Ashwood Nitrate Investigation Summary

Report details

This document is a summary of the detailed information provided in the main nitrate investigation report for the site (ref. 63684K R1), completed by ESI. The purpose of the document is to provide an overview of the nitrate modelling work and catchment assessment for the site, for internal use by South Staffordshire Water (SSW) and as a communication tool with relevant stakeholders. Referenced acronyms are described in the glossary section and figures are included at the end of the summary report.

Site details

NGR:	SO 8660 8774	Number of active boreholes:	4 (AW1, AW2, AW3 & AW4) +2 unlicensed (AW5 & AW6)
Catchment area (modelled):	7.9 km^2	Average monthly abstraction (1970 – present):	16.6 Ml/d

Water quality details

Monthly average nitrate concentration (1994 - 2016):	AW1: 52.0 mg NO_3/l AW2: 53.9 mg NO_3/l AW3: 39.5 mg NO_3/l AW4: 39.9 mg NO_3/l	Observed nitrate range (as monthly average):	AW1: 27.8 to 71.8 mg/l AW2: 12.7 to 72.4 mg/l AW3: 19.4 to 59.2 mg/l AW4: 15.9 to 54.7 mg/l
Overall observed nitrate trend:	Increasing by ~0.8 mg/l per year until 2010 Decreasing by ~2.5 mg/l per year since 2013	Nature of peaks:	Concentrations peaked between 2010 and 2013. Peak concentrations were particularly high in AW1 & AW2 during 2010 and 2011 when the borehole was out of supply.

Site background

Ashwood PWS is located 1.3 km west of the outskirts of Kingswinford, Worcestershire. All boreholes are completed in the Wildmoor Sandstone and Kidderminster Formations of the Triassic Sherwood Sandstone Group. AW1 and AW2 are located 5 m apart and are completed approximately 87 metres below datum (mbd). AW3 and AW4 are located 10 m north and are also 5 m apart. They are completed at approximately 155 and 104 mbd respectively. AW1 and AW2 are cased with plain lining to the base, with the exception short 'cut-out' sections in the Kidderminster Formation. In contrast, AW3 and AW4 are unlined from 12.3 mbd to their base, and abstract from both of the above sandstone formations.

Pumped water levels in AW3 and AW4 are predominantly between 30 and 40 mbd, although water does enter the borehole from fissures in the Wildmoor Sandstone Formation between approximately 14 mbd and 51 mbd. Pumped water levels in AW1 and AW2 are generally between 30 and 50 m and there is evidence of leaking casing joints above this. Average annual abstraction has remained stable, between 14.1 and 18.0 Ml/d since 1970.

The groundwater catchment was delineated using historical groundwater flow patterns (for 1970 to 2010) from the Environment Agency's West Midlands Worfe groundwater model, and then input to the FlowSource post-processing utility. The historical catchment is based on data from 1970 to 2010. Most groundwater contribution to the abstraction yield is from cells 1.5 to 2.5 km north east of the abstraction, underlying the outskirts of Kingswinford; the predominant flow direction is from the north east.

There are no superficial deposits surrounding the boreholes however there is fairly substantial coverage of glaciofluvial sand and gravel deposits in the south east and centre of the catchment. Generally, the unsaturated zone is less than 30 m thick, although reaches up to 70 m to the south east (Figure 1).

Observed nitrate at the site

AW1 & AW2 have distinctly higher nitrate concentrations than AW3 & AW4, with both the average and peak values being approximately 13 mg NO_3/l greater. Whilst concentrations in AW3 & AW4 have remained below the PCV, of 50 mg NO_3/l, concentrations in AW1 & AW2 surpassed the PCV in 1971 (Figure 2). Despite the difference in concentrations, both pairs of boreholes show similar trends, with nitrate concentrations increasing by approximately 0.8 mg/l per year. Since 2013 concentrations have decreased at a rate of approximately 2.5 mg/l per year.

