Water Resources Management Plan 2024 Statement of Response

Annex 8: Aquifer Storage & Recovery and Managed Aquifer Recharge

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Version 1

from Southern Water

Aquifer Storage and Recovery and Managed Aquifer Recharge

The latest UK climate projections suggest that, as climate change progresses, we will experience hotter drier summers and milder, wetter winters. In addition, the frequency and intensity of extreme weather events such as heat waves, flooding, and droughts is likely to increase. Developing increased water storage capacity to capture water under wetter conditions to use when it is drier will be an essential part of building a resilient water supply system for the future. In our draft Water Resource Management Plan 2024 (dWRMP24) and the Water Resources South East (WRSE) Regional Plan covering South East England, several new storage reservoir options are proposed which will allow us to capture and store water.

Alongside conventional surface reservoirs, another option to capture and store water is to use the natural aquifers, which hold vast amounts of water underground, much like a surface reservoir, but within the pore spaces or fissures in the soil or rock. We already utilise these aquifers as part of our existing water supply base, abstracting groundwater in particular from the Chalk and Lower Greensand aquifers, which make up a large proportion of the drinking water that we provide to our customers.

Our dWRMP24 sets out the future challenges we face in needing to reduce the amount of water we can abstract from these aquifers and rivers, in order to ensure the right balance of water is available for the environment as well as for drinking water. We therefore need to investigate alternative ways to use the natural storage these aquifers provide but also minimise impacts upon the environment and sensitive groundwater-dependant habitats.

Two potential options to generate additional water supply using groundwater aquifers differently from conventional groundwater abstraction are Aquifer Storage and Recovery (ASR) and Managed Aquifer Recharge (MAR). In both options, the key idea is to pump excess water available in winter months into the groundwater aquifer so that it can be used in subsequent summers or dry periods including droughts. The key difference between these two types of water supply option is the way in which the aquifer is used. In MAR, the aim is to enhance the natural groundwater recharge process of the aquifer, to increase local groundwater levels and support nearby groundwater abstraction. In ASR, surplus water is injected into the aquifer via boreholes for storage and is then pumped back for use later. Water is generally stored into aquifers where existing groundwater is not suitable for conventional abstraction. In ASR, a ‘bubble’ of potable good quality water is created around the borehole, displacing the native groundwater in the aquifer. The ‘bubble’ of good quality water then remains in place until it is re-abstracted later for water supply, requiring only chlorination. ASR therefore needs a well bounded, confined aquifer, that will prevent the movement and subsequent loss of the ‘bubble’ of stored water. It therefore requires specific combinations of geologic and hydrogeologic conditions for ASR to work effectively. In contrast, MAR can be carried out more widely, without needing such specific conditions, but it also means that there can be less control and retention of groundwater used to recharge the aquifer, as it will tend to flow naturally with the ambient groundwater.

There are many factors that need to be considered when developing ASR and MAR. Aquifer conditions are critical to their success, with needing sufficient transmissivity (ability for groundwater to move relatively freely through it) to accept the water, sufficient storage to allow a reserve of groundwater to be built up and the right geological structure to allow that water to be preserved and not to be lost via natural discharge. The hydro-geochemical conditions also need to be well understood as the introduction of new water, especially to confined aquifers, may lead to mineralisation which could clog up pore spaces and prevent extraction of the water rendering the scheme useless. There may also be potential for leeching of minerals from the aquifer into the water which may make it more difficult to treat and use as drinking water. These are particularly important factors for ASR, in order to successfully create a ‘bubble’ of potable water.

An additional key factor is having excess water available for ASR or MAR, and not simply intercepting water that would otherwise already be used for supply, or would be naturally recharging the aquifer anyway. Recycled water for example could be a good example of excess water available for both options.

ASR and MAR schemes do offer several advantages compared to conventional surface water storage reservoirs. The surface footprint is much smaller and hence the environmental impact and planning process is likely to be easier and faster. Our previous studies have concluded that ASR is only potentially viable if the scheme involves limited infrastructure. Long transfer mains, pump-to-waste pipelines or complicated water treatment are likely to make the scheme un-economic and would face significant planning challenges.

