CaBA
Chalk Stream Restoration Strategy 2021

This CaBA Chalk Stream Restoration Strategy was prepared by Charles Rangeley-Wilson, chair of the CaBA chalk stream restoration group, (CSRG) in consultation with:

The CaBA CSRG Panel

Sarah Powell, Environment Agency, Chalk Stream Manager
Sophie Broadfield, Defra
Anne Dacey, Environment Agency
Rose O'Neill, Natural England
Fayza Benlamkadem, Magda Styles, Ofwat
Dave Tickner, WWF
Stuart Singleton-White, Angling Trust
Ali Morse, Wildlife Trust
Barry Bendall, Rivers Trust
Janina Gray, Salmon & Trout Conservation
Andy Thomas, Wild Trout Trust
Richard Aylard, Yvette de Garis Thames Water
Jake Rigg, Affinity Water
Ian Colley, Wessex Water
James Wallace, Beaver Trust
Jake Fiennes, NFU

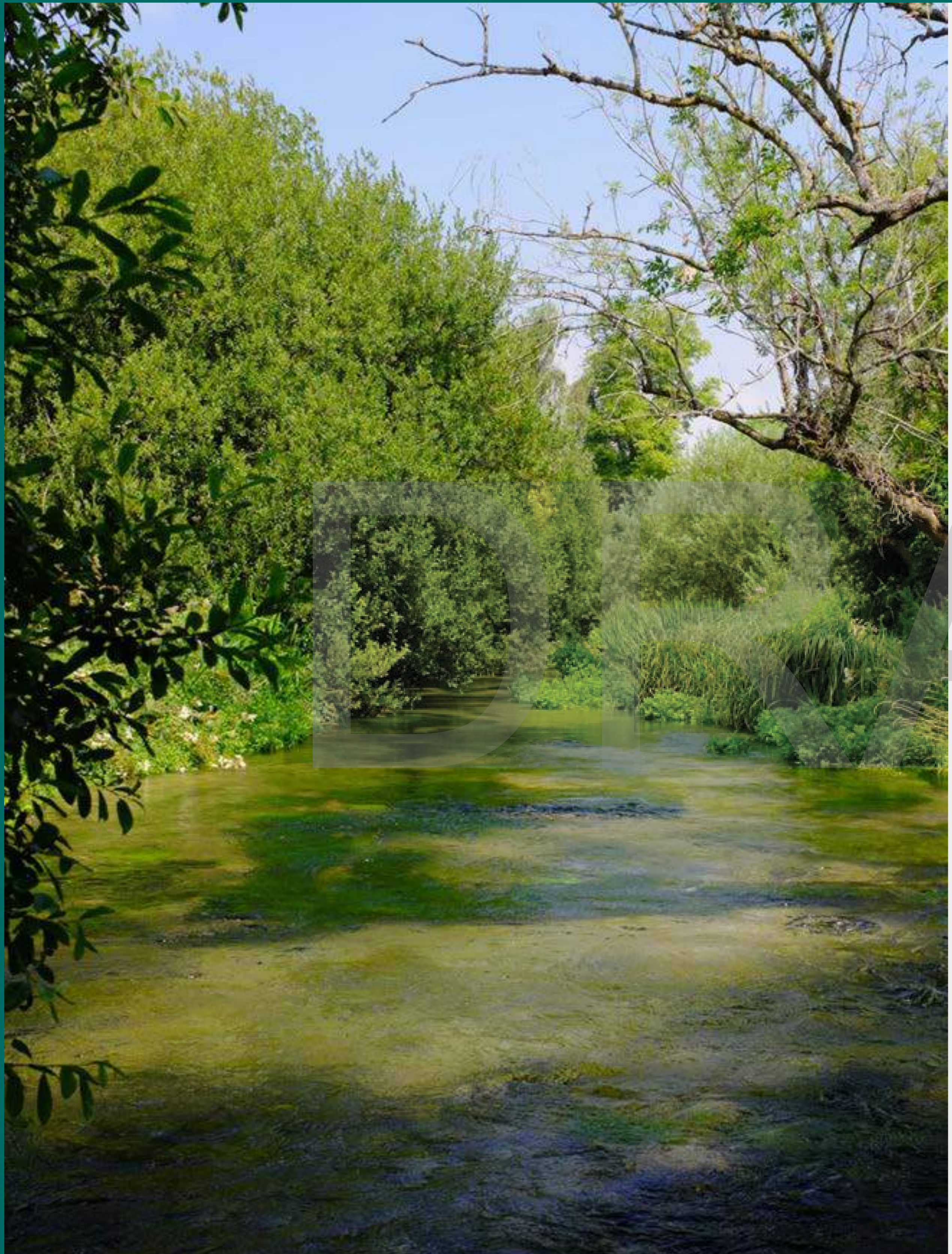
The CaBA CSRG Expert Panel

Chris Mainstone, Natural England
David Sear, Southampton University
Katie Heppell, Queen Mary University
Geraldine Wharton, Queen Mary University
Steve Brooks, Natural History Museum
John Lawson, Independent
Vaughan Lewis, Independent
Tim Sykes, Environment Agency
Carl Sayer, University College London

In addition the following have contributed to meetings and discussions:

All water companies covering the English chalk streams

Mark Lloyd – The Rivers Trust / Paul Knight, Nick Measham – Salmon & Trout Conservation / Stephen Tomkins, Alan Woods – Cam Valley Forum / Doug Kennedy / Graham Roberts / Jonah Tosney – The Norfolk Rivers Trust / Fiona Bowles, John Bass, Wessex Rivers Trust / Cyril Bennet / Martin Janes, Joshua Robins, Marc Naura – River Restoration Centre / Allen Beechey – Chilterns AONB / Jonathan Fisher / Will Best / Gavin Lane / Michael Rae / John Austen / Simon Cain / Roger Harrison



Summary

Chalk streams are an exceptional variety of spring-fed river unique to England and France. Although chalk exists in other parts of the world, nowhere else is there such a mass of it – the remains of an entire sea-floor – exposed at the surface of the earth as rolling chalk hills, washed over by a temperate, maritime climate.

The English chalk downland gives rise to 246 pellucid chalk streams and dozens of small, nameless rills and becks, comprising the vast majority of this river type to be found anywhere in the world. They are our equivalent to the Great Barrier Reef or the Okavango: a truly special natural heritage and responsibility.

When rain falls on chalk hills it soaks down into the body of the rock and there undergoes a kind of alchemy, emerging again from springs as cool, alkaline, mineral-rich water, equable in flow: the perfect properties to create a richly diverse eco-system.

Chalk streams in their natural condition are home to a profusion of natural life. Botanically they are the most biodiverse of all English rivers. For invertebrates, fish, birds and mammals, they offer a vast range of habitat niches. In Wessex they are a stronghold of our chalk stream Atlantic salmon, now known to be genetically distinct. The upper ephemeral reaches, known as winterbournes, are global hotspots for a unique range of specialist plants and invertebrates.

But chalk streams are under immense pressure: they flow through one of the busiest, most urbanised, industrialised and farmed parts of our crowded islands. Three chalk streams flow through London and from every side many more pour into that hub like the spokes on a wheel through the chalk hills which surround the capital. Further afield, though many rise in open countryside that countryside is busily farmed, and invariably villages, towns and cities are sited somewhere along every chalk river. All these streams are impacted in one way or another by the activities of people.

We depend on chalk streams for public water supply, and have leant heavily on the resources of the underground body of water that feeds these streams. And yet every litre of water we take out of the aquifers – and we take billions and billions of litres to irrigate our crops, or run our taps – is water lost to the natural environment. Lost, that is, until we put it back – only by the time we return water

to these rivers it is no longer in the state in which we found it. It has passed through our sewage systems becoming rich in nutrients and other pollutants. We may treat it, we may even treat it to a very high standard in some places, but in many others we do not. Routinely, we put back into these wonderful ecosystems water which makes them eutrophic, so that oxygen is sucked away from the life which depends on it.

Even the water which we don not take out, which actually makes it to the underground aquifer or the stream, is unnaturally changed. Our heavily farmed landscape exerts a huge pressure on water quality, either because rain runs off bare, ploughed land and along roads, accumulating toxins along the way and rushes, unfiltered, into the river, or because it seeps down into the ground carrying with it the chemical fertilisers which have been applied to the land. There is now so much nitrogen in our chalk aquifers that we do not know how long it would take – even if we stopped applying nitrogen as fertiliser – for the aquifers to become clean again.

Finally, we have changed the rivers themselves, modifying them heavily over the centuries, because they are such gentle, malleable rivers. We have used them for milling, for transport, to drive multiple agricultural and industrial revolutions. More recently, in the post-war decades, we made one of the most drastic and permanent changes of all: we dredged them. We took out the gravel river-bed – on which almost all chalk stream life ultimately depends – and dumped it on the banks, all in a misguided attempt to drain the landscape. Not quite understanding river morphology at the time, we mostly created a management nightmare, because the streams now fill with sediment – the only material at their gentle-natured disposal – to fill the void.

So, we have a job ahead of us if we are to leave our wonderful chalk streams in a better state than we found them.

That is the challenge which this **CaBA Chalk Stream Restoration Strategy** is intended to address. The singular qualities of these rivers and the fact we are stewards of a globally distinct ecosystem have strengthened a resolve that is now felt in all quarters of society – from grass-roots stakeholders all the way to Government – to restore to good ecological health these unique rivers and the landscapes which support them.

CaBA is a space in which all stakeholders involved in the management, conservation and (ideally) sustainable exploitation of our chalk streams can come together and agree on a way to achieve that goal. It is not always a comfortable space: NGO's have to be pragmatic; water companies have to be idealistic; government has to listen and act. But this restoration strategy is what has come out of that discussion: an action plan which, if followed, will allow us to become proud custodians of 246 ecologically vibrant chalk streams from Dorset to Yorkshire, streams that may once more flow with a healthy flush of clean water through meandering channels over bright gravel, full of wildlife, beside which it is a pleasure to spend time and which could and should be a credit to the stewardship of our generation.

The trinity of ecological health

Chalk stream ecological health depends on three things. This plan addresses each in turn and all three in combination:

- Water quantity (the naturalness of the flow regime)

- Water quality (how clean the water is)

- Physical habitat quality (the physical shape of the river but incorporating biological factors like invasive species which can degrade habitat directly and indirectly)

We look at these issues singly because it helps to focus, but together too, because it is important to remember how each one either positively or negatively affects the others. Re-naturalising flow will improve river health by improving water quality and physical habitat. But the beneficial impact of re-naturalising flow is greatly increased if water quality and physical habitat are improved too. Improving water quality or physical habitat will likewise enhance the health of the chalk stream although not as much as when flow is also strengthened.

Therefore the best restoration strategy will address all three together: re-naturalising flow and improving water-quality while using landscape-scale physical-habitat improvements to consolidate the beneficial impacts of both and thus deliver maximum ecological improvement. Combining all three will achieve this outcome better by orders of magnitude than when the elements are improved in isolation.

Water quantity

• Groundwater abstraction from chalk aquifers accelerated markedly in the post-war years and reached a peak in the mid 1980s when in some catchments over half – and in dry years all – of the water available to the river was abstracted.

• A multi-year drought in the late 1980s early 1990s brought the scale of this crisis to pubic attention. The National Rivers Authority identified 15 chalk streams which were suffering from acute over-abstraction and launched a scheme to address the issue called 'Alleviation of low flows'.

• Thirty years later only five of those fifteen chalk streams have flows which support 'good ecological status' (a Water Framework Directive requirement).

• In the interim period, multiple reports have identified actions to tackle unsustainable abstraction in chalk streams, and some action has been taken: the Environment Agency's Restoring Sustainable Abstraction programme has delivered alterations to 124 abstraction licences on chalk streams, returning 105 Ml/d of water to the environment (37 billion litres per annum). The government has changed the law with regard to compensating abstractors when licences are revoked or changed and the EA has established environmental flow targets.

• And yet still many chalk streams suffer from acute low flows. In the spring of 2017, a time of year when chalk streams should be at their fullest, many of the chalk streams around London were once again either dry or drying.

• The Water Framework Directive uses a set of flow targets which state that for a river's flows to be deemed to support good ecological status there must be no more than a 10% reduction from the natural flow (for an ASB3 stream) at the Q95 point in the flow curve (i.e. at lowest flow, generally in late summer / early autumn). In reality, the flows in some of the most stressed chalk streams are far below this: the River Ver, for example, is 77% below natural, the Chess 41%, the upper Lea 100%.

• 86 chalk stream waterbodies do not support good ecological status (DNSG) for flow, the majority of them around London between Basingstoke and Cambridge.

• A significant part of why this crisis has proved so insoluble is that there is an immense pressure on public water supply in a heavily populated and dry part of the country, only limited water sources are available and finding other sources is expensive.

• The national framework for water resources offers the best chance we have yet had to re-naturalise chalk-stream flows by looking for water-resource options which are not based simply on cost. In seeking best value the framework considers environmental protection and resilience alongside strategic options including reservoirs, water re-use schemes and desalination plants, shared supplies with other sectors and catchment-based work to improve water management. Chalk streams are a priority in this process.

• Other actions which will help include a collective agreement on what constitutes sustainable abstraction and a commitment to publish time-bound goals towards that target; a review of our existing flow assessment methodologies, abstraction-sensitivity banding, assessment points and waterbody boundaries (which do not currently protect flows throughout the chalk streams), and compulsory metering in all chalk catchments.

Water quality

• In their natural state, chalk streams are gin-clear, with little sediment, low nutrient levels and stable temperatures of around 10-11ºC. However, pollution from point sources, especially sewage treatment works and diffuse sources such as agricultural and road run-off, means that many suffer from elevated levels of nutrients, sediment and toxic chemicals such as pesticides.

• Excess sediment settles on and penetrates the gravels on the river bed, and has a direct impact on plants, invertebrates and fish, smothering fish eggs and clogging the interstitial spaces in the gravel where invertebrates live. It makes the water turbid, blocking photosynthesis. Nutrients and toxins accumulate in river-bed silts.

• Excess sediment largely comes from agricultural run-off (77%) in wet weather, especially the winter. Certain forms of agriculture are particularly problematic: open-air pigs, for example, or any form that leaves fields bare in winter. Road run-off is another significant source of sediment pollution, as are fish and cress farms and sewage works.

• Nutrient pollution derives especially from unnatural levels of phosphorus and nitrogen, two chemicals essential to all life in a chalk stream, but naturally present in very low concentrations.

• Excessive nutrients lead through various stages of accelerated plant production, inhibiting root-growth at first, reducing resilience, limiting biodiversity and finally leading to a dominance of algae and extreme oxygen depletion, affecting all life in the chalk stream.

• Nutrient concentrations can and do rise well above their 'trigger levels' and to effect an improvement in ecology they have to be brought back down to below that level. However, in chalk rivers, of the two main macro-nutrients, when phosphorus is at its trigger level, nitrogen is almost invariably multiple times higher. In fact, nitrogen pollution in our chalk aquifer alone is usually above the trigger level as a result of a legacy of farm pollution going back decades. This means that targeting reductions in phosphorus is likely to yield the greatest short-term benefits, albeit nitrogen must be tackled too. Measures to reduce phosphorus will also tend to reduce nitrogen by default.

• Nutrient pollution in chalk streams derives largely from sewage works and agricultural run-off but also from other sources such as fish farms, and septic tanks.

• Great improvements have been made in phosphorus reduction from sewage works over the past 20 years, driven by the Urban Waste Water Treatment Directive and the Water Framework Directive.

• But except in designated SSSI and SAC catchments where all sizes of sewage works have been improved, elsewhere these improvements have been confined to larger sewage works – which tend to be in the lower reaches of any given river – and works in sensitive area (SAe) catchments. Numerous small sewage works on rural chalk streams still only treat to secondary stage, which results in a lot of phosphorus being discharged into small, headwater chalk streams.

• Nutrient pollution from farming is largely bound up with sediment pollution. Nutrients applied to farmland adsorb to sediment particles and wash into the river in wet weather. The condition of the river affects the degree of damage which nutrients do. An impounded and dredged stream corralled by leveed banks is much more vulnerable than a naturally shaped stream that can spill onto its floodplain in high flows.

• Nitrogen and phosphorus can wash down into the aquifer too. Chalk binds phosphorus but not nitrogen. Nitrogen pollution of chalk aquifers is a vast problem. Mixed-geology chalk streams, especially those with upper greensand tend to have higher levels of phosphorus in the aquifer pore-water. It is still not known for certain if the cause is natural or anthropogenic.

• Continuing to upgrade small sewage treatment works must be a high priority for restoring chalk-stream health. Cost-benefit assumptions should be addressed if undesignated catchments are precluded from upgrading (as they tend to be) because improving water quality from the headwaters downstream has a disproportionately beneficial impact on ecology throughout the river system.

• Storm overflows are a significant problem which appalls the public. All efforts must be taken to address the duration and frequency of storm overflows while priority protection in this respect ought to be given to chalk streams, reflecting their iconic status and global rarity.

• The agricultural sector must do its fair share to reduce nutrient pollution of chalk aquifers and direct run-off to chalk streams. Simple rules to address run-off in chalk catchments should be compulsory and enforced as part of the Sustainable Farming Initiative. (SFI)

• Beyond SFI, considerable opportunities exist to be exploited within the Environmental Land Management (ELM) schemes which might enable changes to land management at catchment scale and the removal from production of critical land, prioritising headwater regeneration, spring-line fen, riparian zones and tracts of floodplain.

Physical habitat quality.

• Chalk streams have been heavily modified throughout human history: deforestation, water-mills, flash-locks pound-locks and water-meadows, the ditching and draining of floodplains, dredging and canalisation have all contributed to the modification of chalk streams at the expense of their ecological health, integrity and resilience.

• These modifications all have the impact of disabling the river's power to process and behave as a river does. Since ecology adapts to physical habitat, if the physical state is altered the ecology will be so too.

• Chalk streams are gentle, low-energy rivers, shaped by forces which have long since retreated from the landscape. Once damaged or modified, chalk streams are prisoners of their own nature, lacking the stream power for self-repair.

• Compared to higher-energy streams, chalk streams are much more dependent on ecological processes:

• on macrophytes interacting with flow,
• on tree-fall,
• on spawning salmonids mobilising gravel
• even on midge-larvae in ranunculus beds filtering diatoms from the water.

Therefore chalk stream restoration should restore that which enables process:

• stream slope
• an intact gravel-bed
• a dynamic interaction with fallen trees and living riparian trees
• a dynamic interaction with the floodplain

The aim by means of the above should be to restore ecological processes and the habitat requirements of the ecosystem's engineers (fish, insects, mammals and plants) which shape a truly heterogenous and dynamic chalk stream.

• Chalk-stream restoration has, to date, been largely carried out at the reach-scale on an opportunistic basis, taking advantage of available funding. Reach-scale projects can and do make a tangible difference. There is an opportunity to magnify their impact, however, by adding multiple reach-scale improvements together so that they operate at the catchment scale: this is how we will start to see really significant improvements.

• The CaBA Chalk Stream Restoration Strategy offers an excellent opportunity to do just this, starting with a national network of flagship catchment restoration projects in which *all* aspects of the CaBA plan are to be given maximum possible expression. Only at this scale can we bring the three components of our discussion together – water quantity, quality and habitat – into a concept of restoration which magnifies the improvements made in any one aspect, by combining them with improvements in the other two.

Summary – key actions

The CaBA Chalk Stream Restoration Group has identified **key actions** essential to progress under the headings of **water quantity**, **water quality** and **physical habitat quality**. These actions are ambitious but pragmatic. Sometimes it is important to distinguish between what should be done and what can be done now. The actions try to encompass both.

As much as possible it has been the intention of the CaBA CSRG to agree all these actions, but this is not always straightforward: for example some require changes to legislation. That being a political process government agencies must be wary of seeming to show partiality. Furthermore many of these actions require additional government funding, or water company investment, and the processes of enabling that funding / investment are not in the gift of the CaBA group. It is our job to identify what needs to be done and it is the job of stakeholders who care about our chalk streams to make that passion and concern felt, so that the changes which need to happen, do happen.

The actions (dealt with in more detail deeper into the report) include:

- **an overarching protection and priority status for chalk streams and their catchments to give them a distinct identity and to drive investment in water-resources infrastructure, water treatment and catchment-scale restoration.**

- **a consensus agreement on the definition of sustainable abstraction as that which ensures flows are reduced by no more than 10% of natural at the most water-stressed times of the year (Q95) and an equivalent target for an acceptable increase (10%) in drying for winterbournes.**

- **a commitment to set time-bound goals to meet this target on all chalk streams where the target is technically feasible and ecologically beneficial.**

- **a review of waterbody boundaries and assessment points to ensure that methodologies for assessing flows and water quality protect all of the chalk stream and especially its headwaters**

- **prioritising chalk streams from the headwaters downstream in the national framework process for planning future water resources**

- **designating all chalk stream regions where public water supply is heavily reliant on groundwater abstraction as ‘water-stressed’ to enable compulsory metering in these areas**

- **multiple actions to drive down the nutrient loading of chalk streams to ecologically appropriate levels, including:**

- **prioritisation of investment in all sewage treatment works contributing to WFD nutrient failures**

- **reduction in the frequency and duration of storm overflows spilling to chalk streams**

- **a suite of practical farming rules for chalk-stream catchments specifically to address pathways of diffuse agricultural pollution from landscape to river with farm payment contingent on compliance and with strict enforcement**

- **using the new Nature Recovery Network (NRN) and Environmental Land Management (ELM) schemes to deliver landscape-scale biodiversity gains in chalk catchments, focusing on water quality and hydrological connectivity and the restoration of process-driven recovery in chalk streams and their wider landscape settings**

- **a national network of flagship full-catchment restorations where all parties in the CaBA partnership will cooperate to enact all aspects of the restoration strategy – addressing flow, pollution and physical habitat in unison. These projects will act as exemplars for what is possible.**

Foreword

This CaBA Chalk Stream Restoration Strategy represents the collective passion and ambition of all sorts of people and organisations who care about chalk streams and who wish to see them restored to good ecological condition.

In terms of our stewardship of the environment, chalk streams are a considerable challenge – because they flow through the busiest part of the country – and a weighty responsibility – because they are such rare and special rivers. Chalk-stream ecological health is under pressure everywhere and failing in many places. This CaBA plan identifies what we need to do to relieve that pressure and address those failings. We will only succeed by working together. And we will only succeed by acknowledging and living up to our individual responsibilities and roles.

The CaBA Chalk Stream Restoration Group

One big wish – enhanced status for all chalk streams

As will be shown in this report, people who are passionate about chalk streams have asked for one big thing again and again over the last twenty years and that is for the government to give chalk streams a status which reflects the fact that these rivers are not just locally precious, but globally unique, by providing a statutory driver for the investment needed to restore their ecological status.

Six chalk stream catchments are currently designated as sites of special scientific interest (SSSI) and four as special areas of conservation (SAC)*, the latter our highest designation. These streams are designated for particular reasons which mark them out even amongst chalk streams, but the results of their enhanced protection are obvious when you look at the investment afforded to their protection in comparison with the rest.

All chalk streams are classified as priority habitat, and once they were THE river priority habitat, with their own investment driver: the Biodiversity Action Plan (BAP) priority habitat driver. Now, chalk rivers are one of a subset of criteria of priority habitat, and the designation itself has not always been that powerful.

Over and over, while preparing this report, it has been made clear that when it comes to the investment decisions which determine the health of our chalk streams – in reducing abstraction, or pollution or paying for habitat work – a powerful *statutory* driver makes all the difference. A statutory driver allows the regulators, industry and NGOs to do what they need to do to bring our chalk streams back to ecological health, not just in a few privileged places, but right across the map.

Rivers are found all over the world, but chalk streams exist only in England (and France). They should be our pride and joy. Enhanced status which drives investment – whatever form that needs to take – will allow them to become so.

Charles Rangeley-Wilson. Chair CaBA Chalk Stream Restoration Group.

*SSSI catchments: lower Frome / Bere Stream / Test / Kennet / Nar / Hull h’waters SAC catchments: Avon / Itchen / Wensum / Lambourne

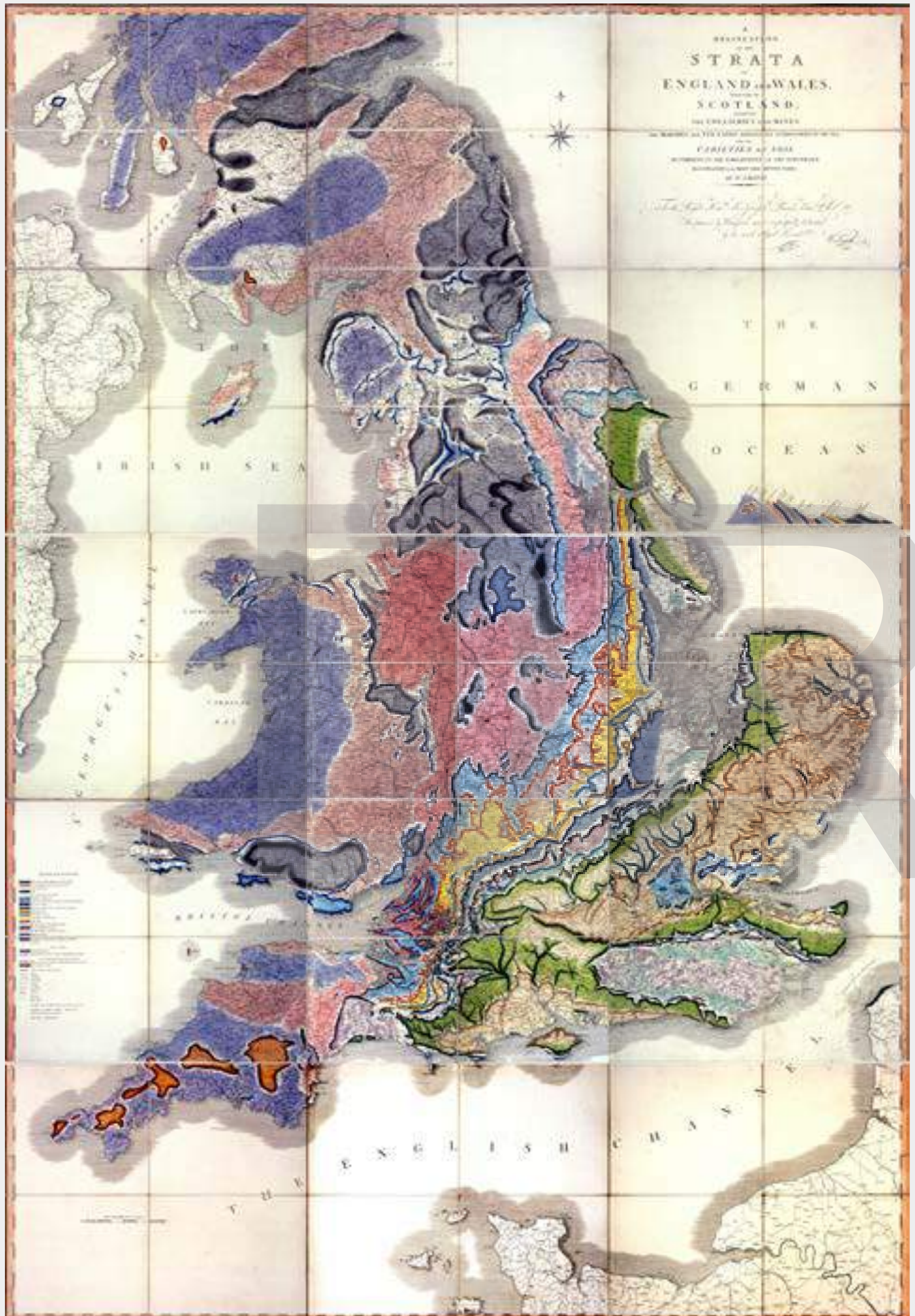
1. Introduction

Chalk streams are a special type of spring-fed river unique to England and northern France. Like other spring-fed streams, chalk streams derive most of their flow from underground aquifers, but the chalk aquifer and the chalk landscape are distinctive and give to these rivers a blowsy and gentle quality which marks them out historically, aesthetically and ecologically: chalk streams flow through a busy, modern landscape which is nevertheless steeped in history; they have been shaped extensively by man over the centuries and yet they also possess – because of their alkalinity, minerality and their cool, stable and gentle flows – a rich ecology and biodiversity.

Chalk is a form of limestone made of the remains of countless billions of tiny marine fossils, which is distinct from the harder, more heavily fissured limestone of the Cotswolds, northern England, or Ireland. Chalk is a softer and younger form of limestone and the chalk landscape and the chalk-stream flow regimes and characters reflect this. They are exceptionally *equable* rivers. Crucially, the geology and flow regime of a chalk stream define its unique physical character – the 'bankful' appearance, for example, a result of the channel shape and dense aquatic plant communities, which create a close interconnection between the stream and its floodplain – and which define its ecology.

Also distinguishing chalk from the more globally widespread forms of limestone is the fact that the chalk beds laid down across Europe in the Cretaceous geological epoch have either been extensively worn away (because chalk is so soft) by glaciers or buried deep beneath younger deposits. It is an accident of geological history that only in southern and eastern England (from Dorset to the eastern wolds of Yorkshire) and in France (an area known as the Anglo-Parisian basin), do we find a chalk massif of rolling downland at the surface of the earth and as mother to a relatively tiny global total of chalk streams. In England there are 246 named chalk streams on the map which has been revised as part of this restoration strategy.

There are a few dozen very famous chalk streams: Hampshire's Test and Itchen are the most obvious, arguably the jewels in the chalk-stream crown. But the Frome, Piddle, Allen, Wylye, Avon and Kennet, and in Yorkshire the Driffield Beck are all comparable. Amongst and between these, however, are dozens of less well-known streams that are every bit as precious, given that together these amount to most of the chalk streams in the world: the Meon, Ebble, Pang, Wye, Chess, Mimram, Beane, Ivel, Cam, Nar, Babingley, Burn, Great Eau, Foston Beck and Gypsey Race, to name just a few. In addition and almost innumerable are the scarp-face springs that rise along the north-eastern-facing ridge of the chalk, especially from the Sussex Downs, through the Chilterns and north through Lincolnshire and Yorkshire: a spring-line assemblage of chalk rills which is also a



The world's first geological map, drawn by William Smith (who also built water meadows) picks out the English chalk in a serpentine band of green.

distinctive and precious resource.

It is no coincidence that the confluence of geological history which created such globally rare and ecologically rich rivers also shaped a part of the world which has been a crucible of human activity for thousands of years and is now the busiest, most intensely inhabited part of the United Kingdom. The conflict between the ecological integrity of spring-fed streams and busy human activity is a global phenomenon because spring-fed streams by their natures flow through habitable and malleable landscapes. If the pressure on spring-fed streams from agriculture, population and industry is intense almost everywhere, it is probably at its most intense in southern and eastern England and even there it is pushed to a peak of intensity on the chalk streams which surround London.

There are multiple pressures on chalk streams: we extract water from them, we pollute them with treated and not-so-treated sewage, and we have re-shaped them again and again over the centuries, through deforestation, milling, canalisation, dredging. All this has combined to create what has been called the 'chalk-stream crisis': a collapse in ecological condition which in the worst places means that rivers are hardly rivers (the headwaters of the Beane, the Misbourne and other rivers near London either do not flow at all or flow very rarely) and which elsewhere leads to low flows, eutrophication, excessive siltation and denuded, de-natured physical habitat.

Over the last three decades the ecological state of England's chalk streams has become a subject of growing concern. In some respects and in some places, the condition of these rivers has improved as a result of intense lobbying, passionate and proactive restoration and because of the enhanced protection afforded to designated chalk streams: protection which drives investment in sewage treatment works, for example. Elsewhere the widespread perception is of a general decline under increasing pressures, whether from water abstraction, agriculture, population growth, the impact of invasive species or a multiplicity of other causes.

But the extraordinary characteristics of these rivers and the fact we are stewards of a globally scarce ecosystem has also strengthened a resolve which is now felt in all quarters of society, from grass-roots stakeholders all the way to Government, to restore to good ecological health these unique rivers and the landscapes that support them.

This **restoration strategy** is designed as a road-map to guide us on that journey. It will take some time to get to the destination – to think otherwise would be to underestimate the scale of the undertaking or the ambition in our vision: to see 246 ecologically vibrant chalk streams from Dorset to Yorkshire flowing with a healthy flush of clean water through meandering channels over bright gravel; streams full of wildlife which are a pleasure to spend time beside and which could and should be a credit to the stewardship of our generation.

2. The chalk stream: origins and ecology

2.1 A brief history of chalk

All our chalk streams share a special and rich ecology which derives from their geological origins. To fully understand the place that ecology has in our landscape, it is helpful to first understand the geological history.

The story of chalk began in a warmer world 100 million years ago. Carbon dioxide levels were four times what they are today – and sea levels were much higher. The supercontinent of Pangea (when all the continents on earth were crammed into one landmass) had fragmented into Laurasia and Gondwanaland and the Atlantic Ocean was in the early stages of formation.

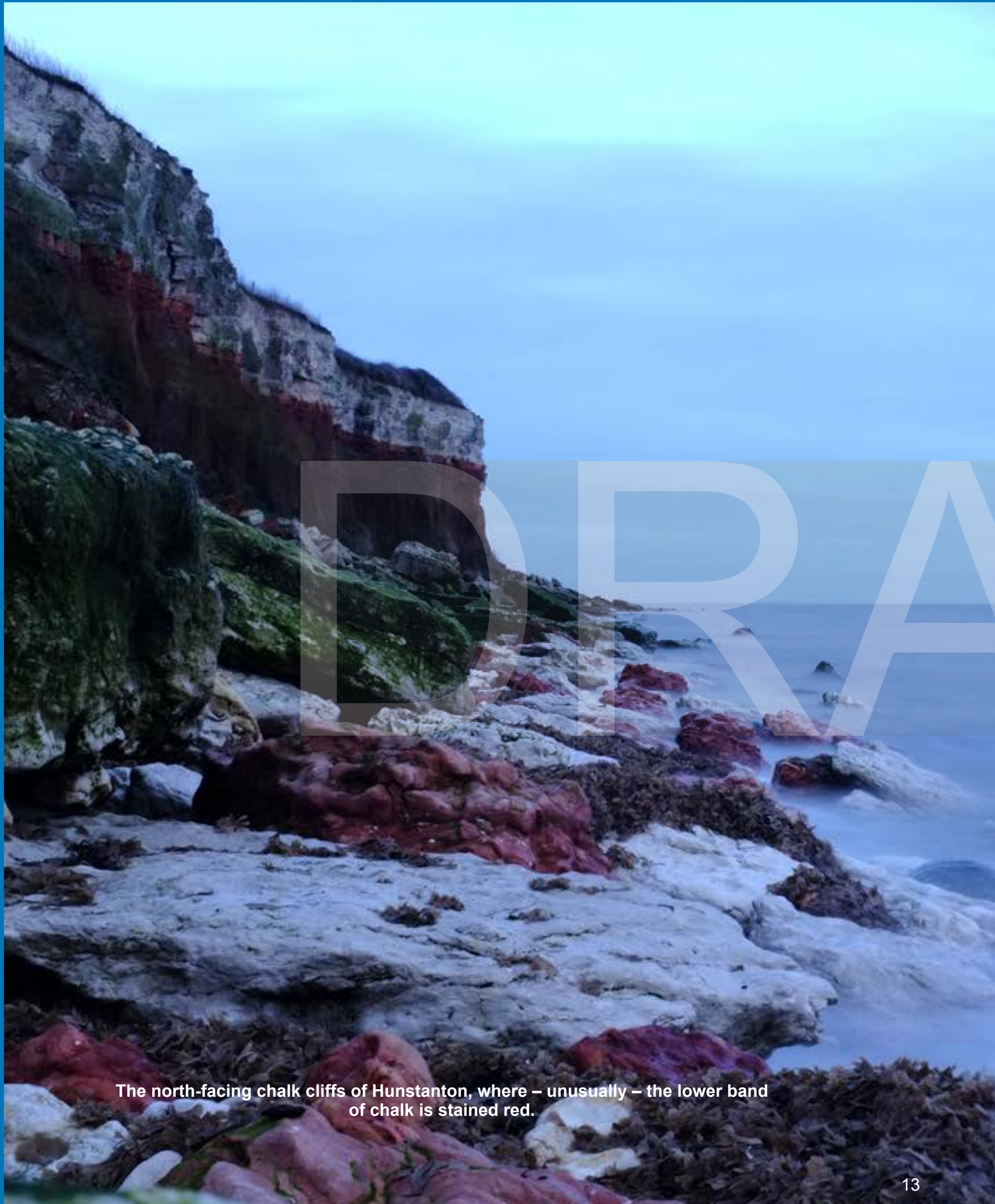
As tectonic plates rifted and shifted, undersea mountain chains rose along the mid-ocean divides. This tectonic / volcanic activity enriched the oceans with calcium and pushed the sea levels higher still, to create shallow inland seaways across large tracts of the Eurasian plate which later became the British Isles, Europe and Russia.

There were few mammals then. On land mostly dinosaurs, and insects. In the sea, rays, sharks and reptiles. But also and especially in the sunlit and shallow seas covering Europe, there were vast clouds of a phytoplankton called a coccolithophore, each microscopic organism wrapped in an interlocking exoskeleton of calcareous plates called coccoliths.

For millions of years these coccolithophores swarmed in infinite abundance, and at death their tiny exoskeleton plates rained down to the bed of the sea, accreting into deep layers. With sea levels so high and all the land flooded, there were no rivers and therefore no sources of sediment which might otherwise have muddied the fossil graveyard. Europe lay at the floor of a perfect kind of tropical infinity pool, and those dead skeletons were left to accumulate uncorrupted by any other substance into the most amazingly pure, deep beds of what became the bright, white calcium carbonate known as chalk.

Stand at the white cliffs of Dover, Hunstanton or Flanborough Head and consider that this sea-bed deepened by about 1cm every 1000 years and you will get some idea of the length of time the chalk sea lasted: 30 million years or so. Hence chalk lent its name to an entire geological epoch – the Cretaceous (from the Latin *creta* meaning chalk).

The Cretaceous period – and the accumulation of chalk on the floor of this pre-historic sea – ended when a giant meteorite struck the earth near the Yucatan



The north-facing chalk cliffs of Hunstanton, where – unusually – the lower band of chalk is stained red.

peninsula in Mexico. The collision caused giant tsunamis, which radiated in all directions, and threw enough dust into the atmosphere to cause global cooling on a vast scale. Most animals including the dinosaurs were wiped out. As was that eustatic engine of chalk creation, the pure chalk sea.

Chalk was laid down across a much larger area than where we now find chalk streams. A map of the globe in the Cretaceous era shows shallow, inland seas stretching in a belt across Europe as far as the Urals. Not to mention across parts of America, Australia and Arabia too. So, why do we find chalk-streams only in England and France?

The process that created the chalk landscape of south-east England began in the early Cenozoic period, as the continents of Europe and Africa slowly collided, lifting and rippling the Anglo-Parisian basin – which was once the sea floor – into a gently rumpled surface that across subsequent epochs of glacial advance and retreat was progressively worn away, while the remains that were left behind after the final glacial retreat were sculpted to form a distinct arc of rolling chalk downs, wrapped around basins of younger deposits and in one place – the Sussex Weald – broken open to expose a dome of older ground with the two ridgeways of chalk either side.

England was once joined to France by that same ridge of chalk hills, which curled south into Normandy, showing how all the chalk streams of the Anglo-Parisian basin are essentially part of the same super-catchment. That link was severed when a vast amount of glacial meltwater from the southern North Sea spilled over the ridge of downs into the English Channel and wore the chalk hills away, leaving behind the iconic white cliffs of Dover.

Across geological time what lies at the surface of the Earth in any given place is in constant flux: but if we slow the clock down to the almost standstill passage of time which is the world we inhabit, for 17,000 years, since the last time glaciers covered Europe, the precise arrangement of those layers at the surface has given us the distinctive topography of chalk hills that is the rolling English chalk downland.

You can almost run a ruler along the north-eastern scarp of those hills from Dorset all the way to Yorkshire. While to the south-west and west the chalk dips progressively under younger rocks and post-glacial sedimentary deposits. To the north-east of that line the chalk has been worn away, exposing Jurassic, Triassic and Devonian layers. Whereas in the other direction, hundreds or even thousands of miles away, the plains of chalk which lie across parts of Europe, through Lithuania, Estonia, Belarus, the Ukraine and Russia, even as far as Kazakstan, are hidden under such deep layers of peri-glacial drift that the rivers in those regions are deeply incised and do not resemble chalk streams as we know them.

The explanation then, as to why chalk streams are globally so rare, points to a serendipitous collision of geology, weathering and climate which means that only in south-eastern England and northern France do we find a mass of chalk rumpled into rolling downs which stretch for hundreds of miles, a chalk massif polished clean by glaciers, but crucially not worn away, nor covered with glacial deposits, which coincides with a temperate, maritime climate and which therefore gives birth to the pellucid, calcareous, spring-fed rivers we call chalk streams.

2.1.1 The chalk aquifer and equable flows

In a natural chalk catchment the chalk aquifer acts like a vast sponge, soaking up rainfall over the winter months, releasing it slowly through the summer. Only a small proportion of flow reaches a chalk stream by surface run-off. This creates a stable flow-regime with the stream comparatively buffered against the extremes of wet weather and drought compared to ‘freestone’ (run-off dominated) rivers.

This stability can be seen in the ratio between high and low flows, generally less than 10:1 in a chalk stream (as low as 3:1), contrasting with ratios of more like 100:1 in clay-dominated catchments. Conversely, although the peak flows in chalk streams are lower than in run-off rivers, they last longer. Naturally, an unmodified chalk stream may flow at the bank-full stage (when the water is at the limit of the holding capacity of the channel) for 30% of the year, compared to only 5% in a freestone river.

The chalk aquifer, water chemistry and temperature

As with flow, the aquifer bestows stability to the chemical and physical properties of the groundwater too. A slow journey through the chalk makes the chalk stream’s flow calcareous and cool, its pH generally around 7.4 to 8 and the water temperature at the springs a steady 11ºC, winter or summer.

The filtering effect of the chalk and the stable, gentle flows also make the natural chalk stream notoriously bright and clear-watered. Even in the downstream reaches, an unmodified chalk stream would run clear after rain, with a high degree of connectivity between the river and the floodplain allowing the surrounding land to act as a secondary filter, in addition to the aquifer. Nutrient levels would naturally have been very low in the unmodified chalk catchment, with total phosphorus around 10 - 30µ/l and nitrogen 200 µ/l allowing for a degree of natural increase in the downstream reaches as a result of nutrient spiralling and the likelihood of the impact of mixed geologies further down the catchment.

2.2 Types of chalk stream

No two chalk-streams are exactly alike, however. Chalk varies in its hardness, stratification, fracturing, and permeability. The layers of superficial deposits which lie on top of the chalk also vary from one valley to the next. There's quite a difference, therefore, between the River Nadder and the River Itchen, although both are considered chalk streams. Similarly, many chalk streams flow from or through deep deposits of glacial drift, and these chalk streams (rivers like the Nar in Norfolk as compared to its purer chalk neighbour the Babingley) are also relatively more responsive to rain.

Even so, all chalk streams are *relatively* equable, low-energy rivers and this underpins their character as rivers and their rich biodiversity.

In reality, we have a spectrum of pure chalk rivers and chalk-influenced rivers. A river is the product of its landscape, especially its geology. The geological map shows our landscape as a marbled swirl of bedrocks and superficial layers and the precise mix of these in any given valley will shape the characteristics of the river that flows through it.

A 'pure' chalk stream, like the upper Itchen, flows from an uninterrupted sweep of chalk hills chalk, overlain by the thinnest layer of limey top-soil. But on the upper Frome in west Dorset, you will find in the headwaters a much more complex mix of chalk, greensand, mudstone and clay, and in places impermeable, clayey top-soils, with the river increasingly flowing over a purer chalk bedrock as it moves downstream. The Itchen is a more equable and gentle river as a result, very rarely coloured by rain (never in its natural state). The Frome is more incised, flashy and powerful.

Even though no one chalk stream is exactly like the next it can be helpful to broadly group chalk streams into four types.

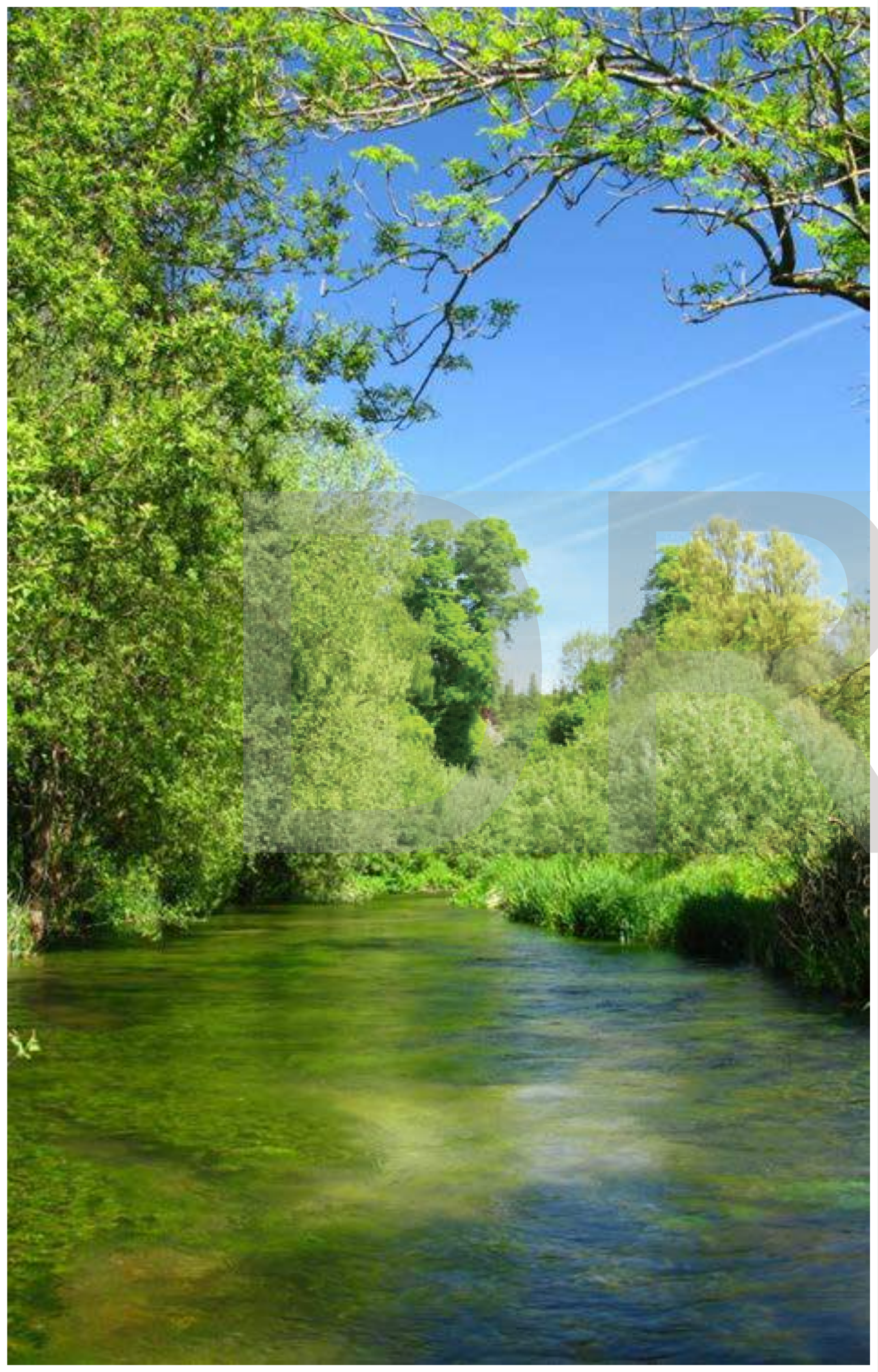
Group A: classic slope-face chalk streams. These are streams that rise directly from the chalk, flow over chalk and then in some cases – usually in their lower reaches – over younger tertiary (sand and clay) deposits. This group would include the majority of the Hampshire-basin streams and the majority of those that flow into the Thames basin. Most of the iconic chalk-streams like the Itchen or Test or Kennet are in this group. Group A can be sub-divided into slope-face streams that flow from and largely across chalk (eg Chess) and those that rise from chalk but mostly flow over tertiary outcrops (eg Wandle)

Group B: mixed-geology chalk streams. These are streams which tend to rise beyond (ie to the north and west) of the chalk but then flow over / through the chalk – this is a minority of chalk streams but the Great Stour in Kent is a good example, rising on Gault clay / greensand and then flowing through the chalk. The Nadder is another example, as is the Hampshire / Wiltshire Avon and the Dorset Frome. These streams will have 'flashier' flow regimes, will tend to colour after heavy rain and take longer to clear too, because of the influence of the headwater geology.

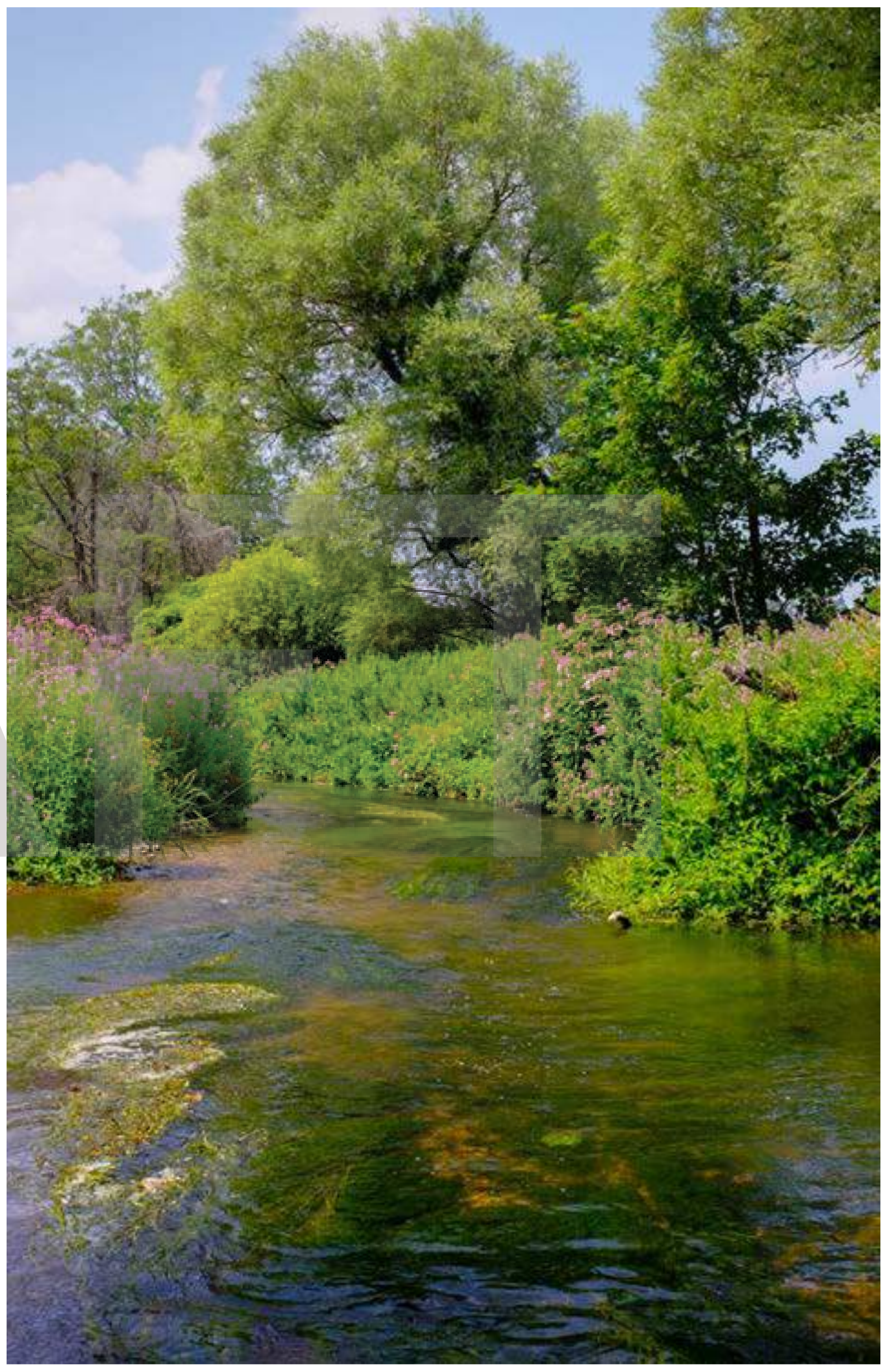
Group C: scarp-face chalk streams. These are the scarp-slope streams which rise at the base of the chalk and tend to run for a short distance over older (clay rich) chalk and then flow out onto the underlying Gault clay and greensand beds. The Fontmell Brook in Dorset is a scarp-slope stream, as are the Lewknor and Chalgrove west of the Chilterns, likewise the streams rising along the spring-line of the Sussex Downs, or the north-flowing streams of the Gog Magog Hills, the westward flowing streams in north-west Norfolk and all the streams east of the Yorkshire Wolds.

Group D: Pleistocene ice chalk streams can fall into any one of the above categories but these streams rise from chalk that was directly impacted by major glacial action during the Pleistocene Ice Age. This group would include the northern Chiltern streams and the East Anglian, Lincolnshire and Yorkshire streams. Group D could be further subdivided into streams that flow from chalk over glacial outwash deposits (the Wensum) and those that flow from chalk onto older (pre-glacial) river deposits, such as the pre-glacial Bytham River which flowed eastwards from the Midlands across Norfolk and emptied into the North Sea north of Lowestoft: the streams that lie between the Chilterns and Norfolk.

