Better Thames Network
Groundwater Workshop

Case Study 1 - Soluble conservative pollutants from point sources in Thames Basin Chalk

WFD Background

Point sources, as opposed to diffuse sources, are generally related to Urban Development which is identified as a Significant Water Management Issue in the Thames River Basin.

Nitrate from diffuse sources, such as agriculture fertiliser use, is believed to be the reason for failure for a large number of groundwater bodies. Nitrate from fertilisers has been studied extensively since the 1970s but there has been far less investigation of possible point sources.

The Bromate pollution in the Vale of St Albans illustrates the impact these pollutants can have. It is identified as a large pollution plume and is one of the reasons for failure in both the Mid Chilterns Chalk and the Upper Lee Chalk groundwater bodies. It is therefore presented as an example here.

Case study 1a, Bromate

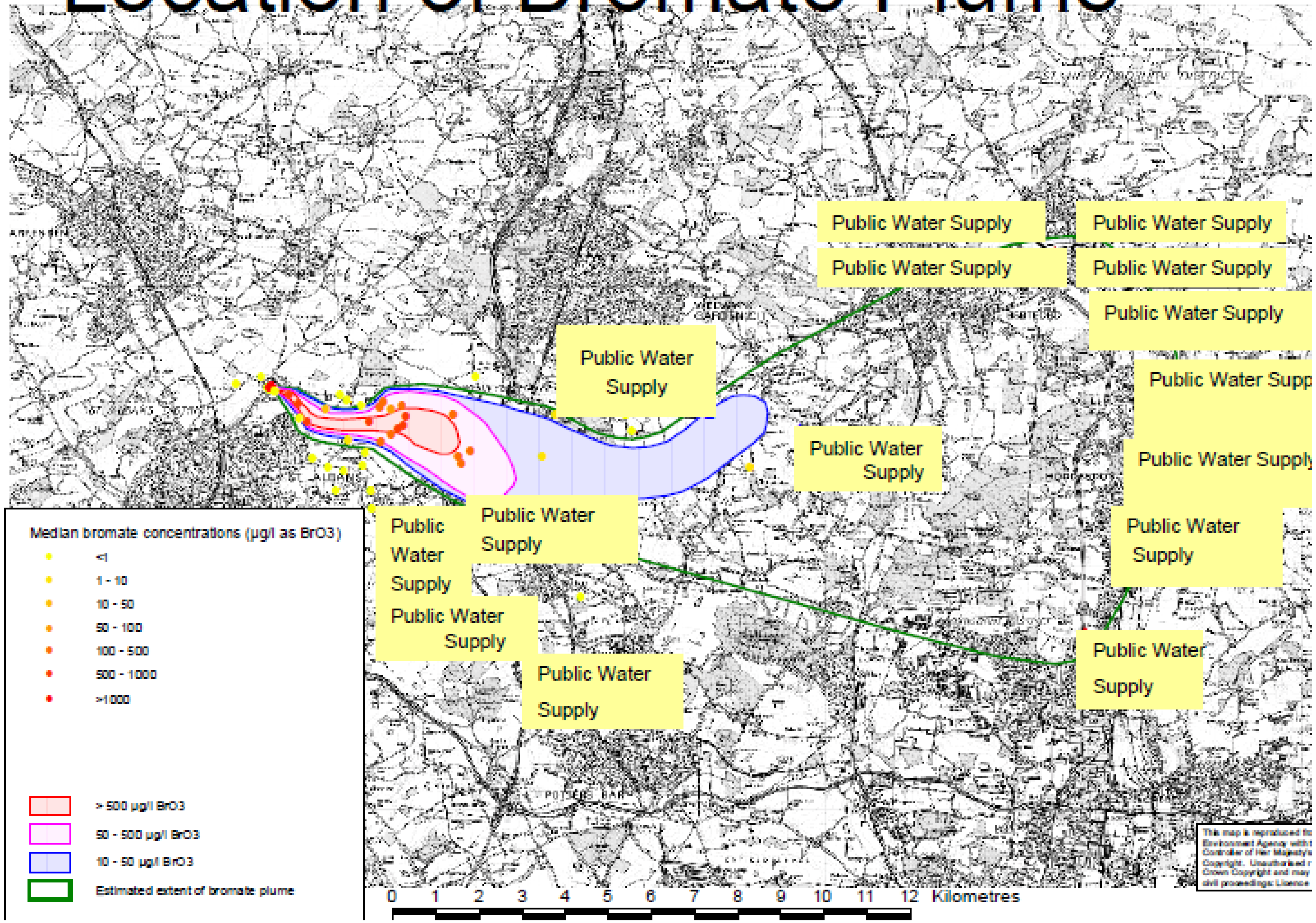
Bromate occurs in 10s of mg/l to over 100mg/l in the groundwater beneath the site of a former chemical works. Off-site concentrations are in the many 100s µg/l to over 1000µg/l. It was first discovered in groundwater during testing in preparation for a new bromate water quality standard. The history of losses from the source are not known in detail but are a combination of the following.

