Expert Opinion

on:

Groundwater contamination aspects of the proposed quarrying activity at Hatfield Aerodrome,

specifically:

Response to the Hertfordshire CC consultation on the Groundwater Management Plan (GWMP) (Final v5) and SLR borehole data

Date: 18th March, 2020

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Client: Hatfield Town Council

Preamble, report aim and disclaimer

This requested Expert Opinion (EO) is provided by Dr Michael Rivett of GroundH_2O Plus Ltd to Hatfield Town Council in support of their response to the Hertfordshire CC consultation on the Hatfield Aerodrome Groundwater Management Plan (GWMP) Version 5 and SLR borehole data.

Expert opinion is formed from Dr Rivett's critical review and discussions of the above and relevant supporting materials (e.g. previous planning consultation documentation, published PhD theses on the bromate plume, monitoring data). It raises technical issues of material concern to the proposed development relating to groundwater and groundwater contamination and provide Expert Opinion.

Expert Opinion is founded upon Dr Rivett's expertise and long experience in groundwater contamination research and practice dating from the mid-1980s. He has a significant experience and track record of published research per his CV or listing of publications: https://scholar.google.com/citations?user=8H8pUbUAAAAJ&hl=en.

This Expert Opinion may only be used in aspects directly relevant to determination of a planning decision on proposed quarrying activity at the Hatfield Aerodrome site. For any other purpose, permission in writing should be obtained from both Hatfield Town Council and GroundH_2O Plus Ltd.

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Expert Opinion

Expert opinion is provided on Groundwater contamination aspects of the proposed quarrying activity at Hatfield Aerodrome, specifically: *Response to the Hertfordshire CC consultation on the Groundwater Management Plan (GWMP) (Final v5) and SLR borehole data.* It includes reference to supporting materials or responses on this consultation documents as indicated.

Summary bullet points are provided immediately below that are substantiated by the technical detail of the numbered points that follow, within which several figures provide useful conceptual illustration of key issues.

Summary points

A summary of key points is made below. To note these bullet points are not inclusive of all issues raised in the technical detail numbered point further below. These should be examined to allow more meaningful consideration and use of the following bullet points:

S1. The most significant groundwater-related problems and risks that arise from the proposed development described within the GWMP, stem from the proposed excavation below the boulder clay *of* the lower mineral horizon (LMH) gravels overlying the Chalk. These are focused on herein. This activity compromises:
   - the protection of the Chalk aquifer groundwater resource;
   - optimal remediation of the > 20 km bromate/bromide groundwater pollution plume.

S2. The Environment Agency has proposed three 'EA Conditions' that are predicted herein to be breached, primarily due to consequences arising from activities relating to gravel extraction from the LMH.

S3. Regarding EA Condition ii, "*any activities close to the plume must not change the existing hydrogeological flow regime*", this condition will be permanently breached post and during development by the proposed replacement of excavated LMH permeable sand and gravel aquifer formation with permanent insertion of roughly 4.4 million tonnes of low permeability clay backfill across the site. This will cause considerable changes to the existing LMH hydrogeological flow regime - groundwater flows will be deflected around, rather than pass through the current Site with some groundwater flowlines previously extracted by the Bishop's Rise plume remediation scavenger well no longer extracted (conceptualised in later Fig. 1).

S4. The knock-on impact of failure to meet EA Condition ii above, will be failure to meet EA Condition iii – "*any activities close to the plume must not interfere with the remediation of the bromate and bromide pollution*". The proposed low permeability backfill of the LMH void will effectively 'push' parts of the very close by bromate/bromide plumes in the surrounding LMH gravel aquifer away from the site, potentially beyond the reach of the Bishop's Rise scavenger well, thereby increasing the risk of diverted bromate/bromide plumes migrating to other public water supply wells (conceptualised in later Fig. 2).

S5. Regarding EA Condition i "*No mineral is extracted from within the existing plume of bromate and bromide groundwater pollution*", *O*ccurrence of bromate groundwater contamination in the LMH and chalk underlying the Quarry Site is significantly controlled by the groundwater pumping rates of the Bishop's Rise scavenger well (conceptualised in later Fig. 3). The conceptualisation indicates that the pumping rate of the Bishop's Rise scavenger well exerts a significant, likely overwhelming, control on bromate occurrence in quarry Site LMH groundwater. Higher abstraction rates of 4 – 5 Ml/d (megalitres per day) preferred for more optimal plume remediation will lead to greater bromate plume migration into the site LMH aquifer gravels to be quarried and increased risk of breaching EA Condition i. Recent observations of low, but still significant bromate at the Quarry site perimeter, with very high bromate nearby, likely arise from lower scavenger well pumping rates in recent years due to technical issues. However, Site bromate may be expected to gradually increase on Site with recent resumption of higher scavenger pumping rates. Hence the viability of meeting EA Condition i is not controlled by the Site developer primarily, but rather the operator of the Bishop's Rise scavenger well.

S6. Hence, primarily due to the inappropriate choice of quarry Site location between the bromate source and single scavenger remediation well, quarry development meeting EA Condition i would require scavenger well pumping rates to be sub-optimal for remediation. This is not appropriate and constitutes interference with the remediation of the bromate and bromide pollution, thereby breaching EA Condition iii. Given the severity of the groundwater pollution and the need to optimise the remediation of what is Europe's largest groundwater plume and safeguard many public water supply borehole sources, such quarry development is not considered appropriate.

Technical detail

The technical detail supporting the above includes the following. It should be noted that the depth of technical detail provided is 'light touch', hopefully seeking to convey understanding of issues of concern to a non-specialist (still, it may be 'hard-work'). As ever, opposing arguments to aspects below can be made and are sometimes indicated.

1. **The most significant groundwater related problems and risks that arise from the proposed development described within the GWMP, stem from the proposed excavation below the boulder clay *of* the lower mineral horizon (LMH) gravels overlying the Chalk.** This activity compromises the protection of the Chalk aquifer groundwater resource, the UK's 'No. 1 aquifer'. Moreover, the proposed activity interferes with the current scavenger well remediation of the > 20 km bromate/bromide groundwater pollution plume, by far Europe's largest groundwater plume in the chalk aquifer, if not any aquifer.

