromate concentrations at the BR scavenging well and help lower risks generally to other PWS abstractions. The removal of around 4 million cubic metres of LMH gravels and replacement with low permeability backfill local to the bromate plume and BR scavenging well reduces irreversibly this potential for 'dynamic buffer storage' of the bromate plume and reduces the above benefits. A significant concern for granting quarrying permission would be the precedent set for near-plume quarrying and backfill of the LMH at further sites (see further below).

[83] Due to the focus on the bromate plume in the chalk rather than the LMH gravels, and the uncertainties in the exchange of groundwater between the LMH gravels and the chalk (in either direction), it is not surprising that the LMH gravel capacity for 'dynamic buffer storage' of the bromate plume is likewise poorly understood but needs to be in order to prevent its loss.

[84] Much further research – investigation via field work and numerical modelling works would be required to prove the significance of this 'dynamic buffer storage' influence. In the meantime, it would not be prudent in my opinion to backfill a quarry volume of around 4 million cubic

metres that will irreversibly lose this capacity without understanding its influence first.

2.7. Increased groundwater vulnerability

[85] To make the point briefly that removal of the interburden clay layer (intervening 'aquitard' layer) of low permeability clays between the UMH gravels and LMH gravels over such a wider area is a significant and leads to a step-change in groundwater vulnerability.

[86] In that the LMH gravels are in direct hydraulic continuity with the underlying chalk aquifer used for public water supply (PWS), removal of the interburden clay layer removes the main, indeed only geological layer providing significant protection of the chalk resource by virtue of its very low permeability. Noting too flows from the Site are clearly towards BR.

[87] The large hole quarried through this protective layer leads to much increased groundwater vulnerability from site operations (fuel spillages etc) compared to just quarrying the UMH gravels.

[88] Also, reinstatement of the intervening layer at completion of the quarrying is likely challenging. It is doubtful that similarly low permeabilities to those of the natural interburden clay layer removed may be consistently obtained throughout the large site area during the challenging reinstatement operation.

[89] Although the site is not located Source Protection Zone (SPZ) – 1 where such removal of the intervening layer is likely to be refused, it is located in an Outer SPZ - 2 and hence there are risks still posed. It should be recognised that delineation of SPZ boundaries is challenging in the chalk as it is difficult to reliably represent the fractured zone, fast pathways in the numerical models used due to the discrete nature and uncertainties in field observations characterising the location and flow properties of these pathways. It is hence not impossible for fast discrete pathways to exist from SPZ – 2 localities that may allow rapid transit to the Source abstraction well corresponding to, or approaching SPZ-1 timeframes of 50 days. It should also be recognised that due to the adit ('tunnel') system associated with the BR abstraction, travels distances/times need to BR be considered in relation to the adit spatial configuration extending out from the mapped point locality of BR shown (Fig. 1).

[90] In light of this, widescale removal of the protective intervening layer that has provided good aquifer protection since its geological deposition is questioned.

2.8. Concern of setting a precedent

[91] A key overarching concern is the precedent set by granting permission for the Application to quarry the LMH gravels and the consequence of

further similar LMH quarrying activity being subsequently granted at sites elsewhere similarly close to the bromate plume. The negative impacts outlined above would be multiplied and make the bromate plume management increasingly challenging to undertake.

[92] Similarly extensive low permeability backfill of a quarried LMH in proximity to the bromate plume and similar deflection of the groundwater flow regime around backfilled low-permeability islands would yet further reduce the capacity of the LMH gravels to offer buffer storage to the plume and increasingly give the bromate plume 'nowhere to go' other than remain in the Chalk leading to heightened risk to PWS abstractions.

[93] Similar deployment of dewatering abstractions at further quarry sites would likewise result in lateral pull of the plume, possibly plume entry to sites, but inevitable extending the lateral width of the plume and increased extent of secondary source zone diffused mass and hence exacerbated plume remediation.

[94] Hence granting of permission at this Site for quarrying would set a dangerous precedent for also granting permission at other near-plume LMH quarry sites that additively would prove very significant and aggravate bromate plume remediation and management at large. The decision taken at this Site needs to entertain the multiplication of problems that may transpire from the precedent set by a granted permission and the possibility of multiple near-plume quarry sites being proposed in the future.

3. Conclusions

[95] The serious groundwater pollution by bromate, an exceptional case internationally, begs the need to optimise bromate plume remediation and to safeguard Herts public water supply borehole sources.