Operational site, before re-development
A combination of small frequent and larger occasional losses while the chemical works was in operation (1955-1980). Inevitably during this period there would have been small leakages as pollution prevention was not well –developed at the time. There were also two sumps within the production buildings and anecdotal evidence suggests that these leaked at least on occasion.

During re-development
At the time of demolition the site was left open to recharge for a long period and enhanced leaching of contaminants is likely to have occurred.

Post re-development
We now believe that more contaminated material than was suggested at the time remained following re-development. Further, the capping layer does not provide the protection from recharge intended. Due, at least in part, to these factors, there is ongoing input of bromate to groundwater.

Location of Bromate Plume



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The plume, as shown in the figure above, is over 20km long. Mid-plume in the Hatfield area, it is at least 40 metres thick. Over the period of monitoring, since 2000, the size of the plume and concentrations within it have remained generally stable. This has been surprising since bromate was not expected to be stable in the natural environment.

The size and stability of the plume indicate the large amount of bromate stored within the matrix of the dual porosity Chalk aquifer system. Especially given that there are significant losses of bromate from the system via discharges from abstractions and springs, including a scavenging scheme of up to 9ML/day at the former Hatfield Public Water Supply.

Abstraction reduces groundwater concentrations further down the plume as shown by a rise in concentrations when pumping from the abstraction is reduced or ceases. Seasonal variations have a diluting effect on concentrations, again, more markedly at the down-gradient end of the plume. This lower half of the plume is influenced by the renowned karstic system associated with the swallow-hole system at North Mymms which allows rapid flow rates of kilometres a day providing significant dilution at some abstractions of the polluted, slower- moving water.

There is also a bromide plume following a similar but not identical pathway. Whilst bromate is a hazardous substance with a drinking water standard of 10µg/l, bromide is classified as a non-hazardous pollutant with no drinking water standard but expert toxicological opinion identifies an appropriate threshold of 3,000 µg/l.   In addition, bromide is of concern since it can form bromate and brominated organic compounds during water treatment. It goes without saying that despite the presence of contaminants, the water supplied from these sources is treated or otherwise managed to ensure public health is maintained.

The above example relates to a rare occurrence of a soluble and apparently conservative ion which is also a hazardous substance. Other soluble, conservative ions are non-hazardous, for example chloride, fluoride, bromide, nitrate and sulphate.

Point source pollution from these substances is currently believed to be rare but could this be a problem being stored up for the future?

Diffuse pollutants are expected to migrate more readily into the matrix of the dual porosity system of the Chalk. Whereas in the case of point sources where there is a driving head such as a soakaway taking a high volume of drainage or a leaking storage tank or sump, fissure flow may be the dominant flow mechanism.

Peaks in concentrations in groundwater pass rapidly where fissure flow is dominant and are unlikely to be detected in quarterly monitoring of a spatially low density network such as the Environment Agency's Groundwater Quality Monitoring Network. Whilst there will be some diffusion into the matrix groundwater, this will be slower and less widespread than in the case of diffuse pollution.