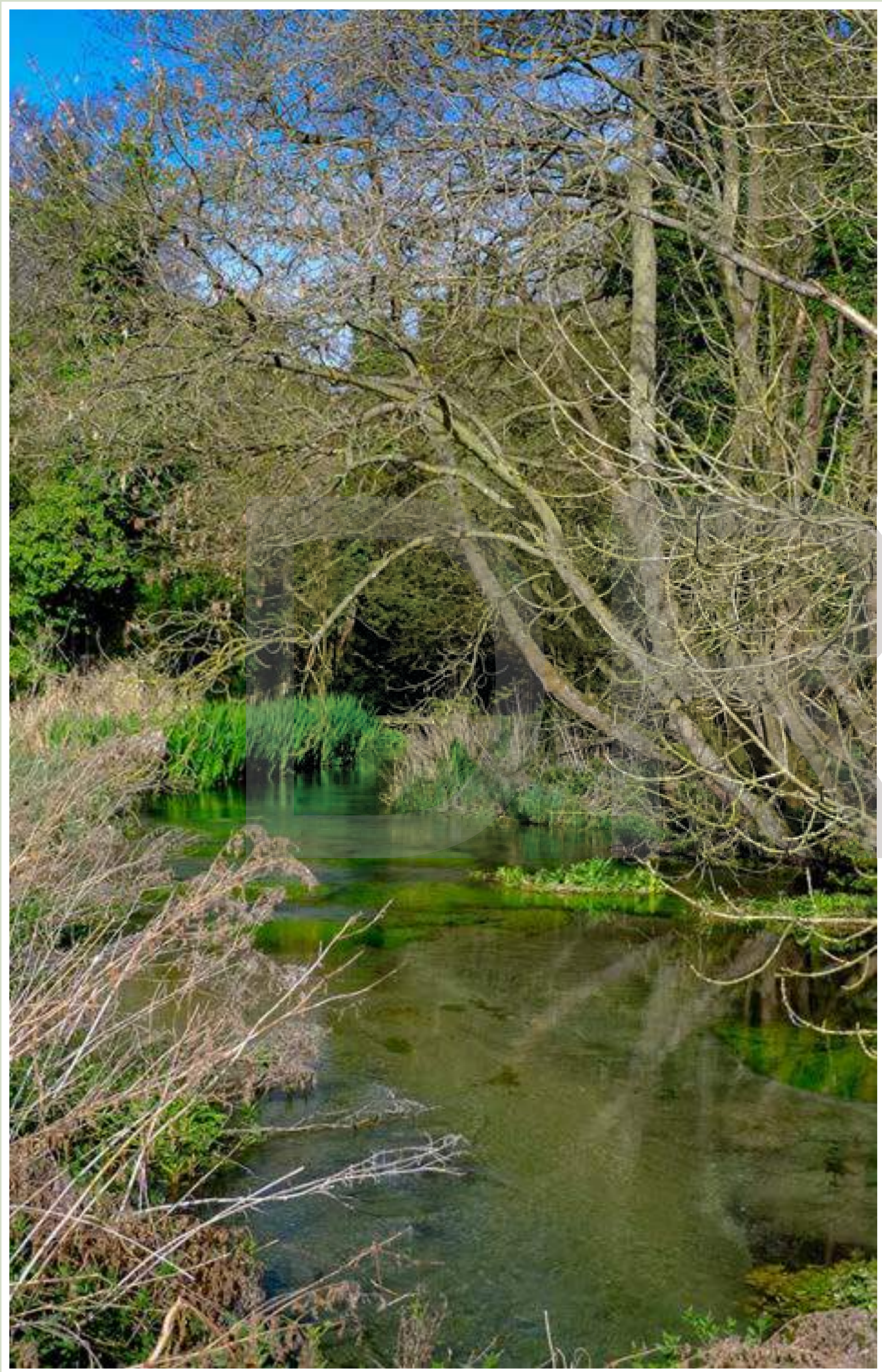
For a list and map of all English chalk streams and their grouping, see Appendix G



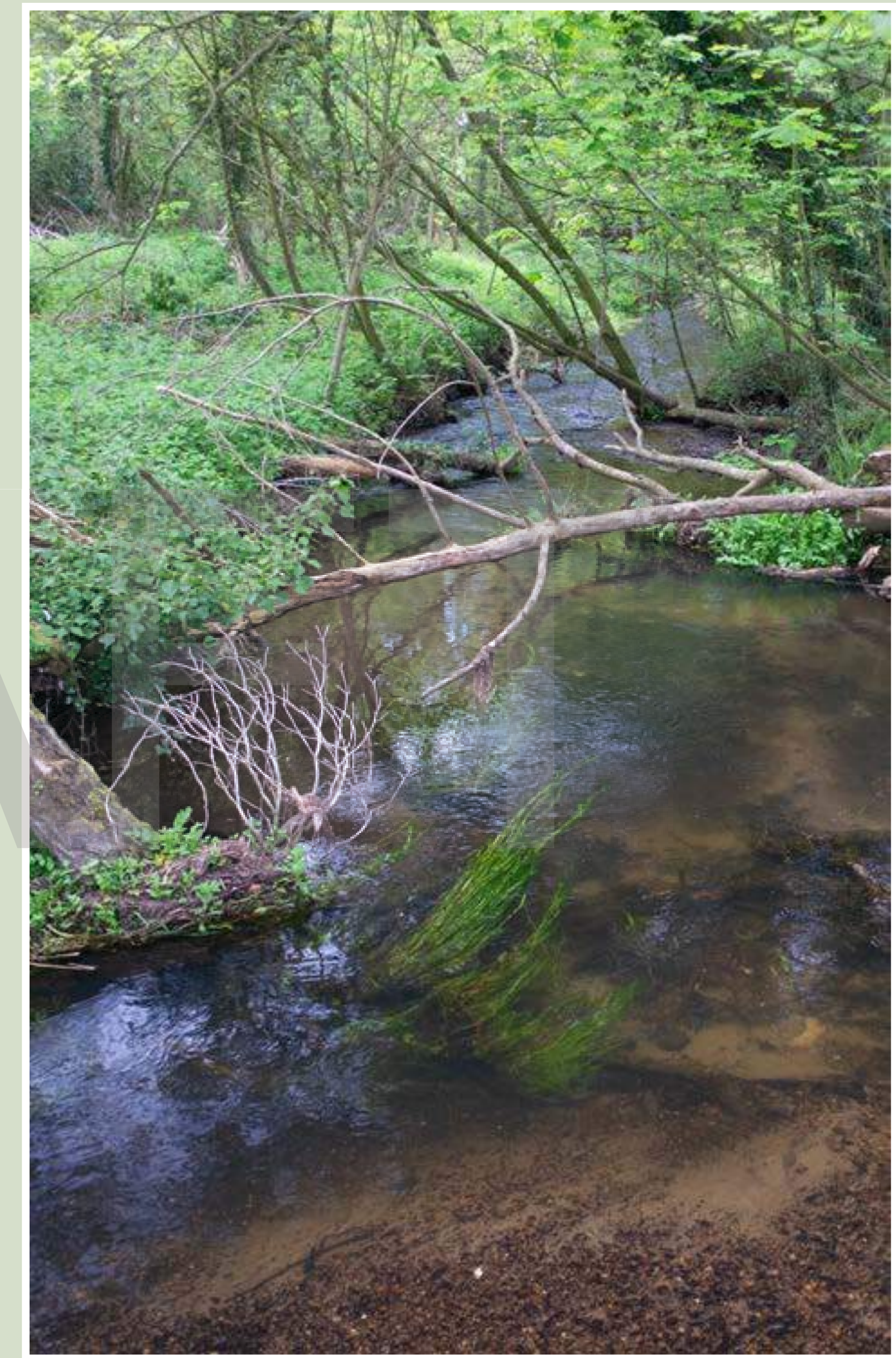
The River Alre in Hampshire: a slope-face ‘classical’ Group A chalk stream.



The River Frome in Dorset: a typical mixed-geology Group B chalk stream



The River Babingley in Norfolk: a scarp-face Group C (and D) chalk stream.



The River Glaven in Norfolk: a Group D ‘under the Pleistocene ice’ chalk stream

2.3 Chalk-stream ecology

The geological foundations of any chalk stream catchment shape the hydrology and physical form and therefore the ecology of the stream. But the ecology shapes the stream too.

The shaping forces of glaciation

Chalk streams are low-energy, equable rivers. The distinctive, rolling valleys they flow through, however, were carved by much more energetic forces during multiple phases of glaciation which began a little over half a million years ago and ended with the Pleistocene glaciation, 70,000 to 9,000 BC. The protracted freeze and thaw at the edge of the ice generated massive meltwater flows which rushed south over semi-frozen chalk hills, carving our distinctive chalk downland. Much of the chalk – being porous, soft and soluble – was worn away, but the insoluble and harder flint buried within it (flint also derives from the remains of sea animals: it is a precipitate of the silica-based exoskeletons of diatoms, radiolarians and sponges) was crushed by glacial action into sand and gravel and debouched onto the valley floors.

The shaping forces of ecology

When the glaciers finally retreated about 10,000 years ago, the chalk thawed and the more gentle engine of spring-fed flow kicked into life, as did the ecological forces of landscape engineering: the vegetation and animals which shaped the evolving chalk stream.

The role of wood and vegetation

Higher-altitude spring-fed streams in New Zealand or Patagonia may give some indication of the shape of the early Holocene chalk stream, with their multiple primary and secondary interconnected and ultra-stable channels meandering through tussocky, steppic grassland. On the English chalk stream, however, trees and beavers would have come to play a more decisive roll as the climate warmed. Progressively the open grassland of a frigid and chilly post-glacial climate will have made way for the early colonisers of pine, dogwood, juniper, successive invasions of birch, then finally the oak, alder and willow of a deciduous and temperate wet woodland.

The succession onto the chalk-stream floodplain of trees like alder, willow and oak, growing and dying, blown over by wind or felled by beavers, would have had a significant shaping impact on the evolution of the pre-human chalk stream. Fallen trees and beaver dams will have energised and subtly destabilised the formerly ultra stable grassland channels, compelling the streams to break out of their banks and find new pathways across the floodplain.

Then there was the more subtle but just as vital role of riparian and in-stream plants, as well animals, fish, invertebrates all adding not only to the variety of habitat in a chalk stream, but the morphological processes too: ranunculus, for example, fractures the flow into a series of mini channels within channels, packing out the water level, causing localised scour or deposition and the sustained saturation of riparian soils. Vast numbers of spawning salmonids would have mobilised the gravel. Large herbivores would have grazed the banks and the mosaic of woodland and meadow.

The 'natural' chalk stream

We could probably call this post-glacial, pre-human phase of the chalk stream's existence, the natural chalk-stream: meandering, broad and shallow, gravelly channels, oozing under and around fallen trees, breaking out into ponds, nuzzling the tussock-lined banks in semi-drowned meadows.

Suffice to say, it is difficult to find a chalk stream today in anything like what we might call this 'natural' (pre-human) physical and ecological state. There are wild sections of headwater scarp-streams in the Sussex Downs, parts of the Wraxall Brook and Bere Stream in Dorset, or the Nar in Norfolk, where the river flows in multiple channels through woodland and fen. Similarly, there are few examples of the natural fen habitat which would have surrounded the streams, and the springs: most of the spring-line fens have by now been drained into a fretwork of ditches. It is a key message in this plan that chalk-stream restoration should include landscape-scale restoration of these fen landscapes along the spring line: the benefits would roll on down through the whole system.

While it is not impossible to think that we might be able to restore a larger proportion of our chalk stream habitats to something much closer to this state than we have today, by taking agriculture away from the river's edge and off the floodplain, by restoring natural flow regimes, groundwater levels, floodplain saturation and channel forms, for much of the resource we have greatly modified rivers which are nevertheless home to a diverse, sometimes rare and endangered range of plants and animals, from the winterbourne reaches, all the way through the chalk stream system and across the wider riparian and surrounding landscape.

The winterborne stonefly (above right)

Discovered in England as recently as 2009 *Nemoura lacustris* appears to be unique to ephemeral streams in southern England, specifically Dorset, Wiltshire and West Sussex. Like the scarce purple dun, the species survives the dry phase as dormant eggs, requiring cool, damp conditions and exposure to cold to remain viable. The eggs can hatch as late as December and then develop quickly to their adult stage. They are nationally rare.

Winterborne black flies

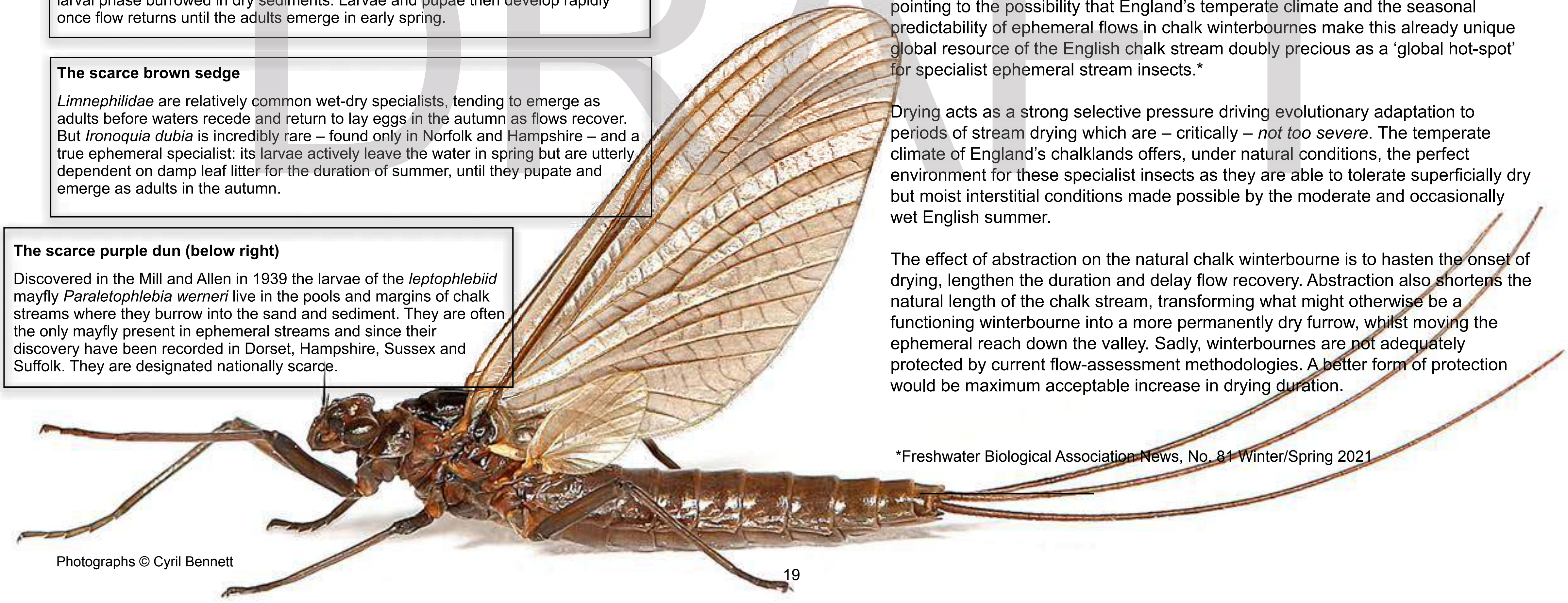
First discovered by Mike Ladle and John Bass in Dorset's south Winterbourne in 1975, *Metacnephia amphora* is restricted to ephemeral streams in southern England. The filter-feeding larvae of *Metacnephia* and also *Simulium latipes* (discovered in 2013) have adapted to contrasting abiotic conditions, with a dormant larval phase burrowed in dry sediments. Larvae and pupae then develop rapidly once flow returns until the adults emerge in early spring.

The scarce brown sedge

Limnephilidae are relatively common wet-dry specialists, tending to emerge as adults before waters recede and return to lay eggs in the autumn as flows recover. But *Ironoquia dubia* is incredibly rare – found only in Norfolk and Hampshire – and a true ephemeral specialist: its larvae actively leave the water in spring but are utterly dependent on damp leaf litter for the duration of summer, until they pupate and emerge as adults in the autumn.

The scarce purple dun (below right)

Discovered in the Mill and Allen in 1939 the larvae of the *leptophlebiid* mayfly *Paraletophlebia werneri* live in the pools and margins of chalk streams where they burrow into the sand and sediment. They are often the only mayfly present in ephemeral streams and since their discovery have been recorded in Dorset, Hampshire, Sussex and Suffolk. They are designated nationally scarce.



Photographs © Cyril Bennett

2.3.1 Winterbournes

Chalk streams can dry quite naturally in their upper reaches when groundwater levels fall through the summer and into early autumn. Natural winterbournes are ecologically important, dynamic habitats in which the shifts between naturally-flowing and seasonal, occasionally-dry states supports high biodiversity and communities of plants and insects which are uniquely adapted to these conditions.

Pondwater crowfoot (*Ranunculus peltatus*), watercress (*Rorippa nasturtium-aquaticum*), fools watercress (*Apium nodiflorum*) sweetgrass (*Glycera spp.*) and brooklime (*Veronica beccabunga*) are typical of chalk stream winterbourne plant communities.

Some rare species of insect are specially adapted too, with life-cycles which enable them to survive dry stages – see opposite. Notably, these insects rely on the wet and dry shifts that characterise chalk winterbournes. Recent research is pointing to the possibility that England's temperate climate and the seasonal predictability of ephemeral flows in chalk winterbournes make this already unique global resource of the English chalk stream doubly precious as a 'global hot-spot' for specialist ephemeral stream insects.*

Drying acts as a strong selective pressure driving evolutionary adaptation to periods of stream drying which are – critically – *not too severe*. The temperate climate of England's chalklands offers, under natural conditions, the perfect environment for these specialist insects as they are able to tolerate superficially dry but moist interstitial conditions made possible by the moderate and occasionally wet English summer.

The effect of abstraction on the natural chalk winterbourne is to hasten the onset of drying, lengthen the duration and delay flow recovery. Abstraction also shortens the natural length of the chalk stream, transforming what might otherwise be a functioning winterbourne into a more permanently dry furrow, whilst moving the ephemeral reach down the valley. Sadly, winterbournes are not adequately protected by current flow-assessment methodologies. A better form of protection would be maximum acceptable increase in drying duration.

*Freshwater Biological Association News, No. 81 Winter/Spring 2021

2.3.2 Chalk-stream plants

Chalk streams feature a higher species richness of in-stream and riparian plants than any other type of river in the country. Most distinctive of all plants in the perennial reaches is the chalk stream ‘classic’ brook water-crowfoot, (*Ranunculus pencillatus subs pseudofluitans)* whose constellations of white flowers rise above the waterline in spring and early summer. Ranunculus needs swift-flowing water to grow, and its dense clumps are home to millions of simulidae larvae which filter diatoms from the water: the perfect example of ecological engineering.

Other distinctive perennial chalk stream species include: river water-dropwort (*Oenanthe fluviatilis*); water starwort (*Callitriche*) which grows in neat clumps, and can tolerate slower, shadier and siltier water than ranunculus, and is often the dominant plant in wooded and slower reaches, or in low-flow years; lesser water-parsnip (*Berula erecta*) with its dense, creeping clumps of broad and bright green leafage; water speedwell (*Veronica anagallis-aquatica*); fool’s water-cress and water cress; water forget-me-not and the distinctive unbranched bur-reed, aka eel-grass (*Sparganum emersum*). In slower reaches in addition to starwort you can expect to find the handsome, and eponymous mare’s- tail (*Hippuris vulgaris*) sashaying from side to side in the flow, water millfoil (*Mirriophyllum spicatum*), various species of pondweed (horned and fennel-leaved), and common club-rush, with its tall, rod-like leaves rising above the surface.

The channel margins feature reed canary-grass (*Phalaris arundinacea*), reed sweet-grass (*Glyceria maxima*), drifts of common reed (*Phragmites australis*) and tall, vibrant stands of the spear-leaved bur-reed (*Sparganum erectum*). Then there are the architectural stands of hemlock water-dropwort (*Oenanthe crocata*), and greater tussock-sedge (*Carex paniculata*).

Flag-iris (*Iris pseudacorus)* with its distinctive yellow flowers, is the almost quintessential marginal flower, decking out the channel margins in early summer like celebration-day bunting. But purple loosestrife (*Lythrum salicaria*) is another plant which brings colour to the river’s edge, along with white and purple comfrey (*Symphytum officinale*), water-mint (*Mentha aquatica*), hairy willow-herb, (*Epilobium hirsutum*), water forget-me-not (*Myosotis scorpiodes*) and marsh marigold (*Caltha palustris*).

If the land around the stream is uncultivated the banks will merge seamlessly to fen, swamp and carr wet-woodland, dominated by reed-grass and common reed, as well as greater tussock sedge and tree-species that thrive on base-rich moist or saturated soils: willow, alder, ash (threatened now, sadly) and oak. These carr woodlands are vital to the morphological function of the stream: the patchily shady and sunlit river is more bio-diverse; dead or wind-blown trees in the stream provide vital refugia for fish and invertebrates; and vitally, they give energy to the benign and ultra-stable flows of the chalk stream, leading to a more varied and dynamic channel form.

Healthy chalk streams feature incredible biodiversity and to describe every characteristic plant, fish and insect would take up dozens of pages. A comprehensive listing can be found in the English Nature, Environment Agency 1999 publication *The Conservation and Management of Chalk Streams* (details in Appendix A).

2.3.3 Chalk-stream invertebrates

Chalk streams feature abundant and diverse invertebrate communities, with such a large number of distinct species that a comprehensive list would take up half this report. To keep things simple, the chalk stream invertebrates can be grouped as a) insects including Ephemeroptera (the upwinged mayflies), Plecoptera (stoneflies), Trechoptera (caddis flies) and Coleoptera (beetles); b) Crustaceans, including freshwater shrimps, hoglice and crayfish; c) molluscs (Gastropoda) including snails, mussels and slugs and d) Hirudinea, including leeches, flatworms and round-worms.

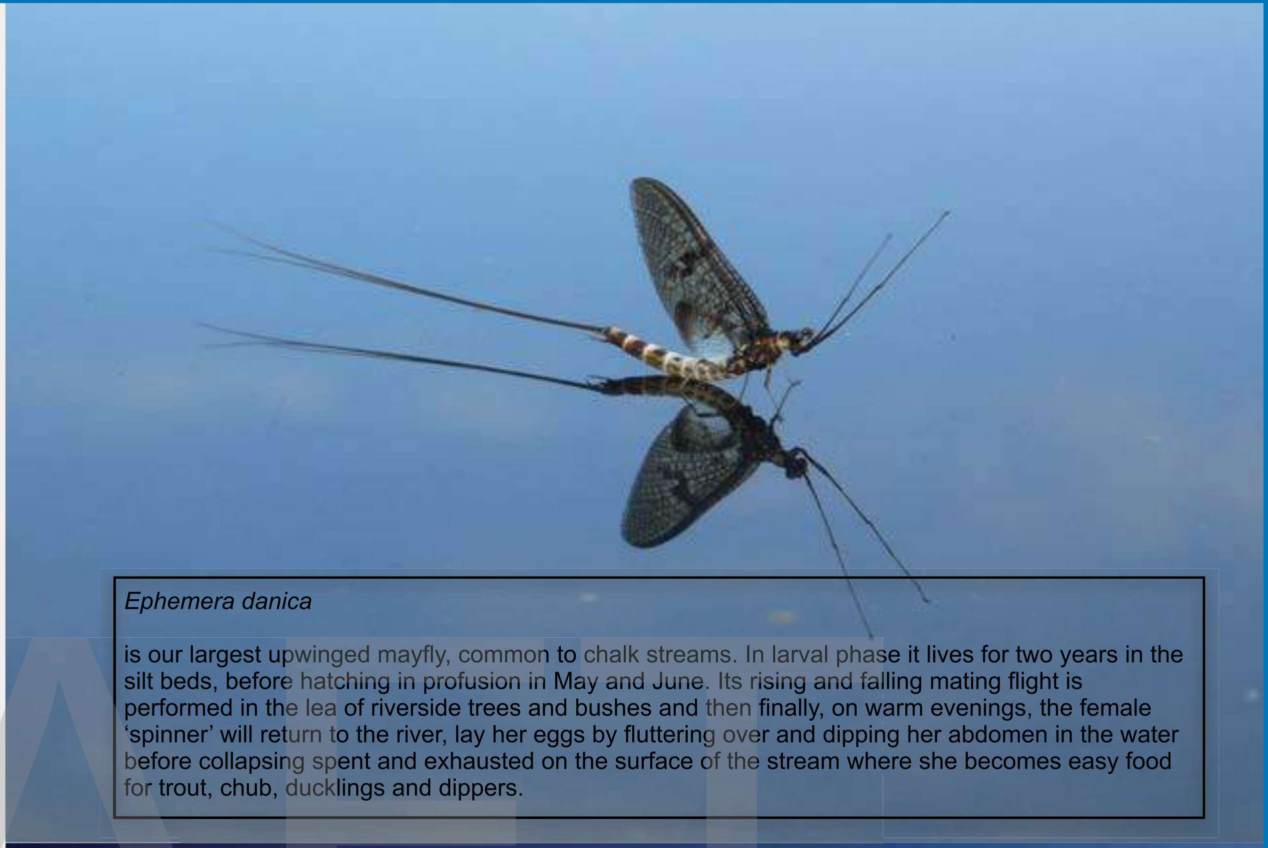
The population balance in terms of presence and abundance changes according to subtleties of habitat and to location on the river system: for example there are specialist winterbourne species as described on page 16; many of the Ephemeroptera species thrive in the gravelly, well-oxygenated reaches of the perennial upper river, while the hoglouse *Asselus aquatics,* for example, and certain species of pea mussel are much more common in the downstream, slower-flowing reaches of the larger chalk streams.

The famous *Ephemera danica* mayfly, so prominent because of the the size of the insect (it is the largest upwinged mayfly) and the abundance of its hatches (legend has it they were once used to fertilise allotments in the Kennet valley), is actually rare or absent from the very upper reaches of the swiftest, clearest chalk streams, because in its larval, underwater phase it lives in silt.

It is worth underlining the historical and natural abundance of many of the chalk stream's invertebrate species, an abundance that is rare to find nowadays. The mineral-rich, pure, equable, cool and oxygenated waters and sheer volume of habitat in the gravel substrates and dense macrophyte growth marked chalk streams out for their stunning abundance of fly-life and this is a large part of why these rivers gained such a reputation in the 19th century as streams on which dry fly anglers could practice their craft to a highly refined degree.

The reliable presence of upwinged mayflies on the stream surface is one easy way to mark out the *relative* ecological health of the stream: you will see good numbers of upwinged flies almost every day of the year on the Alre in Hampshire. You will rarely see them on the Cam. This is down to the *relative* degradation of the habitat and water quality: many of the classic chalk-stream invertebrate species, and those that are most visible during the final stages of their life-cycle when they hatch and float in flotillas down the stream, are profoundly sensitive to pollution (see section 5.2.2), reduced flows and siltation.

The native white-clawed crayfish (*Austropotomobius pallipes*) deserves special mention: although not confined to chalk streams, it requires hard, alkaline water, and chalk streams should be a natural stronghold for this greatly endangered indigenous crustacean. Sadly, the chalk rivers in which one can find white-clawed crayfish are now few and diminishing rapidly as the invasive signal crayfish continues to spread (see section 6.3.6).



Ephemera danica

is our largest upwinged mayfly, common to chalk streams. In larval phase it lives for two years in the silt beds, before hatching in profusion in May and June. Its rising and falling mating flight is performed in the lea of riverside trees and bushes and then finally, on warm evenings, the female 'spinner' will return to the river, lay her eggs by fluttering over and dipping her abdomen in the water before collapsing spent and exhausted on the surface of the stream where she becomes easy food for trout, chub, ducklings and dippers.

The table opposite lists well-known chalk-stream species of mayfly, caddis fly and stonefly according to their pollution sensitivity. Monitoring the invertebrate populations in chalk streams is a vital component of tracking the ecological health of these streams (see fba.org.uk and riverflies.org).

10 = highest sensitivity.
Ref: DoE / NWC Biological Monitoring Working Party.

Group	Family	Species (angler's name)	Score
Mayfly	Heptageniidae	Heptagenea sulphuria (Yellow May) Rithrogena semicolorata (Olive Upright)	10
Mayfly	Leptophlebiidae	Paraleptophlebia submarginata (Turkey Brown)	10
Mayfly	Ephemerellidae	Ephemerella notata (Yellow Evening Hawk) Serratella ignita (Blue-winged Olive)	10
Mayfly	Ephemeridae	Ephemera danica (Mayfly or Green Drake)	10
Stonefly	Perlidae	Isoperla grammatica (Yellow Sally)	10
Caddis	Goeridae	Silo nigricornis (Black Sedge)	10
Caddis	Brachycentridae	Brachycentrus subnubilus (Grannom)	10
Caddis	Sericostomatidae	Sericostoma personatum (Welshman's Button)	10
Caddis	Leptoceridae	Anthripsodes cinereus (Brown Silverhorn) Mystacides azurea (Black Silverhorn)	10
Caddis	Rhyacophilidae	Rhycophilia dorsalis (Sandfly)	7
Caddis	Polycontropodidae	Polycentropus flavomaculatus (Dark Sedge)	7
Caddis	Limnephilidae	Halesus radiatus (Caperer) Limnephilus binotatus Limnephilus lunatus (Cinnamon Sedge) Potamophylax latipennis (Large Cinnamon)	7
Mayfly	Caenidae	Caenis luctuosa (Angler's Curse) Caenis mucrura (Angler's Curse) Caenis rivulorum (Angler's Curse) Caenis pusilla (Angler's Curse)	5
Caddis	Hydropsychidae	Hydropsyche instabilis (Grey Flag) Hydropsyche pelucidilla (Grey Flag)	5
Mayfly	Baetidae	Alainites muticus (Iron-blue) Baetis fuscatus (Pale Watery) Baetis rhodani (Large Dark Olive) Baetis scambus (Small Dark Olive) Baetis vernus (Medium Olive) Centroptilum luteolum (Small Spurwing) Cloeon dipterous (Pond Olive) Nigrobaetis niger (Iron-blue) Procleon bifidum (Pale Evening) Procleon pennelatum (Large Spurwing)	4

2.3.4 Chalk-stream fish

The salmonids indigenous to all English chalk streams include the brown trout (*Salmo trutta*) and Atlantic salmon (*Salmo salar*). The grayling (*Thymallus thymallus*) is considered a native in chalk streams, but is only indigenous to the Avon and Thames chalk stream catchments*. It has been introduced to many other chalk streams but the distribution is still patchy.

The distribution of the threatened Atlantic salmon is also patchy, for a different reason: barriers to migration. It is now very much limited to the southern chalk streams of Wessex, and a few in the Thames. Once in a blue moon salmon will show up in other catchments, the Kentish Stour, or the Ouse, for example. These are likely strays, as are some of the salmon in the Thames, but straying is an evolutionary adaptation which enables salmon to repopulate streams from which they have been lost.

The brown trout is closely related to the salmon: they can even hybridise and often do in the Dorset Frome. But brown trout do not depend on a marine phase in their life cycles (though a proportion of any trout population does go to sea) and so they remain in at least the headwaters of almost every English chalk stream and are a hallmark of these rivers. Salmon, trout and grayling are all highly sensitive to pollution, and will be rare or absent in severely abstracted, eutrophic reaches.

If the faster-flowing, cooler upper reaches of most chalk streams are apparently dominated by brown trout, they are also heavily populated, though less visibly, by bullheads (*Cottus gobio*), minnows (*Phoxinus phoxinus*) and stickleback (*Gasterosteus aculeatus*) which thrive in the upper reaches and though diminutive can make up nearly a third of the fish biomass in chalk streams. Eels (*Anguilla anguilla*) will also thread their way to the headwaters of chalk streams, though the eel population builds in a downstream direction. The sea and river lamprey (*Lampetra marinus and fluviatilis*) are also migratory, feeding in coastal / estuarial waters and entering the river at spawning time.

Grayling, if present, will build in number through the lower-upper to middle reaches: they spawn on slightly finer substrates than trout and salmon and tend to prefer medium-paced glides. Rheophillic cyprinids, especially dace (*Leuciscus leuciscus)*, but also roach (*Rutilus rutilus*) and chub (*Leuiscus cephalus*) are common in the middle-to-lower reaches of most chalk streams, along with perch (*Perca fluviatalis*) and pike (*Esox lucius*) and the brook lamprey (*Lampetra planeri*).

While salmon, sea trout and lamprey migrate to sea to feed and eels migrate to sea to spawn, all of the rheophillic cyprinids and brown trout also are at least partially migratory within the river system itself, underlining the importance of removing barriers to migration (of which there are many) in any good catchment-scale restoration programme; bearing in mind that barriers can also be chemical-, flow- and temperature-based.

* The grayling is also native to the Ribble, Trent, Severn, Wye, Welsh Dee and Yorkshire Ouse.

While the brown trout (above) is a widespread and defining chalk stream fish, the protected species present in chalk streams include its close and threatened cousin the Atlantic salmon, as well as the bullhead, brook, river and sea lamprey, spinned loach and grayling.

2.3.5 Chalk-stream birds and mammals

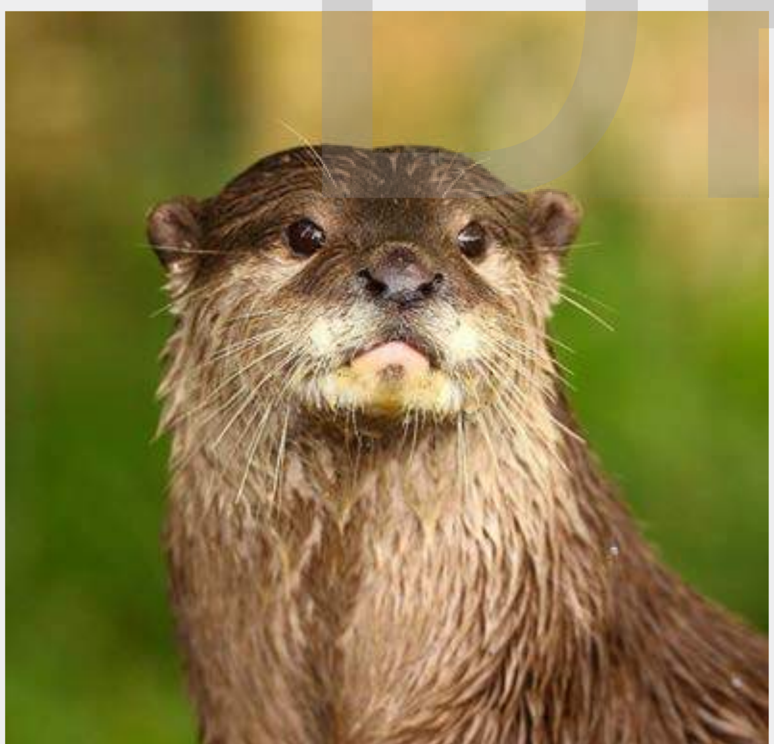
The richly biodiverse, fecund chalk stream, with its sustained spring flows, saturated floodplain, and abundance of food is also home to a great variety of birds and some key mammals. Marshy areas in the riparian zone, the valley sides and springheads attract snipe (*Gallinago gallinago*), which may stay to breed in the right habitat, redshank (*Tringa totanus*) and lapwing (*Vanellus vanellus*). Scrub and reed-beds support sedge warbler (*Acrocephalus schoenobaenus*) and reed bunting (*Emberiza schoeniclus*). On and around the river itself the kingfisher (*Alcedo atthis*) is a common sight (and sound), as is the dipper (*Cinclus cinclus*) on the riffles, the little grebe (*Tachybaptus ruficollis*), moorhen (*Gallinula chloropus*) and even the rare water rail (*Rallus aquaticus*).

The occasionally-inundated floodplains of the larger chalk streams are important areas of flooded meadow and provide habitat for white-fronted geese (*Anser albifrons*), Bewick's swan (*Cygnus columbianus*) and mute swan (*Cygnus olor*), golden plover (*Pluvialis apricaria*) and yellow wagtail (*Motacilla flava*). Dense beds of phragmites are home to the reed-warbler (*Acrocephalus scirpaceus*), while chalk streams are a nationally important habitat for the rare Cetti's warbler (*Cettia cetti*), grasshopper warbler (*Locustella naevia*) and pochard (*Aythya ferina*).

Swifts (Apus apus), swallows (Hirundo rustica), house and sand martins (Delichon urbica and Ripiria riparia) all use the excellent feeding opportunities provided by dense hatches of insects. Like the hirundines, Daubenton's bat (*Mysotis daubentonii*) feeds low over water, and is a common sight for anglers making the most of the evening rise in summer. The less-cultivated chalk streams, with broad riparian corridors of woodland provide the best habitat, with roosting sites in old decaying trees, fractured bark and branches.

Chalk streams provide good habitat for the otter (Lutra lutra), water vole (*Arvicola terrestris*) and water shrew (*Neomys fodiens*). The otter is making a comeback and is now a relatively common site on healthy reaches. The water vole has suffered extreme decline nationally, mostly because of the spread of American mink. Chalk streams where the mink are absent or regularly trapped provide excellent habitat where the endearing vole can reach very high densities: it is partial to dredged river-banks, making restoration projects aimed at addressing this particular problem more challenging where vole numbers are high. Like the vole, the water shrew is also threatened by the American mink, but where mink are absent the water shrew finds favourable habitat in and around a healthy chalk stream. Mink are most usually controlled by fishermen and river keepers.

Below: the otter, kingfisher and water vole are distinctive sights on chalk streams



© Tim Filce / Wikimedia

© Andeas Trepte www.avifauna.info / Wikimedia

© Peter Trimming / Wikimedia

3. The trinity of ecological health

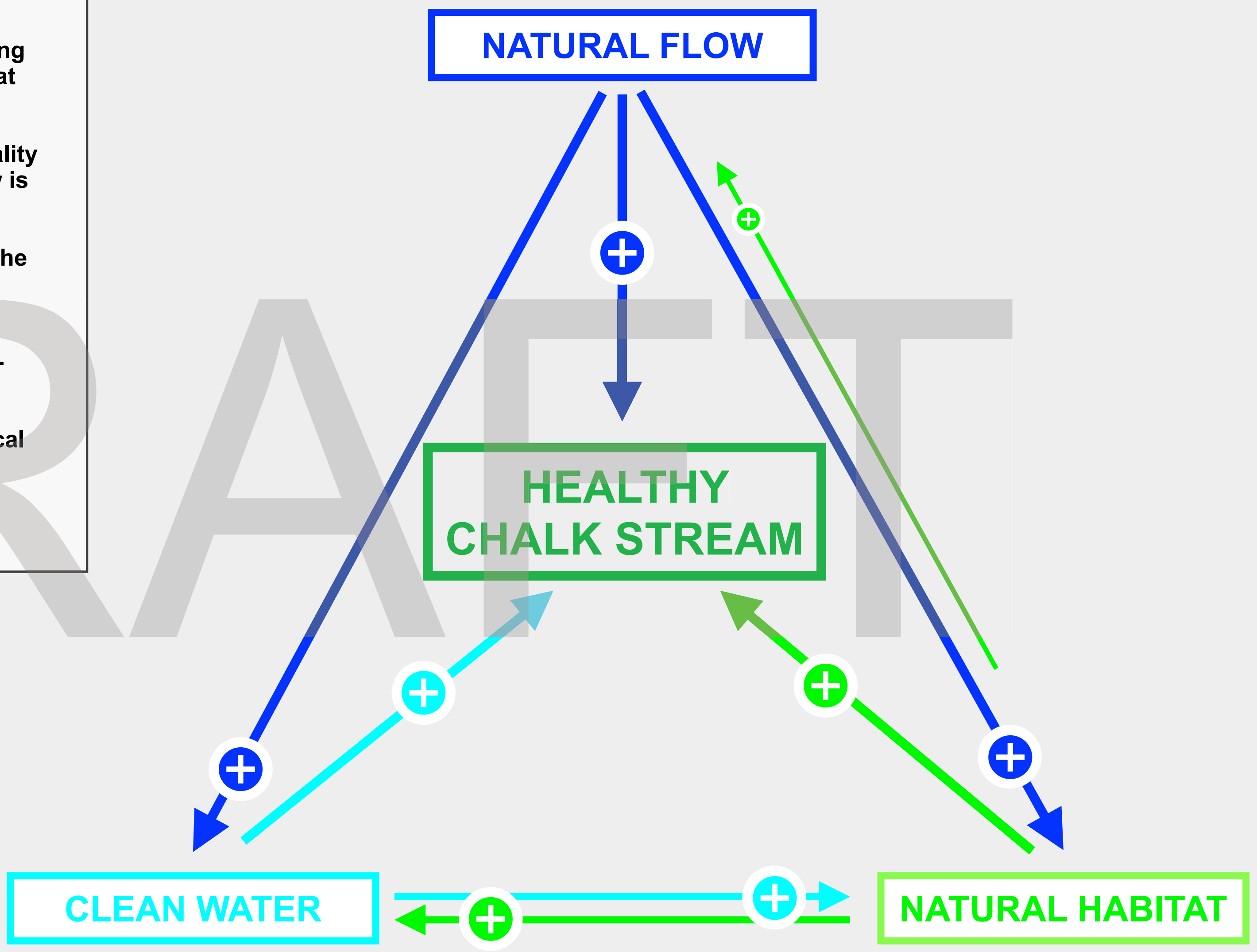
Chalk-stream ecological health depends on three things:

- **Water quantity (the naturalness of the flow regime)**
- **Water quality (how clean the water is)**
- **Physical habitat quality (the physical shape of the river, incorporating biological factors such as invasive species which can degrade habitat both directly and indirectly)**

Re-naturalising flow will improve river health by improving water quality and physical habitat. But the beneficial impact of re-naturalising flow is increased if water quality or physical habitat are also improved.

Improving water quality or physical habitat will benefit the health of the chalk stream but not as much as when flow is also improved.

The best restoration strategy will address all three together: re-naturalising flow and improving water-quality while using landscape-scale physical-habitat improvements to consolidate the beneficial impacts of both (by, for example, re-saturating floodplains, restoring headwater fen, or floodplain connectivity) in order to deliver ecological improvements which are more effective by orders of magnitude than when the three elements are improved in isolation.



A simple diagram illustrating the positive correlations between flow, water quality and physical habitat, to show how positive gains in ecological health are maximised by making improvements to all three components.
The arrows may be reversed for negative correlations, showing how water quality and habitat diminish as flow is lost to abstraction.

4. Water quantity: restoring flow

4. Water quantity

4.1 The ecological impacts of low flows

Equable flows are a notable feature of the natural chalk stream (see 2.3.1 above) to which the ecology is naturally adapted. Occasional low flows resulting from dry periods are also a natural phenomenon. Many chalk streams feature winterbourne reaches which dry naturally for a few weeks in most summers and some of the plants and insects in these reaches are winterbourne specialists, with life cycles specially adapted to brief periods of drying. There is a significant difference between this seasonal and climatic but natural phenomenon and the unnaturally suppressed flows caused by groundwater abstraction, which are the subject of this analysis.

In terms of the impact on ecology, the key points are that chronic and unnaturally low flows adversely impact the ecology of a chalk stream by:

- reducing velocity of the current
- reducing water depth and the spatial volume of in-channel habitat
- increasing the residence time of water in the river channel
- increasing the temperature of water in the channel
- increasing the concentration of pollutants
- reducing oxygen levels
- increasing sediment deposition
- reducing or interrupting the lateral connectivity between the river and its marginal, riparian habitats and floodplain
- disrupting the passage of migratory fish

It is important to understand the ***interaction between*** and the ***spiralling effects*** of these pressures. For example reduced water velocity will limit the growth of the rheophilic (current-loving) plants like ranunculus and increase the deposition of sediment in the channel. The sediment in turn also limits the growth of ranunculus. The lack of ranunculus reduces the inter-crown scour that flushes sediment. Already reduced summer flow velocities are reduced yet further because the channel is effectively bigger relative to the volume of water for the lack of ranunculus (which naturally has the effect of packing out the summer flows). The reduced flow and the lack of ranunculus drive up water temperature, decrease oxygen levels, limit habitat for fish and insects. And so on. The chalk stream becomes locked in a vicious circle of decline and the negative impact of every other stress exerted on the system is magnified.

Many of the plants and animals native to chalk streams are adapted to and depend upon adequate **flow velocity**, including the designated / protected ranunculus and salmon as well as other rheophilic plants (starwort, berula etc), salmonid and cyprinid fish species, and numerous species of riffle-dwelling invertebrates. The presence and abundance of these animals and plants are fundamental features of a healthy chalk stream. All of them suffer under unnaturally suppressed flows and the range of concomitant impacts.

The spiralling impact of low flows on ranunculus will reduce the depth of water, but low flows definitively **reduce water depth** anyway: the combined impact is a reduction in the volume and value of available habitat for fish and insects.

Low flows will **increase the temperature** of the water, but the chalk-stream ecology is adapted to cool water: for the salmonid fish community, for example, temperatures over 22ºC can be fatal. Increasing water temperature will impact metabolic rates in animals and raise biochemical reaction rates in plants, causing significant diurnal fluctuations in oxygen levels, stressing fish and insects.

Low flows **increase the concentration of pollution** because as flows diminish there is less water as dilutant. Nutrient levels that might otherwise be tolerable can become damaging, even with the nutrient source at a constant. Low flows also increase pollutant levels by increasing the deposition of sediment on the bed of the river: deep beds of sediment hold chemical and biological pollutants, but sediment also **fills in and smothers the interstitial spaces in the stones and pebbles** on the river bed in which many chalk stream insects species live. Sediment also smothers and kills salmonid eggs through effective suffocation, physical and biological.

Naturally a chalk stream flows at bank-full stage for a very high proportion of the year (30%). Saturated riparian margins and floodplains and a fluency of connection between the river and those wetted marginal areas are hallmarks of a healthy chalk stream. Although other factors, especially dredging, and the creation of perched channels to drive mills and water-meadows, have caused rivers to sag back inside unnaturally disconnected channels, reduced flows is another very significant cause of this **disconnection between the river and its surrounding landscape**. It is also important to note the ways in which these channel modifications render the chalk streams less resilient to the ecological impacts of low flows, whether natural or unnatural in origin.

The value of re-establishing the hydrological connectivity between the chalk stream and its supporting riparian, fen and floodplain habitats is a key tenet of this strategy: re-naturalising flows is essential to this process.

4.2. A history of groundwater abstraction

While chalk streams, springs and wells have for centuries been used as a source of water, groundwater abstraction for public water supply accelerated markedly through the second part of the 20th century particularly following the 1945 Water Act.

The 1945 act marked the beginning of a national water-supply policy, making it a requirement by law to obtain a licence from the Minister to dig boreholes and abstract water. Ecological protection was built into the Act: where the rights would, in the opinion of the Minister, substantially reduce the flow of water in a stream, the Minister could insist on gauges and minimum flows below which no abstraction should take place. But with groundwater abstraction the water is taken from the chalk aquifer, not ‘from the stream’. Unlike surface-water abstraction, whose immediate impact on flow can be measured with a gauge, groundwater abstraction reduces flows by lowering the groundwater level which drives flows: nothing in the wording of the Act allowed for this basic difference.

The new Ministerial power combined in the post-war years with burgeoning demand for water across the south east and thus drove a surge in the growth of groundwater abstraction. Groundwater abstraction on chalk streams reached a peak in the mid-1980s.

On the River Misbourne for example, groundwater abstraction which had slowly increased from zero to about 4 Ml/d (millions of litres per day) between 1900 and the late 1930s then doubled in the six years or so to 1945, then trebled again to a peak of 35 Ml/d in the mid 1980s, almost half the 73 Ml/d annual recharge of the catchment.

Similarly, on the River Ver there was a steady increase from zero to approximately 7 Ml/d between 1865 and 1945 when abstraction surged, climbing to a mid-1980s peak of 45 Ml/d, almost half the 102 Ml/d annual recharge of the river. In the drier years of 1964/5, 1972/3 and 1975/6 abstraction exceeded the winter recharge in both catchments.

Left: The River Mimram – once the pride of Hertfordshire’s chalk streams – barely flowing in May 2017

The River Wey in Dorset
The River Piddle
The River Allen
The Wallop Brook
The Bourne Rivulet
The River Meon
The River Wey in Surrey
The River Pang
The Letcombe Brook
The River Ver
The River Misbourne
The River Darent
The Little Stour
The River Hiz
The Hoffer Brook

Above: the fifteen chalk streams identified by the National Rivers Authority in 1991 as suffering from acute low flows caused by abstraction.

The flows of those in green support good ecological status in 2021, those in red do not. The Hiz and Hoffer Brook are not assessed.

4.2.1 The Community & Government Responses to Low Flows

In the late 1980s and early 90s a series of dry years brought the scale of abstraction and its impact on chalk streams into focus, with numerous chalk streams like the Darent in Kent, the Misbourne in the Chilterns and the Piddle in Dorset, drying up completely.

This provoked an outcry from anglers, locals and conservationists. Numerous associations were formed: the River Piddle Protection Association, Action for the River Kennet, the Ver Valley Society, the River Beane Restoration Association, the Darent River Preservation Society and others.

The National River's Authority's (NRA) Alleviation of Low Flows (ALF) scheme was catalysed by these complaints. The NRA identified 40 rivers nationally, including 15 chalk streams that were suffering acutely from low flows caused by abstraction and directed urgent investigations and remedial actions.

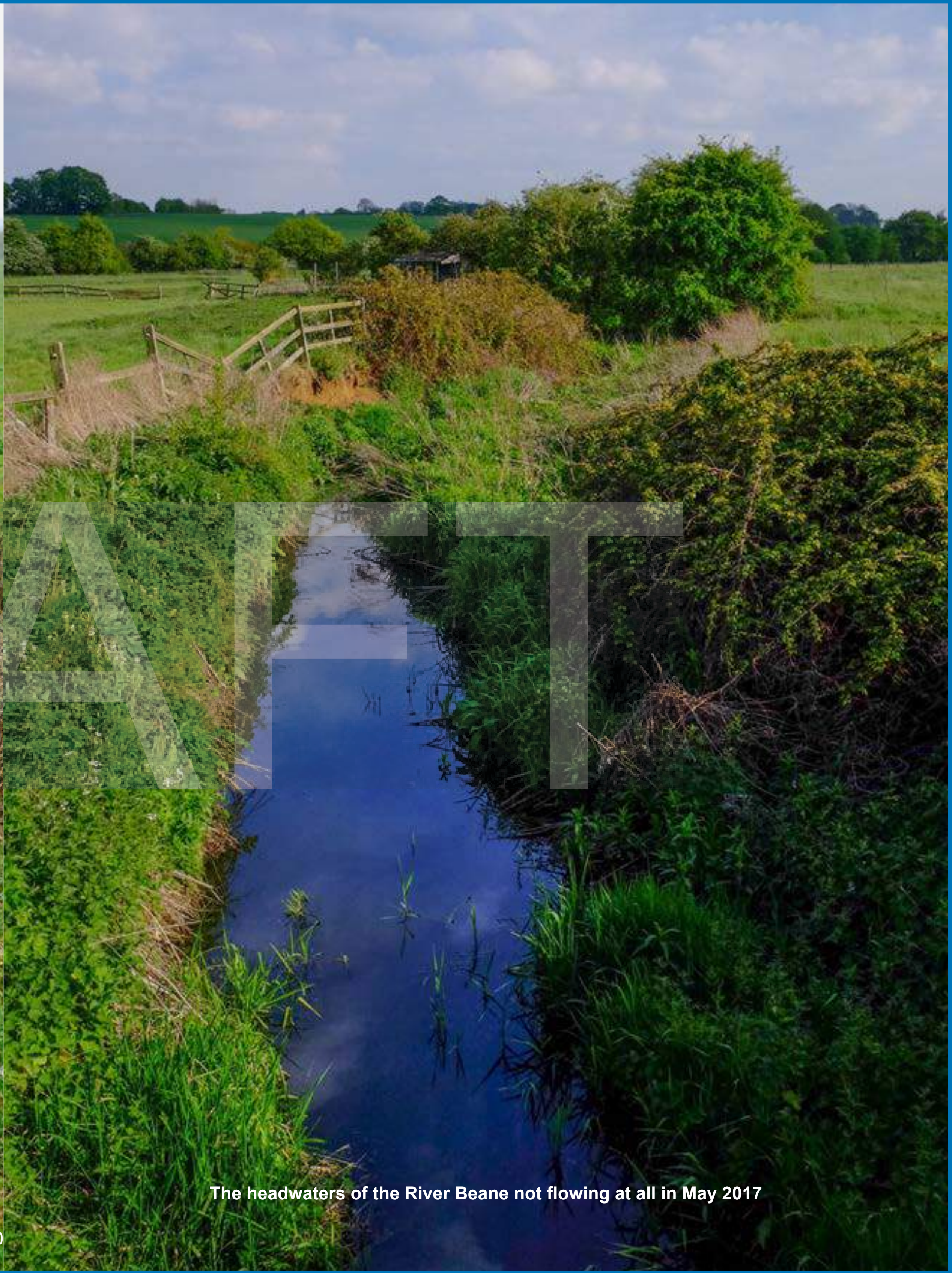
For example, on the River Pang where groundwater abstraction had accounted for 35% of the water available to the river, the NRA agreed a reduction at Compton Pumping Station from 13.5 to 5 Ml/d. On the River Piddle where abstraction amounted to 42 Ml/d, Wessex Water agreed to halve its pumping from Briantspuddle.

ALF evolved into the EA's Restoring Sustainable Abstraction (RSA) programme which has thus far delivered alterations to 124 abstraction licences on chalk streams, returning 105 Ml/d of water to the environment, and removing 284 Ml/d of licence headroom.

As a result of the RSA programme, abstraction on the River Ver, for example, has been reduced from 45 Ml/d to 27 Ml/d today (26% of the catchment recharge of 102 Ml/d). On the River Misbourne abstraction has been reduced from 32 Ml/d to 16 Ml/d today (22% of the catchment recharge of 73 Mld).

ALF and RSA have undoubtedly been moves in the right direction, but in the drought of spring 2017 many of the chalk-streams in the Chilterns and Hertfordshire were dry or drying along much of their lengths.

The headwaters of the River Beane barely flowing in April 2009



The headwaters of the River Beane not flowing at all in May 2017

4.2.2 Action plans and charters

Consequently, a number of reports, charters and action plans have been published over the past 20 years both by Government and NGOs, all addressed at a range of issues affecting chalk streams, including groundwater abstraction. These have included:

- **1999 English Nature: Chalk Rivers: Nature, Conservation and Management**
- **2004 UK Biodiversity Action Plan Steering Group for Rivers – The State of England's Chalk Streams**
- **2009 WWF – Rivers on the Edge**
- **2013 Angling Trust & Partners – A Chalk Stream Charter**
- **2014 WWF – The State of England's Chalk Streams**
- **2017 WWF Water for Wildlife – Tackling Drought and Unsustainable Abstraction**
- **2019 The Angling Trust – Chalk Streams in Crisis**
- **2020 NGO coalition – Chalk Streams First**

It is worth examining the headline information, complaints and called-for remedial actions of these various publications. They can all be found by following links listed in **Appendix A** at the end of this report.

Requested Actions Over 20 Years

The reports and charters cited above and in Appendix A have articulated the points in section 4.1 – with a growing body of evidence and case studies – regarding the ecological impact of low flows caused by consumptive groundwater abstraction, especially on the chalk streams around London.

Various actions to mitigate this impact have been repeatedly called for over the years – some have been addressed, or partially addressed, while others have not. These actions fall into four groups as shown on the table on page 24.

Modelling and Flow Targets

- Modelling of natural and impacted flows, flow targets, and the correlation of flow targets to ecological stress

Modifying the abstraction regime

- Re-aligning abstraction via pricing mechanisms and / or replacing groundwater abstraction with surface water and moving the point of abstraction to less sensitive areas

Reducing the demand for water

- Management of water demand through metering, the targeting of inefficiencies and through building regulations

Legislation

- Calls for Ofwat to be charged with a duty of care for the environment
- Abstraction licence reform
- Powers to revoke licences without compensation
- Protected designation for ALL chalk streams

4.2.3 Key government actions & responses

In response to the actions identified by NGOs and government agencies, various schemes, acts and environmental targets have been delivered, including:

- NRA / EA schemes for **Alleviation of Low Flows** and **Restoring Sustainable Abstraction**.
- **Environmental flow targets / indicators** in 2008 and & 2013.
- **Catchment Abstraction Management Strategies**.
- **Enhanced powers** for the Environment Agency to revoke or vary abstraction licences without paying compensation.
- **Abstraction incentive mechanism**.
- The transposition of the **Water Framework Directive** into UK Law.
- **Reform** of abstraction licensing.

The table on the following page summarises the various actions identified by government agencies, NGOs and stakeholders showing whether or not they have been delivered, either wholly or partially. There are some accompanying notes of explanation in the second table.

Further details and analysis of these actions can be found in Appendix B.

Identified Need / Demand	1999 Natural England	2004 UK BAP	2009 WWF	2013 Angling Trust	2014 WWF	2017 WWF	2019 Angling Trust	2020 Chalk Streams First
Detailed modelling of natural flows	✓							✓
Flow targets	✓	✓				✓		✓
Definition of 'serious damage'						✓		
Abstraction incentive mechanism – inception or reform			✓	✓	✓	✓		
Replacing groundwater abstraction with surface-water and storage				✓				✓
Moving abstraction to areas of surplus	✓			✓				✓
Demand reduction via public awareness and targeting inefficiencies	✓	✓	✓	✓				
Water-efficient housing			✓					
Compulsory metering			✓	✓	✓		✓	
Ofwat duty of care for environment				✓			✓	
Abstraction-licence reform			✓		✓	✓		
Powers to revoke all licences without compensation						✓	✓	
Protected designation of all chalk streams				✓	✓		✓	

The called-for actions from reports and charters 1999 to 2020

Identified Need / Demand	Delivered ?	Comment
Detailed modelling of natural flows	✓	There are now groundwater models for many chalk stream catchments but these are not easily available or comprehensible to the public
Flow targets	✓	We have flow targets, but the EFI could be better adapted to protecting natural flows in headwater and ephemeral reaches of chalk streams.
Definition of 'serious damage'		There is still no firm definition of 'serious damage'
Abstraction incentive mechanism – inception or reform	✓	We have AIM, although the degree to which AIM schemes yield meaningful amounts of additional flow at times when it is most needed in chalk streams is questionable.
Replace groundwater abstraction with surface-water and storage		This is a key part of the Chalk Streams First proposal – an idea held back for three decades by the cost of infrastructure, but now potentially realisable in the Chilterns and Hertfordshire.
Moving abstraction to areas of surplus		Some chalk groundwater abstraction points have been relocated, but in some cases that has created pressure on other chalk streams: for example the reduction of pumping on the Ver and Misbourne and commensurate increase on the Chess in 2003 / 2004
Demand reduction via public awareness and targeting inefficiencies		Water companies are addressing per-capita consumption in their current water resources plans but there is the potential to do far more
Water-efficient housing		Defra may soon recommend adoption in all chalk catchments of currently-optional enhanced requirement of a water consumption standard of 110 litres per day
Compulsory metering		Still no compulsory metering in areas dependent on chalk aquifers in spite of requests in 2009, 2013, 2014 and 2019
Ofwat duty of care for environment	✓	From Defra's guidance to Ofwat, March 2013: 'The Government expects Ofwat to support abstraction reform through its regulatory functions'
Abstraction-licence reform	✓	Reform is in progress.
Powers to revoke all licences without compensation	✓	The EA now has this power but it has rarely been used.
Protected designation of all chalk streams		There is still no overarching designation that adequately reflects the international rarity of chalk streams.

