# Chlorthal Treatment Options Review

## 14th May 2015

# Introduction

- Attendees.
  - *Introductions.*
  - *Attendance list.*
- Health and safety.
  - *Fire Alarms.*
  - *Welfare.*
- Timetable.
  - *Coffee.*
  - *Lunch.*

# Background

- The pesticide chlorthal was detected at levels above the regulatory limit (0.1ug/l) in the sources of four WTWs.
    - *Pipe Hill WTW.*
    - *Slade Heath WTW*
    - *Shenstone WTW*
    - *Sandhills WTW*
- Chlorthal is a metabolite of the herbicide chlorthal-demethyl which is no longer approved for use in the EU.
- The nitrate treatment plant at Pipe Hill WTW has been found to remove chlorthal from the raw water. The works has remained in service at a reduced flow (4Ml/d) with all the flow passing through the ion exchange plant.
- Slade Heath WTW (4Ml/d) was removed from service.

# Background cont.

- Somerford WTW (2Ml/d) which relies on Slade Heath WTW for blending has also been removed from service.
- Shenstone WTW and Sandhills WTW are currently ‘out of service’ and require investment to make operational.
- WRc was employed to carry out laboratory and pilot scale tests to assess the potential for the following treatment processes for chlorthal removal.
    - *Granular activated carbon.*
    - *Ultraviolet (UV) light irradiation - also with hydrogen peroxide.*
    - *Ozonation and ozonation with hydrogen peroxide.*
- Imtech has been employed to assess the options for returning Pipe Hill, Shenstone, Sandhills, Slade Heath and Somerfield WTWs to service.

# Summary of Sites.

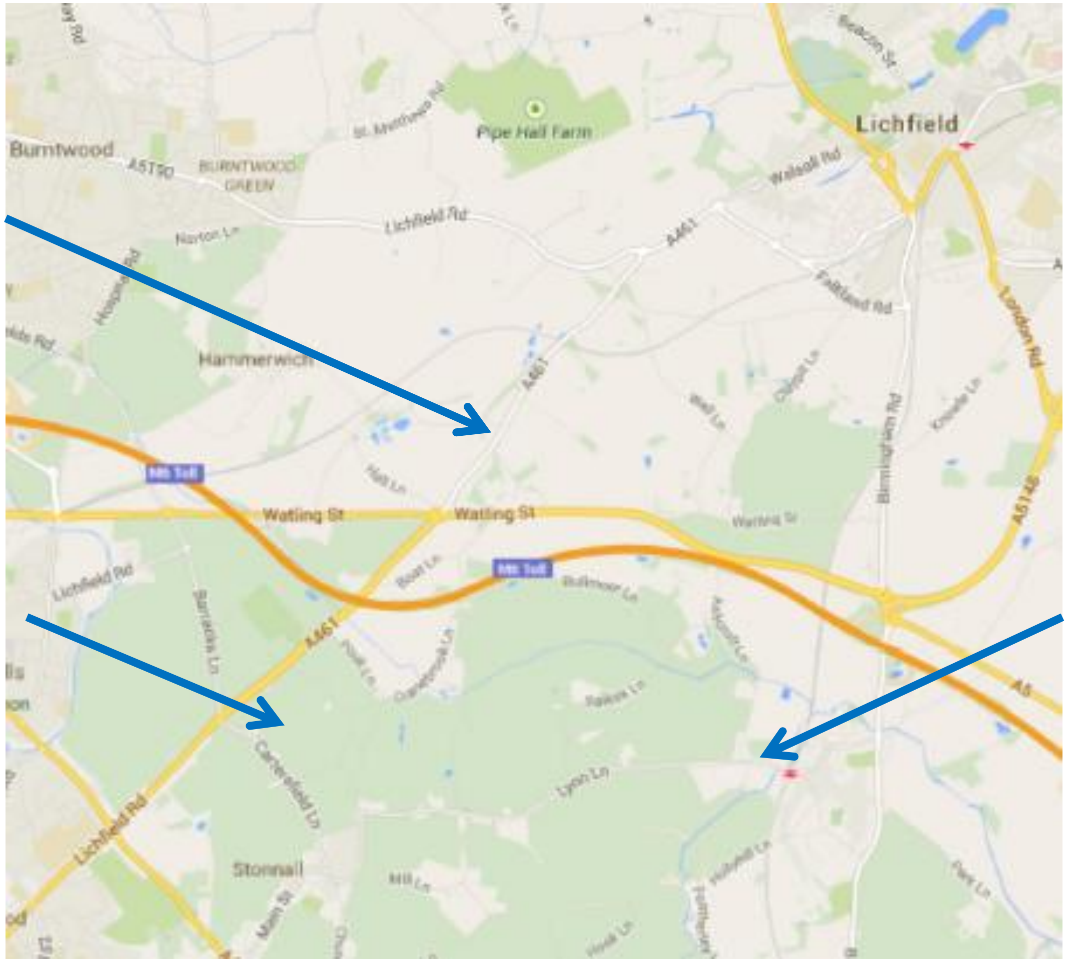
- **Pipe Hill WTW**
  - *Output – 11 Ml/d.*
  - *Raw water currently has up to 0.9 µg/l of chlorthal in the source water.*
  - *Chlorthal currently removed in ion exchange plant.*
- **Shenstone WTW**
  - *Output – 5.5 Ml/d.*
  - *Only used as a “drought” / high demand source and therefore run infrequently.*
  - *Recent raw water samples contain up to 0.1µg/l of chlorthal.*
  - *Raw Water also contains high levels of nitrate and trichloroethene.*
  - *Part of nitrate strategy for AMP6.*

# Summary of Sites cont..

- **Sandhills WTW**
  - *Potential Output – 5-6 Ml/d (Design for 3Ml/d)*
  - *Out of operation for approximately 10 years.*
  - *Historical issues with nitrate.*

# Location of sites

Pipe Hill WTW




Sandhills WTW

Shenstone WTW

**NH Note: Requires clearer picture**

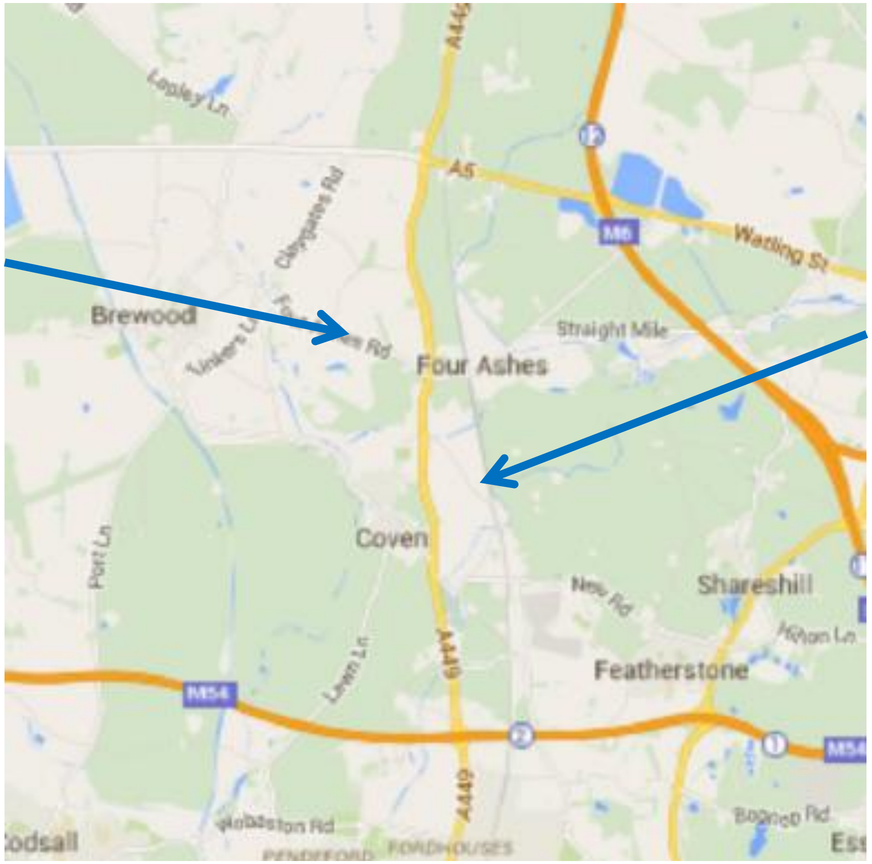
NH Note.
Insert diagram of distribution system

# Summary of Sites cont.

- **Slade Heath WTW**
  - *Output – 4 Ml/d.*
  - *Source water contains concentrations of chlorthal up to 3.3µg/l.*
  - *Raw water contain manganese (up to 180µg/l) which is controlled by oxidation and filtration.*
  - *Site currently switched off.*
- **Somerford WTW**
  - *Output – 2 Ml/d.*
  - *No Chlorthal detected but source has high levels of sodium (>250mg/l), chloride (>300mg/l) and arsenic c.15µg/l which are controlled by blending with Slade Heath treated water.*
  - *Site currently switched off due to high chlorthal concentrations at Slade Heath.*

# Location of sites

Somerford WTW




Slade Heath WTW

NH Note: Requires clearer picture

**NH Note:**
**Insert diagram of distribution system**

# Approach to Options Assessment

- Phases involved in scoping and delivering the schemes

IDENTIFICATION OF NEED | OPTIONS ASSESSMENT | OUTLINE & DETAILED DESIGN | DESIGN AND CONSTRUCTION | COMMISSIONING AND TESTING | OPERATION

- Identify the treatment options available for each site and to develop costed strategies for each group of sites.
- Little information is currently available on the treatment of chlorthal apart from the work commissioned by South Staffs Water (SSW) from the WRc.
- Experimentation work will be required in providing the necessary assurance over the both the effectiveness of treatment and how to operate the process within a WTW.

# Approach to Options Assessment

- Our approach is for any experimental work to be broken down into two separate phases to ensure any work carried out is both necessary and focused.
- The first phase of experimental work will focus on gathering sufficient information to generate high level CAPEX and OPEX estimates for the various technologies and thus establish if they are viable and cost effective.
- A second phase of experimental work will then only be carried out on a technology to provide sufficient information to confirm key design information and to provide assurance on the controllability and operability of that treatment process.

# Structure of Workshop.

- Based upon traditional ‘gap analysis’ approach to problem solving.
- Workshop Structure.
  - *Water Resources and Water Demand.*
  - *Raw water quality.*
  - *Treated water quality.*
  - *Available treatment options.*
  - *Results from initial testing programme.*
  - *Impact on potential plant design.*
  - *High level CAPEX and OPEX costs.*
  - *Rationalising choice for different supply systems.*
  - *Discussion on strategy – affordability, resilience, operability.*
  - *Information gaps and future testing requirements.*

# Water Resources and Future Water Demand.

# Raw Water Quality.

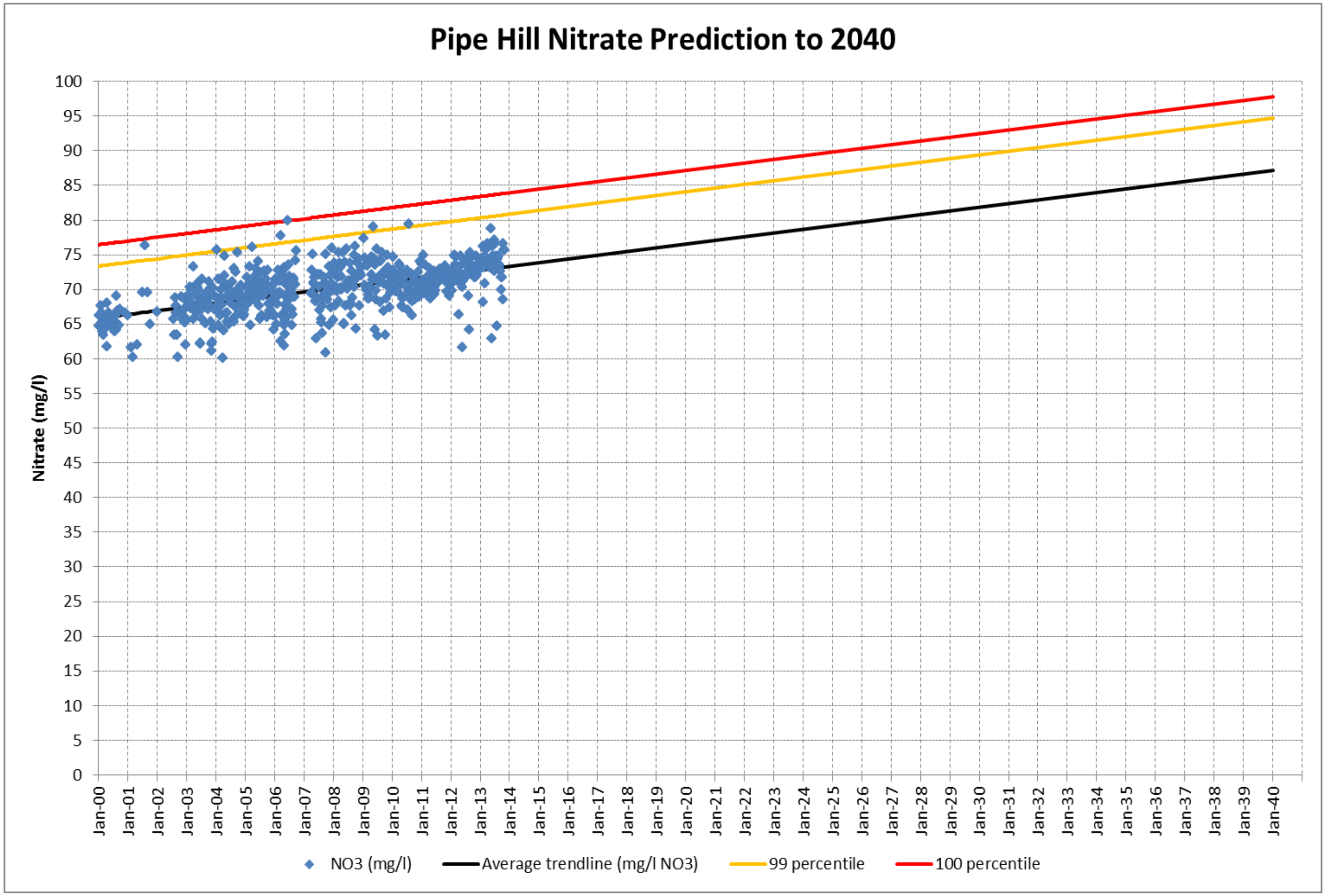
# Pipe Hill WTW

**Historical Data 2009 -2014**

| Parameter | Units | Min | Ave | Max |
|---|---|---|---|---|
| **Turbidity** | NTU | <0.08 | 0.15 | 0.65 |
| **Colour** | Hazen | | | |
| **TOC** | mg/l | 0.3 | 0.88 | 2.3 |
| **pH** | | 6.64 | 7.49 | 8.11 |
| **Alkalinity** | mg/l as (HCO3) | 100 | 172 | 246 |
| **Total Hardness** | mg/l (as Ca) | 107 | 126 | 144 |
| **Conductivity** | uS | 234 | 624 | 713(1) |
| **Nitrate** | mg/l as NO3 | 14.3 | 70.8 | 79.4 |
| **Sulphate** | mg/l | 56.7 | 74.5 | 95.7 |
| **Chloride** | mg/l | 45 | 51 | 131(1) |
| **Sodium** | mg/l | | | |
| **Iron** | ug/l | <4 | 10 | 23 |
| **Manganese** | ug/l | <4 | 5 | 11 |
| **Chlorthal** | ug/l | 0.394 | 0.697 | 0.895 |