A recent study of road salt entry into motorway soakaways indicates no current or likely future risk to groundwater supplies.

Case Study 1b Road Salt to M4 soakaways

Although cases of elevated chloride in groundwater due to road salt application are common, examples where pollution has been caused are rare and generally short-lived. An example which may have been the result of other causes was that affecting the Amersham PWS in the early 1980s.

Following the cold winters of 2009-10 and 2010-11 there have been concerns that road salt application could be causing adverse environmental impacts (Rivett et al. 2011). To test whether this was the case in West Thames, chloride data from soakaways and groundwater collected for several years from 2001 on the M4 at Membury was assessed.

Chloride concentrations in the run-off to the motorway soakaways reach almost 2000mg/l. Generally chloride concentrations in the groundwater just down-gradient of the soakaways range from background levels to just over 300 mg/l. The plot on the next page shows the relationship between groundwater levels and chloride concentrations in a nearby borehole. This shows that concentrations are related to the timing of winter road salt application. A detailed look at the data indicates a time lag of a few months as a result of the 40m unsaturated zone thickness. However, low groundwater levels appear to have a greater impact on chloride concentrations. This has been confirmed in January 2012 when the highest chloride level recorded to date (558 mg/l) follows an exceptionally mild winter but corresponds to a time when groundwater levels are very low.

However, the lowest concentration (15mg/l) is only marginally above background suggesting that chloride moves through the aquifer relatively quickly.

Model predictions undertaken using Consim achieved a good fit to the actual data. However to replicate actual values at off-site locations in the model required a very low lateral dispersivity. This implies the transport in the Chalk aquifer is primarily through fracture flow.

In summary the study shows:

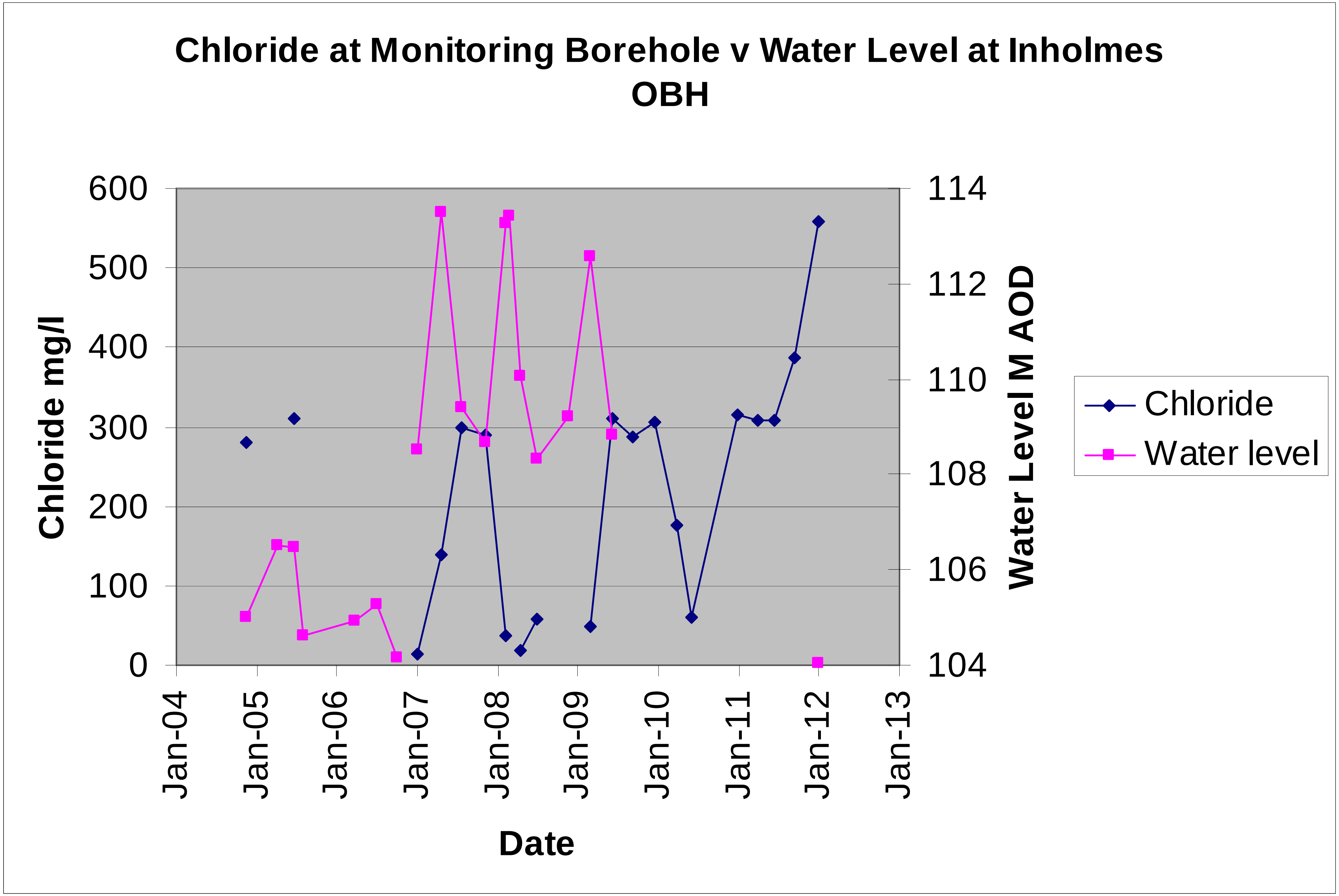
- Water levels are the main factor controlling groundwater chloride concentrations at this location.

