Out of date

This report has been withdrawn because it is out of date.

For a copy of the updated River Severn drought order environmental report please contact the Environment Agency.

River Severn Drought Order Environmental Report

(Working Draft)

Version 7 - December 2013

We are the Environment Agency. We protect and improve the environment and make it a better place for people and wildlife in England.

We operate at the place where environmental change has its greatest impact on people's lives. We reduce the risks to people and properties from flooding; make sure there is enough water for people and wildlife; protect and improve air, land and water quality and apply the environmental standards within which industry can operate.

Acting to reduce climate change and helping people and wildlife adapt to its consequences are at the heart of all that we do.

We cannot do this alone. We work closely with a wide range of partners including government, business, local authorities, other agencies, civil society groups and the communities we serve.

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Foreword

This environmental report has been produced by the Environment Agency, in consultation with Natural Resources Wales and two of its predecessors (Environment Agency Wales and the Countryside Council for Wales). From 1 April 2013 Natural Resources Wales, which was formed by the Welsh Government, took over the functions previously carried out by Environment Agency Wales, Countryside Council for Wales and the Forestry Commission Wales. The relationship between Natural Resources Wales and the Environment Agency was set out in a Memorandum of Understanding, with the Environment Agency remaining the lead organisation for water resources planning activities in the River Severn catchment. However, the River Severn flows through England and Wales and the geographical area covered includes Powys, which is now the overall responsibility of Natural Resources Wales

While site-based work is only generally undertaken by Environment Agency staff in England and by Natural Resources Wales staff in Wales, we plan together in relation to shared water bodies, water catchments, estuaries, and groundwater resources. The Environment Agency leads on water resources planning activities in the Severn catchment, which includes River Severn regulation and drought planning, while Natural Resources Wales lead in the Dee and Wye catchments which also flow through England and Wales.

To produce this report the Environment Agency has also actively consulted with Natural England to ensure protected areas of land, designated sites and the wildlife habitats within these areas are considered appropriately. We also consulted the water companies, Severn Trent Water Ltd and South Staffordshire Water Ltd, to ensure we assessed the potential combined impacts of the water companies operating their drought orders on the River Severn whilst we operated the River Severn Drought Order.

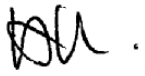
Version Control

Version 1: 2008-2009	AMEC 2008 draft report reviewed, scope for improvements produced.
Version 2: 2009-2011	Update project; water resource and water quality modelling, environmental impact assessments and complete report re-write.
Version 3 : January 2012	Draft report refined for initial consultation in preparation for building drought event.
Version 4: April 2013	Draft amended to address initial consultation feedback (from EA, EA Wales, CCW, NE, STWL & SSW) and organisational changes. Draft edited to reduce size and fill gaps.
Version 5: May 2013	Draft reformatted to appropriate Environment Agency template. Maps inserted and further content reduction.
Version 6: June 2013	Draft edited following APEM consultant's quality review against Defra guidance.
Version 7 - December 2013	Draft updated to address external consultation comments.

Update project sign off

River Severn Drought Order (RSDO) Environmental Report

Approved by:

(1) **Project Manager**		**(2)** **Project Executive and Environment Agency West Area Drought Manager**	
Name: Signature: Date:	Kate Evans  12 December 2013	Name: Signature: Date:	Mark Bowers  12 December 2013

(3) **Natural Resources Wales**	
Name: Signature: Date:	Rhian Jardine  22 January 2014
Comments:	*Please refer to the Further Work section and consultation responses.*

Activities Audit

	Item	Comments
Project management		
	Project timescale	2010-2013
	Project initiated, staffed and documentation set up.	Complete
	Communication with internal stakeholders	Specialists in hydrology, water quality, ecology, biodiversity, fisheries, water resource licensing and environment planning formed the internal project group and wider network. This included staff from West area, Midlands region, South West region and Environment Agency Wales (South East and North region). Advisory support was received from National and legal teams. Organisational change on 1 April 2013, Welsh Government formed Natural Resources Wales.
	Communication with other external stakeholders	Natural England, Countryside Council for Wales (now part of Natural Resources Wales), Severn Trent Water Ltd, South Staffordshire Water Ltd and the Canal and River Trust (formerly British Waterways).
	External consultation	Draft report published for external consultation July 2013-August 2013. Consultation was open to the public and key organisations contacted directly to encourage involvement. Responses included National Farmers Unions, United Utilities, Dŵr Cymru Welsh Water, the Institute for Civil Engineers and the above external stakeholders.
File location		
	Environment Agency project files at update project sign off	*N:\Midlands\FP\Environment Management\Monitoring\Water\Rivers\Hydrologists\West Area\Drought work\3 Drought Orders for West\Sev DO*
	Final report sharing with Natural Resources Wales at update project sign off	*O:\EADP\EADP2011\C - Midlands\Severn Drought Order*
	Final (working draft) report published on external website	Publication January 2014, to be located next to the Midlands Drought Plan or adjacent page via a clear link.

Future update time table

The River Severn Drought Order Environmental report will remain a live document, allowing for minor updates to be made as appropriate. However a set timetable for comprehensive reviews will also be set as the following;

- RSDO Environmental Report and supporting documents (e.g. HRA and SGS ER) to undergo a full review/update every 3-3.5 years or following a drought event. **Next programmed update: 2016/17**
- RSDO environmental monitoring programme to be reviewed annually (spring time recommended). This will include a summary of the data collected and a review of the sites and methods being used.

Executive summary

Droughts are infrequent events in the UK but when they do occur their impact can be significant. The Environment Agency has responsibility for alleviating the effects of drought on people, businesses and the environment through sensible management of water resources in England.

The River Severn is the UK's longest river. The majority of its catchment sits in England but substantial parts of it also sit in Wales. Since April 2013 the Environment Agency and Natural Resources Wales (NRW) have had joint responsibility for drought planning in the River Severn catchment. We are committed to working together where there is an environmental need or benefit; for drought planning it has been agreed the Environment Agency will take the lead in the River Severn catchment.

This environmental report has been written to support an application for a River Severn Drought Order. A drought order outlines the procedures we will use to better manage our water resources during prolonged or extreme spells of dry weather. Around six million people rely on the River Severn catchment for drinking water as well as a huge number of businesses, leisure clubs and wildlife. The Environment Agency and NRW ensure that the River Severn is able to support all of these uses without compromising the environment. We must decide how much water needs to be released to the river from both surface water and groundwater storage sources to balance the needs of the river against the demands of abstraction. This is called River Severn regulation, and involves legal responsibility under the Joint Clywedog Reservoir Act (1963).

The robustness of the water supply in the River Severn is judged by water levels in Llyn Clywedog reservoir in Wales. Procedures from the River Severn Drought Order will only be enforced when critical water levels in the reservoir are reached. The River Severn Drought Order would allow us to reduce the quantity of water released from the reservoir and restrict abstractions from the River Severn. This would preserve the remaining water resources and allow support to continue for longer to protect people and the environment against extended droughts.

Llyn Clywedog reservoir is the main surface water store used to support the River Severn. Without its support the river levels we need to protect could not be achieved. This would result in a reduction of flow and water levels down the River Severn.

The River Severn Drought Order is our final option for managing the impact of a severe drought in the catchment. It aims to protect public water supply and the environment along the river. We believe it is safer for everyone if we limit our water use earlier in order to be able to continue supporting the River Severn for longer during a drought. We believe that taking no precautionary action risks running out of water in the reservoir, which could lead to severe environmental and human impacts.

This report looks at the positive and negative impacts to the environment and people of implementing and not implementing a drought order for the River Severn. It considers the short (acute) and long term (chronic) impacts from modelled drought conditions; whether the impacts could result directly or indirectly because of the drought order; and whether they are likely to be temporary or permanent. The report also considers what the in combination impacts could be if the River Severn Drought Order was operated at the same time as the water company's drought orders, and the maximum Canal & River Trust abstraction for the Gloucester & Sharpness Canal.

In the short-term the River Severn Drought Order would seek to lower flows and water levels along the River Severn in order to make the water in Llyn Clywedog reservoir last longer in case the drought continues. Our modelling found that during this initial period flows along the river would be reduced and there could be some additional pressure on the environment. Water Framework Directive standards would not fail as a result of the River Severn Drought Order and water quality

would not be significantly impacted. Flows along the majority of the River Severn should not fall greatly below what is expected under natural drought conditions.

Our models found that if the drought continued and the drought order was not operated, water supply from Llyn Clywedog reservoir could run out. This could result in a severe impact on river levels, the environment and communities as no releases could be made. By reducing input from the reservoir earlier we preserve the stores for longer and enable releases to continue during the worst part of the drought. This would benefit all river users and the environment by preventing the upper River Severn catchment (below Llyn Clywedog reservoir) from drying up and maintaining higher flows and levels throughout the river.

In the long-term, the River Severn Drought Order would seek to conserve storage in Llyn Clywedog reservoir for subsequent years. This should accelerate refill by reducing the amount of rainfall needed to restock the reservoir in time for the following year. This would greatly reduce the impacts of any further dry winters and drought summers on the River Severn. More water would be available for a subsequent dry year and potentially prevent the need for a second River Severn Drought Order application. This means that the river could be regulated normally, which would maintain flows significantly higher than would naturally occur. People and the environment of the River Severn would benefit greatly, whilst neighbouring unsupported rivers may be suffering another drought year.

The impacts from operating the River Severn Drought Order are predicted to be temporary and are not expected to cause any new Water Framework Directive failures. Once normal rainfall returns, the environment should improve naturally and recover within one to three years. This is consistent with the expected natural drought recovery period. This means that although the drought conditions may cause environmental stress, the River Severn Drought Order is not predicted to make conditions worse, and would provide benefits to people and the environment, especially in the long term.

The in combination assessment with the water company drought orders on the River Severn, and the maximum abstraction for the Gloucester & Sharpness Canal, found the lower part of the River Severn and important migratory fish could be at risk of negative impacts under extreme conditions. There was a high amount of uncertainty because the Canal & River Trust abstractions do not currently require a licence and the quantity of water taken varies significantly, the risk will also change depending on what the tide height is and what time of year the drought occurs. To satisfy the Habitat's Directive and reduce the risk to the Severn Estuary, during River Severn Drought Order operation an abstraction cap of 300 Ml/d (figure subject to change) will be imposed on the Canal & River Trust when flows drop below 1200 Ml/d at Deerhurst[1].

Reports and data from previous periods when a drought order has been in operation have been used to assess the impact of the River Severn Drought Order both alone and in combination with other abstractions and discharges. Drought orders have been in operation in 1976, 1984 and 1989. Using this data we have modelled the likely impacts of the River Severn Drought Order on hydrology, water quality, ecology and fish, and designated sites. A separate Habitat Regulation Assessment (including Appropriate Assessment) has been produced for the Severn Estuary Natura 2000 site (Annex 1), and a separate Shropshire Groundwater Scheme Environmental Report (Annex 2) has been produced to consider its more local impacts.

[1] The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operation of the Gloucester and Sharpness Canal and the Bristol Water abstraction it supports, which the Trust are investigating. If sufficient evidence is provided to show a higher abstraction is justified then the 300Ml/d limit will be reviewed.

Crynodeb gweithredol

Digwyddiad prin yw sychder yn y Deyrnas Unedig ond pan fydd yn digwydd gall ei effaith fod yn sylweddol. Mae gan Asiantaeth yr Amgylchedd gyfrifoldeb am liniaru effeithiau sychder ar bobl, busnesau a'r amgylchedd trwy reolaeth synhwyrol ar adnoddau dŵr yn Lloegr.

Yr Afon Hafren yw afon hwyaf y DU. Mae rhan fwyaf ei ddalgylch yn Lloegr ond mae rhannau sylweddol ohono yng Nghymru. Ers Ebrill 2013 mae Asiantaeth yr Amgylchedd a Chyfoeth Naturiol Cymru (NRW) wedi cael cyd-gyfrifoldeb am gynllunio sychder yn nalgylch yr Afon Hafren. Rydym yn ymrwymedig i gydweithio lle mae angen neu fudd amgylcheddol; ar gyfer cynllunio sychder cytunwyd y bydd Asiantaeth yr Amgylchedd yn arwain yn nalgylch yr Afon Hafren.

Ysgrifennwyd yr adroddiad amgylcheddol hwn er mwyn cefnogi cais am Orchymyn Sychder Afon Hafren. Mae gorchymyn sychder yn amlinellu'r gweithdrefnau y byddwn yn eu defnyddio i reoli ein hadnoddau dŵr yn well yn ystod cyfnodau hir neu eithafol o dywydd sych. Mae tua chwe miliwn o bobl yn dibynnu ar ddalgylch yr Afon Hafren am ddŵr yfed yn ogystal â nifer anferth o fusnesau, clybiau hamdden a bywyd gwyllt. Mae Asiantaeth yr Amgylchedd ac NRW yn sicrhau bod yr Afon Hafren yn gallu cefnogi'r holl ddefnyddiau hyn heb beryglu'r amgylchedd. Mae'n rhaid inni benderfynu faint o ddŵr sydd angen ei ryddhau i'r afon o ffynonellau storio dŵr wyneb a dŵr daear er mwyn cydbwyso anghenion yr afon yn ôl gofynion tynnu dŵr. Gelwir hyn yn rheoleiddio Afon Hafren, ac mae'n cynnwys cyfrifoldeb cyfreithiol dan Gyd-ddeddf Cronfa Ddŵr Clywedog (1963).

Bernir cadernid y cyflenwad dŵr yn yr Afon Hafren gan lefelau dŵr yng nghronfa ddŵr Llyn Clywedog yng Nghymru. Gorfodir gweithdrefnau'r Gorchymyn Sychder Afon Hafren dim ond pan gyrraeddir lefelau dŵr difrifol yn y gronfa ddŵr. Byddai'r Gorchymyn Sychder Afon Hafren yn caniatáu inni leihau'r maint o ddŵr a ryddheir o'r gronfa ddŵr a chyfyngu ar dynnu dŵr o'r Afon Hafren. Byddai hyn yn cadw'r adnoddau dŵr sy'n weddill a chaniatáu i gymorth barhau'n hwy er mwyn amddiffyn pobl a'r amgylchedd yn erbyn sychderau estynedig.

Cronfa ddŵr Llyn Clywedog yw'r prif storfa ar gyfer dŵr wyneb a ddefnyddir i gefnogi'r Afon Hafren. Heb ei chymorth ni allem gyflawni'r lefelau mae angen inni eu hamddiffyn yn yr afon. Byddai hyn yn achosi gostyngiad yn lefelau llif a dŵr i lawr yr Afon Hafren.

Y Gorchymyn Sychder Afon Hafren yw ein hopsiwn olaf ar gyfer rheoli effaith sychder llym yn y dalgylch. Mae'n anelu at amddiffyn y cyflenwad dŵr cyhoeddus a'r amgylchedd ar hyd yr afon. Credwn ei fod yn ddiogelach i bawb os cyfyngwn ar ein defnydd o ddŵr ynghynt er mwyn gallu parhau i gefnogi'r Afon Hafren am gyfnod hwy yn ystod sychder. Credwn fod peidio â chymryd camau gweithredu rhagofalus yn peryglu rhedeg allan o ddŵr yn y gronfa ddŵr, a allai arwain at effeithiau amgylcheddol a dynol difrifol.

Mae'r adroddiad hwn yn edrych ar yr effeithiau cadarnhaol a negyddol ar yr amgylchedd a phobl sydd ynghlwm wrth weithredu a pheidio â gweithredu gorchymyn sychder ar gyfer yr Afon Hafren. Mae'n ystyried effeithiau tymor byr (aciwt) a hirdymor (cronig) amodau sychder a fodelwyd; a allai'r effeithiau ymddangos yn uniongyrchol neu'n annuniongyrchol oherwydd y gorchymyn sychder; ac a ydynt yn debygol o fod dros dro neu'n barhaol. Hefyd mae'r adroddiad hwn yn ystyried beth allai'r effeithiau cyfun fod pe byddai'r Gorchymyn Sychder Afon Hafren yn cael ei weithredu ar yr un pryd â gorchmynion sychder y cwmni dŵr, a thyniad dŵr mwyaf yr Ymddiriedolaeth Camlesi ac Afonydd ar gyfer camlas Gloucester & Sharpness.

Yn y tymor byr byddai'r Gorchymyn Sychder Afon Hafren yn ceisio lleihau llifau a lefelau dŵr ar hyd yr Afon Hafren er mwyn peri i'r dŵr yng nghronfa ddŵr Llyn Clywedog barhau am gyfnod hwy rhag ofn bod y sychder yn parhau. Canfu ein modelu y byddai llifau ar hyd yr afon yn ystod y cyfnod cychwynnol hwn yn cael eu lleihau a gallai fod rhywfaint o bwysau ychwanegol ar yr amgylchedd. Ni fyddai safonau Cyfarwyddeb Fframwaith Dŵr yn methu o ganlyniad i'r Gorchymyn

Sychder Afon Hafren ac ni fyddai effaith sylweddol ar ansawdd dŵr. Ni ddylai llifau ar hyd rhan fwyaf yr Afon Hafren syrthio llawer yn is na'r hyn a ddisgwylir dan amodau sychder naturiol.

Canfu ein modelau y gallai'r cyflenwad dŵr o gronfa ddŵr Llyn Clywedog ddod i ben pe byddai'r sychder yn parhau ac na weithredid y gorchymyn sychder. Gallai hyn achosi effaith lem ar lefelau afonydd, yr amgylchedd a chymunedau gan na ellid gwneud unrhyw ollyngiadau. Trwy leihau mewnbwn o'r gronfa ddŵr ynghynt rydym yn cadw'r storfeydd am gyfnod hwy ac yn galluogi gollyngiadau i barhau yn ystod rhan waethaf y sychder. Byddai hyn o les i holl ddefnyddwyr yr afon a'r amgylchedd trwy atal dalgylch uchaf yr Afon Hafren (islaw cronfa ddŵr Llyn Clywedog) rhag sychu a chynnal llifau a lefelau uwch trwy gydol yr afon.

Yn yr hirdymor, byddai'r Gorchymyn Sychder Afon Hafren yn ceisio cadw storfeydd yng nghronfa ddŵr Llyn Clywedog ar gyfer blynyddoedd dilynol. Dylai hyn gyflymu ail-lenwi trwy leihau faint o law y byddai ei angen ar gyfer ail-lenwi'r gronfa ddŵr mewn da bryd am y flwyddyn ddilynol. Byddai hyn yn lleihau effeithiau unrhyw aeafau sych a hafau sychder eraill ar yr Afon Hafren yn fawr. Byddai mwy o ddŵr ar gael ar gyfer blwyddyn sych ddilynol ac o bosibl byddai'n atal yr angen am ail gais am Orchymyn Sychder Afon Hafren. Mae hyn yn golygu y gellid rheoleiddio'r afon yn arferol, a fyddai'n cynnal llifau sylweddol o uwch na'r hyn a fyddai'n digwydd yn naturiol. Byddai pobl ac amgylchedd yr Afon Hafren yn elwa'n fawr, tra gallai afonydd digymorth gerllaw ddioddef blwyddyn arall o sychder.

Rhagwelir y bydd effeithiau gweithredu'r Gorchymyn Sychder Afon Hafren dros dro yn unig ac ni ddisgwylir y byddent yn achosi unrhyw fethiannau newydd ynghylch y Gyfarwyddeb Fframwaith Dŵr. Ar ôl i law arferol ddychwelyd, dylai'r amgylchedd wella'n naturiol ac adfer o fewn un i dair blynedd. Mae hyn yn gyson â'r cyfnod naturiol disgwyledig ar gyfer adfer ar ôl sychder. Mae hyn yn golygu, er y gallai'r amodau sychder achosi pwysau amgylcheddol, na ragwelir y bydd y Gorchymyn Sychder Afon Hafren yn gwneud pethau'n waeth, a byddent yn darparu manteision i bobl a'r amgylchedd, yn enwedig yn yr hirdymor.

Canfu'r asesiad cyfun gyda gorchmynion sychder y cwmni dŵr ar yr Afon Hafren, a'r tyniad dŵr mwyaf ar gyfer camlas Gloucester & Sharpness, y gallai rhan isaf yr Afon Hafren a physgod ymfudol pwysig fod mewn perygl oherwydd effeithiau negyddol dan amodau eithafol. Roedd cryn dipyn o ansicrwydd gan nad yw tyniadau dŵr yr Ymddiriedolaeth Camlesi ac Afonydd angen trwydded ar hyn o bryd ac mae maint y dŵr a dynnir yn amrywio'n sylweddol, hefyd bydd y risg yn newid gan ddibynnu ar uchder y llanw ac adeg y flwyddyn mae'r sychder yn digwydd. Rydym yn gweithio gyda'r Ymddiriedolaeth Camlesi ac Afonydd i ganfod datrysiadau er mwyn lleihau'r risg cyn bod angen cais am Orchymyn Sychder yr Afon Hafren. I fodloni'r Gyfarwyddeb Cynefinoedd ac i leihau'r risg i Aber yr Hafren, yn ystod gweithrediad Gorchymyn Sychder yr Hafren, gosodir cap tyniad o 300 Ml/d (ffigwr yn amodol i newid) ar yr Ymddiriedolaeth Camlesi ac Afonydd ar y tyniad hwn pan fydd llif yn gostwng islaw 1200 Ml/d yn Deerhurst[2].

Defnyddiwyd adroddiadau a data o gyfnodau blaenorol pan oedd gorchymyn sychder yn cael ei weithredu er mwyn asesu effaith y Gorchymyn Sychder Afon Hafren ar ei ben ei hunan ac ar y cyd â thyniadau a gollyngiadau eraill fel ei gilydd. Gweithredwyd gorchmynion sychder yn 1976, 1984 a 1989. Gan ddefnyddio'r data hwn rydym wedi modelu effeithiau tebygol y Gorchymyn Sychder Afon Hafren ar hydroleg, ansawdd dŵr, ecoleg a physgod, a safleoedd dynodedig. Cynhyrchwyd Asesiad Rheoleiddio Cynefinoedd (gan gynnwys Asesiad Priodol) ar gyfer safle Natura 2000 yr Aber Hafren (Atodiad 1), a chynhyrchwyd Adroddiad Amgylcheddol ar Gynllun Dŵr daear Swydd Amwythig ar wahân (Atodiad 2) er mwyn ystyried ei effeithiau mwy lleol.

[2] Mae'r Ymddiriedolaeth Camlesi ac Afonydd wedi nodi pryderon y gallai 300Ml/d gyflwyno risg i'w gwaith o weithredu Camlas Gloucester & Sharpness a'r tyniad Bristol Water mae'n ei gefnogi, yr hyn mae'r Ymddiriedolaeth yn ymchwilio iddo. Os gellir darparu tystiolaeth ddigonol i gyfiawnhau tyniad uwch, yna byddwn yn adolygu'r terfyn tynnu.

Contents

Supporting Documents (separate)

APPENDICES: River Severn Drought Order Appendices

ANNEX1: Habitat's Regulations Assessment (River Severn Drought Order (31 October 2013))

ANNEX 2: Shropshire Groundwater Scheme Drought Order Environmental Report (25 October 2013)

Non Technical Summary

Purpose of this Environmental Report

Droughts are infrequent events in the UK but when they do occur their impact can be significant. The Environment Agency has responsibility for alleviating the effects of drought on people, businesses and the environment through sensible management of water resources in England. The Environment Agency also leads on drought management for the River Severn in Wales, in consultation with Natural Resources Wales.

Drought order applications must be accompanied by an environmental report, which provides an assessment of the potential environmental effects of the order alone or in combination with other known plans, drought permits/orders and abstractions. The requirements of an environmental report are defined in Defra guidance (Defra, 2011). This environmental report is to accompany an application for the River Severn Drought Order. A separate environmental report has been produced for the Shropshire Groundwater Scheme Drought Order (ANNEX 2), which may form part of the River Severn Drought Order application according to the type and duration of drought.

Catchment Background

The River Severn is the longest river in Great Britain, travelling approximately 354 km (220 miles) from its source in Plynlimon down to the Severn Estuary. Excluding the River Wye, the catchment covers approximately 11,420 km^2 with an estuary over five miles wide. The Severn has twenty one tributaries and flows through four counties, Powys, Shropshire, Worcestershire and Gloucestershire.

The River Severn is an artificial system; water stored within Llyn Clywedog and Lake Vyrnwy reservoirs in Powys, and the Shropshire Groundwater Scheme in Shropshire are used to maintain a minimum average flow at Bewdley gauging station. The Environment Agency and Natural Resources Wales manage the daily releases according to the Llyn Clywedog reservoir Joint Authority Act (1963), in cooperation with water companies and the Canal & River Trust. This is known as River Severn regulation and is designed to provide a major source of water for public consumption, industry, electricity generation, navigation and agriculture, whilst maintaining an acceptable flow for the purposes of fisheries, conservation, recreation, effluent dilution and other in-river uses.

River Severn Drought Order

In normal and dry years the water available for River Severn regulation from Llyn Clywedog, Lake Vyrnwy and the Shropshire Groundwater Scheme are sufficient. In the event of a severe drought it is possible that these sources may become depleted and need temporary changes in how we operate the system to protect people and the environment.