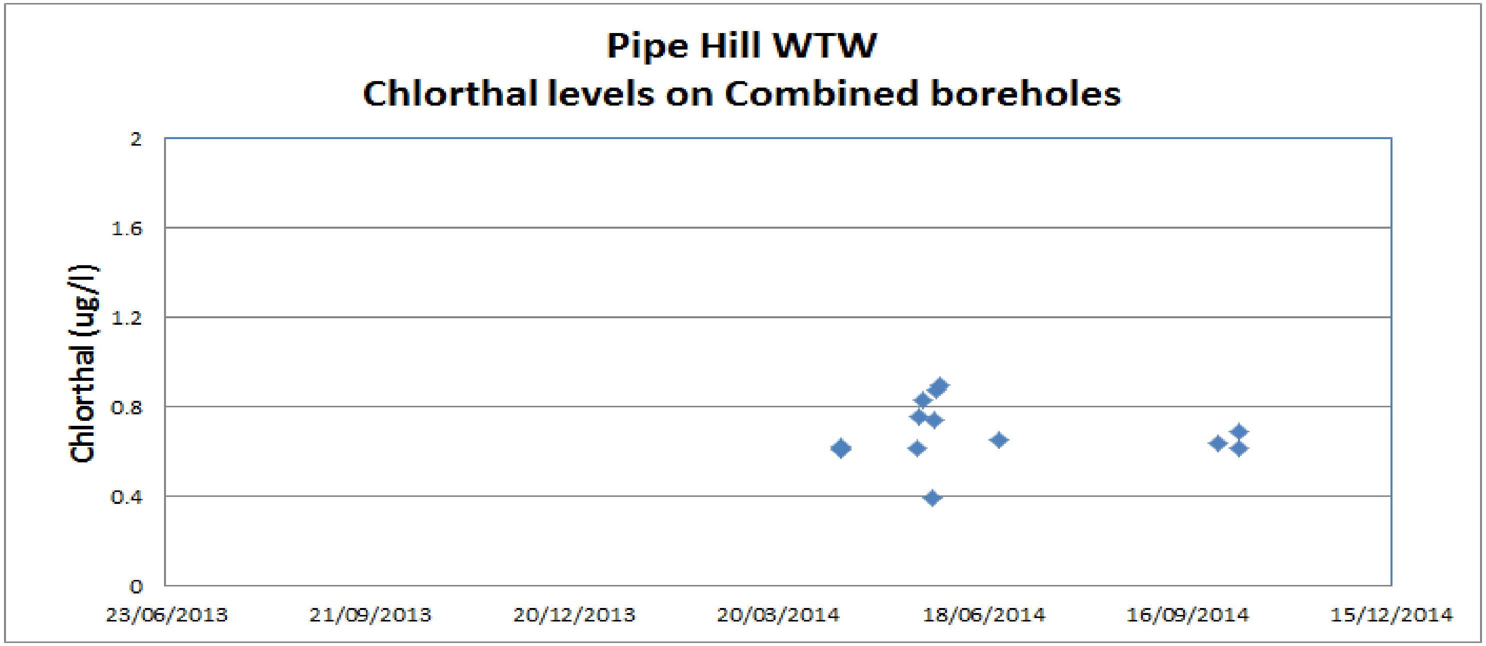
- Single sample with 12000uS/cm and 4410mg/l Cl removed from dataset.
- Single sample with 6.65mg/l TOC removed from dataset

# Pipe Hill WTW




Graph provided by SSW.

# Pipe Hill WTW – Raw Water Quality



# Pipe Hill WTW

- Water Quality Risks
  - Nitrate (increasing trend)
  - Chlorthal
  - Turbidity (presumably on start up)
  - Pathogens
- Disinfection Requirements
  - Marginal chlorination only

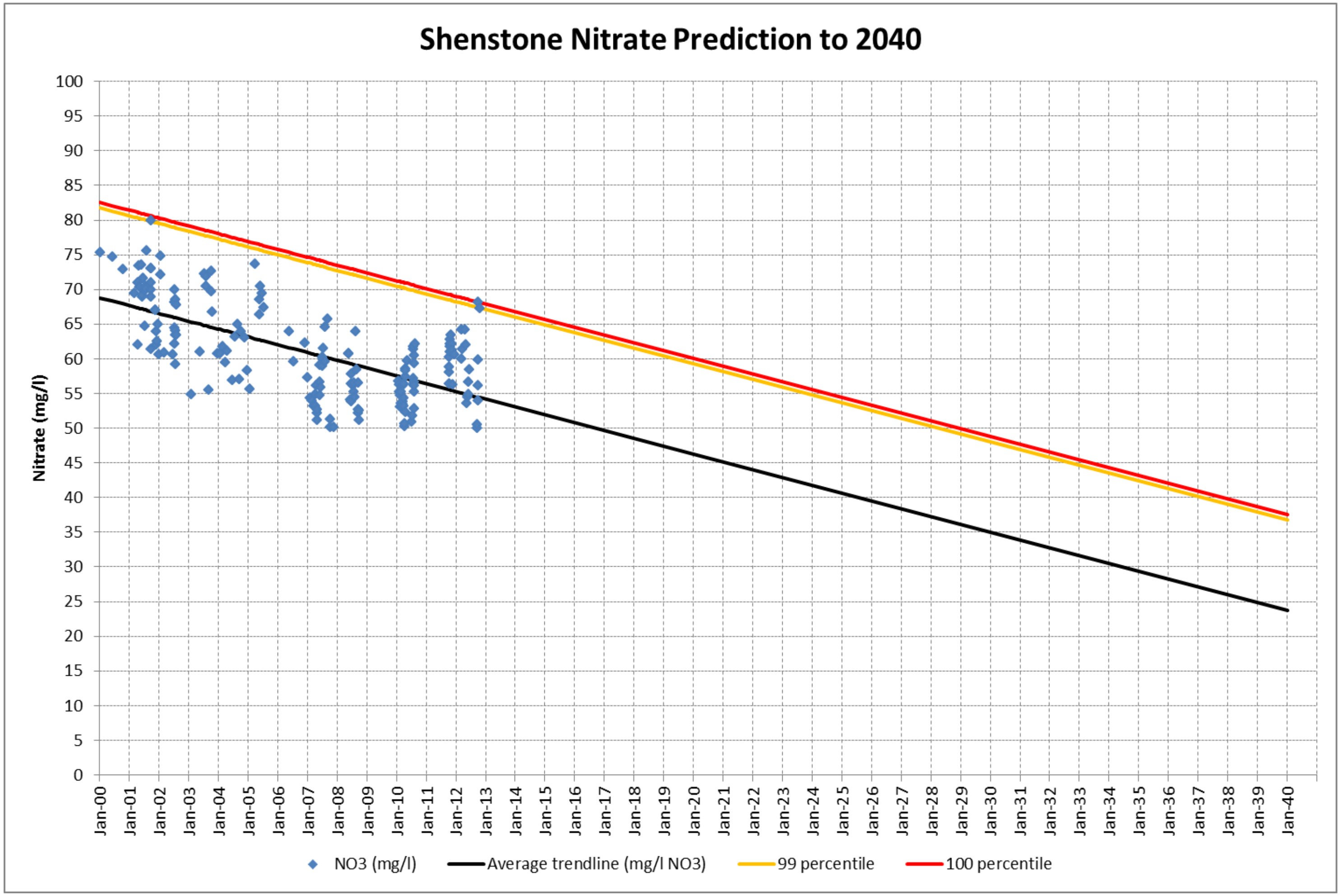
# Raw Water Quality – Shenstone WTW

**Historical Data 2009 -2014**

| Parameter | Units | Min | Ave | Max |
|---|---|---|---|---|
| **Turbidity** | NTU | <0.03 | 0.27 | 0.79 |
| **Colour** | Hazen | | | |
| **TOC** | mg/l | 0.65 | 1.0 | 4.04 |
| **pH** | | 6.5 | 7.4 | 7.7 |
| **Alkalinity** | mg/l as (HCO3) | 168 | 196 | 242 |
| **Total Hardness** | mg/l (as Ca) | 83 | 100 | 112 |
| **Conductivity** | uS | 443 | 661 | 1120 (1) |
| **Nitrate** | mg/l as NO3 | 38 | 55 | 68 |
| **Sulphate** | mg/l | 37 | 39 | 41 (1) |
| **Chloride** | mg/l | 22.8 | 82 | 236 (1) |
| **Sodium** | mg/l | 16 | 53 | 139 |
| **Iron** | ug/l | <7 | 16 | 70 |
| **Manganese** | ug/l | 2.1 | 1.6 | 7 |
| **Chlorthal** | ug/l | 0.064 | 0.107 | 0.134 |
| **Atrazine** | ug/l | 0.022 | 0.051 | 0.074 |

- Sample on 17/12/2009 with >1600uS/cm from both boreholes removed from dataset

# Shenstone WTW – Raw Water Quality




Graph provided by SSW.

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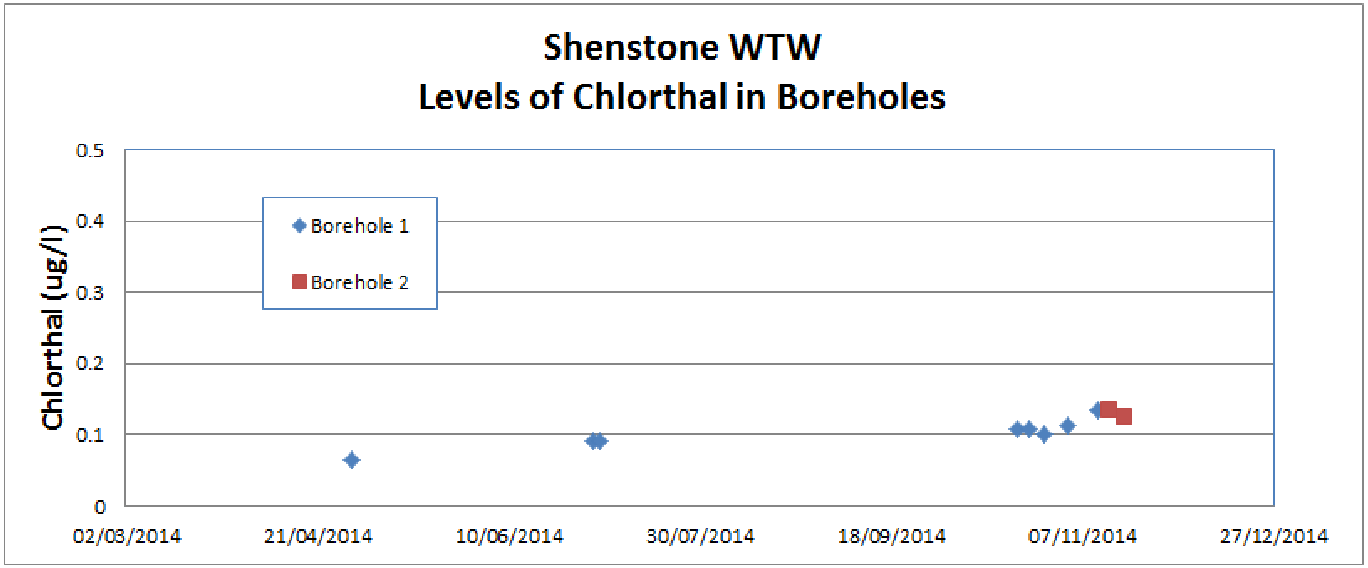


# Shenstone WTW

- Water Quality Risks
  - *Nitrate (possible decreasing trend?).*
  - *Chlorthal.*
  - *Turbidity/iron (presumably on start up).*
  - *Atrazine (historical issue).*
  - *Tri-chloroethene.*
  - *Pathogens.*
- Disinfection Requirements.
  - *Enhanced disinfection with a Ct of 15mg.min/l.*

# Sandhills WTW

## Historical Data 2009 -2014

| Parameter | Units | Min | Ave | Max |
|---|---|---|---|---|
| **Turbidity** | NTU | 0.08 | 0.6 | 3.17 |
| **Colour** | Hazen | | 0.9 | |
| **TOC** | mg/l | 0.66 | 1.51 | 3.0 |
| **pH** | | 7.25 | 7.38 | 7.6 |
| **Alkalinity** | mg/l as (HCO3) | 160 | 160.3 | 161 |
| **Total Hardness** | mg/l (as Ca) | 104 | 117 | 127 |
| **Conductivity** | uS | 559 | 624 | 662 |
| **Nitrate** | mg/l as NO3 | 32 | 76 | 84 |
| **Sulphate** | mg/l | | 87 | |
| **Chloride** | mg/l | 50 | 53 | 57 |
| **Sodium** | mg/l | | | |
| **Iron** | ug/l | 4 | 97 | 270 |
| **Manganese** | ug/l | | | |
| **Chlorthal** | ug/l | | 1.41* | |

**Very limited date set (most of data is based upon 3 samples taken in 2012/3**

# Sandhills WTW

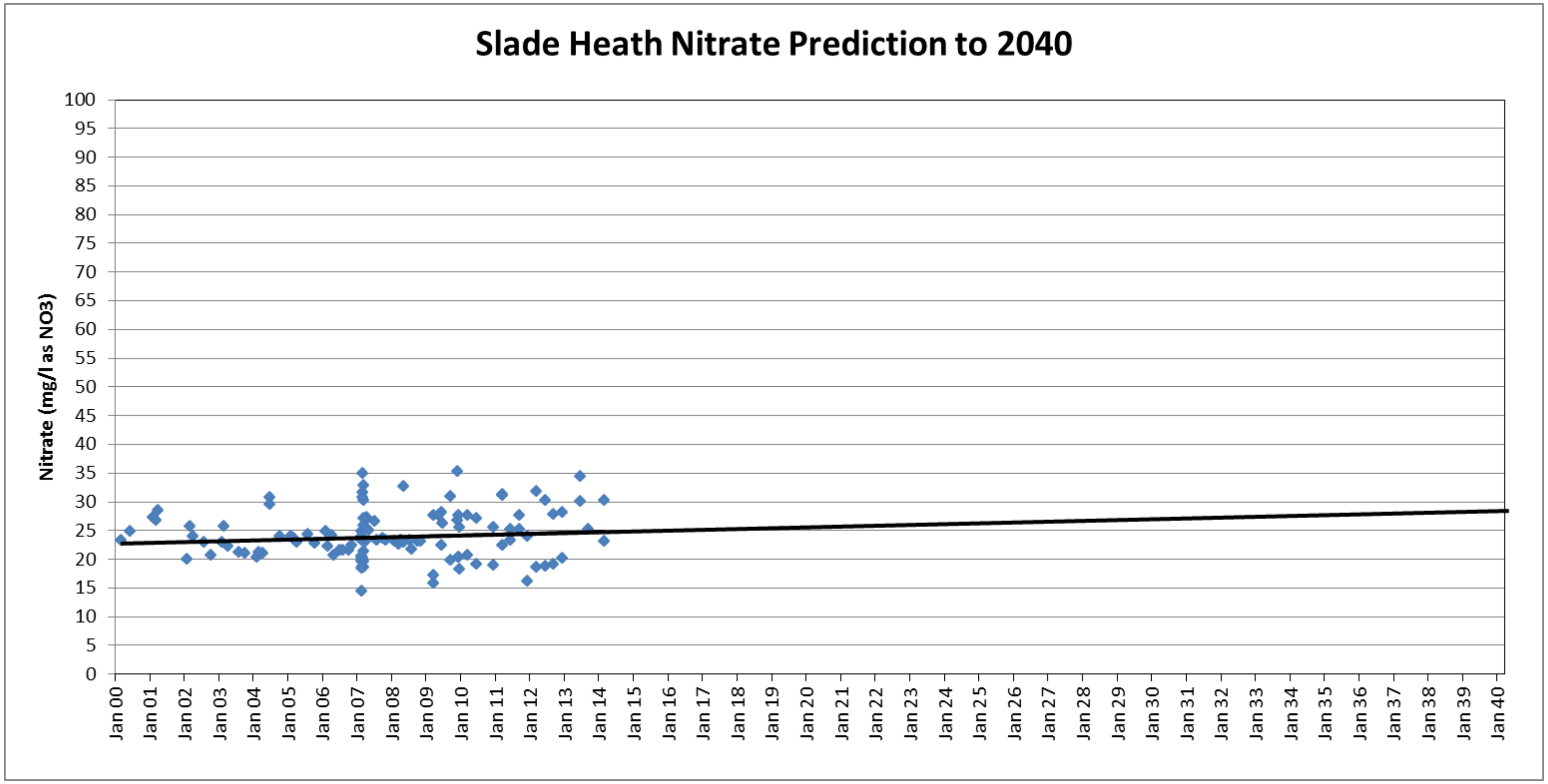
- Water Quality Risks.
  - *Nitrate (limited recent data).*
  - *Chlorthal (very limited data).*
  - *Turbidity/iron (presumably on start up).*
  - *Aerated water.*
  - *Pathogens.*
- Disinfection Requirements.
  - *Enhanced disinfection with a Ct of 15mg.min/l.*