- Significant chloride impacts at this location do not appear to extend far beyond the soakaways, so natural dilution within the aquifer is a sufficient control under normal climatic conditions. Private supply boreholes approximately 1 and 2km down-gradient do not fail drinking water standards. Concentrations were on average about 10 mg/l higher than background, about 1km from the motorway, decreasing to about 5 mg/l at 2 km from the motorway.

- Only at locations very close to the soakaways does there appear to be the possibility that water quality standards could be breached.

- There was no evidence that levels of salt application are increasing other than what might be expected for colder years.

- Dual porosity flow within the Chalk aquifer appears to occur with dispersion into the surrounding Chalk matrix likely to further reduce chloride concentrations.



Chloride at Monitoring Borehole v Water Level at Inholmes OBH
Chloride mg/l
600
500
400
300
200
100
0
Water Level M AOD
114
112
110
108
106
104
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Date
Chloride
Water level

Questions Raised by these 2 cases

The case studies show very different outcomes. One producing a large plume of high concentrations, the other impacting only the immediate area close to the source.

Whilst we do not know when the bromate pollution first affected groundwater abstractions, we do know that the concentration remains constant suggesting a large reservoir of bromate (and bromide) within the Chalk matrix, both above and below the water-table. This would have required high concentrations of bromate to enter the Chalk and diffuse into the matrix.

Workshop Objectives and Questions

The “prevent and limit” WFD objective is the most important for groundwater. Therefore it is important to understand acceptable input limits for even common conservative ions.

Some current WFD failures of nitrate may be better explained by point sources than diffuse sources?

What is the capacity of the Chalk in terms of dilution and dispersion of conservative ions?

What is the critical input concentration and duration from a point source?

Could the impact on groundwater only become evident once the contaminant diffuses back out from the matrix?

What affect might climate change have?

A predictive tool for the Thames Chalk? (It is acknowledged that this is a big ask since there will be site specific variation.)

A review of the existing literature on the dual porosity of the Chalk as an initial step?

Workshop Feedback

Questions and objectives from Case Study 1

- A review of the existing literature on the dual porosity of the Chalk as an initial step?
- We need to understand acceptable input limits for common conservative ions – mainly non-hazardous pollutants.
- Can a clear relationship between concentration in and concentration out be defined?