It is expected that tributaries of the River Severn and neighbouring rivers would be experiencing significant drought stress and abstraction restrictions, whilst regulation would have largely protected the River Severn during the developing drought. The River Severn Drought Order is designed to ration out the remaining regulation water used to support the River Severn, balancing human and environmental needs during a severe drought.

The River Severn Drought Order aims to reduce the risk of running out of regulation water, by maintaining lower flows along the River Severn the remaining water can be used for longer. If the

regulation system were to run out of water, river levels and flows along the River Severn would drop suddenly and some sections may dry up. Water supplies would be threatened and significant environmental damage would be expected. The River Severn Drought Order is the Environment Agency's final drought management option; other measures would be in force, including abstraction restrictions and public appeals.

The River Severn Drought Order aims to ration out water by:

- reducing the target for prescribed flow at Bewdley from 850 Ml/d to 730 Ml/d;
- capping the maximum release from Llyn Clywedog at 300 Ml/d instead of 500 Ml/d;
- imposing a 5 percent reduction on non spray irrigation licensed abstractions; and
- imposing restrictions on the Canal & River Trust abstractions for the Montgomery Canal in Wales (as detailed in the Operating Rules for the River Severn Resource/Supply System) and the Gloucester & Sharpness Canal in England (new restriction).

The River Severn Drought Order is triggered by the amount of water in Llyn Clywedog reservoir, and not by the amount of water flowing in the river. Llyn Clywedog reservoir was constructed solely to provide water for the Severn regulation system, and represents the largest supply of water currently available to support the River Severn and is critical to manage the water efficiently. Storage levels in the reservoir are monitored against the control curves to track the available water resources and raise awareness of developing dry conditions.

Previous River Severn Drought Order applications

Variations of the River Severn Drought Order were operated in 1976, 1984 and 1989. No drought order applications have been made since these events; most notably the 1995-1996 drought event did not trigger the drought order requirement.

How often would a River Severn Drought Order be needed?

The timing of any drought order would depend on when rainfall shortages occurred, and whether the drought lasted long enough for the drought order to be implemented. A River Severn Drought Order is only expected to be needed under long term and severe drought conditions. Due to the water resource support given to the River Severn as part of the regulation system, nearby river systems and tributaries would be expected to be in a more seriously stressed condition.

The Environment Agency predicts the River Severn Drought Order would be needed on average once in 50 years. This is based on the number of times the drought order has been implemented since Llyn Clywedog was built, and also considers the extra water now available to support the River Severn. It is important to note the probability of a River Severn Drought Order application being made is greater than the probability of the River Severn Drought Order being ‘implemented.’

Drought Scenarios

The resilience of the River Severn catchment under prolonged drought has been tested using the surface water model Aquator. Modelling indicated a River Severn Drought Order implementation would no longer be triggered by droughts of the same magnitude as 1976 because more water resources have been developed. In order to test the drought order, 1975-1976 drought conditions were prolonged and increased to create theoretical ‘Acute’ and ‘Chronic’ drought conditions. The Acute condition tested two dry winters/springs and an acute drought summer situation, while the Chronic condition built on this to create a third dry winter/spring followed by a second acute summer drought.

For each condition, three model scenarios were tested; a baseline ‘Do Nothing' scenario, a ‘Drought Order Only’ scenario and a ‘Full In-Combination’ scenario. The 'Do Nothing' scenario represented conditions under the Acute and Chronic conditions if normal Severn regulation continued, without the operation of a drought order. The 'Drought Order Only' scenario represented the Acute and Chronic conditions, all existing abstractions and discharges, and the operation of the River Severn Drought Order. The 'Full In-Combination' scenario builds on this, adding potential water company drought permit/order operations to represent the predicted worst case situation.

Summary of Environmental Effects

Water Resources (Hydrology)

River flows and water levels would initially be reduced by the River Severn Drought Order but should not reduce greatly below the natural drought flows and levels that would occur if no regulation support were available. The River Severn Drought Order modelling indicated no additional ecological flow target (WFD standards) failures beyond what the natural drought was predicted to cause. The duration of failure may be slightly increased but all impacts would be temporary and unlikely to have a significant impact on the ecology.

If a drought continued without rainfall for a long time (i.e. Acute condition), or a third dry winter occurred (i.e. Chronic condition), the modelling showed clear benefits associated with operation of the River Severn Drought Order. Prolonging storage in Llyn Clywedog would prolong compensation releases and reduce the risk of the upper section of the river drying up, which was a risk identified if the drought order were not operated. Water saved by operating the drought order was predicted to allow Llyn Clywedog to refill more quickly. This ensured storage was higher for the following year and potentially prevents the need for a second drought order application if another drought followed. This would have significant benefits to people and the environment.

The lower tidal River Severn, above the Severn Estuary Natura 2000 designation, was found to be most at risk to low flows and levels under the 'Full In-Combination' scenarios. There was high uncertainty around the maximum abstraction the Canal and River Trust may take for the Gloucester & Sharpness Canal. This operation is currently exempt from licensing. An operating agreement between the Environment Agency and the Canal & River Trust ensures the Severn Estuary is voluntarily protected during normal to low flow conditions, however droughts are not covered.

Water Resources (Other Abstractors)

Before a River Severn Drought Order application is made, it is anticipated the majority of impacts on water abstractors along the River Severn would have already come into force as part of the Environment Agency's water resource and drought management procedures (i.e. they are not directly related to the drought order). Direct implications of the River Severn Drought Order for water companies with abstractions from the River Severn would include enforcement of 5 percent reductions to abstraction licenses and potential for further reductions (up to 20 percent) that could be sought if storage at Llyn Clywedog crossed the 18 percent emergency storage curve. There would be a degree of flexibility around when restrictions could be relaxed temporarily and/or the drought order could be fully removed. However a drought order can legally remain in force for six months, or a year if extensions are sought.

Modelling indicated the River Severn Drought Order could operate for approximately 144 days from 25 August, for which the minimum 5 percent reduction would apply. The 18 percent emergency storage curve was predicted to be crossed for a total 22 days between 15 October and 6 November. Potential impacts on water company abstractions would alter according to current abstraction demands and whether or not the Environment Agency requested further abstraction reductions. Close discussions would therefore be held with the relevant water companies.

There is a risk of conflicting interests between some water company drought permits/orders (identified in their own Drought Plans) and the River Severn Drought Order. The River Severn Drought Order would seek to lower River Severn flows and lower abstraction pressures to enable regulation to last for longer to support people and the environment, while water companies with abstractions directly from the River Severn would seek to maintain or increase abstraction solely to support public water supplies. The Environment Agency and the relevant water companies would meet early to discuss any potential conflict. If no alternative could be found the water companies would be directed to apply to the Secretary of State for a drought order on the grounds of Imperative Reasons of Overriding Public Interest (IROPI).

The Montgomery Canal Agreement 1988 contains abstraction restrictions under the River Severn Drought Order operation. Modelling suggested the River Severn Drought Order would be of benefit to the Montgomery Canal abstraction, as even though it would cap abstraction quantities for longer, it would reduce the period of no abstraction enforced if Llyn Clywedog storage falls below 25 percent. Modelling suggested approximately 140 days of restrictions from August onwards, with 76 days of no permitted abstraction between 16 September and 30 November, compared to 120 days between 2 September and 30 December if no drought order were operated.

The Gloucester & Sharpness Canal abstraction is known to have a potentially significant impact on the lower tidal Severn and inflows to the Severn Estuary depending on tide heights and the volume of abstraction. Abstraction during drought periods is not covered by the 1998 Operating Agreement with the Environment Agency, and historic River Severn Drought Order applications did not include specific restrictions for this canal. Due to the Habitat Regulation Assessment findings a new restriction is being introduced under the River Severn Drought Order to mitigate potential risk to the Natura 2000 site. The maximum amount of water that can be taken for the canal when the River Severn Drought Order is in place will be 300 Ml/d, to be enforced when flows at Deerhurst drop below 1200 Ml/d. The restriction aims to protect environmental needs whilst still allowing the Canal & River Trust enough water to meet its main obligations. The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to its operation of the canal and work is ongoing to assess the full impact this restriction could have. If sufficient evidence can be provided to show a higher abstraction is justified then the abstraction limit will be reviewed.

The Canal & River Trust's internal drought management flow trigger at Deerhurst was used to assess the potential impact of the River Severn Drought Order operation on navigation. The Acute 'Do Nothing' scenario identified 106 days of potential impact between 2 July and 1 November and the Chronic 'Do Nothing' scenario 101 days. When compared with the 'Drought Order Only' and 'Full In-Combination' scenarios, 38 of these days coincided with the activation of the River Severn Drought Order. Owing to the consistency compared to the 'Do Nothing' scenarios and period of River Severn Drought Order operation, no additional canal closures are predicted as a result of activating the drought order when compared to the Canal & River Trust's 1150 Ml/d trigger to consider drought restrictions.

Testing the proposed new abstraction cap of 300 Ml/d (figure subject to change) concluded the Canal & River Trust abstraction from the River Severn was impacted for 38 days out of the year; all days which had already crossed the 1150 Ml/d Deerhurst trigger for considering drought restriction implementation and potential canal closure.

Bristol Water's public water supply abstraction at Purton is taken directly from the Gloucester & Sharpness Canal. Due to its proximity to the Severn Estuary there is a risk of saline intrusion into the canal. This is normally mitigated by the Operating Agreement rules, which are all linked to tide heights and flows at Deerhurst. Reports identified that during the 1976 drought, salinity was reaching critical levels at Purton just before rainfall returned. The theoretical Acute and Chronic conditions modelled for the River Severn Drought Order extended this drought period, increasing the risk of saline intrusion up the lower tidal Severn and therefore the risk of saline water entering the Gloucester & Sharpness canal.

With careful water management and the continued interception of several tributaries, the Environment Agency believe a 300 Ml/d restriction from the River Severn, only when flows drop below 1200 Ml/d at Deerhurst, should still allow the Canal & River Trust to supply Bristol Water with enough water. The Canal & River Trust have raised concerns that 300 Ml/d may not be sufficient to meet all their obligations. In respect of this concern the Environment Agency has committed to working with the Canal & River Trust to investigate the restriction figure further.

Water Quality

Comparing the 'Drought Order Only' and 'Do Nothing' scenarios (under both Acute and Chronic conditions), the River Severn Drought Order modelling predicted no additional water quality WFD failures. Water quality was found to improve with the operation of the River Severn Drought Order because the higher minimum flows created greater dilution. Nutrients and phosphates were found to increase as a consequence of the natural drought; but the River Severn Drought Order had no negative impacts on concentrations of these parameters.

Ecology (macroinvertebrates and macrophytes)

Ecological impacts of the River Severn Drought Order were assessed with reference to potential effects upon river macroinvetebrate communities at various points along the river. Historical information from the 1975/76 drought and several subsequent drought periods provided indications of potential future impacts, while predictions of flow patterns allowed an assessment of severity of impact and how these may change if the drought order were applied. Close to the Llyn Clywedog and Lake Vyrnwy reservoirs, the drought order would require a compensation flow higher than the river flow which would be expected naturally under drought conditions and therefore low flow sensitive taxa would benefit. However, there would be potential detrimental impacts: the large volume of water released would necessitate a longer time to replenish the reservoir following the end of the drought, thereby reducing natural flow variability while the reservoir refills. Further downstream, releases under the drought order would reduce the negative impacts on the macroinvetebrate fauna, particularly because a larger proportion of the river bed would remain immersed than predicted under natural drought conditions. Water quality has improved along much of the river since the 1975/6 drought, making this less likely to cause problems under future drought conditions.

Towards the lower reaches of the River Severn, predictions of ecological impacts are more difficult, as the data available are patchy. There is also too little information to predict the effect of a drought, or the mitigating effect of the drought order, on macrophytes.

Ecology (Fish of the Severn Corridor)

An assessment of potential impacts on fish was conducted by considering flow requirements of different species and examining hydrographs indicating predicted flows based on Acute and Chronic low flow conditions under the three drought order scenarios ('Drought Order Only', 'Full In-Combination' and 'Do Nothing'). Under the Acute drought condition it was considered that the River Severn Drought Order could cause impacts of moderate significance at Lower Parting; minor significance at Afon Clywedog, Afon Vyrnwy, Bewdley, Saxons Loade and Haw Bridge/Deerhurst; and negligible impacts at Buildwas. Under the Chronic drought condition the significance of impact was considered to be the same at each location with the exception of Afon Clywedog, where impacts were assessed to be of moderate significance. Overall, it was concluded that operation of the River Severn Drought Order would be beneficial to the fish population in the upper River Severn although further downstream, and in particular near the estuary, the benefits would be greatly reduced.

Ecology (Invasive Non Native Species)

Specific within the area covered by the River Severn Drought Order, only American Signal Crayfish, Giant Hogweed, Japanese Knotweed, Himalayan Balsam and Mink are likely to be problematic. Considering the individual reproduction and dispersion methods for each of these

species did not identify an increased risk through the River Severn Drought Order implementation, no adverse impact was concluded.

Designated Sites connected to the River Severn

All the nationally and internationally designated sites connected to the River Severn by water pathways were assessed for potential impact from the River Severn Drought Order. Thirteen sites were taken through the Habitat's Directive Assessment screening process because they could potentially be sensitive to lowered water levels and flows. Only the Severn Estuary was found to be at potential risk, all other sites were concluded as having no impact from the River Severn Drought Order.

Severn Estuary (Natura 2000 site)

A Habitats Regulations Assessment was carried out for the River Severn Drought Order, working closely with Natural England and the Countryside Council for Wales, which now forms part of Natural Resources Wales. The assessment concluded the River Severn Drought Order alone was unlikely to have a significant effect on the designated estuary feature, sub features or supporting habitats. The main area of risk was identified as the lower tidal Severn, just upstream of the designated Estuary site, extending upstream to where the River Severn splits at Gloucester. The assessment considered the in combination operation of the Canal & River Trusts maximum potential abstraction for the Gloucester & Sharpness Canal, and water company drought Permits/Orders. The assessment was unable to conclude no significant effect on migratory fish, the greatest uncertainty remaining around the exempt operations of the Gloucester & Sharpness Canal and what the maximum abstraction might be during a severe drought.

As a competent authority under the Habitat's Directive we have to either mitigate against potential environmental harm, or apply for the River Severn Drought Order on the grounds of Imperative Reasons of Overriding Public Interest. The most appropriate option to balance water needs and the requirements of the Habitat's Directive was found to be limiting the abstraction to the Gloucester & Sharpness Canal. The Habitats Regulations Assessment was able to conclude a maximum abstraction of 300 Ml/d to the canal (in-combination) was unlikely to cause harm to the Natura 2000 site designations. Applications for this Drought Order will therefore now include an abstraction cap of 300 Ml/d on the Canal & River Trust, when flows at Deerhurst drop below 1200 Ml/d. If the Drought Order is granted, the conditions set would become legally enforceable. This action should successfully mitigate any potential harm to the Natura 2000 site and satisfy the Habitat Directive requirements.

The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operation of the Gloucester & Sharpness Canal and the Bristol Water abstraction it supports, work is ongoing to assess the full impact this restriction could have. If sufficient evidence can be provided to show a higher abstraction is justified then the abstraction limit will be reviewed.

Water Framework Directive

The potential impacts of the River Severn Drought Order are considered to come under Article 4.6 of the Water Framework Directive (WFD), allowing for temporary deterioration as a *'result of circumstances of natural cause which are exceptional or could not reasonably have been foreseen, in particular extreme floods and prolonged droughts.'* Modelling indicated flows and water quality would deteriorate below local WFD targets as part of the natural drought process, regardless of whether the River Severn Drought Order was operated or not. Data from historic drought events support this conclusion, with regulated flows under historical drought order operations having exceeded or equalled what would have naturally occurred at Bewdley and Haw Bridge. The River Severn Drought Order is not expected to delay the recovery of the environment following the drought event, having only a temporary impact on surface water flows. It is concluded there will be no significant impact on WFD targets.

Archaeology and Cultural Heritage

No impact was concluded on archaeology and cultural heritage from operating the River Severn Drought order.

Navigation and Recreation

No information exists which relates volumes and levels in Llyn Clywedog reservoir to recreational use. Despite this, it can be assumed implementation of the River Severn Drought Order would have a positive impact on sailing and boating activities on Lyn Clywedog by conserving water resources and prolonging the sailing season compared to not operating the drought order. The post drought recovery time, including time for the reservoir to refill, would also be reduced by operating the drought order. This would subsequently reduce the duration of drought impact on the sailing club and help to protect against a second year of impact.

No information was found to relate volumes and levels in Lake Vyrnwy reservoir to recreational use. The River Severn Drought Order does not seek to alter the maximum quantity of water released from the reservoir compared to normal operation, therefore no impact was concluded.

Navigation along the River Severn from the middle to lower catchment would be impacted by the lowered water levels experienced during a drought, making passage over weirs and through locks limited depending on the drought severity. During 1995 commercial vessels experienced considerable difficulty in navigating between Gloucester and Tewkesbury with a water depth of only approximately 1.44 m. The degree of impact is likely to vary locally and be exacerbated by the River Severn Drought Order and in combination abstractions. Taking a worst case approach, navigation by the majority of vessels during droughts of the modelled magnitude could be largely prevented until high rainfall events return.

Angling will be impacted by the naturally falling water levels, initially having a beneficial effect upon fish catches, regardless of whether the drought order is operated or not. Extremely low levels may have adverse effects on fish survival, particularly in the lower catchment where locks and weirs are extensive. If angling is considered to be leading to additional stress on fish it may be necessary to introduce a temporary cessation of fishing activities. The duration of any restrictions is unlikely to be different whether the River Severn Drought Order is operated or not, therefore no additional impact is expected on angling.

Crynodeb Annhechnegol

Diben yr Adroddiad Amgylcheddol hwn

Digwyddiad prin yw sychder yn y Deyrnas Unedig ond pan fydd yn digwydd gall ei effaith fod yn sylweddol. Mae gan Asiantaeth yr Amgylchedd gyfrifoldeb am liniaru effeithiau sychder ar bobl, busnesau a'r amgylchedd trwy reolaeth synhwyrol ar adnoddau dŵr yn Lloegr. Mae Asiantaeth yr Amgylchedd hefyd yn arwain ar reolaeth sychder ar gyfer yr Afon Hafren yng Nghymru, gan ymgynghori â Chyfoeth Naturiol Cymru.

Mae'n rhaid i geisiadau am orchymyn sychder ddod gydag adroddiad amgylcheddol, sy'n darparu asesiad o effeithiau amgylcheddol posibl y gorchymyn ar ei hunan neu ar y cyd â chynlluniau eraill hysbys, trwyddedau/gorchmynion sychder a thyniadau dŵr. Diffinir gofynion adroddiad amgylcheddol mewn cyfarwyddyd gan Defra (Defra, 2011). Mae'r adroddiad amgylcheddol hwn i ddod gyda chais am y Gorchymyn Sychder Afon Hafren. Cynhyrchwyd adroddiad amgylcheddol ar wahân ar gyfer y Gorchymyn Sychder Dŵr Daear Sir Amwythig, a allai ffurfio rhan o'r cais am Orchymyn Sychder Afon Hafren yn ôl math a hyd y sychder.

Cefndir y Dalgylch

Yr Afon Hafren yw'r afon hwyaf ym Mhrydain Fawr, yn teithio oddeutu 354 km (220 o filltiroedd) o'i tharddle ym Mhumlumon i lawr i'r Aber Hafren. Ac eithrio'r Afon Gwy, mae'r dalgylch yn cynnwys oddeutu 11,420 km^2 gydag aber sy'n fwy na 5 milltir o led. Mae gan yr Hafren 21 o is-afonydd ac mae'n llifo trwy 4 sir, Powys, Sir Amwythig, Sir Gaerwrangon a Sir Gaerloyw.

Mae'r Afon Hafren yn system artiffisial; defnyddir dŵr a gedwir o fewn cronfeydd dŵr Llyn Clywedog a Llyn Fyrnwy ym Mhowys, a Chynllun Dŵr Daear Swydd Amwythig yn Swydd Amwythig er mwyn cynnal llif cyfartalog lleiaf yng ngorsaf mesur Bewdley. Mae Asiantaeth yr Amgylchedd a Chyfoeth Naturiol Cymru'n rheoli'r rhyddhad dyddiol yn ôl Deddf Cyd-awdurdod cronfa ddŵr Llyn Clywedog (1963), ar y cyd gyda chwmnïau dŵr a'r Ymddiriedolaeth Afonydd a Chamlesi. Gelwir hyn yn rheoleiddio'r Afon Hafren, wedi'i gynllunio i ddarparu ffynhonnell fawr o ddŵr ar gyfer defnydd gan y cyhoedd, diwydiant, cynhyrchu trydan, llywio ac amaethyddiaeth, wrth gynnal llif derbyniol at ddibenion pysgodfeydd, cadwraeth, hamdden, gwanhau carthffrydiau a defnyddiau eraill 'yn yr afon'.

Gorchymyn Sychder Afon Hafren

Mewn blynyddoedd arferol a sych mae'r dŵr ar gael ar gyfer rheoleiddio Afon Hafren o Lyn Clywedog, Llyn Fyrnwy a Chynllun Dŵr Daear Swydd Amwythig yn ddigonol. Os digwydd sychder llym mae'n bosibl y gallai'r ffononellau hyn fynd yn llai a gallent fod angen newidiadau dros dro i'r ffordd rydym yn gweithredu'r system i amddiffyn pobl a'r amgylchedd.

Disgwylir y byddai is-afonydd yr Afon Hafren ac afonydd gerllaw yn profi pwysau sylweddol oherwydd sychder a chyfyngiadau ynghylch tynnu dŵr, tra byddai rheoleiddio wedi amddiffyn yr Afon Hafren yn ystod y sychder a oedd yn datblygu. Cynllunir y Gorchymyn Sychder Afon Hafren i ddogni'r dŵr rheoleiddio sy'n weddill a ddefnyddir i gefnogi'r Afon Hafren, yn cydbwyso anghenion dynol ac amgylcheddol yn ystod sychder llym.

Mae'r Gorchymyn Sychder Afon Hafren yn anelu at leihau'r risg y bydd dŵr rheoleiddio'n dod i ben, trwy gynnal llifau is ar hyd yr Afon Hafren gellir defnyddio'r dŵr sy'n weddill am fwy o amser. Pe byddai'r system reoleiddio'n rhedeg allan o ddŵr, byddai lefelau a llifau afonydd ar hyd yr Afon

Hafren yn lleihau'n sydyn a gallai rhai adrannu sychu'n gyfan gwbl. Byddai cyflenwadau dŵr yn cael eu bygwth a disgwylid niwed amgylcheddol sylweddol. Y Gorchymyn Sychder Afon Hafren yw opsiwn rheoli sychder olaf Asiantaeth yr Amgylchedd; byddai mesurau eraill mewn grym, gan gynnwys cyfyngiadau ar dynnu dŵr ac apeliadau at y cyhoedd.

Mae'r Gorchymyn Sychder Afon Hafren yn anelu at ddogni dŵr trwy:

- leihau'r targed ar gyfer llif rhagnodedig yn Bewdley o 850 Ml/d i 730 Ml/d;
- capio'r rhyddhad mwyaf o Lyn Clywedog ar 300 Ml/d yn lle 500 Ml/d;
- gorfodi gostyngiad o 5% ar dyniadau dŵr trwyddedig ar gyfer dyfrio di-chwistrell; a
- gorfodi cyfyngiadau ar dyniadau dŵr yr Ymddiriedolaeth Afonydd a Chamlesi ar gyfer camlas Trefaldwyn yng Nghymru (fel y manylir arno yn y Rheolau Gweithredu ar gyfer System Adnoddau/Cyflenwi Afon Hafren) a chamlas Gloucester a Sharpness yn Lloegr (cyfyngiad newydd).

Sbardunir y Gorchymyn Sychder Afon Hafren gan faint o ddŵr sydd yng nghronfa ddŵr Llyn Clywedog, ac nid gan faint o ddŵr sy'n llifo yn yr afon. Adeiladwyd cronfa ddŵr Llyn Clywedog dim ond i ddarparu dŵr ar gyfer system reoleiddio'r Hafren, ac mae'n cynrychioli'r cyflenwad mwyaf o ddŵr sydd ar gael ar hyn o bryd i gefnogi'r Afon Hafren, sy'n golygu ei bod yn allweddol i reoli'r dŵr yn effeithlon. Monitrir lefelau cadw yn y gronfa ddŵr yn ôl yr ystumiau rheoli er mwyn olrhain yr adnoddau dŵr sydd ar gael a chodi ymwybyddiaeth o amodau sych sy'n datblygu.

Ceisiadau blaenorol am Orchymyn Sychder Afon Hafren

Gweithredwyd amrywiadau o'r Gorchymyn Sychder Afon Hafren yn 1976, 1984 a 1989. Ni wnaed ceisiadau am orchymyn sychder ers y digwyddiadau hyn; yn bennaf oll ni wnaeth digwyddiad sychder 1995-1996 sbarduno'r gofyniad am orchymyn sychder.

Pa mor aml fyddai angen Gorchymyn Sychder Afon Hafren?