What has and has not been delivered from the list of called-for actions from reports and charters 1999 to 2020

The River Quin in 2017

4.3 Existing programmes

4.3.1. Water abstraction plan

Following the 'Making the most of every drop' consultation in 2013 -2016 (see Appendix B) Defra published in December 2017 (now updated in September 2020) their Water abstraction plan (WAP) setting out how Government intends to reform the abstraction regime and protect the environment by:

• Making full use of existing regulatory powers to move 77% of groundwater bodies to the required status by 2021.

• Developing a stronger catchment focus bringing together the EA abstractors and catchment groups to develop local solutions.

These local solutions will include:

• Changing abstraction licences to reflect water availability and reduce the environmental impact of abstraction.

• Creating flexible licence conditions that encourage water-storage, trading and efficiency.

The policy paper states 'having the right flow in our rivers and protecting groundwater levels is essential to supporting healthy ecology, enhancing natural resilience to drought, and ensuring that rivers continue to support wellbeing and recreation. Sustainable water abstraction is therefore essential to ensure that river flows and groundwater levels support ecology and natural resilience'. Chalk streams are specifically cited as iconic, globally rare and important habitats that are 'diminished' by unsustainable abstraction.

The Environment Agency will review and update the status of chalk streams and groundwater body status when it updates the river-basin management plans in 2021.

4.3.2. Environment Agency actions

The plan states that where 'where the environment cannot cope' Government 'will take action'. In priority water bodies such as Natura 2000 sites, that will be all actions required, regardless of cost. In other sites action will *depend on cost-benefit analysis*.

To meet this goal the Environment Agency will:

• Use the **Water Industry National Environment Programme** (WINEP), to ensure water companies take a continuing and leading role in addressing unsustainable abstraction.

• **Review time-limited licenses**. Approx 25% of all 20,000 abstraction licences are time-limited: 2,300 of these will expire before 2021. The Agency will renew these licences only if: the abstraction is sustainable / the abstractor has a reasonable need of the water / the abstractor will use the water efficiently.

• **Complete its RSA programme***. Due to have been completed by March 2020.

• The EA will continue to **prioritise changes** to the most 'seriously damaging' licences.

• The EA has already made changes to protect **Natura 2000 and SSSI's**.

• Investigate all licences not used in the last ten years and revoke (January 2017 - January 2019) an estimated 600 unused licences that are no longer needed.

• Bring into regulation all significant abstractions that have been exempt historically (approximately 5,000 in addition to the 20,000 licensed abstractions).

* The 1990s ALF project evolved into the EA's restoring sustainable abstraction (RSA) programme, which has thus far delivered alterations to 124 abstraction licences on chalk streams, returning 105 Ml/d of water to the environment. Further sustainability reductions amounting to 100 Ml/d will be delivered by 2025 through the Water Industry Environment Programme (WINEP).

4.4 Next steps - national framework

Through the new initiative the national framework for water resources, regional planning groups have been set up to identify the best strategic-resource solutions to deliver more suitable abstraction and a better environment. Each regional group must produce a regional water-resources plan (RWRP), considering answers to a range of scenarios, including an enhanced scenario which looks to give greater protection to chalk streams.

These groups are tasked with identifying options that provide the best value to customers, society and the environment, rather than simply focusing on the lowest cost. The water company components of the regional plans will be included in water company Water Resources Management Plans in 2024.

The plans need to address the following:

• Increasing resilience to drought.

• Greater environmental improvement, in order to achieve a sustainable abstraction regime across all sectors.

• **Reducing water usage** – with a target of 110 litres of water use per person per day by 2050, while also reducing demand in business, industry and agriculture.

• **Reducing leakage** by 50% by 2050.

• Reducing the use of drought permits and orders.

• Increasing supplies by exploring options to develop new supplies such as:

- **reservoirs**
- **water re-use schemes and desalination plants**
- **shared supplies with other sectors**
- **catchment-based work to improve water management**

This regional planning is supported by the water-regulators' alliance for progressing infrastructure development (RAPID). Ofwat has made an allowance of £469m to progress 17 potential strategic regional solutions in the current water-company business plans, which may then be included in plans for the next price review. If the schemes are approved through the water company Water Resources Management Plans and the price review in 2024, they will still take several years to plan, build and commission. For example, if chosen, the South-east strategic resource option (reservoir) is expected to be completed in 2037/38.

Government has launched a consultation on the draft revised Water Resources Planning Guidelines for water companies to use in drawing up their Water Resource Management Plans in 2024. The most significant changes are that water companies:

• should use natural capital in decision-making and provide environmental net gain through their WRMPs, and

• should plan to reduce abstraction where it is causing the most environmental damage.

Specific to chalk streams, the enhanced scenario would see nearly all chalk streams treated as if they were in abstraction sensitivity band 3, greatly increasing the reductions in abstraction needed to meet the desired environmental destination.

Examples:

For example the EA has identified:

• The River Ver is currently 77% below natural at Q95 (recent actual 9.1 Ml/d versus 39.7 Ml/d modelled natural at Q95) and 73% below the EFI with a deficit of 24.7 Ml/d

• The River Chess is currently on average 41% below natural at Q95 (recent actual 11.5 Ml/d versus 19.6 Ml/d modelled natural at Q95) and 31% below the EFI with a deficit of 5.2 Ml/d.

These calculations are made using the EFI RAM methodology and therefore take into account upstream discharges and are made at the waterbody boundary.

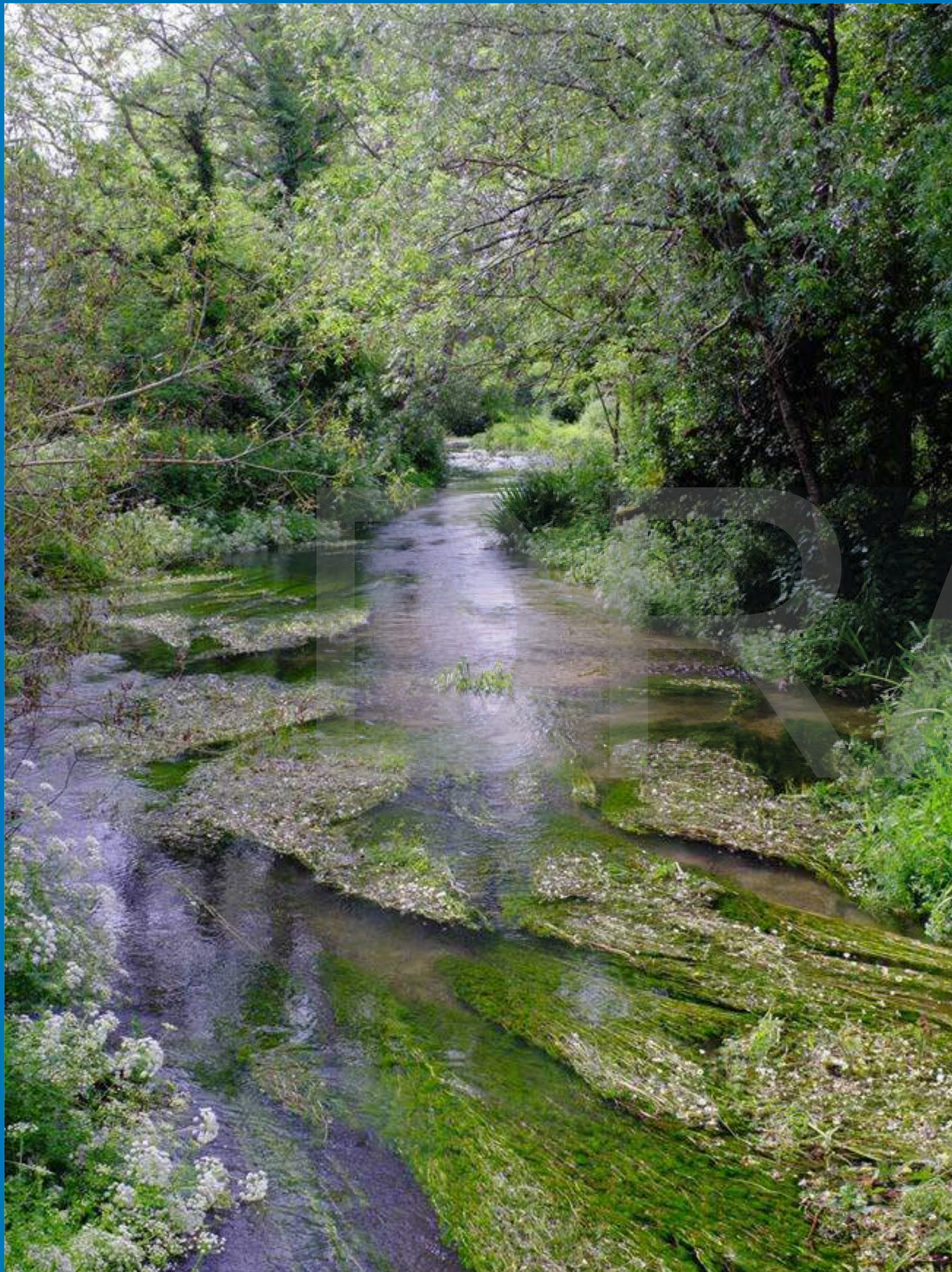
The need to prioritise where flows are recovered.

It is worth noting, by contrast, the flow deficits identified on the Lower Colne – 246 Ml/d and the Lower Lea 273 Ml/d, many times the size of those on the tributary chalk streams.

Thus far there is no explicit distinction between the ecologically-essential flow recoveries of the tributary chalk streams and those that are arguably less ecologically beneficial on the lower, highly-modified urban main rivers. In addition, any flow recovery realised on the tributaries will by definition benefit the main river.

Healthy flows for all chalk streams?

The regional planning process and RAPID's strategic resource options could mark the step-change needed to bring about better protection of flows in our chalk streams.



4.5 Next Steps - Joint NGO Perspective

As of the 2013 - 2015 WFD assessment cycle flow in 86 chalk-stream waterbodies (34.5%) and 69 different chalk streams (see the table on p.39) have been judged: Does Not Support Good. Fifty-four of these waterbodies (62% of the failures) are on chalk-stream tributaries of the Thames and Ouse around London and north into Cambridgeshire. That corresponds with where the public are most frustrated at the condition of their failing chalk streams.

If what we are already doing for chalk streams were working well, the current heightened levels of frustration among chalk-stream advocacy groups, the media and public would not have arisen. Whilst actions and schemes delivered thus far may have brought progress, such that chalk streams like the Allen, Piddle and Bourne which were once at crisis point now support good ecological status. Nevertheless, ALF and RSA and schemes like AIM, and incremental abstraction reform under the EFI assessment criteria will only ever deliver so much.

On the rivers most stressed by groundwater abstraction the deficits between present flows and flows within 10% of natural (an acceptable level of reduction) are vast. The national framework now recognises this. But how can we move from talking about the issue to doing something about it?

To save the most flow-stressed chalk streams – to leave *their* environment in a better state than we found it – *and* to protect public water supply, we need to develop a different system of abstraction, one that re-naturalises the chalk stream's flow and shifts the point of abstraction to less environmentally sensitive points in the catchment.

This approach was identified in the very first 1999 NE report into the state of our chalk streams and indeed in the 1993 NRA report into the 'Alleviation of low flows'. It was also identified in the 2013 Defra paper 'Making the most of every drop'.

We need to listen to these oft-repeated ideas and design a system of abstraction better fitted to the hydro-ecological properties of the chalk aquifer and chalk streams.

Each and every water-resources option for increasing resilience and supply *and* improving the environment, from strategic reservoirs to inter-regional transfers of water, to desalination and demand management will depend on the principle of flow recovery if chalk stream flows are also to recover sufficiently to support good ecological status. The principle of flow recovery, therefore, should be addressed as an integral part of regional planning.

Left: The River Piddle was once threatened by acute abstraction but is now in good ecological condition with healthy flows.

County	Chalk Stream Waterbody
Dorset	Hooke GB108044009800
	Wey GB108044010210
	Devil's Brook incl Cheselbourne GB108044010130
	Shreen Water GB108043022450
Wiltshire	Nine Mile GB108043022360
	Fonthill Stream GB108043022500
Hampshire	Anton upper GB107042022810
	Anton lower GB107042022810
	Candover GB107042022620
	Itchen GB107042022580
	Meon incl Whitewool Stream GB107042016640
	Ems GB107041012370
Berkshire	Pang incl the Bourne GB106039023300
	Og GB106039023180
Bucks and Herts (incl Colne)	Hamble Brook GB106039023720
	Colne h'waters incl Mimshall Brook & Catherine Bourne GB106039029850
	Colne upper to Ver GB106039029820
	Ver GB106039029920
	Colne middle to Gade GB106039029840
	Upper Gade to Bulbourne GB106039029900
	Lower Gade GB106039029860
	Bulbourne GB106039029900
	Chess GB106039029870
	Misbourne GB106039029830
	Colne lower GB106039023090

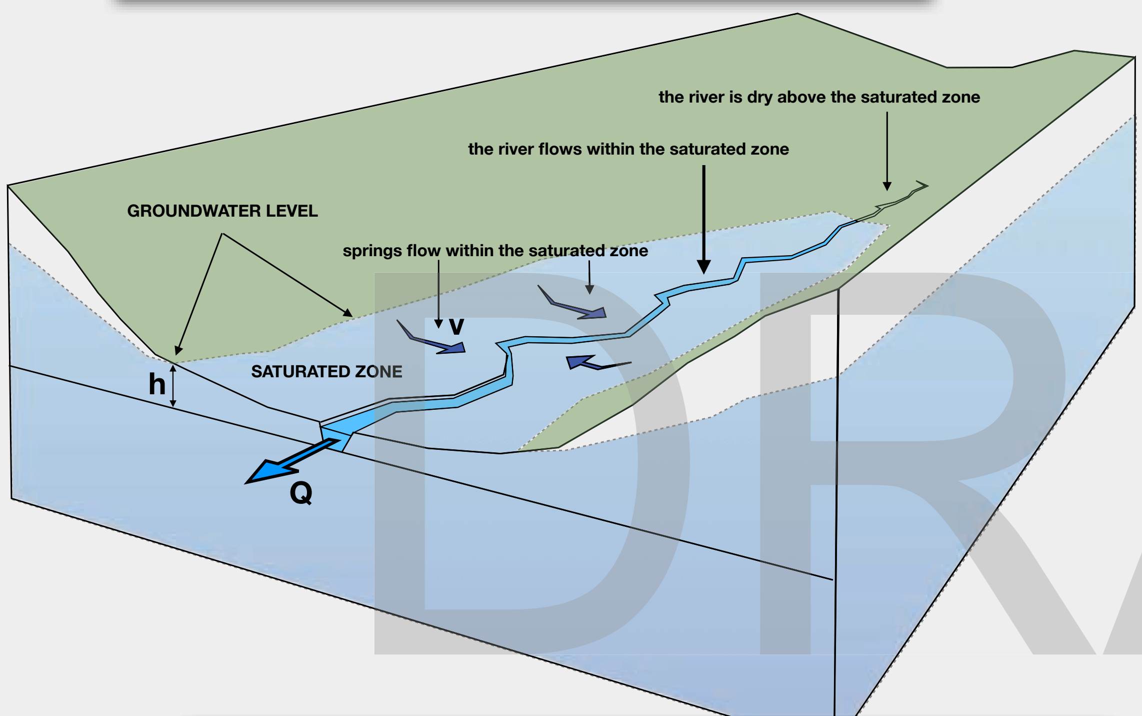
County	Chalk Stream Waterbody
Surrey	North Wey at Alton GB106039017800
	North Wey GB106039017830
	Tillingb'rne GB106039017840
	Wandle Carshalton Branch GB106039017640
Herts (Lee)	Lee upper to Luton GB106038033391
	Mimram upper GB106038033460
	Mimram lower GB106038033270
	Beane lower GB106038033310
	Rib lower GB106038033360
	Ash lower GB106038033290
	Stort GB106038040130
	Bourne Brook GB106038033340
Kent	Cray upper GB106040023990
	Cray lower GB106040024150
Bucks and Herts (incl Colne)	Darent Upper GB106040024221
	Darent middle and lower GB106040024222
	Great Stour upper GB107040019660
	Nailbourne & Little Stour GB107040019590
	Northbourne incl Broad Dike GB107040019720
	Dour h'waters GB107040019490
	Dour GB107040073310
Herts (Ouse)	Cat Ditch GB105033037740
Essex & Cambs (Cam / Ouse)	Wicken Water GB105033037540
	Cam upper to Audley End GB105033037550
	Wenden Brook aka Fluten GB105033037560

County	Chalk Stream Waterbody
Essex & Cambs (Cam / Ouse)	Cam middle to Stapleford (GB105033037590
	Cam lower GB105033037600
	Granta incl Bourne GB105033037810
	Hobson's Brook GB105033037620
	Cherry Hinton Brook GB105033042670
	New River GB105033042780
Suffolk (Ouse)	Lark upper GB105033042940
	Kennett GB105033042990
Norfolk (incl Ouse)	Tuddenham GB105033043010
	Little Ouse h'waters US Theltenham GB105033043060
	Little Ouse Theltenham to Hopton Common GB105033043110
	Little Ouse middle Hopton to Sapiston GB105033043100
	Little Ouse Sapiston to Thetford GB105033043090
	Wissey lower GB105033047630
	Gadder GB105033047880
	Old Carr aka Beachamwell Stream GB105033047820
	Nar upper GB105033047791
	Nar lower GB105033047792
	Babingley GB105033047620
	Heacham River GB105033053480
	Binham Stream GB105034055830
	Wensum GB105034055881
Lincs	Bain upper GB105030062350
	Bain middle GB105030062300
	Lymn (h'waters of Steeping) GB105030062430

County	Chalk Stream Waterbody
Lincs	Great Eau middle and lower GB105029061660
	Laceby Beck GB104029067530
	Keelby Beck inc in North Beck Drain GB104029067575
	Skitter Beck GB104029067655
	Barrow Beck GB104029067605
	Nettleby Beck (Caistor Canal Catchment) GB104029061920
Yorks	Lark uppMoor Beck incl Leavening Beck – included in Derwent Kirkham to Elkington waterbody assessment GB104027068312er GB105033042940
	Leppington Beck – included in Derwent Kirkham to Elkington waterbody assessment GB104027068312
	Driffield Trout Stream aka Eastburn incl. Wellsprings Drain and Southburn GB104026067031
	West Beck upper incl Elmswell Beck and Little Driffield Beck GB104026067080
	Foston Beck aka Lowthorpe / Kelk / Frodingham Beck GB104026067101

4.8 The chalk stream waterbodies that 'Do Not Support Good Ecological Status for Flow' under the Water Framework Directive (2013 - 2015 assessment cycle).

A SIMPLIFIED DIAGRAM OF A CHALK-STREAM VALLEY SHOWING HOW THE GROUNDWATER LEVEL – WHICH RISES AND FALLS – DETERMINES THE EXTENT OF THE SATURATED ZONE IN THE VALLEY FLOOR FROM WHICH SPRINGS RISE AND THROUGH WHICH THE CHALK STREAM FLOWS.



In theory the chalk stream flow (Q) is broadly proportional to the height (h) of the groundwater level above the river bed, so that $Q = ah^{2.5}$

where (a) is a constant determined by the shape of the valley and properties of the chalk and will vary from one valley to the next.

If (h) is the average height of the groundwater level above the valley bottom, elementary hydraulics shows the velocity flow (v) from the spring sources in the valley upstream is proportional to $h^{0.5}$. Assuming a V-shaped valley, the area of the exposed fissures is proportional to h^2. Therefore, the baseflow (Q) in the river from the springs upstream is proportional to $h^{0.5} \times h^2 = h^{2.5}$

In simple and general terms this means that a 10% increase in the height of the groundwater above the valley bottom effects a 25% increase in flows

4.6 How a chalk stream works – groundwater drives flow

A chalk stream's flow is dominated by groundwater from the chalk aquifer. Chalk is permeable and a large proportion of the rain that falls on chalk hills, especially in winter, sinks into the ground and percolates through the rock to form the saturated zone of the chalk aquifer. It can take some time for groundwater levels to respond to rainfall and this varies from valley to valley, depending on the localised aquifer permeability, which is strongly influenced by the fracturing of the chalk.

The groundwater level rises and falls through the year as the underground body of water fills and slowly empties. Typically, the groundwater level rises from November through to April, when the growing season is over and the air is colder and a larger proportion of the rain sinks into the ground. It then falls through the summer when the air is warmer, and evapotranspiration soaks up much of the rain instead while the groundwater continues to discharge to the river. Generally, chalk-stream flows are at their lowest in the early autumn.

The total amount of winter rainfall and how much of it sinks into the ground (known as 'effective rainfall') largely determines flows through the following summer. If groundwater levels are high in the spring after a good winter recharge, then (natural) flows will hold up well through the summer. If groundwater levels are low in the spring after a dry winter, then generally the chalk stream will be very low by the end of summer.

The diagram on the opposite page represents a simplified chalk-stream valley. It shows how a chalk stream flows within the saturated zone of the valley floor, where the aquifer intersects with the surface topography. In the upper reaches of a typical chalk-stream valley, the upper boundary of that saturated zone moves up and down the valley with the rising and falling groundwater level. These ephemeral reaches are known as winterbournes.

From the point at which the chalk stream starts to flow (the upper boundary of the saturated zone) groundwater levels determine the intensity of the flow in the channel – because the amount of water flowing down a chalk stream is dependent on the height of the groundwater above the river bed. In very broad terms a 10% increase in the height of the groundwater above the river bed equates to a 25% increase in flow.

KEY POINTS

• A chalk stream’s flow is driven by groundwater.*

• There is a fundamental relationship between the height of the groundwater above the river bed and the flow in the river.

• Groundwater levels follow an annual cycle, generally rising from late autumn to spring, and generally falling from spring through to early autumn.

• The height of the groundwater in the spring underpins and determines flows throughout the following months.

• Naturally flows tend to fall away through the summer and are typically at their lowest in early autumn.

* Geological variations from one chalk stream to the next will shape the flow regime of a given river, the way the river responds to direct rain, ‘quick-flow’ through heavily fissured chalk or sands and gravels, and the degree to which the aquifer base-flow underpins these other flows.

Base-flow is the proportion of the flow that comes from the aquifer, which does vary from one chalk stream to the next depending on the geology and – increasingly nowadays – on the land-use in a given valley. The base-flow proportion of flow is likely to have been altered in almost all chalk streams by modern land-use and urban development, meaning that a higher proportion of rainfall runs off into the rivers than was once the case. The concept of base-flow is important, however, because with all chalk streams it is the foundation of the flow regime in the river.

The source of the River Wye above West Wycombe, where the saturated zone of the aquifer meets the surface.

4.6.1 How chalk stream flows are currently assessed / location of assessment points.

Appendix B.2 gives details of the existing Environment Agency methodology of flow assessment, the environmental flow indicator (EFI).

The EFI defines ecologically acceptable reductions in flow from natural at various points in the flow curve. It says that a greater reduction is acceptable when the flows are high (30% reduction), than when they are low (10% reduction, for an ASB3 river).

This is based on the same concept of environmental protection enshrined in the 1945 Water Act, that abstraction should cease (or reduce) when flows fall below certain targets: it is a well-adapted system of protection for flows impacted by surface-water abstraction (because when you stop abstracting the effect is immediate), but it is limited as a way of protecting flows in a groundwater system, because the water taken out of the ground in, say, February, will have an impact on flows in September.

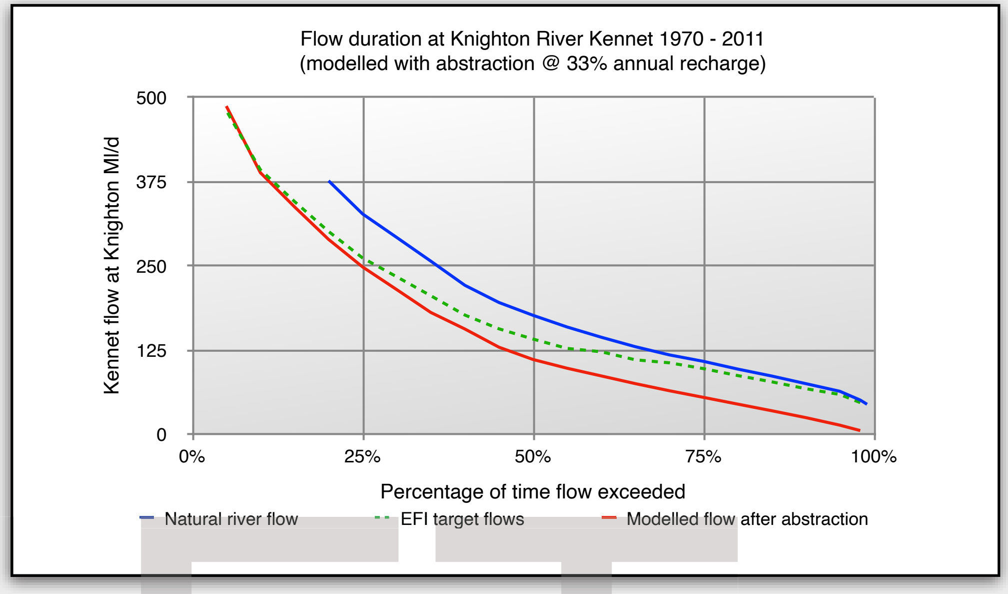
For example the EFI doesn't protect flows in a winterbourne, because 90% of 0 ml/d is 0. From an ecological point of view, the degree to which a winterbourne is unnaturally dried by abstraction relates not to whether it dries at all but to the number of days it dries for and how far down the river the winterbourne extends.

A secondary aspect of the EFI RAM methodology (in terms of protecting flows in chalk streams) is the potential distance between the upper reaches of the chalk stream that might be impacted by groundwater abstraction and the position where the flows are assessed. As was shown on page 22, the EFI RAM formula depends on modelling the 'natural' flow in the river, then adding the discharges from sewage works, then subtracting from that total the licensed abstractions to arrive at a scenario called fully-licensed flow (FLF). If the FLF is below the environmental flow indicator (EFI), then the river is deemed 'non-compliant' (ie. the flows potentially do not support 'Good Ecological Status').

However, the assessment points tend to be at waterbody boundaries. The River Chess, for example, is a single waterbody, and its flow is assessed at the downstream boundary. This is a long way from the source and downstream of sewage discharges. Even if the flow at that point is compliant (on the River Chess it is not) this does not mean that the flow in the headwaters is also compliant.

A third issue relates to whether or not it is possible to conform groundwater abstraction to the staged % allowable reductions from natural flow.

The graph above right shows a flow-duration curve for the Upper Kennet



modelled as if the abstraction were running at 33% of aquifer recharge. This is roughly equivalent to the current regime of abstraction as a % of recharge on the River Ver. The graph shows three flow-duration curves: the modelled natural flow of the River Kennet (blue) / the modelled flow assuming abstraction at 33% catchment recharge (red) / the environmental flow indicator flow curve (green).

The EFI flow curve moves across the space between the modelled abstracted and the modelled natural flow because – according to the EFI – abstraction should account for a smaller and smaller volume of natural flow as flows in the river diminish through Q50, Q70 and Q95, towards the end of summer.

It is very difficult to manage groundwater abstraction in such a way as to get chalk stream flows to conform to this EFI line. Reducing groundwater abstraction does not have the immediate or direct impact on flow that reducing surface water abstraction does. By the time you get to the given trigger point, the flow-duration curve is already on another, lower trajectory and nothing will get it back up except aquifer recharge, which tends to occur in the winter.

Appendix C.3. and C.4. give further information on two types of flow protection – hands-off flow and the abstraction incentive mechanism – that use this idea of managing flows through reducing groundwater abstraction in the summer.

Appendix D is a summary of NGO recommendations ref existing flow- and abstraction-management methodologies.

4.6.2 Abstraction as % of recharge

Assessing abstraction as a % of the annual recharge (A%R) of the aquifer – that is, abstraction as a % of the amount of effective rainfall that sinks down into the ground to drive base-flows in the river – is potentially an additional, and usefully simple and accessible way to determine whether or not groundwater abstraction is 'sustainable'.

A%R does not require sophisticated computer modelling nor the relatively complex calculations of EFI RAM, is not dependent on the 'noise' of sewer discharges as a component of ecological flow. Moreover A%R accounts for ephemeral flows in the ecologically valuable headwater reaches of chalk streams.

The two charts opposite show modelled flow at two points on the River Ver, the naturalised flow in dark blue, the Environment Agency's EFI flow (as if for an ASB3 river – although in fact the Ver is ASB2) in dotted green, and the flow under four levels of abstraction as a % of annual catchment recharge.

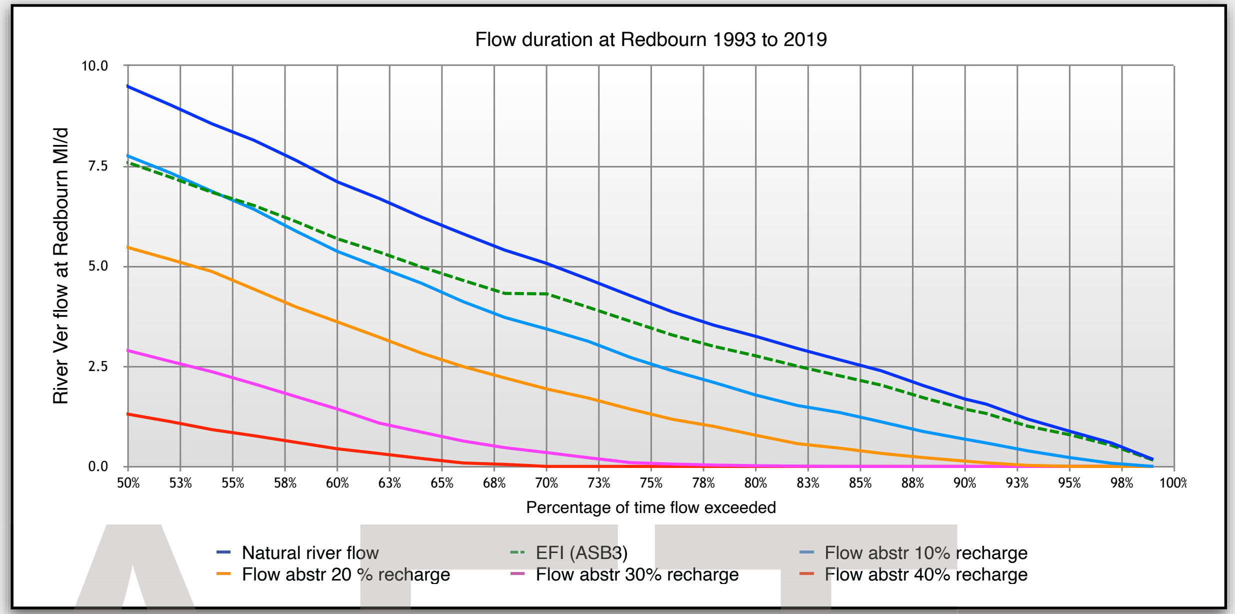
The Ver is about 18 miles long. Redbourne is 8 miles from the source, while Hansteads is close to the downstream confluence with the Colne.

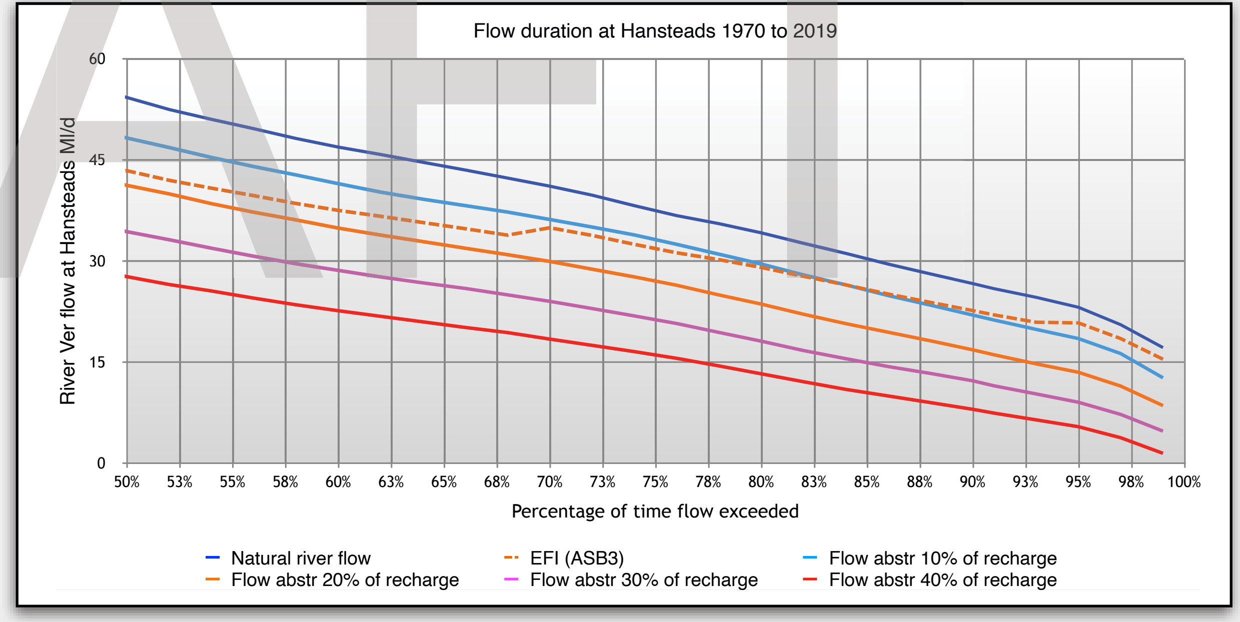
The existing abstraction of the River Ver accounts for about 35% of catchment recharge (red) (although historically it has been higher). As can be seen, this level of abstraction yields flows that are a long way short of the EFI.

At Redbourn A30%R means that the river dries for almost 30% of the year when otherwise it might not dry at all. Note also that an A%R which meets the EFI as far as Q60 (roughly 10%) is a very long way below the EFI at Q95.

At Hansteads A30%R yields flows at Q95 of 5 Ml/d when naturally they would be 23 Ml/d. Again the A%R which meets the EFI at Q50 is about 18%, BUT by Q95 the A%R needs to be closer to 5% (although 10% meets the EFI at Q90)

Results from this form of assessment of the Ver and other chalk streams suggest that groundwater abstraction should account for no more than between 5% to 10% of catchment recharge if the stream's flows are to meet (or get close to meeting) the EFI at Q95.





Abstraction as 5, 10, 20 and 30% of recharge on the River Ver. (5% is not in the EFI but is the allowable Q95 reduction on SAC / SSSI rivers and so is included for reference)

4.6.3 The potential of flow recovery

In addition to the strategic resource options listed in section 4.6, the potential of flow recovery to re-naturalise flows while maintaining a high proportion of the water as a resource to be abstracted lower down the catchment should be explored. It is theoretically possible, with the right infrastructure and water-storage capacity, to use flow recovery to re-align abstraction so that water is allowed to travel through its environment before it is taken for public water supply.

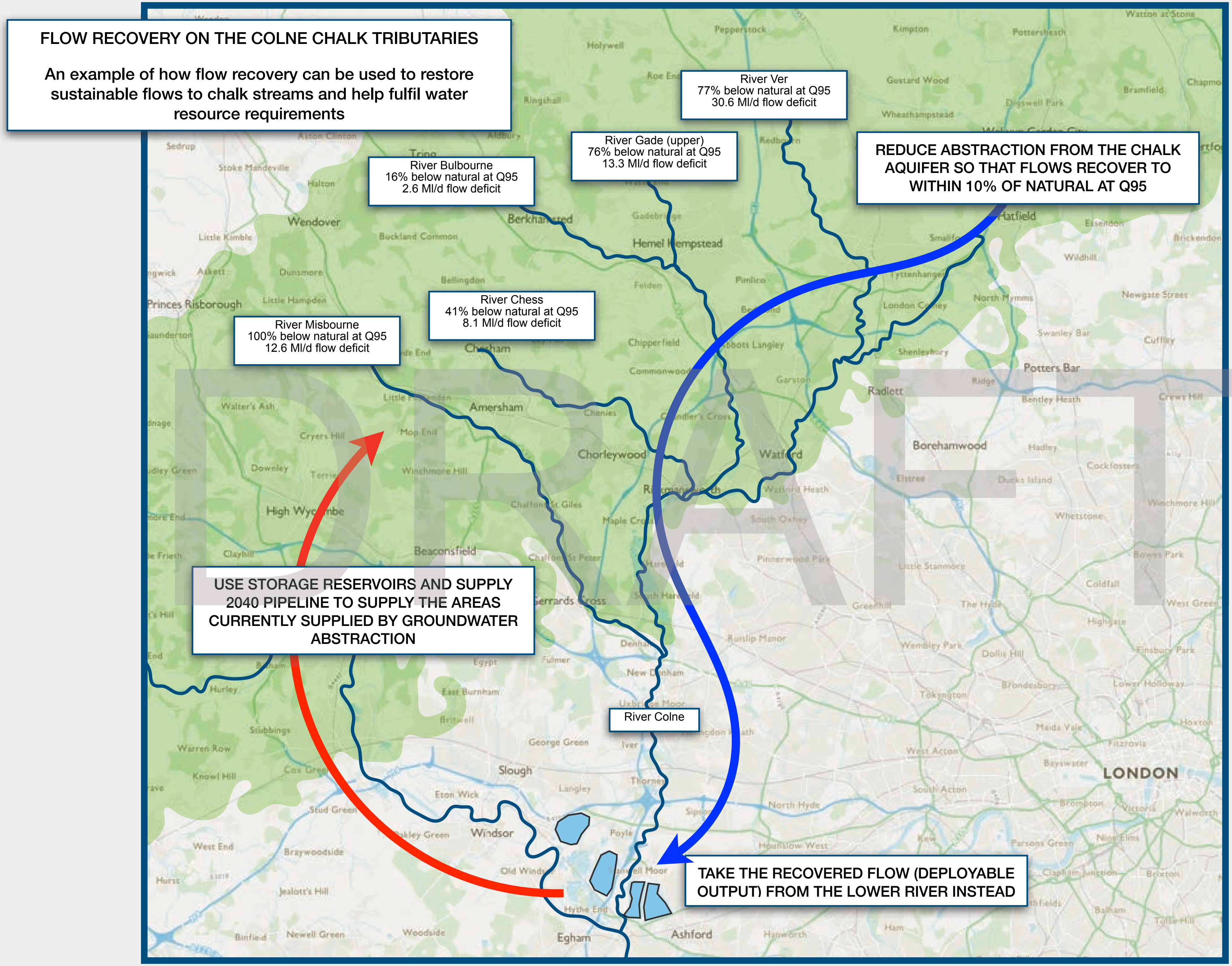
In simple terms we could stop taking the water from the aquifer, allow it to travel down the river and take it from the surface flows at the bottom of the catchment instead. Rivers are universally used as conduits for water supply from reservoirs and this is the same concept, only in this case the aquifer is a reservoir and the chalk stream itself is the means of delivery.

For example, Chalk Streams First (CSF) is an existing NGO proposal based on the potential of flow recovery as a means to re-naturalise the flows in the Chilterns chalk-streams (which currently make up 20% of chalk streams whose flows fail the Water Framework Directive) with potentially only a small net loss to overall public water supply. CSF could form a model for how to re-align abstraction on other over-abstracted chalk streams**.** This scheme could be delivered in the near future using infrastructure already planned-for and costed in the water-company management plans.

CSF would make use of the way chalk streams function by moving the point of abstraction from the groundwater at the top of the valley, to surface water at the bottom of the catchment. From there it can be taken into storage in the reservoirs around London and / or redistributed through a network of pipelines called Supply 2040 to the towns currently supplied by groundwater abstraction. Supply 2040 is in Affinity Water's business plan and is a vital component for other strategic infrastructure schemes currently under consideration, including Abingdon Reservoir.

Storage and pipeline infrastructure will be important components of any flow recovery scheme and extreme droughts still present an existential threat that water companies must plan for. Alongside strategic use of emergency groundwater abstraction, flow recovery should be investigated for its potential to re-naturalise flows in the chalk streams, but with a considerable % of the water which is not abstracted in the headwaters still being available for public water supply.

The River Chess May 2017 above and in December 2020 below: the before and after of flow recovery


FLOW RECOVERY ON THE COLNE CHALK TRIBUTARIES
An example of how flow recovery can be used to restore sustainable flows to chalk streams and help fulfil water resource requirements
River Ver
77% below natural at Q95
30.6 Ml/d flow deficit
River Gade (upper)
76% below natural at Q95
13.3 Ml/d flow deficit
River Bulbourne
16% below natural at Q95
2.6 Ml/d flow deficit
REDUCE ABSTRACTION FROM THE CHALK AQUIFER SO THAT FLOWS RECOVER TO WITHIN 10% OF NATURAL AT Q95
River Chess
41% below natural at Q95
8.1 Ml/d flow deficit
River Misbourne
100% below natural at Q95
12.6 Ml/d flow deficit
USE STORAGE RESERVOIRS AND SUPPLY 2040 PIPELINE TO SUPPLY THE AREAS CURRENTLY SUPPLIED BY GROUNDWATER ABSTRACTION
River Colne
TAKE THE RECOVERED FLOW (DEPLOYABLE OUTPUT) FROM THE LOWER RIVER INSTEAD
LONDON
DRAFT

A shrunken River Gade at Great Gaddesdon: 76% below natural at Q95

4.7 Demand Management & Water Metering

Reducing water demand should be a key tool in any strategy to restore natural flows to chalk streams. Using water efficiently helps to minimise the amount taken out of chalk streams and aquifers.

New infrastructure takes time and is expensive. It can have wider impacts on the environment. There is a carbon cost, for example, in pumping water from other sources. If we save water, we can reduce pressure on existing water resources. Above all, adopting habits of efficient water use makes our supply more resilient against the impacts of climate change and droughts.

The link between the ways people use water, and the impact they have on chalk streams must be recognised. There may be a growing trend in the UK towards more resource-efficient behaviour, but water use in England is still far too high.

Per capita consumption in some of our worst affected chalk-stream areas is excessive. In the Chilterns area, water consumption rates are amongst the highest in Europe at approx. 155 litres per person per day: over 20 litres above the national average and 40 litres above Ofwat's target for UK per-capita consumption. We need action to reduce personal water use: education, labelling of goods, building regulations etc. We need to ramp up our collective efforts on this.

The Waterwise and Ideal Standard Water Efficiency Annual Tracking Survey in Great Britain (2016) found that:

- 86% of adults who pay for their water via a fixed rate take actions to specifically reduce their water use, rising to 94% among those with a water meter.
- 82% of adults with a water meter reduce their water usage in order to save money.

To achieve wide-scale water efficiency, a water-saving culture must be developed throughout the UK. We know that most people take some actions to save water, but we also know that there is a lot more to do. Water efficiency needs to become the norm across all activities throughout everybody's lives – wasting water should be seen as going against the norm.

Water efficiency in new developments

The Housing White Paper (2017) set out a need for 225,000 to 275,000 new homes per year to keep up with population growth. However, if these homes are not built to higher levels of water efficiency there will be an inevitable increased demand for water.

The Waterwise UK Water Efficiency Strategy calls for variable infrastructure charges for new developments in order to encourage water-efficiency measures. Waterwise is trialling this approach with Southern Water in Eastleigh. Developers in Eastleigh are being offered a 50% discount in their water infrastructure connection charge for new builds if they use fittings rated A or B under the European Water Label. The scheme is simple and easily verifiable and uses market incentives to reward developers for environmental improvements.

Metering

The UK is one of the few countries in the developed world not to have either full water metering or a clear programme to implement universal metering. In England, water companies can compulsorily meter customers if they have been designated as being in an area of 'water stress' (designated by the Secretary of State based on evidence from the Environment Agency).

The Environment Agency recently consulted on 'Updating the determination of water stressed areas in England' (February 2021). Feedback is being reviewed and will provide advice to the Secretary of State on the areas that should be determined as areas of serious water stress.

The following company / areas would be classed as seriously water stressed for metering purposes using the updated analysis that was included in the consultation (this list has been edited to cover the chalk streams regions only):

- Affinity Water
- Anglian Water – East Anglia
- Cambridge Water
- Essex and Suffolk Water
- Portsmouth Water
- SES Water
- South East Water
- Southern Water
- Thames Water
- Veolia Water
- Wessex Water
- South West Water – Bournemouth

Water companies in areas which are under serious water stress are able to charge all customers for the volume of water used. This is measured by a water meter on each property. They must evaluate compulsory metering alongside other options through their Water Resources Management Plans.

Metering has been shown to change customer behaviour and save water. Southern Water's Universal Metering Programme has shown that domestic metering can save 16.5%. If people do not pay for the amount of water they use, there is no financial incentive to use water efficiently.

Metering enables not only customers, but also water companies to manage water more effectively. Customers can be incentivised to save money through tariffs, but the data collected can help to inform water companies where consumption is high, and therefore where water efficiency measures should be targeted. **All in all using water meters in all chalk regions is the key to demand management, an incentive in itself and a tool to drive intelligent strategies and resource planning.**

Tariffs

Metering with appropriate tariff structures - such as the rising block tariff (where the unit charge rises for progressively higher volumes of water taken by customers), or a seasonally-varying or aridity-indexed tariff (where water costs more per unit when it is less plentiful) – has the potential to be a major incentive for water efficiency in the future. Should the water that someone fills a swimming pool with really cost as little as the water everyone else makes a cup of tea or washes their hands with?

The flow gauging weir at Redbourne on the River Ver

4.8 Collective Action Towards an Agreed Goal

From the Water Act of 1945 onwards the link between groundwater level and flows in chalk streams has not been fully accounted for in abstraction management and therefore chalk streams have not been properly protected by the law or in practice.

Even now, although the EA may revoke licences which cause serious damage, we lack a solid definition of what serious damage is, and revocation is rarely done in practice. Meanwhile the methodologies for managing abstraction fail to protect all chalk streams, especially their headwater reaches far upstream of discharges, Assessment Points and WFD Waterbody Boundaries.

However, the flow deficits recognised by the EA and now put forward to the Regional Groups of the National Framework signal the possibility of a step-change in the way we manage abstraction on chalk streams. These deficits show just how depleted from natural flows chalk streams like the Ver and Beane really are.

The global deficits are so vast, however, that there is a clear need for Regional Groups to distinguish between those that are ecologically essential and those that might be desirable, but are arguably of less benefit, especially when the comparative scale of the deficits between headwaters and lower main rivers is taken into account. And especially because any recovery in flow made in the headwaters will definitively benefit the lower main rivers anyway.

This principle of using flow recovery to move the point of abstraction from headwaters to the lower catchment is a potentially sustainable means of balancing the needs of water resources and the environment. It has been identified several times before in reports from within and without government but it has never been wholeheartedly strived for because the schemes which would enable this approach, while technically possible, are expensive. Meanwhile, the environment has paid the price for keeping water bills down.

But attitudes have changed. People care about the environment and are prepared to pay a little more for their water, if it means they can enjoy healthy rivers full of wildlife. And indeed, healthy chalk streams full of wildlife are perfectly possible, even around London. But only if we collectively work together towards a realistic, strategic and staged process of delivery.

4.9 Water Quantity Actions: Achieving Sustainable Abstraction

1. Defining Sustainable Abstraction	CaBA CSRG agrees that "sustainable groundwater abstraction" means that which equates to a maximum reduction from natural flows of 10% at Q95 – which is the existing ASB3 EFI limit for flows deemed to support *good ecological status* in the Water Framework Directive (see also Action 5. below) and in winterbournes a maximum 10% increase drying duration.
2. Reviewing Abstraction Sensitivity Banding	All chalk streams should be banded ASB3, unless there is compelling evidence to support a lower band. ASB3 may not be appropriate on the lower reaches of big chalk catchments (eg Lower Colne).
3. Enhanced Scenario for the National Framework	CaBA CSRG therefore endorses the National Framework's 'Enhanced Scenario' for chalk streams but based on local evidence. Flow deficits should be grouped as being either ecologically 'essential', 'beneficial' or 'of limited benefit' and prioritised accordingly. See section 4.6 National Framework.
4. Waterbody Boundaries and Assessment Points	The Environment Agency should set and publish a timetabled undertaking to review all chalk stream WFD waterbody assessment points and boundaries and make changes to ensure that the EFI methodology adequately protects ephemeral and headwater chalk streams.
5. Time-bound goals towards Sustainable Abstraction	Government, regulators and industry should set and publish time-bound goals (short, medium and long-term) towards achieving 'Sustainable Abstraction' (see Action 1) on all chalk streams, in accordance with Regional Planning process and the recommended prioritisation articulated in Section 4.6.
6. Evidence	Where existing (or future revised) methodologies indicate that abstraction is causing environmental stress or damage (chalk stream waterbodies where flow DNSG) the EA should gather evidence, including to native flora and fauna typical of the chalk stream habitat: this will require investment in assessment points and monitoring.
7. Reviewing the Abstraction Incentive Mechanism	Ofwat should review and adapt the Abstraction Incentive Mechanism and consider whether it remains fit for purpose, and if or how it can be adapted to increased effectiveness.
8. Demand Management	All areas dependent on water resource supply from chalk aquifer groundwater abstraction should be defined as Water Stressed, enabling compulsory metering. Water Companies should set and publish time-bound goals to achieve complete water-meter coverage in these areas.
9. Flow Recovery Flagship	Government, regulators and industry should set a short-term goal to achieve Sustainable Abstraction in the chalk tributaries of the Colne and Lea catchments, where a technical solution is available within a shorter time-frame because of existing infrastructure plans, as set out in the *Chalk Streams First* proposal. This iconic scheme would bring regional re-naturalisation of flows to the chalk streams most acutely impacted by groundwater abstraction, representing 20% of the chalk stream waterbodies where flow does not support good ecological status.
10. Independent Review of Abstraction as a % of Recharge	CaBA CSRG recommends an independent review of abstraction as a % of catchment recharge (A%R) for chalk streams in order to a) understand the scale of groundwater abstraction in chalk stream catchments and b) to investigate A%R as a simple and accessible method for independent assessment of abstraction impact and prioritising action. The results of the review will form part of the information made available to stakeholders and catchment partnerships via the CaBA Chalk Stream online hub.

5. Water Quality: Reducing Pollution

5. Water Quality

5.1 Water Quality Issues

In their natural state, chalk streams are 'gin clear' with little sediment, low nutrient levels and stable temperatures of around 10-11ºC. However, due to inputs from point sources such as sewage treatment works and diffuse sources such as agricultural run-off, many suffer from elevated levels of nutrients, sediment and chemicals, such as pesticides.

5.2 Sediment

Clean river gravels are essential for many of the species typical of chalk streams, such as brook water-crowfoot (*Ranunculus)*, invertebrates and fish.

Chalk streams are gentle rivers with limited natural flushing capacity so are very susceptible to siltation of gravels. Problems arise when too much sediment enters the system and low flows allow the silt to settle out. These problems are then exacerbated by reduced interaction between the river and the floodplain, by over-sized channels, structures such as weirs and excessive weed-cutting.

Chronic deposition of fine material will eventually lead to colmation of the river gravels, when the finer sediment accumulates within the coarser substrate of the river bed. Colmation, also commonly referred to as siltation, is particularly damaging to chalk river habitats. It reduces porosity and flow connectivity between groundwater and river-water and causes the compaction of the stream bed, which gradually alters the bed structure and morphology. This has a direct impact on plants, invertebrates and fish spawning-habitat.

5.2.1 Sources of sediment

The main sources of sediment are diffuse pollution, particularly from agricultural runoff, but urban and road run-off can also be significant in some catchments.

Point sources can also be important, such as fish farms and cress farms, although these are more easily controlled through permits to discharge.

Point source sediment is typically organic, while diffuse sources are more generally inorganic soil particles. However, other pollutants can be transported with the sediment, such as nutrients and pesticides from farmland or hydrocarbons from roads. The organic content will vary depending on the source: slurry, for example, contains a high proportion of organic matter.

Scientific research over the past decade has greatly improved our understanding of the role of fine sediment (<2mm) in chalk stream ecosystems. Work on

Left: In a chalk landscape, agricultural run-off is highly dependent on tracks and roads as hydrological pathways to the river

sediment fingerprinting demonstrates that fine sediment sources in chalk streams are derived from:

• cultivated fields (especially those left bare or lifted / ploughed in winter)

• pasture fields (especially as a result of overstocking)

• in-channel vegetation

• fish and watercress farms

• road-verge erosion (especially an issue on narrow, rural roads frequented by heavy farm traffic)

• sewage treatment works.

77% of fine sediments in England and Wales are derived from agriculture. In chalk streams bank erosion is a minor source due to their low energy and low rates of bank erosion (although bank erosion can be significant where chalk streams are overgrazed, dredged or impacted by invasive signal crayfish or Himalayan balsam).

In strategising how to manage the impacts of fine sediment it is important to distinguish between fine sediment *delivery* and fine sediment *retention.* They are two halves of the same problem and should be addressed as such.

5.2.2 Road run-off.

Chalk catchments are noted for the naturally limited networks of river channels. In a natural chalk stream there are few hydrological pathways from the wider catchment to the river (there are rather more in a mixed-geology chalk stream). However, wet weather in a modern landscape turns every road into a potential tributary: the road system has become a vastly and unnaturally extended drainage network that operates to convey diffuse pollutants into the chalk stream. These pollutants include salt applied to the roads in winter, rubber from tyres, oils and fuels. In rural areas large agricultural machinery crushes the verges of the narrow lanes these machines travel down and the lanes themselves become virtual 'streams', adding vastly to the total length of eroding 'riverbank' in any given chalk catchment. Finally, the roads are a means of conveyance of sediment eroded from farmland. Fields left bare in winter (crops like carrots and parsnips are lifted increasingly late into the autumn and even through the winter), maize fields and open-air pig fields are particularly problematic. Rainwater rushes across plough-lines and ruts in these fields, discharges onto the road network and flows rapidly downhill to the chalk stream where grips cut in the road verges allow the pollutant-laden water to spill directly into the river.

5.2.2. The impacts of fine sediment on fish & invertebrates

In 2017 Salmon & Trout Conservation (S&TC) published reviews on the impacts of fine sediment on invertebrates and fish (see link in Appendix A)

Healthy river systems require sediment input to maintain habitats and provide nutrient input, but *excessive* sediments loads can have a very significant impact on ecological health, primarily by swamping out and homogenising habitat, filling the interstices in the gravel bed, or cloaking the bed of the river in particulate matter to which is attached phosphorus and other toxic chemicals.

Excess sediment also causes unnatural turbidity in the water, with a range of knock-on negative impacts: on weed-growth, for example, and therefore oxygen levels, the inter-crown scour of the river bed, habitat heterogeneity and so on. Excessive sediment, in suspension and deposited, impacts directly on the health and diversity of a chalk stream's invertebrate community by reducing scour, swamping interstitial habitat, burying the insect refugia, homogenising habitats, clogging gills and reducing primary production.

Similarly for fish, excessive sediment, in suspension and deposited, has a range of negative impacts, especially on salmonids. Sediment, particularly highly organic sediment, reduces salmonid egg survival by clogging the spaces in the gravel redd, effectively suffocating the eggs.

Excessive sediment has a range of sub-lethal impacts too. For example, it drives premature emergence of fry from the gravel redd, it reduces the ability of young fish to detect predators, it degrades fry habitat, causes gill irritation, alters blood physiology, and reduces feeding opportunities and rates.

In concluding remarks, S&TC highlighted a lack of assessment or a reference base for sediment limits emphasising that 'the WFD objective of Good Ecological Status cannot be achieved without addressing this important pressure' and that 'urgent action is required to identify more meaningful revised sediment targets for England and Wales'.

The report identified the aggravating or mitigating role of river morphology and flow regime emphasising that 'managing excess sediment requires prevention and restoration measures, all of which require sound understanding of the key sources' concluding that 'in order for sediment management to progress in England and Wales, better-informed sediment targets, and replicable monitoring methods are urgently required for compliance testing'.