Our History of Investigation into ASR Schemes:

Neither ASR nor MAR is new to water resource planning at Southern Water. We have investigated potential ASR and MAR schemes in both Kent and Sussex as far back as the 1970s. We have historically undertaken extensive reviews[1][2][3][4][5][6] of the potential across South East England for ASR and developed associated options. The results of this review are summarised in Table 1. Early studies considered the following issues over the whole of the Southern Water area including:

- The suitability of the geology and hydrogeology for ASR
- The suitability of the water distribution network for ASR
- The environmental impact of ASR

The review considered the ASR potential of all aquifer units within 500m of the ground surface in terms of their aquifer properties, depth to groundwater and type/degree of confinement. We also undertook a wide-ranging literature review and discussion with other water companies, including Thames Water and South East Water on the success and challenges in developing their own ASR schemes. This study concluded that the Lower Greensand within the Sussex North, Sussex Brighton, and Sussex Worthing Water Resource Zones (WRZs) was the only potentially viable target aquifer for a successful ASR scheme within the Southern Water supply area.

Further work then led to a scheme in our Sussex North WRZ being dismissed because the pumping boreholes would have been close to the geological outcrop of the aquifer, and there may have been undesirable environmental impacts. The Sussex Brighton WRZ scheme was also dismissed because of the length of transformation required to supply water into the Sussex Brighton WRZ from the River Rother at Pulborough[7].

[1] Southern Science Limited, 1996, Aquifer Storage and Recovery (ASR) Preliminary Feasibility Study Report No 96/7/1417, Southern Water Services Ltd.

[2] Southern Water Technology Group, 1998, Aquifer Storage and Recovery Feasibility Investigation Report - Report No. 70881TR60.98 - ASR opportunities for Southern Water Services within the context of contemporary demand/resource balance issues and existing licenced headroom

[3] Southern Science Limited, 2006, Hardham Basin Artificial Recharge Review, Report No. 96/7/1621, Southern Water Services Ltd.

[4] Atkins, 2007 Southern Water Regional Review – Phase 2 Review of ASR Potential for Sussex

[5] Atkins, 2013 SWS AMP5 ASR, Assessment of ASR Feasibility at Findon WSW. Ref: 5100295/70/DG/022 v1.0 (Draft only)

[6] Atkins, 2016 AMP5 Aquifer Storage and Recovery Feasibility and Literature Review Final Report Southern Water Services Limited

[7] Atkins, 2007 Southern Water Regional Review – Phase 2 Review of ASR Potential for Sussex

Table 1 Summary of regional ASR potential from our AMP4 options appraisal[8]

Region	Aquifer	Comments	ASR Potential
Hampshire	Bagshot Beds	Semi-confined. Poorly consolidated fine sands which are likely to result in severe well construction / clogging problems	Very Low
	Chalk	Largely unconfined. Where confined, permeabilities are too low	Very Low
	Greensand	At too great a depth in the south (> 600 m). Potentially suitable in the Winchester area, but information is limited.	Low
Isle of Wight	Bembridge Marls and Limestones	Low hydraulic conductivity.	Very Low
	Bagshot Beds	Too close to outcrop, otherwise likely hydraulically connected to the sea.	Very Low
	Chalk	Too close to outcrop. Too steeply dipping.	Very Low
	Upper Greensand	In continuity with the Chalk. Too close to outcrop. Too steeply dipping.	Very Low
Sussex North	Tunbridge Wells Sands	Low permeabilities except the Ardingly Sandstone, which is heterogeneous. Significantly faulted. Abstraction boreholes have siltation problems	Very Low
	Ashdown Beds	High permeabilities are limited in extent, limited thickness especially where well confined. Significantly faulted.	Very Low
	Greensands	Generally unconfined or close to outcrop within this WRZ, with the possible exception of the Hythe Beds, which may be sufficiently confined within the Hardham Basin to provide some potential for ASR.	Medium
	Portland Sandstone	Clogging may be a problem. Heterogeneous and limited information available.	Low
Sussex Brighton and Sussex Worthing	Chalk	Limited confined area	Very Low
	Upper Greensand	Hydraulically connected to the Chalk	Very Low
	Lower Greensand	Important aquifer. Artesian, and at depth, which will both have cost implications	High
	Tunbridge Wells Sands	No information available	Low
	Ashdown Beds	No information available	Low
East Sussex	Tunbridge Wells Sands	Low permeabilities except the Ardingly Sandstone, which is heterogeneous. Significantly faulted. Abstraction boreholes have siltation problems	Very Low
	Ashdown Beds	High permeabilities are limited in extent, limited thickness especially where well confined. Significantly faulted.	Very Low
	Portland Sandstone	Clogging may be a problem. Heterogeneous and limited information available.	Low
	Thanet Sands	In connectivity with the Chalk. Limited extent of confined formation	Very Low