2. The fundamental need to avoid excavation below the natural boulder clay layer (in place for millennia) to protect the chalk aquifer below would be a position I anticipated the Environment Agency should have adopted in their duty to protect groundwater resources given the local bromate/bromide plume pollution management circumstance and Source Protection Zone 2 locality. Without very proactive intervention, the PhD thesis of Fitzpatrick (2010) "*predicts bromate concentrations to remain above regulatory limits for around 200 years*". The fundamental need to avoid excavation below the boulder clay does, however, form the critical substance of the original representation made by Affinity Water (AW) (24/01/18) to the Draft Minerals Plan specifically related to the Hatfield Aerodrome site Hatfield Aerodrome: "*This site falls within a Source Protection Zone 2, corresponding to our Roestock source. This is a public water supply, operated by Affinity Water.* ***Any mineral extraction work at this location should ensure that there is no excavation below the boulder clay, in order to retain the protection to the Chalk aquifer****. The plan references proposed workings into the "lower mineral horizon"; if this means the gravels overlying the Chalk and underlying the boulder clay,* ***then this would constitute a very high-risk activity in regards to groundwater***." Whilst it is recognised that the GWMP has put in place proposed measures to manage these 'very high risks', it remains wanting, as shown below.

3. Whilst it is recognised the GWMP contains proposed measures attempting to meet the three principal Environment Agency (EA) proposed 'EA Conditions' (below), **the proposed activity of excavation of LMH below the boulder clay will inevitably lead to breaching of EA Conditions ii and iii, and as such provides grounds for removal of such activity, i.e. excavation below the boulder clay**. The Environment Agency position and proposed 'EA Conditions' (their 10 Oct 2019 letter): "*Controlled waters are particularly sensitive in this location because the proposed development site lies close to groundwater pollution of bromate and bromide from an off-site source. As previously stated, we advise that:*
   - **i.** ***No mineral is extracted from within the existing plume of bromate and bromide groundwater pollution***
   - **ii.** ***any activities close to the plume must not change the existing hydrogeological flow regime***
   - iii. ***any activities close to the plume must not interfere with the remediation of the bromate and bromide pollution.***".

4. **Regarding failure to comply with EA Condition *ii*,** *"any activities close to the plume must not change the existing hydrogeological flow regime"* - Whilst the GWMP makes efforts to reduce risks of temporary flow regime change by attempting to limit extraction of groundwater from the LMH, what appears overlooked, and of much more significance, is the **permanent change in the existing groundwater flow regime (with associated nearby bromate/bromide plume consequences) that will arise from the wide-scale removal of very permeable sand-gravel Lower Mineral Horizon aquifer material below the boulder clay and its subsequent replacement with near 'impermeable' backfill "*site won overburden and interburden material*"** (GWMP, Section 2.2.3 (LMA meaning Lower Mineral Aquifer has been replaced by LMH aquifer here and elsewhere for ease of reading) (Also, described in Brett Response to Hatfield Road Quarry, Consultation Questions and Statements (21 August 2019): "*The LMH within all phases will be backfilled with site won* ***clay forming a low permeability flow barrier*** …"). The net outcome of the proposed extraction of around 55% of the 8 million tonnes of sand/gravels by the development **is to replace some 4.4 million tonnes (~ cubic metres) of highly permeable sand-gravel LMH aquifer material over an area of ~ 500 m by 500 m that currently transmits significant groundwater flow, with a vast plug of aquitard, near**

impermeable, clay material; this will act as a "*low permeability flow barrier"* and fail to transmit barely any of the LMH aquifer flows continuing from upstream of the site – these flows will have to, forever post-development, divert around this vast near impermeable, permanent plug of aquitard. Ironically, the protective boulder clay aquitard has become the replacement aquifer, a very poor one at that. **The divergence in flow, and "*existing hydrogeological flow regime"* change constitutes a significant and permanent breach of EA condition ii, with knock-on breaching of EA Condition iii due to its influence on the nearby plume and consequent change in plume capture by the plume-remediation scavenger well.**

5. Expanding on the groundwater flow detail and breaching of EA Condition ii caused by aquifer excavation and backfill by "*site won overburden and interburden material*" - Impact of the backfill is briefly mentioned in the GWMP predicting "*As the filling proceeds and given the permeability of the LMH aquifer, it is expected that any resulting mounding of the groundwater surface created by the infilling process will be slight and short-lived and the groundwater equilibrium will quickly re-establish itself because of the hydraulic connection between the chalk and the LMH aquifer*." (GWMP, Section 2.2.3). Some process aspects are valid, however the outcome indicated is not. **The impact of the considerable volume of low permeability material used to fill the former aquifer void on the hydrogeological flow regime is long-term, permanent and significant.** Examination of the current groundwater flow field contouring in the GWMP (DWG No. 02 (page 32)) and reproduced in Fig. 1a below indicates a currently **unhindered** (even contoured) groundwater flow gradient through the site's sand/gravel LMH aquifer. Moreover, added groundwater flow direction arrows (approx.. ~ perpendicular to contours) confirm site groundwater currently convergent on the Bishop's Rise scavenger well. **The data strongly supports all current LMH aquifer groundwater flow across the site ultimately reaches and is extracted by the scavenger well. Hence, any perturbation of site flows must interfere with the extracted water scavenged by the well. The permanent insertion of roughly 4.4 million tonnes (~ cubic metres) of low permeability clay backfill across the site into the LMH has to cause considerable changes to the existing LMH hydrogeological flow regime; flow will simply not be able to easily migrate cross site post backfill within the LMH.** Whilst 3-D numerical flow modelling would be required to predict this accurately, **reasonable conceptualisation illustrated in Fig. 1b is that the majority of diverted LMH groundwater flow will laterally flow around the site's low permeability aquitard plug, moving more easily horizontally into the wider LMH aquifer** (flow may occur through ~20% of a porous gravel unit compared to just ~2% of the fractured chalk, recognising relative transmissivities are also influential). L**ateral spreading of groundwater will also be enhanced by the flow-restricting, capping boulder clay unit remaining beyond the Site boundary.** Whilst it could be argued some limited flow my still traverse site in the deep thin layer of LMH gravels not extracted, flows may be partly restricted due to partial plugging by **wash out of the backfilled over/interburden fine clay particles accumulating there**. Further wash out of backfill fine sediments and groundwater transport especially into wider chalk fissures, could also lead to **'Suspended sediment' problems at the Scavenger well** and reduce its efficiency. A complex 3-D integrated numerical model of both the LMH and Chalk would be required to predict the flow diversion created and the alteration of flowlines of groundwater arriving at the scavenger well. **Certainly though, the EA Condition *ii) any activities close to the plume* (it is, see following point(s)) *must not change the existing hydrogeological flow regime*, cannot be met.**