Road run-off in the River Wissey catchment May 2021

5.3 Nutrient enrichment

5.3.1 The importance and natural scarcity of nitrogen and phosphorus

Of the various chemicals dissolved in water, the macronutrients phosphorus (P) and nitrogen (N) are fundamental to primary productivity and to sustaining freshwater ecosystems.

Although essential, these two chemicals would nevertheless present in very low concentrations in the natural chalk stream, unaffected by man. Natural sources of P and N would include leaching from the catchment soils and decomposing vegetation, release of P from the geology, atmospheric deposition of N in rain and the biological N fixation of cyanobacteria, converting atmospheric nitrogen to ammonia. Very little P is available from natural geologies, especially chalk, and the natural chalk stream is exceptionally stable with little bank erosion. The nutrient levels would be largely dependent on retention and downstream spiralling within the system.

5.3.2 Anthropogenic sources of nitrogen and phosphorus

Farming and wastewater add significant amounts of P and N to both the chalk stream and the chalk aquifer.

The intensification and industrialisation of farming, especially in the post-war decades, added vastly to the quantities of fertiliser spread on farmland. Phosphorus and ammonium bind very easily to soil particles and sediment and wash into the streams via surface run-off, while nitrogen is highly soluble and mobile and is readily leached into the aquifer and river via subsurface flow. As a consequence there is now an enormous legacy of nitrogen in our chalk aquifers.

Human wastewater is usually dominated by dissolved inorganic nitrogen and phosphorus which is readily available for uptake by plants (known as bio-available) but the concentrations at the wastewater outfall will largely depend on the quality of treatment at the sewage works. Secondary treatment includes an element of settling and filtration, but tertiary treatment is necessary to remove more significant amounts of N and P.

5.3.3 Eutrophication - the result of excess levels of nutrient

Elevated nutrient enrichment (known as eutrophication) in chalk streams has a direct impact on plant populations, with secondary effects on other organisms, such as fish and invertebrates, which are dependent on plants for shelter, reproduction and food.

Eutrophication is responsible for toxic algal blooms, water anoxia, habitat and biodiversity loss, the degradation of estuaries and coastal areas. Nutrient enrichment can also affect human health by impairing drinking water.

Left: The sewer outfall from Fakenham Treatment Works on the River Wensum, one of four SAC chalk streams

There are four primary ways in which excess nutrient levels can affect chalk stream plant communities:

• by excessively driving the growth rate of plants – which can cause problems with sediment retention, and the spiralling of nutrients when the plants break down in the winter

• by encouraging the higher-order plant species adapted to higher nutrient levels, skewing the balance of the plant community and reducing bio-diversity

• by boosting the growth of epiphytic, epibenthic, filamentous and planktonic algae

• by limiting the root depth of the higherorder plants like ranunculus, making them more susceptible to being ripped out in high flows

Although higher order and important chalk stream plants like ranunculus thrive best at very low, background natural nutrient concentrations, the first effect of nutrient enrichment is – counter-intuitively – an increase in the growth-rate of the higher order plants, but with commensurate weakening in root growth – making the plants vulnerable in high flows.

As nutrient levels increase further, the ecology shifts towards a dominance of the higher order plants that are more tolerant of nutrient enrichment, leading to a reduction in the overall bio-diversity of the plant community.

Finally, if nutrient concentrations keep on rising, the river's ecology switches to a more algal dominated plant community. Benthic algae smothers the river bed and the interstices in the gravel in which many insect species live and epiphytic algae cloaks the leaves and stems of the higher order plants, reducing their ability to photosynthesise. The prevalence of algae will also cause extreme diurnal variations in dissolved oxygen levels, which stresses fish and insects alike.

5.3.4. Nitrogen and phosphorus limitation

The concept of nutrient limitation is important in strategising pragmatic improvements to water quality in chalk streams. As nutrient concentrations increase above natural levels the plant community changes in the ways outlined above until a point is passed whereafter no amount of additional increase in the concentration effects any additional change.

If the nutrient concentration rises far above this trigger point (and on many chalk streams and chalk aquifers it has), then it needs to be reduced all the way back down to the trigger point and below before an improving effect is discernible (something that is further complicated by the legacy of stored nutrients in river bed sediments and the aquifer).

Of the two nutrients, phosphorus is typically in shortest supply in freshwater systems, especially chalk streams. Research (Mainstone et al 1995) at 5000 sites surveyed in England and Wales has shown that wherever the phosphorus concentration is at a level that might conceivably be a limitation to growth (the trigger point), nitrogen is typically over 8 times the value and relative to phosphorus is surplus to requirements.

This finding is endorsed by more recent research (Jarvie et al, 2017) into nitrogen and phosphorus limitation in different types of river and headwater stream, where: 'preliminary assessments suggest that reducing P concentrations in the Lowland-High-Alkalinity headwater streams, and N concentrations in the Upland-Low-Alkalinity rivers, might offer greater overall benefits for water-quality remediation at the national scale, relative to the magnitude of nutrient reductions required. This approach could help inform the prioritisation of nutrient remediation, as part of a directional approach to water quality management based on closing the gaps between current and target nutrient concentrations'.

The same rationale informed the basis of the Hampshire Avon Nutrient Management Plan: 'as this is the chemical that is thought to be most significant in preventing favourable conservation status from being achieved across the catchment … Controlling anthropogenic enrichment of phosphorus in the River Avon at levels that limit the growth of plant species is necessary to restore and protect the characteristic biodiversity'.

Clearly, driving down both nitrogen and phosphorus is important to the restoration of chalk stream ecology, however, a combination of the sheer scale of the nitrogen problem and the fact that phosphorus is almost invariably the limiting chemical, means that prioritising reductions in phosphorus concentrations towards background levels is a vital step in the shorter term maintenance / and restoration of higher plant communities.

Moreover, many of the actions that will contribute to this incremental reduction of phosphorus in chalk streams, will also contribute to a reduction of nitrogen.

It is worth noting that there are some key actions such as the restoration of the fen habitat in headwater chalk catchments and around the spring-line and the restoration of hydrological connectivity between the river and the floodplain that would make significant contributions to the reduction of nitrogen.

5.3.5. How nutrients get in to a chalk stream.

The ways in which nutrients get into and stay in a chalk stream are key to understanding how to plan and prioritise strategies to reduce their impact.

Nutrients gets into a chalk stream from 'point', 'diffuse' and 'intermediate' sources. Typically, point sources of nutrients are municipal wastewater, whereas diffuse runs off the agricultural landscape, into either the river or the groundwater, while intermediate sources include septic tanks and urban run-off.

The main point-source supply of P and N is through the human sewage system, but fish farms and cress farms are also point-sources: a large fish farm (40 tonnes annual production), for example, can generate as much P as a secondary sewage treatment works serving 1000 people.

Diffuse source nutrients (and other chemicals), on the other hand, flow in multiple pathways from the wider landscape, and particularly from farmland and get into the river by surface or shallow sub-surface flow, especially during the winter. N from the aquifer is also a diffuse source.

5.3.6. The relative impacts of different sources of nutrients

The relative impacts that point and diffuse nutrients have on river ecology are not necessarily in proportion to the relative loading by weight from each source.

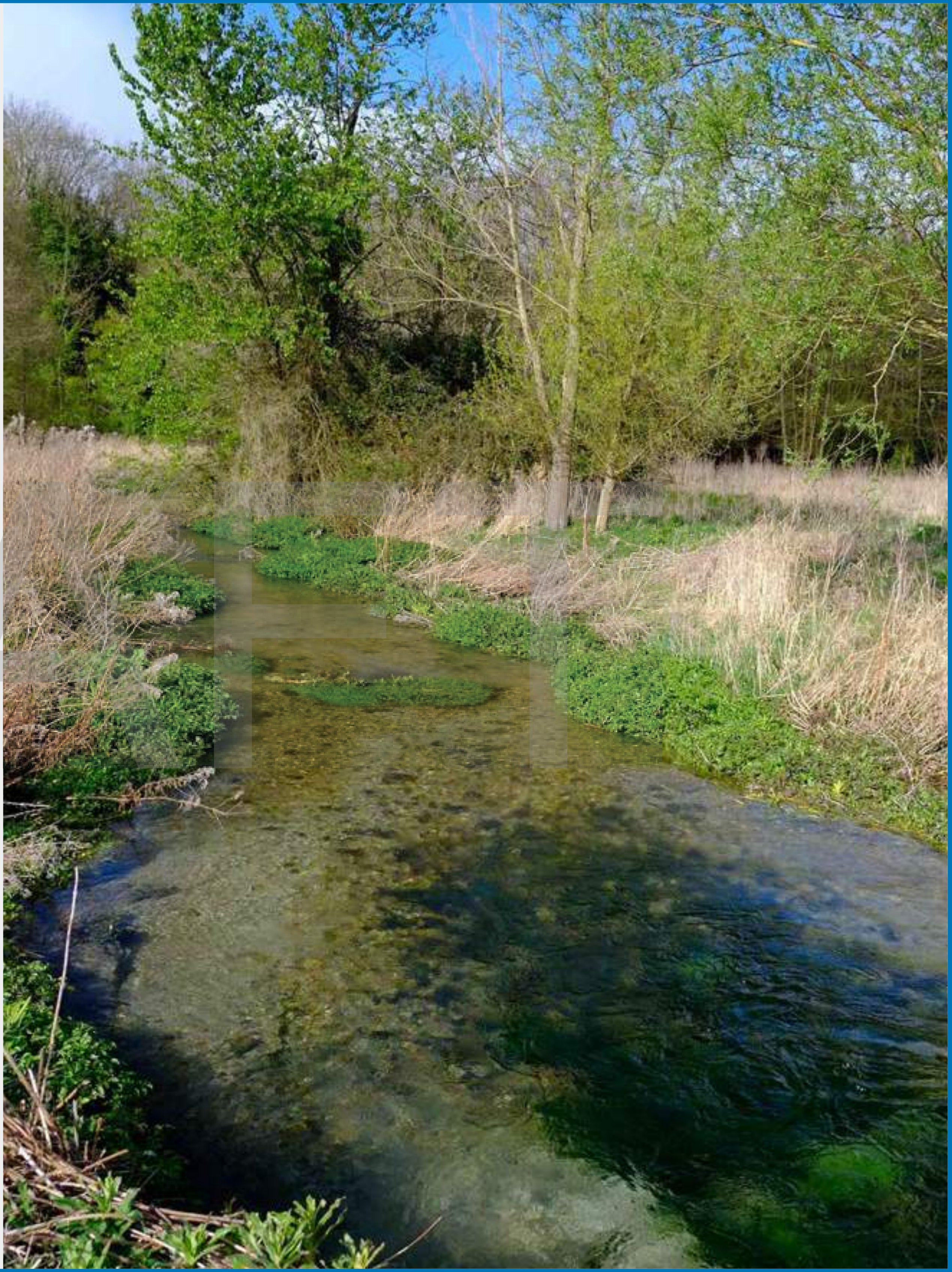
Point source P and N, especially from the human sewage system, is released directly into the river in a fairly constant stream (with spikes or flushes), and in a form that is readily available for uptake by plants and algae (known as bio-available), including during the growing season as flows diminish and temperatures and daylight hours increase: the constant supply of nutrient from sewage effluent, therefore, becomes more highly concentrated in the receiving chalk stream in sync with the biological activity (in the growing season) that precipitates its negative impact.

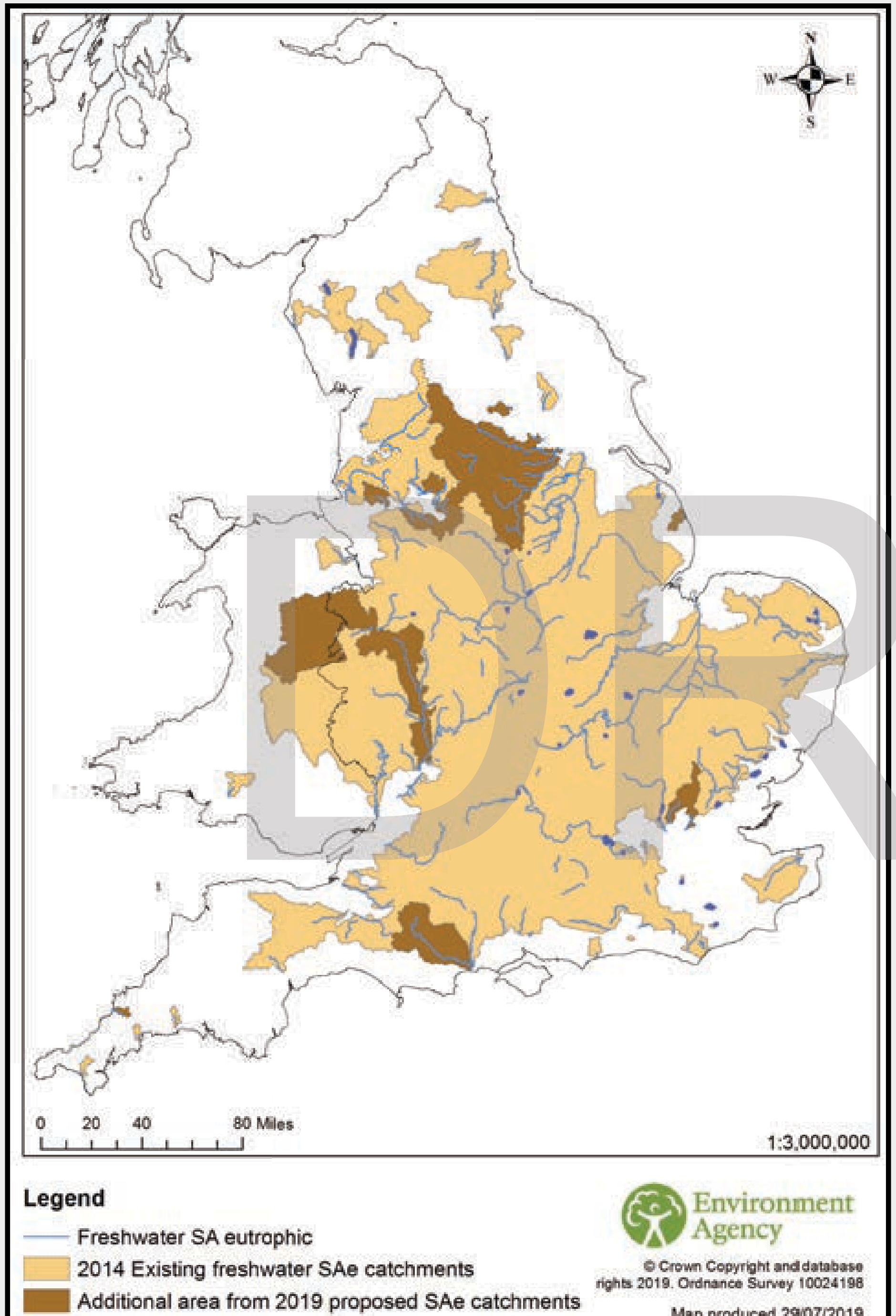
By contrast, much of the dissolved nutrient that washes into a chalk stream in the high flow and run-off events that bring the pollution from the landscape to the river, is flushed through the river by the same high flows and often outside the growing season. Nitrate, however, will wash down into the aquifer, while P readily binds to soil particles which then settle in the river. A proportion, high in places, of diffuse pollution can be organic too: for example slurry and run-off through farmyards.

This is where nutrient and sediment pollution overlap and where it is also important to consider the physical condition of the channel. A free-flowing chalk stream with good hydrological connectivity with the floodplain will be less adversely impacted by nutrient / sediment pollution, than a dredged or impounded channel which cannot flush itself or escape on to the floodplain in high flows.

Ameliorating the impact of nutrient enrichment is one respect, among many, where restoring the physical morphology of chalk streams and their catchments is a vital part of a holistic restoration strategy.

Right: the River Babingley is High status for Phosphate and Ammonia. The Ingol in the neighbouring valley is Poor status. There is no STW on the Babingley. There is a large (6,500 pop.) STW on the Ingol. 80% of chalk streams at High status have no STW. 83% of failures have STWs that do not remove phosphorus.





Map showing the distribution of Sensitive Area eutrophication catchments

5.3.7 Environment Agency Phosphorus Narrative

The Environment Agency Phosphorus Narrative (see link in Appendix A) is an analysis of the progress made over the past 20 years and an assessment of the remaining challenges with regard to phosphorus pollution in rivers.

P concentrations in our rivers increased greatly between 1950 and the 1980s due to the introduction of P-based detergents, population growth and the growing use of artificial P fertilisers.

However, from a peak in the 1950-80s to 2020 total P loadings have been reduced by more than 66%. P stripping on the River Kennet, for example, has led to an overall reduction of 88%.

These gains have largely been driven by the Urban Wastewater Treatment Directive (UWWTD) and the Water Framework Directive (WFD) and have applied to relatively large sewage treatment works (STWs), but with smaller STWs targeted in each price review, so that now many medium scale STWs are fitted with phosphate removing processes, especially in the vulnerable catchments designated by the UWWTD or by SAC and SSSI status.

Despite good progress in tackling phosphorus pollution since 1990, 55% of river water bodies in England do not meet WFD phosphorus standards for good ecological status.

The picture is slightly better for chalk water bodies at 37%. Phosphorus is *the most common cause of water quality failures* under the WFD in England. In addition 50% of N2K rivers currently fail their long-term target for P. A small number of groundwater bodies are also at poor status for P.

Source Apportionment and Future Risks

The largest source of P is still sewage effluent, but this varies between catchments. In failing waterbodies the relative apportionment of P between sewage and agriculture is 60-80% sewage and 20-30% agriculture.

Future risks

Climate change could lead to more extreme flow regimes, with lower summer flows leading to increasing concentrations of pollutants and higher winter flows leading to greater run-off. Increased P dosing of drinking water to meet tighter Drinking Water Directive standards and housing / population growth will also add to the risks, especially across our chalk streams.

Ecological Recovery – a Long Road

Ecological recovery from nutrients can be lengthy and uncertain. Despite great reductions in P there has to date been a disappointing ecological gain. This is partly because the P reductions have still not gone far enough. But it is also because so much P has been applied to the land over the decades and is locked into the soil and the sediments on our river beds (as is Nitrogen). P failures of WFD waterbodies also tend to coincide with sediment and morphology failures.

Point Source Improvements

By 2015 60% of the population had been connected to STWs fitted with P removal. By 2027 with WFD reductions building on UWWTD reductions, 95% of the population in England will be connected to STWs fitted with P removal. The map on page 54 shows the rivers and catchments where the UWWTD stipulates that P removal must be fitted to large STWs.

The UWWTD and WFD will drive further STW P reduction measures through the current Water Industry National Environment Programme (WINEP) which covers the period 2020-25. This is mainly targeted at the water industry's 'fair share' of meeting WFD good ecological status for P and will improve some 5,000km of river at a capital cost of around £1.65 billion. Under this programme, around 900 STWs serving 15 million population equivalent will have new or tighter P reduction by 2027. This will result in reductions of 88% in the STW P loading to rivers compared to the position in 1995.

So far, so good: and yet the EA SAGIS (Source Apportionment GIS) SIMCAT (simulation catchment) models project that in spite of these actions, P compliance will only improve nationally by 2%: 'this is primarily because although the water industry is 70% compliant with its fair share of the P reductions needed to meet good status for river P, agriculture is only 48% compliant and this constrains the extent of progress towards the good status objective'.

Despite this, it is essential that water companies continue to innovate to improve P removal from sewage treatments at the same time as actions are taken to reduce P inputs from agriculture.

Diffuse Pollution Improvements

Until recently there were no direct regulatory controls on agricultural P application to soil or the prevention of P losses from farmland to rivers. However, the Reduction and Prevention of Agricultural Diffuse Pollution (England) Regulation - commonly known as the Farming Rules for Water - came into force from April 2018.

These rules embed in law various good practices such as nutrient planning, soil and manure management and a step-by-step checklist aimed at ensuring that fertilisers are spread to meet crop and soil needs, when it is best to apply fertilisers, where to store manures and how to avoid pollution from soil erosion. Cross-compliance contains some measures such as those that protect soils which will indirectly control P losses.

In addition, P fertiliser use, livestock numbers and manure P inputs to land have all been reducing nationally in recent years mainly due to economic factors.

Not yet enough

Nevertheless, Defra analysis indicates that agriculture needs to reduce P loss by an average of 48% nationally to achieve the required WFD standards. This assumes that the burden of reductions should be proportionate to the contributions from water company discharges and agriculture.

Measures to tackle diffuse P pollution from agriculture are more cost effective when parallel reductions in other pressures (sediment, nitrate, faecal indicator organisms) are considered. The benefits, in terms of reducing loss of P and N from the landscape, of nutrient management planning, manure storage and separation of clean and dirty water in farmyards, are widely recognised.

Future Scenarios

In considering potential strategies for managing P at river catchment level it may be useful to consider the relative priorities for action of the following two scenarios:

• High P concentrations, often in **high alkalinity lowland rivers (**ie chalk streams), due to sewage and agricultural sources, with good local evidence of ecological harm (eutrophication), high confidence that some reduction in concentration/load will be achieved but low likelihood it will be sufficient to achieve P standards and thus uncertainty over ecological improvement. ***Tackling P from sewage treatment works*** is an essential starting point in these situations but ***agricultural sources are increasingly important***.

• Low P concentrations, often in sensitive low alkalinity or headwater river reaches, where local evidence of eutrophication is likely to be weaker, but deterioration needs to be prevented and ***measures for agriculture, small STWs*** *and* ***rural sewage sources (septic tanks)*** might reduce P concentrations from just failing to levels that will deliver ecological improvement.

5.3.8 Nitrogen

The main concerns with high concentrations of N in water are:

- the risk to human health from drinking-water abstracted from ground or surface waters with high N concentrations
- eutrophication of surface waters
- nutrient enrichment in other sensitive habitats like groundwater dependent ecosystems

N pollution is so endemic that nearly 30% of groundwater used for drinking water supply in England must now be blended, treated, or replaced in order to meet tap water nitrate standards.

Treatment is expensive with a nitrate removal plant costing upwards of £8m and this cost is ultimately passed on to the water consumer through higher bills.

Agriculture is the dominant source of N in water (about 70% of total inputs), with sewage effluent a secondary contributor (25-30%) nationally.

In general, N concentrations are greatest in the drier, arable-dominated chalk stream catchments of southern and eastern areas of England.

55% of England is designated as a Nitrate Vulnerable Zone (NVZ) due primarily to elevated N concentrations in groundwater and rivers. NVZ action programmes to reduce agricultural nitrate pollution have been in place since the late 1990s. During that time, river N concentrations have seen a general reduction, but not a dramatic reduction.

Groundwater N concentrations are broadly stable in many places except in southern England where they are still rising in some areas. This is partly because of the lag time or delay it takes for the peak agricultural N loadings of the 1980-90s to percolate through the water table.

The Farming Rules for Water and Nitrate Vulnerable Zones form the regulatory baseline. Catchment schemes, safeguard zone action plans and the proposed new Environmental Land Management Scheme (ELMS) will have important roles to play in securing the necessary improvements.

For agriculture, the most effective measures (in terms of cost and reducing N leaching) are achieved through:

- nutrient management plans and knowledge of the N content of manures, composts and slurries
- cover crops
- careful calibration of fertiliser spreaders
- land-use change, for example converting intensively farmed arable land to less intensively managed grassland or woodland (this is the most effective and also the most cost-effective measure)
- reduced stocking density is the most effective measure to reduce N loading from livestock

Local circumstances would dictate which combinations of measures could be the most cost-effective

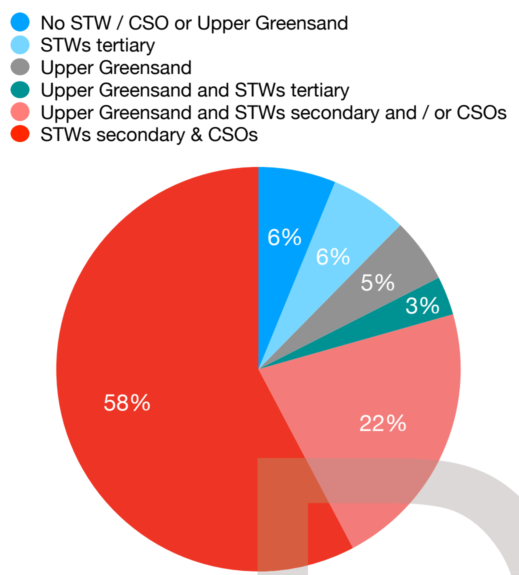
For sewage, conditions on permits for discharges are used to regulate the contribution of nitrate entering surface waters from sewage treatment works and industry.

Conventional primary and secondary treatment at sewage works removes 20-30% of the N in raw sewage. Where effluent needs tertiary treatment, for example to meet Urban Waste Water Treatment Directive (UWWTD) requirements affected by eutrophication, levels of N reduction can be around 70-80% to meet effluent N standards of 10-15 mg/l.

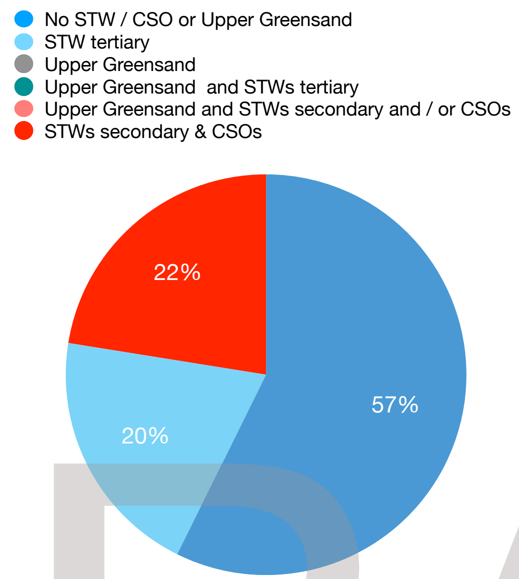
Improvements to leaking sewers will reduce nitrogen loss to groundwater, and to surface waters where there is good connection with groundwater.

Leakage reduction programmes for mains water pipelines where N in drinking water is at relatively high concentration will have the additional benefit of limiting the return of this pollutant to groundwater.

Following billions of pounds of investment by water companies in sewage treatment works, the agricultural sector must play its part in addressing the diffuse run-off that also pollutes our chalk streams and chalk aquifers



Chalk Streams MODERATE, POOR OR BAD STATUS for phosphate	
No STW, CSO or Upper Greensand	6
STWs tertiary only	6
Upper Greensand	5
Upper Greensand & STWs tertiary only	3
Upper Greensand & STWs and / or CSOs	21
STWs secondary only and / or CSOs	56



Chalk Streams HIGH STATUS for phosphate	
No STW, CSO or Upper Greensand	51
STWs tertiary only	18
Upper Greensand	0
Upper Greensand & STWs tertiary only	0
Upper Greensand & STWs and / or CSOs	0
STWs secondary only and / or CSOs	20

*Upper Greensand is implicated in a very high % of failures. See section below.

** Four of these (the Wintringham, Gowthorpe, Shep and Cherry Hinton Brook) are small chalk streams subsumed into larger waterbodies of a different morphology and incorporating Assessment Points downstream of the chalk stream reaches, while the Shep, Cherry Hinton Brook, Bourne Brook and Ewelme are all small, suburban chalk streams

** Of these the Caker is a small stream serving a large town (Alton), the Lee is impacted by Luton, Harpenden, Mill Green and Hatfield STWs (all tertiary), the Pix Brook is a small stream serving a large town (Letchworth), and the Slade, Quy and Kneeswell are small chalk streams subsumed into larger waterbodies of a different morphology.

**** All but three of these are small STWs on pure geology chalk streams, while the Wye, Ver and Misbourne all have much higher P readings downstream of their STWs

5.4 WFD Phosphorus (P) Status Analysis

5.4.1 All Chalk Streams

There are 249 chalk stream waterbodies (some individual chalk streams are divided into several waterbodies). Of these 249 there are 97 (39% nationally) failures for P status (Moderate or worse). As with Flow the % of failure does not fall evenly across the map.

As can be seen in the chart opposite WFD failure for P appears to correlate closely to the presence of STWs that do not remove P / and or CSOs and also the presence of Upper Greensand in a catchment.*

Moderate, Poor or Bad Status for Phosphorus

• Only 6% of the Failures for P are on waterbodies with no Sewage Treatment Works, Upper Greensand** or SOs (storm overflows . See section 5.8 below)

• Only 6% of the Failures have STWs which do remove P.***

• Upper Greensand can be associated with 5% of the failures and a further 25% can be associated with Upper Greensand along with STWs and CSOs

• 58% of the failures are on waterbodies with discharging STWs which do not remove P.

High Status for Phosphorus

• Conversely HIGH status for P correlates closely to an absence of any STW on a given waterbody or to the STWs operating to a standard that removes P.

• There are also **no** chalk streams of High status for P with Upper Greensand in their catchments.

• 57% of High P status chalk streams have no STW / CSO or Upper Greensand, while a further 20% have STWs which remove P. 22% have STWs which do not remove P (though the P status of some of these STWs is unconfirmed).****

The WFD charts in Appendix E show WFD P data from three chalk streams, the Misbourne, Whitewater and Kennet.

Appendix F is a case study of P status in the Frome and Piddle catchments.

5.4.2 Upper Greensand

Detailed analysis undertaken for the SAC Nutrient Management Plan for the Hampshire Avon suggests that background P readings in the Avon chalk streams with Upper Greensand (UGS) in their catchments are much higher than other purer chalk geology streams. Chalk is known to bind P within the aquifer, whereas Greensand does not.

This correlates with the P readings in other chalk-stream catchments which feature an element of UGS in the geological make-up: the Upper Frome, the Nadder, the Kentish Stour. Also individual rivers like the Fontmell, Lavant, Lockinge, Lewknor, Shalborne and Tillingbourne.

100% of the failures south and west of the Thames catchment feature UGS in their catchments. A much smaller number of rivers north and east of this: eight in the Thames, two in the Kentish Stour, one in the Ouse catchments feature a significant amount of UGS in their catchments. These also all fail WFD status for P.

There is currently some debate as to whether the high P concentrations of groundwater from UGS aquifers is a natural phenomenon, which might have suggested that WFD P targets are too high for these systems, or is the result of anthropogenic activity.

For example the Hampshire Avon NMP states that 'there are significant natural sources of phosphorus entering the Avon from minerals in the Upper Greensand aquifer' (a background porewater concentration of about 0.15 mg/l)

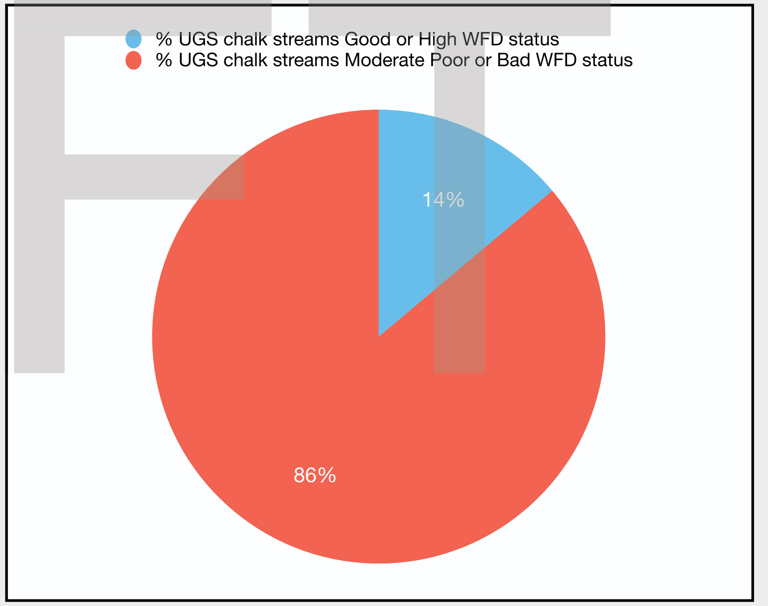
By contrast, Penny Johnes et al researching the origins of phosphorus in Upper Greensand catchments concluded: 'Natural or near-natural P concentrations in the aquifer, deriving from the much slower dissolution of primary fluorapatite in the UGS would be substantially lower than current concentrations, based on this mineralogical, geochemical and modelling evidence'.*

Whether the elevated P in Upper Greensand aquifers is natural, or anthropogenic in origin, it is also true that mixed geology chalk streams tend to be more flashy in nature, featuring a higher proportion of impermeable surface soils and a greater density of hydrological pathways and that agricultural practice in these catchments is therefore likely to create an even more significant diffuse run-off issue than it does on the classic 'pure' chalk streams, with their more limited pathways and more permeable soils.

In the upper Frome catchment for example an increasing amount of land is now used for maize production, which is fertilised with slurry from Dorset's large, industrialised dairy units. Anecdotally (from those who have known the upper Frome for many years) siltation, poor ranunculus growth, benthic algal growth and declining invertebrate numbers all point to a eutrophication problem that has developed in line with changing agricultural practices.

Upper Greensand chalk streams are notably (among chalk streams) impacted by elevated groundwater P levels, which are probably exacerbated by subtly distinct farming practices in these mixed surface soil catchments. Poorly managed septic tanks are also likely to be a problem in these catchments, because of the density of hydrological pathways and the impermeable soils.

There is therefore a good case for prioritising Upper Greensand chalk catchments as **Water Protection Zones** with bespoke mitigating strategies designed to address the full range of nutrient and sediment pollution issues.



% Pass or Fail WFD for Phosphate of the 36 chalk streams with mixed chalk and Upper Greensand geologies

* Determining the Nature and Origins of Riverine Phosphorus in Catchments Underlain by Upper Greensand / Penny Johnes, Evangelos Mouchos, Heather Buss, Sam Bingham (University of Bristol) and Daren Gooddy (British Geological Survey)

Mixed geology chalk streams like the River Frome feature notably higher P concentrations than other chalk streams

5.4.3 Designated Chalk Streams

Notwithstanding the impact of the Upper Greensand in the Avon (an SAC), affecting 14 of the 25 waterbodies in the catchment, it is clear that P standards in the designated SAC and SSSI chalk streams are much higher than across the other chalk streams.

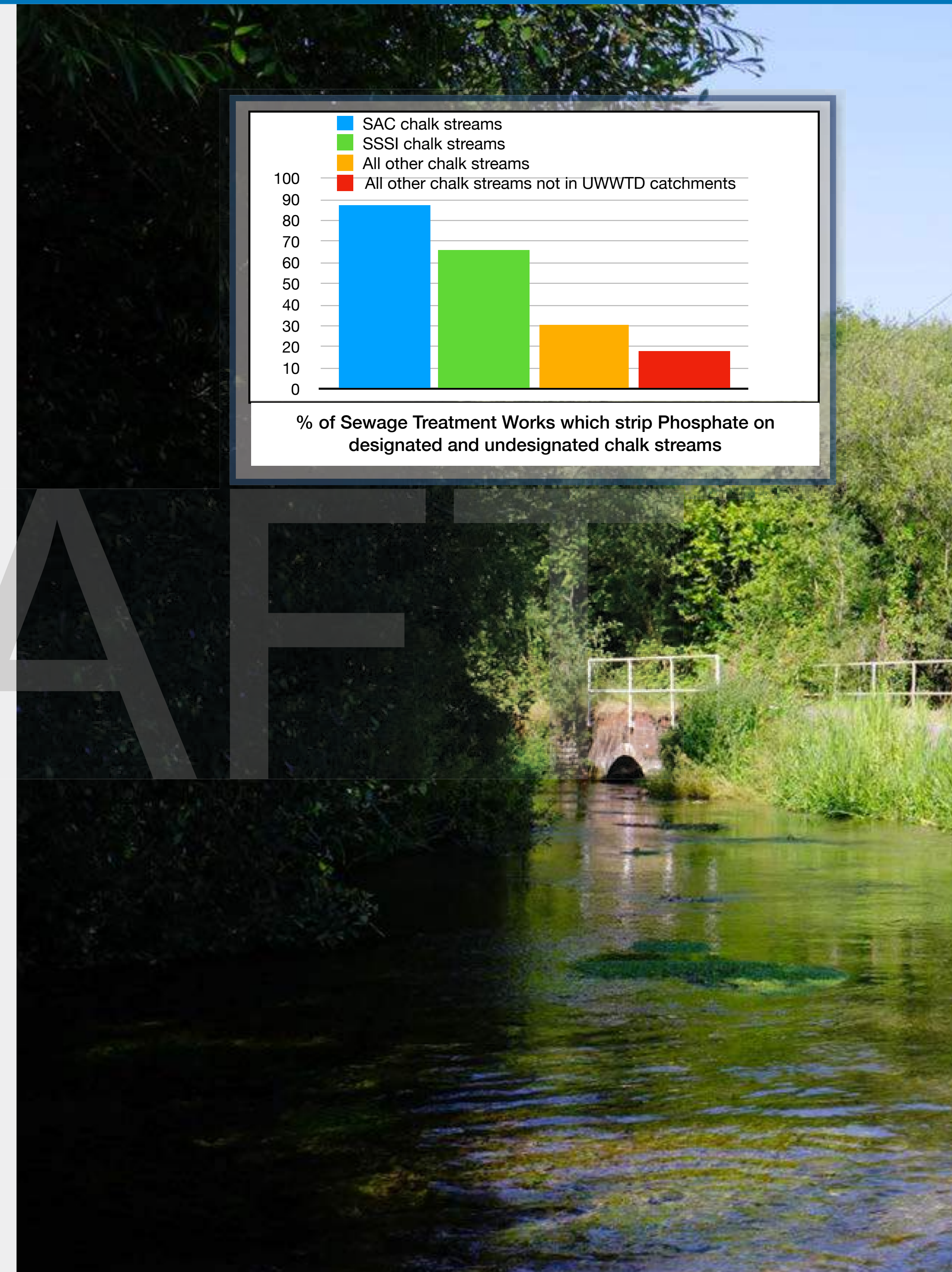
- The Frome SSSI has 33% STWs with P removal and all 4 of its failures are associated with the STWs which do not remove P and with Upper Greensand.
- The Avon SAC has 60% STWs with P removal and all 13 of its failures are associated with Upper Greensand, and some also with STWs and CSOs.
- The Test SSSI has 54% STWs with P removal and no failures.
- The Itchen SAC has 100% STWs with P removal and no failures.
- The Kennet SSSI, including the Lambourn SAC, has 61% STW's with P removal and only one failure which is associated with Upper Greensand, a secondary STW and a CSO.
- The Nar SSSI has 100% STWs with P removal and no failures.
- The Wensum SAC has 100% STWs with P removal and no failures.
- The Driffield SSSI has 84% STWs with P removal and one failure, the Nafferton Beck, the only waterbody in the catchment with secondary STWs (two).

On average nearly 90% of STWs on SAC chalk streams and 65% of STWs on SSSI chalk streams strip P.

Conversely on undesignated chalk streams only 30% of STWs strip P.

That figure falls to 18% on chalk streams that are not in UWWTD SAe catchments.

Right: chalk streams like the Lambourne in Berkshire, an SAC chalk stream in an SAe catchment have benefitted greatly from progress made over the last two decades to remove phosphate from sewage discharges



% of Sewage Treatment Works which strip Phosphate on designated and undesignated chalk streams

5.5 Storm Overflows

Storm overflows (SOs) are designed to allow exceptional discharge of sewage to rivers at times of heavy rainfall when the sheer volume of water threatens the capacity of the works, to prevent sewage backing up into homes and streets.

But a growing population, urban development and more intense rainfall means they discharge more often.

In 2017 WWF published an investigation of SOs, reporting that of the 80% of rivers then failing to reach ‘Good Ecological Status’, sewage pollution was linked to the majority of the failures.

Data provided by one company indicated that 14% of their combined sewer overflows were discharging, on average, at least once a week, 50% once a month, while some were spilling hundreds of times a year. This is in spite of the Urban Wastewater Treatment Directive requirement that SOs should ‘only be used after heavy rainfall’.

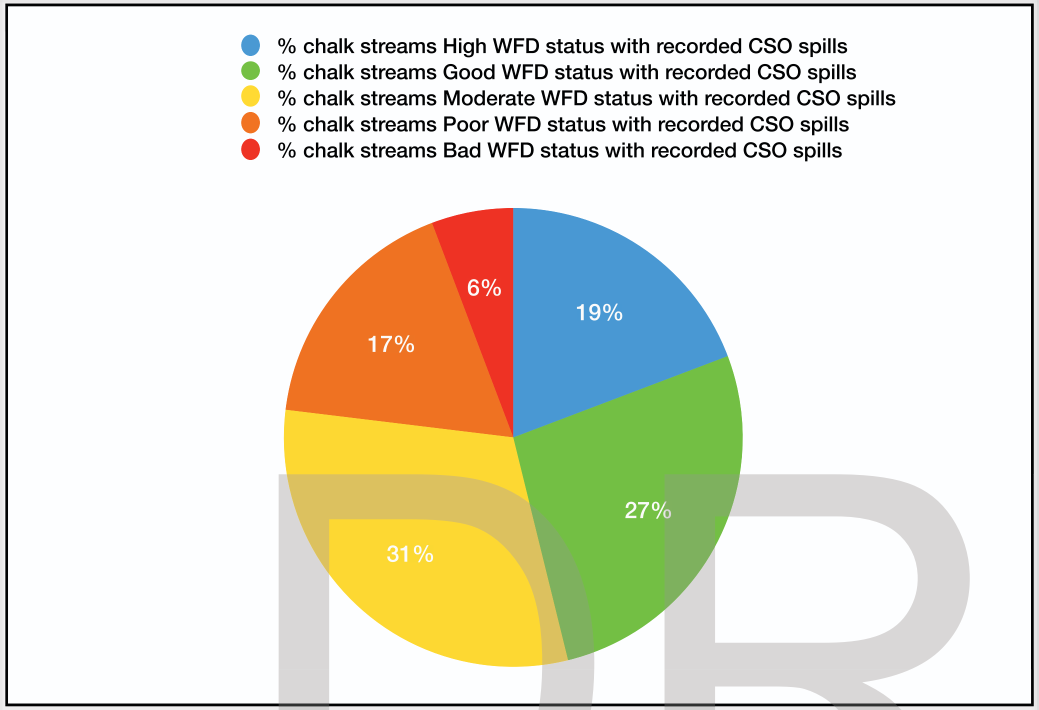
Infrastructure investment

WWF highlighted the fact that most of the present-day sewerage infrastructure was installed over half a century ago. Investment in sewage treatment works is not keeping pace with the deterioration of the works or the growing pressures and at the current rate of progress it will take 800 years to replace ageing assets.

Water companies are relying on storm overflows to compensate for under-capacity, as was strongly suggested in the recent Panorama exposé of storm overflows broadcast on BBC1 in April 2021.

There are 17,684 permitted sewer overflows across England and Wales, where water companies are allowed – under certain conditions – to discharge untreated sewage. 89% of these discharge to rivers. The table on page 58 gives details of the storm overflows to chalk streams in 2019.

A specific issue for chalk streams is groundwater infiltration to sewer networks, which means in wet winters, when groundwater levels are high, groundwater enters the sewers leading to extended operation of storm overflows. These spills can lead to a multitude of effects: risk to human health arising from bacteria and viruses; reduction in oxygen and therefore damage to the ecology; plus nutrient enrichment at a sensitive time for river ecology – early spring when groundwater levels are high and fish are spawning.



WFD status for P* of the 52 chalk stream waterbodies with significant recorded CSO spills in 2019

***Note this is indicative only: because storm overflows bypass the sewage works (albeit there is an element of settling) they discharge much more than just phosphorus. See the case study on the P.54.**

Water companies should manage and maintain their sewer networks properly.

We need action to prevent surface water getting in to sewers – a combination of sustainable drainage systems (SuDS), household behaviour change initiatives and catchment management.

Government/Defra should empower water company to control surface water entering their sewers, reviewing the right to connect surface water to combined sewer, powers to disconnect surface water from combined systems or discharge surface water to rivers and powers to rectify private drains that are allowing significant infiltration.

5.5.1 Storm Overflow 2019 data

As can be seen from the 2019 data, storm overflows are implicated in 30 WFD P failures, while significant SO spills occurred on 54 chalk stream waterbodies in 2019.

Some notable recorded spills occurred in waterbodies that nevertheless are of Good or High status: the Sydling, the Till, the Wiltshire Bourne, the Kennet h'waters, the Lambourne, lower Kennet, Loddon, Bucks Wye, Quin, Hiz and Glaven. These tend to be either:

• SO's which (in 2019) spilled for a very high number of hours: for example the Sydling SO which spilled for 1813 hours, almost three months. These are likely to be caused by high groundwater ingress through leaky pipes and, if from a small agglomeration, may not show an impact in WFD monitoring.

or

• SOs that spilled only infrequently: for example on the Glaven there were 8 spills, totalling 88 hours, which is not outside the bounds of what the SO legislation allows for: only in the event of 'unusually high rainfall'.

The SO's that are likely to be contributing to WFD failure, and are almost certainly causing ecological damage, are more typically like the one at Bentley on the Wye, spilling in 2019 56 times (once a week) for 344 hours. Or the large total of SOs spilling in Canterbury at the upper and of the Great Stour. Or SO on the Chess (see Chess case study section 5.7.2) which is often triggered by groundwater ingress, but on a large sewage treatment works. Note also that the first 10% time duration of a given overspill event is by far the most toxic, especially after a prolonged dry spell. Toxic spikes of this kind are unlikely to be picked up with any reliability by EA monthly monitoring.

SO's are now receiving a lot of attention from a general public concerned to find that raw sewage is routinely spilled into their local rivers. Monitoring is better, but still not good enough. Information on spills is more freely available, but here too there is room for more transparency.

It is vital that EA permitting and enforcement of regulation of SOs adequately protects and reflects the iconic global ecological and heritage value of chalk streams as the receiving waterbodies and that policy is directed at greatly reducing the volume and frequency of spills, if not eliminating these spills altogether.

Storm Overflows on Chalk Streams 2019

HIGH STATUS | GOOD STATUS | MODERATE STATUS | POOR STATUS | BAD STATUS

Chalk Stream Waterbody	CSO Spill Records 2019
Bride incl Litton Cheney Brook GB108044009550	Burton Bradstock CSO 2019: 4 spills 4 hours
Hooke GB108044009800	Toller Porcorum CSO 2019: 29 spills 197 hours
Frome Upper GB108044009691	Maiden Newton CSO 2019: 32 spills 744 hours
Sydling GB108044009700	CSO 2019: 84 spills 1813 hours
Tadnoll Brook h'waters GB108044009660	Broadmayne CSO 2019: 51 spills 946 hours
Frome Lower GB108044009692	Dorchester Mill Stream CSO 2019: 30 spills 170 hours Wool CSO 2019: 29 spills 195 hours
Piddle Lower GB108044010080	Wareham CSO 2019: 15 spills 275 hours (spills to extreme DS of river)
Bere Stream GB108044009630	Milbourne St Andrew CSO 2019: 51 spills 1188 hours.
Shreen Water GB108043022450	Mere CSO 2019: 53 spills 405 hours & 28 spills 292 hours.
Iwerne GB108043016010	Iwerne Minster CSOs 2019: 26 spills 482 hours
Etchilhampton Water GB108043022430	Spaniels Bridge CSO 2019: 107 spills 2,200 hours
Avon East GB108043022410	North Newnton CSO 2019: 16 spills 351 hours
The Swan GB108043022540	Warminster Park CSO 2019: 68 spills 84 hours
Wylye GB108043022550	Hanging Langford CSO 2019: 177 spills 3450 hours via reedbed
Till GB108043022570	Shrewton CSO 2019: 112 spills 2522 hours
Wylye lower GB108043022510	Great Wishford CSO 2019: 3 spills 16 hours
Fovant Brook GB108043016190	Fovant CSO 2019: 68 spills 1339 hours
Nadder lower GB108043015880	Barford St Marton CSO 2019: 21 spills 323 hours
Bourne GB108043022390	Hurdcott CSO 2019: 213 spills 4367 hours
Horsenden Stream (included in Kingsey Cuttle Brook) GB106039030200	Princes Risborough CSO 2019: 20 spills 412 hours
Pang incl the Bourne GB106039023300	Bucklebury CSO via Briff Lane Stream 2019: 66 spills 1022 hours
Kennet h'waters GB106039023171	Fyfield CSO 2019: 49 spills 647 hours
Kennet middle to Hungerford GB106039023173	Marlborough CSO 2019: 87 spills 989 hours
Upper Dun GB106039017350	East Grafton CSO 2019: 23 spills 263 hours Great Bedwyn CSO 2019: 10 spills 128 hours
Shalborne GB106039017370	Shalbourne CSO 2019: 42 spills 148 hours
Kennet middle to Newbury GB106039023174	Kintbury CSO 2019: 36 spills 684 hours Hamstead Marshall CSO 2019: 62 spills 864 hours via Hamstead Stream
Lambourne GB106039023220	East Garston CSO 2019: 32 spills 319 hours
Kennet lower Lambourne to Enborne GB106039017420	Newbury CSO 2019: 17 spills 49 hours
Loddon h'waters GB106039017080	Basingstoke CSO 2019: 5 spills 54 hours

Chalk Stream Waterbody	CSO Spill Records 2019
Loddon middle GB106039017330	Sherfield on Loddon STW & CSO 2019 38 spills 298 hours via Bow Brook.
Wye GB106039023880	High Wycombe CSO 295 spills 6398 hours
Chess GB106039029870	Chesham CSO 2019: 2 spills 3 hours
Colne lower GB106039023090	Maple Lodge STW & CSO 2019: 13 spills 91 hours
North Wey at Alton GB106039017800	Newnham Lane CSO 2019: 3 spills 13 hours
North Wey GB106039017830	Holybourne CSO: 2 spills 1 hour Bentley CSO 2019: 56 spills 344 hours
Hogsmill GB106039017440	Hogsmill CSO 2019: 24 spills 225 hours
Wandle GB106039023460	Beddington CSO 2019: 23 spills 17 hours
Beane upper GB106038040110	Weston CSO 2019: 43 spills 435 hours Cottered CSO 2019: 15 spills 324 hours
Quin GB106038040120	Barkway CSO 2019: 17 spills 175 hours
Stort GB106038040130	Stansted Moutfitchett CSO 2019: 22 spills 30 hours Little Hallingbury CSO 2019: 15 spills 299 hours Hatfield Heath CSO 2019: 40 spills 752 hours via Pincey Brook
Great Stour GB107040019741	Bybrook Ashford CSO 2019: 10 spills 170 hours Kingsnorth Road CSO 2019: 23 spills 43 hours Dover Place CSO 2019: 18 spills 17 hours Canterbury Road Cemetery CSO 2019: 7 spills 16 hours Queen's Road CSO 2019: 2 spills 1 hour Field End Garden CSO 2019: 16 spills 65 hours Ball Lane CSO 2019: 25 spills 254 hours Mill Lane CSO 2019: 28 spills 273 hours Stonebridge Road CSO 2019: 5 spills 63 hours + 16 unmonitored CSOs
Great Stour lower GB107040019743	Fordwich Road CSO 2019: 12 spills 103 hours
Hiz incl Oughton GB105033037700	Hitchin CSO 2019: 52 spills 936 hours
Soham Lode aka Snail River GB105033042860	Soham CSO 2019: 27 spills 276 hours
Lark middle GB105033043051	Fornham All Saints CSO 2019: 52 spills 1202 hours
Wissey lower GB105033047630	Mundford CSO 2019: 56 spills 339 hours
Ingol GB105033053470	Ingol CSO 2019: 300 spills 295 hours
Burn GB105034055750	Burnham Market CSO 2019: 7 spills 60 hours
Glaven GB105034055780	Holt CSO 2019: 8 spills 88 hours
Laceby Beck GB104029067530	Laceby - Caister Road CSO 2019 55 spills 410 hours
Rase GB104029061870	Caister CSO. 2019: 107 spills 2001 hours (probs not impacting the chalk stream US of discharge)
Nettleby Beck (Caistor Canal Catchment) GB104029061920	Caister CSO. 2019: 107 spills 2001 hours (probs not impacting the chalk stream US of discharge)
Pocklington Beck incl Ridings Beck & Millington Beck GB104027063480	George St CSO 2019: 10 spills 4 hours
Goodmanholme Beck – incl in Foulness waterbody GB104026066690	Holme Road CSO 2019 87 spills / 569 hours

5.5.2 Storm Overflow Case Study - The River Chess

The community-led ChessWatch project uses a sensor network as an engagement platform to raise public awareness of threats to the River Chess and to engage and include the public in the management and health of the river.

Funding for the initiative was provided by Thames Water together with the Centre for Public Engagement at Queen Mary University of London.

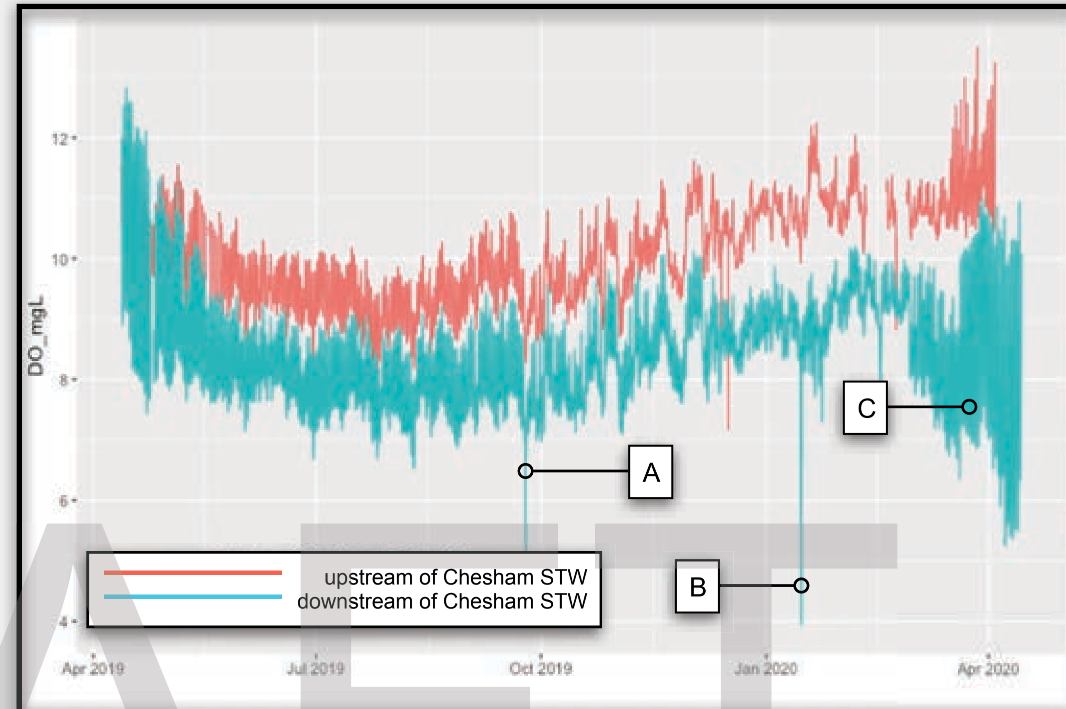
In 2019 four water-quality sensors were installed in the river to provide stakeholders with real-time water-quality data (15-minute intervals). The probes record water level, dissolved oxygen, pH temperature, turbidity, chlorophyll-a and tryptophan. The graph here shows preliminary results from the dissolved oxygen sensors.

From September 2019 to March 2020 five high-intensity rainfall events caused intermittent storm tank discharge to the river from Chesham STW. Our sensors show that not every storm tank discharge event has had the same effect on oxygen status, but some events (A and B) are characterised by a marked transient drop of 3 to 5 hours duration in dissolved oxygen concentrations in the river.

C denotes a period during which groundwater levels were high and the sewage treatment works was discharging excess flows from storm tanks due to groundwater ingress.

The gradual decline in oxygen concentrations at night during period C suggest that organic material settling on the riverbed is changing the river metabolism and enhancing respiration. Photosynthesis during the day enables oxygen levels to recover during daylight hours. The overall effect on ecology will depend on the duration of the repeated discharge.

The ChessWatch data indicates that there is a notable impact on oxygen levels from repeated storm tank discharges due to groundwater ingress.



Right: Two parts of the River Chess running parallel, one clear and the other turbid with storm overflow discharge: this has been a regular sight since 2020 on the River Chess, where the sewage works is frequently overwhelmed by groundwater ingress and storm overflows.