# Raw Water Quality – Slade Heath WTW

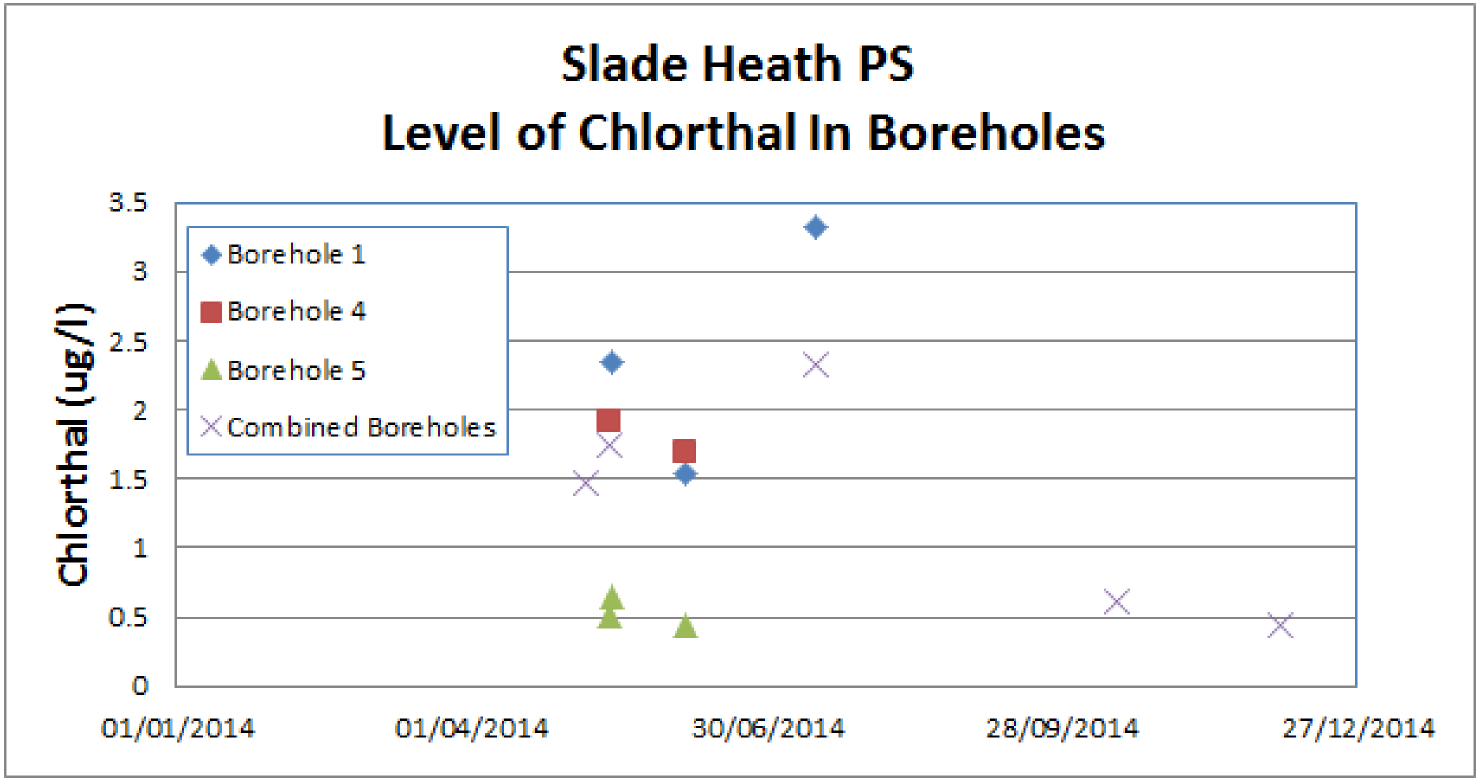
**Historical Data 2009 -2014**

| Parameter | Units | Min | Ave | Max |
|---|---|---|---|---|
| **Turbidity** | NTU | 0.04 | 0.24 | 4.74 |
| **Colour** | Hazen | 0.7 | 1.0 | 1.3 |
| **TOC** | mg/l | 0.5 | 0.896 | 3.8 |
| **pH** | | 7.06 | 7.55 | 7.9 |
| **Alkalinity** | mg/l as (HCO3) | 222 | 250 | 273 |
| **Total Hardness** | mg/l (as Ca) | 88 | 111 | 126 |
| **Conductivity** | uS | 442 | 555 | 651 |
| **Nitrate** | mg/l as NO3 | 15.9 | 24 | 35 |
| **Sulphate** | mg/l | 33 | 39 | 52 |
| **Chloride** | mg/l | 25 | 36 | 43 |
| **Sodium** | mg/l | 14 | 18 | 22 |
| **Iron** | ug/l | 4 | 14 | 44 |
| **Manganese** | ug/l | 67 | 104 | 180 |
| **Arsenic** | ug/l | 1.8 | 2.6 | 3.4 |
| **Chlorthal** | ug/l | 0.442 | 1.462 | 3.32 |

# Shenstone WTW – Raw Water Quality



# Slade Heath WTW – Raw Water Quality



# Slade Heath WTW

- Water Quality Risks.
  - *Chlorthal (variable concentrations?).*
  - *Manganese.*
  - *Turbidity .*
  - *Pathogens.*
- Disinfection Requirements.
  - *Enhanced disinfection with a Ct of 15mg.min/l.*

# Raw Water Quality – Somerford WTW

**Historical Data 2009 -2014**

| Parameter | Units | Min | Ave | Max |
|---|---|---|---|---|
| **Turbidity** | NTU | 0.08 | 0.18 | 0.41 |
| **Colour** | Hazen | | | |
| **TOC** | mg/l | 0.4 | 1.8 | 17.8* |
| **pH** | | 7.29 | 8.05 | 8.21 |
| **Alkalinity** | mg/l as (HCO3) | 231 | 253 | 281 |
| **Total Hardness** | mg/l (as Ca) | 40 | 43 | 48 |
| **Conductivity** | uS | 1160 | 1271 | 1800 |
| **Nitrate** | mg/l as NO3 | 1.4 | 2.8 | 4.4 |
| **Sulphate** | mg/l | 51 | 54 | 57 |
| **Chloride** | mg/l | 239 | 297 | 346 |
| **Sodium** | mg/l | 12 | 256 | 386 |
| **Iron** | ug/l | 12 | 36.7 | 570 (1) |
| **Manganese** | ug/l | 2 | 8 | 49 (1) |
| **Arsenic** | ug/l | 2.4 | 14.75 | 27 (1) |
| **Chlorthal** | ug/l | | <0.012 | |

•Single sample with max values of iron, manganese and arsenic,

# Somerford WTW

- Water Quality Risks.
  - *Sodium.*
  - *Chloride.*
  - *Arsenic.*
  - *Iron/Manganese (on start up????).*
  - *Pathogens.*
- Disinfection Requirements.
  - *Enhanced disinfection with a Ct of 15mg.min/l.*

# Available Treatment Options.

# Nitrate Treatment Options

- Blending.
- Ion Exchange
  - *Nitrate selective resin – treatment technology of choice.*
  - *Counter current – MIEX.*
  - *Weak base anion resin – only pilot scale at present.*
- Reverse Osmosis – high power costs.
- EDR – high power costs.
- Biological Denitrification – operation at low temperatures?
- Chemical Denitrification – not tested at full scale.

# Chlorthal Treatment Options

- Blending.
- Ion Exchange.
  - *Nitrate selective resin – evidence of removal at Pipehill WTW.*
  - *Other resins – DWI approval.*
- Activated Carbon.
  - *GAC – results from WRc accelerated tests.*
  - *PAC.*
- Reverse Osmosis – based upon membrane pore size.
- Advanced oxidation – WRc tests showed ozone to be ineffective and UV oxidation to require very high doses.

# Tri-chloroethene Treatment Options

- Air Stripping.
- GAC.

# Sodium and Chloride Treatment Options

- Blending.
- Reverse Osmosis.
- EDR.
- Thermal desalination.

# Arsenic Treatment Options

- Blending.
- Granular Ferric Hydroxide (GFH).
- Ferric Sulphate/Filtration – as Fradley WTW.
- Reverse Osmosis.
- Electrodialysis Reversal (EDR).
- Ion exchange

# Initial testing programme.

# Testing programme

- Activated Carbon.
  - *Determine dose of PAC required for Chlorthal removal at Pipe Hill, Slade Heath and Shenstone.*
  - *Investigate performance of different PAC types.*
- Nitrate Selective Resin.
  - *Confirm nitrate selective resin removes chlorthal from the raw water at Slade Heath WTW and Shenstone WTW.*
  - *Confirm chlorthal removal occurs with both Purolite and Dow nitrate selective resins.*
  - *Determine what happens beyond nitrate breakthrough.*
  - *Balance chlorthal removed from raw water with levels in regen waste.*

# Testing programme

- MIEX.
  - *Confirm chlorthal removal by MIEX resin.*
  - *Carry out breakthrough tests with water from Slade Heath WTW.*
- Arsenic removal.
  - *Confirm removal by GFH media and precipitated ferric hydroxide.*
  - *Analysis of key raw water parameters.*

# WRc GAC Tests

# GAC – Rapid Column Test (RCT)

## Breakthrough of chlorthal (Norit 1240 GAC)

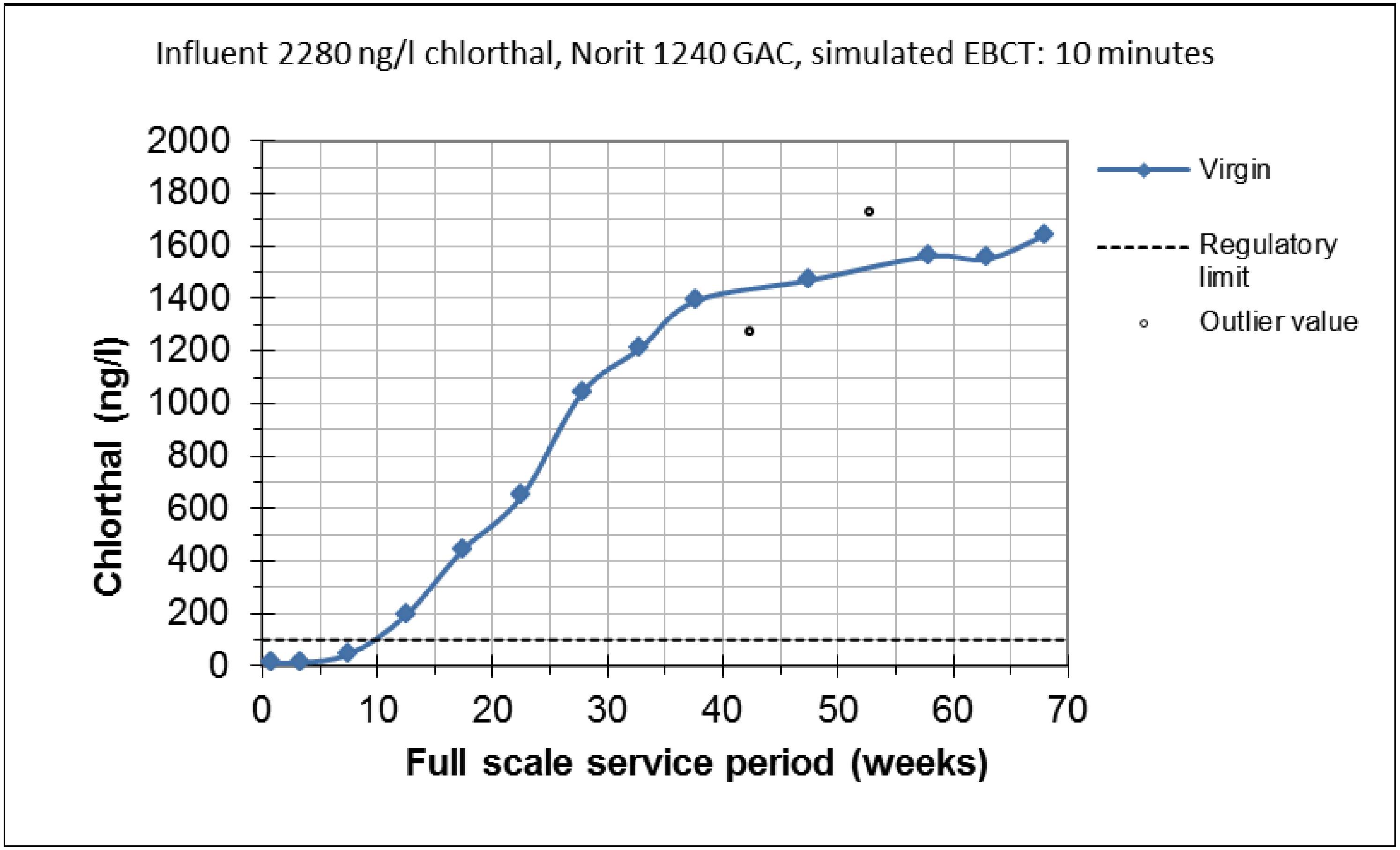
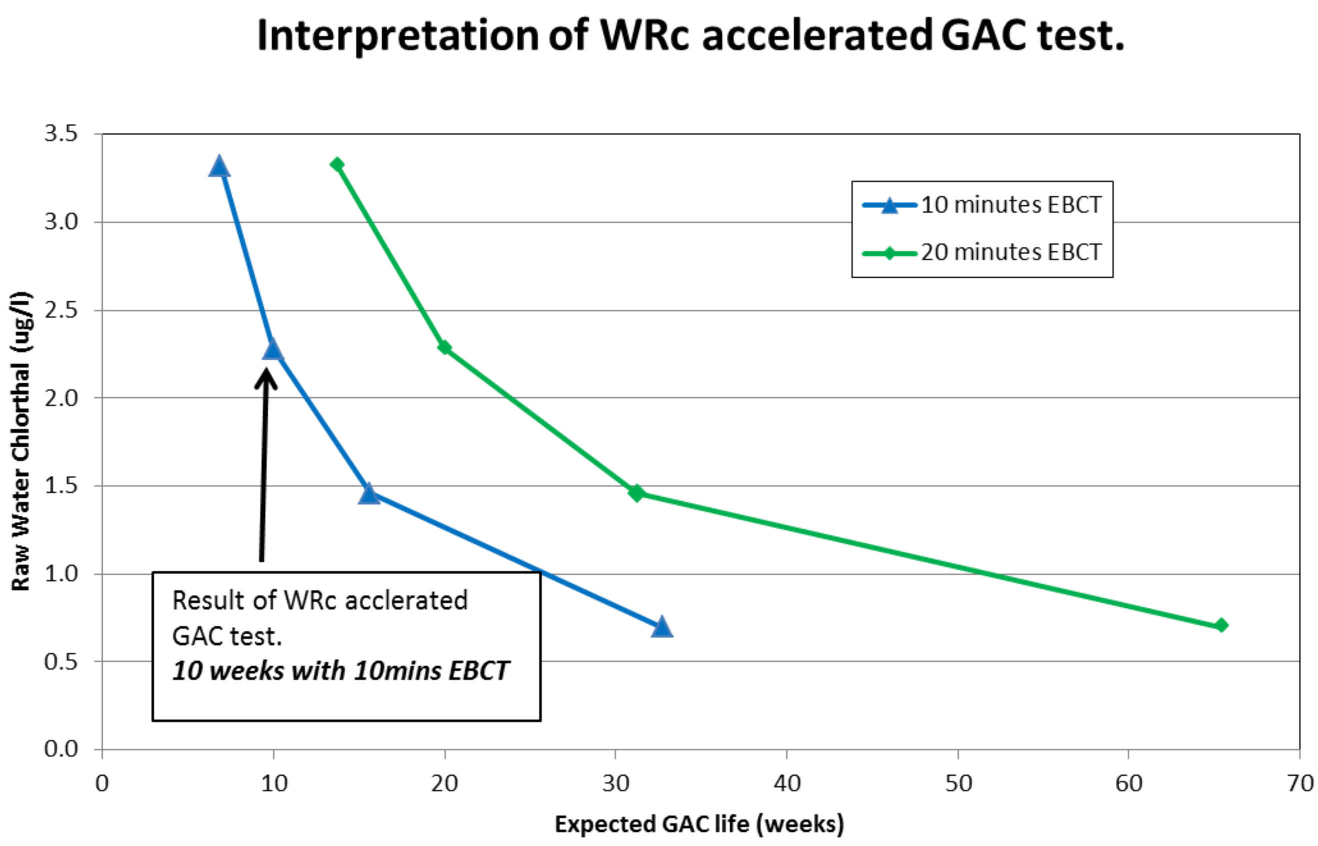