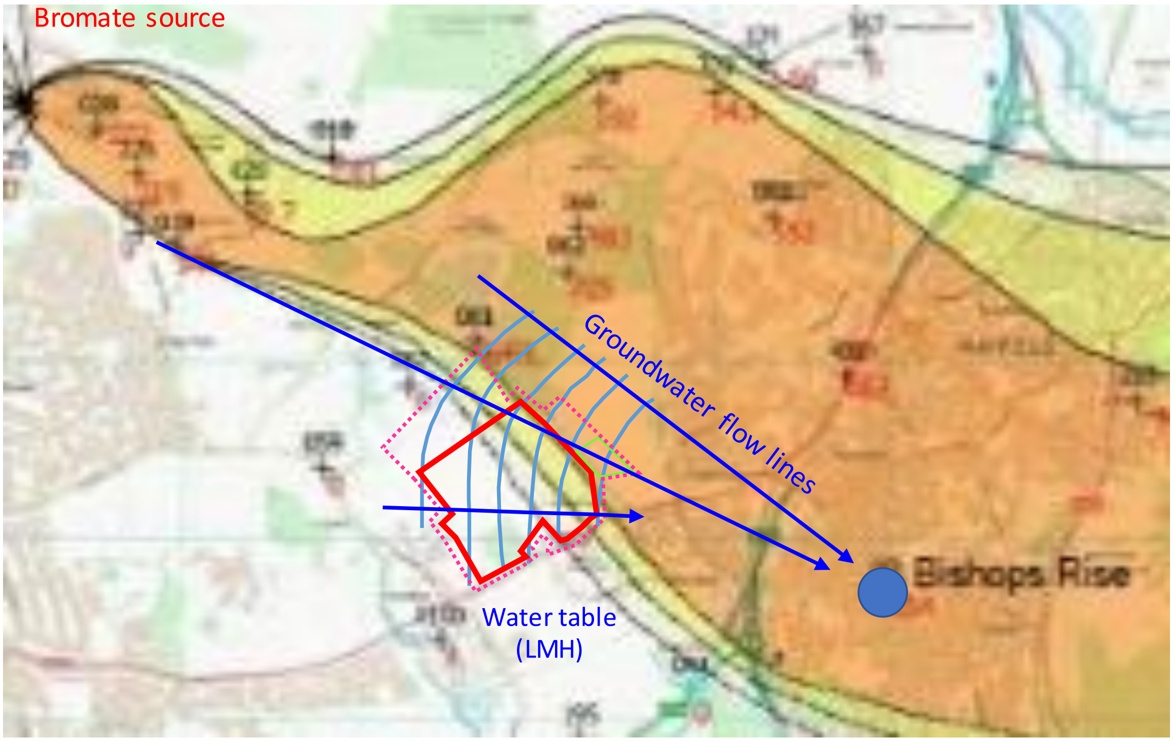

Fig. 1a. Current groundwater flow in LMH aquifer (using actual site hydraulic head contours obtained from GWMP DRW 02). The convergent contours support that groundwater flowing through the Site will be extracted by the Bishop's Rise scavenger well.

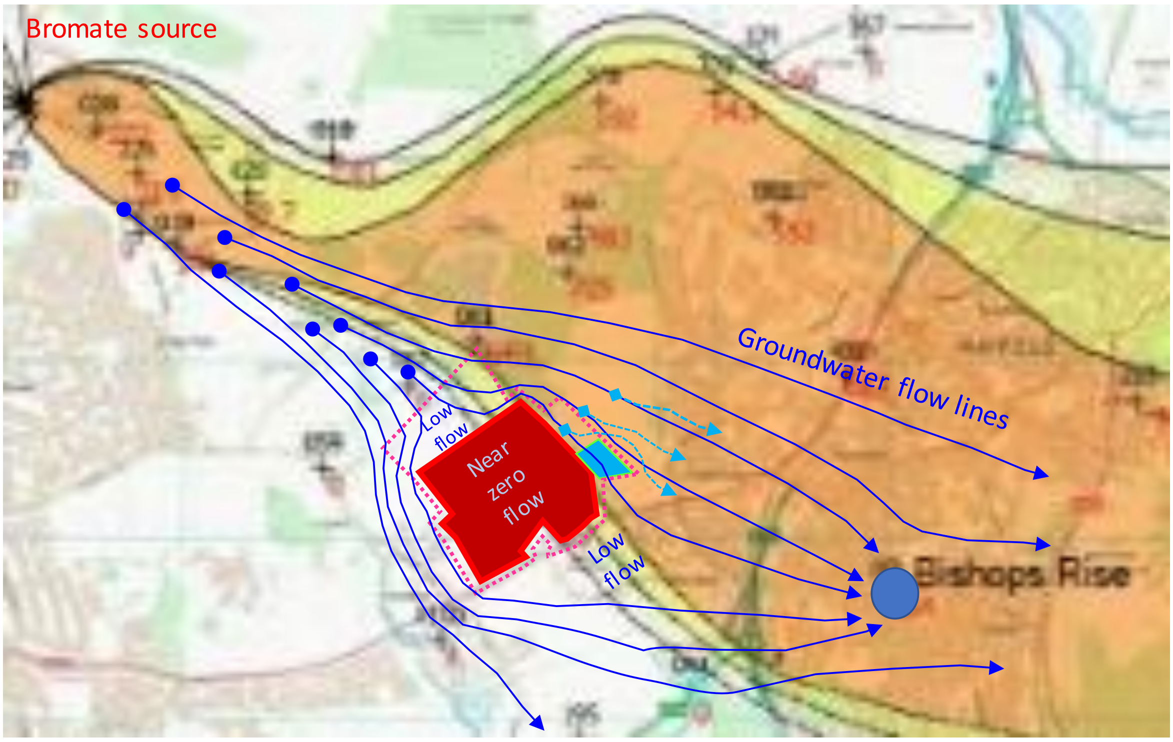

Fig. 1b. Conceptualised LMH aquifer groundwater flow being deflected around low permeability clay backfill of quarried LMH void with increased potential for flowlines to now evade capture by the Bishop's Rise scavenger well. Deflection (light blue pathlines) is also induced by temporary infiltration lagoon discharges to LMH. Distortion of flowlines will be influenced also by distribution of the gravels to some degree (not shown). The conceptualisation illustrates the permanent breaching of EA Condition ii.