5.6 Small Sewer Discharges (including septic tanks)

Septic tanks, cesspits and small sewage treatment plants are systems for collecting and treating domestic sewage in locations that do not have mains sewers. All systems must comply with the British Standards and Building Regulations in force at the time of installation and must meet the General Binding Rules (See Appendix G)

Sewage treatment plants

A small sewage treatment plant, also known as a 'package' plant, provides primary and secondary treatment. The primary treatment breaks the sewage down into gases, liquids and solids. The secondary treatment introduces air to the process, improving the quality of the effluent. Package plants should discharge effluent of a standard that allows it to be discharged either to a watercourse or to ground through a drainage field.

Septic tanks

Septic tanks break down sewage into gases, liquids, and solids. Gases are released through a vent, liquids overflow through an outlet into an infiltration system and any solids are left at the bottom of the tank. The solids which have settled in the tank need to be periodically emptied and disposed of.

The liquid created from the septic tank cannot be discharged into a watercourse and must go to ground via an infiltration system. A drainage field infiltration system is the only infiltration method that meets the GBRs.

Impacts on water quality

Septic tank effluent contains a wide variety of pollutants including pathogens, faecal bacteria, phosphorus (P), nitrogen (N), organic matter, suspended solids, household detergents and chemicals. When used and maintained properly small sewage treatment plants do their job well. However, septic tanks are not actively regulated or monitored by regulators, so in many cases, they may not be complying with the rules.

Septic tanks are a potentially significant source of nutrients to surface waters but few data exist in the UK to quantify their impact. Research by Withers, Jarvie and Stoate* showed that:

- Nutrient emissions from septic tank systems affect water quality in rural areas.
- Septic tank soakaways to impermeable soils failed to adequately treat the septic tank effluent.
- The downstream eutrophication impact of septic tank systems largely depends on stream discharge volumes.
- Septic tank systems act as mini-point sources and need to be better managed in catchment management planning.

There is a need for further investigation to identify septic tank hotspots in chalk stream catchments with action taken to improve their performance where pollution is identified.

Septic tanks must be maintained to ensure they do not cause pollution and meet the general binding rules. If they cannot meet the GBRs there are a number of options depending on the operator's situation, including:

- Connecting to a mains sewer where available;
- If there are potential problems with the systems of more than one property in the area, the residents may be able to apply for first-time mains sewerage;
- Replacing the septic tank with a package plant, to either meet the GBR or get an environmental permit.

Connecting to mains sewer

Sewerage undertakers have a duty to provide a public sewer under section 101A of the Water Industry Act 1991 (s101A), where certain criteria are met. These are that:

- The drainage of premises in a locality is giving rise, or is likely to give rise, to adverse effects on the environment or amenity;
- Actual or likely adverse effects on the environment are from more than one building the relevant premises are not currently connected to a public sewer;
- Drainage of a premises is for 'domestic sewerage purposes': this includes the discharge of lavatories, water used for cooking and similar domestic activities, but it does not preclude non-residential buildings.

Applications under s101A are usually made by local residents or the relevant local council. The sewerage undertaker carries out an assessment of the application and decides whether it believes a duty exists to provide a public sewer connection under s101A. This assessment will take into account the comparative practicability and cost of alternative solutions.

The EA is responsible for the determination of appeals from first time sewerage applicants who have been refused connection to the public sewers.

* 'Quantifying the impact of septic tank systems on eutrophication risk in rural headwaters' Environmental International, Vol. 37, April 2011

5.7 Integrated Wetlands - a cost-effective measure for polishing discharges from small STWs

Integrated wetlands may offer a cost-effective alternative to chemical treatment specifically *for small and remote works that do not pass conventional, cost-benefit analysis*, but nevertheless have a major ecological impact, especially on the numerous undesignated and headwater chalk streams.

Richard Cooper (University of East Anglia)* examined the nutrient removal efficiency of two Integrated Constructed Wetlands (ICWs) in Norfolk, one on the River Ingol and the other on the River Mun, 1-year and 5-years old respectively at the time of the study. Analysing water samples collected across the ICWs between February and September 2019, significant reductions in both effluent nutrient concentration and load were recorded.

• Mean nutrient concentrations were reduced between inflow and outflow of the works by 34-62% for N and 27-64% for P, whilst nutrient loads were reduced by 56-72% for N and 58-69% for P.**

• The higher nutrient removal performance of the 5-year-old ICW demonstrates that the operational efficiency of ICWs increases over the early years of operation, with minimal maintenance required during this time.

• there is evidence to support the wider adoption of ICWs at smaller STWs that currently have no legal obligations to minimise effluent nutrient concentrations through conventional treatment

The overall conclusion was that ICWs can 'significantly reduce the eutrophication risk associated with WWTP discharges, whilst providing a cost-effective alternative to conventional tertiary wastewater treatment'.

However, it is important to contextualise the performance of ICWs relative to:

• the number of people linked to the works
• the size of the works (spatial area) and
• the size of the receiving stream

In spite of good reductions through the works – total P 8.53 mg/l to 1.89 mg/l -78%, total N 48.08 mg/l to 16.96 mg/l River Mun – nutrient levels remained high in both the Mun and Ingol. Instream total P and N reduced by approx 25% but at 1.08 mg/l and 17.21 mg/l remained well above levels needed to achieve ecological improvements. Biervalt et al found that other sources of N to the Mun were higher than the ICW effluent, but that high in-stream levels of P were harder to explain, given that the STW comprises much of the flow: however, legacy sources (for example accumulated sediments) are known to buffer in-stream P levels after reductions at source.

Harrington and McInnes found that P removal is strongly correlated to functional area. The Mun site at 0.3 ha, serving 772 people is equivalent 2573 people/ha. The Ingol works, serving 6,056 people/ha is effectively 2.5 times smaller. Biervalt et al*** conceded that the Mun site was 'sub-optimal in comparison to the volume and nutrient concentrations to be treated' comparing it to Glaslough ICW serving 800 people with 3.25 ha or 246 p/ha. The ratio of influent discharge / functional area of wetland of the Mun ICW was 237:1, and that of the Glaslough ICW was 32:1.

Water quality experts on the CaBA CSRG expert panel have also highlighted that the performance of ICWs can reduce over time, that the sediment in the ICW can become saturated with P (and therefore act as a source not sump) and that preferential pathways develop reducing water residence time. ICWs require regular maintenance.

Nevertheless, in the right context and with due consideration of their limitations, ICW's may have a role to play in driving down nutrient levels in chalk streams (as a way of 'polishing' existing permitted secondary STW effluent) especially where works are:

• remote
• attached to small agglomerations
• in rural areas with plenty of potentially available land
• unlikely to pass existing cost-benefit analysis

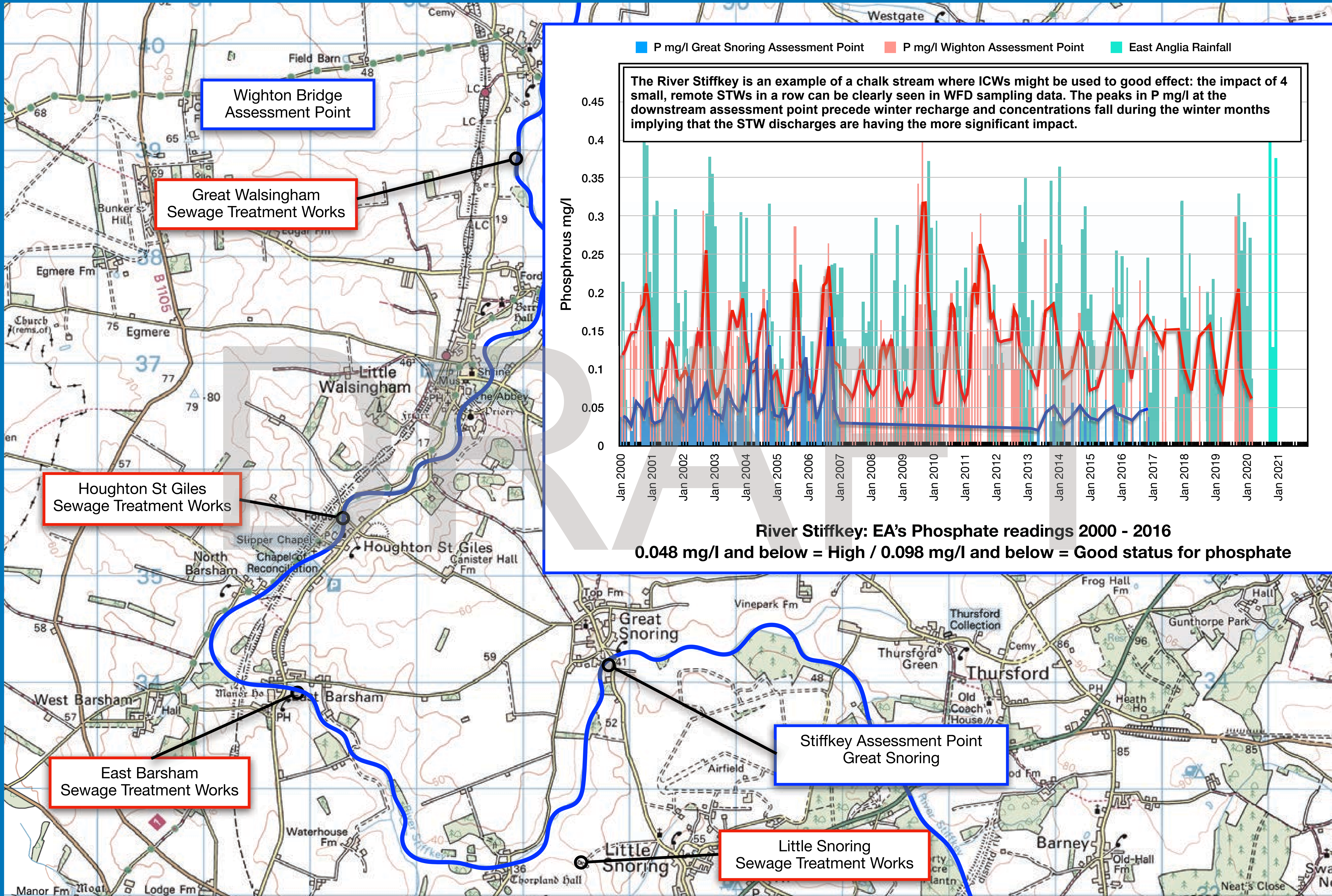
The chart and map on the following page give a good example of the kind of setting where ICWs could play a role in driving down bio-available P concentrations.

* Assessing the environmental and economic efficacy of two integrated constructed wetlands at mitigating eutrophication risk from sewage effluent: Richard Cooper, Elizabeth Hawkins, Jake Locke, Terry Thomas and Jonah Tosney

** Results post-dating this survey suggest that once the wetland is mature P reductions can be in the order of up to 90%.

*** Can an Integrated Constructed Wetland in Norfolk Reduce Nutrient Concentrations and Promote In Situ Bird Species Richness? Olly van Biervliet & Robert J. McInnes & Jonathan Lewis-Phillips & Jonah Tosney

DRAFT


Wighton Bridge Assessment Point
Great Walsingham Sewage Treatment Works
Houghton St Giles Sewage Treatment Works
East Barsham Sewage Treatment Works
Stiffkey Assessment Point Great Snoring
Little Snoring Sewage Treatment Works
P mg/l Great Snoring Assessment Point
P mg/l Wighton Assessment Point
East Anglia Rainfall
The River Stiffkey is an example of a chalk stream where ICWs might be used to good effect: the impact of 4 small, remote STWs in a row can be clearly seen in WFD sampling data. The peaks in P mg/l at the downstream assessment point precede winter recharge and concentrations fall during the winter months implying that the STW discharges are having the more significant impact.
Phosphrous mg/l
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jan 2000
Jan 2001
Jan 2002
Jan 2003
Jan 2004
Jan 2005
Jan 2006
Jan 2007
Jan 2008
Jan 2009
Jan 2010
Jan 2011
Jan 2012
Jan 2013
Jan 2014
Jan 2015
Jan 2016
Jan 2017
Jan 2018
Jan 2019
Jan 2020
Jan 2021
River Stiffkey: EA's Phosphate readings 2000 - 2016
0.048 mg/l and below = High / 0.098 mg/l and below = Good status for phosphate
DRAFT
Little Walsingham
Houghton St Giles
Great Snoring
Little Snoring
Thursford
West Barsham
East Barsham
North Barsham
Egmere
Barney
Westgate
Field Barn

5.7.1 Using Wetlands to Tackle Storm Overflows

Each winter, at Hanging Langford on the River Wylye, the water table inundates the sewerage system. Historically, the Environment Agency (EA) had allowed Wessex Water, under emergency powers, to pump out the sewerage to the River Wylye. This is known as a groundwater ingress storm overflow. This was not an officially permitted arrangement. Nor was it sustainable.

A new groundwater land drainage scheme would have been prohibitively expensive. Similarly, upsizing the sewer network's capacity and pumping to the downstream sewage works would also have been an expensive and a less sustainable solution (loss of flow). The most cost-effective and pragmatic solution involved an innovative intermittent treatment using a wetland.

Once Wessex Water had ensured that its sewerage system was sealed as far as practical, the EA agreed to permit a pumped, screened overflow for periods when groundwater ingress was liable to cause property flooding. Wessex Water provided a reed bed adjacent to one of the nature reserve lakes to treat the storm flows prior to discharge to the River Wylye.

The storm reed bed, constructed in 2010, covers an area of $2000m^2$. For most of the year it is kept wet using water from the adjacent lake. The bacteriological impact of the storm overflow on the River Wylye for the few days it is utilised each year is imperceptible.

Samples sets were taken from the river upstream and downstream of the discharge point, and also of the treated flows from the reed bed. The river consistently shows higher bacteriological counts – both upstream and downstream – than are found in the reed bed effluent.

Wessex Water now works closely with Wiltshire Wildlife Trust to manage the reed bed, which provides a valuable habitat for a range of species such as dragonflies and warblers.

Where the STWs are small and there is available space, as at Hanging Langford, wetlands may have a role to play as one in a suite of measures addressed at driving down nutrient levels at the catchment scale.

Reviewing options

Appropriate options for treating storm overflows should be articulated through water company Drainage and Wastewater Management Plans (DWMPs) and the Storm Overflow Assessment Framework investigations.

5.8 Reducing Diffuse Sediment Pollution from Farmland to Chalk Streams and Aquifers
Case Study - Diffuse Pollution on a Norfolk Chalk Stream

A Geomorphological Appraisal of the River Nar made by English Nature in 2006 showed that sediment washing into the stream from the wider catchment was a significant problem on the River Nar, a chalk stream surrounded by arable, sugar beet and pig-rearing farmland in Norfolk.

The report revealed that – coupled with the historic canalisation of the river and a reduction in flows caused by abstraction – sediment pollution was having a considerable impact on the ecology of the river, smothering the substrate of the river bed and harming the plant, fish and insect communities.

The audit found that fine sediment mostly derived from:

- **Arable fields –** especially when they are recently ploughed.
- **Pig units –** especially on steep land, close to the river.
- **Road-side verges –** especially when they are crushed each winter by farm vehicles too large for the roads they are driven down: this is a worsening problem.
- **Dirt tracks –** especially where these join up with the road network or run directly to the river.

And enters the river via:

- **Road crossings –** where road drains discharge into the river.
- **Footpaths, tracks and fords –** where they cross the river.
- **Intersections –** where the dry valley network meets the main river.
- **Drains and ditches** – especially in the headwaters.

The floodplain of the upper Nar is characterised by low intensity land-use, which would ordinarily buffer the river against fine sediment run-off within the wider catchment. Points of ingress therefore were quite localised, though the area of origin may be broad.

The audit recommended that the issue of fine sediment pollution should be tackled strategically:

- **In the river –** dealing with the sediment once it is in the river – restoring connectivity.
- **At the points of entry –** by identifying and dealing with the points of ingress.
- **In the wider landscape –** encouraging catchment sensitive land-use so as to lessen the amount of soil lost to erosion in the first place.

5.8.1 Farming Rules for Water

Farming Rules for Water were introduced in 2018 as a 'first step towards a new approach to regulating the agricultural sector that might be adapted more widely in the future with rules that are outcome focussed and risk based'.

The intention was to create a clear and simple set of rules designed to help farmers optimise their use of manures and soils whilst also protecting the environment.

The rules address and govern various farm activities including:

- compulsory assessment of soil nutrient levels every five years
- the storage of manures and fertilisers away from springs and rivers
- the application of manures and fertiliser in wet weather
- the application of manures and fertilisers near springs and rivers
- reasonable efforts to control soil erosion
- the siting of livestock feeders near springs and rivers

In terms of enforcing compliance the rules are advice led, with enforcement 'proportionate and fair with the emphasis on working with farmers to achieve compliance'.

A challenging and evasive problem

Anyone who works intimately with chalk streams will know that agricultural run-off is a vast and constantly shape-shifting problem.

The run-off from one open-air pig field, or maize field can bring vast quantities of sediment into a chalk stream (researchers on the River Nar observed a rate of delivery from one pig unit of over one ton every ten minutes during a 30-minute storm event on the 28.9.2004. See River Nar Fluvial Audit).

In addition, farmers have to earn a living in a challenging market-place and will change practice if and when market forces or subsidies dictate, meaning that a run-off problem solved today might very easily be unsolved tomorrow.

In this sense making basic payment contingent on a simple set of unambiguous rules was a good first step. But three years on any drive through chalk country in February will show that agricultural run-off is still a vast problem, with compliance conspicuously patchy. This bothers most farmers as much as anyone. It is irksome to follow rules in a competitive market place only to find a neighbour gaining advantage by not bothering and not being reprimanded either.

5.8.2 Sustainable Farm Incentive: Farming Rules for Chalk Streams

In putting together this report the CaBA chair canvassed a number of farmers in Dorset and Norfolk, all of whom expressed a desire for simple rules that are easy to follow and do not adversely impact of the economic viability of the farm, but they all stated also that the basic rules should go further in protecting rivers, should be compulsory (because incentives are never high enough to compete with the most profitable and destructive forms of farming) and that they should be visibly enforced, because one or two high profile cases will bring about compliance far more effectively than any number of advice-led consultations.

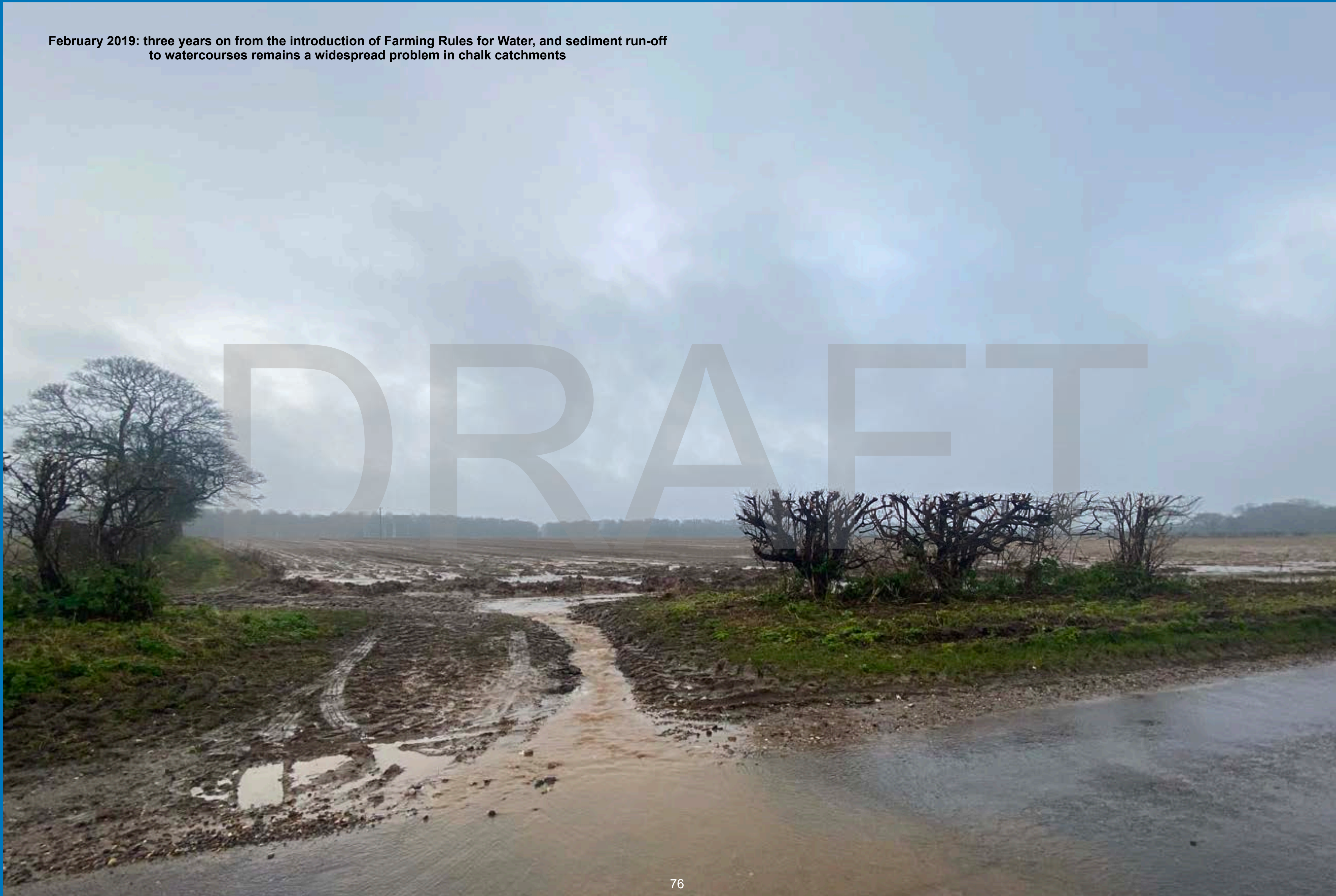
These farmers offered the following simple principles for sloped land in chalk catchments, all of which are easy to do and none of which threaten the economic viability of the farm.

These ideas are in sympathy with those being discussed by Defra for ELM. CaBA CSRG strongly urges their adoption in chalk stream catchments.

- **For 'destructive' but profitable farming such as outdoor pigs, carrots, parsnips, beet, maize, asparagus and potatoes – there should be a compulsory 20-metre buffer around the perimeter of the field**
- **For other arable crops there should be a 10-metre buffer**
- **There should be no ploughing within a 25-metre radius of field gateways**
- **There should be no gateways at the downhill edge or corner of any given field**
- **The plough should always be turned across the downhill corner and or edge of sloped fields**
- **There should be no crop lifting after the end of October**
- **Advisory zero-till but as a minimum there should be over-winter cover crops to protect the soil**

The new Sustainable Farm Incentive should be contingent on compliance with the above. The following could also apply as incentives:

- **Zero till**
- **Green swales runnings through field dips**
- **Settlement ponds**
- **Restoration of hedges especially those running perpendicular to slope**



February 2019: three years on from the introduction of Farming Rules for Water, and sediment run-off to watercourses remains a widespread problem in chalk catchments

The River Wensum is impounded along the majority of its upper course: in terms of processing sediment the river is almost completely disabled. Sediment run-off and the morphological condition of the channel are two halves of the same problem.

5.9 A Strategic Approach to Reducing Pollution in Chalk Streams

Siltation and nutrient enrichment are significant water quality issues affecting chalk stream ecological health. However, although the *range* of issues is common to most chalk streams, the comparative levels of impact vary river to river.

In undesignated, suburban rivers close to London the nutrient enrichment from large sewage treatment works is likely to be a comparatively more significant issue than agricultural run-off. On the other hand, on a designated rural chalk stream where the sewage treatment works have benefited from a lot of investment, then agricultural run-off is likely to be the more significant problem. On a mixed geology chalk stream where background levels of phosphorus are already higher than in purer geology chalk streams, and where there is more surface and sub-surface run-off, farming as well as septic tanks are likely to have a comparatively larger impact than in pure geology chalk streams.

It is also important to remember that sediment *supply* and sediment *retention* are two parts of the same problem. The negative ecological impacts caused by diffuse sediment pollution largely depend on the sediment remaining in the river. This it does to a greater extent in an impounded, dredged and canalised channel, than in a channel with a natural, gradient and flood-plain connectivity. For example on the River Wensum – the worst performing river in the S&TC's fly census – out of a total fall of 34 metres from upstream of Sculthorpe Mill to Hellesdon Mill, 60% of that fall occurs at 14 mill structures. Almost 70% of the river is impounded by mills. Most of the river has been dredged and there are levees along most of both banks. In terms of processing its sediment load the River Wensum is almost completely disabled. Therefore, efforts to reduce diffuse pollution and sediment supply must, through river morphology restoration, go hand in hand with efforts to reduce or control its retention.

With regard to STWs and other point source supplies, the WFD evidence suggests that on the numerous chalk streams still impacted by STWs which do not strip P, the national programme of P stripping must continue into the headwaters of these rivers and at the smaller works at which the existing statutory driver does not currently compel the investment needed.

In purely ecological terms, there is arguably more to be gained starting at the uppermost part of a given chalk stream and working downstream, the opposite of what has happened over the last twenty years, during which time total point-source P has been drastically reduced, but mostly on protected rivers or from large works which tend to be quite far down a given catchment. This has left many smaller and headwater chalk streams behind.

5.10 Water Quality Actions: Reducing Pollution

1. Sewage Treatment Works that do not strip Phosphorus	CaBA CSRG recommends the EA reviews the status the Sewage Treatment Works on all chalk stream waterbodies that are at Poor, Moderate or Bad Status for Phosphorus, that it prioritises and timetables remediation via WINEP.
2. Cost Benefit Analysis	CBA should include a gearing / weighting that A) recognises the ecological value of chalk streams and B) magnifies the value (per head or kg of nutrient) of addressing nutrient inputs in the headwater reaches of chalk streams on the basis that a) headwaters are ecologically valuable and b) tend to get left behind by existing WFD and UWWTD drivers and c) improvements in the headwaters will benefit the full length of the river system.
3. Integrated Constructed Wetlands	Notwithstanding changes to CBA (see 2. above) CaBA CSRG endorses the use of Integrated Constructed Wetlands (ICW) and biological nutrient reduction at small, remote works where conventional treatment is too difficult or expensive.
4. Waterbody Boundaries and Assessment Points	As with Water Quantity Action 4 the Environment Agency should set and publish a timetabled undertaking to review all chalk stream WFD waterbody assessment points and boundaries to ensure that they provide adequate means of assessing and protecting chalk stream health. Particular attention should be paid to ephemeral and headwater chalk streams and chalk streams subsumed within larger, non-chalk waterbodies.
5. Storm Overflows	CaBA CSRG recommends all necessary actions are taken with a view to achieving significant reductions in the frequency and volume of overflows to chalk streams to ensure they are adequately protected from ecological harm and that their iconic status is recognised, including adoption of the findings of the Storm Overflow Taskforce
6. Groundwater Ingress at small works	CaBA CSRG recommends an investigation of the practicability of using ICWs as a cost-effective measure to mitigate SO groundwater ingress pollution, with a view to the limitations of ICWs ref size of works and spatial area of available land. This is likely to relate to smaller works in rural settings.
7. Septic Tank Hot-Spots	CaBA CSRG recommends a review of SAGIS and / or programme of research to identify septic tank 'hot-spots' in chalk stream catchments and based on evidence of harm a pilot trial of monitoring and policing poor septic tank performance.
8. Septic Tank Point of Sale	CaBA CSRG recommends a law that requires homeowners at point of sale to register and bring septic tanks up to standard.
9. Farming Rules for Chalk Streams	CaBA CSRG recommends that the rules for farming in chalk stream catchments set out in section 5.11.2 are adopted into the new Sustainable Farming Initiative (SFI).
10. Farming Incentives for Chalk Streams	CaBA CSRG recommends that new ELM incentive schemes beyond SFI must be structured so as enable changes to land management at the catchment scale, taking critical land areas out of production, prioritising the restoration of headwater, spring-line fen, riparian zones and large tracts of floodplain.
11. Highways	Roads are the primary pathway of sediment to chalk streams in chalk catchments and therefore roadside drainage grips should not feed directly into chalk streams or unplugged drains which feed into chalk streams. Highways Agency standard practice for construction / maintenance of roadside grips that discharge run-off to chalk streams must either: discharge to plugged ditches or to settlement areas.

6. Physical Habitat: Restoring Process

6. Physical Habitat Quality

6.1 Restoring Process

Restoring high quality physical habitat to the chalk stream is fundamental to realising the full potential of any other improvements made in flow and water quality. Habitat quality is where all elements of a good restoration strategy come together.

And yet while it is relatively easy to appreciate that a drying, dry or heavily polluted river is in a poor state, it is much more challenging to read a river and interpret what is wrong with it physically. It is all too easy to prescribe ‘restoration’ that only makes the problems worse. A classic version of this is structures that further impound an already impounded stream – imported gravel bars usually – inadvertently adding to, rather than subtracting from, problems associated with sediment retention.

Good quality river restoration requires a resolved understanding of what one is trying to restore, informed by a knowledge of the history of the river and the processes which shaped and continue to shape it.

Scale is key. Even if projects are carried out on an opportunistic basis at the reach scale – as is so often the case, because that is simply how these things come about – it is much better if these projects can tie in to an overarching strategy and vision. But this has hardly been possible until recently. Funding streams have been so small and intermittent that restoration work has often depended on the passionate efforts of individuals who have had no opportunity to consider the catchment scale.

This CaBA Chalk Stream Restoration Strategy represents a great opportunity on the chalk streams to drive restoration towards that catchment-scale vision and to make a strong case for restoring the fundamental thing that has been removed from chalk streams over centuries of physical modification: **process**. The capacity for the river and the ecological elements within it, to operate naturally.

Because they are such gentle rivers, chalk streams are uniquely vulnerable to physical modification and to the consequent de-coupling of process, to becoming imprisoned by whatever we do to them. It is vital that river restoration doesn’t become just another layer of anthropogenic imposition, further or differently imprisoning what should be a dynamic system. A good restoration strategy outlines and then delivers whatever it takes to let the river be a river. No more. But no less.

6.2 Defining the Reference Conditions of a Natural Chalk Stream

The paper '*Defining Reference Conditions for Chalk Streams'* 2004 Sear et al (see Appendix A) attempts to identify key features of the natural chalk stream.

Studies of post-glacial chalk streams in Dorset and Hampshire point to relatively wide, shallow river-channels and a complex mosaic of wet, open woodland in the riparian zone. A review of studies focusing on semi-natural, groundwater dominated streams, describes the features listed in the table opposite.

The key ideas in terms of helping to visualise the natural chalk stream are:

• The high width-to-depth ratio and relatively shallow channel.

• The long duration of bank-full flows, creating a high water-table and an open wet-woodland / herbaceous riparian zone.

• The importance of in-stream plant communities in shaping complex dynamics of flow and scour.

• The duration time and importance of fallen trees in shaping the mosaic of habitats in the chalk stream channels and the floodplain.

Wide, shallow and sinuous

The high width-to-depth ratio of chalk streams correlates with relatively unmodified spring-fed streams globally, in New Zealand, and North and South America. Groundwater streams, wherever they are, tend to be distinguished by relatively equable flow regimes. The flow regime on its own favours the development of in-stream plant communities (they don't get blown out in floods) but spring-fed streams in general and chalk streams in particular, tend to be fertile, mineral-rich streams whose lush plants pack out the flow and hold up water levels as flows diminish through the summer.

Calcareous spring-fed streams (chalk and the more globally widespread limestone) also tend to develop a concrete like tufa on the bed of the river, which along with bed materials made of glacial deposits of flinty gravels, means the river beds are relatively much more resistant to erosion than the banks: hence the limited development of gravel bars (riffles) compared to higher energy rivers.

The long time duration of bank-full flows, shored up by macrophyte growth, combined with the relative armouring of the bed, means that chalk streams, of definitively low erosive power, will erode their banks more than their beds: this of course becomes a self-defining morphology, because as the banks widen the stream-power lessens.

Key Features of the Natural Chalk Stream

• Low drainage density / limited tributary network.

• Low stream power relative to catchment area.

• Relatively high width-to-depth ratios ie. shallow and wide channel cross-sections.

• A mix of single, meandering channels with side channels and in lower reaches, anastomosed multiple channels.

• Limited in-channel coarse sediment storage (bars (or "riffles").

• High residence time of Large Organic Matter (Woody Debris).

• Presence of woody debris islands but few debris dams.

• High floodplain water-tables leading to organic-rich floodplain soils.

• Low rates of lateral channel adjustment.

• Limited accumulation of fine sediments on bed surface in undisturbed catchments.

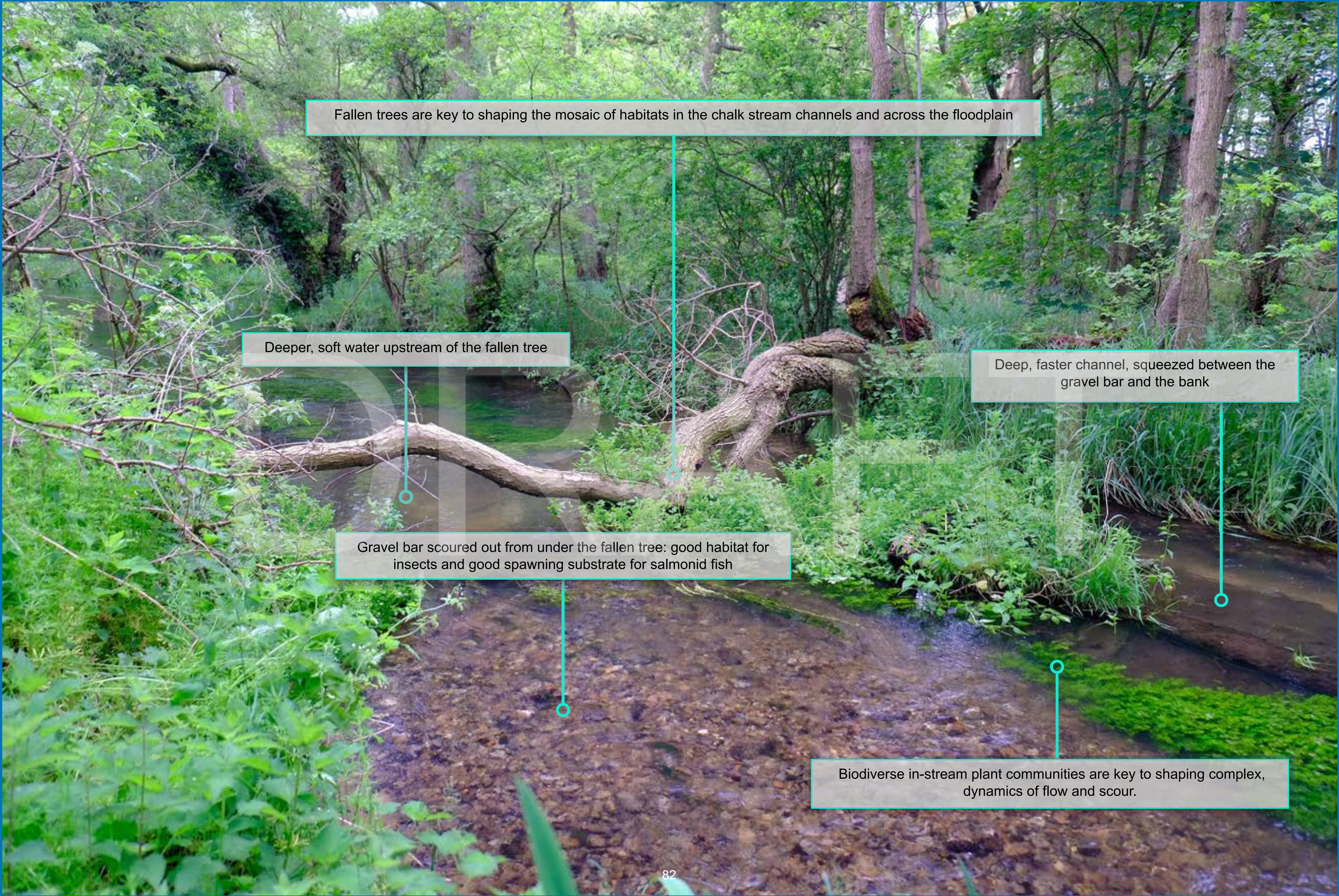
• Tufa deposition and concretion of gravels at points of groundwater upwelling.

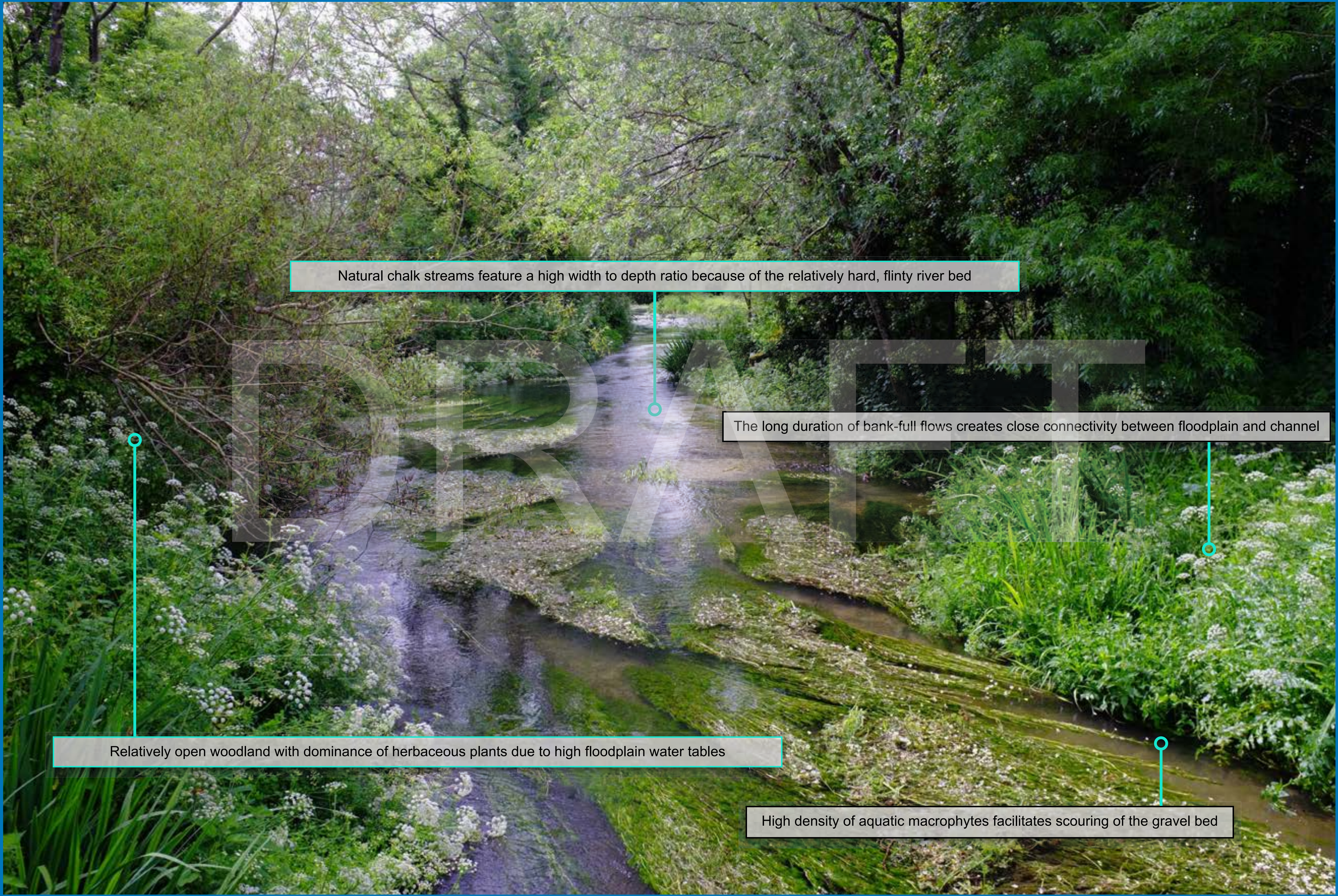
• Long duration of bank-full / out of bank flows.

• High density of aquatic macrophytes that facilitate flushing of fines.

• Relatively open woodland with dominance of herbaceous plants due to high floodplain water tables.

• Marsh habitat with open groundwater pools in floodplain where strong coupling with groundwater is evident.


Fallen trees are key to shaping the mosaic of habitats in the chalk stream channels and across the floodplain
Deeper, soft water upstream of the fallen tree
Deep, faster channel, squeezed between the gravel bar and the bank
Gravel bar scoured out from under the fallen tree: good habitat for insects and good spawning substrate for salmonid fish
Biodiverse in-stream plant communities are key to shaping complex, dynamics of flow and scour.



Natural chalk streams feature a high width to depth ratio because of the relatively hard, flinty river bed
The long duration of bank-full flows creates close connectivity between floodplain and channel
Relatively open woodland with dominance of herbaceous plants due to high floodplain water tables
High density of aquatic macrophytes facilitates scouring of the gravel bed
DRAFT

Even within the range of chalk stream types this varies considerably, with the more energetic, mixed geology streams like the Frome, Nadder and upper Avon being relatively more deeply incised, with more prominent riffle-to-pool sequences, especially notable in the headwaters. Moreover the make-up of the floodplain material will also help to define the width-to-depth ratio: clayish / silty material being more resistant to erosion than sandy / loamy material.

The importance of trees

This characteristic suite of high, bank-full flows and low stream-power, means that in chalk streams the long residence time of large woody material (when a tree falls in it tends to stay there and if that tree is an oak, it may well stay for a very long time) is the most significant factor in determining and ensuring a varied physical habitat. A tree fall will catalyse a whole sequence of channel adjustments: pushing the river's flow down into the river bed or into the bank, throwing up bars of gravel.

The episodic, but continual cycling of fallen trees interacting with the flowing river will over time lead to a varied and complex morphology.

Once upon a time, of course, beavers contributed greatly to this cycling of woody material and process.

Inherited morphology

Another key point is the concept of the inherited morphology. Stream power in some way determines the capacity of a river to restore itself, once modified. Put simply, it doesn't take long (in the scheme of things) for an energetic, upland river to erase the hand of man, and it would be almost impossible to so corral the power of the river as to incapacitate its natural processes.

This is not true of chalk streams: they are such benign rivers that once modified (and almost all have been modified) they more or less stay modified. In terms of the impact of dredging, for example, where the bed substrate has been removed and there is no replacement supply, it would quite literally take another ice-age to re-set the clock and allow chalk-streams to evolve to their natural state once again. In terms of riverine process, everything happens in slow motion on a chalk stream: the complex habitat evolves over centuries, not years or months.

This raises some vitally important issues and challenges when it comes to river restoration and suggests that in order to avoid 'restoration' becoming the imposition of just another state of modification, the thing one must most concentrate on restoring is the chalk-stream's **capacity for process**.

6.3 A Brief History of Modifications to Chalk Streams

6.3.1 Early Human History 3000 BC to 900 AD

If the natural chalk stream was a wide, shallow, sinuous and braided river system, threading through a mosaic of wet woodland and park-like grassland, then we started to change all that as long as 3000 years ago.

As evidence of the early impact of humans, the pollen record, mollusc fossil record and the stratigraphy of our floodplains – evidence of tilling, soil erosion and the slumping / accretion of soil at the base of slopes and in gullies – shows that there was an increase in forest clearance from the late Neolithic onwards, with short-term agricultural clearings followed by a period of large-scale, longer-term agricultural clearings in the Middle Bronze Age.

Through the Iron Age and until the end of the Roman occupation forest clearance and regeneration appears to have ebbed and flowed. Then, following the retreat of the Romans and through the Dark Ages, the floodplain woodlands and no doubt the chalk streams gained a short reprieve from the hand of man.

An upturn in climatic conditions at the start of the medieval period, the rediscovery of water-milling technology and the invention of the heavy plough then all marked a step-change in the modification of our chalk streams, their floodplains and surrounding hills.

6.3.2 Mills

Most significant were the mills: by the time William invaded there were 5,600 watermills in England, and most were on the malleable chalk-streams. Unlike the Norse mills in the north – built to the sides of the main river, fed by leats with mill wheels horizontal with the current – the chalk stream mills were 'Roman'. Roman mills feature a vertical mill wheel which is turned through gears to the horizontal milling stone. Their efficiency is proportional to the extent to which they obstruct and impound the flow.

Mills were constructed towards the edges of the floodplain and fed by leats: diversions which carried the flow from the centre-line of the valley along a much shallower contour line at the edge of the floodplain, until enough of a height difference had been established to turn the wheel, either as an under-shot, a breast-shot or and over-shot mill-wheel. Natural river channels flowing along the valley floor were generally retained as relief channels, with water control structures at the diversion of the leat. Once the water had dropped across the face of the mill wheel it flowed via the mill race back to the natural channel. Or on down the next mill leat. The linear length of valley needed to build up the head to drive the mill – defined by the valley gradient – defined the spacing of the mills, but most chalk streams were at mill saturation point, by the time William audited his new Kingdom in 1086.

Over the centuries mills were adapted again and again, from flour to flax to paper, electricity, cardboard, wire, grinding whalebones and all sorts of light industrial uses. Generally they remained in use until the middle of the Twentieth century but their legacy of modified channels is almost more significant now that they are no longer in use. The relief channels that were the relics of the original river are generally lost, filled in, disused. The mill leats have tended to become the primary mapped river, and the millboards are very rarely lifted nowadays, meaning that the impounding impact of the mills has been fixed into the river morphology and the mill leats have become repositories for accumulated, nutrient-soaked, sediment.

6.3.3 Locks and barges

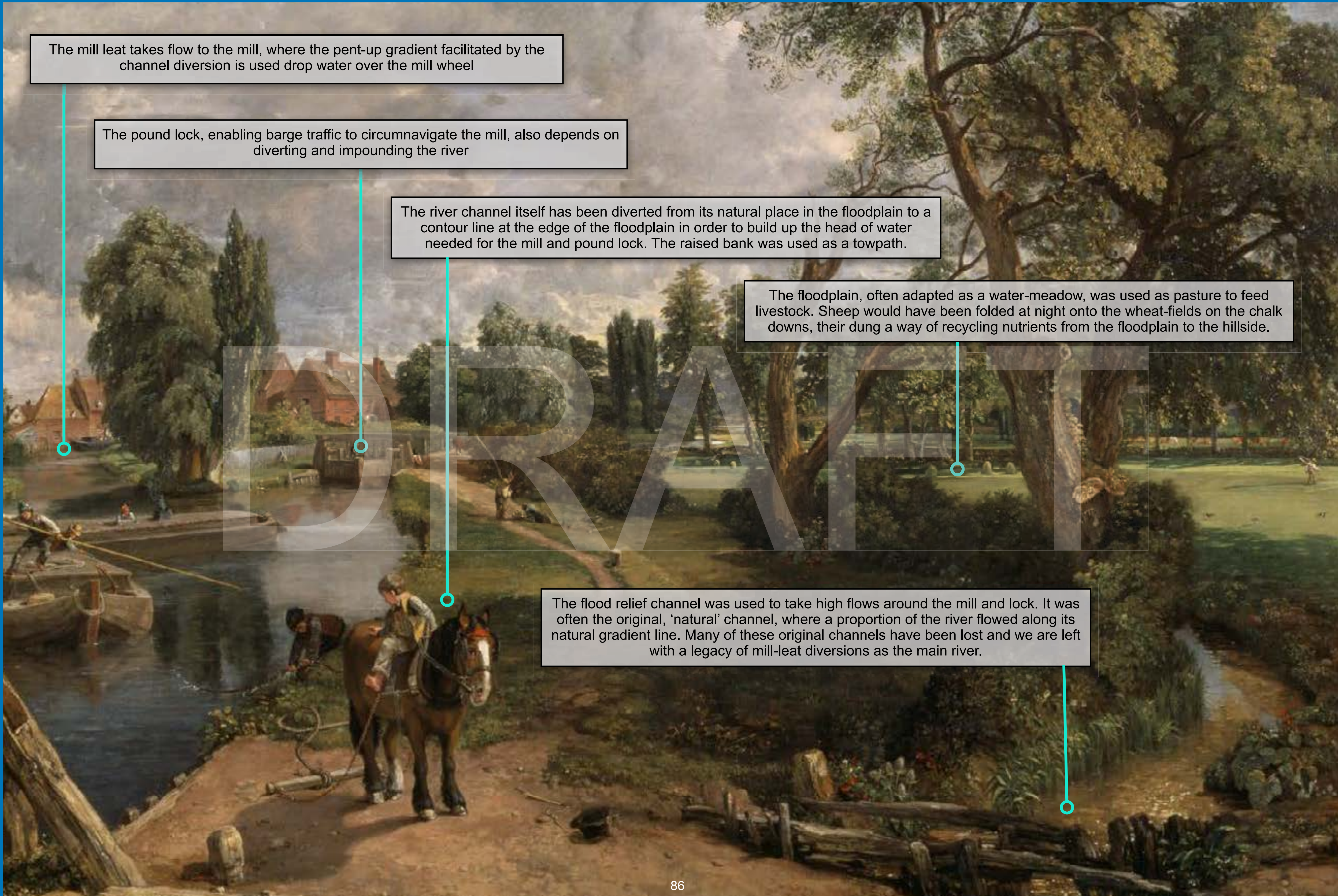
Chalk streams have even be used for commercial transport, first by the Romans and then busily from the middle ages onwards. On the River Nar, for example, crude flashlocks were constructed so that the canalised stream could be used to float barges laden with stone upstream and down, to be used in the construction of all the abbeys and priories.

A flash lock is a crude opening in an impounded wall: the barge will ride downstream on the flood, or be pulled upstream lock by lock. Flash locks were unpopular with millers, however, given it might take a day to restore the head of water.

Pound locks were better, locking the elevator of water between two pairs of gates, exactly as used on canals today. Pound locks are as old as the hills but in England only as old as 1560. From then on they turned our lowland rivers into invaluable means of transporting goods, and in this role were not superseded until the railways.

6.3.4 Watermeadows

In England water-meadows date from about the same period as flashlocks: late Jacobean. It is not known who exactly dreamt them up and the idea may well have floated across from the Continent, just like mills and pound locks. But Rowland Vaughan of Herefordshire is credited with the notion, having one day noticed how green the grass was around a breach in the mill leat that had been caused by a mole.


The mill leat takes flow to the mill, where the pent-up gradient facilitated by the channel diversion is used drop water over the mill wheel
The pound lock, enabling barge traffic to circumnavigate the mill, also depends on diverting and impounding the river
The river channel itself has been diverted from its natural place in the floodplain to a contour line at the edge of the floodplain in order to build up the head of water needed for the mill and pound lock. The raised bank was used as a towpath.
The floodplain, often adapted as a water-meadow, was used as pasture to feed livestock. Sheep would have been folded at night onto the wheat-fields on the chalk downs, their dung a way of recycling nutrients from the floodplain to the hillside.
The flood relief channel was used to take high flows around the mill and lock. It was often the original, ‘natural’ channel, where a proportion of the river flowed along its natural gradient line. Many of these original channels have been lost and we are left with a legacy of mill-leat diversions as the main river.

Vaughan set about creating a watery Utopia in the golden valley of the River Dore, wrote about it and eventually the idea caught on, driving a second agricultural revolution (the first being 1000 AD and the invention of the heavy plough), especially on the chalk streams of Wessex, the earliest examples of the truly intricate ‘floated’ water-meadows that so characterise our chalk streams.

Water-meadows worked by carrying water along a higher level ‘carrier’ channel, before releasing it through a series of catch drains and hatchways, across ridged and furrowed meadows, to gather in the natural river channel at the foot of the valley.

The idea was to keep a thin film of water moving across the grass all through the winter: this kept off the frost, and gave an early boost to the pasture. Water-meadows trebled the number of sheep a farmer might keep and this more than trebled his yield of wheat. In this sense water-meadows were really about recycling the goodness of the floodplain to the drier hillsides via the digestive systems of sheep, which were ‘folded’ onto the hills at night: a wonderfully sustainable way of recycling nutrients which we could learn from today.

Water-meadows, like mills, will have had an adverse ecological impact, by impounding the river, and diverting flow. On the other hand they more or less guaranteed that the floodplain was utilised to filter excess nutrients from floodwater, and in their own, ornate way, replicated the anastomosed channels of earlier times.

6.3.5 Dredging and canalisation

If deforestation, water-meadows, mills and pound locks took a huge toll on the natural chalk stream, shifting the baseline of what we regard as natural or ecologically good, the twentieth century brought three more calamitous changes to chalk streams – abstraction, acute diffuse and point-source pollution and finally dredging / land drainage. These changes reached their zenith of impact in the drought years of the 1970s and 80s, and were the catalyst for the birth of the river restoration movement in England.

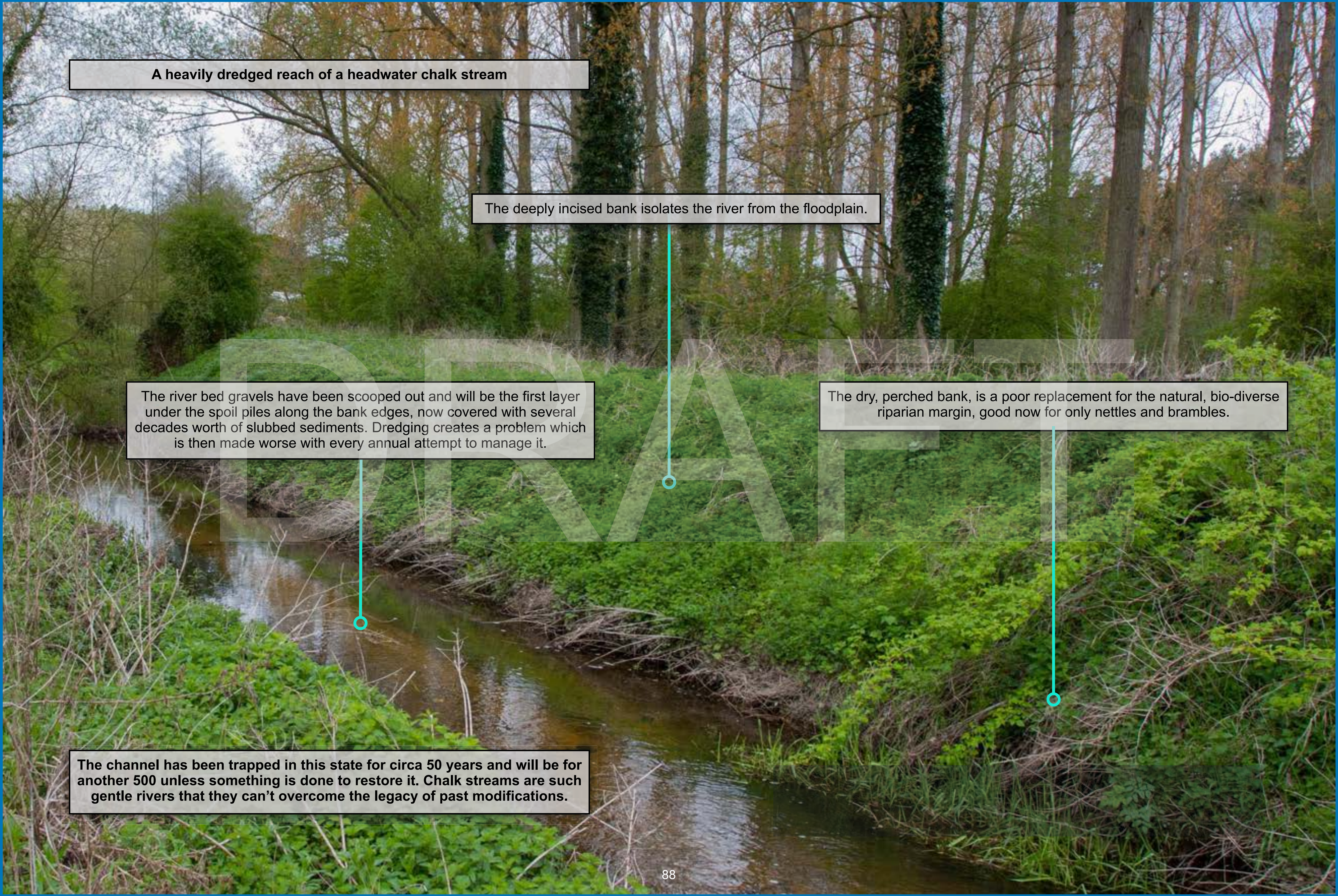
Dredging and land drainage were driven by the determination of post-war Britain to be self sufficient in food production. Traditional pasture land in floodplains was given over to arable or intense livestock production and to drive that water tables had to be lowered.