The higher nitrate concentrations in AW1 & AW2 relative to the concentrations in AW3 & AW4 are thought to be related to the shallower depth of AW1 & AW2, where there is less dilution of the nitrate by deeper, unpolluted groundwater. The shallower depth of AW1 & AW2 could also be the reason for the earlier apparent peak in nitrate concentrations, due to a shorter vertical travel time.

Between 2009 and 2013 AW1 & AW2 were not on supply, and nitrate concentrations appear to have increased. When AW1 & AW2 are in use there is requirement to blend with Hampton Loade.

Land use and sources of nitrate

60% of the catchment is used for arable farming, and 5% for rearing livestock. Kingswinford is the largest urban area, covering nearly 35% of the catchment (Figure 1).

Agricultural nitrate: Within the catchment, NEAP-N nitrate concentrations are generally highest in the south west and around the Ashwood abstraction, up to 66.8 mg NO_3/l (Figure 1). Between 1980 and 2010 there has been an average annual decrease of 0.75 mg NO_3/l moving through the soil zone across the catchment (Figure 3). Most (~60%) nitrate is from fertilised arable land within the catchment, ~20% is from grazed animals on pasture and ~15% is expected to be from urban land.

Surface water infiltration: Up to 10% of the boreholes' yield is drawn from the Smestow Brook. The average concentration of nitrate in the Smestow Brook between 2000 and 2009 was approximately 62 mg NO_3/l.

Point sources: No significant point sources were identified during the review of the groundwater catchment.

Summary of model parameters & results

Using the quantified impacts on the concentration of nitrate at the Ashwood boreholes, two long-term rising trends peaking around 2013 and recent declining trend have been fitted to the Ashwood data (Figure 2). The only parameters which differ between the two trends are dilution by fresh groundwater and hydraulic conductivity (K).

Hydrogeological parameters:

Hydraulic conductivity of the aquifer (K) of 9.5 m/d for AW1 & AW2 and 5 m/d for AW3 & AW4	Hydraulic gradient (i) of 0.015
Porosity (n) of 15%	Hydraulic conductivity of the unsaturated zone (K_{usz}) of 0.0055 m/d
Unsaturated zone thickness ranging between 0.1 and 70 m (Figure 1)	

Observed nitrate data and the modelled trends are illustrated in Figure 2. With the information currently available for the site regarding potential sources of nitrate, the following parameters were used:

- 16% of AW1 & AW2 borehole yield and 37% of AW3 & AW4 borehole yield comprises fresh groundwater (3.3 mg NO_3/l).
- 10% of borehole yield comprises surface water (62 mg/l as NO_3).
- No point source was required to fit the trend.

A good model fit is achieved for both sets of boreholes at the Ashwood site, using the parameters discussed above.

The counterfactual (or 'do nothing'/'business as usual') scenario (the 'Source Model' line of Figure 2) predicts that average and peak concentrations of nitrate will decline at both sets of boreholes. However, the average concentrations at AW1 & AW2 are predicted to remain around the PCV concentration (including long periods of exceedance) and regular exceedances in peak concentration (Source+2SD) are likely to continue.

Catchment management

Catchment management mitigation measures (for nitrate) considered suitable for the groundwater catchment are listed below (for further information see 63684K TN1). The timing and magnitude of an estimated impact of such measures (light touch catchment measures) to the concentration of nitrate at the PWS is shown on Figure 2 ('Future Model' trend line).

Measures for Severn Valley, arable farms, free-draining soils	Measures for Severn Valley, livestock farms, free-draining soils
Use plants with improved nitrogen use efficiency	Establish cover crops in the autumn
Use a fertiliser recommendation system	Use plants with improved nitrogen use efficiency
Use manufactured fertiliser placement technologies	Use a fertiliser recommendation system
Fertiliser spreader calibration	Integrate fertiliser and manure nutrient supply
Unfertilised cereal headlands	Use clover in place of fertiliser nitrogen

At the Ashwood site, measures such as these will likely take up to 5 years to begin to have an effect on nitrate concentrations at the abstraction. Peak nitrate concentrations will be reduced from the counterfactual scenario by approximately 2 mg NO_3/l in both sets of boreholes after 15 years.