Byddai amseriad unrhyw orchymyn sychder yn dibynnu ar bryd roedd diffygion glaw yn digwydd, ac a fyddai'r sychder yn parhau'n ddigon hir i weithredu'r gorchymyn sychder. Disgwylir y bydd angen Gorchymyn Sychder Afon Hafren dim ond dan amodau sychder hirdymor a llym. Oherwydd y gefnogaeth adnodd dŵr a roddir i'r Afon Hafren fel rhan o'r system reoleiddio, disgwylid y byddai systemau afonydd ac is-afonydd gerllaw mewn cyflwr â phwysau mwy difrifol.

Yn seiliedig ar y nifer o ysgogiadau ers i Lyn Clywedog gael ei adeiladu, ac yn cyfrifo am y gwelliannau a wnaed i system reoleiddio'r Afon Hafren mewn blynyddoedd diweddar, mae Asiantaeth yr Amgylchedd yn rhagweld y byddai angen y Gorchymyn Sychder Afon Hafren unwaith bob 50 mlynedd ar gyfartaledd.

Mae'n bwysig nodi bod y tebygolrwydd y gwneir cais am Orchymyn Sychder Afon Hafren yn fwy na'r tebygolrwydd y 'gweithredir' Gorchymyn Sychder Afon Hafren.

Senarios Sychder

Profwyd gwytnwch dalgylch Afon Hafren dan sychder hir gan ddefnyddio'r model dŵr wyneb Aquator. Roedd modelu'n awgrymu na fyddai Gorchymyn Sychder Afon Hafren yn cael ei sbarduno mwyach ar gyfer sychderau blaenorol sydd wedi'u cofnodi, gan fod mwy o adnoddau wedi'u datblygu. Er mwyn profi'r gorchymyn sychder, cafodd amodau sychder 1975-1976 eu hymestyn a'u cynyddu er mwyn creu amodau sychder 'Aciwt' a Chronig' damcaniaethol. Profodd y cyflwr Aciwt ddau aeaf/wanwyn sych a sefyllfa o sychder aciwt yn yr haf, tra adeiladodd y cyflwr Cronig ar hyn i greu trydydd gaeaf/gwanwyn sych yn cael ei ddilyn gan ail sychder aciwt yn yr haf.

Ar gyfer pob cyflwr, profwyd tair senario model; senario waelodlin 'Gwneud Dim Byd', senario 'Gorchymyn Sychder yn Unig' a senario 'Llawn Ar y Cyd'. Roedd y senario 'Gwneud Dim Byd' yn cynrychioli amodau dan yr amodau Aciwt a Chronig pe byddai rheoleiddio arferol yr Hafren yn parhau, heb weithredu gorchymyn sychder. Roedd y senario 'Gorchymyn Sychder yn Unig' yn cynrychioli'r amodau Aciwt a Chronig, yr holl dyniadau dŵr a gollyngiadau presennol, a gweithredu'r Gorchymyn Sychder Afon Hafren. Mae'r senario 'Llawn Ar y Cyd' yn adeiladu ar hyn, yn ychwanegu gweithrediadau trwydded/gorchymyn sychder cwmni dŵr er mwyn cynrychioli'r sefyllfa achos gwaethaf rhagweledig.

Crynodeb o Effeithiau Amgylcheddol

Adnoddau Dŵr (Hydroleg)

Byddai llifau afon a lefelau dŵr yn cael eu lleihau ar y cychwyn gan y Gorchymyn Sychder Afon Hafren ond ni ddylent leihau'n ormodol islaw'r llifau a lefelau sychder naturiol a fyddai'n digwydd os nad oedd cymorth rheoleiddio ar gael. Awgrymodd y modelu Gorchymyn Sychder Afon Hafren na fyddai methiannau targed llif ecolegol ychwanegol (safonau WFD) y tu hwnt i'r hyn y rhagwelwyd y byddai'r sychder naturiol yn eu hachosi. Efallai y byddai hyd y methiant yn cael ei gynyddu rywfaint ond dros dro byddai'r holl effeithiau ac mae'n annhebygol y byddent yn cael effaith sylweddol ar yr ecoleg.

Pe byddai sychder yn parhau heb law am amser hir (h.y. cyflwr Aciwt), neu pe byddai trydydd gaeaf sych yn digwydd (h.y. cyflwr Cronig), dangosodd y modelu fanteision amlwg yn gysylltiedig â gweithredu'r Gorchymyn Sychder Afon Hafren. Byddai cadw'r dŵr yn Llyn Clywedog am fwy o amser yn ymestyn gollyngiadau adfer a lleihau'r risg y byddai adran uchaf yr afon yn sychu, risg a adnabuwyd pe na fyddai'r gorchymyn sychder yn cael ei weithredu. Rhagwelwyd y byddai dŵr a arbedwyd trwy weithredu'r gorchymyn sychder yn caniatáu i Lyn Clywedog ail-lenwi'n gynt, gan sicrhau bod storio'n uwch ar gyfer y flwyddyn ddilynol ac o bosibl yn atal yr angen am ail gais am orchymyn sychder pe byddai sychder arall yn dilyn. Byddai hyn yn cyflwyno manteision sylweddol i bobl a'r amgylchedd.

Canfuwyd fod yr Afon Hafren lanwol isaf (uwchben dynodiad Aber Hafren Natura 2000) yn wynebu'r perygl mwyaf oherwydd llifau a lefelau isel dan y senarios 'Llawn Ar y Cyd', gydag ansicrwydd mawr ynghylch y tyniad mwyaf y gall yr Ymddiriedolaeth Camlesi ac Afonydd ei gymryd ar gyfer y gamlas Gloucester & Sharpness. Ar hyn o bryd mae'r gweithrediad hwn wedi'i eithrio rhag trwyddedu. Mae cytundeb gweithredu rhwng Asiantaeth yr Amgylchedd a'r Ymddiriedolaeth Camlesi ac Afonydd yn sicrhau yr amddiffynir yr Aber Hafren yn ystod amodau o lif arferol i isel, fodd bynnag ni chynhwysir sychderau. Mae gwaith parhaol yn cael ei wneud gan Asiantaeth yr Amgylchedd a'r Ymddiriedolaeth Camlesi ac Afonydd i ddod o hyd i opsiynau lliniaru addas.

Adnoddau Dŵr (Tynwyr Dŵr Eraill)

Cyn gwneud cais am Orchymyn Sychder Afon Hafren, rhagwelir y byddai'r mwyafrif o effeithiau ar dynwyr dŵr ar hyd yr Afon Hafren eisoes wedi dod i rym fel rhan o weithdrefnau adnoddau dŵr a sychder Asiantaeth yr Amgylchedd (h.y. nid ydynt yn perthyn yn uniongyrchol i'r gorchymyn sychder). Byddai goblygiadau uniongyrchol y Gorchymyn Sychder Afon Hafren ar gyfer cwmnïau dŵr gyda thyniadau dŵr o'r Afon Hafren yn cynnwys gorfodi gostyngiadau o 5% ar drwyddedau tynnu a photensial am ostyngiadau pellach (hyd at 20%) y gellid eu ceisio pe byddai'r lefel storio yn Llyn Clywedog yn mynd heibio i'r pwynt storio argyfwng o 18%. Byddai rhywfaint o hyblygrwydd ynghylch pryd y gellid llacio cyfyngiadau (dros dro) ac/neu y gellid tynnu'r gorchymyn sychder yn gyfan gwbl, fodd bynnag gall gorchymyn sychder aros mewn grym dan y gyfraith am gyfnod rhwng 6 mis a blwyddyn gron (os ceisir estyniadau).

Awgrymodd modelu y gallai'r Gorchymyn Sychder Afon Hafren weithredu am oddeutu 144 diwrnod o 25 Awst, y byddai'r gostyngiad lleiaf o 5% yn gymwys ar ei gyfer. Rhagwelwyd y byddai'r pwynt

storio argyfwng o 18% yn cael ei groesi am gyfanswm o 22 diwrnod rhwng 15 Hydref a 6 Tachwedd. Byddai effeithiau posibl ar dyniadau cwmnïau dŵr yn newid yn ôl gofynion tynnu cyfredol ac a fyddai Asiantaeth yr Amgylchedd yn gofyn am ostyngiadau pellach ynghylch tynnu neu beidio. Felly cynhelid trafodaethau agos gyda'r cwmnïau dŵr perthnasol.

Mae perygl o fuddiannau gwrthdrawiadol rhwng rhai trwyddedau/gorchmynion sychder cwmnïau dŵr (a adnabyddir yn y Cynlluniau Sychder priodol) a'r Gorchymyn Sychder Afon Hafren. Byddai'r Gorchymyn Sychder Afon Hafren yn ceisio lleihau llifau'r Afon Hafren a lleihau pwysau tynnu er mwyn galluogi rheoleiddio i barhau'n hwy i gefnogi pobl a'r amgylchedd, tra byddai cwmnïau dŵr gyda thyniadau yn uniongyrchol o'r Afon Hafren yn ceisio cynnal neu gynyddu tyniadau er mwyn cefnogi cyflenwadau dŵr cyhoeddus yn unig. Byddai Asiantaeth yr Amgylchedd a'r cwmnïau dŵr perthnasol yn cwrdd yn gynnar i drafod unrhyw anghydfod posibl, os na ellir dod o hyd i ddewis arall byddai'r cwmnïau dŵr yn cael eu cyfarwyddo i wneud cais i'r Ysgrifennydd Gwladol am orchymyn sychder am Resymau Hanfodol sef er Budd Cyhoeddus tra Phwysig (IROPI).

Mae Cytundeb Camlas Trefaldwyn 1988 yn cynnwys cyfyngiadau ynghylch tynnu dŵr dan weithrediad y Gorchymyn Sychder Afon Hafren. Awgrymodd modelu y byddai'r Gorchymyn Sychder Afon Hafren er lles tynnu dŵr o Gamlas Trefaldwyn; er y byddai'n capio meintiau tynnu dŵr am fwy o amser byddai'n lleihau'r cyfnod o beidio tynnu dŵr a orfodir os yw'r maint storio yn Llyn Clywedog yn syrthio o dan 25%. Awgrymodd modelu oddeutu 140 o ddiwrnodau o gyfyngiadau o fis Awst ymlaen, gyda 76 diwrnod o beidio tynnu dŵr a ganiateir rhwng 16 Medi a 30 Tachwedd, o gymharu â 120 o ddiwrnodau rhwng 2 Medi a 30 Rhagfyr pe na weithredid gorchymyn sychder.

Mae'n hysbys bod tynnu dŵr o gamlas Gloucester & Sharpness yn cael effaith a allai fod yn sylweddol ar yr Hafren lanwol isaf ac mae'n llifo i mewn i'r Aber Hafren yn ôl uchderau'r llanw a graddau'r tynnu dŵr. Ni chynhwysir tynnu dŵr yn ystod cyfnodau o sychder yng nghytundeb gweithredu 1998 gydag Asiantaeth yr Amgylchedd, ac nid oedd ceisiadau Gorchymyn Sychder Afon Hafren yn cynnwys cyfyngiadau penodol ar y gamlas hon. Oherwydd casgliadau'r Asesiad Rheoleiddio Cynefin, mae cyfyngiad newydd yn cael ei gyflwyno dan y Gorchymyn Sychder Afon Hafren i liniaru risg posibl i'r safle Natura 2000. Uchafswm y swm o ddŵr y gellir ei gymryd ar gyfer y gamlas pan fydd y Gorchymyn Sychder Afon Hafren yn weithredol fydd 300Ml/d, i'w weithredu pan fydd y llif yn Deerhurst islaw 1200 Ml/d. Nod y cyfyngiad yw diogelu anghenion amgylcheddol gan ddal i ganiatáu digon o ddŵr i'r Ymddiriedolaeth Camlesi ac Afonydd gyflawni ei brif rwymedigaethau. Mae'r Ymddiriedolaeth wedi nodi pryderon y gallai 300 Ml/d gyflwyno risg i weithrediad o'r gamlas ac mae gwaith yn mynd rhagddo i asesu effaith lawn bosibl y cyfyngiad hwn. Os gellir darparu tystiolaeth ddigonol i ddangos y gellir cyfiawnhau tyniad uwch, yna byddwn yn adolygu'r terfyn tynnu.

Defnyddiwyd ysgogydd llif rheoli sychder mewnol yr Ymddiriedolaeth Camlesi ac Afonydd i asesu effaith bosibl gweithrediad Gorchymyn Sychder Afon Hafren ar lywio. Nododd y senario 'Gwneud Dim Byd' Acíwt 106 o ddyddiau o effaith bosibl rhwng 2 Gorffennaf a 1 Tachwedd a'r senario 'Gwneud Dim Byd' Cronig 101 o ddyddiau. Wrth gymharu'r senarios 'Gorchymyn Sychder yn Unig' a 'Llawn Mewn Cyfuniad', roedd 38 o'r dyddiau hyn yn cyd-fynd ag actifadu'r Gorchymyn Sychder Afon Hafren. O ganlyniad i'r cysondeb o gymharu â'r senarios 'Gwneud Dim Byd' a chyfnod gweithrediad y Gorchymyn Sychder Afon Hafren, ni ragwelir cau pellach i gamlesi o ganlyniad i actifadu'r gorchymyn sychder o gymharu ag ysgogydd 1150 Ml/d yr Ymddiriedolaeth Camlesi ac Afonydd i ystyried cyfyngiadau sychder.

Daeth profion ar y cap tyniad newydd arfaethedig o 300 Ml/d (ffigwr yn amodol i newid) i'r casgliad yr effeithiwyd ar dyniad yr Ymddiriedolaeth Camlesi ac Afonydd o'r Afon Hafren am 38 niwrnod o'r flwyddyn; oll yn ddyddiau oedd eisoes wedi croesi'r ysgogydd 1150 Ml/d Deerhurst ar gyfer ystyried gweithrediad cyfyngiad sychder a chau camlesi posibl.

Mae tyniad dŵr cyflenwad dŵr cyhoeddus Bristol Water yn Purton yn cael ei gymryd yn uniongyrchol o gamlas Gloucester & Sharpness. Oherwydd ei agosrwydd i'r Aber Hafren mae risg o amhariad hallt i'r gamlas, a liniarir fel arfer gan reolau gweithredu'r Ymddiriedolaeth Camlesi ac

Afonydd yn Deerhurst. Adnabu adroddiadau bod halltedd yn cyrraedd lefelau difrifol yn Purton ychydig cyn i'r glaw ddychwelyd yn ystod sychder 1976. Ymestynodd yr amodau Aciwt a Chronig damcaniaethol a fodelwyd ar gyfer y Gorchymyn Sychder Afon Hafren y cyfnod sychder hwn, yn cynyddu'r risg o amhariad hallt i fyny'r Hafren lanwol isaf ac felly'r risg y byddai dŵr hallt yn mynd i mewn i gamlas Gloucester & Sharpness.

Gyda rheolaeth dŵr gofalus a'r rhyngdoriad parhaus o nifer o lednentydd, mae Asiantaeth yr Amgylchedd yn credu y dylai cyfyngiad 300 Ml/d o'r Afon Hafren, dim ond pan fydd y llif yn gostwng islaw 1200 Ml/d at Deerhurst, ddal i ganiatáu i'r Ymddiriedolaeth Camlesi ac Afonydd gyflenwi digon o ddŵr i Bristol Water. Mae'r Ymddiriedolaeth Camlesi ac Afonydd wedi mynegi pryderon na allai 300 Ml/d fod yn ddigon i fodloni eu rhwymedigaethau i gyd. O ran y pryder hwn, mae Asiantaeth yr Amgylchedd wedi ymroi i weithio gyda'r Ymddiriedolaeth Camlesi ac Afonydd i ymchwilio ymhellach i ffigwr y cyfyngiad.

Ansawdd dŵr

O gymharu'r senarios 'Gorchymyn Sychder yn Unig' a 'Gwneud Dim Byd' (dan amodau Aciwt a Chronig fel ei gilydd) ni ragwelodd modelu'r Gorchymyn Sychder Afon Hafren unrhyw fethiannau WFD ychwanegol ynghylch ansawdd dŵr. Canfuwyd fod ansawdd dŵr yn gwella wrth weithredu'r Gorchymyn Sychder Afon Hafren gan fod y llifau lleiaf uwch yn creu mwy o wanhad. Canfuwyd fod maetholion a ffosffadau'n cynyddu o ganlyniad i'r sychder naturiol; ond ni chafodd y Gorchymyn Sychder Afon Hafren unrhyw effeithiau negyddol ar grynoadau'r paramedrau hyn.

Ecoleg (macroinfertebrata a macroffytau)

Aseswyd effeithiau ecolegol y Gorchymyn Sychder Afon Hafren gan gyfeirio at effeithiau posibl ar gymunedau o facroinfertebrata ar bwyntiau amrywiol ar hyd yr afon. Darparodd gwybodaeth hanesyddol o'r sychder yn 1975/76 a nifer o gyfnodau sychder dilynol arwyddion o effeithiau posibl yn y dyfodol, tra oedd rhagfynegiadau o batrymau llif yn caniatáu asesiad o ddifrifoldeb yr effaith a sut y gallai'r rhain newid pe byddai'r gorchymyn sychder yn cael ei weithredu. Yn agos i gronfeydd dŵr Llyn Clywedog a Llyn Fyrnwy, byddai'r gorchymyn sychder angen llif adfer sy'n uwch na llif yr afon a ddisgwylid yn naturiol o dan amodau sychder ac felly byddai data sensitif i lif isel yn elwa. Fodd bynnag, byddai effeithiau niweidiol posibl: byddai'r maint mawr o ddŵr a fyddai'n cael ei ryddhau angen mwy o amser i ail-lenwi'r gronfa ddŵr yn dilyn diwedd y sychder, a thrwy hynny'n lleihau amrywioldeb y llif naturiol tra bod y gronfa ddŵr yn ail-lenwi. Ymhellach i lawr yr afon, byddai gostyngiadau dan y gorchymyn sychder yn lleihau'r effeithiau negyddol ar y fawna macroinfertebrat, yn arbennig gan y byddai cyfran fwy o wely'r afon yn aros dan ddŵr nag a ragwelwyd o dan amodau sychder naturiol. Mae ansawdd dŵr wedi gwella ar hyd llawer o'r afon ers sychder 1975/6, yn golygu bod hyn yn llai tebygol o achosi problemau o dan amodau sychder yn y dyfodol.

Tuag at hydau isaf yr Afon Hafren, mae rhagfynegiadau o effeithiau ecolegol yn anos, gan fod y data sydd ar gael yn fylchog. Hefyd nid oes digon o wybodaeth i ragweld effaith sychder, nag effaith liniaru y gorchymyn sychder, ar facroffytau.

Ecoleg (Pysgod Coridor yr Hafren)

Cynhaliwyd asesiad o effeithiau posibl ar bysgod trwy ystyried gofynion llif rhywogaethau gwahanol ac archwilio hydrograffau yn awgrymu llifau rhagweledig yn seiliedig ar amodau llif isel Aciwt a Chronig o dan y tair senario ar gyfer gorchymyn sychder ('Gorchymyn Sychder yn Unig', 'Llawn ar y Cyd' a 'Gwneud Dim Byd'). O dan yr amodau sychder Aciwt ystyriwyd y gallai'r Gorchymyn Sychder Afon Hafren achosi effeithiau o arwyddocâd cymedrol yn Lower Parting; arwyddocâd bach yn Afon Clywedog, Afon Fyrnwy, Bewdley, Saxons Loade a Haw Bridge/Deerhurst; ac effeithiau dibwys yn Buildwas. O dan yr amodau sychder Cronig ystyriwyd fod arwyddocâd yr effaith yr un peth ym mhob lleoliad ac eithrio Afon Clywedog, lle aseswyd bod effeithiau o arwyddocâd cymedrol. Yn gyffredinol, casglwyd y byddai gweithredu'r Gorchymyn Sychder Afon Hafren o fudd i boblogaeth y pysgod yn yr Afon Hafren uchaf er, ymhellach i lawr yr afon, ac yn arbennig ger yr aber, byddai'r manteision yn llai o lawer.

Ecoleg (Rhywogaethau Anfrodorol Ymwthiol)
Yn benodol o fewn yr ardal sydd wedi ei chwmpasu gan Orchymyn Sychder Afon Hafren, dim ond Cimychiaid yr Afon America, Efwr Enfawr, Clymog Japan, Jac y Neidiwr a Mincod sy'n debygol o fod yn drafferthus. O ystyried na wnaeth y dulliau atgenhedliad a gwasgariad unigol ar gyfer pob un o'r rhywogaethau nodi risg cynyddol trwy weithrediad Gorchymyn Sychder Afon Hafren, ni chasglwyd fod unrhyw effaith andwyol.

Safleoedd Dynodedig a gysylltir â'r Afon Hafren

Aseswyd yr holl safleoedd a ddynodir yn genedlaethol ac yn rhyngwladol a gysylltir â'r Afon Hafren gan lwybrau dŵr am effaith bosibl gan y Gorchymyn Sychder Afon Hafren. Cymerwyd un deg tri o safleoedd trwy broses sgrinio'r Asesiad Cyfarwyddeb Cynefinoedd gan y gallent fod yn sensitif o bosibl i lefelau is o ddŵr a llifau. Dim ond yr Aber Hafren y canfuwyd ei fod mewn perygl o bosibl (cyfeiriwch at yr adran berthnasol), casglwyd na fyddai'r holl safleoedd eraill yn profi effaith gan y Gorchymyn Sychder Afon Hafren.

Aber Hafren (safle Natura 2000)

Cynhaliwyd Asesiad Rheoleiddio Cynefinoedd ar gyfer y Gorchymyn Sychder Afon Hafren, gan weithio'n agos gyda Natural England a Chyngor Cefn Gwlad Cymru (rhan o Gyfoeth Naturiol Cymru erbyn hyn). Casglodd yr asesiad nad oedd y Gorchymyn Sychder Afon Hafren yn debygol o gael effaith sylweddol ar nodwedd ddynodedig, is-nodweddion neu gynefinoedd cefnogol yr aber. Adnabuwyd y prif faes risg fel yr Hafren lanwol isaf, ychydig i fyny'r afon o safle dynodedig yr Aber, yn ymestyn i fyny'r afon i ble mae'r Afon Hafren yn rhannu yng Nghaerloyw. Ystyriodd yr asesiad weithrediad ar y cyd tyniad dŵr mwyaf posibl yr Ymddiriedolaeth Camlesi ac Afonydd ar gyfer camlas Gloucester and Sharpness, a Thrwyddedau/Gorchmynion sychder cwmnïau dŵr. Nid oedd yr asesiad yn gallu casglu na fyddai effaith sylweddol ar bysgod ymfudol, gyda'r ansicrwydd mwyaf ynghylch gweithrediadau eithriedig y gamlas Gloucester and Sharpness a beth allai'r tyniad mwyaf fod yn ystod sychder llym. Mae gwaith cydweithredol parhaol yn cael ei wneud gyda'r Ymddiriedolaeth Camlesi ac Afonydd i drefnu opsiynau lliniaru yn unol â deddfwriaeth Reoleiddio Cynefinoedd.

Fel awdurdod cymwys dan y Gyfarwyddeb Cynefinoedd, rhaid i ni naill ai liniaru yn erbyn niwed amgylcheddol posibl, neu wneud cais am, Orchymyn Sychder Afon Hafren ar sail Rhesymau Hanfodol sef er Budd Cyhoeddus Tra Phwysig. Canfuwyd mai'r opsiwn mwyaf priodol i gydbwyso anghenion dŵr a gofynion y Gyfarwyddeb Cynefinoedd oedd cyfyngu echdyniad Camlas Gloucester a Sharpness. Roedd yr Asesiad Rheoliadau Cynefinoedd yn gallu casglu nad oedd tyniad uchafswm o 300 Ml/d i'r gamlas (mewn cyfuniad) yn debygol o achosi niwed i ddynodiadau safle Natura 2000. Felly bydd ceisiadau ar gyfer y Gorchymyn Sychder hwn nawr yn cynnwys cap tyniad o 300 Ml/d ar yr Ymddiriedolaeth Camlesi ac Afonydd, pan fydd y llif yn Deerhurst islaw 1200 Ml/d. Os caniateir y Gorchymyn Sychder, byddai modd gorfodi'r amodau yn gyfreithiol. Byddai'r weithred yn lliniaru unrhyw niwed posibl i'r safle Natura 2000 yn llwyddiannus ac yn bodloni'r gofynion Cyfarwyddeb Cynefinoedd.

Mae'r Ymddiriedolaeth wedi nodi pryderon y gallai 300 Ml/d gyflwyno risg i weithrediad o Gamlas Gloucester a Sharpness a'r tyniad dŵr yn Bristol Water mae'n ei gefnogi, ac mae gwaith yn mynd rhagddo i asesu effaith lawn bosibl y cyfyngiad hwn. Os gellir darparu tystiolaeth ddigonol i ddangos y gellir cyfiawnhau tyniad uwch, yna byddwn yn adolygu'r terfyn tynnu.