It was ultimately a failed experiment, because it is more or less impossible to lower a water table all the way to the sea: high points and pinch points were left behind, under bridges, and power lines and through immovable woods, meaning that dredging more than anything turned chalk streams into a series of sediment sumps, engine rooms of excessive plant growth which did little more than choke the stream and compel the drainage engineers to go back year after year, endlessly slubbing out the mud.

We were still dredging chalk streams until very recently. The threat of doing it again never quite goes away.

But dredging as a management concept is based on a misunderstanding of a river’s morphology. It is a definitively unsustainable operation because it fights the physical forces that shape a river, and it is usually counter-productive, in that while it is possible to drain an upper catchment meadow with a ditch, that process will only send unnaturally high sediment loads downstream to fill all the sumps that have been dredged lower down the river.

The whole operation, carried out on the scale it was in the 1950s to 80s, massively increases sediment supply (from the drainage and ditching) and retention (in the widened and deepened channels) at the same time, destabilising the river and ultimately contributing to, if not actually causing, flooding, when the whole intention was the opposite.


A heavily dredged reach of a headwater chalk stream
The deeply incised bank isolates the river from the floodplain.
The river bed gravels have been scooped out and will be the first layer under the spoil piles along the bank edges, now covered with several decades worth of slubbed sediments. Dredging creates a problem which is then made worse with every annual attempt to manage it.
The dry, perched bank, is a poor replacement for the natural, bio-diverse riparian margin, good now for only nettles and brambles.
The channel has been trapped in this state for circa 50 years and will be for another 500 unless something is done to restore it. Chalk streams are such gentle rivers that they can't overcome the legacy of past modifications.

6.3.6 Invasive Species

A number of invasive, non-native species (INNS) is present on our chalk streams, most notably – because of the damage they do – Japanese knotweed (*Fallopia japonica*), Himalayan balsam (*Impatiens glandulifera*), and signal crayfish (*Pacifastacus leniusculus*).

Japanese knotweed and Himalayan balsam

Japanese knotweed and Himalayan balsam were introduced by Victorian naturalists, but they long ago escaped their garden setting and both are now common on British riverbanks. They are a significant threat because of how easily they spread, how difficult they are to eradicate and because they outcompete other plants, causing erosion and reducing biodiversity.

Japanese knotweed has extensive, deep rhizomes and can spread from the smallest cutting. It is very challenging to control: its rhizomes, or any part of the plant are notified as a 'controlled waste' and it must only be disposed of at registered landfill sites. It is probably best to destroy the plant on site, if possible, by burning it. It's a hell of a job to dig up however, and usually some small part will be left behind and away it goes again. It takes three or four seasons to kill knotweed with glyphosate, which would need very careful use anywhere near a chalk stream. All in all it is probably best to get professional help to deal with Japanese knotweed.

Himalayan balsam produces innumerable seed pods which split and twist when ripe, especially if they are disturbed, hurling the seeds several metres from the plant. Himalayan balsam – which is widespread on chalk streams – forms dense, tall clumps which swamp out other plants, reducing riparian macrophyte diversity. Then it dies away in the winter, leaving bare river banks, which are vulnerable to erosion. Balsam can do as much bank damage as herds of livestock. It seems to do particularly well on the more flashy, mixed geology chalk streams like the Nar or Bure, probably because their more deeply incised channels create very favourable riparian conditions for setting seed. The seeds of balsam will float downstream and can remain viable for two years.

Himalayan balsam, though more pervasive than knotweed, can be defeated by home-spun efforts, applied with persistence. You can strim it before it sets flower and if you keep on strimming it, eventually it will die. But this will take a season or two and you have to be thorough, because one plant can start a new infestation in next to no time. Or you can pull it, again ideally before it sets flower, though it is much easier to spot individual plants when they have flowered. It pulls up very easily and you can leave it in the sun to dry. But you have to go back again and again, and be strategic. Balsam bashing can be a very useful activity for volunteers.

The upper River Bure at Blickling, a mixed geology Norfolk chalk-stream, is infested with signal crayfish. In the last decade the stream has doubled in width and is now turbid, silted and weedless

Signal crayfish

American signal crayfish were introduced by the UK government in the 1970s as a commercial ruse to export to the Scandinavian market. They soon escaped and spread rapidly through British waterways, where they have outcompeted and infected our smaller, white-clawed crayfish (*Austropotamobius pallipes*).

White-clawed crayfish are well adapted to English chalk streams, but are increasingly rare and in real danger of being wiped out. They do not survive an infestation of signals and the signal crayfish is spreading rapidly: once in a river system they can move through it easily. They are also being spread, unwittingly, or carelessly from river to river, either by people trapping them for food and then not cleaning their nets, or via boots, boats and vehicles.

Apart from the threat signal crayfish pose to our native white-clawed crayfish, they are voracious predators and will eat juvenile fish, invertebrates, amphibians and plants. They also burrow into soft riverbanks. The burrowing causes the river-banks to collapse and progressively the stream widens. As more and more sediment is released into a widening channel the macrophyte and invertebrate communities spiral downhill. Their constant warring stirs up the silt and the stream becomes turbid, further cutting down primary production.

There is some controversy about what you can do to control signal crayfish. Some maintain that trapping is futile, because it tends to pull out the larger crayfish, above the size at which they achieve sexual maturity. Larger crayfish predate on smaller crayfish, and so not only does trapping fail to remove the breeding population, but it does remove a significant predator, and thus the population actually goes up, even if the average size goes down. On the other hand, some methods of trapping have been shown to be effective: neutering and returning the larger males, while removing all others has been shown to have an impact. Refugia traps catch juvenile crayfish as well as older ones. Really intensive trapping can make a localised difference. And predatory fish like trout, chub and eels can exert an impact. Note that with *any* trapping, bio-security is of paramount importance and EA permission must be sought.

Habitat can also make a difference: crayfish love tall earth banks, but they don't manage to get the same foothold where the banks are flinty, or where there is a steadily sloping riparian margin with good plants growth. Redressing the impact of dredging with bank re-sectioning can limit their habitat, as can armouring the banks with gravel. With enough resources and persistence, the localised destructive impact of crayfish can probably be ameliorated, even if it is probably impossible to get rid of them entirely.

Longer term the best hope is probably a form of gene-drive control, Directed Inheritance Gender Bias, which could theoretically eliminate the signal crayfish altogether, by skewing the sex of the crayfish, leading to a population crash. This is a novel science, and inevitably controversial (although it uses gene editing not the insertion of alien DNA), but it has been proven effective with other species like mosquitoes in controlled settings and there is a serious proposal to use it to address the grey squirrel problem. Given the huge threat signal crayfish pose, gene drive should be taken seriously as an option.

6.4 River Restoration / Process Restoration

Restoring process means restoring:

- **river-bed gradient (longitudinal connectivity)**
- **meander planform (because river ecology & nature abhor a straight line)**
- **river bed-level relative to floodplain (lateral connectivity)**

followed by felling lots of trees into the river.

These are the drivers of river process that have been removed by the ways we have harnessed and modified chalk streams.

Restoration of the above elements allows the river's ecological engineers – insects, plants, fish and mammals – to get to work

6.4.1 River-Bed Gradient

Most of the ways we have modified chalk streams have compromised the gradient and longitudinal connectivity of the river channel. In short, mankind has turned the steady slope of the river beds left behind by the last Ice Age into a staircase of channel diversions in order to harness the power of the river to drive mills, or to use it for transport or to get it out of the way of farming activities.

Stair-casing the chalk steams in this way has had serious ecological consequences.

• Interrupting the passage of migratory fish like salmon. Salmon would once have been indigenous to all English chalk streams but we had shut most of them out by the Middle Ages. There is evidence that our only remaining chalk stream salmon are genetically distinct. They could well be amongst Britain's longest, resident animals, as salmon would have been able to survive in spring-fed rivers on the edge of the ice-sheets. Lamprey, eels, and sea trout all also depend on open migratory pathways in the river channel.

• Altering the balance of the plant community: some of the key chalk stream macrophytes, like ranunculus, need swift flows to grow. Ranunculus is home to millions of blackly larvae which filter diatoms from the water: the perfect example of an ecological engineer (operating at a scale you might never guess at) facilitated by natural channel morphology, or disabled by unnatural channel morphology.

• Altering the balance of fish and insect communities: many key chalk stream invertebrates and fish species are rheophillic, thriving in cool, swift, well oxygenated water. Impounded channels accumulate sediment and favour a limited range of plants and invertebrates. The naturally flowing chalk stream is far more bio-diverse than the impounded chalk stream.

• Increasing the residence time of water in impounded channels: there is a world of difference between slowing the flow via natural fen and saturated floodplain habitat and slowing the flow with impounded mill-leats or dredged channels: the former helps to address nutrient enrichment, natural flow regime and to stabilise temperatures, the latter drives up water temperature and nutrient levels through the accumulation of sediments, leading to more eutrophic conditions.

Restoring natural gradient restores a key driver to natural ecological process.

Circumnavigating mill leats

Restoring gradient can be as easy as removing an old farm weir, but it is usually rather more complex as the gradient tends to be compromised either by mill-leats (attached to expensive mill houses) or dredging. Of the two, mill impoundments are technically easier to deal with, either by lifting the boards under the mill allowing the river to flow freely underneath, or by diverting some or most of the flow around the mill through a version of the original flood relief channel. But mill owners tend to be very wary of this kind of proposal and attach a lot of value to the mill leat. Many have been persuaded, however, either by the ecological gains, or by the examples that now exist (for example Glandford Mill on the River Glaven, a project managed by Tim Jacklin and the Wild Trout Trust) of beautiful, swift-flowing channels that have successfully replaced anoxic, silt-filled mill leats.

6.4.2. River-bed cross-section: restoring dredged channels

The widespread dredging of chalk streams in the 1950s to 1980s took these naturally wide, shallow and bank-full rivers and locked them inside a jail. Dredging is a form of impoundment albeit the effect is made by unnaturally lowering the river and the impoundments become the parts of the channel that were left behind, under power lines, under bridges.

However, dredging is the most damaging and difficult to fix modification of all, because once the gravel has been taken out off the river bed, there is just no bringing it back this side of another Ice Age. It is usually smeared in a thin film on the flood-plain peat and buried under decades worth of slubbed sediment, crowned with a line of nettles.

Historically river managers have replaced river gravels with imported, graded gravel from quarries. This is not the best option. Graded gravel is peculiarly immobile once placed in the river, and cannot be sifted or winnowed by the flow. Plants don't like it and and fish don't seem to spawn on it. River bed gravels should be restored 'as dug', ideally from very close by, to ensure they are appropriate for the stream. Luckily the dredgers only ever removed gravel from the river bed and so the undamaged gravel floor of the floodplain is usually only a few yards away from the edge of the bank.

Provided there is space and a willing landowner a double habitat gain can be effected by digging the gravel from 'borrow-pits' beside the river, then refilling these as shallow depressions and pseudo oxbows that can be inundated by groundwater or flood-flows in the winter. They can be connected to the channel to form refuge habitat for fish.

Another option is to restore the gravel bed and the meander planform by excavating a new channel to the side of the dredged one. This can actually involve moving less material than pulling gravel out of borrow pits into the existing channel, as all you have to do is peel the floodplain peat aside and let the water flow through: you don't have to move the gravel.

It is worth doing the former if you are restoring gravel to an original, meandering planform channel in the centre of the floodplain. But if that channel is itself a diverted and canalised one, then the better option might be to recreate, or restore (if you can find it) the original course of the river. The photos on pages 77 and 80 are examples of this approach.

6.4.3. Meanders

Meanders are a vital part of the functioning process of a river. Because rivers are water moving over a surface, a process in which friction unevenly slows the passage of liquid, all river channels are shaped by the same physical forces – albeit operating at differing intensities and timescales – and conform to the same basic mathematical formula.

In a river channel friction acts on the water at the edges and bed of the channel more than in the middle: this sets up a divergence in flow velocity that translates into circular back flows along the edges. The back-flow eddy grows in a downstream direction, pulling the water from the middle to the sides, but it can never grow to a diameter greater than half the width of the channel because it will always meet a similar eddy emanating from the other side.

The eddies do not slide downstream in perfect opposition however: instead they grow and shrink in opposing pattern, pulling the river from side to side, creating a waveform in the channel shape (seen from above) that is reliably described (if many meanders in a given river are measured and averaged) by the formula 2 x Pi x channel width.

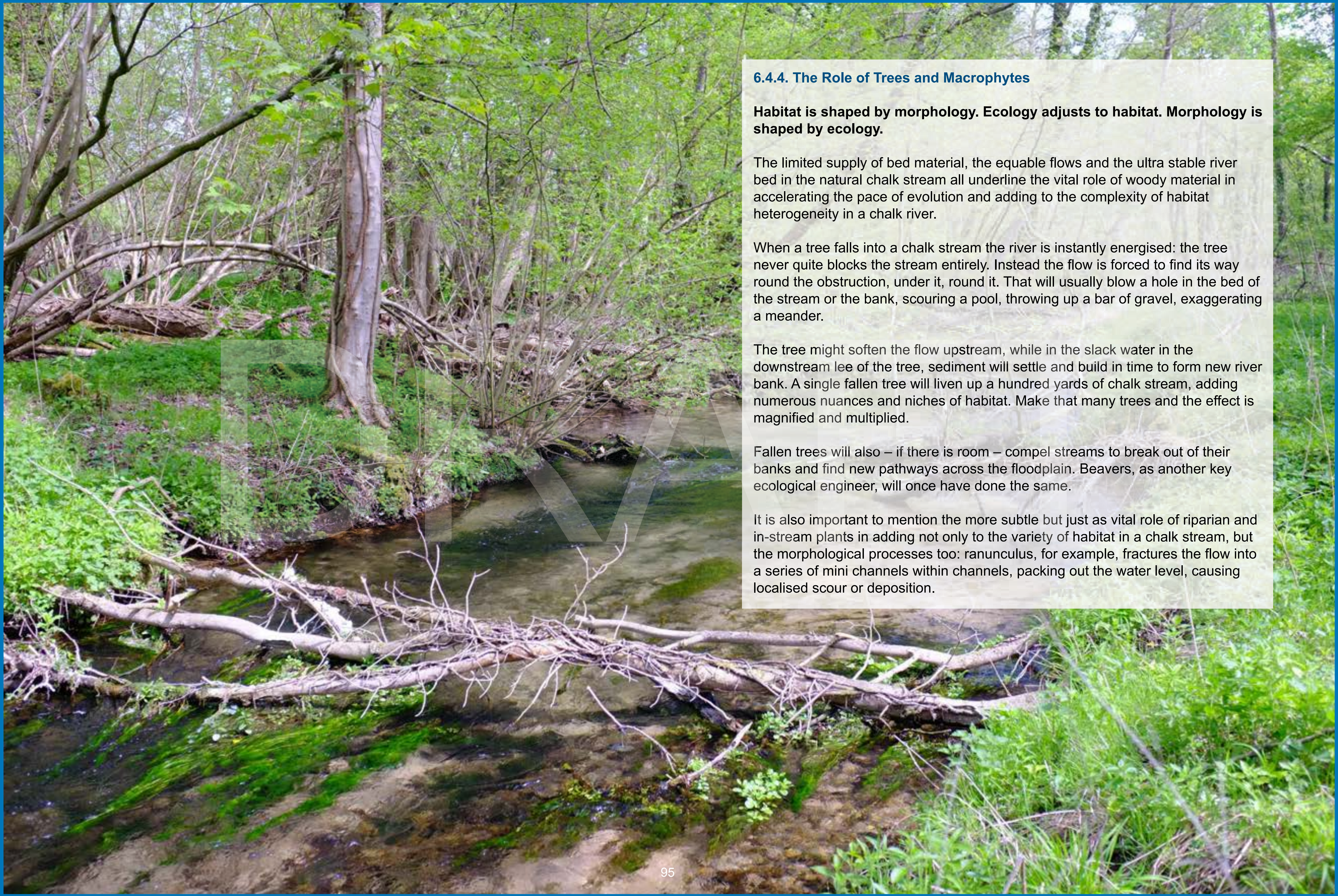
The meandering motion of the river pushes the erosive force of the water on to the outside of each bend. In addition there is a corkscrew circular motion in the water as it travels down “the tube” of the river channel. The erosive force moving from one side to the other and the corkscrew motion of the water as it travels downstream, have the effect of scouring material from the bed and banks on the outside of the bend, creating a pool. The scoured material then drops out of the current and is deposited in a riffle downstream, or is shifted from the outside of the bend in spiralling back eddies until it drops out of the slower flow on the inside of the bend.

This is a very simplified description of the shape of the river bed, which in reality is sculpted by the flowing water into very subtle humps and hollows, synclines and anticlines. A river, therefore, acts as a conveyor of material: the gravels, sands and sediments move steadily downstream and must be replaced by an equal amount coming from the catchment, headwaters and banks of the river. A stable, natural river is one where this supply and transport of bed material is in balance.

But in a natural chalk stream the supply is very limited – because of the spring-fed nature of the system, with very little surface run-off – but then again the transport of sediment is also limited – because of the equable, low energy flows and river bed hardened by tufa.

Left: The ornate, multi-channelled planforms of relatively unmodified spring-fed streams in places like New Zealand give insights into what our chalk streams were once like

These meanders on the River Glaven look like they've been there forever, but were in fact designed according the mathematical principles described on page 87 above by Richard Hey in 2014 on behalf of the Norfolk Rivers Trust & Wild Trout Trust



6.4.4. The Role of Trees and Macrophytes

Habitat is shaped by morphology. Ecology adjusts to habitat. Morphology is shaped by ecology.

The limited supply of bed material, the equable flows and the ultra stable river bed in the natural chalk stream all underline the vital role of woody material in accelerating the pace of evolution and adding to the complexity of habitat heterogeneity in a chalk river.

When a tree falls into a chalk stream the river is instantly energised: the tree never quite blocks the stream entirely. Instead the flow is forced to find its way round the obstruction, under it, round it. That will usually blow a hole in the bed of the stream or the bank, scouring a pool, throwing up a bar of gravel, exaggerating a meander.

The tree might soften the flow upstream, while in the slack water in the downstream lee of the tree, sediment will settle and build in time to form new river bank. A single fallen tree will liven up a hundred yards of chalk stream, adding numerous nuances and niches of habitat. Make that many trees and the effect is magnified and multiplied.

Fallen trees will also – if there is room – compel streams to break out of their banks and find new pathways across the floodplain. Beavers, as another key ecological engineer, will once have done the same.

It is also important to mention the more subtle but just as vital role of riparian and in-stream plants in adding not only to the variety of habitat in a chalk stream, but the morphological processes too: ranunculus, for example, fractures the flow into a series of mini channels within channels, packing out the water level, causing localised scour or deposition.

6.5 Next Steps Chalk Stream Restoration

The modern chalk stream

This is what we have inherited: spring-fed, gentle rivers greatly modified by mankind: by deforestation and pastoralisation, and by the imposition of mills, weirs, pound locks, and water-meadows. Then, in the twentieth century, we grandfathered the mills and water-meadows, denuded the river's flows with groundwater abstraction, dredged and straightened wherever we could, and added greatly to the supplies of diffuse and point-source pollution.

The Government's stated ambition in the 25-year Environment Plan is to **"leave the environment in a better state than we found it"** and that, with regard to chalk streams, is our challenge.

Chalk streams are in crisis: some hardly flow at all, even the best are ecologically impoverished. It is not quite true that they are worse now than they have ever been. The late 1980s and early 1990s probably marked the summit of their degradation, when phosphorus pollution was worse than today, when abstraction in the Chilterns was more severe than it is now, when even rivers like the Piddle and Allen in Dorset were running dry and when the needs of flood defence and drainage dominated the shaping of river channel morphology.

The power of river restoration

Restoration is a troubled term because it begs the question, restoration to what state? Clearly it would be impossible to restore chalk streams back to a state pre-Neolithic wildness and who is to say which version of the variously modified states imposed since is the best? We have been modifying these rivers for centuries.

That is why this strategy focuses on the restoration not of a state but of process. In restoring process we let the river do most of the work, concentrating primarily on relieving the pressure of whatever it is that is inhibiting process: flow and water quality, gradient and hydrological connectivity: these are all key to ecology. A healthy ecology then starts to shape its own physical habitat. Our place is as facilitators and then privileged observers: in that space, where people meet nature, without overwhelming it, but very much able to become overwhelmed by it, there is a cathartic beauty that is genuinely priceless: its strength and weakness. It is an almost spiritual space which we fail to capture in terms like 'natural capital' and 'existence value', but which nevertheless defines us and anchors us to the natural world. It is where we go lose ourselves for a while, to walk the dog, watch birds, swim and fish.

River restoration is about bringing that space back.

6.6. Key Foundations of Chalk Stream Restoration

• Chalk streams were shaped by forces that have long since retreated from the landscape.

• Once damaged or modified, chalk streams are prisoners of their own equable nature, lacking the stream power for self-repair.

• Compared to higher energy streams, chalk streams are more dependent on ecological processes: on macrophytes interacting with flow, on tree-fall, on spawning salmonids (mobilising gravel), even on midge-larvae in ranunculus beds filtering diatoms from the water. Recent research underlines the importance of these ecosystem engineers.

• The common chalk stream modifications – mills and other impoundments, canalisation, dredging – combine to a) alter the natural physical condition (eg. altering slope or denuding flow) and thus disable the eco-hydrological processes (eg. plant community structure, salmonid spawning.)

6.6.1. Principles of Chalk Stream Restoration

• Therefore the 'restoration' in chalk stream restoration, should be a restoration of that which catalyses process:

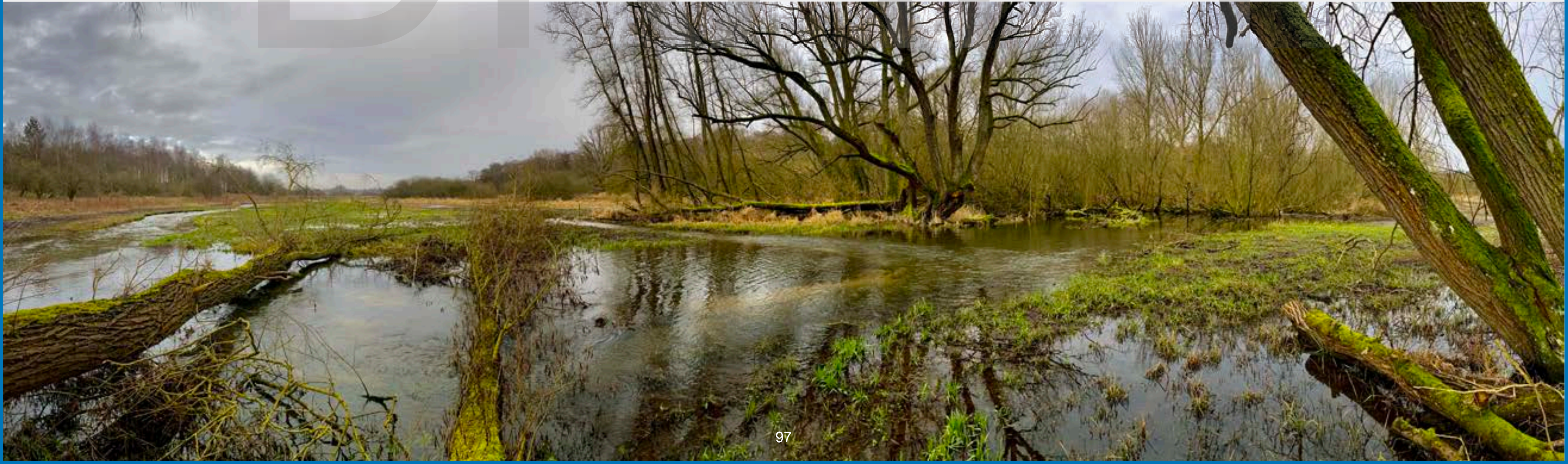
• The restoration of stream slope (longitudinal connectivity)

• The restoration of an intact gravel-bed (by returning gravel to the existing channel or by restoring, or reconstructing the original one)

• The restoration of a dynamic interaction with fallen trees and living riparian trees

• The restoration of a dynamic interaction with the floodplain (lateral connectivity)

• And through all the above the restoration of the ecological processes and the habitat requirements of the ecosystem engineers (fish, insects, mammals and plants) that shape a truly heterogenous and dynamic habitat



6.7 Catchment scale restoration case study - The River Nar

6.7.1 Restoring headwater fen and wetland

The headwaters of the River Nar, like many East Anglian chalk streams, have been straightened and lowered over the centuries and function more as drainage ditches than a chalk stream. Here the floodplain was re-graded, and a meandering channel and series of ponds was restored, with natural lateral and longitudinal connectivity: the stream is now able to break out of the banks in high flows. The water-table is resaturated. The farmer extensively grazes water buffalo and hardy soay sheep.

6.7.2 Restoring gravel to dredged reaches

The river bed in this meadow on the River Nar had been lowered by half a metre, resulting in a silt-laden channel choked with bur-reed. Gravel was taken from borrow pits beside the river and used to restore the natural bed-level and gradient. Now the channel contains starwort and ranunculus, and has yielded record fish numbers in EA surveys. The borrow pits form wetted hollows, like old relic channels, and have added to the biodiversity of the site.

6.7.3 Restoring meanders and gradient

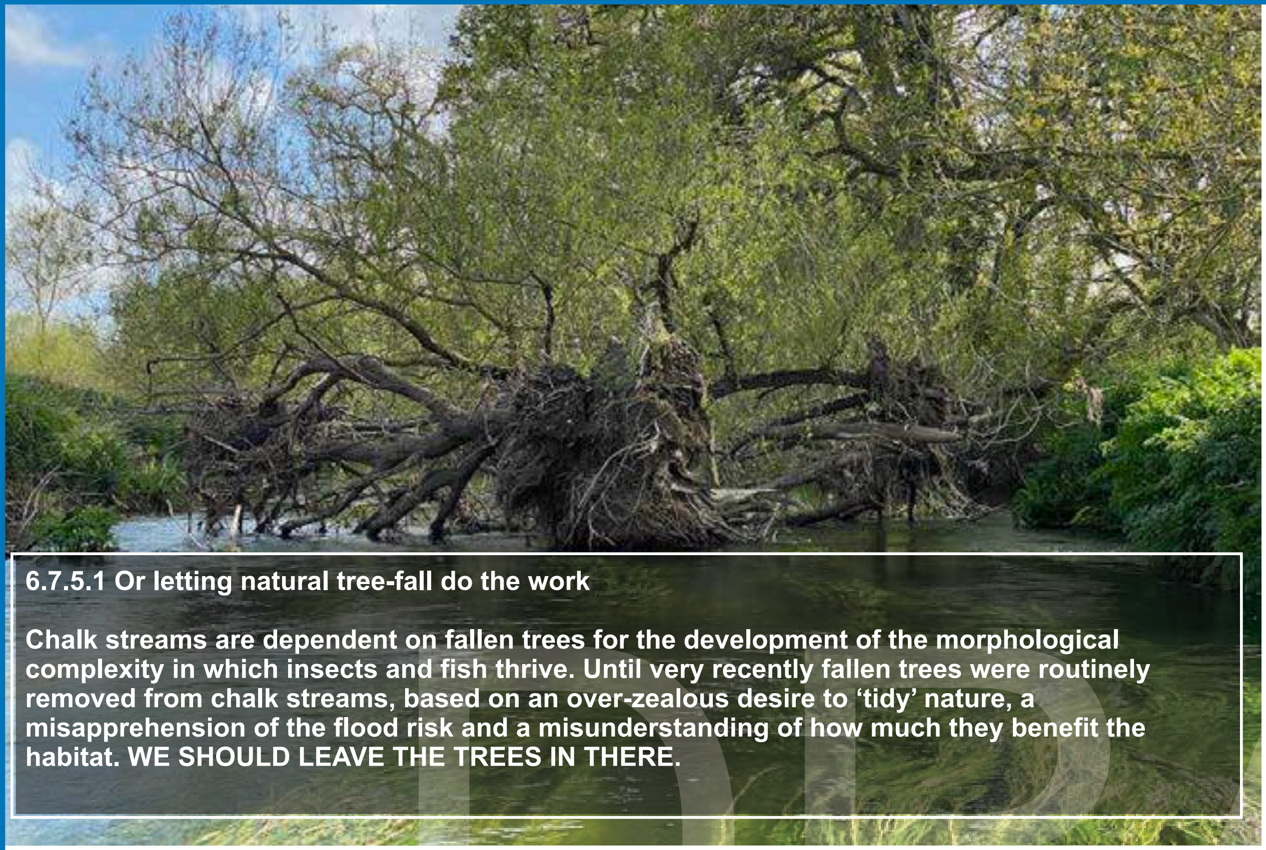
The river through Castle Acre Common was diverted hundreds of years ago to the side of the floodplain, into a perched contour-line leat of a much lower gradient than natural. In the mid-20th century this channel was then dredged, further isolating the chalk stream from its floodplain. With a Water Environment Grant, the Nar Restoration Group have recreated a 2km swift-flowing, meandering channel in the middle of the flood-plain and have pinned into it dozens of ‘fallen trees’. The old channels have been retained as fen-like oxbows adding the habitat variety across the width of the floodplain. See also pictures on pages 85 and 95.

6.7.4 Restoring longitudinal connectivity: by-passing mill-leats

Most chalk streams feature mill-leats, diversions of the original channel designed to build up a head of water to drive a mill. These leats are perched at the sides of the floodplain and impounded by the mill. The original channels, which were once preserved as the mill's flood-relief channel, are often disused nowadays and have grown in. At the lower end of Castle Acre Common, the restored channel now bypasses the perched mill-leat channel, and is back where it used to be, at the centre of the floodplain.

6.7.5 Restoring dynamic interaction with trees

This reach of the River Nar was incised, overshaded, and much wider than the natural channel, with little in the way of cover for fish. The surrounding woodland was semi-commercial, but overgrown and unnaturally dense. The riparian area and channel were restored by imitating the impact of a storm, felling dozens of the multi-stemmed alders across and along the edges of the channel. The result has been the creation of an almost primeval stream, with marshy, riparian habitats, a swift-flowing central channel, full of cover and now full of fish.



6.7.5.1 Or letting natural tree-fall do the work

Chalk streams are dependent on fallen trees for the development of the morphological complexity in which insects and fish thrive. Until very recently fallen trees were routinely removed from chalk streams, based on an over-zealous desire to 'tidy' nature, a misapprehension of the flood risk and a misunderstanding of how much they benefit the habitat. WE SHOULD LEAVE THE TREES IN THERE.

6.7.6 Floodplain rR-connection

Pushing the canalised and unnaturally extended headwaters out of their confined, ditched channels and across the floodplain offers multiple benefits to biodiversity, natural catchment function, and the attenuation of siltation and agricultural run-off. It is cost effective and easy to do if the land-owners are willing.

6.8 Chalk stream restoration in the context of landscape-scale nature recovery

Ideally chalk stream restoration should not be confined to the river corridor and floodplain, but should encompass the broader sweep of the landscape which supports the chalk stream.

As with restoration of process at the river scale, restoring nature at the landscape scale is largely about controlling or eliminating the adverse pressures of human activities, and giving biodiversity the space and conditions to thrive.

Chalk streams, from their winterbourne reaches all the way downstream to where they are large chalk rivers, should be seen as one component of the ecosystems that need to be cherished and restored within chalk stream catchments: from the grassland, scrub and woodland mosaics of downlands, to the springs, flushes and fens of headwater and valleyside areas, to the wetland, grassland and woodland mosaics of floodplains.

Integrating the recovery of these various ecosystems through landscape-scale planning of nature recovery strengthens the actions taken on each component and maximises the natural capital benefits (Natural England 2018). Restore downland habitat mosaics and the water quality and recharge of chalk aquifers is improved for all downstream ecosystems dependent on water. Restore natural hydrological function to headwater and valleyside springs, flushes and fens and the flow, sediment and water quality regimes of the winterbournes and perennial chalk streams that flow from them are restored. Restore naturally functioning floodplain wetland mosaics and the ability of chalk streams to support their characteristic wildlife takes another huge leap forward. Restoring natural function to chalk streams themselves is an integral part of restoration of the wetlands they are naturally associated with, from their headwater beginnings to their saline endings.

Targeted re-establishment of natural and semi-natural habitats

A good way to start this landscape-scale approach is to facilitate a reversion to natural and semi-natural vegetation mosaics across critical parts of the catchment, at the same time ensuring that land use in the rest of the catchment is as supportive of wildlife as possible and makes as large a contribution as possible to restoration of natural catchment processes. For example through effective soil conservation and efficient nutrient management on farms.

Selecting which areas to prioritise for reversion to natural / semi-natural vegetation relies on a good understanding of how the catchment functions naturally, particularly in terms of the natural pathways (and associated volumes) of water through the landscape and how underground pathways naturally pop up and feed wetlands and pools and then streams and river channels. Land reversion is best targeted in and around these pathways to support the restoration of naturally functioning habitat mosaics.

- **Riparian and wider floodplain land alongside chalk streams is an obvious target, working in tandem with physical restoration of the channel to help restore natural hydrological and ecological relationships between channel and associated land (as described in section 6.7).**

- **Headwater and valley-side areas are particularly important, where impacts from intensive land use can be eliminated at source and the benefits can be felt by the whole of the downstream catchment.**

- **Natural headwater chalk streams have been channelised and artificially extended by drainage systems, so that it makes it very difficult to understand the difference between a degraded stream and an artificial ditch. Restoration of naturally functioning fens by blocking drains, in conjunction with restoring natural aquifer flows, is a critical activity.**

- **So too is reversing the upward creep of intensive agriculture into the natural and semi-natural grassland, scrub and wooded mosaics of downland, since this is the starting point for chalk stream siltation and pollution downstream.**

- **Towards the base of valley sides, catch-drains have often been dug to catch drained spring-flows and divert them away from the floodplain – targeted removal of catch-drains to re-naturalise spring flows is critical to restoring naturally functioning fens within floodplain fringes.**

Targeting land in this way is the art of the possible.

There will of course be catchments and parts of catchments where such restoration is more feasible and where landowners are more amenable to change. This ought to be a key selection criterion in the flagship catchment restoration scheme detailed in the following section.

Equally, some locations will prove problematic because of constraints associated with urban areas and essential infrastructure (for instance, urban areas that have developed where groundwater levels have been historically suppressed by heavy abstraction).

It is a question of targeting the best locations given local opportunities and constraints. The Nature Networks Evidence Handbook (Natural England 2020) provides guidance on how to approach the targeting of land for nature recovery, and how to factor in socioeconomic objectives.

Targeted reversion to natural and semi-natural grassland, woodland and scrub is a key contribution to good water quality and reduced siltation throughout the catchment: targeting landscape in this way is the art of the possible.

6.9 The role of different delivery mechanisms

Key elements of biodiversity strategy in England post-2020 are the **Nature Recovery Network (NRN)** and **Local Nature Recovery Strategies** (**LNRSs)**.

These will be vehicles for planning the restoration and re-establishment of wildlife-rich habitats in our landscapes, and will work in combination with measures to implement good and best agricultural management practices, with a particular view to minimising the wider reaching potentially negative impacts of farming activities.

Development of the NRN and LNRSs is in the early phases but stakeholder engagement is now building and biodiversity partnerships are forming.

Key delivery vehicles will be the **Future Farming Schemes** being developed to replace existing state aid schemes for farming, as well as the **Net Gain** mechanism being developed to the maximise potential environmental gains in planning and development opportunities.

The climate-change agenda is also providing major additional sources of funding for establishing tree-planting schemes and restoring peatlands, in order to sequester and store more carbon and help achieve Net Zero carbon emissions.

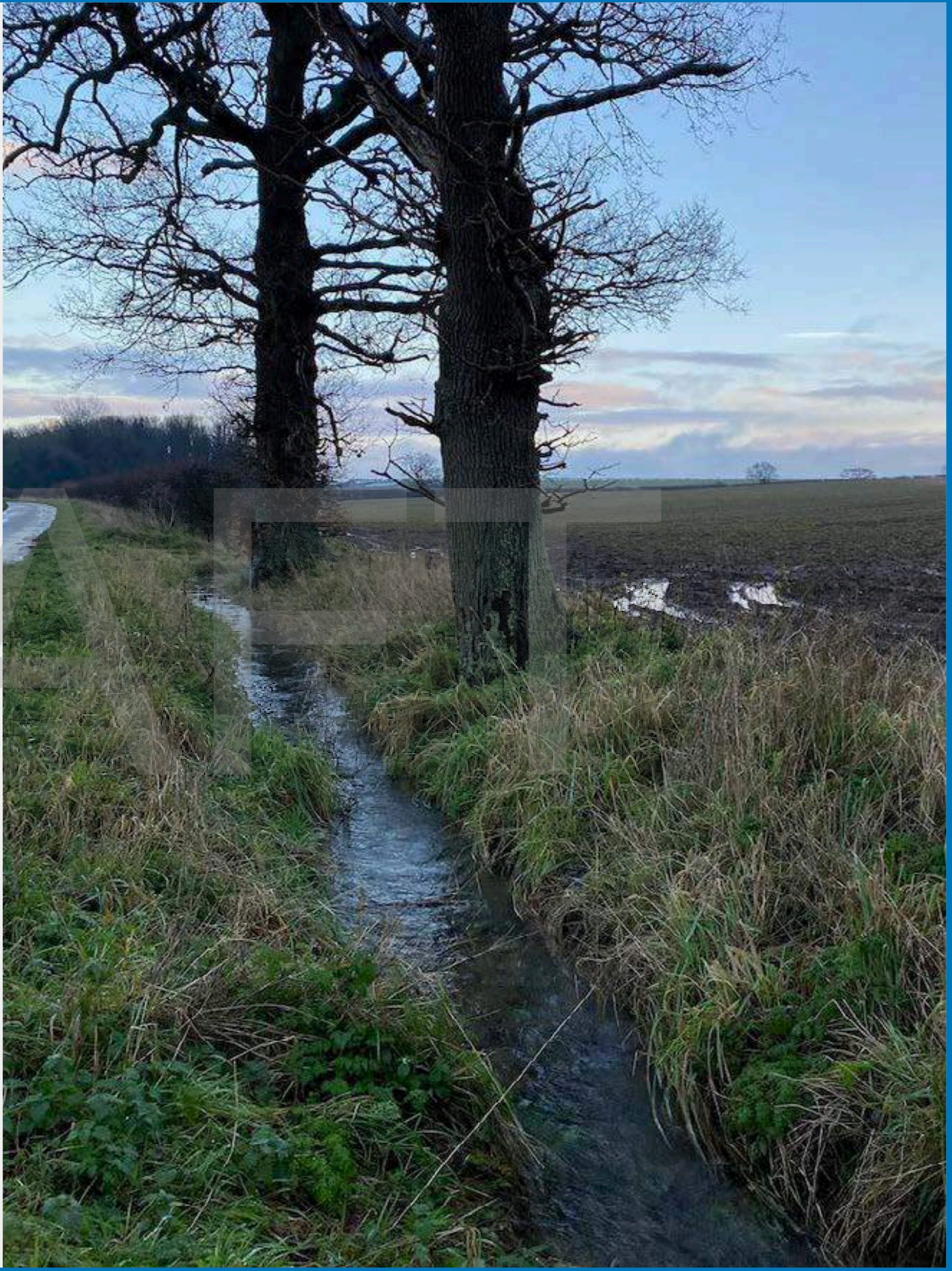
National action plans for trees and peat will be very important for chalk stream catchments, in helping to restore naturally functioning chalk fens and re-establish riparian and floodplain trees (in different densities up to woodland) that are so vital to the natural functioning of streams and rivers.

It will be important to harness all of these mechanisms to get the best outcomes for chalk streams as well as for other ecosystems that are such characteristic natural features of chalk catchments.

Key references:

Natural England (2020) *Nature Networks Evidence Handbook*. Natural England Research Report NERR081. Natural England, York

Natural England (2018) Generating more integrated biodiversity objectives – rationale, principles and practice. Natural England Research Report Number NERR071.



Right: Stepping back farming from the edge of the stream, the floodplain and the headwater reaches, and restoring natural fen and riparian woodland, are key ways to enhance the ecological health of chalk streams, sequester carbon, and manage flooding.

6.9.1 Using the priority habitat driver for chalk streams

Action to restore biodiversity on non-designated sites is focused on priority habitats and species listed under Section 41 of the NERC Act 2006. Chalk rivers are part of the definition of priority river habitat, and this should create additional impetus for their protection and restoration. A framework has been developed to allow stakeholders to use the priority habitat driver to try and secure more action on their chalk streams, adding weight to the prioritisation received under water planning processes. All aspects of this framework can be accessed via the priority habitats website hosted by the Freshwater Biological Association.

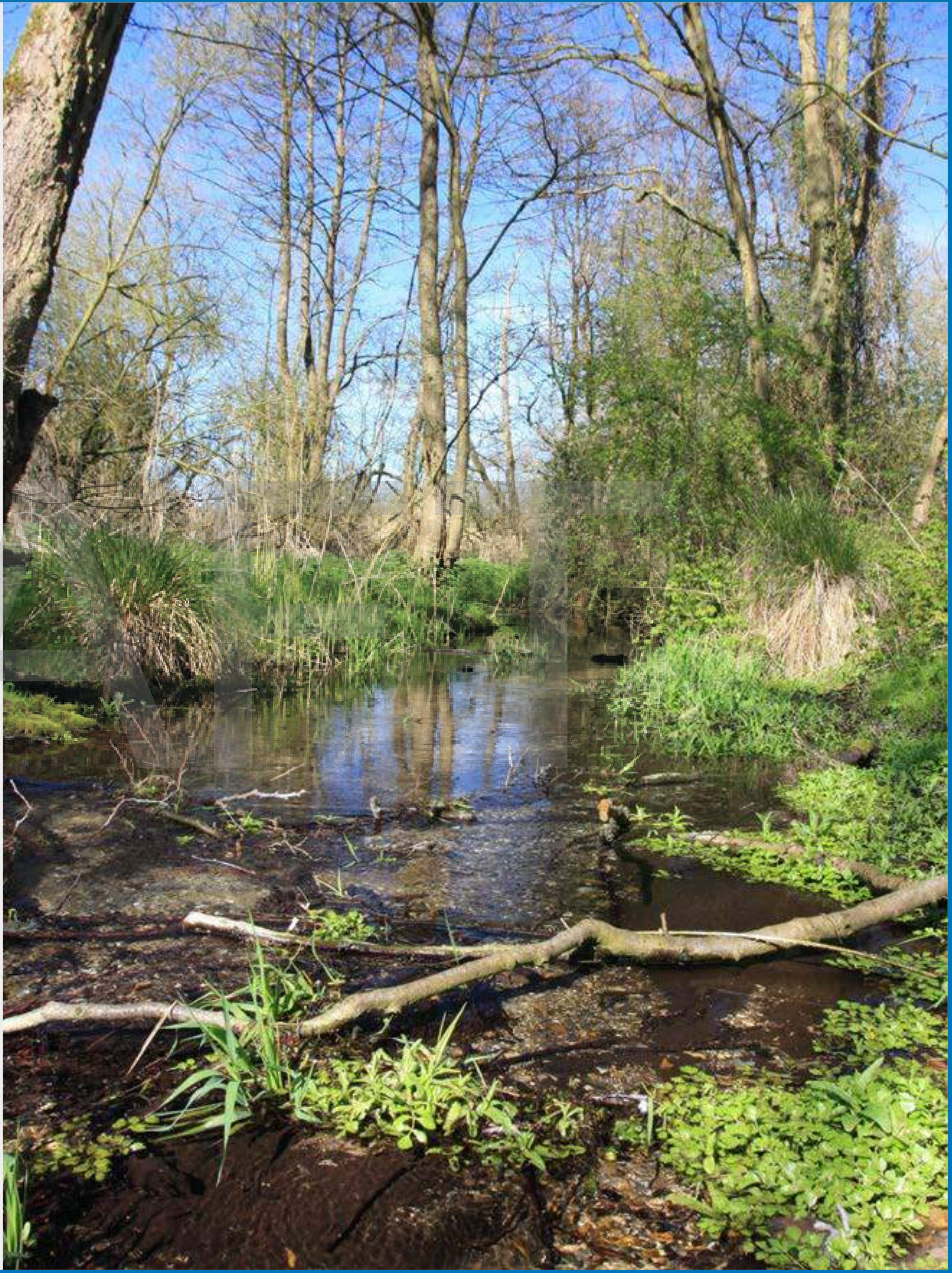
Mapping the chalk stream resource – A refined map of chalk rivers is being developed to take account of the gaps identified by stakeholders, particularly in the coverage of small headwater chalk streams and winterbournes. A provisional revised map has been available on the FBA website since January this year, and is currently in the process of being finalised through stakeholder feedback. This will form a basis for targeting and evaluating whether delivery mechanisms are focusing sufficient attention on chalk streams.

Protecting our most natural remaining examples from future impacts – An official map of priority river habitat has been generated to highlight the most natural remaining examples of all types of river and stream in England. This acts as a vehicle for protecting these sites from deterioration. The map is used to assess applications under water permitting processes and development planning processes. The map is under regular review and sites can be added via an assessment of naturalness that can be undertaken by stakeholders via the FBA priority habitats data portal.

Restoring chalk streams – The FBA data portal includes a facility for stakeholders to highlight priority locations for restoration. This process is independent from Water Framework Directive prioritisation processes and will be used to overlay biodiversity priorities on top of WFD priorities. Various types of restoration can be highlighted, from hydrological to water quality, physical and biological (e.g. control on non-native species). Local chalk stream partnerships can have their own workspaces, and individual stakeholders can get involved. The map is in the early stages of development but will grow over the course of the next year.

All of these facilities feed into the targeting of action on nature recovery under post-2020 biodiversity strategy in England. The more they are used by stakeholders to highlight chalk streams, their status and restoration needs, the better the outcomes will be for chalk streams.

Right: There are unrecorded natural gems in the headwater stream resource just waiting to be put on the map and given protection under the priority habitat driver.



6.10 National Network of Flagship Catchment Restoration Projects

Aim: To facilitate and catalyse this catchment-scale ambition, the CaBA Chalk Streams Restoration Group is working towards the creation of 12 flagship Catchment Restoration Projects.

These projects will be in addition to work on the SSSI and SAC designated chalk streams which already have catchment restoration strategies. The aim is to realise on these flagships streams all the dimensions of ambition the CaBA strategy has articulated to show what is possible and to act as exemplars to assist in the restoration of other chalk catchments.

Scale: The aim is to restore the whole chalk stream catchment over a 10-year period. Identification of the candidate chalk catchments will need to take into account:

- Size: the plan is to identify 10-12 medium-sized chalk streams (c.15km long) widely distributed across the chalk from Dorset to Yorkshire.
- Active stakeholder engagement and support: it is important to have local passion driving the projects forward.
- The number of landowners and their willingness to participate.

The project will be split into two main phases:

Phase 1 – Development of Catchment Restoration Plans

The guiding principles for development of the catchment restoration plans are:

1. They must be developed collaboratively with local stakeholder groups.
2. The aim is to restore natural physical and ecological processes to restore ecosystem function.
3. The plan should be at a catchment scale to show the ambition for the whole river, but broken down into accessible units detailing the problems to be addressed and actions required in each part of the river, including costs and timescales for delivery.
4. The plan must be user-friendly and accessible for local people.

The full catchment restoration strategy should cover proposals:

- to achieve sustainable abstraction;
- to reduce point source and diffuse pollution;
- a reach by reach physical habitat restoration;
- with an overall aim to achieve good or even high ecological status.

We would expect the proposals to cover actions which restore the catchment over a 10 year period.

The strategies will be developed in the next 1-2 years, in time to inform PR24. Where resources and/or actions are deliverable in current business plans they should progress as soon as possible.

Phase 2 – Plan delivery

A programme manager will need to be identified to co-ordinate delivery. The programme manager must work with local stakeholder groups to deliver the programme of work outlined in the plan.

We expect to develop wider catchment restoration drivers for PR24, which would enable water company actions to be included in the Water Industry National Environment Programme (WINEP) in PR24. The 5-10 year plan horizon would require actions during the AMP8 and AMP9 water company plans.

Who should do the work and funding?

The projects should by led by Rivers Trusts, Catchments Partnerships, and other Rivers Groups and Associations. Grassroots stakeholder involvement is fundamental to the plan.

All sources of funding should be explored, but to give long term certainty, we see the water companies as a key contributor or preferably, taking a lead on funding this work, as specific funding could be secured through water company business plans.

We will seek to identify one or two exemplar catchments in each water company region which the water company could ‘adopt’ and focus attention on. Core funding from the water companies to develop the catchment plans could kick-start additional funding from Government/Defra/EA via grants and other catchment partnership funding.

Co-ordinating with Nature Recovery initiatives

There is clearly enormous scope to co-ordinate these Flagship Projects with other nature recovery and restoration schemes including Local Nature Recovery (LRN), Landscape Recovery (LN), Woodlands for Water, Nature for Climate and Biodiversity Net Gain.

6.11 Physical Habitat Actions: Restoring Process

1. Principles of Chalk Stream Restoration	CaBA CSRG endorses the Key Foundations and Principles of Chalk Stream Restoration set out in Section 6.6 and 6.6.1 agreeing that the chalk stream restoration, should be a restoration of that which catalyses process: the natural gradient of the river, an intact river bed, a dynamic interconnection between the river and the floodplain, and through all the above the restoration of the ecological processes and the habitat requirements of the ecosystem engineers (fish, insects, mammals and plants) that shape a truly heterogenous and dynamic habitat.
2. Flagship Restoration Projects	CaBA CSRG will work with Water Companies and other partners to deliver a national network of Flagship Catchment Restoration Projects as set out in Section 7. The aim is to realise on these flagships streams all the dimensions of ambition the CaBA strategy has articulated, to show what is possible and to act as exemplars to assist in the restoration of other chalk catchments.
3. Monitoring and Appraisal	CaBA CSRG endorses the development of a simple, replicable and standardised monitoring initiative, engaging citizen scientists and conservation volunteers, in order to a) build links between various stakeholder communities and the chalk streams and b) to appraise the evolution of these projects and the long-term impacts.
4. Sharing Best Practice / Pooling Expertise	In addition to and complementing this flagship initiative, CaBA CSRG is working towards the establishment of: • A CaBA Chalk Stream online data and information hub. This will be hosted by the Rivers Trust. It will include data and knowledge to help empower and facilitate grass-roots catchment advocacy and river restoration. It will also include information on the ecology of chalk streams, as well best-practice restoration principles and guidelines and will provide a forum for sharing best practice and experience. • An annual CaBA Chalk Stream Restoration conference and programme of site visits, again to promote an open and exciting exchange of information, experience and best practice among those who are passionate about rivers in general and chalk streams in particular.
5. Research into Reference Conditions	There is a need for further research into the reference conditions and characteristics of the different groups of chalk streams to inform our knowledge and understanding of the practice and aims of river restoration.
6. Database of Reference Reaches	Although they are rare, relatively natural reaches of chalk streams do exist, as do reaches where naturalness is being recovered through river processes or restoration. These reference reaches should be recorded, mapped and surveyed to add to our knowledge base.
7. Chalk Stream Map	An important first step in the protection of a natural resource such as a chalk stream is to accurately map the resource. Although we have an index of chalk streams (Appendix B below) this is, as yet, not an officially agreed index. It was prepared on behalf of WWF in 2014 and includes a number of streams not previously included on the EA list. Natural England is working on a complete and agreed map of all English chalk streams. This will be published by Natural England but it will also be included on the CaBA Chalk Stream online hub.

Glossary

Abstraction – taking water from rivers or the aquifer to supply homes, farms, industry

AIM - Abstraction Incentive Mechanism. A regulatory mechanism devised by Ofwat / WWF to encourage water companies to less abstract water from environmentally sensitive sources at sensitive times or when other sources are available

ASB - Abstraction Sensitivity Band. The banding given to a WFD waterbody to indicate its sensitivity to abstraction.

Aquifer – an underground body of water

ALF - Alleviation of Low Flows. A programme of abstraction reduction / flow recovery began by the National Rivers Authority in the early 1990s that evolved into the Restoring Sustainable Abstraction scheme.

BAP – (UK) Biodiversity Action Plan was published in 1994, and was the UK Government's response to the Convention on Biological Diversity (CBD), which the UK signed up to in 1992 in Rio de Janeiro. The CBD called for the development and enforcement of national strategies and associated action plans to identify, conserve and protect existing biological diversity, and to enhance it wherever possible.

CaBA – Catchment Based Approach is an inclusive, civil society-led initiative that works in partnership with Government, Local Authorities, Water Companies, businesses and more, to maximise the natural value of our environment.

CAMS – The EA's Catchment Abstraction Management Strategies.

CBA – Cost Benefit Analysis compares the costs and benefits of achieving environmental improvements.

Catchment - the area of land that feeds rainwater to a river.

Chalk Streams First – a combined NGO proposal to re-naturalise flows in the Chilterns by moving the point of abstraction to the lower parts of the Colne and Lea catchments.

CSRG – Chalk Stream Restoration Group is a subgroup of the CaBA National Support Group.

DNSG – Does Not Support Good Ecological Status

EA – The Environment Agency

Ecosystem Services – the benefits humans get from natural resources.

Ecological engineering – the ways in which plants and animals manage their physical habitat.

EFI – Environmental Flow Indicator is used to indicate where abstraction, or flow regulation, may start to have an undesirable impact on river habitats and species.

ELMs – Environmental Land Management schemes – there are 3 new schemes that will reward environmental land management: sustainable farming initiative, local nature recovery and landscape recovery. Through these schemes, farmers and other land managers may enter into agreements to be paid for delivering environmental improvements.

GBRs – General Binding Rules set out the conditions in the Environmental Permitting Regulations that allow a septic tank or sewage treatment plant to be used without an environmental permit.

Good Ecological Status – the target required status for all waterbodies, including ecological, chemical and morphological condition assessments.

Groundwater – water in the chalk aquifer, which feeds the chalk stream

Groundwater level – the height AOD of the saturated part of the aquifer.

ICW - Integrated Constructed Wetlands. A form of artificial wetland used to treat, or polish waste water.

INNS - Invasive Non-Native Species.
Lateral Connectivity – the connection between the river, its riparian margins and the floodplain

Longitudinal Connectivity – the connectedness (or lack of it) along the length of the river. It can interrupted by artificial structures like weirs.

Ml/d - Megalitres per day. 1 Ml/d = 1 million litres. A standard measure of water volume for example as river flow or abstracted water.

NE – Natural England

NGOs – Non-Government Agencies - non-profit groups that function independently of any government.

NMP – Nutrient Management Plan identifies sources of nutrients that are entering a river and steps that can be taken to manage them.

NRA - National Rivers Authority.

NRN – Nature Recovery Network is a commitment in the government's 25 Year Environment Plan and part of the forthcoming Nature Strategy. It will be a national network of wildlife-rich places. The aim is to expand, improve and connect these places across the country.

PR24 – Price Review (2024) is the process by which Ofwat review the prices that water companies can charge their customers. This takes place every five years. The next review is due in 2024. It results in an Asset Management Plan (AMP).

RAM – Resource Assessment and Management Framework is a technical framework for water resource management including abstraction licensing.

RAPID - Regulators' Alliance for Progressing Infrastructure Development has been formed to help accelerate the development of new water infrastructure and design future regulatory frameworks. The joint team is made up of the 3 water regulators Ofwat, Environment Agency and Drinking Water Inspectorate.

RSA - Restoring Sustainable Abstraction. An EA programme of works to restore sustainable abstraction in stressed catchments.

RWRP - Regional Water Resources Plan.

SAC - Special Area of Conservation.

SA(e) – Sensitive Area (eutrophication) designated under the UWWTD. The UWWTD describes eutrophication as 'the enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned'.

SAGIS – Source Apportionment Geographical Information System is a GIS-based tool to apportion loads and concentration of chemicals to WFD water bodies has been developed to support river basin planning by the UK Water Industry and the Environment Agency to identify effective programmes of measures, whilst maintaining the 'polluter pays principle', thus ensuring a fair proportioning of responsibility for improving water quality across all responsible sectors. SAGIS operates in conjunction with the Environment Agency's SIMCAT (simulated catchment) water quality model, together referred to as SAGIS-SIMCAT.

SFI – Sustainable Farming Incentive scheme will pay farmers to manage their land in an environmentally sustainable way.