Predicted impact of catchment management:

Maximum reduction of peak counterfactual concentrations	AW1 & AW2: 2 mg NO_3/l (3%) AW3 & AW4: 2 mg NO_3/l (4%)
Impact to average concentration	AW1 & AW2: should help to maintain the average concentration below the PCV for a longer total duration over the forecasted data period, but exceedances should still be expected; AW3 & AW4: should help to maintain the supply below the PCV.
Impact to peak concentration	AW1 & AW2: exceedances of the PCV are still expected; AW3 & AW4: could prevent peaks in concentration from exceeding 50 mg NO_3/l.

Spatial outputs from the model (Figure 3) can be used to inform implementation of catchment management options. The areas contributing the most nitrate to the abstraction yield are within 1.5 km of the PS, to the north and east. The travel time plots show that the lowest travel time is from an area of land directly north of the site, the land use here is agricultural and so the catchment management measures outlined above may be applied (Figure 1). Although a slightly lower contribution to yield is calculated for this area any mitigation measures in this area should ensure a response is shown at the boreholes as soon as possible.

Key outcome and recommendations

Catchment management could help maintain peak concentrations below the PCV in AW3 & AW4. In AW1 & AW2, whilst catchment management will reduce the peaks, they will not fall below the PCV.

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Glossary

bgl	Below ground level
mbd	Metres below datum
AW	Ashwood borehole
NEAP-N	The National Environment and Agriculture Pollution Nitrate model
PCV	Prescribed concentration or value*
PS	Pumping station
PWS	Public water supply
SPZ	Source protection zone
SSW	South Staffordshire Water Ltd

*Note that in this case, PCV is interchangeable with drinking water standard (DWS), which is also 50 mg NO_3/l.