Figure from report issued by WRc.

# GAC – Rapid Column Test (RCT)



# PAC Jar Tests

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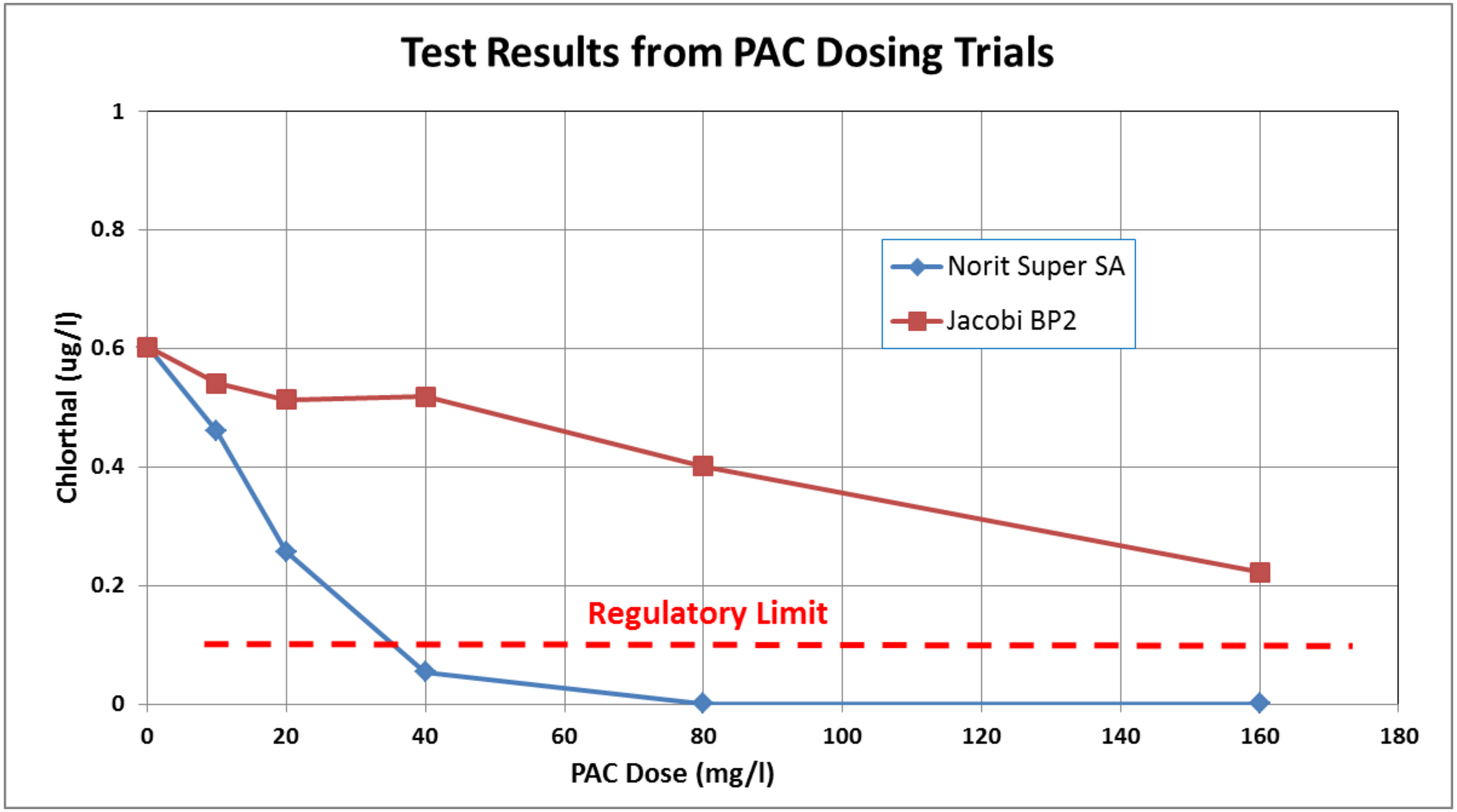
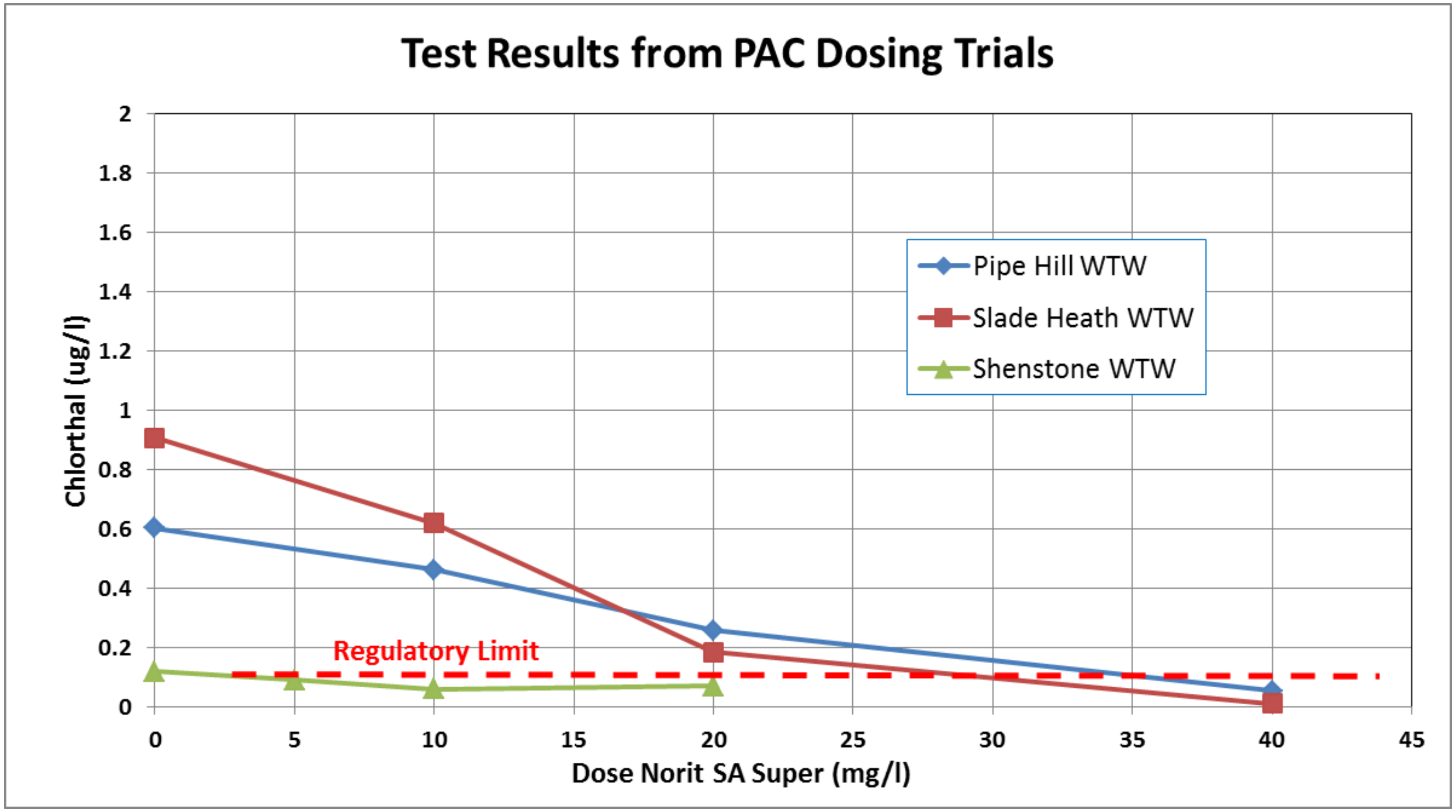


# PAC Jar Tests

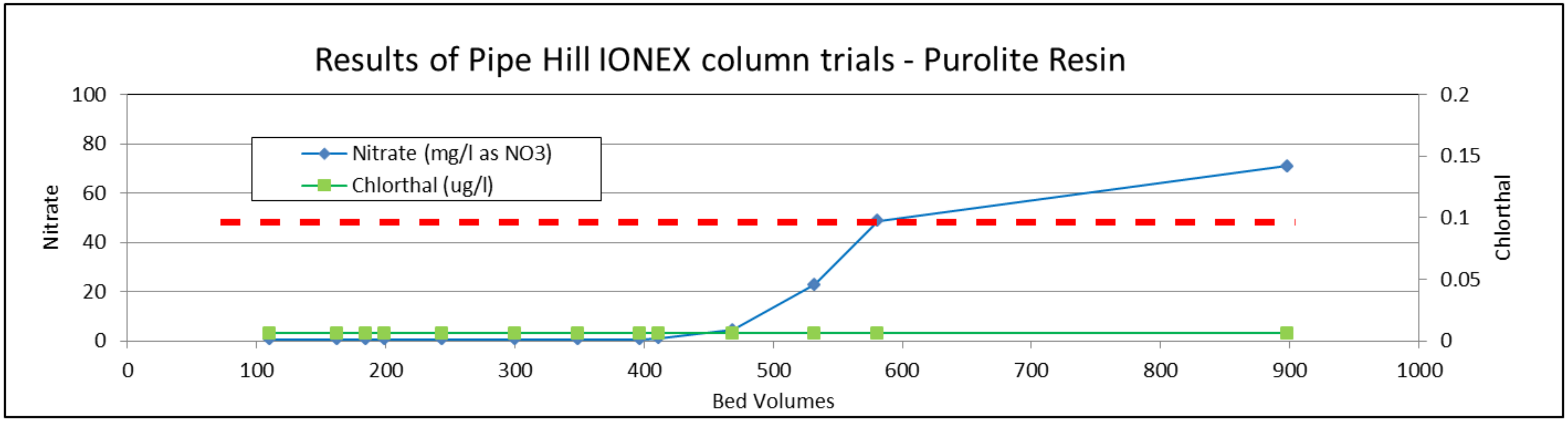


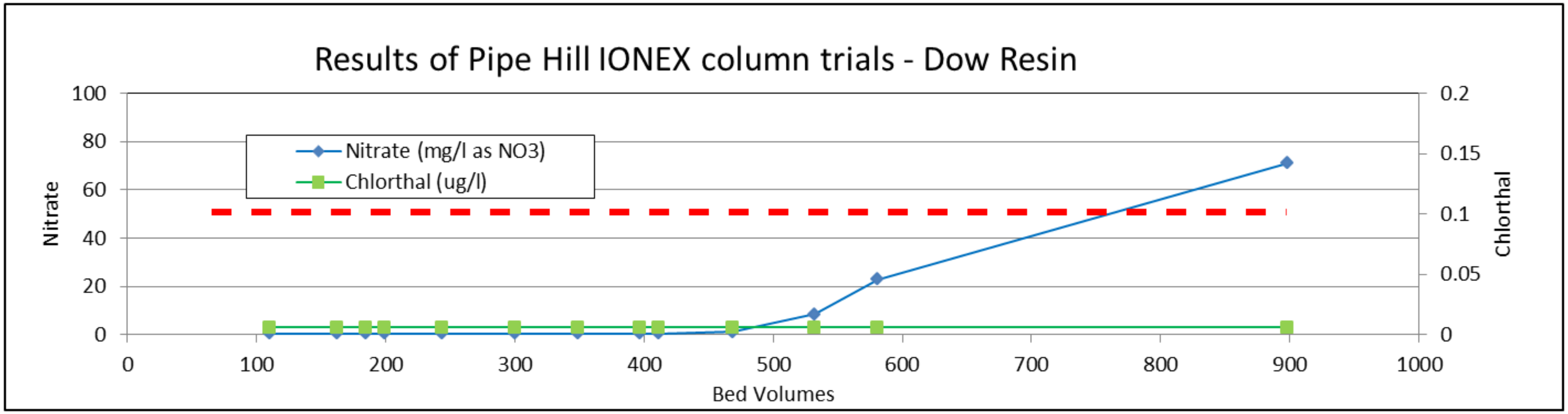
# PAC Jar Tests

- Chlorthal concentration in raw water sample from Slade Heath WTW (0.907ug/l) was lower than historical average (1.462ug/l).
- Graph suggest that PAC dose required to achieve regulatory limit for both Slade Heath and Pipe Hill WTWs is 30-40mg/l. .
- For Shenstone WTW tests indicated that a dose of 5-10mg/l is required to meet the regulatory limit for chlorthal.
- Norit SA Super performed far better than Jacobi BP2 in tests.