Cyfarwyddeb Fframwaith Dŵr

Ystyrir bod effeithiau posibl y Gorchymyn Sychder Afon Hafren yn dod o dan Erthygl 4.6 Y Gyfarwyddeb Fframwaith Dŵr (WFD), yn caniatáu am waethygu dros dro o *'Ganlyniad i amgylchiadau a achosir yn naturiol sy'n eithriadol neu na ellid eu rhagweld yn rhesymol, yn arbennig llifogydd eithafol a sychderau hir.'* Awgrymodd modelu y byddai llifau ac ansawdd dŵr yn gwaethygu'n is na thargedau WFD lleol fel rhan o'r broses sychder naturiol, heb ystyried a fyddai'r Gorchymyn Sychder Afon Hafren yn cael ei weithredu neu beidio. Mae data o ddigwyddiadau

sychder hanesyddol yn cefnogi'r casgliad hwn, gyda llifau rheoleiddedig o dan y gweithrediadau gorchymyn sychder hanesyddol amrywiol (mae llifau rhagnodedig wedi cynyddu) yn mynd heibio neu'n hafal i'r hyn a fyddai wedi digwydd yn naturiol (llifau wedi'u naturioli) yn Bewdley a Haw Bridge. Ni ddisgwylir y bydd y Gorchymyn Sychder Afon Hafren yn oedi adferiad yr amgylchedd yn sgil y digwyddiad sychder, gan gael effaith dros dro yn unig ar lifau dŵr wyneb. Casglwyd na fyddai unrhyw effaith sylweddol ar dargedau WFD.

Archaeoleg a Threftadaeth Ddiwylliannol

Casglwyd na fyddai effaith ar archaeoleg a threftadaeth ddiwylliannol yn sgil gweithredu'r Gorchymyn Sychder Afon Hafren.

Llywio a Hamdden

Does dim gwybodaeth yn bodoli sy'n cysylltu meintiau a lefelau yng nghronfa ddŵr Llyn Clywedog â defnydd hamddenol. Er gwaethaf hyn, gellir tybio y byddai gweithredu'r Gorchymyn Sychder Afon Hafren yn cael effaith gadarnhaol ar weithgareddau hwylio a chychod ar Lyn Clywedog trwy gadw adnoddau dŵr a pharhau'r tymor hwylio o gymharu â pheidio â gweithredu'r gorchymyn sychder. Hefyd byddai'r amser adfer ar ôl sychder (ail-lenwi'r gronfa ddŵr) yn cael ei leihau gan weithredu'r gorchymyn sychder, yn lleihau hyd effaith sychder ar y clwb hwylio yn y pen draw ac yn helpu i amddiffyn yn erbyn ail flwyddyn o effaith.

Ni chanfuwyd unrhyw wybodaeth i gysylltu meintiau a lefelau yn y gronfa yn Llyn Fyrnwy i ddefnydd hamdden. Nid yw Gorchymyn Sychder Afon Hafren yn ceisio addasu uchafswm y swm o ddŵr sy'n cael ei ryddhau o'r gronfa o gymharu â gweithrediad arferol, felly ni chasglwyd unrhyw effaith.

Effeithid ar lywio ar hyd yr Afon Hafren o'r dalgylch canol i'r un isaf gan y lefelau dŵr is a brofir yn ystod sychder, gan olygu bod pasio dros goredau a thrwy lifddorau yn gyfyngedig yn ôl llymder y sychder. Yn ystod 1995 profodd cychod anawsterau sylweddol wrth lywio rhwng Caerloyw a Tewkesbury gyda dyfnder dŵr o oddeutu 1.44m yn unig. Mae'n debygol y byddai graddau'r effaith yn amrywio'n lleol a chael eu gwaethygu gan y Gorchymyn Sychder Afon Hafren ac mewn tyniadau dŵr cyfun. Gan fabwysiadu ymagwedd achos gwaethaf, gallai mordwyo gan y mwyafrif o gychod yn ystod sychderau o'r maint a fodelwyd gael ei atal i raddau mawr nes bod digwyddiadau glaw uchel yn dychwelyd.

Caiff pysgota ei effeithio gan y lefelau dŵr yn syrthio'n naturiol, yn cael effaith fuddiol ar ddalfeydd o bysgod ar y cychwyn, heb ystyried a weithredir y gorchymyn sychder neu beidio. Gallai lefelau eithafol o isel gael effeithiau niweidiol ar oroesiad pysgod, yn arbennig yn y dalgylch isaf lle mae llawer o lifddorau a choredau. Os ystyrir bod pysgota'n arwain at bwysau ychwanegol ar bysgod efallai y bydd angen cyflwyno terfyn dros dro ar weithgareddau pysgota. Mae'n annhebygol y bydd hyd unrhyw gyfyngiadau'n wahanol os gweithredir y Gorchymyn Sychder Afon Hafren neu beidio, felly ni ddisgwylir effaith ychwanegol ar bysgota.

1. Introduction

The Environment Agency is an Executive Non-departmental Public Body responsible to the Secretary of State for Environment, Food and Rural Affairs. Our principal aims are to protect and improve the environment, and to promote sustainable development in England. We play a central role in delivering the environmental priorities of central government.

Natural Resources Wales are the principal adviser to the Welsh Government on the environment in Wales, enabling the sustainable development of Wales' natural resources for the benefit of people, the economy and wildlife.

1.1. Introduction

The Environment Agency Midlands region has identified the option to apply for a Drought Order on the River Severn to support the Severn regulation system (details in section 2.2) during severe drought events. The River Severn Drought Order aims to maintain supported water resources along the River Severn for longer at lower quantities, rather than risking running out of supported water and causing significant and sudden river level/flow declines.

The River Severn Drought Order is triggered by storage levels at Llyn Clywedog (shown in Figure 1) reservoir in Wales (not by river thresholds), and has the potential to alter river flows in Wales and England, from Llyn Clywedog reservoir down to the Severn Estuary (shown in Figure 6, section 4.1).

The Midlands region Drought Plan is available on the Environment Agency website and should be read in conjunction with this report: http://www.environment-agency.gov.uk/homeandleisure/drought/136954.aspx

1.2. Drought Order Requirements

Drought permits and drought orders are drought management actions that, if granted, can allow more flexibility to manage water resources and the effects of drought on public water supply and the environment for up to 6 months, although extensions for a further 6 months can be sought.

Drought Permit applications in England are made directly to the Environment Agency, however we cannot grant ourselves a Drought Permit. The Environment Agency would make a River Severn Drought Order application directly to the Secretary of State, and to the Welsh Government on behalf of both the Environment Agency and Natural Resources Wales.

The drought order application must satisfy that either:

- a serious deficiency of supplies of water in any area, exists or is threatened[3];
- or
- such a deficiency in the flow or level of water in any inland waterway to pose a serious threat to any flora or fauna which are dependent on those waters[4], exists or is threatened;

  and that
- the reason for the deficiency is an exceptional shortage of rain[5].

[3] Section 73(1)(b) of the WRA 1991 as amended by the Environment Act 1995.
[4] Section 73(1)(b) of the WRA 1991 as amended by the Environment Act 1995.
[5] Section 73(1) of the WRA 1991 as amended by the Environment Act 1995.

All drought permit and drought order applications must be accompanied by an environmental report, which provides a detailed and accurate description of the proposal, details of the baseline environment, likely positive and negative impacts from the drought order, a monitoring programme and any mitigation or alternative options. Where adverse effects are likely, the water undertaker must demonstrate that all alternative solutions have been utilised (e.g. publicity campaigns, flow restrictions etc.) or that the scheme is necessary for reasons of overriding public interest.

1.3. Strategic Environment Assessment (SEA) Requirements

The SEA Directive applies to all statutory plans or programmes. Environment Agency drought plans are not required under any legislative, regulatory or administrative provision; therefore the plans are not subject to the SEA Directive due to their voluntary status. Despite this, the principles behind SEA have been considered and applied during the environmental assessment of the River Severn Drought Order (refer to section 9 and 10).

1.4. Habitat's Directive (HD) Requirements

A water undertaker has a duty under Regulation 3(4) of the Conservation (Natural Habitats &c) Regulations (1994) to have regard to the requirements of the Habitats Directive (92/43/EEC) in exercising any of its functions, including any authorised activities associated with a drought order. Where a plan or project is likely to have a significant effect on the interest features of a European Site, either alone or in combination with other plans or projects, an appropriate assessment is required. Under these circumstances, an environmental report prepared in support of a drought order application should include an appropriate assessment to determine whether or not the proposal will adversely affect the integrity of the site. Should the environmental report conclude that the proposal will adversely affect the site, then a drought order will only be granted where there are no alternative solutions and for reasons of overriding public interest. In such cases, compensatory measures must then be implemented to protect the integrity of the site. It is also noted under Planning Policy Statement number 9 that Ramsar designated sites should be treated under the Habitats Regulations as being equivalent to European Sites.

A Habitat's Regulation Assessment (Appropriate Assessment) has been produced for the Severn Estuary Natura 2000 site, and other potentially impacted Habitat Directive sites were appropriately screened. The full report is in ANNEX 1, conclusions are contained within section 11 of this environmental report.

1.5. Objectives and Scope of this Environmental Report

This environmental report was produced in accordance with Defra guidance (2011) to support a potential Environment Agency application for the surface water options of the River Severn Drought Order. The Shropshire Groundwater Scheme (SGS) element (an option to allow abstraction above the licensed quantities to sustain regulatory support to the River Severn) was assessed in a separate, more locally focused environmental report which can be found in ANNEX 2.

This updated environmental report (which builds on the previous AMEC (2008) report) is based on new water resources and water quality modelling, new ecological impact assessments, updated current environment information and incorporates Water Framework Directive requirements[6]. It has been produced in close consultation with Natural England, the Countryside Council for Wales

[6] Water Framework Directive is a piece of European legislation which promotes a new approach to water management through river basin planning.

(now part of Natural Resources Wales), Environment Agency Wales (now part of Natural Resources Wales), Severn Trent Water Ltd and South Staffordshire Water Ltd. The Canal & River Trust have also been consulted in regards to the Gloucester & Sharpness Canal operations in the lower tidal River Severn.

The purpose of this environmental report is to explain the River Severn Drought Order, present information on the current environment within the area of impact, model the potential impacts of the River Severn Drought Order and present an environmental monitoring plan. Where potential negative impacts have been identified, potentially available mitigation options have been highlighted. For impacts associated with in-combination operations with other organisations, mitigation options are currently being sought and options have been summarised in this environmental report. Further details will be included within an annex to this report when discussions and collaborative work are completed.

1.6. Update Programme

It is important that the Environment Agency and Natural Resources Wales remain prepared for a River Severn Drought Order application and keep this Environmental Report and supporting documents fit for purpose.

The reports will remain live documents, allowing for updates to be made as appropriate. A set timetable in line with our Drought Plan guidance has been included to programme more comprehensive reviews/updates;

- River Severn Drought Order Environmental Report and supporting documents to undergo a full review/update every 3-3.5 years or following a drought event.

  Next programmed update: 2016/17
- River Severn Drought Order environmental monitoring programme to be reviewed annually (spring time recommended). This will include a summary of the data collected and a review of the sites and methods being used.

1.7. Compliance with Defra (2011) Guidance

This report and its assessments have been undertaken in accordance with the Defra Guidance on Drought Permits and Drought Orders (2011). Details are contained in Table 1

Table 1: Compliance with Defra (2011) guidance

Defra (2011) specification for environmental report contents	Defra (2011) additional information notes	Location of information within this report
A summary of the main environmental report using non-technical language.	This should include a synopsis of major conclusions, controversial issues, unresolved issues and options selected.	Executive Summary and Non Technical Summary.
A description of the proposal including details of the site, location and duration.	Include maps and plans.	Section 2 and 3.
A statement of need for water	This can be kept brief as the detail will be elsewhere in application.	Section 3.8.
Details of alternative sources considered	This should demonstrate justification for the proposed option.	Section 3.9.
Description of the current environment (such as the aquatic and physical environment and associated habitats) and its setting in a national/regional/local context.	This should include existing features and, if already in a prolonged drought, whether there are any recognised impacts. Key information includes:	Description of current baseline environments contained in Sections 5.1, 6.1, 7.1, 7.2, 8.1, 10.1, 11.1, 12.1 and 13. And information on existing drought conditions will be contained in sections 6.2, 7.3, 9.2, 0, 12.2 and 13 prior to any future drought order application.
	1.the importance of the site (international and domestic designations)	1. Section 9 (Appendix A) and section 11 (Annex 1).
	2.Water Framework Directive classification status and any associated issues relating to the site	2. Section 10. For specific water quality detail section 6.1.3, ecology 7.1.1.3 and fish detail section 7, Appendix O and Appendix P.
	3.surface flow and groundwater data	Section 5.
	4. ecological and habitat sensitivity to flow / level changes and supporting data.	Section 4.2, 7, 8 and 9.
	5.heritage/culture value	Section 11 and 12.
	6. current abstractions.	Section 5.1.5.
Identification and prediction of impacts on the current environment.	This should include short and long term (acute and chronic) direct and indirect, cumulative, and permanent and temporary effects. It should be at the point of change and downstream and include water quality, in-river needs, associated wetlands, other water users and navigation and recreation.	Acute and Chronic conditions tested: method details in Section 4.4. Direct and indirect considered: method details in Section 4.1 and Section 8 (Appendix A). Alone and cumulative impacts tested: method details in Section 4.5.

	The assessment should focus on the features sensitive to flow/level alteration and should be quantified where possible, showing change from base level. Details on the quality of the data used, analysis/ modelling and interpretation methods and the range of uncertainty should be included as well as appendices to present data and references to date source.	With supporting appendices, sections; Water resources: Section 5.3 and 5.4. Water quality: Section 6.3. In-river needs: Sections 5.3 (hydrology), 6.3 (water quality), 7.4 and 7.5 (ecology). Associated wetlands: Section 8, 9, Appendix A and Annex 1. Other water users: Section 5.4 (other abstractors). Navigation and recreation: Section 12.3.
Mitigation measures	Where significant effects are identified, a description of the measures to be taken to avoid, reduce or remedy these effects should be included. Any proposed or actual agreements to minimise impacts on other users (for example lawful abstractors) should also be included.	Section 14. Severn Estuary and in combination mitigation work in Section 9.4, Annex 1 and 17.
Additional information to enable an appropriate assessment of environmental impacts, where a proposal could have an adverse impact on a Habitats Directive site.	The scope and content of this assessment will vary depending on the case but it must relate to the specific site and its conservation objectives. See box one for further information.	Designated sites: Section 8 and Appendix A. Severn Estuary Natura 2000 site: Section 9 and Annex 1.
Additional information to enable the authority under section 28G of Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000) to fulfil its duties, where a proposal can affect a SSSI site.	The scope and content of this assessment will vary depending on the case but it must relate to the specific site and its conservation objectives. See box two for further information.	Section 8 and Appendix A.
Monitoring plan, where proposed	This should include details of what evidence/data collection will be undertaken including locations, timings and frequency.	Section 15 and Appendix S.
Any further information relevant to impact on water users and environment		Annex 1 and 2.
Conclusions	This should draw together and summarise the reasoning (for and against) the proposals.	Sections 13 and 16.
Appendices	Such as methodologies used; data/evidence and surveys taken or planned.	Appendices A to T and Annex 1 and 2.

2. Background Context

2.1. River Severn Catchment Summary

The River Severn is the longest river in Great Britain, travelling approximately 354 km (220 miles) from its source in Plynlimon down to the Severn Estuary. Excluding the River Wye, the catchment covers approximately 11,420 km^2 with an estuary over five miles wide. The Severn has twenty one tributaries and flows through four counties, Powys, Shropshire, Worcestershire and Gloucestershire.

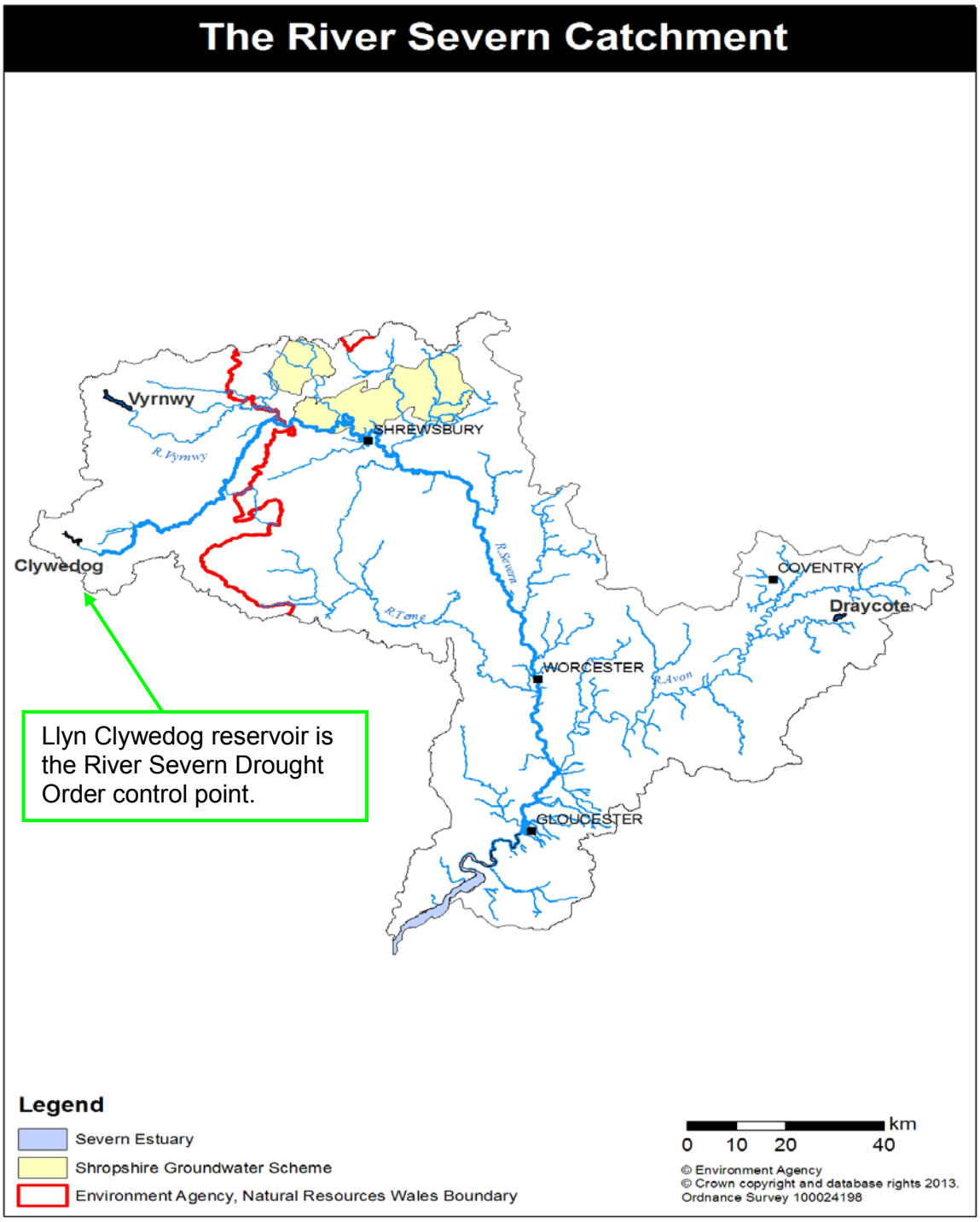


Figure 1: River Severn Catchment

The River Severn provides a major source of water for public consumption, industry, electricity generation, navigation and agriculture and is recognised for its environmental importance, providing habitats and a migratory corridor for many nationally and internationally important species (refer to Appendix A for designated sites). The catchment is largely rural, with the exception of a number of towns which lie along the banks of the River Severn, such as Shrewsbury, Bewdley and the City of Worcester.

The river is navigable from Stourport to Gloucester via the main channel and through links to the inland waterway system and provides an important recreational asset. In addition, Ironbridge Gorge is a World Heritage Site and recognised as the birthplace of industry.

The River Severn is tidal below Maisemore Weir, near Gloucester. The Severn Estuary exhibits an immense tidal range (second largest in the world), which impacts on the physical environment and on biological diversity and productivity. Sediment flows and fluxes are of particular importance for estuarine processes and ecology and the channel morphology is constantly changing. Four major rivers (Severn, Wye, Usk and Bristol-Avon) feed suspended sediments into the estuary, adding to the fine sediments already scoured from the sea bed. The combination of sediments creates high turbidity and therefore restricts light and productivity within the ecosystem. Only a limited range of fauna and flora can survive this environment, resulting in low biodiversity within the Severn Estuary.

The Severn Estuary is designated as a Site of Special Scientific Interest (SSSI), a Special Protection Area (SPA), a Special Area of Conservation (SAC) and is included on the list of wetlands of international importance under the Ramsar Convention (Ramsar Site).

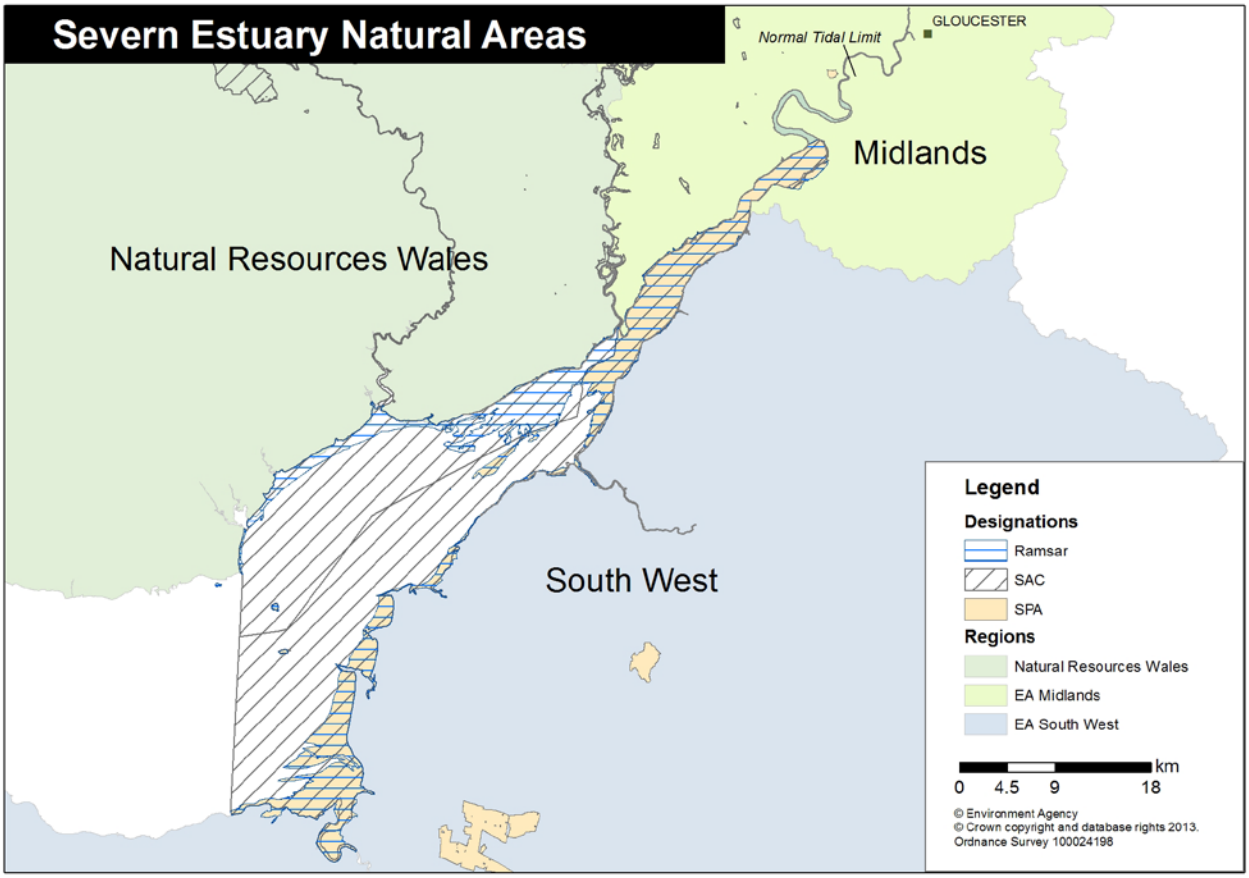


Figure 2: Severn Estuary Natura 2000 site

The area of intertidal mudflats, sand banks, rocky platforms and salt marsh is one of the largest and most important in Britain and supports internationally important populations of waterfowl, invertebrate populations of considerable interest and large populations of migratory fish including Atlantic salmon, sea trout, allis and twaite shad and sea and river lamprey.

The River Severn provides a source of drinking water to over 6 million people across the Midlands as well as meeting demands for a range of agriculture, industry and navigation purposes.

The River Severn is regulated with flows supported by releases from Llyn Clywedog and Lake Vyrnwy reservoirs and from the SGS. The regulation system is designed to meet demands for public water supply, agriculture, industry and navigation as well as maintaining flow levels sufficient to support biodiversity and conservation interests. In practice, this means that baseflow is higher than it would be naturally in the River Severn.

The Llyn Clywedog reservoir Joint Authority Act (1963) requires that river flow is maintained at 850 Ml/d (over a five day average) at Bewdley, in order to provide adequate freshwater flow in the estuary and to meet other demands. The Environment Agency is responsible for managing this requirement, in consultation with Natural resources Wales. Llyn Clywedog reservoir provides the primary resource for regulation with release volumes up to 500 Ml/d. The SGS can provide up to 140 Ml/d net at Bewdley, the rest is lost on route to other abstractors and natural evaporation processes. The water bank from Lake Vyrnwy reservoir provides sustainable releases up to 70 Ml/d, higher releases can be made but the available water would soon be used up if they continued for too long.