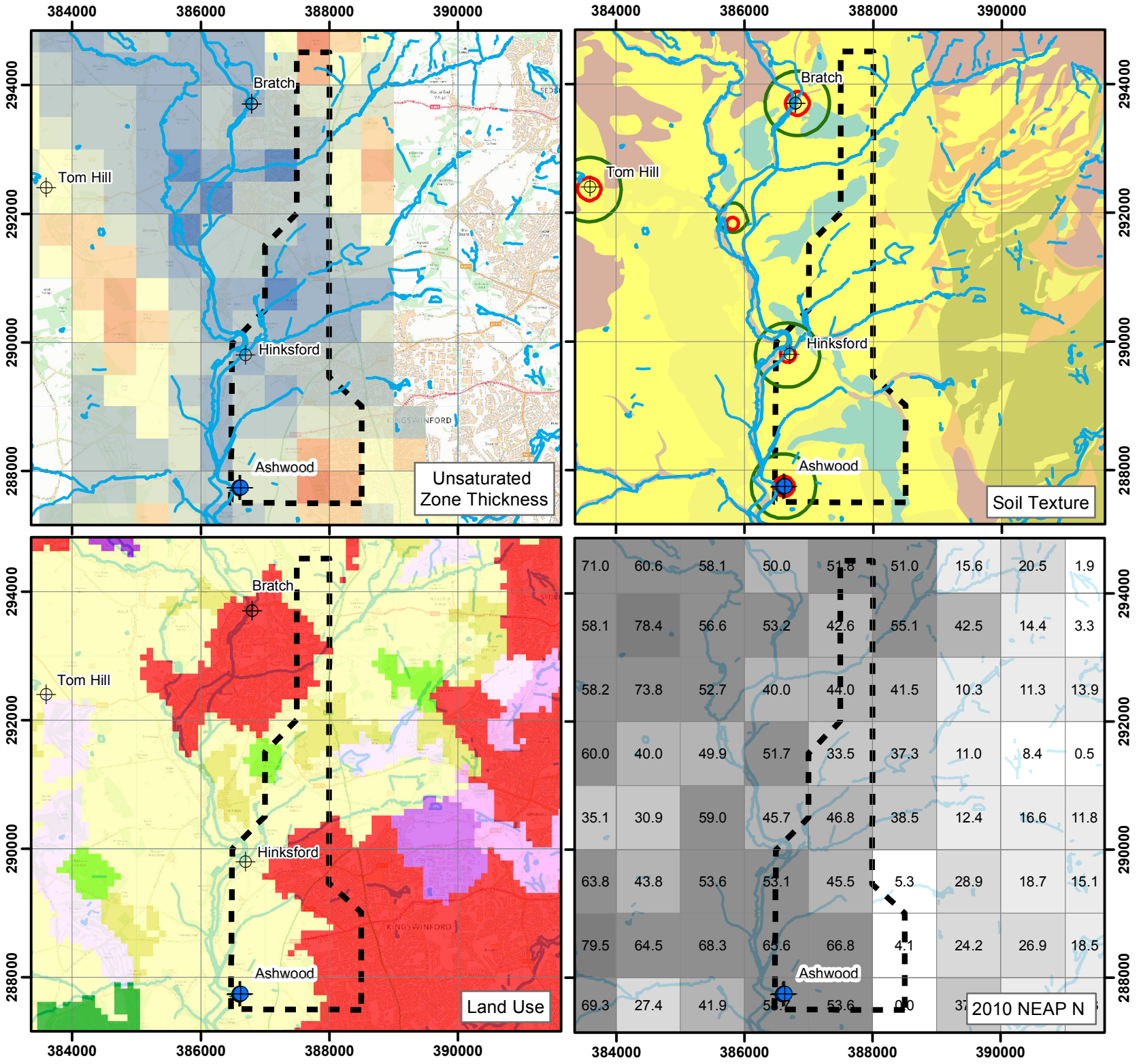

Figure 1
Ashwood catchment

Legend

- Abstractions
- Other PWS groundwater abstractions
- Historical catchment
- SPZ 1
- SPZ 2

Unsaturated zone thickness (m)

- < 0
- 0.1 - 5
- 5.1 - 10
- 10.1 - 20
- 20.1 - 30
- 30.1 - 40
- 40.1 - 50
- 50.1 - 60
- 60.1 - 70
- 70.1 - 80
- 80.1 - 90

Soil Texture

- Clay to Loam
- Silt to Sand
- Sand
- Loam
- Loam to Sand
- Clayey Loam to Sandy Loam

Land Use

- Discontinuous Urban Fabric
- Industrial or Commerical Units
- Mineral extraction sites
- Green Urban Areas
- Sport and Leisure Facilities
- Non-irrigated Arable Land
- Pastures
- Broad Leaved Forests
- Coniferous Forest

NO3 Concentration (mg/l)

- 0 - 10
- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 50
- 51 - 75
- 76 - 100
- 101 - 200

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Date Mar 2017	Drawn EJC
Scale 1:80,000	Checked RFF
Original A3	Revision V1