[8] Atkins, 2016 AMP5 Aquifer Storage and Recovery Feasibility and Literature Review Final Report Southern Water Services Limited

Region	Aquifer	Comments	ASR Potential
Kent Medway	Chalk	In connectivity with the Thanet Sands. Where confined, transmissivities are low.	Very Low
	Greensands	Located at depth in the north. Limited thickness away from unconfined areas.	Low - Medium
Kent Thanet	Thanet Sands	In connectivity with the Chalk. Limited extent of confined formation.	Very Low
	Chalk	In connectivity with the Thanet Sands. Limited extent of confined formation.	Very Low
	Lower Greensand	Thin and of limited extent	Low
	Jurassic Limestone	Thin	Low
	Upper Coal Measures Sandstone	Likely to have been impacted by mining, resulting in impacts from saline and acidic groundwater as well as impacted flow regime	Low

Our Sussex Worthing WRZ ASR Scheme

We undertook further options appraisal and development work on the Lower Greensand aquifer in Sussex Worthing WRZ between 2010 and 2015 (AMP5), in the form of a pilot study to investigate the feasibility of ASR as part of our 2014 Water Resource Management Plan (WRMP14). It was re-selected in our 2019 Water Resources Management Plan (WRMP19).

This was further progressed between 2015 and 2020 (AMP6), into detailed design. Our design process was aided by investigations undertaken by the British Geological Survey, which allowed us to characterise the geometry and geochemistry of the Lower Greensand aquifer in the Worthing area. We estimated this scheme to be able to produce between 2-4Ml/d[9]. However, despite extensive negotiations with landowners and a further review of alternative sites, we were unable to secure a suitable location for the ASR pilot borehole and the scheme was eventually paused and is not currently considered possible to develop further.

Our Proposed Western Area Test MAR/ASR Scheme

Following changes to our abstraction licences from the River Test, and River Itchen in 2019, we are faced with large deficits in water supply in our Western area, with the requirement of leaving more water in the rivers to benefit the environment. This led to the development of our Strategic Regional Options (SROs) alongside the need to find more water from a combination of, water efficiency measures, leakage reduction, and development of other water supply sources.

In southern Hampshire, the Chalk aquifer is confined overlain by younger Palaeocene, silty clay deposits of the London Clay Formation, that provides a low permeability confining layer. The geological setting here (Hampshire geological basin) is similar to the London geological basin, where MAR schemes to the confined chalk have been in operation for a few decades. Wessex Water have undertaken some historical drilling into the confined chalk of south west Hampshire to investigate the potential for ASR and these investigations suggested limited environmental impacts and aquifer properties that might support development of limited ASR schemes. However, these investigations also identified issues with poor raw water quality that would require blending or significant treatment to be useful.

Our earlier reviews had considered the confined Hampshire Chalk as having 'very low' potential for ASR on the basis that the confined chalk was unlikely to be sufficiently well fractured or developed due to the depth of burial and lack of past sub aerial exposure that would allow a natural flow system to develop. We had considered the Lower Greensand to have slightly greater potential than the Chalk in the Winchester area but was buried too deeply further south. Presently, extremely limited information on the properties and geometry of the Hampshire Lower Greensand aquifer exists due to the lack of outcrop and prior investigation.