2.2. River Severn Regulation System

The River Severn is an artificial system, supporting a series of public water supply abstractions (some with large licensed volumes, not all of which are returned to the system), significant navigation abstractions and large discharges. Following the drought of 1959 and increasing abstraction demands a survey of water resources identified the need for a new reservoir to meet future demand and protect against drought impacts on the River Severn.

The main stakeholders, the affected water companies and the Canal & River Trust (was British Waterways), joined together and developed the Llyn Clywedog reservoir Joint Authority Act (1963). This involved the construction of a new reservoir solely for regulating (artificially supporting water volumes in) the River Severn. A minimum daily flow target of 727 Ml/d was set at Bewdley gauging station in England, designed to support abstraction and environmental need. In 1979 Severn Trent Water Authority exercised powers under the Water Resources Act 1963 to increase the regulated flow at Bewdley from a daily 727 Ml/d target to an 850 Ml/d mean over 5 consecutive days, with a minimum of 650 Ml/d in any one day. This was to provide better reliability of flows in the lower reaches of the river where abstractions were increasing rapidly, with the 5 day mean incorporating travel time resilience from Llyn Clywedog.

The River Severn regulation system is designed to meet the water resource demands of abstractors on the river, while maintaining an acceptable flow for the purposes of fisheries, conservation, recreation, effluent dilution and other in-river uses. Table 2 contains the statutory and non statutory flow targets driving regulation.

Table 2: Summary of Principal Flow Issues

Location	Flow driver/target	Statutory
Upper Reaches	Fisheries at Newtown are considered to be adversely affected by early season low flows before regulation releases are required. This has led to an additional flow control point at Dolwen. The current estimate is for a maintained flow of 70 Ml/d which would be supported by releases from Llyn Clywedog. This factor has not been accommodated within the drought management provisions currently being assessed.	No
Middle Reaches	**Maintenance of Prescribed Flow at Bewdley flow gauge: 850 Ml/d 5 day mean, minimum 1 day value of 650 Ml/d**	**Yes**
Lower Reaches/ Upper Estuary	Maintain freshwater inflows to the Seven Estuary Natura 2000 designated site (Habitat's Directive driver). 1992 research recommended maintaining a Mean Residual Flow of 1200-1500 Ml/d during neap tides and 1800-2400 Ml/d during spring tides – Regulation 'freshet' releases were tested but terminated in 2006, concluded as an inefficient use of resources with no reported benefits.	No

The River Severn regulation system maintains higher flows during dry conditions than would naturally be experienced, even with abstraction accounted for, by releasing water into the river and its tributaries as baseflows decrease and fail to meet the prescribed flow at Bewdley. Figure 3 demonstrates how the Severn regulation system protects the River Severn from the majority of low flow stress experienced in non regulated catchments.

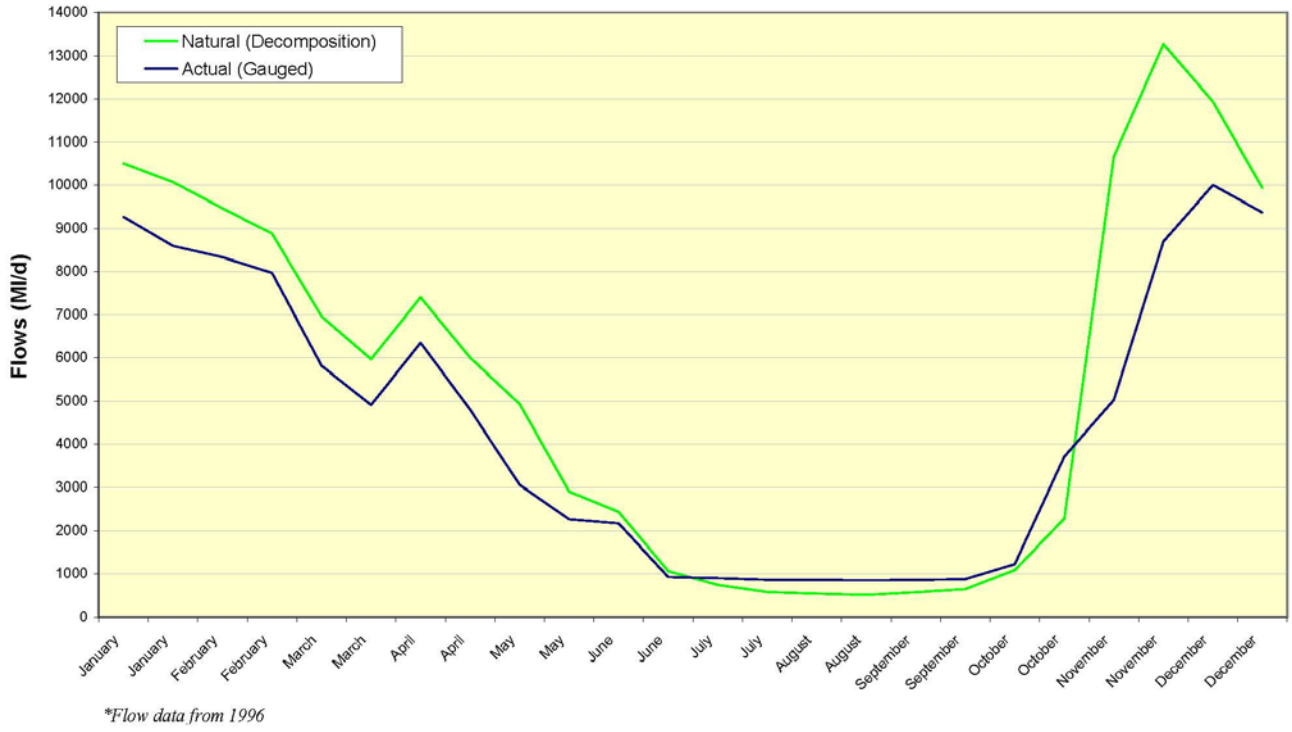


Figure 3: Hydrograph Illustrating River Severn Regulation Operation

Figure 3 demonstrates the general trend of regulation support elevating low flows above the natural, by redistributing mean to high flows.

2.2.1. River Severn Regulation

There are three storage components to the Severn regulation system, illustrated in Figure 4;

- The full resource allocation from Llyn Clywedog Reservoir;
- Limited resources from the Lake Vyrnwy reservoir water bank; and the
- Shropshire Groundwater Scheme (SGS).

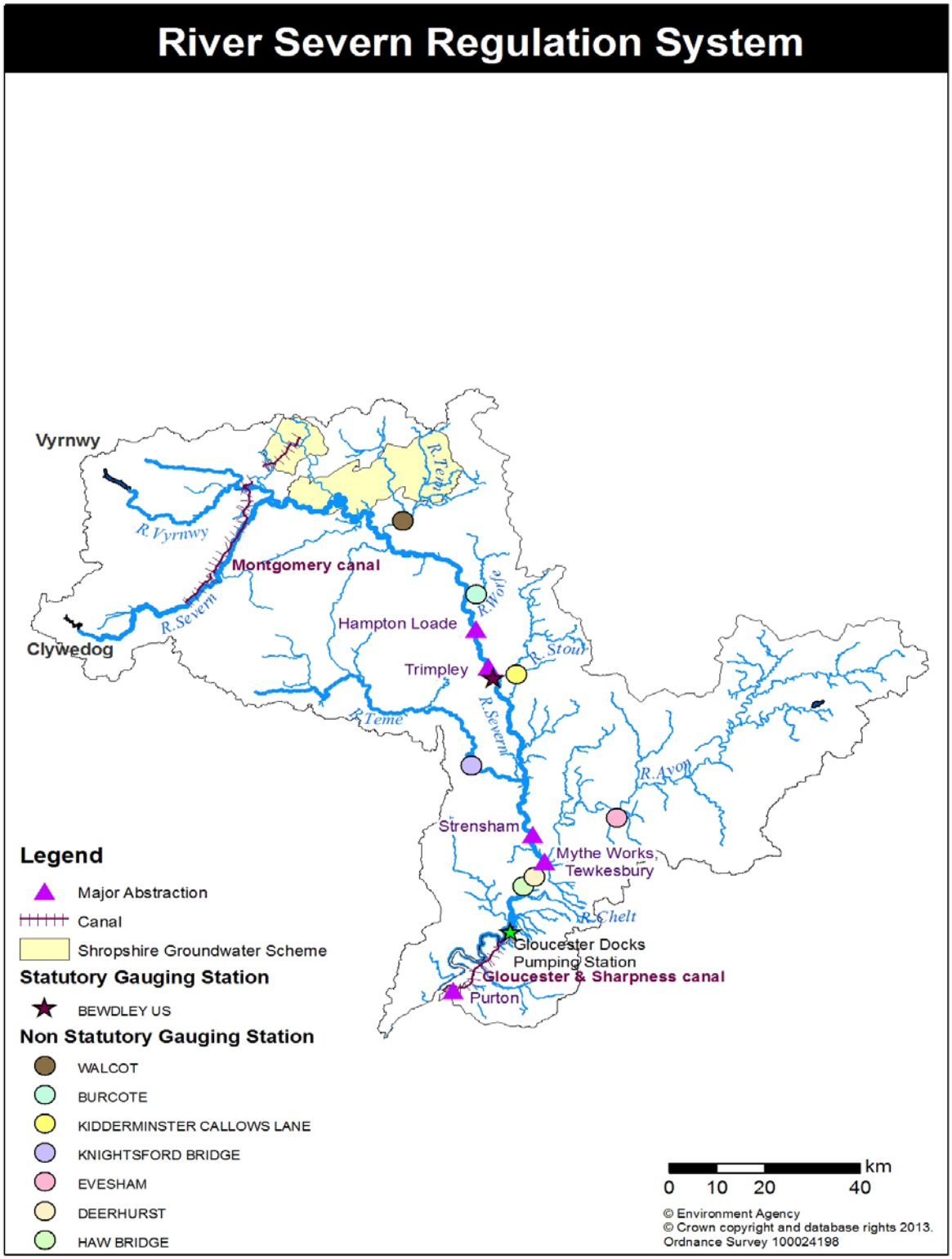


Figure 4: River Severn Regulation

2.2.2. Llyn Clywedog

The drought year 1949 was used to design Llyn Clywedog, a reservoir with a storage capacity of 50,000 million litres solely for River Severn regulation purposes. Release volumes range from a minimum of 18.2 Ml/d to a maximum 500 Ml/d in order to maintain the prescribed flow at Bewdley.

Llyn Clywedog was designed to cope with a lack of runoff during one single summer, based on 50 years data prior to construction. The drought of 1976 considerably exceeded its original design with up to 1% full storage lost each day in July/August 1976. This operational observation provided the basis for the 100 day regulation rule[7] used to restrict major abstractors during drought years.

2.2.3. Lake Vyrnwy

Lake Vyrnwy has a capacity of 59,666 million litres and was constructed with the principal objective of providing a water supply to Liverpool. A small proportion of the volume can be used to supplement regulation of the River Severn when required.

The maximum regulation discharge from Lake Vyrnwy is 405 Ml/d but a more sustainable release is considered to be 70 Ml/d. Normal compensation[8] flow is 45 Ml/d with a reduced daily compensation discharge of 25 Ml/d on any day when the flow at the Afon Cownwy gauge is above 20 Ml/d (at 09.00 hours)[9]. If able to operate at this reduced daily compensation discharge, the stored compensation water is accumulated as a theoretical 'water bank' for the Environment Agency to use in River Severn regulation. An additional 725 Ml is added to the bank on the 1st of every month from March to October inclusive, but at most times of the year all spill from the reservoir is removed from the bank.

The Vyrnwy water bank is reserved solely for the use of Severn regulation and cannot be used without prior agreement for any other purposes. United utilities control a much larger portion of water within Lake Vyrnwy, for which it has identified a drought permit option; to reduce the compensation releases to the Afon Vyrnwy from 45 Ml/d to 25 Ml/d.

2.2.4. Shropshire Groundwater Scheme *(SGS)*

The SGS was given formal approval for development in 1981. It comprises six development areas being constructed in eight phases and provides a means of abstracting groundwater from underlying sandstone aquifers, which can be used for augmentation of the River Severn.

The Permo-Triassic Sandstone in which the SGS has been developed, is one of the most important principal aquifers in the United Kingdom, second only to the Chalk. This favours its use for large scale strategic resource development, as the effects of seasonal abstraction and recharge patterns are more evenly distributed over longer periods within the environment.

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[7] For each day regulation continues after day 100 an abstractor with this condition on their licence will have 1/100th of their 100 day quantity (i.e. the quantity they would be restricted to under Maximum Regulation licence conditions) available for abstraction. In addition they would also have any allocation carried over from the 100 day period and each day could also bank any unused quantity from their daily allocation.

[8] Compensation requirements and/or operations are currently under review through the Afon Cownwy AMP5 investigation, so could be subject to change.

[9] The Lake Vyrnwy catchment artificially incorporates nearly all the flow from the Cownwy tributary, which has been largely re-diverted to flow into Lake Vyrnwy reservoir rather than naturally joining the Afon Vyrnwy downstream.

The primary role of the SGS is to provide a phased level of support (according to regulation risk and SGS operational curves) to help conserve Llyn Clywedog storage during dry years. The SGS draws resources from significant groundwater aquifers, which show a delayed response to drought impacts and provide a reliable extra source when surface water resources are limited. The boreholes are deep enough to have withstood all recent drought events.

The first four phases of the SGS are currently (2013) operational with Phase 5 under development. The combined output from Phases 1, 2, 3 and 4 provides a gross flow of 190 Ml/d and a net of approximately 140 Ml/d. The additional development of phases 5, 6, 7 and 8 would be required to achieve the combined scheme's maximum licensed yield of 330 Ml/d; the net combined volume would be approximately 225 Ml/d.

2.2.5. Water Supply

Llyn Clywedog and Lake Vyrnwy reservoirs provide water by gravity at minimal environmental and financial cost. The SGS must be continuously pumped, and due to the limitation of its maximum discharge rate (i.e. the scheme cannot physically provide greater than 190 Ml/d), the SGS must be used over an extended period to produce a sufficient volume to supplement and help conserve the reservoir resources. The operation of the different resources within the Severn regulation system is appropriately managed according to cost (financial and environmental) and the risk of developing drought.

The need for regulation varies from day to day depending upon rainfall and abstraction demands, the specific use of the SGS varies according to the assessed pre-season risk[10] of the reservoir. The water level in Llyn Clywedog is monitored and plotted on a graph with operational curves developed by the Environment Agency in agreement with all relevant water companies (Figure 5, section 3.2).

Further details on the Severn regulation system operations in accordance with the Llyn Clywedog reservoir Joint Authority Act 1963 (as amended in 1979) are contained in the current version of the Operating Rules for the River Severn Resource/Supply System.

The Severn regulation system maintains higher flows during dry conditions than would naturally be experienced, by releasing water stored during high rainfall/flow events into the river and its tributaries as baseflows decrease and are insufficient to meet the prescribed flow at Bewdley. Appendix B illustrates this behaviour during the 1976 drought event, and Figure 3 demonstrates how the Severn regulation system protects the River Severn from the majority of low flow stress, which would be experienced in neighbouring unregulated rivers.

2.3. High Regulation and Drought Years

For the Midlands region, owing to the significance of major groundwater aquifers in supporting river base flows, it is prolonged shortages of rainfall and dry winters, notably over two consecutive years, that have the biggest environmental impact.

Table 3 shows the ten highest regulation years (i.e. notably dry years) on record, showing how years are often paired together in significance. Years where regulation exceeded 100 days provide a particularly good indication of historical drought stress, as additional restrictions come into force in recognition of the need to manage water resources wisely as dry conditions persist.

[10] Regulation Risk is determined according to current conditions and whether a high regulation season is likely. High regulation can empty Llyn Clywedog in a single season, therefore the SGS would be used early on to prolong surface water sources.

Table 3: Highest Regulation Years (ranked according to No. of regulation days)

Rank	Year	Period of Regulation alert	First day of Regulation Last day of Regulation	Total No. of Regulation days	Total releases (Ml)
1	1989	May - October	30 May -	125	48,600
2	1995	5 May - 23 Nov	17 Jun - 11 Nov	124	42,507
3	1976	22 Apr - Oct?	18 May - 15 Sep	121	39,000
4	1975	9 June - Nov?	10 June - 3 Nov	113	25,000
5	1984	15 May - 1 Oct	15 June - 16 Sep	93	missing
6	2003	11 Apr - 17 Nov	16 Jun - 28 Oct	88	26,494
7	1990	4 May - 3 - Oct	24 May - 30 Sep	85	36,952
8	2006	8 Jun - 12 Oct	21 Jun - 30 Sep	82	27,022
9	1996	17 Jun - 28 Oct	25 Jun - 15 Oct	73	33,702
10	2002	12 Apr - 16 Oct	16 Jul - 13 Oct	70	16,381

Note: data prior to 1990 is patchy with several years missing, the prescribed flow target at Bewdley was increased in 1979 (from 727 Ml/d mean to 850 Ml/d 5 day mean), which will have increased the number of days regulation would be required in subsequent years, and further resources have been developed for River Severn regulation since its original design. All these factors mean the order of ranking does not entirely reflect the order of drought severity.

2.4. Previous River Severn Drought Order Applications

Variations of the River Severn Drought Order were operated in 1976, 1984 and 1989:

- **1975-1976 two separate drought order applications**

  29 July: Lower Bewdley prescribed flow reduced from 727 Ml/d to 545 Ml/d and removed the compensation release obligation (18 Ml/d) from Llyn Clywedog for 6 months. Granted 6 August and operated.

  20 August: Abandon prescribed flow at Bewdley and move to releasing 2% of remaining storage from Llyn Clywedog per day subject to Bewdley not exceeding 545 Ml/d. Granted 3 September but never operated, significant rainfall returned.

- **1984 one drought order application**

  1 August: Cap Llyn Clywedog releases to 2% of storage (no reference to prescribed flow reduction at Bewdley, flow records do not consistently fall below 850Ml/d). Granted 18 August and operated.

- **1989 one drought order application**

  31 August details agreed, application made on 11 September. Lower Bewdley prescribed flow reduced from 850 Ml/d to 730 Ml/d over a 5 day mean. Granted 30 September.

For a drought summary and hydrograph of each of these drought events refer to Appendix B. For more detail on the return periods, refer to section 3.5 and 3.6.

In more than 20 years, and most notably during the 1995-96 events, the River Severn Drought Order has not been required. This reflects the current robustness of the system and ongoing development of further resources in the Shropshire Groundwater Scheme.

An investigation into the potential impact of climate change on the River Severn has been commissioned and will be used to help update this report in the future.

3. River Severn Drought Order Rationale and Proposals

3.1. River Severn Drought Order Proposal

The Environment Agency has developed procedures for the River Severn Drought Order process (summarised in Table 4), driven by the control curves at Llyn Clywedog reservoir (shown in Figure 5).

The River Severn Drought Order proposal includes:

- reducing the target for prescribed flow at Bewdley from 850 Ml/d to 730 Ml/d;
- capping the maximum release from Llyn Clywedog at 300 Ml/d instead of 500 Ml/d;
- imposing a 5% reduction on non spray irrigation licensed abstractions; and
- imposing restrictions on the Canal & River Trust abstractions for the Montgomery Canal in Wales (as detailed in the Operating Agreement 1988 and the Operating Rules for the River Severn Resource/Supply System) and the Gloucester & Sharpness Canal in England (new restriction).

Lowering the prescribed flow at Bewdley aims to balance the existing environmental needs against the need to preserve water to safeguard both people and the environment if the drought continues. The change in prescribed flow at Bewdley equates to a proposed 120 Ml/d reduction, and refers to the 'actual' flows after all abstractions and discharges have been accounted for (not natural). The target of 730 Ml/d is based on an assessment made in 1960 following the 1959 drought (Environment Agency, pers. comm). A paper published by the National Rivers Authority[11] indicated that, while 850 Ml/d would be preferable, 730 Ml/d could be accepted as a minimum flow in the middle of the river to protect fish.

The Clywedog maximum release cap of 300 Ml/d has been set to ensure that Llyn Clywedog would not empty during a repeat of 1976 drought conditions. If Llyn Clywedog reservoir is allowed to empty in a drought, flows and water levels along the whole River Severn would be severely reduced. This would have a significant impact on the environment and people that rely on water from the River Severn. Modelling work in 2006 found a 300 Ml/d cap could have provided approximately 30 days more water storage at the end of the 1976 drought, providing 'back up' resources should a drought of greater severity/duration be experienced.

A reduction on non spray irrigation licences aims to reduce the pressure on remaining water resources in the Severn Regulation system whilst balancing the need to protect abstraction for public water supply. An initial 5% reduction should be achievable for water companies without threatening people's drinking water supply, while still being large enough to benefit the environment and other water users. Higher reductions may also be set if the drought continues, up to 20% if storage in Llyn Clywedog falls below the 'emergency storage' curve. How the abstractor's achieve the reductions will be for their own consideration.

The Environment Agency and the relevant water companies[12] recognise the potential conflict between the water company drought permits/orders and the River Severn Drought Order (refer to section 6.4 for discussion), and close discussions would need to be held to manage this situation, should it arise. It is important to note the River Severn Drought Order seeks to prolong water to

[11] River Severn Control Rules Review Position Statement, NRA, 1994.
[12] Severn Trent Water Ltd and South Staffordshire Water Ltd.

achieve multiple benefits, including the prolonged support of water supply abstractions. Conflicting drought permit/orders may be counterproductive in the longer term.

The Canal & River Trust abstractions are currently exempt from abstraction licensing. This means the Environment Agency and Natural Resources Wales cannot regulate the amount of water abstracted by the Canal & River Trust in a legally enforceable manner. However conditions applied for under a drought order application, if granted, become legally enforceable and would give us the appropriate regulatory powers while the drought order is in force. Imposing restrictions on the Canal & River Trust under the River Severn Drought Order aims to ensure abstractions are operated responsibly during severe drought to benefit both people and the environment. The current operating rules for the Severn Regulation system contain agreed restrictions for the Montgomery Canal abstractions from the River Severn dating back to 1988.

The Gloucester & Sharpness Canal has not been restricted during River Severn Drought Order operations before. In order to satisfy the Conservation of Habitats and Species Regulations 2010 in protecting the Severn Estuary Natura 2000 site under in combination operations, a restriction has now been included as part of the River Severn Drought Order application conditions. The restriction conditions and quantities have been based on the best available information at the time, aiming to balance the Canal & River Trust's obligations with other water user's needs and the environment. During River Severn Drought Order implementation, when flows at Deerhurst drop below 1200 Ml/d the Gloucester & Sharpness Canal abstraction from the River Severn will be capped at 300 Ml/d (figure subject to change). The Habitat's Regulation Assessment (ANNEX 1) concluded this abstraction cap would ensure no significant effect on the Natura 2000 site.

The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operation of the Gloucester & Sharpness Canal and the Bristol Water abstraction it supports. In respect of this concern the Environment Agency has committed to continuing to work with the Canal & River Trust, if sufficient evidence is provided to show a higher abstraction is justified then the 300Ml/d limit will be reviewed.

Before the River Severn Drought Order is operated, Section 57 spray irrigation restrictions would be imposed. Although this is not a direct consequence of the drought order itself, it is part of the sequence for managing water use during a drought situation. It would impact on the agricultural industry, mainly on the existing Licences of Right[13] which normally avoid restrictions.

[13] Licences of Right are abstraction licences that pre-date the current legislation, containing no restrictions (i.e. Hands off Flows) to their rights to abstract water.

3.2. The River Severn Drought Order Control Curves

The River Severn Drought Order is entirely triggered by storage in Llyn Clywedog reservoir, and not by river flows. Storage levels in the reservoir are plotted against the control curves in Figure 5 to track the available water resources and raise awareness of developing dry conditions.