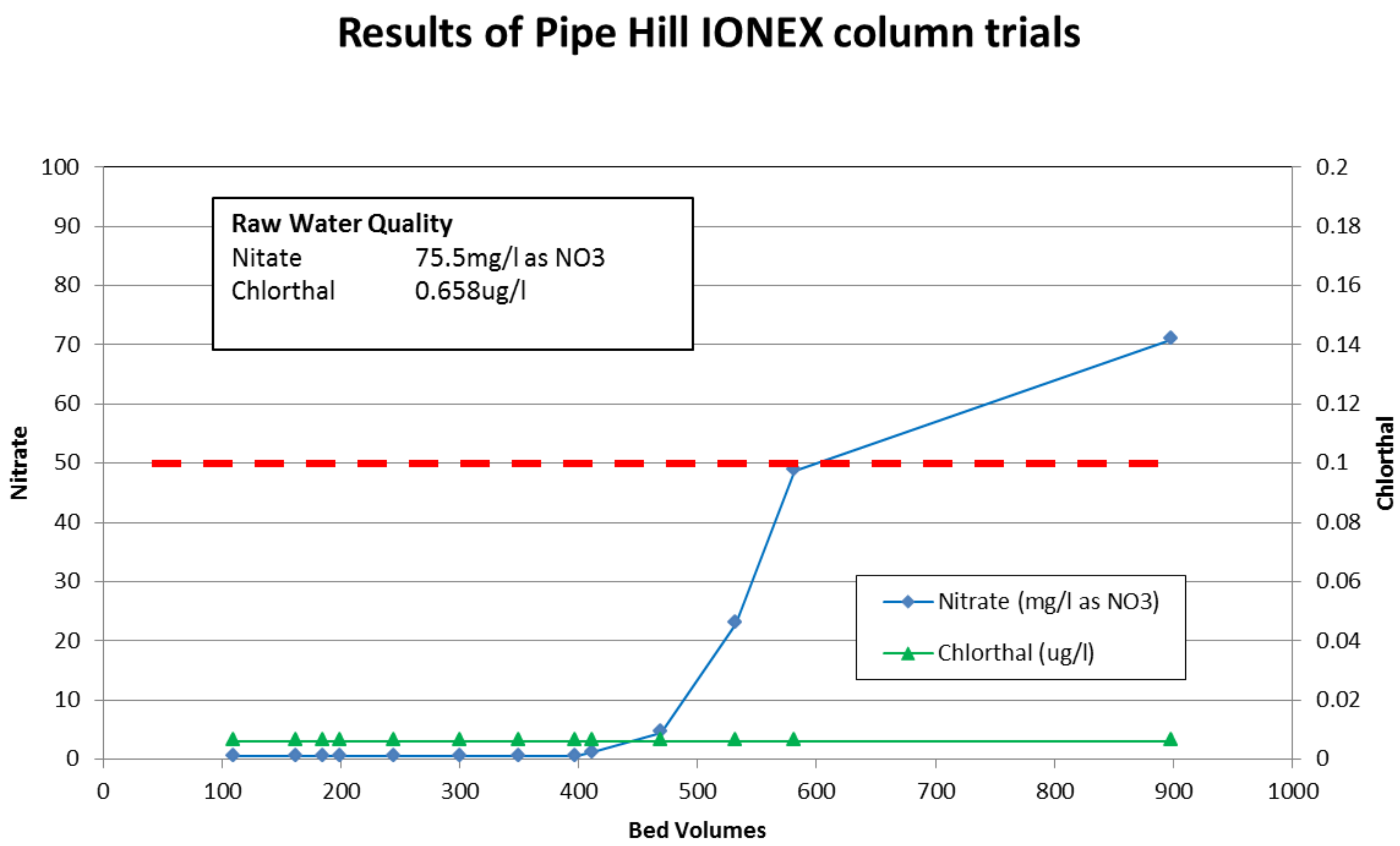
# Nitrate Selective Resin Column Trials

# Ion Exchange – Column Trials



# Ion Exchange – Column Trials



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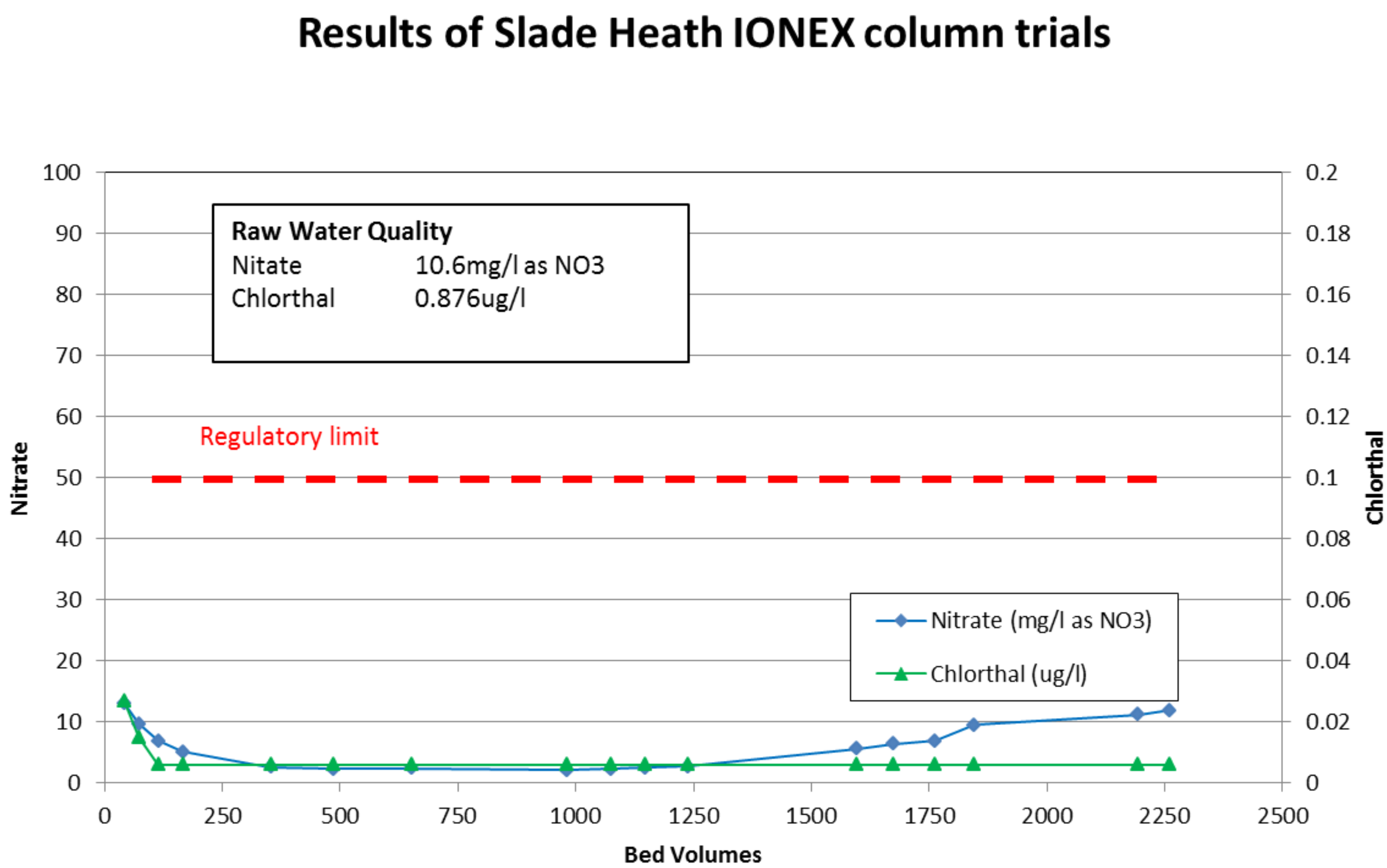

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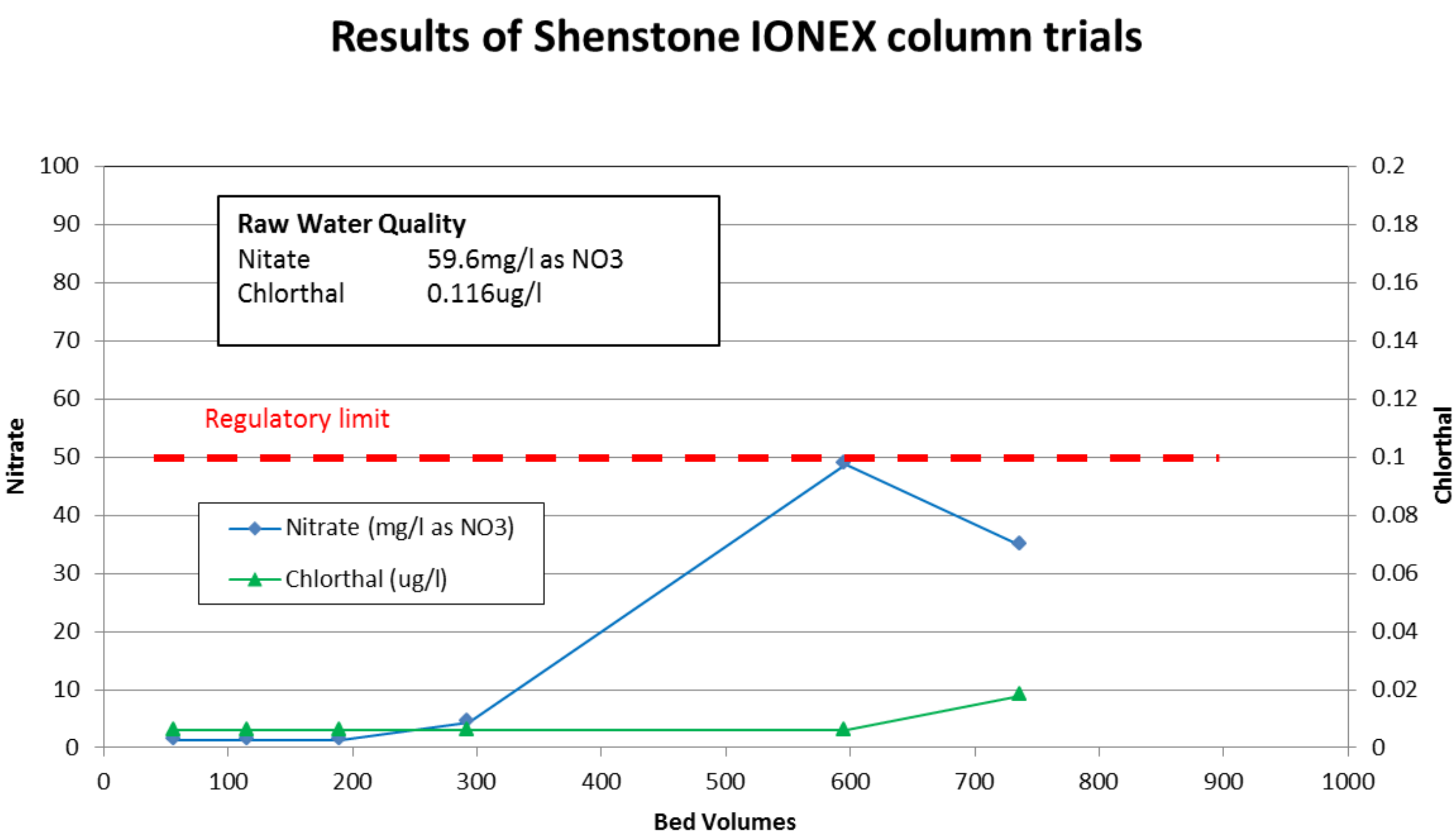
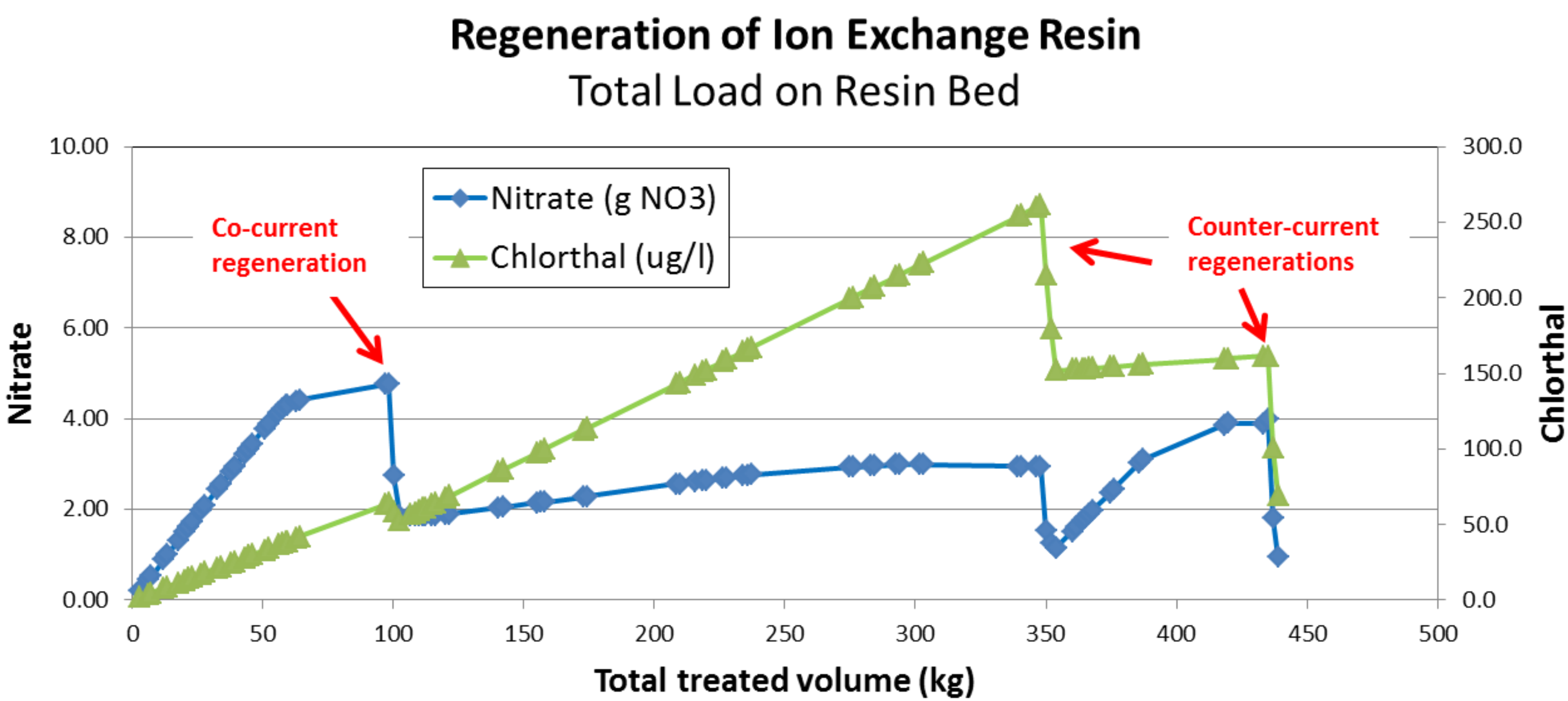


# Ion Exchange – Column Trials



# Arsenic Removal Tests

# Arsenic Removal

| | Arsenic |
|---|---|
| ○ Somerford WTW raw water | 16ug/l |
| ○ Post GFH Treatment | <0.1ug/l |
| ○ Ferric sulphate addition | |
| ▪ *1mg/l as Fe* | *8.9ug/l.* |
| ▪ *2mg/l as Fe* | *5.8ug/l* |
| ▪ *3mg/l as Fe* | *2.6ug/l* |

# Impact on Potential Plant Design

# Design Consideration for Full Scale Plants

- PAC
  - *Membrane suppliers concerned over impact of PAC on membrane life.*
  - *High doses required for Slade Heath and Pipe Hill mean clarification required upfront of Rapid Gravity Filters (RGFs).*
  - *Filters need to be designed for additional solids loading.*
  - *Sludge handling and disposal requires careful consideration.*
- Nitrate Selective Resin (IONEX).
  - *Resin has limited capacity for chlorthal.*
  - *Counter current regeneration required to remove chlorthal from the resin.*
  - *Limited opportunities for waste/salt minimisation due to high % removal requirement for chlorthal.*

# Design Consideration for Full Scale Plants

- GAC
  - *Raw water concentration of chlorthal and EBCT impacts on regen frequency.*
  - *Need to allow for treatment of 'blackwater' produced during GAC delivery/removal .*
  - *Need to consider how beds are conditioned/tested prior to going into service.*

# Design Consideration for Individual Sites

- Slade Heath WTW
  - *Manganese removal by existing chlorination and filtration.*
  - *Preferable to de-chlorinate prior to new GAC and ion exchange plants.*
  - *Upgrades to existing sodium hypochlorite and sodium bisulphite dosing systems may be required to accommodate higher doses.*
  - *A chlorine residual of 0.85mg/l is required to give a CT of 15mg.min/l in existing contact tanks.*
- Somerford WTW
  - *No nearby sewer is available for effluent disposal.*
  - *Work is ongoing to understand the source of salinity within the existing boreholes.*
  - *A CT of 15mg.min/l can be achieved with a free chlorine residual of 0.2mg/l in the main to Slade Heath WTW.*

# Design Consideration for Individual Sites

- Pipe Hill WTW
  - *The existing borehole pumps are fixed speed and restrict the plant flow to a nominal 4, 8 and 11MLD.*
  - *Boreholes 1, 2 and 4 are over 100 years old and it has been recommended that at least one be replaced.*
  - *The existing nitrate plant is close to the end of its asset life.*
  - *Raw water nitrate levels are increasing beyond the design of the existing plant.*
  - *The source requires only marginal chlorination. The contact tank provides a CT of 4.1mg.min/l with the current chlorine residual of 0.4mg/l.*

# Design Consideration for Individual Sites

- Shenstone WTW
  - *The borehole is at high risk of collapse and it has been recommended that it is replaced.*
  - *The existing nitrate plant is close to the end of its asset life*
  - *A chlorine residual of 1.3mg/l would be required to achieve a CT of 15mg.min/l in the existing contact tank.*
- SandhIlls WTW
  - *The site can provide an argumentation flow of 3Ml/d.*
  - *The existing main to Pipe Hill provides a CT of 15mg.min/l assuming a chlorine residual of 0.4mg/l is maintained.*

# Assumptions used in developing CAPEX and OPEX costs

## Nitrate Selective Resin

- Run time based upon nitrate only.
- OPEX values include costs relating to changing nitrate trends.
- Salt consumption
  - 120g/l for chlorthal/nitrate removal.
  - 160g/l for nitrate removal.
- Effluent volumes based upon values provided by equipment suppliers.