[96] This choice of quarry site location between the bromate source and single scavenging remediation well, and the expected breaching of the three 'Environment Agency (EA) Conditions' relating to groundwater - bromate plume management negates this optimisation. The technical reasons for the expected breaching of the EA Conditions have been outlined. It is difficult to see from inevitable breaching of Conditions how they could be used in practice to offer proposed activity control. What control is offered by the legal agreement of Affinity Water (AW) with the Applicant is opaque to other stakeholders and beyond technical scrutiny of its effectiveness.

[97] There are a host of groundwater – bromate plume related issues that remain poorly or insufficiently considered by the Applicant:

i) The Applicant’s proposal fails to value the LMH gravels for bromate plume storage that reduce bromate risks to water supplies downstream (Essendon, East Herts).

ii) There is a failure to recognise the negative consequences of the low permeability backfill material replacing the quarried large volume of LMH gravels amounting to around 4 million cubic metres of lost aquifer.

iii) Even if the Applicant’s groundwater abstraction did not cause the bromate plume to enter site, it is inevitable that the nearby high-concentration bromate plume will be laterally extended drawn towards site and give rise to a semi-permanent ‘footprint of secondary source bromate’ in the low permeability Chalk matrix and clays and further challenge and interfere with plume remediation.

iv) Hence both the Applicant’s low permeability backfill and abstraction operations will aggravate the bromate plume remediation at large and interfere with and make remediation of the plume more challenging.

v) Whilst efforts are made to measure concentrations in the LMH gravel, the contamination of the LMH gravels remains poorly understood at plume and local (site vicinity) scales compared to the chalk aquifer where most investigation (by others) has focused.

vi) The flow linkages between the LMH gravels and chalk are poorly constrained and need to be known to quantify transmission of the influences of the LMH bromate concentration changes induced in the gravels by the proposed quarrying and backfill operations conceptualised herein.

vii) A very high concentration margin edge of the main bromate plume exists immediately adjacent to the quarry site in the LMH gravels and has transiently been observed in site monitoring wells at low concentrations which would not be unreasonable hydrogeologically given the main plume proximity. These observations are clearly important and have not been explained by the Applicant.

viii) A key concern on the Applicant’s groundwater monitoring to date is the major, 800-m long gap between monitoring wells sampling the LMH gravels along the site boundary where plume entry is most probable. This shortfall does not give confidence that the bromate plume has not penetrated a significant portion of the site unnoticed. The foundation for future monitoring intelligent design across this boundary is hence also poor and a key shortcoming.

ix) In general, the role of diffusion of bromate contaminant mass into low permeability clays/materials and the chalk matrix and consequent reverse diffusion of this so-called ‘secondary source’ mass perpetuating the bromate contamination problem appears underestimated. The observations of some bromate concentrations transiently on site and very high concentrations close to the Site need to be understood from a diffusional -

‘secondary source’ perspective so that the risks of bromate migration on to site can be better predicted.

x) This process coupled with the failure by the Environment Agency to secure an effective, near-industrial source, bromate plume remedial management means that the bromate plume problem scenario is highly likely to outlive the Quarry Site lifetime and hence will need to be managed throughout the Applicant’s site activity. Within this challenge, climate change influences need to be accounted for in a greater depth, especially their influence on some of the processes above not considered by the Applicant – e.g. influence of the low permeability backfill under more extreme recharge event conditions.

xi) Numerical modelling has not been undertaken by the Applicant at all to help quantify their potential impacts. This shortfall is mentioned specifically in several specific areas above where modelling would have been reasonably expected to underpin the Application. This lack of modelling leaves much of the proposed activity risks unquantified and too uncertain to justify proceeding with the activity effectively ‘in the dark’.

[98] This proposed quarry development is therefore considered detrimental to Hertfordshire’s future water, and inappropriate when alternative sites are identified in the Local Mineral Plan without bromate plume risks.

[99] There is a legitimate concern that granting permission for quarrying at this Site would set a dangerous precedent and give rise to much increased potential for near-plume quarrying of the LMH gravels at yet further sites that can only multiply problems to the management and remediation of the bromate plume at large.

[100] Hence, my overall recommendation in conclusion is that the original decision to Reject the proposed quarrying activity based on the unacceptable contamination risks involved should be upheld.

References

Fitzpatrick, C.M., 2010. The hydrogeology of bromate contamination in the Hertfordshire Chalk: double-porosity effects on catchment-scale evolution. PhD thesis, University College London.