6. **Failure to meet EA Condition iii (illustrated in Fig. 2) will be the knock-on effect of the failure to meet EA Condition ii arising from LMH aquifer material (gravel) removal and backfill with low permeability inter/overburden clays. This constitutes a significant activity close to the plume that will *"interfere with the remediation of the bromate and bromide pollution."*** It is clear from the Developer's (and other's) groundwater monitoring data that a significant proportion of the bromate/bromide plume resides in the LMH aquifer. Both high bromate/bromide concentrations occur, at minimum, immediately adjacent to the eastern boundary of the site, and arguably on site. **The central concern, overlooked in the GWMP, is that the proposed low permeability backfill of the LMH void will effectively 'push' parts of the bromate/bromide plume away from the site, potentially beyond the reach of the Bishop's Rise scavenger well, thereby increasing the risk of diverted bromate/bromide plumes migrating to other public water supply wells.** The impact may be overlooked in monitoring data later collected as **significant plume diversion may cause Bishop's Rise scavenger well plume concentrations to decline that is misconstrued as an improving situation. A false hope in that the plume components, previously captured are now missed by the scavenger well, deflected elsewhere.** Such impacts may take some time to manifest and LMH quarrying root cause potentially overlooked. **Conceptualisation of the difference in plume capture is shown in Fig. 2** (for simplicity, the detail of bromate/bromide plume discharge from the chalk up gradient into the gravels and control of the exact distribution of the gravels, extensive around the quarry Site, are not illustrated) **.** Before development, current groundwater flow through the site (Fig. 1a) is shown as a near straight flow line from the core of the bromate plume near the pollution source area to the Bishop's Rise scavenger well, with this flow line (long blue arrow Fig. 1a) just clipping, or immediately adjacent to the north-east corner of the site. **This is a critically important observation that shows the north-east corner edge of the Site is directly on the critical flow line connecting the main core of plume contamination near the source to the remediation scavenger well, a flow line that should not be interfered with.** This observation is consistent with current plume concentrations at this north-east site perimeter edge. **It is probable that the Bishop's Rise scavenger well has laterally pulled (aligned) any on-Site older plume contamination (map backdrop plume in Fig. 1a) on to the direct flowline shown, possibly helping to reduce the bromate contamination that had previously drifted on to the Development Site (see later Figure 3). The impact of blocking the groundwater flow field through the LMH aquifer on the Development site and diversion of the groundwater flow field in the LMH groundwater is conceptualised in Fig. 2b that shows stylised example red plume flow path-lines from the core of the source-plume area upstream. The fundamental problem with the low-permeability backfilled Site void groundwater flow defection is that it inhibits the scavenger well access to the upstream-from-Site plume contamination, to some extent shielding that contamination from a direct connection scavenger well access evident in Fig. 2a. Some plume flowlines previously captured by the scavenger well may no longer be captured and follow more northern routes, or perhaps less likely, split to a southern route and pose increased risks to Affinity Water public water supply wells at Tytenhanger and Roestock currently protected.** Again, a numerical model would be required to make plume predictions. It is recognised too, the plume movements indicated here do not apply to that contamination in the chalk that would remain largely unchanged. The impact though on the bromate/bromide plume in the LMH aquifer an important shallow flow horizon that transmits bromate contamination to the scavenger well area received from the deeper chalk upstream is significant with its extraction at the scavenger well also jeopardised. **Certainly, the EA Condition iii – "*any activities close to the plume must not interfere with the remediation of the bromate and bromide pollution.*" cannot be met due to the extraction and backfill of the Site's LMH below the boulder clay and consequent diversion arising of the shallow plumes.**

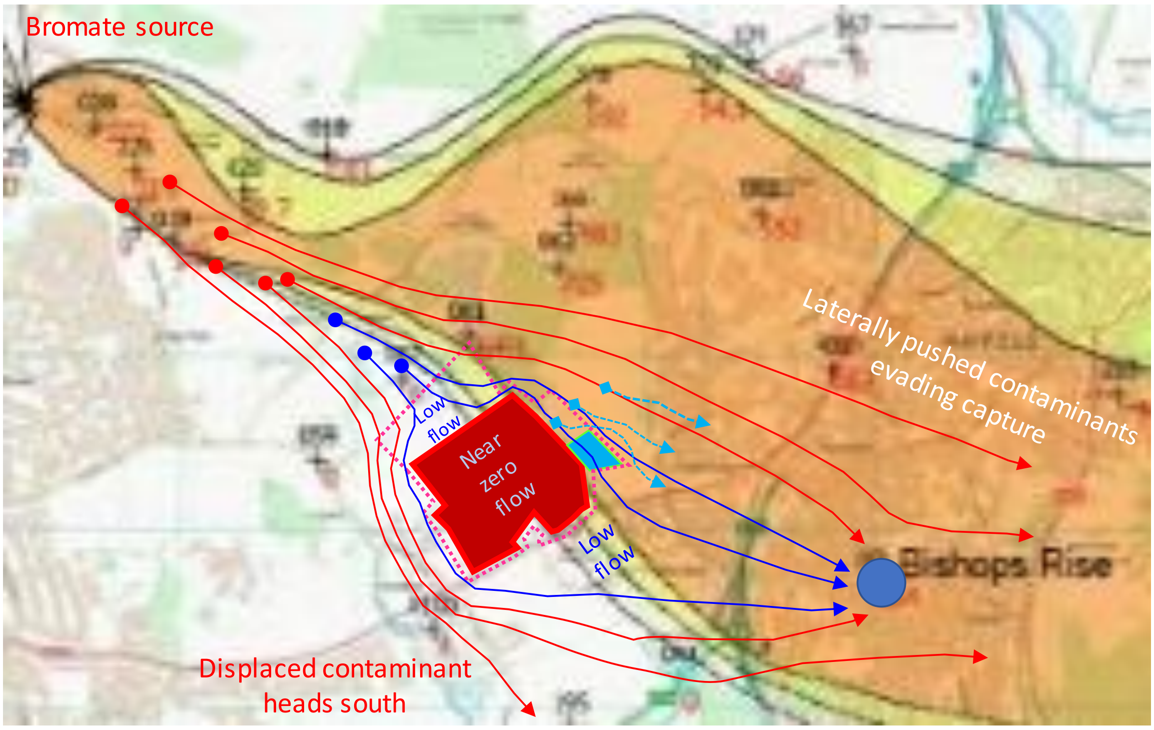

Fig. 2. Conceptualised LMH aquifer groundwater bromate plume stylised flowlines of contaminants (red lines, where particle start in the contaminant plume) being deflected around low permeability clay backfill of quarried LMH void with increased potential for contaminants to be pushed laterally away from site and increased risk of evading capture by the Bishops Rise scavenger well. Temporary deflection also shown from infiltration lagoon discharges to LMH. Note that the bromate plume in the deeper chalk would not be deflected in this manner. The schematic illustrates the processes that effectively cause breaching of EA conditions ii and iii by removal of the LMH aquifer gravel and backfill with low permeability material.