## Granular Activated Carbon

- Carbon life based upon extrapolation of WRc accelerated tests and average raw water chlorthal concentrations using an EBCT of 20minutes.

# Assumptions used in developing CAPEX and OPEX costs

**Powdered Activated Carbon**

Dose based upon jar test results.

-extrapolate for average raw water conditions

-allow for enhanced removal by PAC in sludge (-30%) .

**Sodium and Chloride Removal**

Based upon treatment of side stream only.

Disposal stream available for waste.

**Arsenic removal**

Arsenic remains as Arsenic (V) after de-chlorination.

Media replacement based upon prediction from supplier.

# Assumptions used in developing CAPEX and OPEX costs

## CAPEX

Cost based upon budget quotes and cost models.

Values do not include SSW costs.

## NPV

25 years at 8.5% discount.

## OPEX

| | |
|---|---|
| Power | £0.086/kWh. |
| Salt | £85/tonne. |
| GAC | £374/tonne. |
| Effluent | £528/m3. |
| others | typical costs across industry. |

# Assumptions used in developing CAPEX and OPEX costs

## Pumping

- Delivery Heads (above EHFL)

| | |
|---|---|
| *Slade Heath WTW* | *97m* |
| *Somerford WTW* | *110m* |
| *Sandhills WTW* | *108m* |
| *Shenstone WTW* | *129m* |
| *Pipe Hill WTW (Hopwas)* | *27m* |
| *Pipe Hill WTW ( Barr Beacon)* | *120m* |

- Pump efficiency of 70%.

# Slade Heath WTW

Imtech

# Slade Heath WTW

## Options Considered

**Option 1** New 4Ml/d ion exchange plant for treating chlorthal in new building.

Upgrades to existing sodium hypochlorite and sodium bisulphite dosing systems to accommodate increased demand.

Effluent disposal to local sewer.

**Option 2** New 4Ml/d GAC plant including dirty wash-water treatment system.

Upgrades to existing sodium hypochlorite and sodium bisulphite dosing systems to accommodate increased demand.

**Option 3** New PAC, ferric and polyelectrolyte dosing systems.

New 4Ml/d clarifier

New RGF’s (2 off) to increase filtration capacity.

New dirty wash water treatment plant including sludge treatment and storage.

# Slade Heath WTW

## Options Considered

**Option 4** New 4Ml/d MIEX plant for treating chlorthal.

New pumping station to relift treated water through manganese filters.

Effluent disposal to sewer.

**Option 5** Two temporary GAC units operating at 1.8Ml/d each.

# Slade Heath WTW

## CAPEX, OPEX and NPV values of Options

| | Option 0 | Option 1 | Option 2 | Option 3 | Option 4 | Option 5 |
|---|---|---|---|---|---|---|
| **Description** | Historical (normalised) | Ion Exchange Plant | GAC Plant | PAC Dosing | MIEX Plant | Temporary GAC Plant |
| **OUTPUT** | **4** | **4** | **4** | **4** | **4** | **3.6** |
| **CAPEX (£M)** | | **2.97** | **2.84** | **4.69** | **3.71** | |
| **OPEX (£k/yr)** | **123** | **171** | **152** | **354** | **145** | **317** |
| Power (treatment) (£/Ml) | 42.0 | 51.1 | 44.0 | 54.2 | 52.5 | 42.5 |
| Power (HL pumping) (£/Ml) | 34.6 | 34.6 | 34.6 | 34.6 | 34.6 | 34.6 |
| Chemicals (£/Ml) | 7.6 | 28.6 | 11.2 | 9.7 | 11.8 | 11.2 |
| Effluent (£/Ml) | | 2.6 | 0.1 | 31.3 | 0.5 | |
| Carbon (£/Ml) | | | 14.2 | 113 | | 153 |
| OPEX(£/Ml) | 84.2 | 116.9 | 104.0 | 242.8 | 99.4 | 241.3 |
| **NPV (£M)** | | **4.66** | **4.40** | **7.99** | **4.92** | **3.28** |

# Slade Heath WTW

## Conclusions

- Nitrate selective resin and GAC have similar CAPEX and OPEX costs based upon the assumptions used.
- MIEX has a lower OPEX than nitrate selective resin but higher CAPEX and NPV.
- PAC CAPEX and OPEX are far higher than the other options.
- A temporary GAC system may be attractive if used for ‘drought periods’ only.

# Somerford WTW

# Somerford WTW

## Options Considered

**Option 1** New 2Ml/d RO plant for treating sodium chloride and arsenic.
New phosphoric acid dosing system.
New effluent pumping station and discharge pipe to Four Oaks.

**Option 2** New 2Ml/d EDR plant for treating sodium chloride and arsenic.
New phosphoric acid dosing system.
New effluent pumping station and discharge pipe to Four Oaks.

**Option 3** New borehole.
New GFH plant treating arsenic only.
New dirty wash water treatment plant.
New phosphoric acid dosing system.

# Somerford WTW

## CAPEX, OPEX and NPV Values of Options

| | Option 0 | Option 1 | Option 2 | Option 3 |
|---|---|---|---|---|
| **Description** | Blending with Slade Heath (normalised) | RO Plant | EDR Plant | New borehole and GFH Plant |
| **OUTPUT** | **2** | **1.8** | **1.9** | **2** |
| **CAPEX (£M)** | | **3.29** | **3.39** | **1.65** |
| **OPEX (£k/yr)** | **71** | **157** | **120** | **93** |
| Power (treatment) (£/Ml) | 88.8 | 121.4 | 93.6 | 97.0 |
| Power (HL pumping) (£/Ml) | | 40.2 | 40.2 | |
| Chemicals (£/Ml) | 5 | 16 | 10.8 | 29.4 |
| Effluent (£/Ml) | | 61.6 | 27 | 0.9 |
| Carbon (£/Ml) | | | | |
| OPEX(£/Ml) | 93.8 | 239.2 | 171.6 | 127.3 |
| **NPV (£M)** | **0.73** | **4.66** | **4.4** | **2.48** |

# Somerford WTW

## Conclusions

- Reverse Osmosis and EDR both have very high operating costs and generate large waste stream of brine.
- Granular Ferric Hydroxide OPEX costs are comparable to the predicted operating cost of GAC/Ion Exchange at Slade Heath WTW (but no ‘cheap’ extra water from blending).

# Slade Heath WTW and Somerford WTW

# Option Combinations

# Slade Heath and Somerford WTW

## Combinations considered

**Scenario 0** Historical operation of sites.

**Scenario 1** New 4Ml/d ion exchange plant at Slade Heath WTW for treating chlorthal.

Blending of water from Somerford WTW (2Ml/d) to reduce sodium, chloride and arsenic.

**Scenario 2** New 4Ml/d GAC plant at Slade Heath WTW for treating chlorthal.

Blending of water from Somerford WTW (2 Mld) to reduce sodium, chloride and arsenic.

**Scenario 3** New 2Ml/d EDR plant at Somerford WTW to reduce sodium, chloride and arsenic.

**Scenario 4** New borehole at Somerford WTW (to reduce salinity) and new 2Ml/d GFH plant to remove arsenic.

# Slade Heath WTW/Somerford WTW

## Scenario 0 (historical)

| | Slade Heath | Somerford | Hampton Load | Total |
|---|---|---|---|---|
| **Description** | Manganese Filters | Blending | Conventional surface water treatment | |
| **OUTPUT** | **4** | **2** | | **6** |
| **CAPEX (£M)** | | | | |
| **OPEX (£k/yr)** | **123** | **68** | | **191** |
| Power (treatment) (£/Ml) | 42.0 | 88.8 | | |
| Power (HL pumping) (£/Ml) | 34.6 | | | |
| Chemicals (£/Ml) | 7.6 | 5 | | |
| Effluent (£/Ml) | | | | |
| Carbon (£/Ml) | | | | |
| **OPEX(£/Ml)** | **84.2** | **93.8** | **0.0** | **87.4** |

NH Note – Can include Hampton Load cost if provided by SSW

# Slade Heath WTW/Somerford WTW

## Scenario 1

| | Slade Heath | Somerford | Hampton Load | Total |
|---|---|---|---|---|
| **Description** | IONEX Plant | Blending | Conventional surface water treatment | |
| **OUTPUT** | **4** | **2** | | **6** |
| **CAPEX (£M)** | **2.97** | | | **2.97** |
| **OPEX (£k/yr)** | **171** | **68** | | **239** |
| Power (treatment) (£/Ml) | 51.1 | 88.8 | | |
| Power (HL pumping) (£/Ml) | 34.6 | | | |
| Chemicals (£/Ml) | 28.6 | 5 | | |
| Effluent (£/Ml) | 2.6 | | | |
| Carbon (£/Ml) | | | | |
| **OPEX(£/Ml)** | **116.9** | **93.8** | **0.0** | **109.2** |

# Slade Heath WTW/Somerford WTW

## Scenario 2

| | Slade Heath | Somerford | Hampton Load | Total |
|---|---|---|---|---|
| **Description** | GAC adsorbers | Blending | Conventional surface water treatment | |
| **OUTPUT** | **4** | **2** | | **6** |
| **CAPEX (£M)** | **2.84** | | | **2.84** |
| **OPEX (£k/yr)** | **152** | **68** | | **220** |
| Power (treatment) (£/Ml) | 44.0 | 88.8 | | |
| Power (HL pumping) (£/Ml) | 34.6 | | | |
| Chemicals (£/Ml) | 11.2 | 5 | | |
| Effluent (£/Ml) | 0.1 | | | |
| Carbon (£/Ml) | 14.2 | | | |
| **OPEX(£/Ml)** | **104.0** | **93.8** | **0.0** | **100.6** |

# Slade Heath WTW/Somerford WTW

## Scenario 3

| | Slade Heath | Somerford | Hampton Load | Total |
|---|---|---|---|---|
| **Description** | | EDR | Conventional surface water treatment | |
| **OUTPUT** | | **1.9** | | **2** |
| **CAPEX (£M)** | | **3.39** | | **3.39** |
| **OPEX (£k/yr)** | | **119** | | **119** |
| Power (treatment) (£/Ml) | | 93.6 | | |
| Power (HL pumping) (£/Ml) | | 40.2 | | |
| Chemicals (£/Ml) | | 10.8 | | |
| Effluent (£/Ml) | | 27 | | |
| Carbon (£/Ml) | | | | |
| **OPEX(£/Ml)** | | **171.6** | **0.0** | **171.6** |

# Slade Heath WTW/Somerford WTW

## Scenario 4

| | Slade Heath | Somerford | Hampton Load | Total |
|---|---|---|---|---|
| **Description** | | New borehole and arsenic removal plant | Conventional surface water treatment | |
| **OUTPUT** | **0** | **2** | | **2** |
| **CAPEX (£M)** | | **1.65** | | **1.65** |
| **OPEX (£k/yr)** | | **93** | | **93** |
| Power (treatment) (£/Ml) | | 97.0 | | |
| Power (HL pumping) (£/Ml) | | | | |
| Chemicals (£/Ml) | | 29.4 | | |
| Effluent (£/Ml) | | 0.9 | | |
| Carbon (£/Ml) | | | | |
| **OPEX(£/Ml)** | | **127.3** | **0.0** | **127.3** |

# Slade Heath WTW/Somerford WTW

## Scenario 5

| | Slade Heath | Somerford | Hampton Load | Total |
|---|---|---|---|---|
| **Description** | Temporary GAC adsorbers | Blending | Conventional surface water treatment | |
| **OUTPUT** | **3.6** | **2** | | **6** |
| **CAPEX (£M)** | | | | |
| **OPEX (£k/yr)** | **317** | **68** | | **386** |
| Power (treatment) (£/Ml) | 42.5 | 88.8 | | |
| Power (HL pumping) (£/Ml) | 34.6 | | | |
| Chemicals (£/Ml) | 11.2 | 5 | | |
| Effluent (£/Ml) | | | | |
| Carbon (£/Ml) | 153 | | | |
| **OPEX(£/Ml)** | **241.3** | **93.8** | **0.0** | **188.6** |

# Slade Heath WTW/Somerford WTW

## Summary of scenarios

| | Scenario 0 | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
|---|---|---|---|---|---|---|
| **Description** | Pressent operation | New IONEX Plant at Slade Heath WTW | New GAC Plant at Slade Heath WTW | New EDR plant at Somerford WTW | New GFH plant at Somerford WTW | New temporary GAC Plant at Slade Heath WTW |
| **OUTPUT (Ml/d)** | **6** | **6** | **6** | **2** | **2** | **6** |
| Slade Heath WTW | 4 | 4 | 4 | 0 | 0 | 3.6 |
| Somerford WTW | 2 | 2 | 2 | 1.9 | 2 | 2 |
| Hampton Load WTW | 0 | 0 | 0 | 0 | 0 | 0 |
| **CAPEX (£M)** | | **2.97** | **2.84** | **3.4** | **1.7** | |
| OPEX (£k/yr) | 191 | 239 | 220 | 120 | 93 | 386 |
| **OPEX(£/Ml)** | **87.4** | **109.2** | **100.6** | **173.7** | **127.3** | **188.6** |

# Discussion

# Discussion

- Required resilience.
- Affordability.
- Operability.

# Sandhills WTW

# Sandhills WTW

## Options considered.

**Option 1.** New 3Ml/d borehole pumps to allow site to pump to waste and provide 3MLD argumentation flow.

300m of new buried pipe from site to new discharge point.

**Option 2.** New 6Ml/d borehole pumps to allow site to pump to waste and provide 3MLD argumentation flow.

300m of new buried pipe from site to new discharge point.

New 3Ml/d ion exchange plant to remove chlorthal and nitrate.