SO - Storm Overflow: when a water company bypasses the sewage works and discharges raw sewage into a watercourse

SSSI - Site of Special Scientific Interest.

S&TC – Salmon and Trout Conservation

STW – Sewage Treatment Works

WRMP – Water Resources Management Plans are used by water companies to set out how they intend to achieve a secure supply of water for their customers and a protected environment.

UWWTD - Urban Waste Water Treatment Directive. A directive governing wastewater standards in certain catchments.

WFD - Water Framework Directive.

WINEP – Water Industry National Environment Programme – a set of actions the EA sets the water industry to contribute to meeting their environmental obligations.

WWTP – Wastewater Treatment Plant.

Winterbourne – the ephemeral part of the chalk stream that routinely and naturally dries for a short period each summer.

Appendix A
Bibliography

An Evidence Base for Setting Nutrient Targets to Protect River Habitat • 2010 Natural England
http://publications.naturalengland.org.uk/publication/30027

Assessing River Condition: A Multiscale Approach Designed for Operational Application in the Context of Biodiversity Net Gain
https://qmro.qmul.ac.uk/xmlui/handle/123456789/66002

Assessing the environmental and economic efficacy of two integrated constructed wetlands at mitigating eutrophication risk from sewage effluent • Richard Cooper, Elizabeth Hawkins, Jake Locke, Terry Thomas and Jonah Tosney 2020
https://onlinelibrary.wiley.com/doi/10.1111/wej.12605

A Chalk Stream Charter • Angling Trust & Partners 2013
https://anglingtrust.net/wp-content/uploads/2020/05/Chalkstream-Charter.pdf

Chalk Rivers: Nature, Conservation and Management • English Nature / The Environment Agency / Conserving Water for Life 1999
http://publications.naturalengland.org.uk/publication/5981928

Chalk Streams First • WWF, The Wild Trout Trust, The Angling Trust, Salmon and Trout Conservation, The Rivers Trust 2020
https://anglingtrust.net/wp-content/uploads/2020/09/Chalk-Streams-First-Report.pdf

Chalk Streams in Crisis • The Angling Trust 2019
https://anglingtrust.net/wp-content/uploads/2020/10/Chalk-Streams-in-Crisis.pdf

Determining the Nature and Origins of Riverine Phosphorus in Catchments Underlain by Upper Greensand • Penny Johnes et al 2020
https://www.researchgate.net/publication/303939030_Determination_of_the_nature_and_origins_of_riverine_phosphorus_in_catchments_underlain_by_Upper_Greensand

Flushed Away • 2017 WWF
https://www.wwf.org.uk/sites/default/files/2017-12/Flushed%20Away__Nov2017.pdf

Freshwater and Phosphorous Eutrophication Pressure Narrative • Environment Agency 2019
https://consult.environment-agency.gov.uk/++preview++/environment-and-business/challenges-and-choices/user_uploads/phosphorus-pressure-rbmp-2021.pdf

Geomorphological Appraisal of the River Nar SSSI • Natural England 2006
http://publications.naturalengland.org.uk/publication/59058

Housing White Paper (2017)
https://www.gov.uk/government/collections/housing-white-paper

Low Flows and Water Resources / Facts on the Top 40 Low Flow Rivers in England and Wales • 1993 Environment Agency
http://www.environmentdata.org/archive/ealit:3190/OBJ/20000192.pdf

Making the Most of Every Drop • Government Response January 2016
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/492411/abstraction-reform-govt-response.pdf

National Framework for Water Resources – Environment Agency (March 2020)
https://www.gov.uk/government/publications/meeting-our-future-water-needs-a-national-framework-for-water-resources

Phosphorus and nitrogen limitation and impairment of headwater streams relative to rivers in Great Britain: A national perspective on eutrophication
https://www.sciencedirect.com/science/article/pii/S004896971733187X

Quantifying the impact of septic tank systems on eutrophication risk in rural headwaters
https://www.sciencedirect.com/science/article/pii/S0160412011000043

Reduction and Prevention of Agricultural Diffuse Pollution (England) Regulation – (Farming Rules for Water) April 2018
https://www.gov.uk/government/publications/farming-rules-for-water-in-england

Restoration of a chalk stream using wood: assessment of habitat improvements using the Modular River Survey
https://qmro.qmul.ac.uk/xmlui/handle/123456789/56191

River Avon Nutrient Management Plan • The Environment Agency, Natural England, Wiltshire County Council 2015
https://www.gov.uk/government/publications/nutrient-management-plan-hampshire-avon

Riverfly Census • Salmon and Trout Conservation 2015
https://salmon-trout.org/wp-content/uploads/2017/08/2015-Report_Riverfly-Census.pdf

Rivers on the Edge • WWF 2009
http://assets.wwf.org.uk/downloads/rivers_on_the_edge.pdf

Simple large wood structures promote hydromorphological heterogeneity and benthic macroinvertebrate diversity in low-gradient rivers
https://link.springer.com/article/10.1007/s00027-016-0467-2

The Environmental Flow Indicator. What it is and What it Does.
http://www.hwa.uk.com/site/wp-content/uploads/2017/12/SWCD11.5-EA-Guidance-on-EFI-January-2013.pdf

The Impact of Elevated Phosphorous on Flora and Fauna in Riverine Systems • Salmon & Trout Conservation 2017
https://salmon-trout.org/wp-content/uploads/2017/08/STC-The-impact-of-elevated-phosphorus-inputs-on-flora-and-fauna-in-riverine-systems_web.pdf

The Impact of Excess Sediment on Invertebrates and Fish in Riverine Systems • Salmon & Trout Conservation 2017
https://salmon-trout.org/wp-content/uploads/2017/08/STC-The-impact-of-excess-fine-sediment-on-invertebrates-and-fish-in-riverine-systems_web.pdf

The State of England's Chalk Rivers • UK Biodiversity Action Plan Steering Group for Rivers 2004
http://adlib.everysite.co.uk/adlib/defra/content.aspx?doc=57246&id=57247

The State of England's Chalk Streams • WWF 2014
http://assets.wwf.org.uk/downloads/wwf_chalkstreamreport_final_lr.pdf

The Water Act 2003. Consultation Document on Withdrawal of Compensation on the Grounds of Serious Damage
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/82498/water-act-condoc1202.pdf

Water for Life • Defra 2011
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/228861/8230.pdf

Water Abstraction Plan • Defra 2017. Updated Sept 2020
https://www.gov.uk/government/publications/water-abstraction-plan-2017/water-abstraction-plan

Waterwise and Ideal Standard Water Efficiency Annual Tracking Survey in Great Britain (2016)
https://www.waterwise.org.uk/knowledge-base/annual-tracker-survey-2016/

Water for Wildlife – Tackling Drought and Unsustainable Abstraction • WWF 2017
https://www.wwf.org.uk/sites/default/files/2017-07/Water%20For%20Wildlife_Abstraction%20Report_July%202017.pdf

The Waterwise Water Efficiency Strategy for the UK (June 2017)
https://www.waterwise.org.uk/knowledge-base/water-efficiency-strategy-for-the-uk-2017/

Appendix B
Water Quantity: Government actions in more detail.

B.1 Alleviation of Low Flows 1993

The National Rivers Authority NRA was formed in 1989, the first of a series of unusually dry years that drew attention to the acute impact of excessive abstraction, especially on our chalk streams. In its 1993 report Low Flows and Water Resources the NRA highlighted that the *extreme* low flows and drying of many rivers was not caused by drought (although the drought had exacerbated the low flows) so much as the "excessive authorised abstractions" granted as a result of the Water Act in 1963 which gave existing abstractors the right to a licence regardless of the environmental impact.

As a first step in its Alleviation of Low Flows (ALF) programme the NRA published a list of the 40 most heavily abstracted rivers and from that a short-list of the 20 most acute cases which needed urgent mitigation. Fifteen chalk streams were in that Top 40 list, but twelve of those were in the Top 20.

The Bourne Rivulet, Meon and Little Stour were in the Top 40. The Dorset Wey, Piddle, Allen, Wallop Brook, Hampshire Wey, Pang, Letcombe Brook, Misbourne, Ver, Hiz, Darent and Hoffer Brook were in the Top 20.

The NRA had been given powers in the 1991 Act to revoke abstraction licences which were causing unacceptable environmental damage, but under those circumstances it was liable to pay compensation to the abstractor. As a result most of the Alleviating Low Flows proposals involved lengthy negotiations, while solutions were very much in the gift of the water companies.

The report highlighted a number of the ways in which low flows could be alleviated: lining the bed of a river, augmenting flows from groundwater, water recycling, relocating the point of abstraction:

> *"A further technical solution is to relocate the offending abstractions within the same water source. For example it can be possible to alleviate low flows by moving groundwater abstraction locations further downstream within the catchment, thus allowing upstream recovery. Although the downstream flows could diminish, the impact of this reduction is minimised due to higher natural downstream flows"*

in essence, a version of the principle of using flow recovery to replace headwaters groundwater abstraction with lower river surface water abstraction, where there would be some net loss to supply but not the 100% involved with total replacement.

The report also stated:

> *"The first step in moving towards the alleviation of a low flow problem is to establish that a problem really exists. This can involved detailed investigation and complex hydraulic modelling … lack of fish or low water levels may be due to factors other than reduced flows. For example, in some rivers lack of weed growth has caused levels to drop without loss of flow"*

suggesting that where the competing demands of resource and ecology are at their most acute, the path of least resistance is always further research.

By 1993 the "implementation of a solution" had been completed on two of the chalk streams: the River Pang and the Letcombe Brook.

Implementation was "under way" on the Ver and Darent.

Solutions had been "identified" on the Bourne Rivulet and Wallop Brook.

"Further investigations" were under way on the Hiz, Allen, Little Stour, Meon, Misbourne, Piddle, Hampshire Wey and Dorset Wey.

While the little Hoffer Brook had been deemed "too small to be significant for fisheries and conservation".

Twenty-three years later, the 2015 WFD Assessment for Flow was assessed as Supports Good in only five of these fifteen chalk streams: The Letcombe Brook, Bourne Rivulet, Wallop, Allen and Piddle. The rest were assessed as Does Not Support Good and the Hiz was not assessed.

B.2. Environmental Flow Indicators - 2008

Both the 1999 Natural England (NE) Report and the 2004 UKBAP report highlighted the need for scientifically-based flow targets for chalk streams.

RIVER TYPE	Q30	Q50	Q70	Q95
ASB3 HIGH SENSITIVITY	24%	20%	15%	10%
ASB2 MODERATE SENSITIVITY	26%	24%	20%	15%
ASB1 LOW SENSITIVITY	30%	26%	24%	20%

2008 EFI STANDARDS FOR ACHIEVING GOOD ECOLOGICAL STATUS FOR CHALK STREAMS GIVEN AS % OF ALLOWABLE REDUCTION OF NATURAL FLOW

The EA developed Ecological River Flow Objectives in 2001 based on a comparison of fully licensed and recent actual flows to ecological flow standards, a precursor to WFD assessment standards.

In 2008 the EA adapted the UKTAG targets – varying percentages of allowable flow reduction correlated to the flow rate in the river (the flow rate is expressed as Qx, with x being the % of time that the flow is exceeded), the time of year and river type (headwater or main river reaches) – to form the **Environmental Flow Indicator (EFI)**. The EFI formed part of the Resource Assessment and Management Framework (RAM). The EFI is used to assess whether a river's flow supports Good Ecological Status (GES). However:

• Any decision to recover water in rivers that don't meet the EFI flow targets requires 'further evidence to provide ecological justification'.

• EFI is also used in Abstraction Management Strategies (AMS) to indicate where water might be available for abstraction without causing 'unacceptable risk to the environment'.

The EFI is defined for four conditions of flow and three Abstraction Sensitivity Bands (ASB) based on the physical / macrophyte typology, the expected macro-invertebrate community and the expected fish community of a given river.

For chalk streams the ASB currently varies through all bands. For example the River Mimram and the Candover Brook are ASB3, the Rivers Piddle, Chess and Beane are ASB2, and the River Nar and the Great Eau are ASB1.*
The EFI was adapted from the UKTAG figures to fit the existing abstraction regulatory regime, namely the Resource Assessment Methodology (RAM) which is used to calculate if and when water is available for abstraction.

* For individual chalk streams Abstraction Sensitivity Bands see WFD table in Appendix H.

The RAM calculation is illustrated below:

The natural flow of a river at Q95 + All Effluent Returns = X Mld.

X Mld – All Abstraction Licences (surface and g'water) = 'Fully Licensed Flow' (FLF).

FLF must equal or exceed EFI at Q95 for a river to be compliant. An example:

The natural modelled flow of the River Y at Q95 is 100 Ml/d.

100 Ml/d + All Effluent Returns (say 7 Ml/d) = 107 Ml/d.

107 Ml/d – All the Abstraction Licences (say 23 Ml/d) = FLF of 84 Ml/d.

River Y is ASB1. The EFI at Q95 would be 80 Ml/d. Therefore the River Y is compliant.**

If a river is non-compliant the degree of non-compliance is then banded as shown in Figure X below. The compliance bands 'help to prioritise where the abstraction pressure and therefore the risk of not supporting good ecological status is greatest'.

RIVER TYPE	FLOW ADEQUATE TO SUPPORT GOOD ECOLOGICAL STATUS	FLOW NOT ADEQUATE TO SUPPORT GOOD ECOLOGICAL STATUS LOW CONFIDENCE (UNCERTAIN)	FLOW NOT ADEQUATE TO SUPPORT GOOD ECOLOGICAL STATUS MODERATE CONFIDENCE (UNCERTAIN)	FLOW NOT ADEQUATE TO SUPPORT GOOD ECOLOGICAL STATUS HIGH CONFIDENCE (QUITE CERTAIN)
	COMPLIANT WITH EFI	NON-COMPLIANT BAND 1 UP TO 25% BELOW EFI Q95	NON-COMPLIANT BAND 2 25% - 50% BELOW EFI Q95	NON-COMPLIANT BAND 3 GREATER THAN 50% BELOW EFI Q95
ASB3 HIGH SENSITIVITY	<10%	(10% + 25%) <35%	(10% + 50%) <60%	(10% + 50%) >60%
ASB2 MODERATE SENSITIVITY	<15%	(15% + 25%) <40%	(15% + 50%) <65%	(15% + 50%) >65%
ASB1 LOW SENSITIVITY	<20%	(20% + 25%) <45%	(20% + 50%) <70%	(20% + 50%) >70%

COMPLIANCE BANDING: % DEVIATION OF FLOWS FOR EACH COMPLIANCE BAND AND HOW THIS RELATES TO SUPPORTING GOOD ECOLOGICAL STATUS**

** The EFI RAM methodology may not fully assess / protect the headwater and ephemeral reaches of some chalk streams, especially if the assessment point is a long way downstream of the point of groundwater abstraction.

B.3. Water For Life - Defra 2011

In 2011 Defra published the Water for Life white paper. It acknowledged that the system (as of 2011) for managing abstraction, set up in the 1960s, was not designed for protecting the environment or to manage competing demands for water and has lead to over abstraction. The main points were:

• Although the regime had evolved since the 1960s, and newer abstraction licences were granted with in-built environmental protection (hand-off flows), for the majority of abstractors little had changed.

• Too much water was being taken from some catchments.

• The cost of abstraction licences did not reflect the scarcity value of water.

• The then-current process for changing licences (where abstractors were entitled to compensation) was untenable and mired in bureaucracy and expense.

• The then-current system failed to incentivise abstractors to manage their abstraction or take into account environmental risk and created barriers to efficient sharing of water.

The White Paper set out a two-tiered approach to reforming the abstraction regime, a longer-term reform to construct a system better able to cope with a water-stressed future; and shorter-term measures to tackle site-specific instances of unsustainable abstraction.

• The EA would publish by 2012 ‘extensive information on progress with implementing its RSA programme’.

• The EA would develop an action plan for addressing unsustainable abstraction in the RBMPs, up to 2027 and beyond.

• The paper proposed that the cost of compensating water companies for removal of licences and funding solutions for RSA should be incorporated into the price review process and the Water Resources Management Plans.

• Ofwat’s Abstraction Incentive Mechanism would encourage water companies to reduce abstraction from environmentally sensitive sources during defined periods of low surface flow.

• A power in the Water Act 2003 enabled the revocation of licences causing ‘serious damage’ to rivers, lakes or groundwater to be removed or varied without compensation. The EA would start using this power from 2012 and consult shortly on how to do so.

B.4. The Water Act 2003 - implemented 2012

In 1998 the government began consultation on abstraction licence reform taking into account the environmental impact of abstraction. The government responded to its consultation signalling that it would bring forward legislation to withdraw the right of compensation where the alteration or revocation of an abstraction licence was needed to protect the environment from ‘serious damage’ and that the implementation date would be 15 July 2012.

Section 27 of the Water Act 2003 gave effect to that policy. The provision in section 27 said that:

Withdrawal of compensation for certain revocations and variations:

(1)This section applies where –

(a) a licence to abstract water is revoked or varied on or after 15th July 2012 in pursuance of a direction under section 54 or 56 of the WRA (which provide the Secretary of State to direct the Environment Agency to revoke or vary a licence in certain circumstances)

(b) the licence was granted before the coming into force of section 19 of this Act;

(c) the licence is one which is expressed to remain in force until revoked; and

(d) the ground for revoking or varying the licence is that the Secretary of State is satisfied that the revocation or variation is necessary in order to protect from serious damage

(i) any inland waters,

(ii) any water contained in underground strata,

(iii) any underground strata themselves, or any flora or fauna dependent on any of them.

(2) Where this section applies, no compensation is payable under section 61 of the WRA in respect of the revocation or variation of the licence.

(3) Expressions used in sub-paragraphs (i), (ii) and (iii) of subsection (1)(d) are to be construed in accordance with section 221 of the WRA; and “waters”, in relation to a lake, pond, river or watercourse which is for the time being dry, includes its bottom, channel or bed. 3.8.

During the passage of the Water Act 2003 through Parliament, the then Government undertook to consult on guidance on the interpretation of ‘serious damage’ to the environment. Serious damage has never been defined. In theory this marked a step-change in the progress of abstraction reform, and would unblock progress in the EA’s RSA programme.

B.5. What is Environmental 'Damage'?

A result of powers given in the Water Act 2003 / 2014 the Minister of State may revoke or alter a water company abstraction licence without compensation if it is causing damage to the environment. In practice the Environment Agency has never changed a water company abstraction licence without compensation and this power has not been tested in court. Instead changes to Water Company licenses have and do take place through the Water Industry National Environment Programme.

However, for non-water company abstractors, the Minister may only revoke or alter a licence (without compensation) if it is causing 'serious damage'. Clause 82 in the new Environment Bill will lower that bar, so that for non-water company abstractors the minister may revoke or alter an abstraction licence either 'having regard to an environmental objective' or 'to protect the water environment from damage' and under those circumstances no compensation will be payable. With regard to flow 'serious damage' and / or 'damage' have never been officially defined and the process is unresolved. The tables below are examples from a Defra consultation document.

Principle 1 – establish the qualitative nature of the damage.

Damage - but not serious	Serious damage
Deterioration in flow as a supporting element of WFD12 status, but no measurable change in overall WFD classified status.	Deterioration in WFD water body classified status which is caused by an abstraction pressure.
WFD Groundwater body status remains above poor and drawdown effects are localised.	Deterioration in WFD groundwater body status overall to poor.
Damage to flora or fauna notified under section 28 the Wildlife and Countryside Act 1981 or protected by the Habitats Regulations; but that is considered localised and does not affect the integrity of the protected flora/fauna and site.	Damage to flora or fauna notified under section 28 the Wildlife and Countryside Act 1981 or protected by the Habitats Regulations where the level of damage has an adverse effect on the integrity of the protected flora/fauna and/or site.
Damage to modified (agriculturally improved) or degraded land	Destruction or major damage to part of a statutory protected site
Localised damage to native flora and fauna not thought to affect viability of the species at that site.	Extinction of a protected species or habitat from a specific area.
	Extensive damage to habitat, or death of native flora or fauna typical to the habitat
	Extensive damage to Biodiversity Action Plan (BAP) species (on any stage of the life cycle) or habitat.

Principle 2 - establish the extent and magnitude of the damage.

Damage - but not serious	Serious damage
A measurable reduction in surface water flow below natural flows.	Complete loss of flow in any river caused by an abstraction.
Substantial loss of flow that has only a localised effect e.g. less than 1km of river.	Substantial reduction in flows e.g. over 60 per cent lower than natural flows and over more than one km of river.
A small loss of habitat attributable to abstraction.	Loss of main groundwater supply to a wetland indicated through cessations of springs and seepages.
Localised destruction of habitat which supports fish or other water-dependent species.	Substantial loss of habitat (e.g. more than 10 per cent of a site).
Low numbers of mortality, not thought to have adverse effects on a local population.	Substantial change in habitat type e.g. over more than 30 per cent of a defined site.
	Substantial loss of flow which is visible outside of drought periods.
	Substantial loss of individuals (e.g. 100* dead juvenile fish, 100* dead crayfish) or large adverse effects on a wildlife population (e.g. more than 10 per cent of a local population).

Principle 3 - establish whether the damage is reversible and how long recovery may take

Damage - but not serious	Serious damage
Substantial loss of flow seen only during drought conditions.	Reduction of flow outside of drought periods which restricts fish movement during key life stages – for example upstream / downstream migration or loss of juvenile holding areas.
Substantial, but temporary, loss of flow where any effects are reversed after a short period of time.	Permanent loss of native species or habitat.
Short-term loss of habitat but outside of key life stages of fauna dependent on that habitat.	Short-term loss of habitat during key life stages not caused by drought. For example drying out of pools during or after amphibian spawning or lowering of water levels and drying of marginal river habitat during or after fish spawning.
	Reduced long term distribution and abundance of populations.
	Reduced capacity for natural regeneration.

B.5.1. How the Assessment of Damage Works in Practice

The example for how this might apply to flow in the consultation outcome has the following scenario:

Background: An abstraction for water supply [sits across the full width of a river and] collects most of the flow. There is a substantial loss of flow in the river for about 200m. A number of tributaries enter the river about 200m downstream of the intake and flow is restored, but still depleted. The river is not designated. It contains a declining salmon population, which has spawned in other tributaries. Upstream of the intake there is estimated to be as much suitable and good quality spawning habitat as that currently available.Impacts:

• Substantial loss of flow that has only a localised effect over 200m, with the flow depleted for approx five km further downstream

• Substantially depleted reach and intake structure act as a barrier to salmon migration into a key spawning area.

Principle	Principle 1	Principle 2	Principle 3
Triggered?	Y	N	Y
	There has been damage to a Europoan protected species in that the capacity of the species for propagation is restricted which has resulted in the risk of extinction of a protected species (in the area) due to restricted access to spawning area.	Substantial loss of flow over 200m of river	There is a loss of river life within the 200m section of river. Due to the restriction of fish movement during key life stages the salmon population will continue to decline if access to spawning areas is limited.

Conclusion: The damage is considered serious. The direct impact from the abstraction on the viability of the salmon population by restricting access to a substantial spawning area is considered serious. However, the loss of river life from the 200m of substantially depleted river reach would be considered a localised effect and not, in itself, serious.

A salmon smolt – a protected species dependent on good flows – from a non-designated Wessex chalk stream. The CaBA CSRG supports Clause 82 of the Environment Bill which will help the government and its regulators to protect species like the Atlantic salmon from the damage caused by abstraction.

B.6. Making the Most of Every Drop - Defra 2013

In 2013 the Government published its abstraction reform consultation. In January 2016 it published a range of approaches following that consultation including – among other proposals related to encouraging abstractors to trade water and share licences, and to develop the infrastructure to facilitate this – the following:

• replacing the seasonal conditions on abstraction licences and instead basing licences on the availability / scarcity of water;

• allowing additional abstraction (over and above the licence) at high flows.

However, Defra recognised that these proposals were less relevant to groundwater abstraction because groundwater systems respond much more slowly to rainfall than freestone (surface water) systems.

Defra consulted on the concept of adjusting abstraction to match the quantity of water received into the aquifer as recharge based on a long-term average of, say, 25 years. 'The total groundwater abstraction permitted from an aquifer over a year could then be adjusted to fit actual recharge. Over a longer period of time, this flexing could help to balance abstraction and recharge.'

The Environment Agency assessed the benefits of the proposal on different types of aquifer including the Berkshire and Lincolnshire chalk and concluded that basing groundwater abstraction on recent and historical recharge reduced abstraction availability by more than 50% with 'limited environmental improvements', and, 'It is better for the abstractors and the environment to vary groundwater abstraction through a catchment review process that is able to consider the individual attributes of the aquifer, the pressures the catchment is facing and to use expert judgement to develop the best response.'

Defra proposed to 'change and develop' its approach to managing groundwater so that groundwater abstraction licences will only be reviewed as part of a 'catchment rules review process' and Defra will not uniformly vary licences on the basis of pre-defined rules linked to recharge and weather patterns. The potential role of put-and-take trading as a way to support surface water abstraction were noted and would also fall under catchment rules review process.

B.7. Abstraction Incentive Mechanism - Ofwat 2016

The Abstraction Incentive Mechanism (AIM) was proposed by the AIM Taskforce (water companies, WWF, the EA & Ofwat) in 2013, and adopted by Ofwat in 2016 to encourage water companies to reduce abstraction from environmentally sensitive sources during periods of low flow.

A water company identifies a site where abstraction is having an adverse impact on surface flows. It sets set a surface-flow trigger point below which the AIM 'switches on' and identifies its historic abstraction regime at the site during the times when the AIM would have 'switched on' had it been running. This is the AIM baseline. Say the AIM baseline is 5 Ml/d. If the following year the company abstracts 4 Ml/d from the site over the AIM period, (which in this year lasted for 100 days), they will have outperformed their AIM by 100 Ml and get a score of -100.

Water Company	Chalk stream	AIM performance 2019/20 Total Ml
Wessex Water	Shreen Water	-332.200
Southern Water	River Itchen	-104.910
Thames Water	River Lee	-538.520
Thames Water	River Pang	-215.603
Thames Water	River Kennet	-181.057
Thames Water	River Wye	-81.890
Thames Water	River Cray	0.000
Affinity Water	River Colne	0.000
Affinity Water	River Hiz	-785.280
Affinity Wate	River Mimram	-8.800
Affinity Water	River Beane	-0.300
Affinity Water	River Ver	-0.640
Affinity Water	River Gade	-53.940
Affinity Water	River Misbourne	4.200
Affinity Water	River Chess	-30.380
Affinity Water	Upper Lee	-870.750
Affinity Water	River Rhee	-108.770
Affinity Water	River Dour	-203.040
Anglian Water	River Nar	0.000
Anglian Water	River Wensum	-652.700
Total AIM saving chalk streams 2019/20		**4164.580 Ml (11.8 Mld)**

AIM savings on Chalk Streams in 2019/20

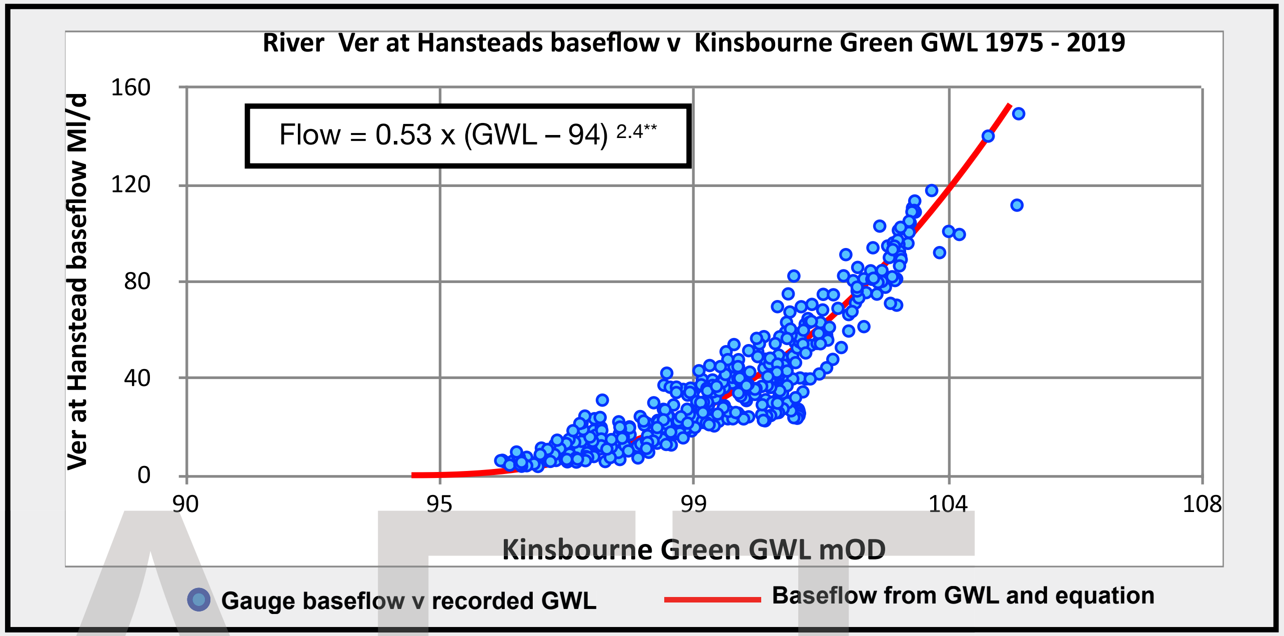
Appendix C.
Groundwater Levels and Flow

C.1. Examples from the Ver and Misbourne

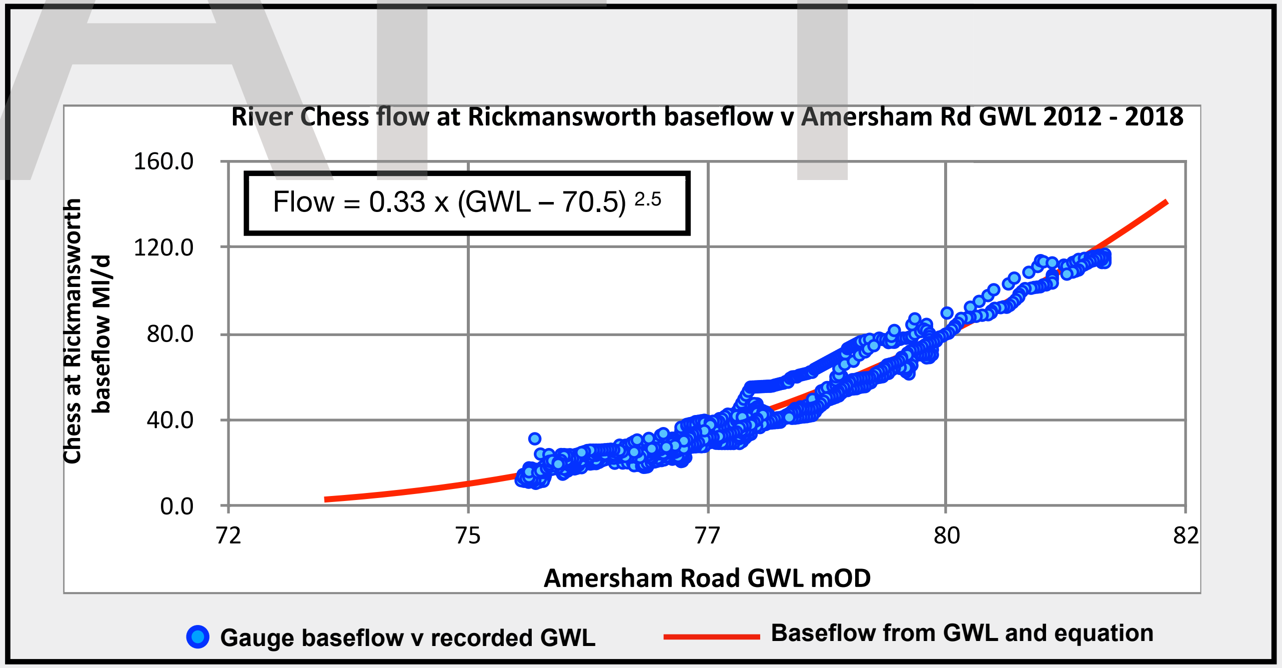
The graphs opposite illustrate the fundamental relationship between groundwater levels and flow in two Chilterns chalk streams. They show flows in the River Ver at Hansteads relative to groundwater levels at Kinsbourne Green and in the River Chess at Rickmansworth relative to the groundwater level at the Amersham Road observation boreholes. In both graphs as the groundwater levels rise, so too does the flow, and both conform to the basic formula $Q = ah^{2.5}$

The constant (here it is 0.53 or 0.33) will vary from valley to valley and relates to the size and shape of the upstream catchment and the properties of the chalk. The groundwater levels in each formula (here they are 94 mOD and 70.5 mOD) are the levels at the given borehole below which the respective rivers run dry where the flow is measured: thus the Ver at Hansteads runs dry when the groundwater at Kinsbourne Green falls to 94 mOD whereas the Chess at Rickmansworth doesn't dry even when the groundwater at Amersham Road falls to its lowest levels.

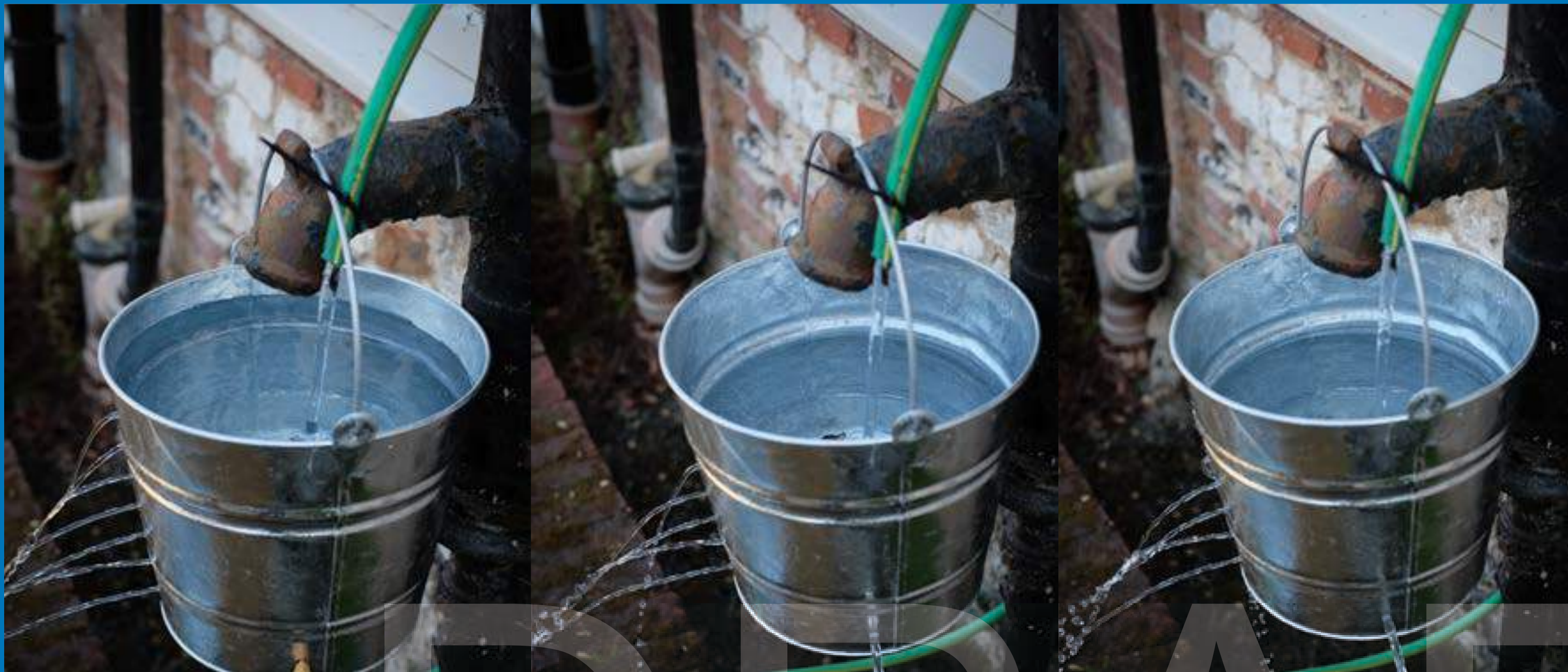
If you take a reading of flow in the Ver at Hansteads when the groundwater level at Kinsbourne is 99 mOD, the groundwater level is then effectively 5› meters above the level at which the river would dry at Hansteads.



**You would expect less than to the power of 2.5 in a U-shaped valley and 2.4 proved a better fit for the Ver model between observed and modelled flows



Note: the modelling in Appendix C was done with the Chalk Streams First lumped parameter model and is available on request.



A simple way to see the impact of abstraction on groundwater levels and therefore flow: the first pictures shows water flowing into a bucket (the aquifer) from a hose (rain) and out of the bucket through a series of holes drilled up the side (a chalk stream). In this picture exactly as much water is coming in as is flowing out and the water level is in balance. In the second picture a 'groundwater abstraction' has been added by removing the bung from another hole at the bottom of the bucket: immediately the amount of water coming out of the side holes (the river) starts to diminish, until by the third picture the top three holes have stopped flowing and there is less water coming out of the bottom four holes. Turn off the abstraction by putting the cork back in (bottom left) and the water level starts to recover until the flow in the stream has 're-naturalised'.

NB: this is a simple analogue for what is in reality a complex system and it cannot show, for example, the vertical variability of the chalk aquifer or how seams of lower permeability within the chalk (clay, flint) will strongly influence the relationship between the aquifer and the river.

C.2. A simple demonstration of how groundwater level drives flow

In simplified terms, the major inflow of water into the chalk aquifer is from rainfall infiltration through the chalk. The major natural outflow is river flow. In addition there are other smaller outflows such as groundwater 'underflow' beneath the valley and into adjacent valleys, and there is also evapotranspiration, especially in summer.

Groundwater abstraction is, effectively, another form of outflow. Therefore:

• if river base-flows are determined by groundwater level and

• groundwater levels are determined by rainfall minus river flows and abstraction,

then it is inevitable that over the long-run abstraction will lower groundwater levels and thus diminish the water available to the river by an amount that is proportional to and nearly equivalent to the amount of water abstracted.

This fundamental relationship between the **annual cycle** of groundwater level and flow and abstraction's impact on one, therefore the other, is key.

Reviewing all the complaints made over the years by NGOs and the various forms of response made by Government and regulators, the true implications of this relationship have never been fully addressed.

There has been partial address through UKTAG and EFI flow targets, for example, or through AIM and RSA and these schemes have been partially successful. But there has been no breakthrough and that is why this is still a vexed issue in 2020, 30 years after the government launched its own urgent enquiries into low flows on chalk streams in 1990.

C.3. Hands Off Flow

To make that point with an extreme 'hands-off flow' scenario – a modelled complete cessation of abstraction in late spring / early summer: the graph below shows the flow for the River Ver at Hansteads in 2011 (blue line), the modelled flow with abstraction at 30% of recharge (A30%R) (red) and the modelled flow assuming the abstraction *ceased completely* from the beginning of June until the end of the year (green).

This abstraction rate of A30%R equates to 29.4 Ml/d, close to the actual rate of 29.9 Ml/d.

Three months later, during the lowest part of the flow cycle through September, flows are still a long way below natural. Even by December the green line has not got close to the blue.

The green line takes such a long time to reach the blue line – well over six months following a total cessation of abstraction – not because of abstraction in the summer (which has stopped) but because of abstraction in the previous winter, which has repressed groundwater levels and meant that when the flows start to fall in early spring, ***they are falling from a lower base***.

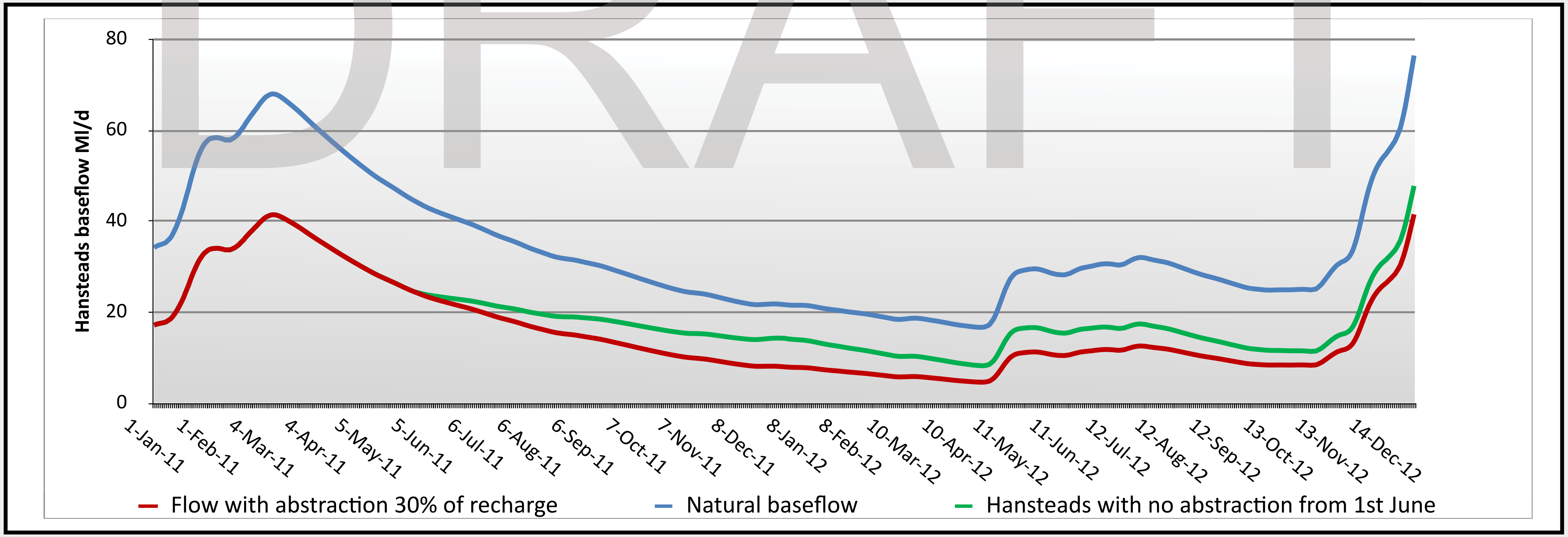
This is a KEY fact never adequately accounted for in groundwater abstraction management.

Therefore, if the **EFI** states that only a **10%** reduction in flow from natural is acceptable at Q95 then we have to **manage abstraction throughout the flow curve** so as to **hit that objective**. In a chalk stream if you look after Q95, you definitively look after the rest of the flow cycle.

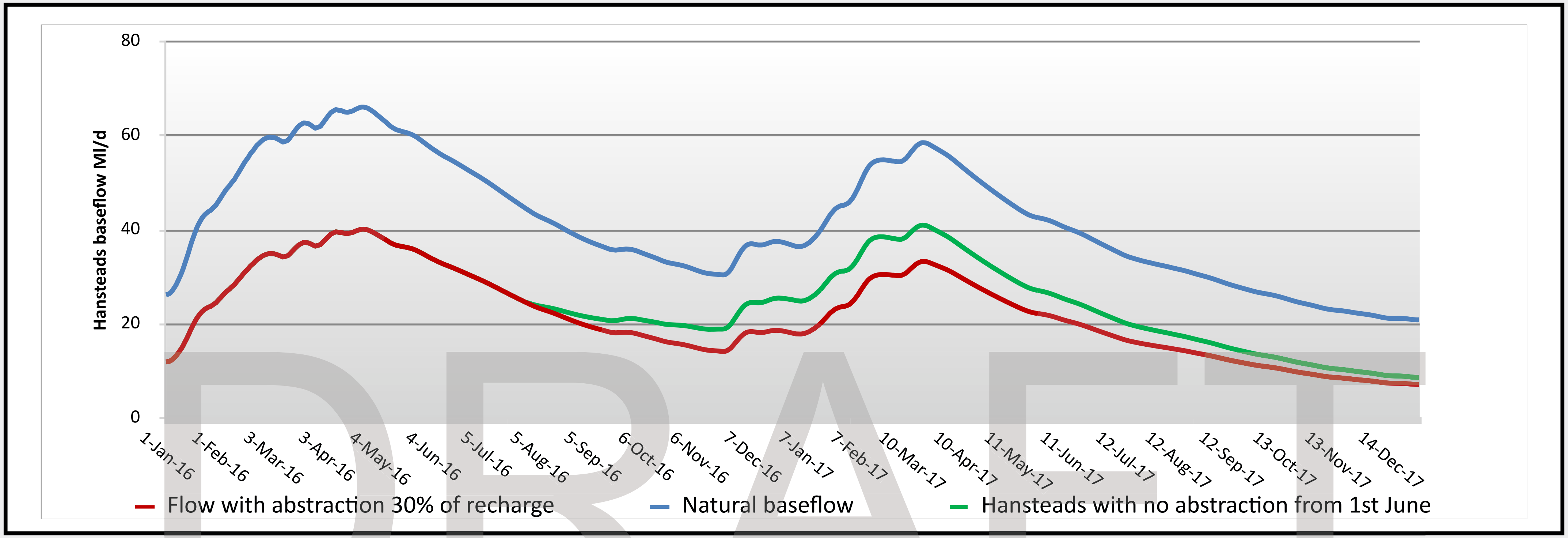
This in most instances will mean either taking less water out of the ground in the higher parts of the flow curve (Q30 and Q50) and none at all in the lower part (Q95).

Or in a more practical world it will mean taking a steady amount, but no more than between 5% to 10% of catchment recharge.

Modelled impact on flows on the River Ver at Hansteads if abstraction had totally ceased on the 1st June.



Modelled impact on flows on the River Ver at Hansteads with an AIM scenario.



C.4. Abstraction Incentive Mechanism

A more realistic existing scenario for achieving protection of low flows would be the Abstraction Incentive Mechanism (AIM). See Appendix B7.

In this modelled AIM type scenario the abstraction ceases when flows fall below 25 Ml/d, which equates to Q50. The plot shows what would have happened in the moderately dry year of 2016, when the AIM would not have triggered until July 28th. The AIM results in a small recovery of flow in the late summer and also a slight acceleration of groundwater recharge in the autumn, but overall its scale of impact in protecting low flows is small to negligible, for the same reasons explained in C3. The flow curve is already on a much lower trajectory and groundwater levels are oil tankers, not speedboats.

Setting the aim to trigger at Q50 and to cease, rather than simply reduce, abstraction is a far more stringent operating parameter than most AIM schemes. For example the Kennet Aim scheme triggers at Q57 and reduces abstraction from 9.3 to 6 Ml/d, while others trigger at even lower flows, Q80 to 93.

AIM and hands-off flow of surface-water abstraction management schemes may be effective ways to protect flows in rivers that are not primarily fed by groundwater, but on chalk streams AIM savings are relatively small (11.8 Ml/d per annum across all chalk streams in 2019/20) and occur too late in the flow curve to make a significant difference to flow recovery.

Note: this observation of AIM relates to groundwater abstraction only. There is no reason why AIM and hands-off flows cannot work on surface water abstractions in chalk streams.

Note: an AIM scheme in place on the Tarrant in Dorset is set to trigger at high flows and delay the onset of drying in the upper river. The AIM approach is new and could be adapted to provide better assistance to a range of flow enhancement scenarios.

It is recommendation of this report that AIM is examined to see how and if it could be adapted to protect flows more effectively.

Appendix D.
NGO comments / recommendations on existing methodologies for assessing and managing flow

Abstraction Sensitivity Bands (ASB) are based on three components: physical / macrophyte typology, the expected macro-invertebrate community and the expected fish community. Currently the ASB on chalk streams ranges through all three ‘sensitivity’ bands. For example the River Mimram and the Candover Brook are ASB3, the Rivers Piddle, Chess and Beane are ASB2, and the River Nar and the Great Eau are ASB1. Given the Sensitivity Banding is supposed to be based on river typology and that all chalk streams are definitively of a type, this variation ought to be reviewed. Do the WFD waterbody boundaries, for example, adequately protect chalk streams?

The existing **EFI methodology** could be better adapted to protecting flows in chalk streams, especially upper chalk streams. Currently, the assessment of flow includes sewer discharges, which can be considerable, while Assessment Points tend to be sited some way down a given valley, or at the downstream waterbody boundary. Under the EFI RAM methodology it is technically possible for headwater reaches some distance from the Assessment Point to suffer from low flows that are not adequately recorded by the EFI methodology.

National Framework abstraction deficits are based on flow at the outfall of the given waterbody. Even with the EA advice of assessing / resolving flow deficits from the uppermost waterbody boundaries moving downstream, this may nevertheless lead to unintended consequences: saving water / flow in lower reaches of a given chalk stream at the expense of the upper reaches that lie above the uppermost assessment points. The National Framework Flow Deficits should therefore be grouped into ‘**ecologically essential**’ ‘**ecologically beneficial**’ and ‘**of limited ecological benefit**’. Ecological sensitivity tests should be applied in order to analyse different scenarios for resolving the deficits, with a view to avoiding the scenarios where flow deficit resolution in the Lower Lee, for example, is made at the expense of the ephemeral and upper reaches of the River Beane: where arguably the ecology is more fragile, more precious and of a greater priority.

The existing **RAM methodology** can theoretically signal an availability of water for groundwater abstraction at, say Q30 to Q60, that in chalk streams directly impacts flows at Q95. In a groundwater-dominated system this so called availability is what drives flows later in the year. In other words, in a chalk stream, abstraction at high flows in February has a direct impact on low flows in September. **Catchment Abstraction Management Plans** should be reviewed in this light with a view to examining the impacts of abstraction at Q30 on flows at Q95.

The EA notes on **non-compliance banding** state that the banding ‘shows where specific scenario flows are below the EFI, and indicates by how much. This is used to identify areas where flows may not be supporting good ecological status and target further investigation of what measures are needed to achieve good ecological status.' In theory an ASB1 chalk stream although it will have failed to ‘support good’ at 20% below natural flows can be up to 70% below before the EA states with ‘certainty’ that flows do not support good ecological status. In practice this means that although the WFD process may signal environmental stress the burden of ‘further evidence to provide ecological justification’ is likely to either preclude action or make action contingent upon further research, just as it was in 1993. This is no longer acceptable.

The **Abstraction Incentive Mechanism** as it currently operates yields modest savings on chalk streams because the triggers tend to be set too low and too late. CaBA CSRG endorses a review of AIM’s effectiveness in mitigating low flows in chalk streams with a view to adapting and improving the methodology for groundwater dominated systems.

Appendix E – Phosphorus in 3 chalk streams

The charts below are assembled from WFD sampling data over the last 20 years on the Rivers Misbourne, Whitewater and Kennet.

The River Misbourne

The chart opposite shows the P readings over 20 years up and downstream of Gerrard's Cross STW on the River Misbourne, relative to winter rainfall. Both Assessment Points are towards the lower end of the river, which is 27 kilometres long but are themselves less than a kilometre apart.

Note the relative scale of P from the 25 km or so of river upstream of the upper Assessment Point compared to downstream of the STW. The river as a whole has a High status for Phosphate, but quite clearly the lower mile or so of the river is actually Poor, occasionally Bad.

The other notable pattern is the "signature" of the phosphate peaks relative to winter rainfall. The uppermost Assessment Point shows that diffuse pollution:

a) manifests as higher concentrations coinciding winter rainfall, and falls off through the following summer and

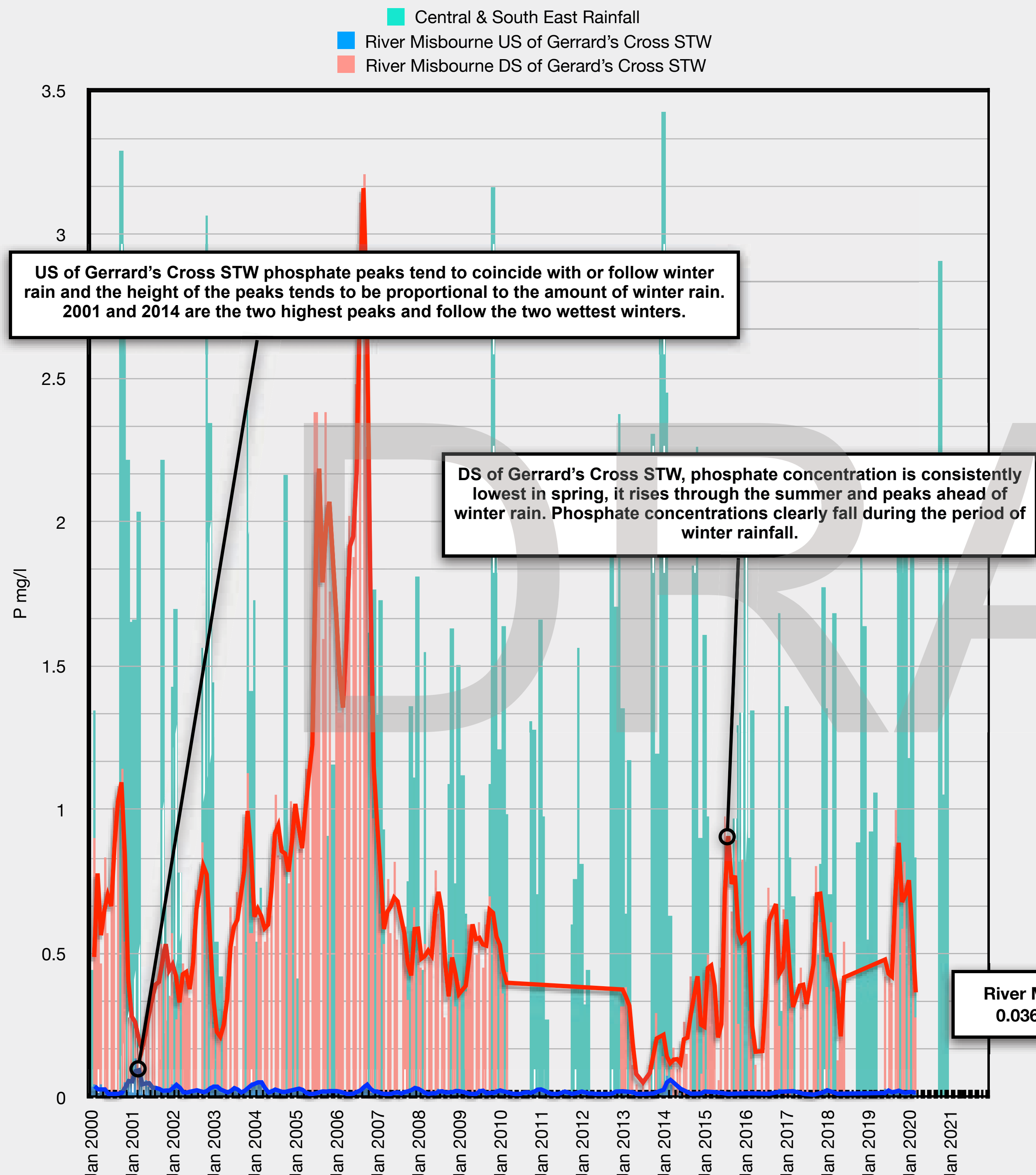
b) is proportional to the amount of winter rain.