- What is the critical input concentration & duration leading to
    - Groundwater degradation/deterioration
    - Exceedance of DWS or EQS?

- In contrast with Case Study 1a, Case Study 1b shows no widespread pollution from a conservative ion but could there be future problems because build up in the matrix is much slower than in the case of diffuse pollution?

- How reliable is the ConSim "soakaway" option for point sources?

- Can Thames Chalk groundwater concentrations be calculated to provide an improved predictive tool?

- Some current WFD failures of nitrate may be better explained by point sources than diffuse sources?

- What is the likely affect of climate change?

<u>Session 1 - Overview of issues</u>

1. **For wider engagement, need to be careful about terminology**
    - Eg. Conservative ions

2. **Problems from current activities are easier to fix than contaminant inputs to groundwater from historic issues.**
    - Re-development is a highly efficient means of dealing with historic pollution as the costs can be absorbed in the market value of the land, selling value of the houses or other types of development.

3. **Conservative pollutants, ie. those that are stable in the groundwater environment and not subject to attenuation within the aquifer, are particularly difficult to remediate within WFD timescales (ie. end of first cycle, 2015, end of all cycles 2027). Especially in a dual porosity aquifer such as the Chalk; no silver bullet, no easy remediation.**
    - We have seen in this morning's presentations that 50 years is a likely time interval before seeing reversal of trends in nitrate concentrations. In very general terms it is likely to be similar for other conservative ions. This does not fit well will the 15 year period in which to fix problems before the end of the 3 WFD cycles.

        - Increasing trend leads to continuing degradation of groundwater
        - One of the aims of WFD is not to increase need for treatment of water prior to use.

4. **Economics and cost-benefit analysis.**
    - Who really pays?

    - Although we may apply the polluter pays principle, in fact the taxpayer or consumer ultimately pays for clean up.

5. **Wider environmental considerations and safety issues**
    - Carbon cost is often closely related to monetary cost
    - Wider issues - cannot reduce amount of salt used if this would lead to more road traffic accidents; other anti-freeze options may be more harmful to the environment.
    - Producer/supply chain/user responsibilities can avoid wastage minimising impact on groundwater .

6. **Climatic, or even weather variability, is not taken into account in WFD.**

<u>Session 2 - Technical issues</u>

1. **How reliable is the ConSim "soakaway" option for point sources?**
    - For conservative ions in a complex aquifer it is particularly important to characterise the flow correctly, so using Modflow is more useful.
    - The bromate case study is a special case in a part of the aquifer where there is known to be well-developed fissuring of the Chalk. This demonstrates one end of a continuum of dual porosity aquifer characteristics where there is a lot of unpredictability.

2. **Chloride concern**
    - Presence of chloride is of concern as a tracer. It indicates that road drainage is entering abstractions and could be an early warning of associated risk of road run-off pollutants, including hazardous pollutants.
    - Reduce risk by having no road soakaways in SPZ1, 2, or even SPZ3? Need to be able to justify such an approach.

3. **Research Ideas**
    - We need to understand the contaminant release mechanism for the Chalk matrix.
    - The biggest unknown in flow modelling is the recharge component. It is complex and low flows cannot be accurately replicated in models using 4 R. This is believed to be at least in part due to time lag to reach water-table due to superficial deposits such as the Clay-with-flints. Also due to lack of understanding of flow through the unsaturated zone of the Chalk, including the varying characteristics of the putty Chalk?

- Understand how contaminants from road runoff to soakaways migrate through the Chalk and predict concentrations in groundwater. Include effect of spillages, as well as chronic contaminants.

- What is the pollutant capacity of the Chalk?

- If we are not going to meet WFD requirements we will need reliable models to technically justify our approach.

- Design and maintenance of soakaway systems to protect the Chalk groundwater.

- Apply knowledge gained in some catchments, for example CSF work in relation to nitrates, to others where conditions are similar.