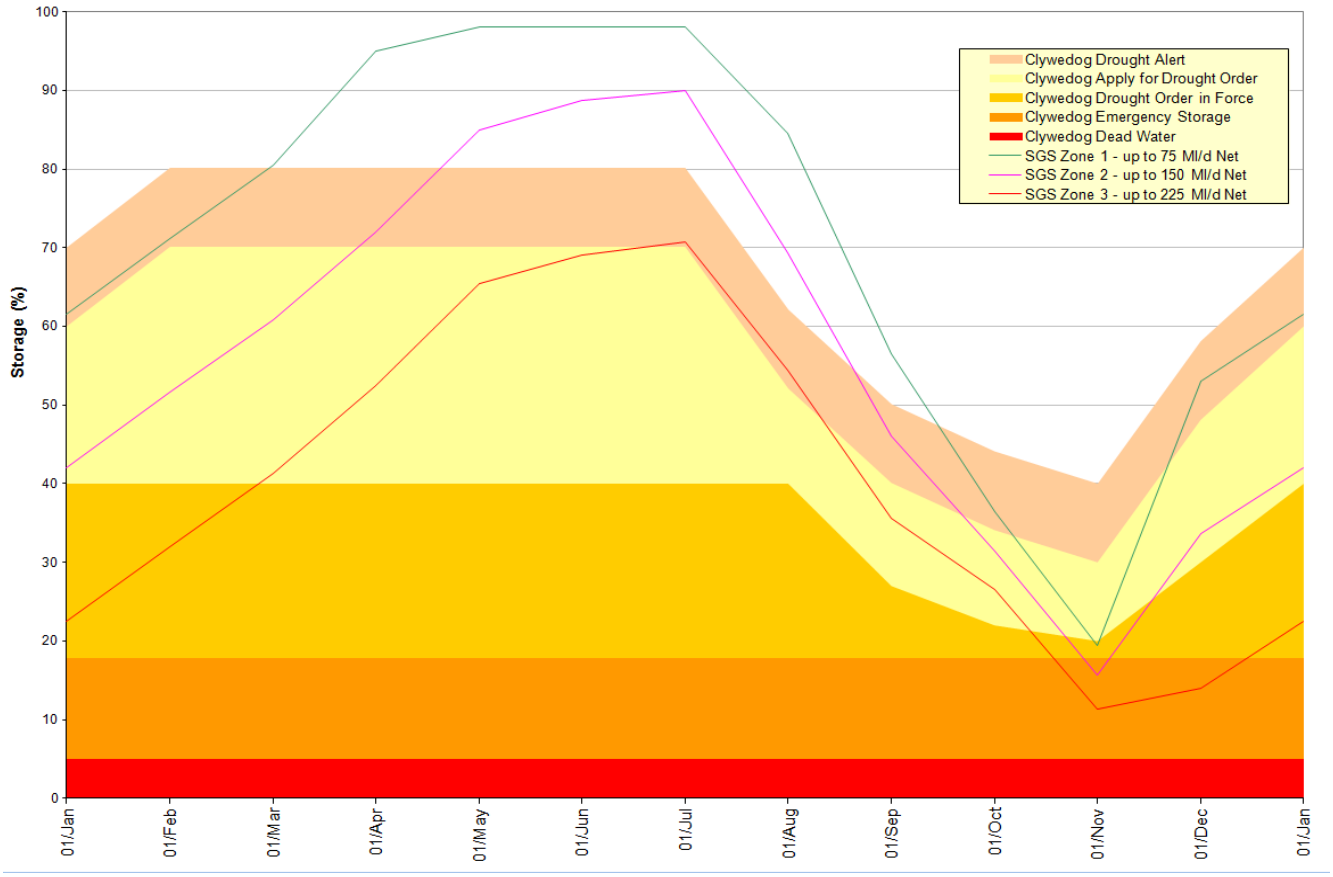

Figure 5: River Severn Drought Order and Shropshire Groundwater Scheme Curves (2012)

** Note, the Shropshire Groundwater Scheme curves provide an operational guide but can be overridden as required. The River Severn Drought Order curves are definitive.*

The River Severn Drought Order control curves (excluding SGS) were last updated in 2006[14] using the Ressim water resources modelling software. Using 2006 abstraction demands, Ressim identified 1976 as the only year between 1920 and 1996 where modelled storage in Llyn Clywedog fell below the 'apply' trigger curve. Modelling work in 2010, using the water resources Aquator model found 1976 conditions no longer triggered the need for the Severn Drought Order; this could be attributable to additional SGS development improving the robustness of the Severn regulation system.

[14] Report on generation of draft trigger curves for Clywedog Reservoir (Environment Agency, February 2006).

3.3. The Environment Agency River Severn Drought Order Process

Table 4 shows the associated actions the Environment Agency would take as storage within Llyn Clywedog reservoir dropped below the specific control curves.

Table 4: The River Severn Drought Order Process

Alert Curve Figure 5	**Drought order preparation:**
	• The Environment Agency will form the River Severn Drought Management Group[15]. Mitigation options to be discussed and feasibility identified.
	• The Environment Agency prepares the drought order application in discussion with other groups (including water companies, the Canal & River Trust, Natural England, Natural Resources Wales, National Farmers Union (NFU), Country Landowners Association, Farmers Union of Wales (FUW), Defra and Welsh Assembly Government) and considers:
	  • The requirement/nature of a Section 57 irrigation licence restriction;
	  • Whether to include emergency storage drought order conditions as part of the application.
	  • Whether the drought order needs to include varying the Shropshire Groundwater Scheme (SGS) Licence.
	• The Environment Agency circulates and discusses reservoir refill prospects.
	
	Communications:
	• The Environment Agency organises a meeting[16] with the River Severn Drought Management Group (plus appropriate stakeholders/partners) to discuss the developing drought situation and implications on the Severn and wider catchments. Further meetings may be required.
	• The Environment Agency will engage with Natural England and Natural Resources Wales, in particular reference to management of the River Severn Estuary.
	• The Environment Agency will meet with the NFU, and FUW and Country Landowners Association as required, to discuss the possible need and implications of S57 Spray irrigation restrictions and how best to manage their implementation.
	• The Environment Agency intensifies its public water conservation appeals in the media. The communication plan will be followed in liaison with water companies, to ensure a consistent message is delivered.

[15] The River Severn Drought Management Group should consist of representatives from: Environment Agency, Natural Resources Wales (to capture what was the Environment Agency Wales and Countryside Council for Wales), Severn Trent Water, South Staffordshire Water, Bristol Water, United Utilities and the Canal and River Trust. The group is flexible and representatives from Natural England should also be considered.

[16] At this meeting the group will decide the frequency of further meetings and consider liaising with other groups including Eon, NFU, Natural England, Consumer Council for Water and Welsh Assembly Government.

Application Curve Figure 5	**Drought order application:**
	• The Environment Agency formally applies for a drought order to the Secretary of State for environment, food and rural affairs (Defra) in England, and the Welsh Government for Wales.
	
	Communications:
	• The Environment Agency will seek opportunities for a Lake Vyrnwy overdraft with United Utilities[17].
	• The Environment Agency will organise a meeting of the River Severn Drought Management Group to discuss:
	  • Voluntary reductions in abstraction that could be implemented immediately.
	  • Abstraction reductions that will be applied once the drought order is granted.
	  • Using mitigation options in section 14 as appropriate.
	• The Environment Agency will inform other external groups of the application and what it means for the River Severn and how it may affect them.
	• The Environment Agency will decide what S57 restrictions are appropriate and begin the process of implementation (expectation is for S57 to be in place before the drought order is activated).
	• The Environment Agency and Natural Resources Wales will decide whether temporary restrictions on fishing activities are appropriate and begin the process of implementation.
	• The Environment Agency will continue public appeals for water conservation in accordance with the Midlands Drought Plan.

Enforce Curve Figure 5	**Drought order conditions become live, if not already implemented:**
	• Section 57 restrictions on surface water irrigation Licences should be in force where appropriate.
	• Prescribed flow at Bewdley reduced to 730 Ml/d 5 day mean (daily 650Ml/d minimum remains in force).
	• Max releases at Llyn Clywedog capped to 300 Ml/d.
	• 5% daily licence reduction in non-spray irrigation abstraction licences enforced for the River Severn.
	  • The 5% reduction will be pro rata to the remaining available licence during the first 100 days of regulation and pro-rata thereafter.
	  • The 5% reduction will be on top of existing constraints during Maximum Regulation.
	• Canal & River Trust abstraction reductions to be enforced;
	  • Montgomery Canal restrictions in accordance with the 1988 Operating Agreement and Operating Rules for the River Severn Resource/Supply System.
	  • Gloucester & Sharpness Canal abstraction cap of 300[18] Ml/d when flows at Deerhurst drop below 1200 M/d.

[17] The feasibility of an overdraft from Lake Vyrnwy will depend on whether there is sufficient excess storage in Lake Vyrnwy, and if United Utilities were able to spare the water at low risk to their own supply network.
[18] The 300 Ml/d cap may be subject to change. The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operations. If sufficient evidence can be provided to show a higher abstraction is justified, then the abstraction volume will be reviewed in the future.

	• When appropriate, activate the Shropshire Groundwater Scheme drought order to vary the annual or five-year rolling licence quantities. **Additional non-drought order actions to be taken:** • If agreement in place – Lake Vyrnwy water bank overdraft used to support flows along the River Severn (subject to need). • If agreement in place - Chelmarsh bankside storage used for short term releases to support the lower River Severn (subject to need). **Timing of drought order conditions:** • It is anticipated that it will take at least 28 days for the drought order to be granted, assuming a public hearing is required. This lead-time is built into the curves. **Communications:** • The Environment Agency will organise a joint meeting with external groups[19] to discuss the drought situation and drought order conditions. Further meetings may be required. • The meeting should look ahead to possible implementation of emergency storage conditions and amendments to the drought order if not included in original application. • The Environment Agency will continue public appeals for water conservation in accordance with the Midlands Drought Plan. [3]*This meeting could include: Severn Trent Water, South Staffordshire Water, Bristol Water, United Utilities, Eon, The Canal & River Trust, Natural England, Natural Resources Wales, Farmers Unions, Water UK, Defra, Welsh Assembly Government, CC Water.*
Emergency Storage curve Figure 5	By this stage in a drought event, unavoidable region and/or country wide drought impacts are expected to be occurring due to the natural shortage of rainfall. **Options considered to enhance drought order conditions: (will depend on the extent and timing of drought).** • Prescribed flow at Bewdley removed, best endeavours will be made according to remaining resources and weather forecasts. • Releases from Llyn Clywedog reservoir capped to 1.5% of remaining useable storage. • Consider reductions in daily licensed quantities of non-spray irrigation licences of greater than 5% (reductions up to 20% to be considered). **Communications:** • The Environment Agency organises a meeting with the River Severn Drought Management Group to discuss the drought situation and enhanced drought order conditions. Further meetings, with other groups may be required within this drought zone. • Ongoing engagement with Natural England and Natural Resources Wales

[19] This meeting could include: Severn Trent Water, South Staffordshire Water, Bristol Water, United Utilities, Eon, The Canal and River Trust, Natural England, Natural Resources Wales, Farmers Unions, Water UK, Defra, Welsh Assembly Government, CC Water.

	(plus other appropriate external groups). • The Environment Agency will continue public appeals for water conservation in accordance with the Midlands Drought Plan.
Dead Water Curve Figure 5	**Llyn Clywedog Reservoir** Best efforts will be made to prevent storage falling below 5% capacity, into the 'Dead Water' zone. Water physically cannot be abstracted from Llyn Clywedog below this point and all releases (including compensation flow) will stop, putting the immediate watercourse at great risk of drying up.
Drought Order Cessation • Consider withdrawing drought order application if storage rises above alert curve. • Consider relaxing drought order conditions once storage rises 10% above enforce curve. (Note: Drought order powers are in place for six months after date granted. Conditions could be implemented again without another application if storage subsequently drops below enforce curve). • Consider relaxing emergency storage drought order once storage rises 5% above emergency storage.	

Note: Drought order powers can be extended within the last 28 days of the agreement. The Environment Agency will discuss with the River Severn Drought Management Group if it intends to apply for an extension to the River Severn drought order.

3.4. What Conditions Trigger a River Severn Drought Order

Owing to the size of the River Severn catchment and complexity of the water demands upon storage at Llyn Clywedog it is difficult to calculate return periods specifically for the River Severn Drought Order. The Welsh Mountains typically receive the highest rainfall of the catchment, keeping the reservoirs (Llyn Clywedog and Lake Vyrnwy) well filled. Localised groundwater recessions from the Shropshire Plains down to the Severn Estuary are a significant driver for high regulation need and depletion of Llyn Clywedog storage. The opposite could also be true, with a lack of rainfall over the Welsh Mountains preventing sufficient recharge during a high regulation season primarily triggering the need for a River Severn Drought Order. Very different return periods are produced according to which rainfall catchment areas and time periods are included in the calculations.

3.5. 1975-1976 Rainfall Return Periods (Tabony Calculations)

For consistency with Environment Agency drought management, Tabony Table calculations (refer to Appendix C for a brief explanation of what a Tabony Table/calculation is) were used to produce return periods based on accumulative rainfall (up to 36 months) compared to expected long term monthly averages (1961-1990).

The 1975-76 drought event remains a primary benchmark for drought planning on the River Severn due to its hydrological severity and spatial impact. The River Severn Drought Order application was made in July 1976 and activated in August 1976. Rainfall data for this period was used to populate the appropriate catchment Tabony Tables, shown in Appendix D graphs and Tables 5 and 6.

Table 5: July 1976 Tabony Table Accumulative Return Periods

Tabony catchment	Accumulative Return Period (1 in x years) - from July 1976 (going back 36 months)							
	1 month	3 month	6 month	9 month	11 month	12 month	15 month	18 month
Severn Tabony	5	10	20	20	20	20	20	10
Welsh Mountains	5	20	20	2	2	5	10	2
Shropshire Plains	5	10	10	50	100	100	200	50
Middle Severn	5	10	20	50	50	50	50	20
Avon	10	10	100	200	200	200	200	50
Lower Severn	10	20	50	100	100	200	200	50

The River Severn Drought Order was triggered during July 1976. Using the Severn Tabony Table (at the full Severn catchment scale) a return period of 1 in 20 years is calculated over 6 to 15 months. However the Welsh Uplands clearly received more winter rainfall compared to the mid to lower catchments, which experienced up to a 1 in 200 year event over 15 months. This highlights the important geographical split that drives the River Severn Drought Order requirement.

Table 6: August 1976 Tabony Table Accumulative Return Periods

Tabony catchment	Accumulative Return Period (1 in x years) - from August 1976 (going back 36 months)							
	1 month	3 month	6 month	9 month	11 month	12 month	15 month	18 month
Severn Tabony	5	50	50	50	100	50	50	20
Welsh Mountains	100	500	200	10	10	10	10	20
Shropshire Plains	20	100	100	100	200	200	200	200
Middle Severn	10	50	50	50	200	100	50	50
Avon	1	10	20	100	200	100	100	50
Lower Severn	2	20	50	100	200	100	200	100

Table 6 shows that by the end of August individual rainfall areas within the Severn basin experienced up to 1 in 500 year return periods over 3 months, and the majority experienced a 1 in 200 year event over 11 months. The difference in return periods between the rainfall areas demonstrates the difficulty in determining an overall River Severn Drought Order estimate.

During 1976 the Welsh Uplands experienced a shorter term but more acute shortage of rainfall compared to the downstream catchments, which was then sufficient to limit recharge to Llyn Clywedog during the critical demand period. The high regulation demand from downstream and the reduced baseflows resulting from the longer period of reduced rainfall caused the River Severn Drought Order to be triggered during August 1976. By the end of August, the whole Severn catchment Tabony calculates a return period of 1 in 100 years over an accumulated 11 month period.

3.5.1. Limitations with Using Rainfall and Tabony Tables to Determine Return Periods

Short term high intensity rainfall events do not provide effective recharge to catchments already experiencing long term dry weather/drought impacts (due to soil moisture deficits and depleted groundwater levels), although they can be vital in refilling reservoirs.

Tabony Tables use monthly rainfall totals and make no assumption about rainfall distribution throughout a month, producing return periods based around the expected monthly totals. Therefore, high rainfall/flood events in particular can skew the monthly results to suggest normal rainfall has been received for a single month and/or accumulatively. This can mask a developing drought and/or conflict with other environmental indicators. In the Midlands, groundwater levels are a crucial parameter in drought development, so rainfall should be used in context of aquifer recharge and groundwater levels during real events, not in isolation.

3.6. River Severn Drought Order Predicted Return Period

New drought scenario's were developed to test the River Severn Drought Order because modelling found the historic droughts no longer triggered the need for the drought order, due to the development of more water resources for River Severn regulation. The drought scenarios created to test the River Severn Drought Order were all based on the 1975-1976 drought event as a starting point; therefore rainfall data for this period was used to populate the initial Tabony Tables.

The water resource modelling in Aquator (Appendix E) assumed that rainfall and flows mimicked the real event into August 1976. From September onwards, inflows were reduced to prolong the drought impacts to test the River Severn Drought Order. Rainfall cannot be directly altered within Aquator, so flow reductions were applied across the whole River Severn catchment, to replicate little to no significant runoff.

Assuming no rainfall was received, the Severn catchment Tabony return periods were pushed into extremes of 1 in 1000 year over 1 month, with accumulative return periods averaging between 1 in 200 and 1 in 500 years over 2 to 11 months for the theoretical September (theoretical drought order activated at the end of August). However, this modelling represented an extreme interpretation of continued flow recessions; some rainfall would be likely even during continued recessions. The real 1976 event (Bewdley prescribed flow was 727 Ml/d at this time) highlighted that at the Severn catchment scale, Tabony return periods of 1 in 20 from 6 to 15 months accumulatively were enough to trigger the Severn Drought Order application during July.

Using the 1976 event as a benchmark (noting the improvements within the regulation system since this event), it could be assumed that a River Severn Drought Order ‘application’ could be triggered for events with Severn catchment scale Tabony return periods of greater than 1 in 20 for 6 months and longer accumulatively. A drought order application would depend on the time of year when rainfall shortages occurred. It is important to note that the probability for an application is more likely than a drought continuing long enough for the River Severn Drought Order to be ‘operated.’

It is the combination of long term rainfall shortages in the middle Severn sub catchments that drive the need for high regulation (owing to significantly reduced baseflows), coupled with a shorter term absence of significant rainfall over the Welsh Uplands, reservoir refill is limited enough to trigger the need for a River Severn Drought Order. Due to the various parameters, timings and sequence of events involved, it is unrealistic to predict a return period/probability with high accuracy. Climate change rainfall variations and/or increased abstraction demands on the River Severn will also increase the frequency of need for a River Severn Drought Order.

3.7. River Severn Drought Order Level of Service

Based on the number of activations since Llyn Clywedog was built, and accounting for the improvements made to the Severn regulation system in recent years (e.g. commissioning new phases of SGS), the Environment Agency propose a service level of 1 River Severn Drought Order operation in 50 years.

3.8. Statement of Need for Water

[Section may be updated when applying for a River Severn Drought Order]

The purpose of Llyn Clywedog is to provide a large strategic source of surface water to supplement flows in the River Severn, balancing the interests of people and the environment. Llyn Clywedog provides the primary source of water to the River Severn regulation system, but no water resource is infinite without recharge. Low storage in Llyn Clywedog could occur as a consequence of exceptional shortage of rainfall. During drought conditions the demand on storage is likely to be significant and prolonged. The Environment Agency recognises there is a risk that Llyn Clywedog could become exhausted if no proactive drought management is taken to conserve the remaining storage. Should Llyn Clywedog storage become exhausted, this would have a significant impact locally, and throughout the River Severn and dependant catchment areas.

Llyn Clywedog was solely designed to support River Severn regulation, which provides drinking water to over 6 million people, supports industry, agriculture and protects the environment from all these daily abstraction pressures. The Severn regulation system cannot cope without Llyn Clywedog but the system is robust and designed to cope with dry conditions and even droughts of the magnitude experienced in 1995. However, with increasing populations, higher environmental protection requirements and risks from climate change, the system is under increasing pressure and droughts of higher severity will push the system beyond its design capacity. Under these conditions the River Severn Drought Order has been designed to help prolong Llyn Clywedog storage, aiming to ensure reduced but consistent support can be provided to the river for longer than if no action were taken.

Without the River Severn Drought Order, Llyn Clywedog could be making maximum 500 Ml/d releases to support the 850 Ml/d prescribed flow at Bewdley flow gauge, lowering reservoir storage by approximately 1% per day. Llyn Clywedog storage can be exhausted in a single regulation season under such circumstances. Modelling identified that once releases exceed 300 Ml/d, continuous regulation and poor/no recharge could result in a drought order application being made after approximately 70 days.

If the River Severn Drought Order were not operated and a drought continued long enough, water in Llyn Clywedog could be exhausted, causing a sudden and significant reduction in flow throughout the River Severn. The upper River Severn is likely to dry up if reservoir compensation releases fail due to lack of storage. Under such circumstances the River Severn would experience record minimum low flows and sections of the lower tidal Severn would be at increased risk of saline intrusion. Water levels would be significantly depleted along the River Severn, causing localised loss of habitat, higher sediment deposition, low dissolved oxygen and extensive barriers to fish migration and boat navigation. Public water supply would be put at risk as the River Severn would no longer be a reliable source of good quality water.

There would also be an increased risk to the following regulation year, should a second drought follow. If storage in Llyn Clywedog is not protected in such a year, there is less likely to be sufficient rainfall to refill the reservoir in time for the following regulation season. This would exacerbate impacts on abstraction and the environment for a second year as there would be less water available for the regulation system.

The Environment Agency considers it to be more beneficial to abstractors of water and the aquatic environment, to regulate the River Severn for longer at a lower flow by using the River Severn Drought Order, than to keep regulating to a higher flow and risk running out of water.

3.9. Alternative Sources Considered

[Section may be updated when applying for a River Severn Drought Order]

The River Severn Drought Order (including SGS option) is considered to be the last resort the Environment Agency can take to protect the ecological status of the river and the licensed water transfers that rely on this system.

Before a River Severn Drought Order application is made, all necessary water saving measures and communications identified in the Midlands Drought Plan will have been taken. The SGS will have been actively supporting Llyn Clywedog, alongside strategic usage of the Lake Vyrnwy water bank system. Section 57 spray irrigation restrictions will have been considered and implemented as appropriate. The Environment Agency will also have been working closely with water companies to ensure they follow their own Drought Plans and manage water resources in a sustainable manner as the drought develops.

In-combination, Llyn Clywedog (50,000 Ml) and SGS phases 1 to 4 (25,500 Ml), represent an annual maximum strategic water resource potential of 75,500 Ml. Their sole purpose is to regulate water resources in the River Severn. Aside from Lake Vyrnwy reservoir (59,600 Ml), and the bank side storage reservoir at Chelmarsh (3,063 Ml), there are currently no alternative strategic water resource structures of equivalent volume within the River Severn catchment.

The majority of the water from Lake Vyrnwy reservoir is exported out of the catchment for use by United Utilities to provide public water supplies to northwest England. Aside from the normal baseline compensation releases to the Afon Vyrnwy, any surplus volume between March to October is already accumulated in the Lake Vyrnwy water bank to provide an extra volume of water for River Severn regulation. Redeploying a higher proportion or all of the storage at Lake Vyrnwy to support flows in the River Severn would not be an Environment Agency decision, and could not be made without compromising United Utilities' resource balance to northwest England.

Chelmarsh is a pumped bank side storage reservoir filled from the River Severn, and as such cannot be considered as an alternative source.

The majority of water companies that abstract from the River Severn have an extensive supply network. In some cases this network could allow the water companies to move water from a resource ‘rich’ catchment, to support supplies (i.e. reduce abstraction) in a ‘stressed’ catchment. The extent to which River Severn public water supply abstractions could be supported by re-deployment of existing sources will always depend on the demands and drought stresses in other parts of each company’s supply network. It is unlikely that sufficient resources would be available to allow all water company abstraction from the River Severn to cease. This is highlighted by the fact that Severn Trent Water, South Staffordshire Water and United Utilities (from Lake Vyrnwy) all have their River Severn catchment sources as potential drought permit sites.

Modelling has shown that for reservoir storage to cross the "drought order in force" curve at Llyn Clywedog, the natural drought conditions across the region would be widespread. Costly environmental impacts outweighing those expected on the River Severn as a result of the River Severn Drought Order operation would be experienced. No alternative action or resources would be available to the Environment Agency other than to apply for the River Severn Drought Order.

In the absence of alternative strategic water resources of equivalent volume within the Severn catchment, the River Severn Drought Order aims to ration out the remaining resources in Llyn Clywedog and seek to extend pumping of SGS beyond its current abstraction licence constraints. This is required to extend the length of time regulation support can be provided along the River Severn during a prolonged drought to protect the ecology of the river and help secure water for public supply.

4. Approach to Assessment of Impacts

To assess the potential positive and negative impacts from operating a River Severn Drought Order, the geographical areas and species of likely impact were identified, likely flow scenarios were generated, and then appropriate assessment methods were used for each component (e.g. water resources, water quality, ecology).

This section outlines the high level generic assessment approaches, and introduces the theoretical drought scenarios applied for impact assessment. Details of the assessment of water resources (section 5.3); water quality (section 6.3) and ecological impacts (sections 7.4, 7.5 and 9.3) can be found in the relevant sections.

4.1. Area of Potential Impact

Figure 6 displays the area which could potentially be impacted (positively or negatively) by the River Severn Drought Order. All impact assessments have focused on these areas, connected conservation sites (refer to Appendix A) have been individually screened and taken through the Habitat Regulation Assessment where appropriate.

The River Severn Drought Order impacts directly ('Primary Path') upon Llyn Clywedog reservoir in Wales, and directly downstream along the River Severn into the Severn Estuary at Bristol. Several connected tributaries are sensitive to alterations because of migratory species trying to reach spawning grounds; these have been identified as 'Secondary Paths.' Due to the role of Lake Vyrnwy in the regulation system, altering releases from Llyn Clywedog will also have direct impact on Lake Vyrnwy, and the reach of the Afon Vyrnwy from the reservoir downstream has therefore also been marked as a 'Primary Path'.

The SGS drought order component would initially have positive impacts, raising surface water flows along several tributaries (e.g. River Perry and Tern); for detail on the localised impacts refer to the SGS Environmental Report (Annex 2).