The lower Assessment Point shows that point-source pollution:

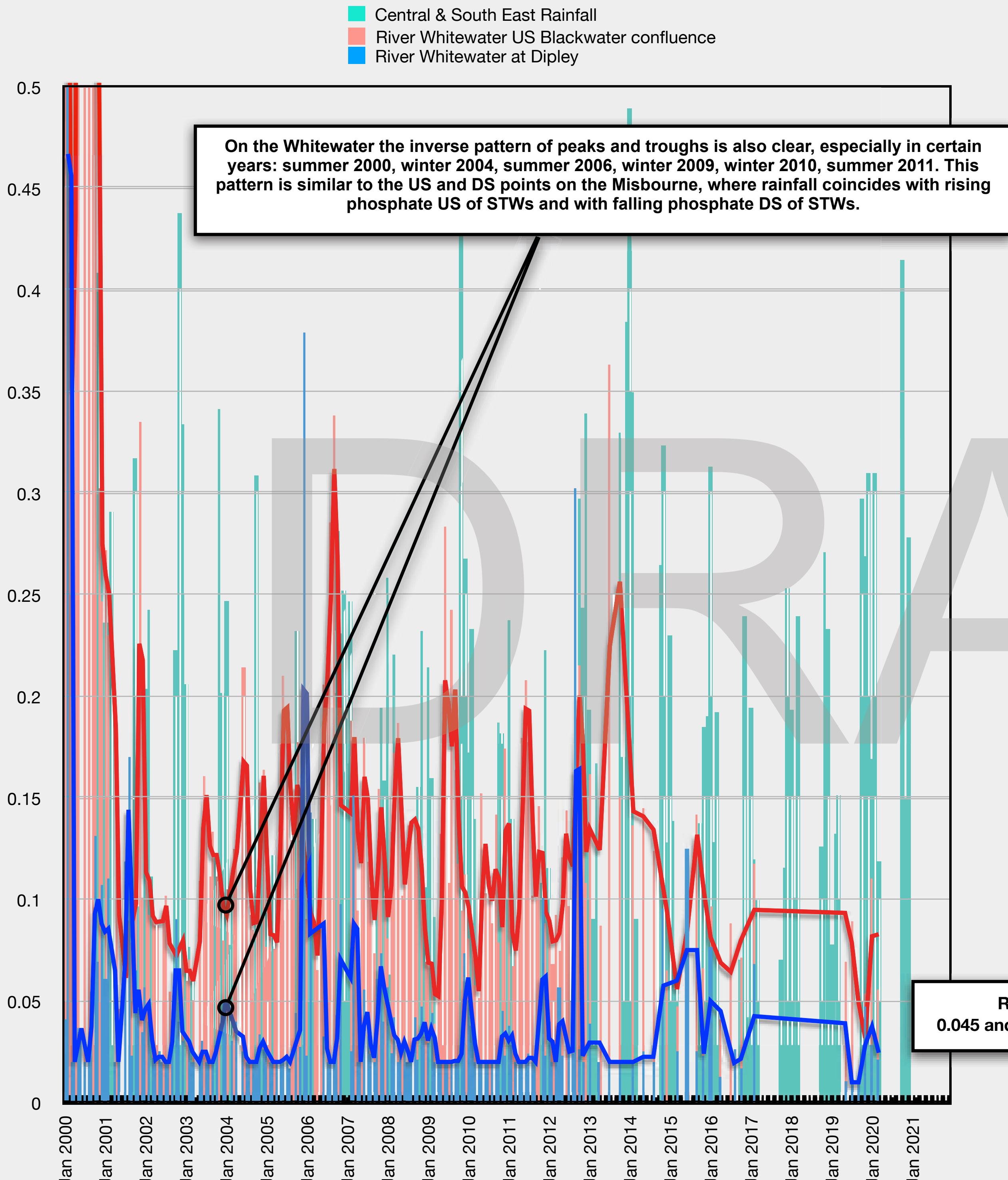
a) manifests as higher concentrations as flows diminish through the summer and into the early autumn and

b) falls during the period of winter rainfall as flows return – exactly the opposite pattern.

Note also that several dry years in a row - 2004 to 2007 - led to acute P concentrations (in a chalk stream that notoriously suffers from over abstraction).



River Misbourne downstream of Gerrard's Cross STW monthly Phosphate readings 2000 - 2020
0.036 and below = HIGH status for phosphate / 1.081 and above = BAD status for phosphate

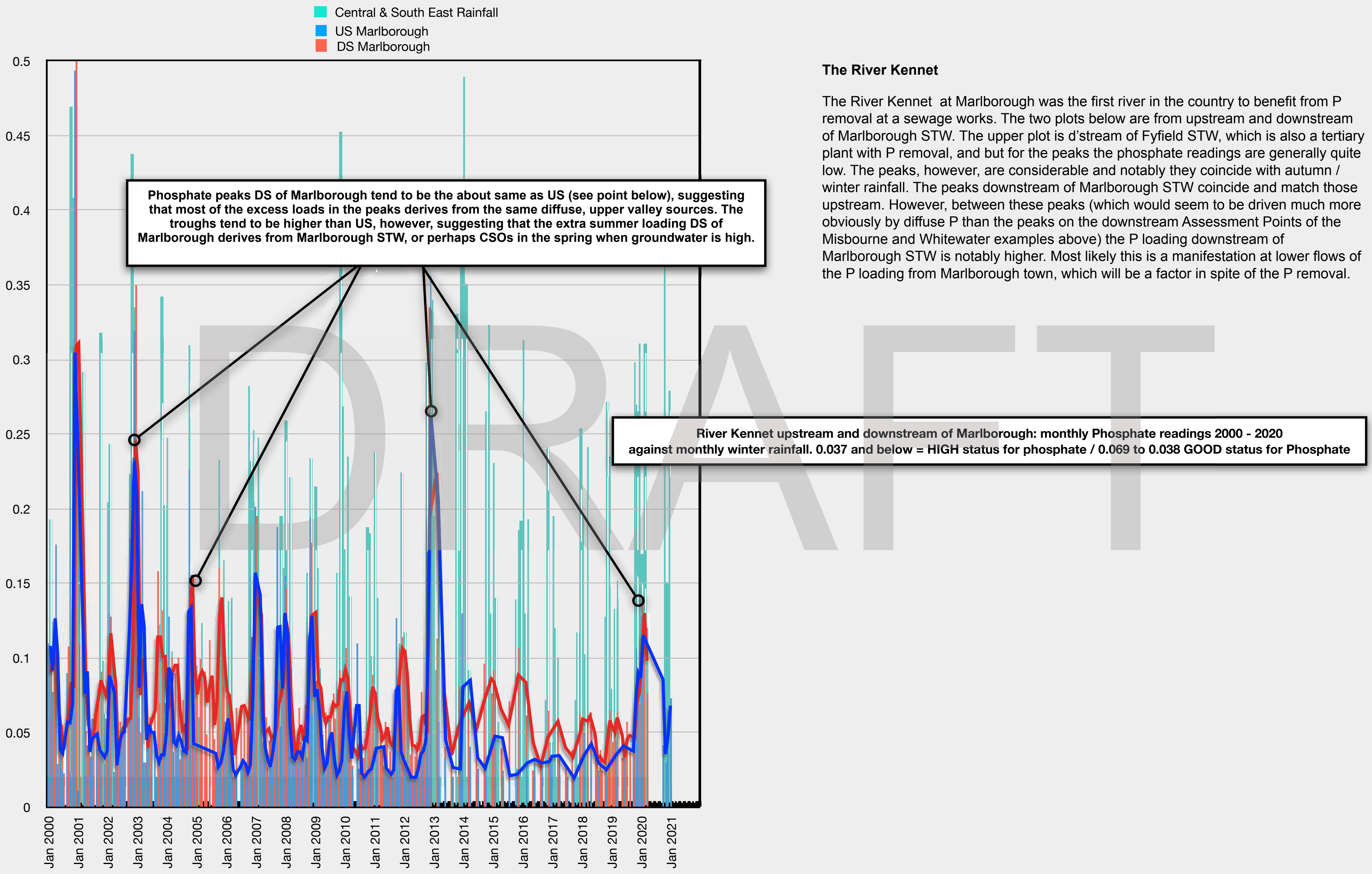


River Whitewater at Dipley and US Blackwater: EA's Phosphate readings 2000 - 2020
0.045 and below = HIGH status for phosphate / 1.036 and below = MODERATE status for phosphate

The River Whitewater

The River Whitewater in Hampshire shows a less extreme but in some ways clearer version of the same pattern. There are numerous small discharges upstreams of Dipley, but no STWs. The lower Assessment Point near the Blackwater confluence is impacted by three STWs, at Fleet and Hartney Witney via a tributary and at Hound Green.

The phosphate peaks upstream at Dipley tend to coincide with or even follow winter rainfall, while the phosphate peaks downstream quite clearly coincide with late summer and precede autumn / winter rain. The peaks and troughs are in a clear inverse pattern. Note how the peak loading from diffuse or disparate sources at Dipley matches the downstream readings as the point sources become diluted by the same high flows, but that between high flows the readings downstream are approx four times greater.



The River Kennet

The River Kennet at Marlborough was the first river in the country to benefit from P removal at a sewage works. The two plots below are from upstream and downstream of Marlborough STW. The upper plot is d'stream of Fyfield STW, which is also a tertiary plant with P removal, and but for the peaks the phosphate readings are generally quite low. The peaks, however, are considerable and notably they coincide with autumn / winter rainfall. The peaks downstream of Marlborough STW coincide and match those upstream. However, between these peaks (which would seem to be driven much more obviously by diffuse P than the peaks on the downstream Assessment Points of the Misbourne and Whitewater examples above) the P loading downstream of Marlborough STW is notably higher. Most likely this is a manifestation at lower flows of the P loading from Marlborough town, which will be a factor in spite of the P removal.

Appendix F Case Study – The Frome & Piddle Catchments

Phosphorus loadings to English rivers from STWs have reduced dramatically since 1995. Almost 60% of England drains to SAe rivers designated as sensitive to eutrophication, with P reduction in place or planned at the major STWs.

However, except on SAC and SSSI rivers, most of this capital investment has been driven by the Urban Waste Water Treatment Directive (UWWTD) and by the Water Framework Directive (WFD), with the former applying to agglomerations serving STWs of over 10,000 people discharging into sensitive environments (see map on page 52) and the latter subject to a cost-benefit analysis which factors in the cost per head of fitting more advanced, tertiary treatments. This has definitively benefitted the lower reaches of chalk streams where the larger towns exist.

Headwater Streams to Main River

The Frome and Piddle catchments form a representative range of different types of chalk-streams with the Frome headwaters being a mixed geology of chalk, greensand and clay with a high proportion of impermeable soil across the catchments of the Hooke, Wraxall and Upper Frome and more numerous hydrological surface pathways from the high ground to the main rivers than the more typically classic type of chalk stream. Whereas the Sydling, Cerne and Winterborne in the Frome catchment and the whole of the Piddle catchment represents a purer form of chalk stream with a largely chalk bedrock, a higher proportion of permeable soils and consequently more limited hydrological surface pathways from the sloped ground to the main rivers.

There are large centres of population on the Frome, small towns on the Piddle, isolated villages in all of the valleys. The broad sweep of the landscape encompasses a range of dairy, livestock and arable farming. The lower Frome is a designated SSSI.

Overall P status

In both the Frome and Piddle the Phosphate status improves directionally downstream from Moderate (0.12214) to Good (0.539) in the Frome and from Good (0.040747) to High (0.03615) in the Piddle

River Piddle

All the Piddle hadwater and tributary waterbodies start life with a lower P status, albeit still Good, rather than the High of the lower river. While diffuse source P may well form part of that pattern, it is likely that the higher concentrations in the upper catchment are largely explained by the absence of P stripping at the upstream STWs at Piddlehinton and Puddletown on the Piddle, at Ansty on the Devil's Brook and by the high density of cress farms on the Bere Stream at Bere Regis.

River Frome

The upper Frome tributaries also have much higher P concentrations than the lower river. A complicating factor in the upper Frome catchment will be the Upper Greensand (see earlier section) which is associated with much higher P readings. Nevertheless there is a notable difference between the P reading in the Wraxall and the Frome h'waters, two adjacent valleys of similar size, geologies, soil permeability and agricultural regimes.

The Wraxall catchment has no STW, a small population of 110 at Rampisham, plus disparate houses (not on mains). The Wraxall P reading is Good at 0.6241 mg/l. The Frome headwater has an STW serving a small population of circa 210 at Evershot. Otherwise there are roughly 150 people at Frome St Quintin (not on the mains). The Frome h'water has a Moderate P reading – double the Wraxall's – of 0.12214. Setting aside the degree to which diffuse pollution from farming and septic tanks elevates both those readings above natural, it is likely that the *difference* between the P readings in the Wraxall and the Frome is accounted for by the presence of an STW on the latter. Note also that in 2019 the Evershot STW also spilled for a combined total of 97 occasions and 346 hours.

Organic Farming

Finally, it is worth comparing the P readings in the Sydling (High status and low readings) and Cerne valleys (Moderate status and high readings for a chalk stream). Although there is some Upper Greensand in the Cerne valley, both these tributaries are of a much purer chalk geology than the Frome / Wraxall and Hooke.

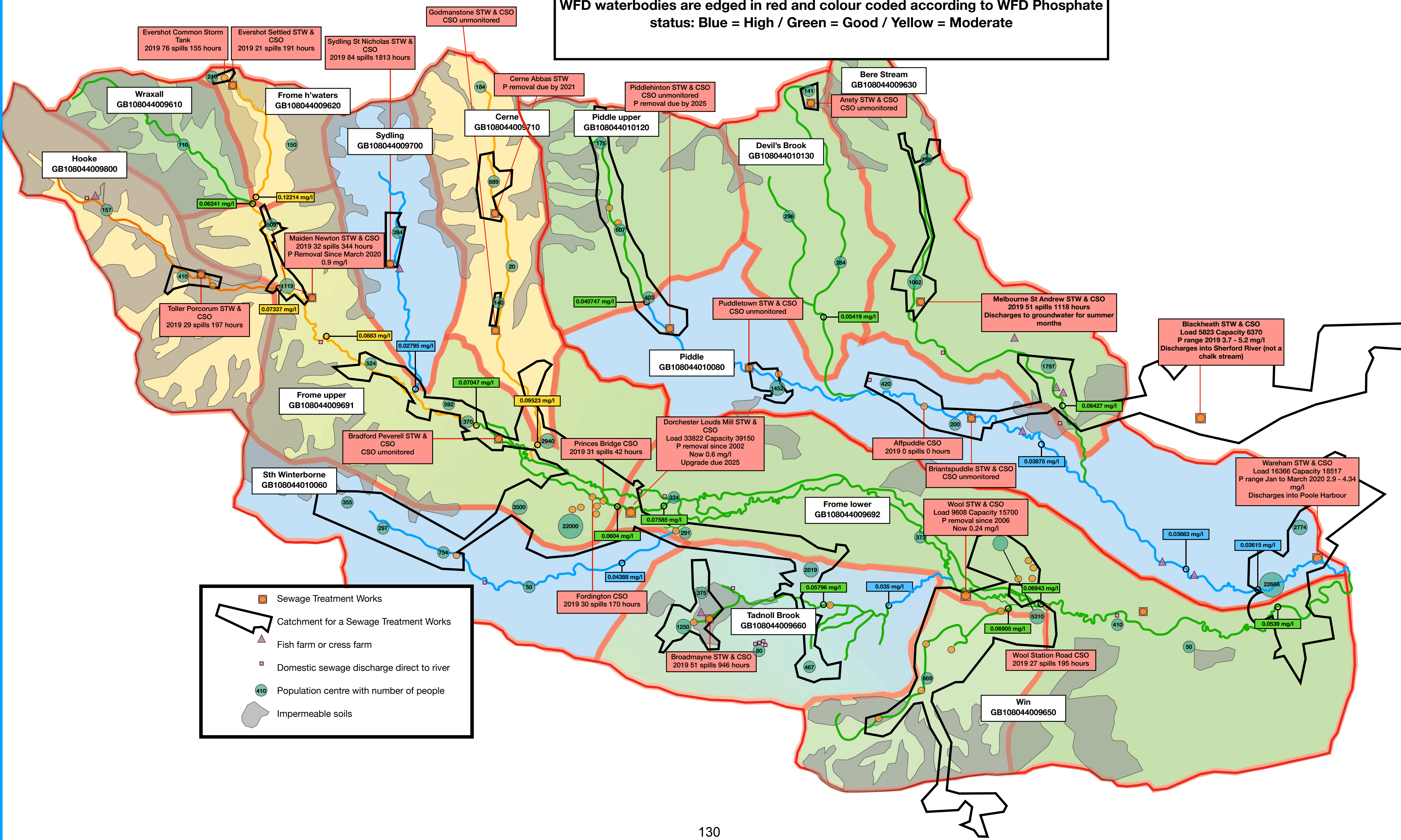
There are two small STWs in the Cerne valley, both without P stripping and only one in the Sydling valley. On the face of it the greensand and STWs might explain the higher P reading in the Cerne. However, almost the entire Sydling valley has been farmed organically for 20 years or so, whereas there is only one organic farm in the Cerne valley. Large tracts of the upper Cerne valley are farmed by commercial agricultural conglomerates and is under plough.

A comparison of all these adjacent chalk valleys shows that the origins of nutrient pollution vary according to the specific pressures of point source and diffuse pollution, complicated by geology and soil permeability and agricultural practice.

In ecological terms there is no one overarching pollution narrative that fits all chalk streams. Meanwhile it is clear that headwater chalk streams which are not designated have not yet adequately benefitted from STW investment.

Frome & Piddle Phosphate Map

WFD waterbodies are edged in red and colour coded according to WFD Phosphate status: Blue = High / Green = Good / Yellow = Moderate



Appendix G General Binding Rules for small sewer discharges.

Rule No.	General Binding Rule	Applies to discharges to surface water?	Applies to discharges to ground?
1	The discharge must be 2 cubic metres or less per day in volume.	No	Yes
2	The discharge must be 5 cubic metres or less per day in volume.	Yes	No
3	The sewage must only be domestic.	Yes	Yes
4	The discharge must not cause pollution of surface water or groundwater.	Yes	Yes
5	The sewage must receive treatment from a septic tank and drainage field infiltration system or sewage treatment plant and drainage field infiltration system.	No	Yes
6	The sewage must receive treatment from a sewage treatment plant.	Yes	No
7	The discharge must not be within a groundwater Source Protection Zone 1 or within 50 metres from any well, spring or borehole that is used to supply water for domestic or food production purposes.	No	Yes
8	For discharges in tidal waters, the discharges outlet must be below the low water mark.	Yes	No
9	All works and equipment used for the treatment of sewage effluent and its discharge must comply with the relevant design and manufacturing standards, such as the British Standard that was in force at the time of the installation, and guidance issued by the appropriate authority on the capacity and installation of the equipment.	Yes	Yes
10	The system must be installed and operated in accordance with the manufacturer's specification.	Yes	Yes
11	Maintenance must be undertaken by someone who is competent.	Yes	Yes
12	Waste sludge from the system must be safely disposed of by an authorised person.	Yes	Yes
13	If a property is sold, the operator must give the new operator a written notice stating that a small sewage discharge is being carried out, and giving a description of the waste water system and its maintenance requirements.	Yes	Yes
14	The operator must ensure the system is appropriately decommissioned where it ceases to be in operation so that there is no risk of pollutants or polluting matter entering groundwater, inland fresh waters or coastal waters.	Yes	Yes
15	For new discharges, any part of the building the treatment system serves must not be within 30 metres of a public foul sewer.	Yes	Yes
16	For new discharges, the operator must ensure that the necessary planning and building control approvals for the treatment system are in place.	Yes	Yes
17	New discharges must not be in, or within 500 m: Special Area of Conservation (SAC) / Special Protection Area (SPA) / Ramsar site / Site of Special Scientific Interest (SSSI) / freshwater pearl mussel population / designated bathing water or protected shellfish water; Or within 200 metres of an aquatic local nature reserve Or within 50 metres of a chalk river or aquatic local wildlife site. Customers can locate information using Defra's Magic map.	Yes	No
18	New discharges must not be in, or within 50 metres of a Special Area of Conservation (SAC), Special Protection Area (SPA), Ramsar site or biological Site of Special Scientific Interest (SSSI) and must not be in an Ancient Woodland.	No	Yes
19	New discharges must be made to a watercourse that normally has flow throughout the year.	Yes	No
20	For new discharges, any partial drainage field must be installed within 10 metres of the bank side of the watercourse.	Yes	No
21	New discharges must not be made to an enclosed lake or pond.	Yes	No

Appendix G
The Index of English Chalk Streams

Note the current chalk Priority Habitat map is currently being developed. The list below does not yet include the large number of scarp-face brooks and springs on the edge of the Sussex Downs which will be mapped as scarp-face spring-line zones, along with the other distinct scarp-slopes of Dorset, the Chilterns and the Lincolnshire and Yorkshire wolds.

How to read this index: rivers are best understood as catchments. The main river (not always a chalk stream) is the lead name and the uppermost tributary is indented and listed first, the lowermost last etc.

Tributaries of tributaries are indented one step further etc.

Some rivers that are not chalk-streams are listed to help make sense of the catchments – *these are in italics*.

Wessex – all the chalk-steams that flow south into the English Channel

River Bride C
– Litton Cheney Brook C

River Asker C

River Wey A

River Jordan A

Wessex – all the chalk-steams that flow south into Bournemouth Harbour

River Frome B
– Wraxall Brook B
– River Hooke B
– Compton Valence Stream A
– West Compton Stream A
– Sydling Water A
– River Cerne A
– South Winterboure A
– Tadnoll Brook B
– River Wyn B

River Piddle A
– Devil's Brook A
    – Cheselbourne A
– Bere Stream A

Wessex – all the chalk-steams that flow south into Christchurch Harbour

River Stour
– Shreen Water B
– Fontmell Brook C
– Iwerne Stream C
– Charlton Marshall Stream A
– Pimperne Brook A
– River Tarrant A
– North Winterbourne A
– River Allen A
    – Crichel Stream A
    – Gussage Stream A
– River Crane A (h'waters)

River Avon (Etchilhampton Water) B
– Eastern Avon B
– Nine Mile River A
– River Wylye A (h'water)
    – The Swan A
    – Heytesbury Bourne A
    – Chitterne Brook A
    – River Till A
– River Nadder B
    – West Fonthill or Fonthill Bishop Stream B
    – Ansty Stream B
    – Swallowcliffe Stream B
    – Chilmark Stream B
    – Teffont Stream B
    – Fovant Brook B
– River Bourne A
– River Ebble A
    – Chalke Water A
– Allen River also known as Ashford Water A
    – Sweatfords Water also known as Rockbourne Stream A

Wessex – all the chalk-steams that flow south into The Solent

River Test – flows into Southampton Water A
– Bourne Rivulet A
    – River Swift A
– River Dever A
– River Anton A
    – Pilhill Brook A
– Wallop Brook A
– Somborne Stream A
– River Dun B

River Itchen or Tichborne in its headwaters A
– River Alre A

– Candover Brook A

River Meon A
– Whitewool Stream A

Sussex

River Ems A/B

River Lavant A/B

Lewes Winterbourne A

Isle of Wight

The Caul Bourne C

The Lukely Brook C

Thames – all the chalk streams that flow into the Thames and Thames Estuary

River Thames
– Letcombe Brook A / B
– Lockinge Brook or West and East Hendred Brook B
– *River Thame*
– Horsenden Stream C
– River Lewknor C
– River Chalgrove C
– River Ewelme C
– River Pang A
– The Bourne A
– River Kennet A
– River Og A
– Aldbourne A
– River Dun A
– Shalbourne A
– Lambourne A
– Winterbourne A
– River Loddon A
– River Lyde A
– *River Blackwater*
– River Whitewater A
– Hambledon Stream A
– River Wye A
– Hughenden Stream A
– River Colne B
– The Brook B
– River Ver A
– River Gade A
– Bulbourne A
– River Chess A
– River Misbourne A
– River Wey B
– Tillingbourne B
– Hogsmill C
– River Wandle C
– River Lea A
– River Mimram A
– River Beane A/D
– Old Bourne
– Dane End Tributary A/D
– River Rib A/D
– River Quin A/D
– River Ash A/D
– River Stort A/D
– Bourne Brook A/D
– River Darenth B
– River Cray B

All the chalk streams that flow into the English Channel

Great Stour B
– Little Stour A
– Nail Bourne A
– Wingham River B
– North & South Stream A

River Dour A

East Anglia – all the chalk-streams that flow into The River Ouse

River Ouse
– River Ivel C/D
– Cat Ditch C/D
– Pix Brook C/D
– River Purwell or Hiz C/D
– River Oughton C/D
– River Cam A/D
– Debden Water A/D
– Wicken Water A/D
– Fulfen Slade A/D
– The Slade A/D
– River Granta A/D
– River Bourne A/D
– River Rhee C/D
– Cheney Water becomes Mill River becomes North Ditch C/D
– Bassingbourne C/D

– Kneeswell Stream C/D
– Melbourne C/D
– River Shep C/D
– Hoffer Brook C/D
– Hobson’s Brook C/D
– Cherry Hinton Brook C/D
– Quy Water C/D
– Little Wilbraham River C/D
– Fulbourne C/D
– Mill Stream aka Swaffham Lode C/D
– New River C/D
– Snail River aka Soham Lode C/D
– River Lark C/D
– River Linnett C/D
– River Kennett C/D
– Tuddenham Mill Stream C/D
– Little Ouse C/D
– The Black Bourne or Sapiston Brook C/D
– Pakenham Fen C/D
– Walsham Stream C/D
– River Thet C/D
– River Wissey C/D
– River Gadder C/D
– Beachamwell Stream C/D
– River Nar C/D

East Anglia – all the Norfolk chalk-streams that flow into The Wash

River Babingley C/D

River Ingol C/D

River Heacham C/D

River Hun A/D

East Anglia – all the Norfolk chalk-streams that flow from The North Sea

River Burn A/D

River Stiffkey A/D
– Binham Stream

River Glaven A/D

East Anglia – all the chalk-streams that flow into The Norfolk Broads

River Bure B/D
– Craymere Beck B/D

River Yare
– River Wensum A/D
– River Tat A/D
– Whitewater B/D
– Blackwater B/D
– River Tud B/D
– River Tiffey B/D
– River Tas B/D

Eastern Wolds – all the Lincolnshire chalk-streams that flow into the Wash

River Witham
– River Bain B/D

Steeping River
– River Lymn B/D

Eastern Wolds – all the Lincolnshire chalk-streams that flow into the North Sea

Willoughby High Drain
– Burland’s Beck A/D
– Hog’s Beck A/D
– Well Beck (trib of Boygrift Drain) A/D

Great Eau or Calceby Beck in headwaters A/D
– Burwell Beck A/D
– Long Eau or The Beck in headwaters A/D

River Lud A/D
– Welton Beck A/D
– Hallington Stream A/D

Waithe Beck A/D
–Thoresway Beck A/D

Eastern Wolds – all the Lincolnshire chalk-streams that flow into the Humber

River Freshney
–Laceby Beck

Keelby Beck C/D

Skitter Beck becomes East Halton Beck C/D

Barrow Beck or Butforth Drain or The Beck C/D

River Ancholme
– River Rase C/D
  – Brimmer Beck C/D
– Otby Beck C/D
– Nettleton Beck C/D

Eastern Wolds – all the Yorkshire chalk-streams that into the Humber

River Derwent
– *Sherburn Beck*
  – East Beck C/D
    – West Beck C/D
– Wintringham Beck C/D
  – Blakey Beck C/D
– Settrington Beck C/D
  – Whitestone Beck C/D
– *Menethorpe Beck*
  – Rowmire Beck becomes Mill Beck C/D
    – Clombe Beck C/D
– Whitecarr Beck C/D
  – Moor Beck C/D
– Leppington Beck C/D
– Bughtorpe Beck *becomes Skirpen Beck becomes Barlam Beck* C/D
  – Salamanca Beck C/D
    – Gilder Beck C/D
– *The Beck*
  – *Blackfoss Beck*
    – *Foss Beck*
      – *Spittal Beck*
        – Gowthorpe Beck C/D
        – Bishop's Wilton Beck C/D
  – *Bieby Beck*
    – Pocklington Beck C/D
      – Ridings Beck or Whitekeld Beck C/D
      – Millington Beck C/D
      – Hayton Beck (Burnby / Nunburnholme Beck) C/D

Market Weighton Canal – drains into the Humber
– Goodmanham Beck C/D
  – *River Foulness or Shipton Beck*
    – East Beck C/D

Mire Beck
– Drewton Beck C/D
  – Ings Beck C/D
    – Church Beck C/D

River Hull
– River Hull or West Beck A/D
  – Driffield Trout Stream A/D
  – Driffield Beck A/D
    – Elmswell Beck A/D
    – Little Driffield Beck A/D
  – The Beck aka water Forlorns A/D
  – Nafferton Beck A/D
  – Skerne Beck A/D
  – Kelk Beck becomes Foston Beck becomes Frodingham Beck A/D

Eastern Wolds – all the Yorkshire chalk-streams that into The North Sea

The Gypsey Race A/D

Appendix H
Chalk Stream ASB + WFD Flow / Phosphorus + STWs

HIGH STATUS | GOOD STATUS | MODERATE STATUS | POOR STATUS | BAD STATUS

SSSI | SAC | Non Designated | Colne / Lea | Part of non-chalk WB

CATCHMENT	ASB1	ASB2	ASB3	FLOW DOES / DOES NOT SUPPORT GES	PHOSPHORUS	STWs Red = Secondary Blue = Tertiary Black = Unconfirmed
English Channel		Bride incl Litton Cheney Brook GB108044009550		SG	MODERATE UGS (Upper Greensand)	Puncknowle STW
Frome (Dorset)		Frome H'waters GB108044009620		SG	MODERATE UGS (Upper Greensand)	Evershot STW
		Wraxall GB108044009610		HIGH	GOOD UGS (Upper Greensand)	
			Hooke GB108044009800	DNSG	MODERATE UGS (Upper Greensand)	Toller Porcorum STW
			Frome Upper GB108044009691	SG	MODERATE to GOOD	Maiden Newton STW
			Sydling GB108044009700	SG	HIGH	Sydling St Nicholas STW
		Cerne GB108044009710		SG	MODERATE UGS (Upper Greensand)	Cerne Abbas STW Godmanstone STW
			S'th Winterborne GB108044010060	SG	HIGH	
		Tadnoll Brook h'waters GB108044009660		SG	GOOD	Broadmayne STW
		Win h'waters GB108044009650		HIGH	GOOD	
		Frome Lower GB108044009692		SG	GOOD	Dorchester Louds Mill STW Wool STW
						Frome SSSI 33% STWs with P removal (3/9)
Wey / English Channel		Wey GB108044010210		DNSG	GOOD	
Piddle			Piddle Upper GB108044010120	SG	GOOD	Piddlehinton STW Puddletown STW
		Piddle Lower GB108044010080		SG	HIGH	Wareham STW
			Devil's Brook incl Cheselbourne GB108044010130	DNSG	GOOD	Ansty STW
			Bere Stream GB108044009630	SG	GOOD	Milborne St Andrew STW
Stour		Shreen Water GB108043022450		DNSG	BAD UGS (Upper Greensand)	Mere STW
		Fontmell Brook GB108043016080		SG	MODERATE UGS (Upper Greensand)	

CATCHMENT	ASB1	ASB2	ASB3	FLOW DOES / DOES NOT SUPPORT GES	PHOSPHORUS	STWs Red = Secondary Blue = Tertiary Black = Unconfirmed
			Iwerne GB108043016010	SG	BAD UGS (Upper Greensand)	Iwerne Minster STW Shroton STW
			Pimperne Brook GB108043016020	SG	NO P RECORD	
			Tarrant GB108043016070	SG	HIGH	
		N'th Winterborne GB108043015990		SG	HIGH	
Stour - Allen			Allen h'waters GB108043015790	SG	HIGH	
			Gussage Stream GB108043015780	SG	HIGH	
			Crichel Stream GB108043015760	SG	HIGH	
			Allen lower GB108043011090	SG	HIGH	Wimborne STW
		Crane GB108043016090		HIGH	GOOD	Cranborne STW
						Rest of Dorset P removal (excl Frome SSSI) 27% 3/11
Hants Avon		Etchilhampton Water GB108043022430		SG	POOR UGS (Upper Greensand)	All Cannings STW Etchilhampton STW Wedhampton STW Stanton St Bernard STW
		Avon West GB108043022370		SG	POOR UGS (Upper Greensand)	Marden STW
			Avon East GB108043022410	SG	MODERATE UGS (Upper Greensand)	Pewsey STW
		Avon upper GB108043022351		SG	MODERATE	Upavon STW Netheravon STW
		Nine Mile GB108043022360		DNSG	HIGH	
		Avon middle GB108043022352		SG	GOOD	Ratfyn STW Amesbury STW
Hants Avon – Wylye			Wylye h'waters GB108043022520	SG	MODERATE UGS (Upper Greensand)	Monkton Deverell STW Warminster STW
		The Swan GB108043022540		SG	MODERATE UGS (Upper Greensand)	
		Wylye GB108043022550		SG	MODERATE UGS (Upper Greensand)	Warminster Garrison STW
			Heytesbury Stream GB108043022530	SG	MODERATE UGS (Upper Greensand)	

CATCHMENT	ASB1	ASB2	ASB3	FLOW DOES / DOES NOT SUPPORT GES	PHOSPHORUS	STWs Red = Secondary Blue = Tertiary Black = Unconfirmed
			Chitterne Brook GB108043022560	SG	GOOD	Chitterne STW
		Till GB108043022570		SG	HIGH	Shrewton STW Berwick St James STW
			Wylye lower GB108043022510		GOOD	Great Wishford STW
Hants Avon – Nadder		Nadder h'Waters GB108043016160		SG	POOR UGS (Upper Greensand)	
		Nadder upper GB108043016200		HIGH	MODERATE UGS (Upper Greensand)	East Knoyle STW via Sem (not a chalk stream)
			Fonthill Stream GB108043022500	DNSG	HIGH	
			Swallowcliffe incl Antsty Stream GB108043016180	SG	MODERATE UGS (Upper Greensand)	
		Nadder middle (incl Chilmark Stream) GB108043022470		SG	MODERATE UGS (Upper Greensand)	Tisbury STW
			Teffont Stream GB108043022471	SG	GOOD UGS (Upper Greensand)	
			Fovant Brook GB108043016190	SG	MODERATE UGS (Upper Greensand)	Fovant STW
		Nadder lower GB108043015880		SG	GOOD	Barford St Martin STW
		Bourne GB108043022390		SG	GOOD	Collingbourne Ducis STW Tidworth Garrison STW Shipton Bellinger STW Hurdcott STW
		Avon lower GB108043015840		SG	GOOD	Salisbury STW Downton STW Fordingbridge STW Ringwood STW
		Ebble GB108043015830		SG	HIGH	Bishopstone STW
		Sweatfords Water GB108043015810		HIGH	HIGH	
		Allen River GB108043015800		SG	HIGH	
						Avon SAC 60% STWs with P removal 18/31
Test			Test h'waters GB107042022710	HIGH	HIGH	
			Bourne Rivulet incl Swift GB107042022720	SG	GOOD	
			Test upper (Bourne to Dever) GB107042022700	HIGH	HIGH	

CATCHMENT	ASB1	ASB2	ASB3	FLOW DOES / DOES NOT SUPPORT GES	PHOSPHORUS	STWs Red = Secondary Blue = Tertiary Black = Unconfirmed
		Dever GB107042022700		SG	HIGH	Sutton Scotney STW Barton Stacey STW
			Test upper (Dever to Anton) GB107042022750	SG	HIGH	Chilbolton STW Fullerton STW
			Anton upper GB107042022810	DNSG	HIGH	Andover STW
			Pillhill Brook GB107042022790	SG	GOOD	
			Anton lower GB107042022810	DNSG	HIGH	
		Test middle (Anton to Dun) GB107042022670		SG	HIGH	Stockbridge STW Kings Somborne STW
		Wallop Brook GB107042022650		SG	GOOD	Evans Close STW School of Army Aviation STW
			Sombourne Stream GB107042022740	SG	HIGH	
		Dun GB107042022640		SG	HIGH	East Grimstead STW
		Test middle (Dun to Tadburn Lake) GB107042016460		SG	HIGH	Romsey STW
`		Test lower GB107042016840			HIGH	
						Test SSSI 54% STWs with P removal (7/13)
Itchen			Alre GB107042022610	SG	HIGH	
			Candover GB107042022620	DNSG	HIGH	
			Cheriton GB107042016670	SG	HIGH	
		Itchen GB107042022580		DNSG	HIGH	Harestock STW Morestead STW Chickenhall Easteigh STW
						Itchen SAC 100% STWs with P removal (3/3)
English Channel		Meon incl Whitewool Stream GB107042016640		DNSG	GOOD	East Meon STW Wickham STW
English Channel		Ems GB107041012370		DNSG	HIGH	
English Channel		Lavant GB107041006520		SG	MODERATE UGS (Upper Greensand)	Lavant STW

CATCHMENT	ASB1	ASB2	ASB3	FLOW DOES / DOES NOT SUPPORT GES	PHOSPHORUS	STWs Red = Secondary Blue = Tertiary Black = Unconfirmed
						Remainder of English Channel 33% STWs with P removal (1/3)
Thames		Letcombe Brook GB106039023350		SG	GOOD	Wantage STW
		Lockinge (or Betterton or Ardington Brook) & Ginge Brook & Mill Brook GB106039023660		SG	MODERATE UGS (Upper Greensand)	Drayton STW DS of chalk stream reach
Thame		Horsenden Stream (included in Kingsey Cuttle Brook) GB106039030200		SG	POOR UGS (Upper Greensand)	Princes Riseborough STW (on Horsenden Stream)
		Lewknor GB106039023750		HIGH	MODERATE UGS (Upper Greensand)	Lewknor STW
		Chalgrove GB106039023740		SG	POOR UGS (Upper Greensand)	Watlington STW
Thames			Ewelme GB106039023610	HIGH	MODERATE	
`			Pang incl the Bourne GB106039023300	DNSG	GOOD	Hampstead Norreys STW Bucklebury Slade STW
						Thames DS to Kennet 25% STWs with P removal (2/8)
Thames / Kennet			Kennet h'waters GB106039023171	SG	HIGH	Broad Hinton STW Fyfield STW
			Og GB106039023180	DNSG	GOOD	
			Kennet middle to Hungerford GB106039023173	SG	GOOD	Marlborough STW Ramsbury STW Chilton Foliat STW
			Aldbourne GB106039023200	SG	GOOD	
			Upper Dun GB106039017350	SG	GOOD UGS (Upper Greensand)	East Grafton STW Wilton STW Great Bedwyn STW Froxfield STW
			Shalborne GB106039017370	HIGH	MODERATE	Shalbourne STW
			Kennet middle to Newbury GB106039023174	SG	GOOD	Hungerford STW Kintbury STW Hamstead Marshall STW
			Lambourne GB106039023220	SG	HIGH	East Shefford STW Boxford STW
			Winterbourne GB106039023210	SG	Good	Winterbourne STW
		Kennet lower Lambourne to Enborne GB106039017420		SG	HIGH	Newbury STW Woolhampton STW
						Kennet / Lambourne SSSI / SAC 61% STWs with P removal (11/18)

CATCHMENT	ASB1	ASB2	ASB3	FLOW DOES / DOES NOT SUPPORT GES	PHOSPHORUS	STWs Red = Secondary Blue = Tertiary Black = Unconfirmed
Thames / Loddon		Loddon h'waters GB106039017080		SG	HIGH	Basingstoke STW
		Lyde GB10609017100		HIGH	HIGH	
			Loddon upper GB106039017150	SG	MODERATE	
		Loddon middle GB106039017330		SG	MODERATE	St John STW & Sherfield on Loddon STW via Bow Brook tributary
		Whitewater GB106039017240		SG	GOOD	Fleet and Hartney Witney STW's via River Hart Hound Green STW via unnamed tributary
Thames			Hamble Brook GB106039023720	DNSG	HIGH	
Thames / Wye			Wye H'waters GB106039023890	SG	HIGH	
			Hughenden Stream GB106039023900	HIGH	HIGH	
			Wye GB106039023880	SG	HIGH	High Wycombe STW
						Thames Kennet to Colne 57% STWs with P removal (4 /7)
Thames / Colne		Colne h'waters incl Mimshall Brook & Catherine Bourne GB106039029850		DNSG	MODERATE	Carpenders Park STW Carpenders Park toilets
		Colne upper to Ver GB106039029820		DNSG	MODERATE	Tollgate Farm STW
		Ver GB106039029920		DNSG	HIGH	Markyate STW
		Colne middle to Gade GB106039029840		DNSG	POOR	Blackbirds STW
		Upper Gade to Bulbourne GB106039029900		DNSG	GOOD	Great Gaddesdon STW
		Lower Gade GB106039029860		DNSG	MODERATE	
		Bulbourne GB106039029900		DNSG	GOOD	Berkhamstead STW
		Chess GB106039029870		DNSG	POOR	Snowhill Cottage STW Chesham STW Chenies STW
		Misbourne GB106039029830		DNSG	HIGH	Gerard's Cross STW
		Colne lower GB106039023090		DNSG	POOR	Maple Lodge STW Iver North STW

CATCHMENT	ASB1	ASB2	ASB3	FLOW DOES / DOES NOT SUPPORT GES	PHOSPHORUS	STWs Red = Secondary Blue = Tertiary Black = Unconfirmed
						Colne Catchment 30% STWs with P removal (4/13)
Thames / Wey			North Wey at Alton GB106039017800	DNSG	GOOD	
			Caker Stream GB106039017730	SG		**Alton STW**
		North Wey GB106039017830		DNSG	POOR	**Bentley STW** **Farnham STW**
		Tillingb'rne GB106039017840		DNSG	POOR	
Thames / London		Hogsmill GB106039017440		SG	POOR	**Hogsmill STW**
		Wandle GB106039023460		SG	BAD	**Beddington STW**
`		Wandle Carshalton Branch GB106039017640		DNSG (Carshalton) / SG	HIGH	
						Thames Colne to Lee 80% STWs with P removal (4/5)
Thames / Lee			Lee upper to Luton GB106038033391	DNSG	GOOD	**Luton STW**
		Lee to Hertford GB106038033392		SG	POOR	**Harpenden STW** **Mill Green, Hatfield STW**
			Mimram upper GB106038033460	DNSG	POOR	**Kimpton STW via River Kym** **Whitwell STW**
			Mimram lower GB106038033270	DNSG	GOOD	
		Beane upper GB106038040110		SG	MODERATE	**Weston STW** **Cottered STW**
		Beane lower GB106038033310		SG (upper) / DNSG	GOOD	
			Rib upper GB106038040140	SG	POOR	**Therfield STW** **Buntingford STW**
		Quin GB106038040120		SG	GOOD	**Barkway STW** **Braughing STW**
		Rib lower GB106038033360		DNSG	POOR	**Standon STW** **Chapmore End STW**
		Ash upper GB106038040100		HIGH	MODERATE	**Feurneux Pelham STW**
		Ash lower GB106038033290		DNSG	POOR	**Widford STW**

CATCHMENT	ASB1	ASB2	ASB3	FLOW DOES / DOES NOT SUPPORT GES	PHOSPHORUS	STWs Red = Secondary Blue = Tertiary Black = Unconfirmed
		Stort GB106038040130		DNSG	MODERATE	Stanstead Mountfitchet STW Clavering STW Manuden STW Bishops Stortford STW Little Hallingbury STW Hatfield Heath STW
		Bourne Brook GB106038033340		DNSG	MODERATE	
						Lee Catchment 33% of STWs with P removal (7/21)
Thames Estuary			Cray upper GB106040023990	DNSG	GOOD	Royal Park STW
		Cray lower GB106040024150		DNSG	MODERATE	
		Darent Upper GB106040024221		DNSG	GOOD	Chipstead STW Dunton Green STW
		Darent middle and lower GB106040024222		DNSG	HIGH	Home Farm STW Broakes Meadow STW
						Thames Lee to Estuary 0% STWs with P removal (0/5)
English Channel	Great Stour upper GB107040019660			DNSG	GOOD	Lenham STW Charing STW Westwell STW
	East Stour			SG	MODERATE	Sellindge STW
	Great Stour GB107040019741			SG	MODERATE	Brook STW (via tributary) Wye STW Ashford STW
	Great Stour GB107040019742			SG	MODERATE	Wye STW Chilham STW Chartham STW
	Great Stour lower GB107040019743			SG	POOR	Canterbury STW Westbere STW Herne Bay STW
	Nailbourne & Little Stour GB107040019590			DNSG		Newnham Valley STW Wingham STW via Wingham River
	Northbourne at Eastry GB107040019730			HIGH	GOOD	Eastry STW
	Northbourne incl Broad Dike GB107040019720			DNSG	HIGH	
English Channel		Dour h'waters GB107040019490		DNSG		
		Dour GB107040073310		DNSG		
						Kent 18% STWs with P removal (3/16)
Ouse / Ivel		Ivel upper GB105033037720		SG	HIGH	

CATCHMENT	ASB1	ASB2	ASB3	FLOW DOES / DOES NOT SUPPORT GES	PHOSPHORUS	STWs Red = Secondary Blue = Tertiary Black = Unconfirmed
			Cat Ditch GB105033037740	DNSG	NO ASSESSMENT	**Newnham STW**
		Pix Brook GB105033037730		SG	POOR	**Letchworth STW**
			Hiz h'waters GB105033037680	NO ASSESSMENT	HIGH	
		Purwell GB105033037690		SG	HIGH	**Ashbrook STW**
		Hiz incl Oughton GB105033037700		NO ASSESSMENT	HIGH	**Hitchin STW** **Poppyhill STW**
						Ivel 80% STWs with P removal (4/5)
Ouse / Cam		Cam h'waters GB105033037480		SG	MODERATE	**Quendon STW**
		Debden Water GB105033037490		NO ASSESSMENT		**Debden STW**
		Wicken Water GB105033037540		DNSG		
		Cam upper to Audley End GB105033037550		DNSG	BAD	**Newport STW** **Wendens Ambo STW** **Audley End STW**
		Wenden Brook aka Fluten GB105033037560		DNSG		
		Slade GB105033037580		SG	POOR	**Saffron Walden STW**
		Cam middle to Stapleford (GB105033037590		DNSG	POOR	**Great Chesterford STW** **Sawston STW**
		Cam lower GB105033037600		DNSG	POOR	
		Granta incl Bourne GB105033037810		DNSG		**Ashdon STW** **West Wickham STW** **Shudy Camps STW** **Linton STW** **Babraham STW**
						Cam DS to Rhee 15% STWs with P removal (2/ 13)
Ouse / Rhee		Rhee upper incl Cheney Water & Chardle GB105033038100		NO ASSESSMENT	POOR	**Ashwell STW** **Guilden Morden STW**
		Mill River (aka Bassingborne) GB105033038030		SG	POOR	**Bassingbourn STW** **Litlington STW**
			Whaddon Brook aka Kneeswell GB105033038020	NO ASSESSMENT	POOR	**Royston STW**
			Mel GB105033038060	NO ASSESSMENT	HIGH	**Melbourn / Meldreth STW**

CATCHMENT	ASB1	ASB2	ASB3	FLOW DOES / DOES NOT SUPPORT GES	PHOSPHORUS	STWs Red = Secondary Blue = Tertiary Black = Unconfirmed
			Shep GB105033038080	SG	MODERATE	
			Hoffer Brook GB105033038120	NO ASSESSMENT	HIGH	
						Rhee 33% STWs with P removal (2/6)
Ouse / Cam		Hobson's Brook GB105033037620		DNSG		
			Cherry Hinton Brook GB105033042670	DNSG	MODERATE	
			Quy Water (incl Wilbraham and Fulbourne) GB105033042700	NO ASSESSMENT	POOR	**Teversham STW**
			Swaffham-Bullbeck Lode aka Mill Stream GB105033042710	NO ASSESSMENT	POOR	**Balsham STW** **Bottisham STW**
			New River GB105033042780	DNSG	HIGH	
		Soham Lode aka Snail River GB105033042860		SG	MODERATE	**Dullingham STW** **Newmarket STW** **Soham STW**
						Cam (Rhee to Lark) 33% STWs with P removal (2/6)
Ouse / Lark		Lark h'waters GB105033042920		SG	MODERATE	**Stanningfield STW**
		Hawkstead GB105033042930		SG	POOR	**Hawkstead STW**
		Lark upper GB105033042940		DNSG	POOR	**Great Welnetham STW** **Rough STW**
		Linnet GB105033042950		SG	POOR	**Chedbergh STW via tributary**
		Lark middle GB105033043051		SG	MODERATE	**Fornham STW** **West Stow STW**
		Kennett GB105033042990		DNSG	MODERATE	**Kirtling STW** **Lidgate STW** **Gazeley STW** **Kennett STW**
		Tuddenham GB105033043010		DNSG	POOR	**Tuddenham STW**
						Lark 27% STWs with P removal (3/11)
Ouse / Little Ouse	Little Ouse h'waters US Theltenham GB105033043060			DNSG	MODERATE	**Botesdale STW** **Crackthorn Bridge STW** **Blo Norton STW**
	Little Ouse Theltenham to Hopton Common GB105033043110			DNSG	GOOD	**Wattisfield STW** **Garboldisham STW** **Elm Grove STW** **Garboldisham Common STW**

CATCHMENT	ASB1	ASB2	ASB3	FLOW DOES / DOES NOT SUPPORT GES	PHOSPHORUS	STWs Red = Secondary Blue = Tertiary Black = Unconfirmed
	Little Ouse middle Hopton to Sapiston GB105033043100			DNSG	GOOD	Gasthorpe STW
		Sapiston Brook GB105033043280		SG	POOR	Elmswell STW Norton STW Thurston STW Honington STW
	Little Ouse Sapiston to Thetford GB105033043090			DNSG	MODERATE	Barnham STW Thetford STW
		Thet h'waters GB105033047830		SG	MODERATE	Attleborough STW Besthorpe Norwich STW Besthorpe Bunwell STW
		Thet GB105033043190		SG	MODERATE	Snetterton STW Roudham STW East Harling STW
						Little Ouse 10% STWs with no P removal (2/20)
Ouse / Wissey		Wissey upper GB105033047890		SG	MODERATE	Necton STW Bradenham STW Swaffham STW & CSO Great Cressingham STW Hilborough STW
	Watton Brook GB105033047870			SG	POOR	Carbrooke Church Road STW Ovington STW Watton STW & CSO
	Wissey lower GB105033047630			DNSG		Mundford STW Foulden STW
			Thompson Stream GB105033047840	SG	GOOD	Thompson STW
			West Tofts Stream GB105033043450	HIGH	HIGH	
		Gadder GB105033047880		DNSG	GOOD	Cockley Cley STW Gooderstone STW
		Old Carr aka Beachamwell Stream GB105033047820		DNSG	HIGH	
						Wissey 15% STWs with P removal (2/13)
Ouse / Nar	Nar upper GB105033047791			DNSG	HIGH	Litcham STW West Acre STW
	Nar lower GB105033047792			DNSG	HIGH	
						Nar SSSI 100% STWs with P removal or discharge to ground
The Wash	Babingley GB105033047620			DNSG	HIGH	Abbey Road STW discharges to ground.
The Wash		Ingol GB105033053470		SG	POOR	Ingol STW
The Wash	Heacham River GB105033053480			DNSG	HIGH	Heacham STW

CATCHMENT	ASB1	ASB2	ASB3	FLOW DOES / DOES NOT SUPPORT GES	PHOSPHORUS	STWs Red = Secondary Blue = Tertiary Black = Unconfirmed
The North Sea	Burn GB105034055750			SG	POOR	Burnham Market STW
The North Sea		Stiffkey GB105034055840		SG	MODERATE	Little Snoring STW East Barsham STW Houghton St Giles STW Great Walsingham STW Warham STW Stiffkey STW
	Binham Stream GB105034055830			DNSG	MODERATE	Langham STW
The Glaven / The North Sea		Glaven GB105034055780		SG	HIGH	Holt STW Cley STW
		Gunthorpe Stream GB105034055770		HIGH	HIGH	
Bure		Bure upper GB105034055690		SG	HIGH	Briston STW Hindolvesten STW
						Norfolk (excluding Nar SSSI and Wensum SAC) 26% STWs with P removal (4/15)
Wensum		Wensum h'waters GB105034051111		SG	HIGH	West Raynham STW
			Tat GB105034055870	SG	GOOD	Sculthorpe STW
		Wensum GB105034055881		DNSG	HIGH	Fakenham STW Swanton Morley STW North Elmham STW Bylaugh STW
						Wensum SAC 100% STWs with P removal (5/5)
Witham			Bain upper GB105030062350	DNSG	HIGH	Donnington on Bain STW
		Bain middle GB105030062300		DNSG	HIGH	Hemingby STW
Steeping	Lymn (h'waters of Steeping) GB105030062430			DNSG	GOOD	Tetford STW
Great Eau	Burlands Beck (h'waters of Willoughby High Drain incl. Hog's Beck) GB105029061710			SG	HIGH	
		Well Beck (trib of Boygrift Drain) GB10502906172		HIGH	HIGH	
		Great Eau upper GB105029061620		HIGH	HIGH	
	Great Eau middle and lower GB105029061660			DNSG	HIGH	
		Burwell Beck (trib of Great Eau) GB105029061630		HIGH	HIGH	
	Long Eau GB105029061670			SG	POOR	Legbourne STW Manby STW

CATCHMENT	ASB1	ASB2	ASB3	FLOW DOES / DOES NOT SUPPORT GES	PHOSPHORUS	STWs Red = Secondary Blue = Tertiary Black = Unconfirmed
Seven Towns North and South Eau		Lud (incl Hallington Stream) GB104029061955		HIGH	HIGH	Louth STW
			Welton Beck (Trib of Lud) GB104029061980	HIGH	HIGH	Welton le Wold STW
Waithe			Waithe Beck GB104029062040	SG	HIGH	Binbrook STW
			Thoresway Beck GB104029062060	SG	NO ASSESSMENT	
The North Sea		Laceby Beck GB104029067530		DNSG	POOR	Laceby STW
Humber	Keelby Beck inc in North Beck Drain GB104029067575			DNSG	NO ASSESSMENT	
	Skitter Beck GB104029067655			DNSG	GOOD	Ulceby STW
	Barrow Beck GB104029067605			DNSG	HIGH	
Ancholme		Rase h'waters GB104029062130		SG / SG	POOR	Tealby STW
		Rase GB104029061870		SG	POOR	Market Rasen STW
		Otby Beck (Kingerby Beck Catchment) GB104029061880		SG	HIGH	
	Nettleby Beck (Caistor Canal Catchment) GB104029061920			DNSG	MODERATE	Caister STW
						Lincolnshire 15% STWs with P removal (2/13)
Derwent		Sherburn Beck incl East and West Beck GB104027067800		HIGH	GOOD	Sherburn STW
		Wintringham Beck incl Blakey Beck (h'waters of Scampston Beck) GB104027067790		HIGH	MODERATE	
		Settrington Beck incl Whitestone Beck GB104027067750		HIGH	GOOD	
		Menethorpe Beck incl Mill Beck & Rowmire Beck GB104027063550		HIGH	HIGH	
	Moor Beck incl Leavening Beck (becomes Whitecarr Beck) – included in Derwent Kirkham to Elkington waterbody assessment GB104027068312			DNSG	HIGH	
	Leppington Beck – included in Derwent Kirkham to Elkington waterbody assessment GB104027068312			DNSG	HIGH	
		Bughthorpe Beck inc Gilder Beck and Salamanca Beck – (becomes Skirpen Beck becomes Barlam Beck) GB104027063510		HIGH	GOOD	Bugthorpe STW

CATCHMENT	ASB1	ASB2	ASB3	FLOW DOES / DOES NOT SUPPORT GES	PHOSPHORUS	STWs Red = Secondary Blue = Tertiary Black = Unconfirmed
		Gowthorpe Beck GB104027063490		HIGH	MODERATE	
		Bishop Wilton Beck GB104027063470		SG	MODERATE	**Bishop Wilton STW**
		Pocklington Beck incl Ridings Beck & Millington Beck GB104027063480		SG	GOOD	**Pocklington STW**
		Nunburnholme Beck (becomes Bielby Beck) GB104027063450		HIGH	GOOD	**Water Village STW** **Nunburnholme STW** **Hayton STW**
		Towthorpe Beck (becomes East Beck – h'waters of Foulness) GB104026066720		SG	GOOD	
		Goodmanholme Beck – included in Foulness waterbody assessment GB104026066690		SG	HIGH	**Market Weighton STW**
			Drewton Beck – Mill Beck 3 waterbody GB104026066670	HIGH	HIGH	
			Ings Beck incl Church Beck – Mill Beck 4 waterbody GB104026066680	SG	HIGH	
Hull			Driffield Trout Stream aka Eastburn incl. Wellsprings Drain and Southburn **GB104026067031**	DNSG	HIGH	**Driffield STW**
		West Beck upper incl Elmswell Beck and Little Driffield Beck GB104026067080		DNSG	HIGH	
			Water Forlorns aka The Beck / Garton Wolds GB104026067130	HIGH	HIGH	
		Nafferton Beck GB104026067090		SG	MODERATE	**Nafferton STW Pumping Station** **Wansford STW**
	Skerne Beck GB104026067041			HIGH	HIGH	
			Foston Beck aka Lowthorpe / Kelk / Frodingham Beck GB104026067101	DNSG	GOOD	**Kilham STW** **Foston on the Wolds STW**
Gypsey Race / The North Sea		Gypsey Race GB104026072790		HIGH	HIGH	
						Yorkshire 15% STWs with P removal (2/13)