New stripping tower to remove excess air from borehole water.

New booster pump station.

New sodium hypochlorite dosing systems for disinfection in main to Pipe Hill WTW.

New waste pipe to Shenstone WTW for effluent disposal.

# Sandhills WTW

## Options considered.

**Option 3.** New 6Ml/d borehole pumps to allow site to pump to waste and provide 3MLD argumentation flow.

300m of new buried pipe from site to new discharge point

New 3Ml/d GAC plant for chlorthal removal including waste water treatment.

New stripping tower to remove excess air from borehole water.

New booster pump station.

New sodium hypochlorite dosing systems for disinfection in main to Pipe Hill WTW.

**Option 4**. New 6Ml/d borehole pumps to allow site to pump to waste and provide 3MLD to Pipe Hill WTW for treatment.

300m of new buried pipe from site to new discharge point.

# Sandhills WTW

## CAPEX, OPEX and NPV values of options

| | Option 1 | Option 2 | Option 3 | Option 4 |
|---|---|---|---|---|
| **Description** | 3Ml/d run to waste. | IONEX Plant + Run to waste | GAC Plant + Run to waste | 3Ml/d Pump Station + Run to waste |
| **OUTPUT** | **0** | **3** | **3** | **3** |
| **CAPEX (£M)** | **0.42** | **4.76** | **4.69** | **0.7** |
| **OPEX (£k/yr)** | **22** | **164** | **130** | **42** |
| Power (treatment) (£/Ml) | *19.8* | *63.0* | *59.4* | *37.9* |
| Power (HL pumping) (£/Ml) | | 38.8 | 38.8 | |
| Chemicals (£/Ml) | | 40.0 | 5.5 | |
| Effluent (£/Ml) | | 5.6 | 0.2 | |
| Carbon (£/Ml) | | | 14.5 | |
| OPEX(£/Ml) | 19.8 | 147.4 | 118.4 | 37.9 |
| **NPV (£M)** | **0.62** | **6.08** | **5.66** | **1.08** |

# Sandhills WTW

## Conclusions

- The water level in the borehole will impact on the pumping cost of providing an argumentation flow from Sandhills WTW.
- The increased raw water nitrate concentration in the raw water increase the relative OPEX costs of ion exchange against GAC
- For GAC option need a large supply of low nitrate water for dilution of nitrate.

# Shenstone WTW

# Shenstone WTW

## Options considered

**Option 1** New borehole on land adjacent to current site.

New 2.0Ml/d ion exchange plant treating nitrate only.

Replacement high lift pumps

**Option 2** New borehole on land adjacent to current site.

New stripping tower for TCE removal.

New 5.5Ml/d ion exchange plant treating nitrate and chlorthal.

New treatment building local to borehole with access road

Replacement high lift pumps.

**Option 3** New borehole on land adjacent to current works.

New 5.5Ml/d GAC plant located in new building local to borehole

New dirty wash water treatment facilities.

Replacement booster pump.

# Shenstone WTW

## Options Considered cont.

**Option 4** New borehole on land adjacent to current works.

New stripping tower for TCE removal.

New 5.5Ml/d pumping station to transfer water to Pipe Hill WTW.

**Option 5** New borehole on land adjacent to current.

New stripping tower for Tri-chloroethene removal.

New UV disinfection plant.

New hypochlorite dosing system.

Replacement booster pump.

# Shenstone WTW

## CAPEX, OPEX and NPV values of options.

| | Option 1 | Option 2 | Option 3 | Option 4 | Option 4 |
|---|---|---|---|---|---|
| **Description** | 2Ml/d IONEX Plant | 6Ml/d IONEX Plant | 6Ml/d GAC Plant | TCE removal and PS to Pipe Hill | TCE removal and disinfection |
| **OUTPUT** | **5.5** | **5.5** | **5.5** | **5.5** | **5.5** |
| **CAPEX (£M)** | **4.64** | **5.20** | **3.94** | **4.18** | **2.81** |
| **OPEX (£k/yr)** | **209.2** | **242.3** | **180.5** | **63.0** | **164.0** |
| Power (treatment) (£/Ml) | 34.7 | 38.9 | 29.1 | 31.4 | 30.1 |
| Power (HL pumping) (£/Ml) | 46.1 | 46.1 | 46.1 | | 46.1 |
| Chemicals (£/Ml) | 20 | 28.8 | 5.5 | | 5.5 |
| Effluent (£/Ml) | 3.4 | 6.9 | 0.2 | | |
| Carbon (£/Ml) | | | 9 | | |
| OPEX(£/Ml) | 104.2 | 120.7 | 89.9 | 31.4 | 81.7 |
| **NPV (£M)** | **6.55** | **7.39** | **5.49** | **4.5** | **4.28** |

# Shenstone WTW

### Conclusions

- The OPEX costs for treating nitrate/chlorthal are cheaper than at Sandhills WTW due to lower nitrate concentration in the raw water.
- The treatment with GAC could be attractive if a suitable supply of blending water is available (Seedy Mill WTW or Pipe Hill WTW)
- Further OPEX saving may be available if the water is blended for both nitrate and chlorthal.

# Pipe Hill WTW

# Pipe Hill WTW

## Options Considered

**Option 1** New borehole.

New 11Ml/d ion exchange plant for treating nitrate and chlorthal.

Relocation of current generator.

New booster pump station for pumping to Hopwas reservoir.

**Option 2** New borehole.

New 11Ml/d GAC plant for treating chlorthal only.

New dirty wash water treatment plant

New booster pump station for pumping to Hopwas reservoir.

**Option 3** New borehole.

New 11Ml/d combined ion exchange and GAC plant for treating nitrate and chlorthal.

New booster pump station for pumping to Hopwas reservoir.

# Pipe Hill WTW

## Options Considered

**Option 4** New borehole.

New 14Ml/d ion exchange plant for treating water from Pipe Hill and Sandhills boreholes for nitrate and chlorthal.

New UV disinfection plant.

New booster pump station for pumping to Hopwas reservoir.

**Option 5** New borehole.

New 19Ml/d ion exchange plant for treating water from Pipe Hill, Sandhills and Shenstone boreholes for nitrate and chlorthal.

New UV disinfection plant.

New/upgraded booster pump stations for pumping increased output to Hopwas and Barr Beacon reservoirs.

**Option 6** New borehole.

New 6Ml/d ion exchange plant for treating nitrate only.

# Pipe Hill WTW

## CAPEX, OPEX and NPV Values of Options

| | Option 0 | Option 1 | Option 2 | Option 3 | Option 4 | Option 5 | Option 6 |
|---|---|---|---|---|---|---|---|
| **Description** | Existing (Normalised) | New 11Mld IONEX Plant | New GAC Plant | New IONEX/GAC Plant | New 14MLD IONEX Plant | New 19MLD IONEX Plant | New 6.5MLD IONEX Plant |
| **OUTPUT** | **3.2** | **11** | **11** | **11** | **14** | **19** | **11** |
| Barr Beacon (Ml/d) | | 11 | 11 | 11 | 14 | 19 | 11 |
| Hopwas (Ml/d) | 3.2 | | | | | | |
| **CAPEX (£M)** | | **5.09** | **4.60** | **6.30** | **5.75** | **8.54** | **4.53** |
| **OPEX (£k/yr)** | **157** | **487** | **353** | **465** | **575** | **738** | **442** |
| Power (treatment) (£/Ml) | 41.4 | 34.9 | 32.1 | 33.4 | *25.2* | *18.6* | 32.1 |
| Power (HL Barr Beacon) (£/Ml) | 42.4 | 42.4 | 42.4 | 42.4 | 42.4 | 42.4 | 42.4 |
| Power (HL Hopwas) (£/Ml) | 10.5 | 10.5 | 10.5 | 10.5 | 10.5 | 10.5 | 10.5 |
| Chemicals (£/Ml) | 71.9 | 38.3 | 5.5 | 31.6 | 39.0 | 39.5 | 31.6 |
| Effluent (£/Ml) | *10.7* | 5.7 | 0.1 | 3.9 | 5.8 | 5.9 | 3.9 |
| Carbon (£/Ml) | | | 7.7 | 4.4 | | | |
| OPEX(£/Ml) | 134.5 | 121.3 | 87.8 | 115.7 | 112.4 | 106.4 | 110.0 |
| **NPV (£M)** | | **8.87** | **6.85** | **9.83** | **10.49** | **13.11** | **9.14** |

# Sandhills WTW, Shenstone WTW, and Pipe Hill WTW

# Option Combinations

# Sandhills, Shenstone and Pipe Hill WTWs

## Comparison of costs of new nitrate plant at Pipe Hill WTW against existing plant costs.

**Scenario 0** Existing nitrate plant at Pipe Hill WTW (3M/ld) and Seedy Mills WTW (53Ml/d) supplying Barr Beacon and Hopwas reservoirs.

**Scenario 1** New replacement nitrate plant at Pipe Hill WTW (3Ml/d).

Seedy Mills WTW (53Ml/d) supplying Barr Beacon and Hopwas reservoirs.

**Scenario 2** New nitrate plant at Pipe Hill WTW (11Ml/d) treating both nitrate and chlorthal.

Seedy Mills WTW (45Ml/d supplying Barr Beacon and Hopwas reservoirs.

# Sandhills, Shenstone and Pipe Hill WTWs

## Comparison of costs of new run to waste facility at Sandhills WTW.

**Scenario 2a** New nitrate plant at Pipe Hill WTW (11Ml/d) treating both nitrate and chlorthal.

Seedy Mills WTW (45Ml/d) supplying Barr Beacon and Hopwas reservoirs.

**Scenario 3** New nitrate plant at Pipe Hill WTW (11MLD) treating both nitrate and chlorthal.

New run to waste faciliity at Sandhills WTW providing 3Ml/d argumentation flow.

Seedy Mills WTW (45Ml/d) supplying Barr Beacon and Hopwas reservoirs.

# Sandhills, Shenstone and Pipe Hill WTWs

## Comparison of cost of new nitrate plants at Pipe Hill, Sandhills and Shenstone WTW.

**Scenario 4** New nitrate plants at Pipe Hill WTW (11M/ld), Sandhills WTW (3Ml/d) and Shenstone (5Ml/d) treating both nitrate and chlorthal.

**Scenario 5** New pumping station at Sandhills WTW.

New nitrate plant at Pipe Hill WTW (14Ml/d) treating water from Sandhills borehole.

New nitrate plant at Shenstone WTW (5Ml/d) treating both nitrate and chlorthal.

**Scenario 6** New nitrate plant at Pipe Hill WTW (19Ml/d)) treating water from Sandhills and Shenstone boreholes for nitrate and chlorthal.

# Sandhills, Shenstone and Pipe Hill WTWs

**Saving from blending with treated water from Seedy Mill WTW.**

**Scenario 7** New nitrate plants at Pipe Hill WTW (11M/ld and Shenstone (5Ml/d) treating both nitrate and chlorthal. An argumentation flow (3Ml/d) provided at Sandhills WTW.

**Scenario 8** New nitrate plants at Pipe Hill WTW (11M/ld) for treating chlorthal and nitrate.

New treatment plant at Shenstone with TCE treatment (air stripping) and disinfection. (Nitrates and Chlorthal controlled by blending with either Pipe Hill or Seedy Mill treated water.)

An argumentation flow (3Ml/d) provided at Sandhills WTW.

**Scenario 9** New nitrate plant at Pipe Hill WTW (11M/ld) for treating chlorthal and nitrate.

New treatment plant at Shenstone WTW with GAC adsorbers for TCE and chlorthal treatment. Nitrates controlled by blending with either Pipe Hill or Seedy Mill treated water.

# Seedy Mill WTW

# Seedy Mill WTW

## Normalised OPEX Costs

| | Seedy Mill | Seedy Mill |
|---|---|---|
| **Description** | Conventional surface water treatment | Conventional surface water treatment |
| **OUTPUT** | **20** | **20** |
| Barr Beacon (Ml/d) | 20 | |
| Hopwas (Ml/d) | | 20 |
| **CAPEX (£M)** | | |
| **OPEX (£k/yr)** | **603** | **235** |
| Power (treatment) (£/Ml) | 6 | 6 |
| Power (HL Barr Beacon) (£/Ml) | 51.4 | 51.4 |
| Power (HL Hopwas) (£/Ml) | 16.9 | 16.9 |
| Chemicals (£/Ml) | 24 | 24 |
| Effluent (£/Ml) | | |
| Carbon (£/Ml) | | |
| **OPEX(£/Ml)** | **82.6** | **32.1** |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Comparison against existing operation

## Scenario 0

| | Shenstone | Pipe Hill | Sandhills | Seedy Mill | Total |
|---|---|---|---|---|---|
| **Description** | | Existing IONEX Plant | | Conventional surface water treatment | |
| **OUTPUT** | | **3.2** | | **53** | **56.2** |
| Barr Beacon (Ml/d) | | | | 34 | 34 |
| Hopwas (Ml/d) | | 3.2 | | 19 | 22.2 |
| **CAPEX (£M)** | | | | | |
| **OPEX (£k/yr)** | | **157** | | **1342** | **1499** |
| Power (treatment) (£/Ml) | | 41.4 | | 6 | |
| Power (HL Barr Beacon) (£/Ml) | | 42.4 | | 51.4 | |
| Power (HL Hopwas) (£/Ml) | | 10.5 | | 16.9 | |
| Chemicals (£/Ml) | | 71.9 | | 24 | |
| Effluent (£/Ml) | | 10.7 | | | |
| Carbon (£/Ml) | | | | | |
| **OPEX(£/Ml)** | | **134.5** | | **69.4** | **73.1** |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Comparison against existing operation

## Scenario 1

| | Shenstone | Pipe Hill | Sandhills | Seedy Mill | Total |
|---|---|---|---|---|---|
| **Description** | | New 6.5Ml/d IONEX Plant | | Conventional surface water treatment | |
| **OUTPUT** | | **3.2** | | **53** | **56.2** |
| Barr Beacon (Ml/d) | | | | 34 | 34 |
| Hopwas (Ml/d) | | 3.2 | | 19 | 22.2 |
| **CAPEX (£M)** | | **4.53** | | | **4.5** |
| **OPEX (£k/yr)** | | **91** | | **1342** | **1433** |
| Power (treatment) (£/Ml) | | 32.1 | | 6 | |
| Power (HL Barr Beacon) (£/Ml) | | 42.4 | | 51.4 | |
| Power (HL Hopwas) (£/Ml) | | 10.5 | | 16.9 | |
| Chemicals (£/Ml) | | 31.6 | | 24 | |
| Effluent (£/Ml) | | 3.9 | | | |
| Carbon (£/Ml) | | | | | |
| **OPEX(£/Ml)** | | **78.1** | | **69.4** | **69.9** |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Comparison against existing operation

## Scenario 2

| | Shenstone | Pipe Hill | Sandhills | Seedy Mill | Total |
|---|---|---|---|---|---|
| **Description** | | New 11Ml/d IONEX Plant | | Conventional surface water treatment | |
| **OUTPUT** | | **11** | | **45.2** | **56.2** |
| Barr Beacon (Ml/d) | | 0 | | 34.2 | 34.2 |
| Hopwas (Ml/d) | | 11 | | 11 | 22 |
| **CAPEX (£M)** | | **5.09** | | | **5.1** |
| **OPEX (£k/yr)** | | **359** | | **1210** | **1569** |
| Power (treatment) (£/Ml) | | 34.9 | | 6 | |
| Power (HL Barr Beacon) (£/Ml) | | 42.4 | | 51.4 | |
| Power (HL Hopwas) (£/Ml) | | 10.5 | | 16.9 | |
| Chemicals (£/Ml) | | 38.3 | | 24 | |
| Effluent (£/Ml) | | 5.7 | | | |
| Carbon (£/Ml) | | | | | |
| **OPEX(£/Ml)** | | **89.4** | | **73.3** | **76.5** |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Comparison against existing operation

| | Scenario 0 | Scenario 1 | Scenario 2 |
|---|---|---|---|
| Description | Present operation | New nitrate only plant at Pipe Hill | New chlorthal and nitrate plant at Pipe Hill WTW |
| OUTPUT (Ml/d) | 56.2 | 56.2 | 56.2 |
| Sandhill WTW | 0 | 0 | 0 |
| Shenstone WTW | 0 | 0 | 0 |
| Pipe Hill WTW | 3.2 | 3.2 | 11 |
| Seedy Mill WTW | 53 | 53 | 45.2 |
| Argumentation Flow | | | |
| CAPEX (£M) | 0 | 4.53 | 5.09 |
| OPEX (£k/yr) | 1499 | 1433 | 1569 |
| OPEX(£/Ml) | 73.1 | 69.9 | 76.5 |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Comparison against existing operation

### Conclusions

- Even with an updated ion exchange plant at Pipe Hill WTW treating nitrate only, OPEX costs are higher than Seedy Mill WTW.