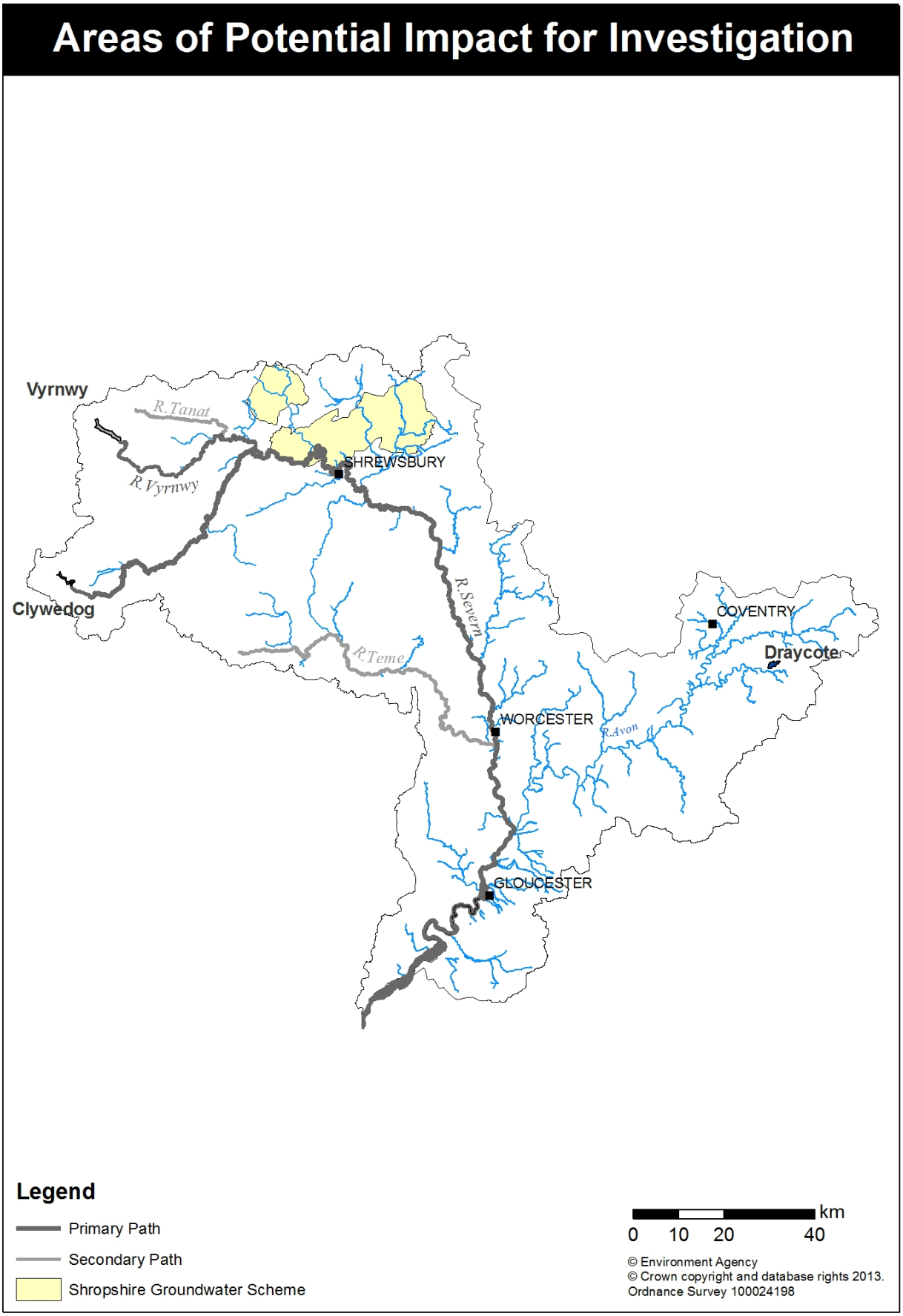

Figure 6: Areas of potential impact from the River Severn Drought Order

4.2. Ecological Sensitivity

The impact a River Severn Drought Order could have on the ecology of the aquatic environment will vary significantly according to the time of year it is needed, and the existing antecedent conditions. Specific flow conditions have been modelled to help assess some of the likely worse case situations; however it is important to recognise the exact timing and scale of flow deterioration cannot be guaranteed. To help assess future droughts as they occur, Table 7 identifies the critical ecological periods, highlighting when the river environment is most vulnerable to flow stress.

Table 7: Critical Periods of Ecological Sensitivity

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Macroinvertebrates		x	x	x	x	x	x	x	x	x	x	x	x
Macrophtyes						x	x	x	x	x			
Resident fish species of note													
Brown trout (Salmo trutta morpha fario)	Adults	x	x	x	x	x	x	x	x	x	x	x	x
	Spawning										x	x	x
	Egg incubation	x	x									x	x
	Fry			x	x	x	x	x	x	x	x	x	x
	Parr	x	x	x	x	x	x	x	x	x	x	x	x
Bullhead (Cottus gobio)	Spawning			x	x	x	x						
	Egg incubation			x	x	x	x	x					
Chub (Leuciscus cephalus)	Spawning				x	x	x						
	Egg incubation				x	x	x	x					
Perch (Perca fluviatilis)	Spawning				x	x	x						
	Egg incubation				x	x	x	x					
Barbel (Barbus barbus)	Spawning					x	x	x					
	Egg incubation					x	x	x	x				
Grayling	Spawning			x	x	x							
	Egg incubation			x	x	x	x						
	Adults	x	x	x	x	x	x	x	x	x	x	x	x
Pike (Esox lucius)	Spawning		x	x	x	x							
	Egg incubation		x	x	x	x	x						

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dace (Leuciscus leuciscus)	Spawning			x	x	x							
	Egg incubation			x	x	x	x						
Roach (Rutilus rutilus)	Spawning					x	x						
	Egg incubation					x	x	x					
Migratory Fish of note													
Atlantic salmon (Salmo salar)	Spring run U/S migration					x	x	x					
	Main U/S migration									x	x	x	x
	Redds	x	x	x									x
	Fry	x	x	x	x	x	x	x	x	x	x	x	x
	Parr	x	x	x	x	x	x	x	x	x	x	x	x
	Smolt D/S migration				x	x	x	x					
Sea trout (Salmo trutta morpha trutta)	Upstream migration				x	x	x	x	x	x			
European eel (Anguila anguila)	Elver U/S migration		x	x	x	x	x	x					
	Silver eel D/S migration									x	x	x	
Severn Estuary Annex II migratory species (SAC status)													
Twaite shad (Alosa fallax)	Upstream migration				x	x	x						
	Downstream migration						*	*	*	*			
	Spawning					x	x						
River lamprey (Lampetra fluviatilis)	Adult U/S migration	x	x	x						x	x	x	x
	Juvenile D/S migration	x	x								x	x	x
	Spawning		x	x	x	x							
Sea lamprey (Petromyzon marinus)	Adult U/S migration				x	x	x	x					
	Juvenile D/S migration	x	x								x	x	x
	Spawning					x	x	x					

*Twaite Shad are not necessarily vulnerable to low flows whilst in freshwater, therefore their downstream migration may not be impacted. However, the cycle has been included in Table 7 for future consideration.

As the table shows, macroinvertebrates can be at risk all year according to the specie and degree of low flows that occurs. Similarly, some fish species could be at risk all year, as low flows could limit their movements, food availability and possibly increase the risk of predation. However some species may only be vulnerable at certain times of year, usually relating to breeding cycles and migration patterns.

This information has been used in the impact assessments for ecology, to investigate the potential impacts the River Severn Drought Order could have as a result of changes in water levels and flows.

4.3. Assessment Points

Eight assessment points (APs) were selected along the main River Severn (Figure 7) to represent and assess the impacts on flows at key points along the river system;

- Vyrnwy (Vyrnwy Weir)
- Clywedog (Bryntail)
- Buildwas
- Bewdley
- Saxons Lode
- Deerhurst/Haw Bridge
- U/S Sharpness
- Lower Parting

The first six sites were located at gauging stations to enable modelled data to be compared against actual recorded flows and existing Environmental Flow Indictors[20] (taken from the Environment Agency's current Catchment Abstractions Management Strategies (CAMS), please refer to Appendix F for more detail).

Deerhurst and Haw Bridge represent the furthest downstream continuous flow gauges, but for this investigation it was decided to have two APs further downstream in order to more accurately assess the inflows to the Severn Estuary. U/S Sharpness and Lower Parting were selected to assess flows up and downstream of the potentially large abstraction to the Gloucester & Sharpness Canal, with Lower Parting representing inflows to the Severn Estuary. Modelled data (using Low Flows Enterprise[21]) was used to represent expected normal and/or natural conditions for comparison against the modelled drought flows. This does represent a change away from the techniques used to assess all the upstream assessment points.

In order to gather and represent ecological and WFD information for the whole River Severn, sample sites close to the assessment points were used to incorporate the longest records possible for analysis. Information on these locations and how they have been paired with the River Severn Drought Order assessment points is contained in Appendix O and section 7.

For macroinvertebrate assessment, two control points were also used to represent unsupported (i.e. more natural) watercourses for comparison. Tenbury on the River Teme and Llanyblodwel on the River Tanat were selected to provide a benchmark for comparing the impacts from low flows/droughts on macroinvertebrates living in non regulated (i.e. unsupported) rivers. This is

[20] Environmental Flow Indicators are used to indicate where abstraction pressure may start to cause an undesirable effect on river habitats and species. For more information refer to Appendix F.

[21] Low Flows Enterprise is an established rainfall runoff model capable of modelling natural and influenced FDCs for surfacewater.

important to illustrate the different scale of drought magnitude that an unsupported river would experience when compared to the supported flows of the River Severn.

Figure 7: Main River Severn Flow Assessment Points

4.4. Modelled Drought Conditions

Studying historic droughts on the River Severn provided a foundation for assessing the potential impacts of a River Severn Drought Order. The last operation was in 1989, when the river environment, permitted activities, monitoring and population size were all very different to present. The capacity of the Severn regulation system has also been increased since the last drought order application. Initial water resource modelling found that even 1976 drought conditions would no longer trigger the operation of the River Severn Drought Order. Therefore the full impacts on the current system could not be tested based on data from historical droughts.

In order to fully test the potential worst case impacts of the River Severn Drought Order, two theoretical drought events were created using the 1975 and 1976 conditions as a starting point. Natural flows[22] and reservoir inflows[23] were then altered to extend and repeat the drought summer of 1976.

The drought conditions and subsequent scenarios produced all resulted in a River Severn Drought Order application during August. The main impacts on flow and therefore ecology were experienced until natural rainfall returned in November, The drought order did however remain in force beyond the natural flow recovery and over the winter until Llyn Clywedog refilled. Although the modelling did test the drought order over the winter months, a separate winter only application was not modelled due to the low probability of occurrence.

The River Severn Drought Order is triggered by low water levels in Llyn Clywedog reservoir, as a direct consequence of making releases to support River Severn regulation. Records show that since Llyn Clywedog was built and Severn regulation began, the latest releases were made on 15 November 1995. During 1975 releases were made between 10 June and 3 November, and for 1976 between 18 May and 15 September. The latest regulation alert end date on record was 29 November 2011.

All the recent drought modelling and historic evidence supports that Severn regulation, and consequently the risk of a River Severn Drought Order application would be during the summer. Therefore a separate winter application scenario was not justified.

4.4.1. Acute Drought Condition

The Acute drought condition represents a severe summer drought event following two dry winters/springs (i.e. below average recharge). The acute drought uses all the rainfall and flow conditions from 1975 up to and including August 1976. For September and October the existing river flow recessions (falling flows and levels) were allowed to continue as if little to no rain had been received, extending the duration of the drought away from the real event and therefore increasing the severity enough to trigger the River Severn Drought Order operation. Real rainfall and natural flows were used from November 1976 onwards, testing the potential recovery from the River Severn Drought order under realistic conditions.

[22] Natural flows refer to the volume of water moving down a river in the absence of any man made influences such as abstractions (removing water) and discharges (returning water).
[23] Reservoir inflows refer to the amount of water entering a reservoir and therefore increasing the storage levels, known as refill.

4.4.2. Chronic Drought Condition

The Chronic drought condition was created to test the long term performance of the River Severn Drought Order, over three dry winter/springs and two drought summers.

The same theoretical acute scenario was used up to mid September, triggering the River Severn Drought Order initially but then a return of some rainfall was modelled before any flow benefits were recognised. To produce the subsequent year's summer drought, real natural flows from mid September 1975 to the end of May 1976 were used with a 10% reduction. The acute scenario flows were then repeated from June onwards.

4.5. Drought Scenarios

Within both the Acute and Chronic drought conditions, three separate scenarios were created to assess the potential benefits and impacts of the River Severn Drought Order;

- Do Nothing (Baseline)
- Drought Order Only
- Full In-Combination

There was a fourth scenario that was modelled but not fully assessed. The 'Water Company Permits Only' scenario created a theoretical situation for Acute and Chronic Conditions to test what could happen to flows if the water company drought permits/orders were operated without the River Severn Drought Order. This was a quick test to justify why we would need the River Severn Drought Order to help protect the environment as well as people, and showed flows and therefore water levels would be decreased further if the River Severn Drought Order were not operated. The scenario was used as a minor reference for some assessments to justify the River Severn Drought Order, but it was not considered to be the Environment Agency's remit to conduct an environmental assessment on behalf of the water companies, which is why it is not referenced in the main report.

It is important to emphasise that the drought scenarios described above and assessed in this report are theoretical. They were developed as a means of assessing the potential worse case environmental impacts associated with managing water resources during a severe drought, providing a guide on flow trends and likely periods of operation. Models cannot predict to a high level of accuracy exactly what each drought will look like (e.g. timing and duration) until the antecedent conditions are known.

4.5.1. Do Nothing (Baseline)

The 'Do Nothing' (Baseline) scenario represents the River Severn regulation system continuing to operate at 'normal' parameters throughout both the acute and chronic drought conditions. This represents the conditions that would be expected if no River Severn Drought Order were operated i.e. if Llyn Clywedog continued to provide the primary resource support and Bewdley prescribed flows were maintained at 850 Ml/d, until resources became exhausted.

The 'Do Nothing' scenario was used as the baseline comparison instead of a natural flow series for this investigation on the basis that it represented a more realistic comparison of likely flows during a severe drought event if no drought management actions were taken to conserve storage in Llyn Clywedog. It should also be noted that the water resource model used (Aquator) could not isolate natural flows away from discharges and some abstractions, making it difficult to accurately

separate and naturalise the flow series for a theoretical event. This approach is different to previous environmental report assessments (e.g. AMEC, 2008), but does not pose any risk to environmental protection.

The River Severn is an artificial watercourse and natural flow regimes can no longer be expected along the main river (due to large water abstractions, transfers, weirs, Severn regulation etc), although flow targets derived from expected natural flows exist to protect the environment. The Severn Corridor Catchment Abstraction Management Strategy (CAMS) identified that current and fully licensed management of water resources along the River Severn is acceptable with respect to Environmental Flow Indicators (EFI) (for a brief introduction to EFIs refer to Appendix F). The Review Of Consents (RoC) stage 3 (2009) conducted a Habitat's Directive Appropriate Assessment into the current flow regime entering the Severn Estuary, marking the furthest downstream point that Severn regulation is designed to protect. Investigations concluded the current licensing policy and operation of the Severn regulation system protect and maintain adequate flows in accordance with WFD transitional waterbody flow targets. The Appropriate Assessment concluded that the current flow regime was having no significant impact on the Severn Estuary features, with the exception of severe drought conditions, which were not assessed.

The assessment described in this report built on the foundations of the RoC, CAMS and WFD assessments of the River Severn using the 'Do Nothing' scenario as a baseline. Historic drought data and report accounts were used to build on this previous work and assess the potential impacts from severe drought.

4.5.2. Drought Order Only (River Severn Drought Order)

The 'Drought Order Only' scenario represents conditions that would be expected if the River Severn Drought Order were granted and operated to full effect. No other drought permits or drought orders were activated during these runs, but all existing abstractions and discharges were represented. The Gloucester & Sharpness Canal abstraction near the Severn Estuary was represented with an average monthly abstraction profile, with a peak abstraction of 300 Ml/d in September (refer to section 5.4.3.2 for further detail). This scenario therefore does not allow the River Severn Drought Order to be assessed entirely in isolation, but involves a degree of in-combination effects that represent a more realistic representation of expected flows on the River Severn.

4.5.3. Full In-Combination

The 'Full In-Combination scenario represents the operation of the River Severn Drought Order and all known water company drought permits/orders which could impact (directly or indirectly) the River Severn. All existing abstractions and discharges were also incorporated.

Information pertaining to water company drought permits/orders was taken from the published (at the time modelling was conducted; 2012) drought plan for each company, with the exception of Dwy Cymru Welsh Water (DCWW) Drought Plan which was still in draft.

Water company drought permits for South Staffordshire Water (SSW), Unities Utilities (UU), Severn Trent Water (STWL) and Dwy Cymru Welsh Water (DCWW) have been included in the investigation. Although not all impact directly on the River Severn, they may alter abstractions on the River Severn as a knock on result or have potential in combination impacts on the Severn Estuary. The permits/orders included are detailed in Appendix E, and listed below, with the exception of DCWW permits/orders. Information for DCWW has been treated as confidential until their Drought Plan has been published; detail has therefore been excluded from this report until it becomes publicly available:

- Hampton Loade Drought permit Scenario 1 (SSW) - River Severn
- Lake Vyrnwy (UU) - Afon Vyrnwy
- River Wye at Wyelands (STWL) - River Wye
- Trimpley (STWL) - River Severn
- River Leam at Eathorpe and Avon at Stareton: Draycote (STWL) - could have a knock impact on operations on the River Severn
- Two drought permit/order options were considered for DCWW (more information will be included once the Drought Plan is published)

Initial consultation with the Canal & River Trust highlighted that the average monthly profile (refer to section 5.4.3.2 for detail) used to represent the Gloucester & Sharpness Canal in the 'Full In-Combination' scenario did not represent the maximum potential abstraction. Data from more recent dry events (e.g. 2010-2011) were not available until after the modelling work had been completed. These data highlighted the fact that the average maximum abstraction 300 Ml/d used in the modelling did not fully represent the high demands of the canal during dry weather. Therefore, for the 'Full In-Combination' assessment, the modelling results were used as an initial guide for interpretation, then the maximum physical abstraction of 691 Ml/d was also considered during interpretation of the results and in concluding whether a likely significant impact was possible. This approach is considered precautionary, but was necessary to ensure all water uses were fully accounted for and that the possible in-combination environmental impacts were assessed in accordance with Defra guidance.

4.6. Impact Assessment Methods

For each element of investigation (e.g. water quality, macroinvertebrates etc) different methods were used to assess and try to quantify the potential impacts from operating the River Severn Drought order when compared to the baseline 'Do Nothing' scenarios. The details of each method are contained within the relevant chapters of this report, and within the relevant appendices.

The River Severn Drought Order impacts can be categorised into positive or negative impacts on individual species and water user interests, although it's important to note the impact can change from negative to positive and vice versa according to which period of the drought is being assessed. The size and diversity of the River Severn catchment, the conflicting interests between water users, the different methods used to assess individual elements and the limitations encountered when trying to predict drought flows and ecological responses, made drawing conclusions consistently together a complex process.

All assessments where the environmental impacts are predicted before the magnitude and extent of an event or incident is known can be open to debate, and a number of different methods can be used. Some environmental impact assessments use a scale from High/Critical to Neutral/Negligible, while others use terminology such as 'significant' or 'likely' effects. It was not feasible to apply a quantifiable methodology for determining the overall magnitude of impact at each assessment point and receptor for this report. There were too many variables, and because impacts changed as the drought developed, trying to apply a conclusive magnitude could have hidden the true nature of each impact. To keep the overall assessment understandable to all and applicable to a catchment of this size, we opted to use a basic scale of risk to summarise the potential impacts and leave the detailed assessments within the relevant chapters.

4.6.1. Summary of Potential Risk Methodology

Individual assessments have been conducted for water resources, water quality, ecology, designated sites, archaeological and cultural heritage and navigation and recreation. Section 13 uses categories of risk to summarise the 'overall conclusion' for each assessment point. The classification uses a principle 'one out, all out' which means that the poorest individual result drives the overall classification (similar to Water Framework Directive). Therefore, where one or more of the individual assessments concluded a potential negative impact, the assessment point risk has been assigned to reflect this.

The scale of risk used to summarise the potential impacts concluded at each of the assessment points consists of;

- Low Risk/Benefit
- Medium Risk
- High Risk
- Potential Indirect Risk

The 'Low Risk/Benefit' category is used to describe where individual assessments concluded there would either be a benefit from operating the River Severn Drought Order, or where any impacts were temporary and/or too small to be considered a threat or investigated further. The 'Medium Risk' category describes where one or more of the individual assessments highlighted there could be some negative impacts during the drought event, but they would be temporary and not concluded as significant or greatly detrimental. The 'High Risk' category describes where significant impacts such as complete loss of flow or complete barriers to fish movements were concluded in the individual assessments. This category has also been used where a large amount of uncertainty in the results or abstraction operations remains.

A further category was used for the watercourses identified in section 4.1 as being indirectly (Secondary Path) at risk from changes to the River Severn. These sites were treated differently because the risk only related to migratory species trying to reach their spawning grounds, rather than the impact affecting the immediate environment.

5. River Severn Catchment Water Resources

5.1. Baseline Environment

The Water Resource environment of the River Severn incorporates the full hydrological cycle, from the precipitation inputs to the flows out to sea via the Severn Estuary. Surface and ground water sources are encompassed, including the abstractions and discharges which interact with the natural movement of water through the River Severn catchment.

5.1.1. Geology

The upper reaches of the Severn catchment from Plynlimon in Wales to just downstream of Shrewsbury, consist predominantly of Palaeozoic strata comprising Ordovician and Silurian aged mudstones and shale's within interbedded sandstones, conglomerates and limestone's. Pre-Cambrian and Cambrian aged igneous rocks such as lavas and intrusive basic rocks outcrop on the northern catchment boundary and are some of the oldest rocks in the world. A small area of limestone, Millstone Grit and Coal Measures, of Carboniferous age, separates Permian sandstones forming a flat plain to the east of Oswestry. Alluvium and river terrace gravels overlie much of the Palaeozoic strata. Elsewhere the solid strata are mainly overlain by unconsolidated Quaternary glacial and post-glacial sands, gravel and clays.

The geology of **the middle reaches** of the catchment (Shrewsbury to Worcester) is dominated by the Permo-Triassic sandstone and mudstone formations. In the northern part of the area these form the North Shropshire Plain although, throughout this area, Quaternary clays generally obscure them. Lying to the south and west of these formations are Carboniferous Coal Measures strata upon which Telford and the beginnings of the Industrial Revolution, in and around the Ironbridge Gorge, were based.

The course of the River Severn in **the lower reaches** (Worcester to Gloucester) is influenced by erosion-resistant Palaeozoic rocks which form the Welsh border hills to the west of the catchment and the Malvern Hills, and the escarpment of the Cotswolds ridge that forms the SE boundary of the catchment comprised of Jurassic oolitic limestone's. Between the Welsh Borders/Malvern Hills and the Cotswolds escarpment, the Severn Vale comprises a low lying plain of Triassic mudstones covered by a broad flat river terraces and modern day flood plain alluvial deposits extending from Gloucester out to the extensive tidal flats of the mouth of the Severn Estuary. .

It is considered that current drought management provisions designed to stabilize river flow under severe drought conditions would not affect the geology within the study area. No further assessment will be undertaken.

5.1.2. Geomorphology

The topography of the River Severn catchment has been strongly influenced by the underlying solid geology. Generally the older hard rocks in the upper part of the catchment forms high topographic elevations whilst the younger less resilient rocks form topographic lows.

The upper Severn and its main tributaries exhibit classic river geomorphologic development from the source to the downstream end of this part of the catchment. The river starts on an upland plateau before dropping through steep sided gorges, eventually flowing through an embanked

floodplain that supports agricultural land. On reaching the floodplain the Severn and its tributaries flow along a medium gradient course, through flat-bottomed valleys comprised mainly of alluvial soils. As a result, erosion and deposition rates are high and give rise to the formation of features such as meanders and oxbow lakes, some of which are of national importance with respect to geomorphology. The reach of the River Severn between Dolwen and Penstroewd has been proposed as a geomorphologic SSSI of high conservation value since it represents one of the most unstable sections of natural gravel-bed channel in England and Wales. This section of the river exhibits a wide range of erosional and depositional features and is an important site for studying the development of sedimentary structures such as bars, islands and braided channels.

The middle Severn can be divided into two areas north and south, separated by the Ironbridge Gorge. The northern section of the middle Severn consists of the flat Shropshire Plain and provides a fairly typical example of the middle course of a river being bordered, characteristically, by a wide floodplain and meanders and in parts forming cliffs on the outside of meanders. The Ironbridge Gorge was formed at the end of the Ice Age when the course of the River Severn was re-directed with the retreat of the glaciers. The gorge remains unstable due to its steep slopes, which have not reached their final angle of repose. The important industrial heritage of the site has exacerbated the problem of instability since the riverbank consists largely of made ground, particularly in the Jackfields area. The southern part comprises the more undulating landscape of the Severn valley. However, many of the tributaries further south in the catchment are small, fast flowing and more characteristic of upland rivers.