During the early options appraisal process for 2024 Water Resources Management Plan (WRMP24) we decided to look again at the potential for either MAR or ASR schemes in Hampshire. Consequently we developed a new option that would involve either MAR or ASR in the vicinity of the Lower River Test. The key principle of this scheme would be to take excess winter water from our existing surface water abstraction from the River Test and inject it into the confined Chalk aquifer nearby to be stored until needed in dry years or summer periods when the river abstraction becomes limited. However, both we and the Environment

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[9] Ml/d = mega or million litres per day

Agency consider there to be several risks with the scheme given our current level of understanding. These include:

- Limited data to constrain the aquifer properties of the confined Chalk aquifer and whether it has sufficient flow or permeability to support an ASR scheme. Recent drilling by Portsmouth Water in a similar geological setting of the confined Chalk of east Hampshire has shown little reliable yield which has cast further uncertainty on the viability of the local aquifer properties for this purpose.
- The potential for poor hydrogeochemical effects of injecting surface water into a dual porosity aquifer like the chalk, and the development of the aquifer 'bubble'.
- Concerns around the potential unproven changes to groundwater levels and movement in the Chalk aquifer, and consequently potential environmental impacts where the Chalk is at outcrop.
- The need to undertake pilot drilling testing and a programme of recharge and discharge cycles to examine the evolution of the aquifer and hydrochemistry the outcomes and timelines for which are uncertain.
- The Water Framework Directive (WFD) imposes a principle of 'No Deterioration' such that any actions taken on a waterbody must not deteriorate the status of either quality or quantity of that water body. There are implications for ASR schemes:
  - The potential unproven changes to groundwater levels and movement in the Chalk will need to be considered to make sure there is no implications for the aquifer itself, and cause a deterioration in water quality to the groundwater body.
- Future application of Natural England's Common Standards Monitoring Guidelines (CSMG) might set flow targets that would restrict abstraction from the River Test even when river flows are high during the winter, as flow targets are defined by an allowable departure from 'natural' flows. This could mean that excess water would not be available for the ASR scheme.

The MAR/ASR water supply scheme was selected in our draft WRMP24 to start providing water from 2041. Although it may be technically possible to develop the River Test MAR/ASR scheme sooner (prior to 2040), we consider the risk and uncertainty surrounding the scheme to be sufficiently high to defer implementation until the 2040s to give us sufficient time to investigate and undertake full feasibility studies. This also means that it could not be relied upon as part of any short to medium term solutions to our supply demand deficits, as it would present an unacceptable risk of failure to supply if the scheme is eventually found, through further investigations and testing, not to be viable.

Environment Agency Representations on our draft WRMP24

We consulted the Environment Agency during the pre-consultation phase of our draft WRMP24 on the River Test MAR/ASR scheme. In its feedback, the Environment Agency noted that such a scheme had never been explored in this area and that there is limited knowledge about the aquifer properties of the confined Chalk in Hampshire. It also expressed concerns over the potential yield of such scheme and that significant work would be required to determine if such a scheme is viable. The Environment Agency further noted that it is critical that the scheme is demonstrated to not having any impact on the designated rivers and must be compliant with the Habitats Directive.

In its representation to our draft WRMP24, the Environment Agency reiterated its previous concerns over the feasibility of this option in particular relating to the aquifer properties (limited storage and tight, poorly fractured chalk). It also restated concerns over flood risk for the potential site and the potential for environmental impacts on the designated rivers.

In recognition of these concerns, we had already deferred the earliest start date for the scheme from 2030 to 2036 in the development of our draft WRMP24 to provide us more time to undertake these feasibility studies. This work is likely to involve:

- Test drilling to establish the aquifer properties of the confined Chalk, at the same time determining geochemistry and hydrochemistry of the aquifer
- A programme of groundwater modelling to understand the potential hydraulics and any environmental impacts of the scheme
- A programme of pilot cycle testing would follow if secondary porosity is sufficiently development in the confined Chalk to allow adequate yield, to understand the geochemical characteristics and development of the 'bubble' within the aquifer, and its potential efficiency
- Further scaling up considerations of the surface works required, if the scheme is deemed viable hydrogeologically, including arrangement of water mains, sewers and other supporting infrastructure

Natural England Representations on our draft WRMP24

Natural England echoed the Environment Agency's concerns around the potential impact on the River Test Site of Specific Scientific Interest (SSSI) and Habitat Directive sites downstream and that further work was needed to ensure that there would not be significant impacts. It also raised concerns over the suitability of the geology of the proposed site.