7. **Regarding EA Condition i -** ***No mineral is extracted from within the existing plume of bromate and bromide groundwater pollution*****,** opinion indicated below is intended to add to the collated, excellent work on this aspect by the Ellenbrook Area Residents Association. I commend their tenacity driven by understandable local resident concerns – a Citizen's Science award should be given! Some opinion nonetheless follows, **the Fig. 3 conceptualisation developed under item i below is of key importance.**

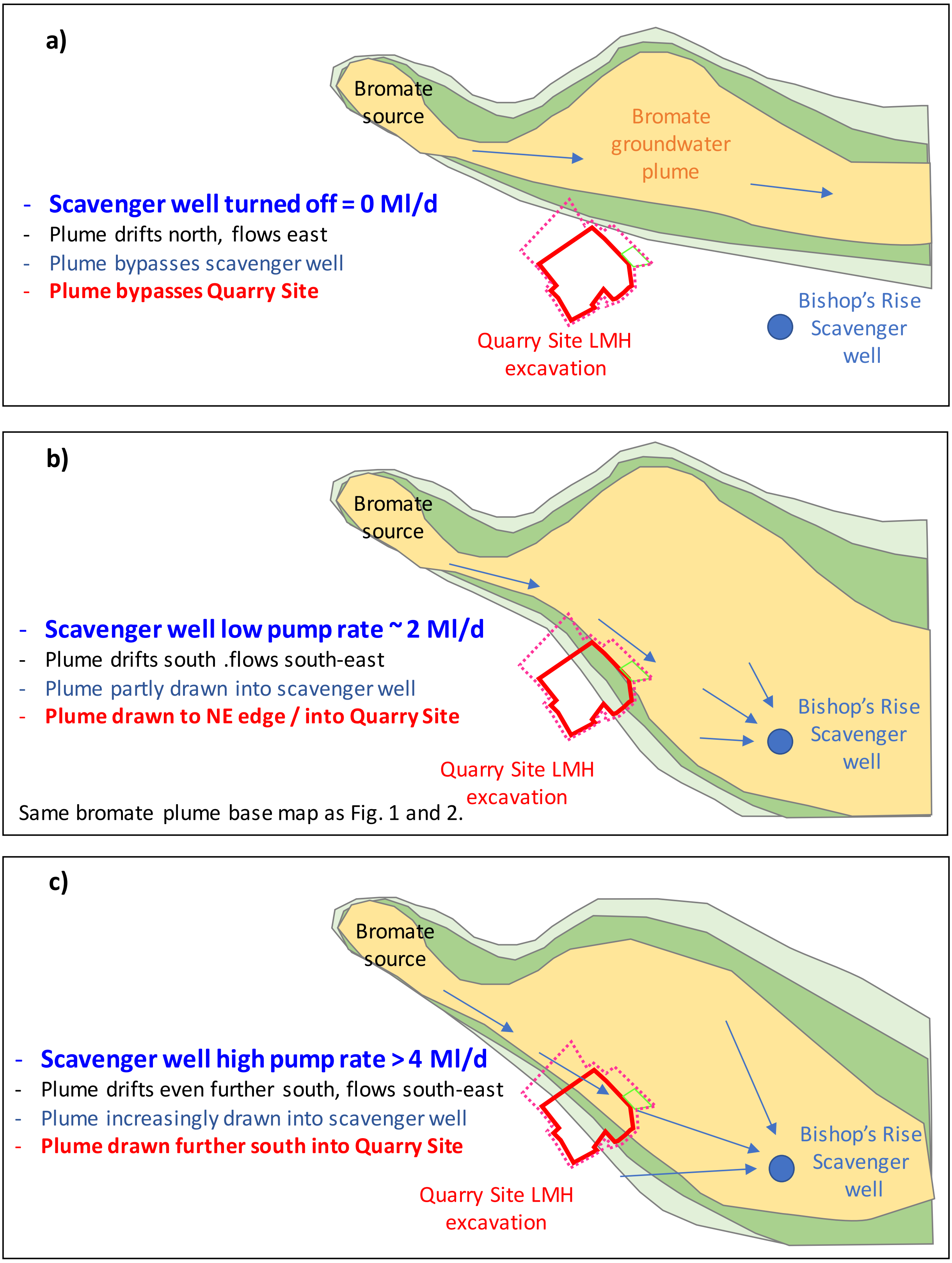

Fig. 3. Conceptualised sensitivity of bromate plume occurrence in Quarry Site LMH aquifer to Bishop's Rise scavenger well extraction rates. Increased pumping causes better plume capture and remediation, but progressive southwards plume movement, increasingly dragging the plume across Quarry Site, and increased risk of breaching EA Condition i.