File Reference
O:\63684K SSW AMP6 NO3 modelling\GIS\Map documents\Site summary

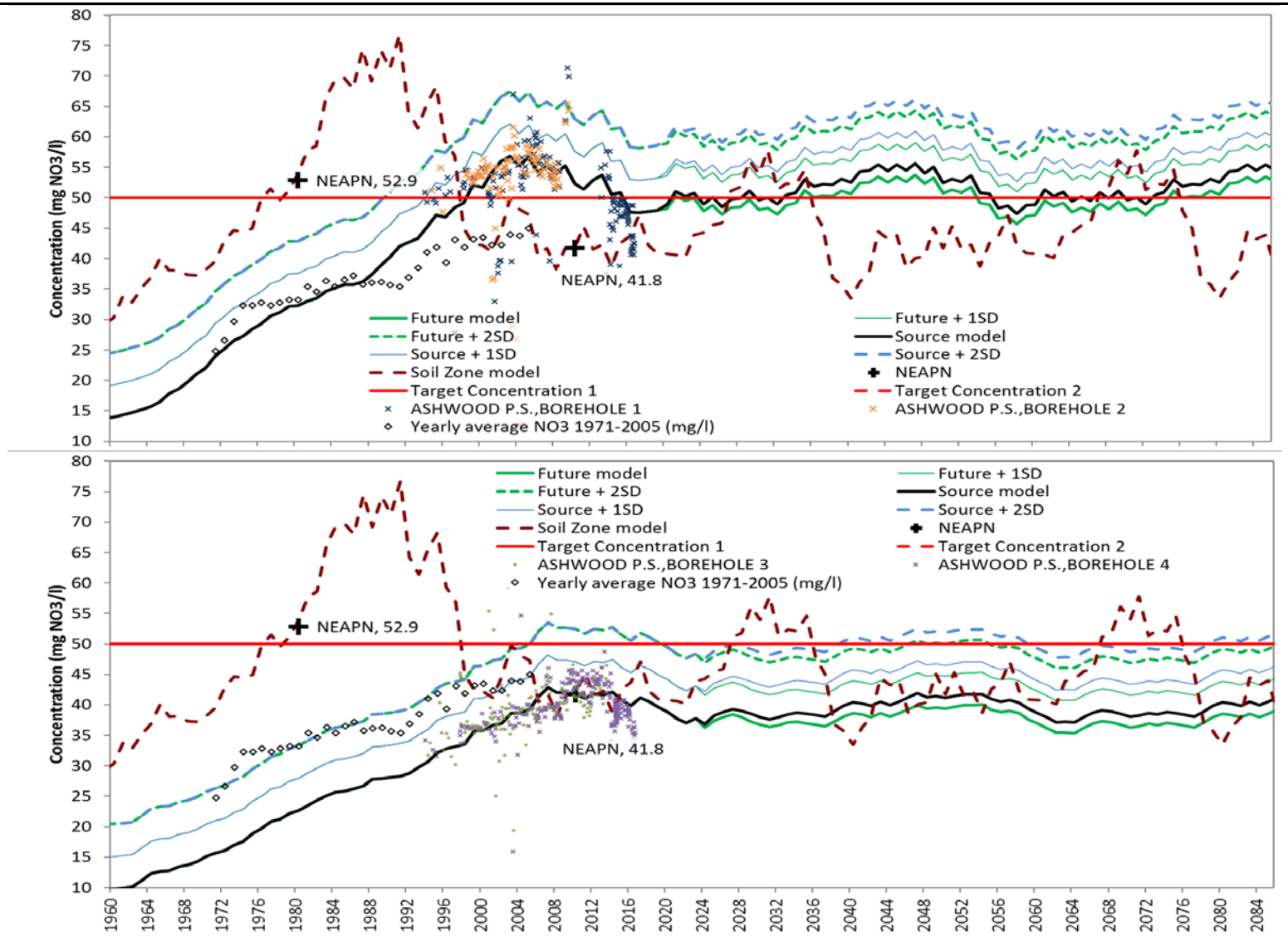

Figure 2

Observed nitrate concentration & modelled trends with justified parameters for AW1&2 and AW3&4

The 'future model' trend shows the estimated impact if catchment management measures targeting agriculture were carried out (equivalent to ~8% reduction in N loading in arable and pasture fields from 2016 onwards).