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Cost of argumentation flow at Sandhills WTW

## Scenario 2a

| | Shenstone | Pipe Hill | Sandhills | Seedy Mill | Total |
|---|---|---|---|---|---|
| **Description** | | New 11Ml/d IONEX Plant | | Conventional surface water treatment | |
| **OUTPUT** | | **11** | | **45.2** | **56.2** |
| Barr Beacon (Ml/d) | | 11 | | 23.2 | 34.2 |
| Hopwas (Ml/d) | | 0 | | 22 | 22 |
| **CAPEX (£M)** | | **5.09** | | | **5.1** |
| **OPEX (£k/yr)** | | **487** | | **1071** | **1558** |
| Power (treatment) (£/Ml) | | 34.9 | | 6 | |
| Power (HL Barr Beacon) (£/Ml) | | 42.4 | | 51.4 | |
| Power (HL Hopwas) (£/Ml) | | 10.5 | | 16.9 | |
| Chemicals (£/Ml) | | 38.3 | | 24 | |
| Effluent (£/Ml) | | 5.7 | | | |
| Carbon (£/Ml) | | | | | |
| **OPEX(£/Ml)** | | **121.3** | | **64.9** | **76.0** |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Cost of argumentation flow at Sandhills WTW

## Scenario 3

| | Shenstone | Pipe Hill | Sandhills | Seedy Mill | Total |
|---|---|---|---|---|---|
| **Description** | | New 11Ml/d IONEX Plant | New 3Ml/d run to waste | Conventional surface water treatment | |
| **OUTPUT** | | **11** | **0** | **45.2** | **56.2** |
| Barr Beacon (Ml/d) | | 11 | | 23.2 | 34.2 |
| Hopwas (Ml/d) | | | | 22 | 22 |
| **CAPEX (£M)** | | **5.09** | **0.416** | | **5.5** |
| **OPEX (£k/yr)** | | **487** | **22** | **1071** | **1580** |
| Power (treatment) (£/Ml) | | 34.9 | *19.8* | 6 | |
| Power (HL Barr Beacon) (£/Ml) | | 42.4 | | 51.4 | |
| Power (HL Hopwas) (£/Ml) | | 10.5 | | 16.9 | |
| Chemicals (£/Ml) | | 38.3 | | 24 | |
| Effluent (£/Ml) | | 5.7 | | | |
| Carbon (£/Ml) | | | | | |
| **OPEX(£/Ml)** | | **121.3** | | **64.9** | **77.0** |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Cost of argumentation flow at Sandhills WTW

| | Scenario 2 | Scenario 3 |
|---|---|---|
| Description | New chlorthal and nitrate plant at Pipe Hill WTW | New chlorthal and nitrate plant at Pipe Hill WTW. New run to waste facility at Sandhills |
| OUTPUT (Ml/d) | 56.2 | 56.2 |
| Sandhill WTW | 0 | 0 |
| Shenstone WTW | 0 | 0 |
| Pipe Hill WTW | 11 | 11 |
| Seedy Mill WTW | 45.2 | 45.2 |
| Argumentation Flow | 0 | 3 |
| CAPEX (£M) | 5.09 | 5.51 |
| OPEX (£k/yr) | 1558 | 1580 |
| OPEX(£/Ml) | 76.0 | 77.0 |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Cost of treating water at different sites

## Scenario 4

| | Shenstone | Pipe Hill | Sandhills | Seedy Mill | Total |
|---|---|---|---|---|---|
| **Description** | New 6Ml/d IONEX Plant | New 11Ml/d IONEX Plant | New 3Ml/d IONEX Plant + 3Ml/d waste | Conventional surface water treatment | |
| **OUTPUT** | **5** | **11** | **3** | **37.2** | **56.2** |
| Barr Beacon (Ml/d) | 5 | 11 | 3 | 15.2 | 34.2 |
| Hopwas (Ml/d) | | | | 22 | 22 |
| **CAPEX (£M)** | **5.19** | **5.09** | **4.76** | | **15.0** |
| **OPEX (£k/yr)** | **190** | **487** | **161** | **833** | **1671** |
| Power (treatment) (£/Ml) | 34.7 | 34.9 | *63.0* | 6 | |
| Power (HL Barr Beacon) (£/Ml) | 46.1 | 42.4 | 38.8 | 51.4 | |
| Power (HL Hopwas) (£/Ml) | | 10.5 | | 16.9 | |
| Chemicals (£/Ml) | 20 | 38.3 | 40.0 | 24 | |
| Effluent (£/Ml) | 3.4 | 5.7 | 5.6 | | |
| Carbon (£/Ml) | | | | | |
| **OPEX(£/Ml)** | **104.2** | **121.3** | **147.4** | **61.3** | **81.5** |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Cost of treating water at different sites

## Scenario 5

| | Shenstone | Pipe Hill | Sandhills | Seedy Mill | Total |
|---|---|---|---|---|---|
| **Description** | New 5Ml/d IONEX Plant | New 14Ml/d IONEX Plant | New 3Ml/d PS + 3Ml/d waste | Conventional surface water treatment | |
| **OUTPUT** | **5** | **14** | **0** | **37.2** | **56.2** |
| Barr Beacon (Ml/d) | 5 | 14 | | 15.2 | 34.2 |
| Hopwas (Ml/d) | | | | 22 | 22 |
| **CAPEX (£M)** | **5.19** | **5.75** | **0.7** | | **11.6** |
| **OPEX (£k/yr)** | **190** | **557** | **42** | **833** | **1621** |
| Power (treatment) (£/Ml) | 34.7 | 25.2 | *37.9* | 6 | |
| Power (HL Barr Beacon) (£/Ml) | 46.1 | 42.4 | | 51.4 | |
| Power (HL Hopwas) (£/Ml) | | 10.5 | | 16.9 | |
| Chemicals (£/Ml) | 20 | 39.0 | | 24 | |
| Effluent (£/Ml) | 3.4 | 5.8 | | | |
| Carbon (£/Ml) | | | | | |
| **OPEX(£/Ml)** | **104.2** | **117.2** | | **61.3** | **79.0** |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Cost of treating water at different sites

## Scenario 6

| | Shenstone | Pipe Hill | Sandhills | Seedy Mill | Total |
|---|---|---|---|---|---|
| **Description** | New BH, stripping tower and PS | New 19Ml/d IONEX Plant | New 3Ml/d PS + 3Ml/d waste | Conventional surface water treatment | |
| **OUTPUT** | **0** | **19** | **0** | **37.2** | **56.2** |
| Barr Beacon (Ml/d) | | 19 | | 15.2 | 34.2 |
| Hopwas (Ml/d) | | | | 22 | 22 |
| **CAPEX (£M)** | **4.18** | **8.54** | **0.7** | | **13.4** |
| **OPEX (£k/yr)** | **64** | **716** | **42** | **833** | **1654** |
| Power (treatment) (£/Ml) | *31.4* | 18.6 | *37.9* | 6 | |
| Power (HL Barr Beacon) (£/Ml) | | 42.4 | | 51.4 | |
| Power (HL Hopwas) (£/Ml) | | 10.5 | | 16.9 | |
| Chemicals (£/Ml) | | 39.5 | | 24 | |
| Effluent (£/Ml) | | 5.9 | | | |
| Carbon (£/Ml) | | | | | |
| **OPEX(£/Ml)** | | **109.2** | | **61.3** | **80.6** |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Cost of treating water at different sites

| | Scenario 4 | Scenario 5 | Scenario 6 |
|---|---|---|---|
| Description | New IONEX plant at Sandhills, Shenstone and Pipe Hill WTW | New IONEX plant at Shenstone and Pipe Hill WTW | New IONEX plant at Pipe Hill WTW |
| OUTPUT (Ml/d) | 56.2 | 56.2 | 56.2 |
| Sandhill WTW | 3 | 0 | 0 |
| Shenstone WTW | 5 | 5 | 0 |
| Pipe Hill WTW | 11 | 14 | 19 |
| Seedy Mill WTW | 37.2 | 37.2 | 37.2 |
| Argumentation Flow | 3 | 3 | 3 |
| CAPEX (£M) | 15.04 | 11.64 | 13.42 |
| OPEX (£k/yr) | 1671 | 1621 | 1654 |
| OPEX(£/Ml) | 81.5 | 79.0 | 80.6 |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Cost of treating water at different sites

### Conclusions

- Treatment of water from Sandhills borehole at Pipe Hill WTW could generate some savings from efficiencies of a single large works.
- A costs for a new 7km pipe from Shenstone WTW to Pipe Hill WTW and an upgraded/new booster pump station significantly increase the CAPEX of a single 19Ml/d works.

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Savings from blending

## Scenario 7

| | Shenstone | Pipe Hill | Sandhills | Seedy Mill | Total |
|---|---|---|---|---|---|
| **Description** | New 6Ml/d IONEX Plant | New 11Ml/d IONEX Plant | New 3Ml/d run to waste | Conventional surface water treatment | |
| **OUTPUT** | **5** | **11** | **0** | **40.2** | **56.2** |
| Barr Beacon (Ml/d) | 5 | 11 | | 18.2 | 34.2 |
| Hopwas (Ml/d) | | | | 22 | 22 |
| **CAPEX (£M)** | **5.19** | **5.09** | **0.7** | | **11.0** |
| **OPEX (£k/yr)** | **190** | **487** | **42** | **922** | **1641** |
| Power (treatment) (£/Ml) | 34.7 | 34.9 | *37.9* | 6 | |
| Power (HL Barr Beacon) (£/Ml) | 46.1 | 42.4 | | 51.4 | |
| Power (HL Hopwas) (£/Ml) | | 10.5 | | 16.9 | |
| Chemicals (£/Ml) | 20 | 38.3 | | 24 | |
| Effluent (£/Ml) | 3.4 | 5.7 | | | |
| Carbon (£/Ml) | | | | | |
| **OPEX(£/Ml)** | **104.2** | **121.3** | | **62.8** | **80.0** |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Savings from blending

## Scenario 8

| | Shenstone | Pipe Hill | Sandhills | Seedy Mill | Total |
|---|---|---|---|---|---|
| **Description** | TCE removal and disinfection | New 11Ml/d IONEX Plant | New 3Ml/d run to waste | Conventional surface water treatment | |
| **OUTPUT** | **5** | **11** | **0** | **40.2** | **56.2** |
| Barr Beacon (Ml/d) | 5 | 11 | | 18.2 | 34.2 |
| Hopwas (Ml/d) | | | | 22 | 22 |
| **CAPEX (£M)** | **2.81** | **5.09** | **0.416** | | **8.3** |
| **OPEX (£k/yr)** | **149** | **487** | **22** | **922** | **1580** |
| Power (treatment) (£/Ml) | 30.1 | 34.9 | *19.8* | 6 | |
| Power (HL Barr Beacon) (£/Ml) | 46.1 | 42.4 | | 51.4 | |
| Power (HL Hopwas) (£/Ml) | | 10.5 | | 16.9 | |
| Chemicals (£/Ml) | 5.5 | 38.3 | | 24 | |
| Effluent (£/Ml) | 0 | 5.7 | | | |
| Carbon (£/Ml) | | | | | |
| **OPEX(£/Ml)** | **81.7** | **121.3** | | **62.8** | **77.0** |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Savings from blending

## Scenario 9

| | Shenstone | Pipe Hill | Sandhills | Seedy Mill | Total |
|---|---|---|---|---|---|
| **Description** | New 5MLD GAC Plant | New 11Ml/d IONEX Plant | New 3Ml/d run to waste | Conventional surface water treatment | |
| **OUTPUT** | **5** | **11** | **0** | **40.2** | **56.2** |
| Barr Beacon (Ml/d) | 5 | 11 | | 18.2 | 34.2 |
| Hopwas (Ml/d) | | | | 22 | 22 |
| **CAPEX (£M)** | **3.94** | **5.09** | **0.416** | | **9.4** |
| **OPEX (£k/yr)** | **164** | **487** | **22** | **922** | **1595** |
| Power (treatment) (£/Ml) | 29.1 | 34.9 | *19.8* | 6 | |
| Power (HL Barr Beacon) (£/Ml) | 46.1 | 42.4 | | 51.4 | |
| Power (HL Hopwas) (£/Ml) | | 10.5 | | 16.9 | |
| Chemicals (£/Ml) | 5.5 | 38.3 | | 24 | |
| Effluent (£/Ml) | 0.2 | 5.7 | | | |
| Carbon (£/Ml) | 9 | | | | |
| **OPEX(£/Ml)** | **89.9** | **121.3** | | **62.8** | **77.8** |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Savings from blending

| | Scenario 7 | Scenario 8 | Scenario 9 |
|---|---|---|---|
| Description | New IONEX plant at Shenstone and Pipe Hill WTW | New TCE plant at Shenstone and IONEX plant Pipe Hill WTW | New GAC plant at Shenstone and IONEX plant Pipe Hill WTW |
| OUTPUT (Ml/d) | 56.2 | 56.2 | 56.2 |
| Sandhill WTW | 0 | 0 | 0 |
| Shenstone WTW | 5 | 5 | 5 |
| Pipe Hill WTW | 11 | 11 | 11 |
| Seedy Mill WTW | 40.2 | 40.2 | 40.2 |
| Argumentation Flow | 3 | 3 | 3 |
| CAPEX (£M) | 11.0 | 8.3 | 9.4 |
| OPEX (£k/yr) | 1641 | 1580 | 1595 |
| OPEX(£/Ml) | 80.0 | 77.0 | 77.8 |

# Shenstone WTW/Pipe Hill WTW/Sandhill WTW

## Savings from blending

**Conclusions**

- Blending Shenstone water at Shenstone WTW can generate savings if a sufficient supply of suitable blending water is available.
- Greater treated water quality security could be gained from a GAC plant at Shenstone WTW.

# Discussion

# Discussion

- Required resilience.
- Affordability.
- Operability.

# Information gaps and future testing requirements.

# Information gaps

- Raw Water Quality Information.
  - *Slade Heath WTW.*
  - *Sandhills WTW.*
  - *Shenstone WTW.*
- GAC.
  - *Certainty on prediction of regeneration frequency.*
  - *Performance of regenerated carbon.*
  - *Tri-chloroethane removal at Shenstone WTW.*
- Nitrate selective resin
  - *Performance with elevated level of chlorthal.*
  - *Optimum regeneration regime.*
  - *On-line monitoring possibilities for chlorthal (UVT?).*

# Chlorthal Treatment Options Review
# $14^{th}$ May 2015