i. **Occurrence of bromate groundwater contamination in the LMH and chalk underlying the Quarry Site is significantly controlled by the extraction rates of the Bishop's Rise scavenger well – this is conceptualised in Fig. 3. Fig. 3a conceptualises if the Bishop's Rise scavenger well is not operating** then the bromate plume would be expected to largely bypass both the scavenger well and the quarry Site, the latter facilitating EA Condition i to be more likely met (subject to draw in of the plume by the quarry groundwater abstraction). The plume pose threats to other public water supply wells, notably Essenden. **Fig. 3b conceptualises increased scavenger well pumping rates to say 2 Ml/d, quite low scavenger rates that are comparable to recent actual rates** (rates that have been lower than optimal due to effluent discharge constraints (sewer pipe partial blocking)), draws the plume southwards, capturing part of the plume in the scavenger well, but also causing the bromate plume to begin to encroach into LMH and chalk groundwater on the eastern side of Site. This would account for recent observations of a bromate plume very close to the north-east corner of the quarry Site. **Fig. 3c conceptualises yet further increased pumping to around 4 – 5 Ml/d more optimal plume remediation rates,** that have been recently implemented at Bishop's Rise (following rectification of the effluent discharge constraint above) would cause the plume to be drawn yet further south giving an increased bromate mass abstraction (i.e. improved remediation), but also increased draw of the bromate/bromide plume through the quarry Site groundwater. **The conceptualisation indicates that a significant and likely overwhelming control of bromate groundwater contamination occurrence in quarry Site groundwater is the pumping rate of the Bishop's Rise scavenger well. Higher abstraction rates of 4 – 5 Ml/d preferred for more optimal remediation (plume capture and protection of other supply wells) will lead to greater bromate plume migration into the quarry site LMH aquifer gravels and increased risk of breaching EA Condition i. Hence the viability of meeting EA Condition i is not controlled by the Site developer primarily, but rather the operator of the Bishop's Rise scavenger well, i.e. Affinity Water** (potentially influenced by other stakeholders, e.g. the EA, local community who may wish to see optimal plume remediation). **This sensitivity of the viability of meeting EA Condition i upon a third party's activity is a direct consequence of locating the quarry close to the high concentration gradient fringe of the bromate plume and directly in between the main bromate source area and the single scavenger well remediating the plume. The viability of extraction of the LMH gravel resource hence appears dependent upon the operation of the Bishop's Rise scavenger well at rates that may be sub-optimal to the remediation of the bromate plume. Development of the quarry and meeting of EA Condition i would hence require the scavenger well pumping rates to be sub-optimal for remediation – this does not seem appropriate - it constitutes interference with the remediation of the bromate and bromide pollution (i.e. breaching of EA Condition iii).** Most of the points that follow can be understood within the above conceptualisation.

ii. Regarding bromate groundwater contamination, the EA indicate bromate concentrations of concern are ≥ 2 μg/l (0.002 mg/l), consistent with application elsewhere. It appears at some time seven boreholes at the Site perimeter, have displayed bromate contamination with six above the 2 μg/l limit. This frequency of discovery points to bromate occurrence on site remaining a viable issue of concern, particularly as the **monitoring of the LMH appears sparse in the perimeter area most likely to be contaminated (the north-east to east side of Site) and extremely sparse on Site in the LMH areas to be quarried.** Regarding very near-to-Site monitoring wells to the immediate east, bromate is very elevated in the LMH at 14, 92 and 233 μg/l and slightly further away laterally at 563 μg/l (Borehole 12) in the plume core, **all very significantly above the EA threshold**. The current low, but above-limit, bromate concentrations on the site perimeter (and potentially on site – little data) but with the bromate plume very close by is attributed to quite low scavenger rates of Bishop's Rise in recent years along the lines of the Fig. 3b conceptual model. **The concern is that with the recent increase in Bishop's Rise pumping rates back to achieve more optimal plume remediation conditions will lead to southward drift of the plume and increases in bromate on site as the site scenario gradually evolves (will not be instantaneous) to a Fig. 3c conceptualisation and increased risk of breaching EA Condition i.**

iii. There is concern that the monitoring of the LMH in the east to north-east site perimeter where the bromate/bromide plume is most likely to enter the site is quite sparse. Within-Site monitoring of the LMH groundwater quality is extremely sparse. A**lthough internal-site boreholes in excavation areas would be sacrificed and lost in quarrying, this does not excuse limited monitoring internal to the quarry site prior to permission being granted and also allowing continual monitoring leading up to mineral resource abstraction. For instance even just least one monitoring well**

placed within each phase of operational area positioned towards the plume-side of phase area centre with quarry excavation on the opposing side initially could provide valuable monitoring of local groundwater before and during much of the excavation (until destroyed by excavation) and forewarn of problems prior to excavation, indeed problems would be potentially intercepted ahead of detection of problematic bromate concentrations being discharged to the lagoons as currently proposed). This would provide much more robust advanced assessment of the likelihood of EA Condition i being breached with time – clearly this is important in relation to the conceptualisation of Fig. 3 site contamination sensitivity to scavenger well extraction rates that may cause bromate to vary over time on site.

iv. **Taken together the sparseness of LMH monitoring internal to the site and in the perimeter boundary of site most likely to encounter the plume, the occurrence of elevated bromate very close to Site, plus the recognition the heterogeneous (variable) geological subsurface and typically complex bromate concentration distributions at the plume fringe may cause significant plume occurrence variability on site with preferential 'channelling' through the more discrete permeable gravel pathways, then the risks of breaching EA Condition i are significant. These risks should be better quantified ahead of development to better assess the risk of a stalled development part way through that arises from breaching of the EA Conditions. A stalled, part-completed quarry development is clearly problematic for all parties.**

v. The occurrences of high bromate plume concentrations very close to site are an important evidence supporting the significance of the above Fig. 2 conceptualised influence of the low permeability backfill of the LMH void and 'pushing' away of the plume from the Site. **These concentrations demonstrate conclusively there is a bromate plume very close to Site to push away that will decrease the capture potential of the scavenger well and hence the failure to comply with EA Condition iii.** Whilst these near-to-site plume concentrations would still likely be captured by the scavenging well, **it is the more laterally displaced plume core, higher concentrations, slightly further away form Site that may ultimately evade scavenger well capture leading to a decrease in scavenger well remedial performance. Combining both Fig. 2 conceptualisation of the diverted flow around the low permeability plug inserted in the LMH aquifer with the Fig. 3 conceptualisation of increased bromate in groundwater on the quarry site with increased scavenger well pumping rates may produce quite complex outcomes** that really require numerical modelling to assess. A key concern though at high scavenger rates is that the higher concentrations drawn down to the south side of site could deflect further southwards towards Tytenhanger and Roestock abstractions.

vi. Clearly there is some bromide contamination on site which is above the *background levels of bromide in groundwater indicated by the EA, in the Hatfield Area, at 50-100 ug/l*. The EA have in earlier letters indicated "If further evidence comes to light demonstrating that current background bromide concentrations near Hatfield in the groundwaters of the Lower Mineral Aquifer and the Chalk aquifer are higher than 125 ug/l then we will reconsider the bromide plume boundary definition.". Some concentrations in both the UMH and LMH on site do exceed this. The EA though point to the confounding problems of various sources of bromide in their letters. Whilst this is in true, and an issue, **the reasonable working assumption is that the bromide observed in this chalk aquifer is a bromide plume from the bromate/bromide source and the onus should be on the Developer to prove it is from another source (e.g. perhaps a nearby landfill?) and does, or does not require management under the conditions set).** Further, in their recent response (letter of 18 Dec 2019) to my earlier Expert Opinion, the EA reiterate the other sources issue and also indicate "*For the purposes of practicable regulation of the existing CEMEX Hatfield Quarry, we have taken the position that bromate concentrations of concern are ≥ 2 μg/l (0.002 mg/l). It is consistent to apply this definition to neighbouring planning and permit applications for mineral extraction and landfill*.". **Hence, the EA appear unwilling to set a bromide-of-concern threshold value unfortunately. This is mystifying given the specific mention of bromide groundwater pollution in the EA condition i, and hence should still be questioned.** There is some expected separation of the bromide and bromate plumes on site that may account for the separation of plumes, for instance at the plume lateral fringe, that may account for the bromate/bromide plume discrepancies at the current Site. This is endorsed by site and next-to-site observations that where just bromide is present then both bromate and bromide are invariably close by. Hence bromide over say 125 *μg/l* would be a good indicator that bromate is likely very close by. **The management/regulation of the site should, at minimum, more proactively use the bromide to**