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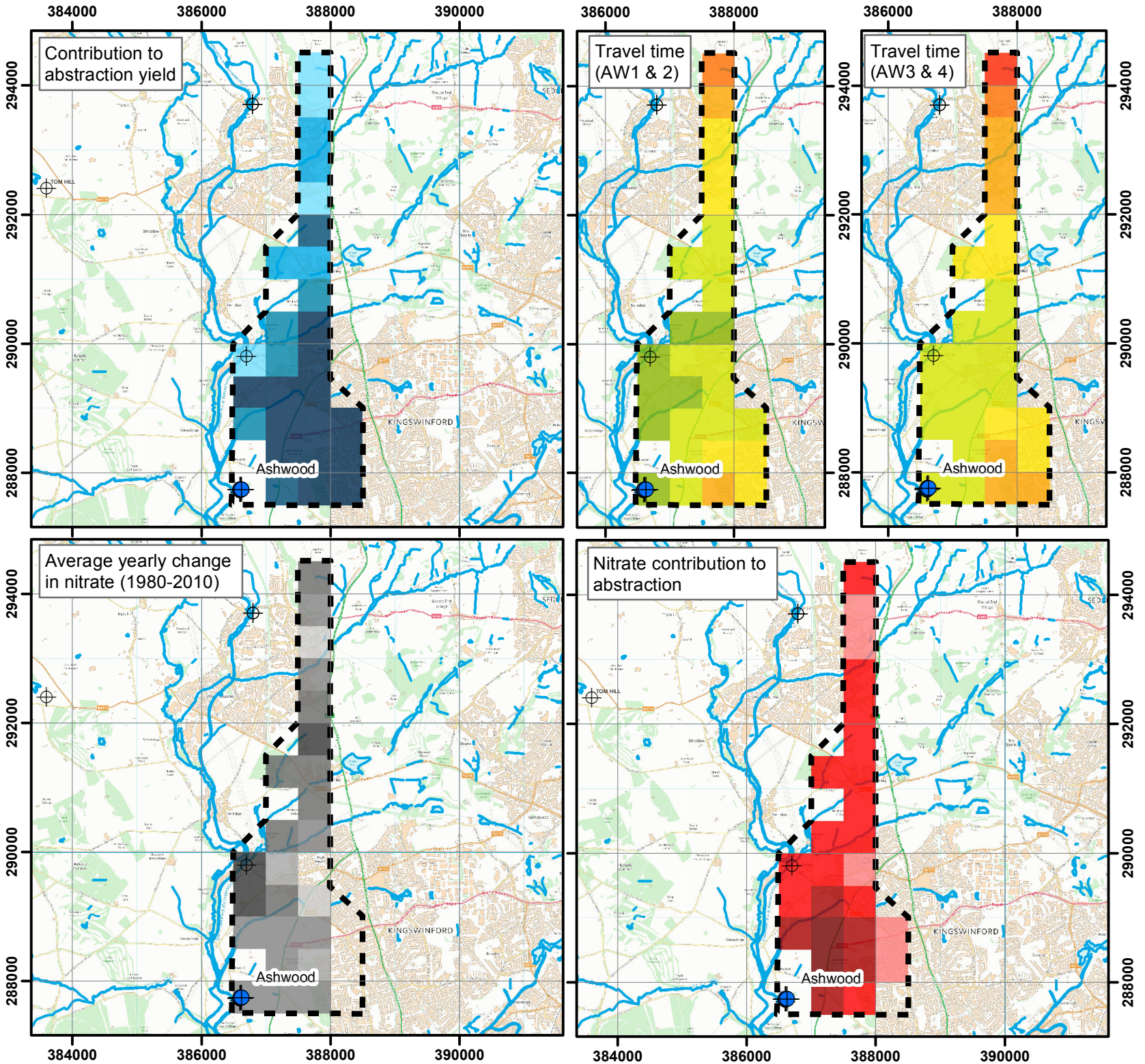

Figure 3
Ashwood spatial outputs

Legend

- Abstractions
- Other PWS groundwater abstractions
- Historical catchment

Abstraction Yield (%)

- 0
- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 3

Travel Time (years)

- 0
- 1 - 5
- 6 - 10
- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 65

Change in N loading per year (kg/ha)

- <-20
- -20 - -10
- -10 - -2.5
- -2.5 - -1
- -1 - -0.5
- -0.5 - -0.25
- -0.25 - 0
- 0
- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 10
- 10 - 20

N contribution (%)

- 0
- < 0.5
- 0.5 - 1
- 1 - 2
- 2 - 5
- 5 - 7.5
- 7.5 - 10

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File Reference
O:\63684K SSW AMP6 NO3 modelling\GIS\Map documents\Spatial Outputs\Ashwood Spatial