WRMP Sensitivity Testing

We share the concerns that the Environment Agency and Natural England have over the hydrogeological viability of this scheme.

For the revised dWRMP24, we have introduced a longer 10 year' lead time for this option to allow sufficient time for further investigations. We have also tested a scenario which excludes this option to understand the impact on our strategy if it is not prove to be viable. This testing is described in Section 7.3 of our revised draft plan..

This option is first selected in 2036 in both our least cost and best value plans. The exclusion of this option under the sensitivity testing results in a deficit in the bulk supply to a large industrial user in Hampshire in 2037 (up to 4.4Ml/d) in situations 1-6 under 1:100 DYAA scenario.

Other Stakeholder and Customer Feedback

Wider use of ASR or MAR schemes received strong support from both customers and stakeholders during the consultation on our draft WRMP24. This is consistent with feedback received on WRMP19 where groundwater schemes such as this were amongst the most highly favoured by customers and stakeholders.

Some concerns were raised that we were not adequately considering ASR and MAR more widely for WRMP24. This stems from the fact that we have already undertaken extensive review and feasibility studies leading up to WRMP24. As mentioned, our feasibility work in AMP5 has shown that much of the South East is not viable for widespread ASR. Where potential has been found (Lower Greensand in Sussex Worthing WRZ) we had developed the feasibility to detailed design, but unfortunately other factors such as planning and land availability has so far rendered the schemes unviable.

It must be noted, the potential for scaling up of ASR schemes as large water supply options is relatively limited, constrained to very specific areas, with yields likely to be relatively small compared to alternative new sources of water. Whilst they have broader appeal, the more limited yields from ASR schemes compared to, for example water recycling or desalination, restrict their usefulness in solving the large supply-demand balance challenges that we face in the long term to ensure that the conventional groundwater sources can be sufficiently reduced in the future to leave more water available for the environment, to protect the unique chalk stream habitats we have within our water supply area.

Potential for other Managed Aquifer Schemes in Hampshire

We have considered the potential for MAR into the unconfined and exposed Chalk aquifer in the central and northern parts of Hampshire. Winter Rainfall already naturally recharges this aquifer where it is meets the ground surface. However, the groundwater flow system is very well developed such that any additional artificial or augmented recharge is likely to be lost back to the River Test or the River Itchen via the natural groundwater discharge / baseflow, and is unlikely to provide a source of water that would persist when it was required in drought years.

In addition, we do already have a de-facto MAR scheme in Hampshire south of Winchester where treated wastewater is discharged to ground and infiltrates into the chalk aquifer, and this likely provides a degree of limited groundwater recharge to the River Itchen catchment.

A further consideration is that our strategic groundwater sources for Hampshire are presently constrained by flow conditions in the rivers which restrict the opportunity to take additional groundwater during drought periods or even under normal conditions should further environmental licence constraints be introduced. This may render any MAR unusable.

During the development of our proposed and preferred SROs, the Havant Thicket Reservoir and Havant Thicket Water Transfer and Water Recycling Project, we did consider the potential for a MAR scheme that would use recycled water discharging to the Hampshire Chalk as an environmental buffer which could then be re abstracted at our existing groundwater or surface water works in the vicinity of the Lower Itchen. However we concluded that due to the volume of water required and the future application of Natural England's CSMG set flow targets on the designated River Itchen Special Area of Conservation (SAC) it would likely be deemed unacceptable by regulators, and so the option was not developed further.

We will though continue to review opportunities for both ASR and MAR for future Water Resource Management Plans.