forewarn of issues, e.g. unusual rises in bromide used as a trigger. How can the regulator specify bromide plume in a condition and then fail to specify any concentration to delimit that plume? Also, understanding of the bromide anomaly on site (high bromide relative to bromate) is likely to inform the bromate plume fringe understanding.

8. **Regarding extraction of groundwater from the LMH aquifer unit (GWMP, Section 2.2.2), the GWMP does not provide sufficient detail required of extracted groundwater volume estimates to establish the risks associated with what appear large daily extraction rates in the GWMP Table 2-3.** Although there would be some uncertainty in estimates, these appear quantifiable based on minimum and maximum groundwater levels (piezometric surface) existing (+ climate change allowance). For instance, a (hydro)geological section (XsectionCutv6) of the north-west face of the site indicated groundwater (piezometric) level range remained within (or perhaps just above) the interburden confining layer and would hence qualify for Method 2 (no groundwater removal) or Method 3 (with groundwater removal). It is unclear what controls which method is chosen and likelihood of more contentious Method 3 being used. It is unclear too as to what proportion of the Site Method 3 could at maximum apply to. Whilst Table 2-3 (Summary of Predicted Volumes of Water to be Managed) does provides an estimate of the LMH extraction and injection of 2,500-4,500 m^3/d (2.5 – 4.5 Ml/d (megalitres per day), it is unclear how many days per year / project would such a volume be extracted. **The extracted volume on a daily basis is quite large, actually greater than the Bishop's Rise scavenger well current (2017) rate of 1.9 Ml/d, but potentially now comparable to more recent rates of 4 – 5 Ml/d that may give a more optimal remediation performance**. **Hence if quarry abstraction rates are maintained at such high values for even a relatively short length of time then it will begin to interfere with the scavenging capture zone of the Bishop's Rise well, it will begin to draw the bromate/bromide plume in.** Whist the quarry's dewatering zone will be biased to some extent up gradient, the rate appears sufficient to cause lateral draw of the plume, based on the 'pull' laterally on the plume seemingly shown by the current and past public water supply well / scavenger pumping in the ~ 2 – 10 Ml/d range. The local influence of the quarry dewatering that will depend somewhat on the separation between the western groundwater extraction area (excavation phase dependent) and the eastern, near-plume, lagoon injection area, and also the degree of low permeability overburden material backfill of quarried voids. Although the applicant indicates the latter will limit the lateral draw of the plume, which it may in part, **it may also force high velocity groundwater flows along the side of the backfill wanting to draw any contamination from the north-east site corner, or accelerate flows laterally through the deepest gravel layer not quarried below the backfill – the latter could cause in fact an enhanced lateral interaction with the plume to the east of site.** It is recognised that the injection lagoon positioning and injection of similar volumes to that extracted will offset some of the above influences, however, it is effect on the flow regime will be complex. To make any quantitative judgement here on groundwater extraction/injection impacts, key information required would be approximate – expected volumes pumped and over what time duration would continual pumping be expected, overall annual volumes in a typical year, whole project volumes, and results (T, S etc) of the pumping test undertaken. **Overall, the combination of extraction of groundwater by the quarry with some risk of plume draw in and the insertion of low permeability backfill into an aquifer disrupting groundwater with a potential to 'push' plumes away from the scavenger well, will both together pose a complex and challenging scenario to effectively manage leading to risks of breaching all EA Conditions i, ii and iii.**

9. Groundwater reinjection to the lagoons (GWMP Section 2.3.4, Table 2) - It is recognised the injection lagoons are close to the bromate/bromide plume (east side of Site) which does offer hydrogeological – infiltration advantage. However, related arguments made by the Developer (Response to Hatfield Road Quarry, Consultation Questions and Statements (21 August 2019)) appear only partially accurate. Specifically, "*The LMH infiltration lagoon will create a local recharge mound that will serve as a hydraulic barrier to the lateral movement of the plume*" – the position of the lagoon to the south-east corner 'tailend' of site and flow off to the south east will mean this barrier effect is modest. Secondly, the argument "*The LMH within all phases will be backfilled with site won clay forming a low permeability flow barrier between the lagoons and the rest of the mineral site, thereby the risk of lateral movement of the plume is further reduced* ", is fair. **However, it should be recognised though that both of the above activities will combine to increase the lateral injected groundwater 'push' eastwards on the main off-site bromide core plume,**

increasing risks of the plume core being pushed further away eastwards from the scavenger well and evading capture by the well (i.e., the same problem outlined above in Fig. 2).

10. The GWMP does indicate monitoring of bromate etc in the effluents / discharges at time intervals, it would be prudent to request, additional to this, that **when there are large volume throughputs to the injection lagoons, monitoring is stepped up** and monitored at a throughput of an agreed number of volumes, i.e. allows a sufficiently frequent monitoring of a large volume throughput.

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CURRENT POSITIONS

GroundH$_2$O plus Ltd,
Quinton, Birmingham
Director and founder, 2016 –
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GroundH$_2$O plus Ltd is an environmental consultancy specialising in research-informed hydrogeological assessment and technical review of groundwater contamination issues that are of topical concern to contaminated land, water-industry, nuclear, energy-development, groundwater regulation and developing-world sectors. Dr Rivett, has 30 years' experience in contaminant hydrogeology, 20 years as a university academic. He has a significant track record of published research and project experience serving these sectors.

University of Strathclyde
Department of Civil & Environmental Engineering
Research Fellow part-time (Birmingham based) 2016 –
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Dr Rivett is a part-time Research Fellow focused on the delivery of published research from the Scottish Government funded Climate Justice Fund - Water Futures Programme. A research programme designed to support the Government of Malawi in meeting SDG 6. His 22 publications since 2014 may be downloaded from: https://strathprints.strath.ac.uk/view/author/1104214.html

SPECIALIST AREAS AND KEY EXPERIENCE

- Technical peer review and research-informed advice on groundwater contamination issues
- Groundwater research: university academic / applied research experience over 30 years
- Contaminated land assessment/remediation: specialising in groundwater, complex sites
- DNAPLs / LNAPLs, chlorinated solvents, VOCs, hydrocarbons, emerging organic contaminants
- Surface water impacts from groundwater plume discharges, highway de-icing salt runoff
- Innovative groundwater monitoring methods, e.g., multilevel monitoring, tracer tests
- Nuclear legacy/disposal sites: radiological contaminant fate - management in groundwater
- Onshore oil and gas: environmental baseline monitoring, groundwater protection
- Developing country hydrogeology: SDG-6 relevant groundwater development / protection
- Experienced BSc/MSc/CPD groundwater lecturer and university programme / PhD examiner
- Experienced author, presenter and reviewer of journal papers, technical guidance, etc.
- Experienced chair/member of professional bodies, industry advisory panels, conferences

PUBLICATIONS

- Rivett publication listing: https://scholar.google.com/citations?user=8H8pUbUAAAAJ&hl=en
- Google Scholar: 2393 citations received to Rivett's publications (>100), h-index 25

EARLIER CAREER & EDUCATION

- **1997-2016** Senior Lecturer / Lecturer in Contaminant Hydrogeology - Earth Sciences, University of Birmingham, School of Geography, Earth & Environmental Sciences
- **1996-97** Area Hydrogeologist, Environment Agency, Leeds
- **1994-96** Area Hydrogeologist, National Rivers Authority, Leeds
- **1989-93** Post Doctorate, Waterloo Centre for Groundwater Research, Univ. of Waterloo, Canada
- **1985-88** PhD Earth Sci. (Hydrogeology), Univ. of Birmingham with Water Research Centre (WRc)
- **1980-84** MA Hons. Chemistry, University of Oxford

CITIZENSHIP, MEMBERSHIPS, PROFESSIONAL BODIES, EXTERNAL POSITIONS - examples

- **2014-18 University of East Anglia (UEA)**, School of Environmental Sciences - External Examiner
- **2012-... International Association of Hydrogeologists**, British Chapter - Committee Member
- **2008-... CL:AIRE** - Technology & Research Group – Member of expert advisory group
- **2008-... Sellafield Ltd**, Land Quality Independent Peer Review Panel - Member (via NNL)
- **2006-... Journal of Contaminant Hydrology**, Editorial board member
- **PhD examiner** – 33 occasions at 13 universities in the UK and internationally
- **International Association of Hydrogeologists**, British Chapter – Chair, 2012-17
- **Geological Society** - Council of the Geological Society – Member 2006-09
- **Hydrogeological Group, Geological Society** - Chair 2004-06, Committee member 2001-06

RELEVANT / RECENT PROJECTS - a selection (**bolding** relevant personal / organisations / topics)

GroundH$_2$O plus Ltd (**Rivett**) – (2020) Consultant to **BGS** to provide expert technical groundwater input to the BGS led project on 'Monitoring and analysis of methane in groundwater' funded by the **Environment Agency**.

GroundH$_2$O plus Ltd (**Rivett**) – consultant to CL:AIRE (2018) to provide authoring and editing of a CL:AIRE report on 'Natural Source Zone Depletion (NSZD)' prepared for the **Environment Agency**.

GroundH$_2$O plus Ltd (**Rivett**) – consultant to **BGS** to provide expert technical groundwater input to the BGS led multi-university consortium project (Phase 4, 2018-19) (and Phases 1-3, 2015-18). Science-based environmental baseline monitoring associated with **shale gas development**, (funded by **BEIS**)

Rivett (2012-13) - Contracted by **Environment Agency** to act as Scientific Advisor to provide external peer review of the Birmingham Sherwood Sandstone groundwater modelling ESI Ltd (**Buss**).

RELEVANT / RECENT PUBLICATIONS - a selection

McMillan, L.A., **Rivett, M.O**., Wealthall, G.P., Zeeb, P., Dumble, P., **2018**. Monitoring well utility in a heterogeneous DNAPL source zone area: insights from proximal multilevel sampler wells and sampling capture-zone modelling. Journal of Contaminant Hydrology, 210, 15-30. https://doi.org/10.1016/j.jconhyd.2018.02.001

Tomlinson, D.**, Rivett, M.O.**, Wealthall, G.P., Sweeney, R., **2017**. Understanding complex LNAPL sites: Illustrated handbook of LNAPL transport and fate in the subsurface. *Journal of Environmental Management*, 204, 748-756 https://doi.org/10.1016/j.jenvman.2017.08.015

Rivett, M.O., Cuthbert, M.O., Gamble R., Connon, L.E., Pearson, A., Shepley, M.G., Davis, J., **2016**. Highway deicing salt dynamic runoff to surface water and subsequent infiltration to groundwater during severe UK winters. *Science of the Total Environment* 565, 324-338. http://dx.doi.org/10.1016/j.scitotenv.2016.04.095

Rivett, M.O., Dearden, R.A., Wealthall, G.P., **2014**. Architecture, persistence and dissolution of a 20 to 45 year old trichloroethene DNAPL source zone. *Journal of Contaminant Hydrology, 170, 95-115. http://dx.doi.org/10.1016/j.jconhyd.2014.09.008*

Rivett, M.O., Turner, R.J., Glibbery, P., Cuthbert, M.O., **2012**. The legacy of chlorinated solvents in the Birmingham aquifer, UK: Observations spanning three decades and the challenge of future urban groundwater development. *Journal of Contaminant Hydrology*, 140-141, 107-123. http://dx.doi.org/10.1016/10.1016/j.conhyd.2012.08.006

White, R.A., **Rivett**, M.O., Tellam, J.H., **2008**. Paleo-roothole facilitated transport of aromatic hydrocarbons through a Holocene clay bed. *Environ. Science & Technology*, 42(19), 7118-7124. http://dx.doi.org/10.1021/es800797u

Rivett, M.O., Chapman, S.W., Allen-King, R.M., Feenstra, S., Cherry, J.A., **2006**. Pump-and-treat Remediation of Chlorinated Solvent Contamination at a Controlled Field-Experiment Site. *Environmental Science & Technology*, 40, 6770-6781. http://dx.doi.org/10.1021/es0602748