The lower Severn is generally low lying and flat, the Severn Vale is situated within an extensive agricultural plain and constitutes the major landscape feature within the lower catchment. Many small streams and rivers meander across the floodplain to join the River Severn.

5.1.3. Rainfall

Within the Severn catchment, rainfall generally decreases from north to south and from west to east. Superimposed upon this pattern is a marked increase in rainfall totals with altitude. Annual rainfall totals average up to 2400 mm on the high ground around the headwaters of the Severn, decreasing to below 700 mm on the North Shropshire Plain and to less than 600 mm around the head of the Severn Estuary. When compared to population density, the highest water demand is located in the areas receiving lower rainfall. Annual variability can be large with a standard deviation of 100 mm being common for mean annual totals of 600 to 700 mm.

The Environment Agency uses Long Term Average (LTA) rainfall figures based on the 1961-1990 period to assess whether a shortage or abundance of rainfall has been received over a catchment each month. This helps predict the onset of drought (or flood) conditions and enables planning to help prepare and mitigate against the worst impacts. The Severn catchment is split into six rainfall catchment areas for reporting, shown in the wider context of the Midlands region in Figure 8:

- Welsh Uplands;
- Shropshire Plains;
- Mid Severn/Teme;
- Avon;
- Lower Severn; and
- Lower Wye.

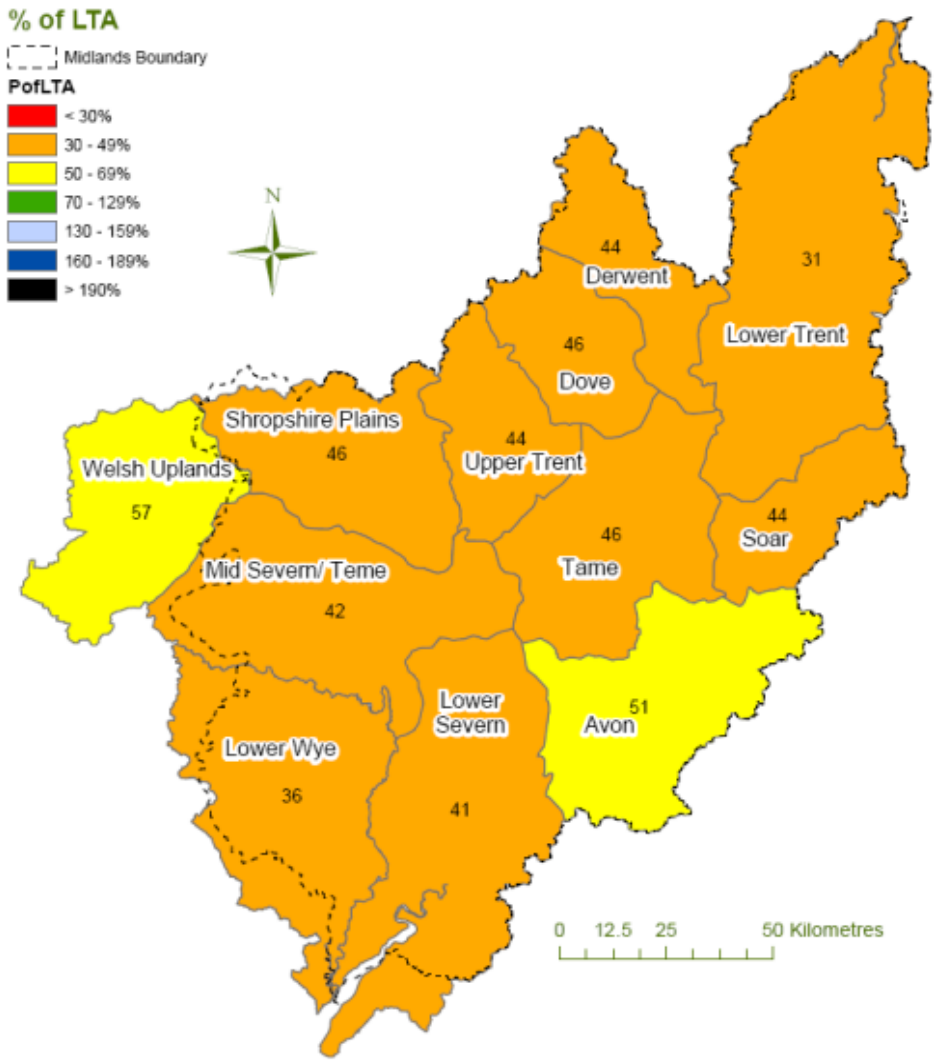

Figure 8: Rainfall Catchments impacting upon the Midlands Region

Figure 8 is taken from the February 2012 Midlands Water Situation Report, produced by the Environment Agency.

Winter rainfall and associated run off normally generates sufficient flow to meet the seasonal abstraction and environmental demands placed on the River Severn. However, during most summers flows have to be augmented by releasing water from the River Severn regulation system in order to meet the Bewdley flow target (section 2.2 for detail). The combination of complex abstractions and Severn regulation makes the River Severn a heavily influenced and artificial watercourse.

5.1.4. Flow Regimes

Flows downstream of both Llyn Clywedog and Lake Vyrnwy are subject to large and often sudden variations, as water releases are altered to satisfy downstream need. Both sites conform to minimum flow requirements to protect the environment as much as possible; there is a requirement to maintain 18.2 Ml/d downstream of Llyn Clywedog and 45 Ml/d downstream of Lake Vyrnwy (although if flows exceed 20 Ml/d at Cownwy Weir (Afon Cownwy) then releases directly from Lake Vyrnwy can be reduced to 25 Ml/d[24].

[24] Compensation requirements and/or operations are currently under review through the Afon Cownwy AMP5 investigation, so could be subject to change.

The River Severn regulation system increases flows significantly above what would naturally occur. Regulation releases are evident as steps in the flow duration curves at gauging locations some distance downstream of the major reservoirs. These steps have largely been smoothed out of the hydrographs by Bewdley as a result of abstraction. Low flows remain elevated above what would naturally occur (Appendix G). This artificial elevation in flows, particularly low flows, illustrates what the Severn regulation system is designed to achieve; balancing abstraction needs with environmental protection.

5.1.4.1. Assessment Points: Hydrology current environment

More detail is contained in Appendix I, including the gauging station specifications and underlying geology.

Clywedog (Bryntail)
The catchment is 49km^2 with steep topography and high rainfall making it naturally flashy. Flows at Bryntail are constantly impacted by regulation, Hydropower, flood and other releases from the reservoir, making it a heavily artificial flow site. Appendix H contains the naturalised and gauged flow duration curves and illustrates how the high to mean flows are reduced and then returned to the system in a stepped approach from mid to low flows. The flow regime is affected and some flow variation lost, but Q95 (flow exceeded for 95% of time) and lower flows (often dry weather/drought related) are protected and raised above what would naturally occur. Subsequently, the environment and ecology is prevented from experiencing drought conditions, as the compensation flow of 18.2 Ml/d is maintained.

Vyrnwy (Vyrnwy Weir)
The natural catchment area (excluding the Cownwy and Marchnant which are now largely diverted into Lake Vyrnwy) is 94.3km^2 with steep topography and high rainfall also making it naturally flashy. Flows at Vyrnwy Weir are particularly dominated by controlled releases from the reservoir during low flows, making it an artificial flow site. Appendix H contains the naturalised and gauged flow duration curves, and also illustrates how the high to mean flows are reduced. However, unlike Llyn Clywedog, due to the large abstractions from Lake Vyrnwy, the mid to lower flows do not display the same stepped return of flows to the system, as the majority of this water is transferred directly out of the catchment. The benefits from the compensation flow are displayed in the more infrequent percentiles; Q95 flows are protected and raised above what would naturally occur.

Buildwas
Buildwas is a just upstream of Ironbridge gorge in Shropshire, with a catchment of 3723.7km^2. The flow regime at Buildwas remains close to natural behaviour under normal conditions, until Q80 onwards when regulation releases can be seen to elevate flows above what could naturally be expected. The site is therefore behaving relatively naturally with flow variation and volumes until dry/summer periods, illustrating how the stepped nature of flows immediately downstream of the reservoirs is gradually smoothed out as it travels downstream.

Once baseflows naturally begin declining, the regulation releases artificially prevent flows at this site from ever dropping to what would have naturally occurred. In effect, when tributaries of the River Severn are beginning to display natural summer/low flow effects, flows at Buildwas are artificially protected (increased) under normal regulation operation. This can be confusing when trying to understand the impacts of drought on the flow dependant environment, as the lowest flows are less likely to occur at the peak of a dry period because the highest regulation releases will be made during these times.

Bewdley
Flows to the 4334km^2 catchment are largely artificial. Bewdley is used as the flow trigger site where the five day rolling mean of 850Ml/d (minimum flow target) is maintained for Severn regulation. Significant public water supply and power generation abstractions take place upstream, removing significant portions of the regulation releases which taken between three and

four days travel time from Clywedog reservoir. Although flows are artificial, they do mirror the naturalised FDC (Appendix H). The gauged FDC (1990-2007) shows the EFI is normally achieved (minor deviations due to stepped representation of the EFI) and from Q97 regulation releases elevate flows above what would naturally occur.

Saxons Lode

The catchment is 6860.6km^2 and incorporates inflows from the River Teme and River Stour (large effluent returns), displaying a slower hydrograph with broad flood peaks. Flows at Saxons Lode can be affected by high tides travelling up the estuary, and operation of tidal gates on the Avon at Tewkesbury. Low flows remain artificially supported by regulation, although to a lesser degree as major abstractions have already removed the majority of additional supported water. Appendix H shows the affect is to return flows from Q95 back towards the natural flow, rather than notably elevating it. The graph also shows the current flow regime (gauged FDC) satisfies the EFI at all times.

Deerhurst/Haw Bridge

The catchment at Deerhurst is 9866.3km^2; flows at both sites are affected by tides. The sites are often used interchangeably, as Haw Bridge provides a much longer record and includes important historic drought events while Deerhurst was designed to cope with tidal movements. Deerhurst and Haw Bridge are the furthest downstream continuous flow gauging stations on the River Severn.

Flows are substantially modified by this point, with further public water supply abstractions and effluent returns (additional effluent received from the Avon and Thames). Low flows are artificially supported by regulation but to a lesser degree than Bewdley and Saxons Lode. Appendix H shows how flows from around Q96 onwards are elevated back to what would naturally have occurred. The current flow regime (gauged FDC) meets the EFI requirements at all times and therefore demonstrates that inflows to the Severn Estuary are still protected at this location.

U/S Sharpness and Lower Parting

U/S Sharpness and Lower Parting were selected to assess inflows to the Severn Estuary more accurately and investigate the potentially large abstraction to the Gloucester & Sharpness Canal. The River Severn abstraction is taken at Gloucester Docks, from the East channel where the river splits. Abstraction remains exempt from abstraction licensing under the Water Resources Act 1991, and can range from 0-691 Ml/d from the River Severn at Gloucester. The channel bifurcation (channel split) itself raises additional modelling and impact assessment challenges; Monitoring between 1990-2004 indicates an approximate flow split of 40% down the East channel and 60% down the West channel. The complex interaction and variability of abstraction coupled with a lack of actual flow data downstream of the canal abstraction make it very difficult to assess with confidence what the true impact on the lower River Severn would be.

Appendix H shows modelled natural and influenced (incorporates abstractions and discharges) rainfall runoff modelled (Low Flows Enterprise) data just downstream of Lower Parting. The EFI used is in accordance with the WFD guidance for transitional waterbody's and conforms with the Stage 3 RoC. Due to the large tidal range of the Estuary (second largest in the world), flow requirements are less sensitive than represented by a normal watercourse so will not match those plotted at Deerhurst.

The flow duration curve suggests flows consistently remain below what would have naturally occurred, meeting only at the severest drought. This could involve errors relating to how the regulation system and Gloucester & Sharpness Canal abstraction is represented within Low Flows Enterprise. However the FDCs do suggest the EFI requirements are met at all times, with only Q99-Q100 showing marginal results. Appendix H therefore indicates normal flow operation protects the lower River Severn and subsequently inflows to the Severn Estuary. Greater confidence could be achieved by investigating how the Gloucester & Sharpness Canal abstraction has been represented (likely to be average abstraction, not accounting for severe droughts) inside Low Flows Enterprise, to verify the results being shown.

5.1.5. Major Abstractions

A number of critical water supply, industrial and waterways abstractions from the River Severn are licensed on the basis of regulation releases being made to support them. This legal agreement dates back to the Clywedog Joint Authority Act of 1963, with regulation operations now the responsibility of the Environment Agency in consultation with Natural Resources Wales. It is the reservoir and supported abstractions which will be referred to as 'major abstractions' for the purposes of this report.

5.1.5.1. Public Water Supplies

The River Severn provides drinking water to over 6 million people via a number of licensed Public Water Supply (PWS) abstraction points. Water is abstracted from these locations by four water companies to enable the provision of water supplies to households and industry in the region:

- United Utilities - Lake Vyrnwy;
- Severn Trent Water - Llandinam, Shelton, Trimpley, Upton-on-Severn and Mythe Works;
- South Staffordshire Water - Hampton Loade; and
- Bristol Water - Purton.

Dŵr Cymru Welsh Water also have unsupported abstractions within the River Severn catchment, however they are located in the upper reaches of the tributary River Teme. Figure 6 identifies the River Teme as a Secondary Pathway for impacts, however the potential impact relates specifically to migratory fish.

Figure 9 includes the location of these abstractions and Table 8 indicates both the licensed and summer average daily abstraction rates (taken as the mean value from June to August, calculated from the historic data set) for the larger consumptive licences.

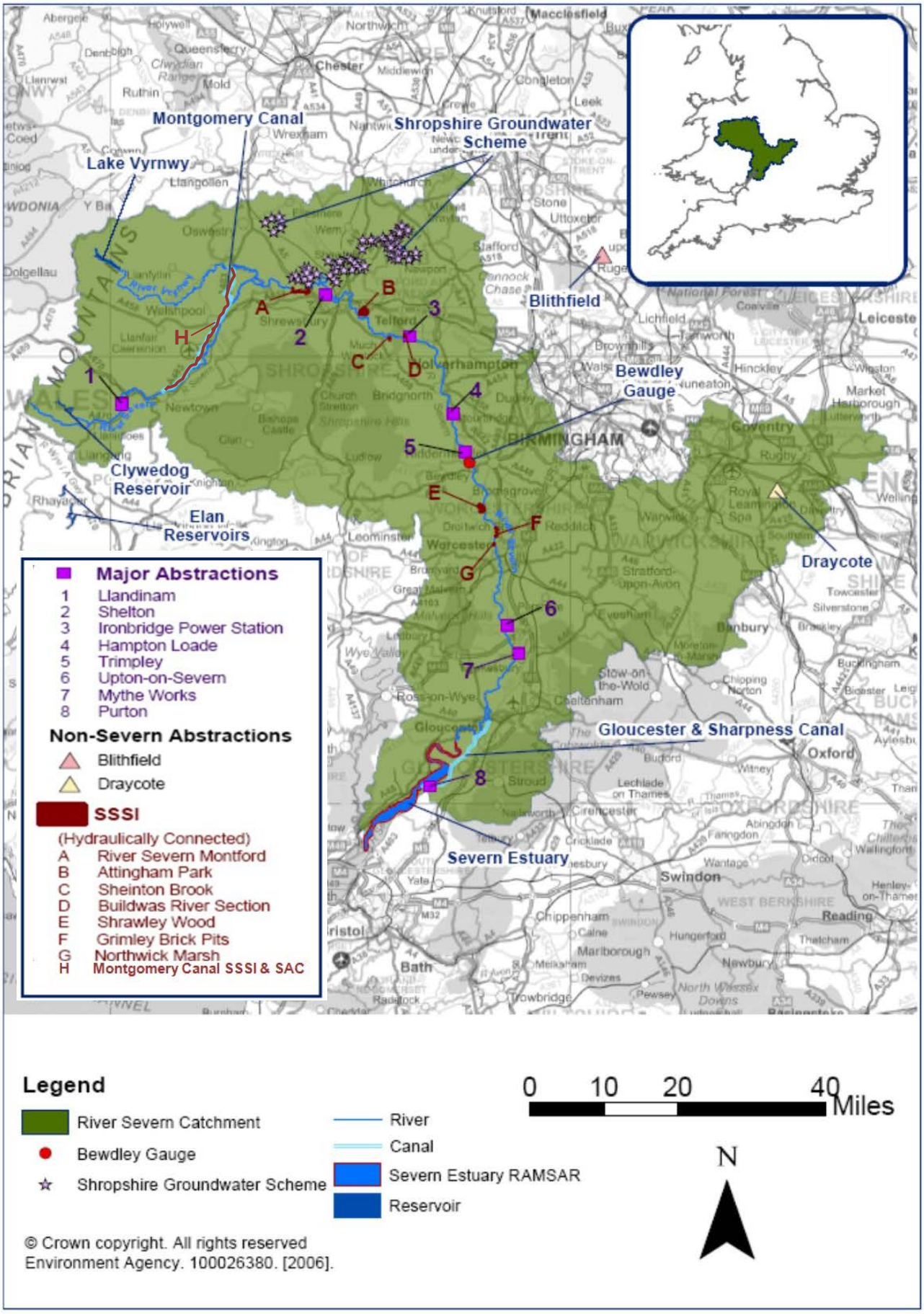

Figure 9: Major Abstractions from the River Severn

Table 8: Public Water Supply Licensed Daily Quantities and Typical Summer abstractions

Abstraction	Water Company	NGR	No regulation (Ml/d)	Regulated (Ml/d)	Summer Average (Ml/d)
Vyrnwy 18/54/01/0157	United Utilities	SJ 012 202; SJ 019 193; SJ 000 180; SJ 042 198	252.8	252.8	191.5
Shelton 18/54/02/0020	STWL	SJ 4679 1374	38.6	38.6	16.3
Hampton Loade 18/54/02/0163 18/54/02/0584	SSW & STWL	SO 7462 8709	280*	212**	173.2
Trimpley 18/4/02/0110	STWL	SO 7718 7859	180*	60**	30.3
Upton*** 18/54/08/0101	STWL	SO 8640 3986	167	141.8	120.3
Mythe 18/54/08/0165	STWL	SO 8890 3355 SO 8889 3350	120	109	95.3
Purton 18/54/20/0138	Bristol WC	SO 6954 0384	245	197^	142

Summer Average - April to October period

* Total combined abstraction from Hampton Loade and Trimpley capped at 400.

** Total combined abstraction from Hampton Loade and Trimpley capped at 272 if river is at full regulation (i.e. Clywedog and SGS operating).

*** Licence entitlement for Worcester (Barbourne) which ceased operation in 1995 was transferred to Upton.

^ The 197 Ml/d constraint actually applies to a Drought Order (and not Full Regulation) on the Severn

In addition to the above surface water sources there are numerous groundwater abstractions made for PWS within the Severn catchment. Little abstracted groundwater is directly exported out of the Severn catchment and most of the water is returned to the river network as treated effluent via various sewage treatment works (STW's), although the location of the water return can effect local flows.

During periods of low flow, when the river is supported by regulation releases of water (from Llyn Clywedog, Lake Vyrnwy or SGS), the permitted licensed abstraction rates are reduced for many of the PWS abstractions. This is undertaken to reduce the stress on the river system. The 'normal' and reduced, 'fully regulated' licensed abstraction rates are shown in Table 8.

In reality the actual volumes of water abstracted from the river vary depending on demand. Therefore in order to provide an impression of the normal level of abstraction, average summer (excluding drought/dry weather events) abstraction rates are also shown separately in Table 8. These values indicate how average abstraction tends to fall below full maximum permitted limits; however during a drought event abstraction is more likely to be closer to the full licensed value.

A significant proportion of the water abstracted from the River Severn is transferred outside the catchment with no return. This includes all of the water abstracted from Lake Vyrnwy (transferred to Liverpool) and Purton (transferred to Bristol) as well as significant proportions of the abstractions from Hampton Loade (>80% exported) and Trimpley (export dependant on amount transferred to

Frankley). Some of the water supplied within the catchment is also subject to consumption and will effectively be lost.

5.1.5.2. Industrial Water Supplies

The only major abstraction from the River Severn for industrial use is at the Ironbridge power station in Shropshire (Figure 10), currently operated by E.ON UK. The licence for the power station allows for an abstraction of 110Ml/d, in reality the net loss is far smaller because the water is used as a coolant and then returned to the river very close to the point of abstraction. It is estimated that approximately 25% of the water abstracted is lost to evaporation.

5.1.5.3. Canal Abstractions

Canal abstractions remain exempt from licensing under the Water Resources Act 1991; leaving the Environment Agency with no regulatory powers to moderate the associated abstractions or discharges. For significant abstractions, the Environment Agency and Canal & River Trust has entered into specific Operating Agreements, although not legally binding documents, they do help safeguard the environment and needs of other water users.

A number of canals feed into and draw water from the River Severn. In the majority of cases the importance of these in terms of water resources is how they deplete flows from the point of abstraction until discharges are returned to the main channel some distance downstream. The most notable examples include the Montgomery Canal in Powys and the Gloucester & Sharpness Canal in Gloucestershire.

The Canal & River Trust (formerly British Waterways) abstraction for the Montgomery Canal is operated according to the Montgomery Canal Agreement 1988 and Operating Rules for the River Severn Resource/Supply System. Under these agreements flows entering the canal are specifically regulated during periods of Severn Regulation and RSDO conditions. The permitted abstractions are:

River Severn at Penarth;

- Llyn Clywedog release 300-499 Ml/d. The Canal & River Trust can abstract from the River Severn at 150 Ml in any 7 day period.
- Llyn Clywedog release at 500 Ml/d. The Canal & River Trust can abstract at 115 Ml in any 7 day period.
- Drought Order – The Canal & River Trust can abstract at 50 Ml in any 7 day period.
- Llyn Clywedog storage falls below 25% – no abstraction by The Canal & River Trust.

River Tanat at Carreghofa Lock;

- During Severn Regulation - 49 Ml in any period of 7 days

River Morda at Maesbury Mill;

- During Severn Regulation - 14 Ml in any period of 7 days

The Gloucester & Sharpness Canal is the largest potential abstraction between Deerhurst and the Severn Estuary, known to have a significant impact on the distribution of water in the lower reaches of the River Severn around the tidal limit (hereafter referred to as the lower tidal Severn). Water is abstracted from the East channel of the River Severn at Gloucester; to supplement the canal at times when demands are not satisfied by several intercepted tributaries (i.e. River Frome, River Cam, Daniels Brook and Sud Brook). The Canal & River Trust reported a peak abstraction of 340 Ml/d in 2011, although a maximum 691 Ml/d could be physically pumped. In addition, Bristol Water abstract up to 245 Ml/d directly from the canal at Purton (licence 18/54/20/138/C). Water from the canal, minus losses due to leakage and/or consumptive use, finds its way back to

the estuary via the lockage at Sharpness, lockage at Gloucester, and leakage/seepage from the canal.

If high abstraction rates into the canal coincide with low flows in the River Severn, dissolved oxygen concentration could decrease rapidly and other water quality impacts along the tidally influenced reaches of the river can be exacerbated, particularly when combined with spring tides. As a result of this (and other factors less relevant to this study) an Operating Agreement (1998) was set between the Canal & River Trust and the Environment Agency stating that;

"No pumping for 3 hours after high water springs in March, April and May when flows are less than 2400 Ml/d at Deerhurst and when tides > 8.5m at Sharpness."

This measure helps to critically increase the flow in the river during spring tide conditions and thereby helps reduce the adverse impacts previously reported. The stage 3 RoC and more recent Severn Corridor CAMS assessments both concluded that Severn Estuary inflows were adequate under current operations (i.e. Seven regulation and the Operating Agreement) to protect the site designations. The Operating Agreement does however contain a clause for drought conditions, recognising the more extreme scarcity of resources and difficulties that would be faced in balancing navigation, abstraction and environmental needs.

Clause 7 of the Operating Agreement means the Canal & River Trust could not be held liable for the failure to observe any of its obligations under the agreement during a drought. This is particularly significant to this investigation because it potentially allows the maximum pump capacity of 691 Ml/d to be abstracted at Gloucester. The Environment Agency currently has no legal powers to prevent this, and therefore the Full In-Combination scenarios have had to consider this maximum abstraction volume.

5.1.5.4. Spray Irrigation

There are a large number of licences for spray irrigation within the Severn catchment, permitting over 24500 Ml of abstraction from ground and surface water sources within a calendar year. For the purposes of this assessment it has been assumed that the full amount (i.e. both groundwater and surface water abstractions) would be abstracted annually and would directly and instantaneously impact the surface water system of the Severn catchment. In reality the distribution of these abstractions is varied, both spatially and temporally.

5.2. Summary of Existing Drought Impacts

[Section to be completed when applying for a River Severn Drought Order]

5.3. Assessment of Impact on the Current Environment: Hydrology

The assessment aimed to determine the impact of the River Severn Drought Order on river flows during the Acute and Chronic drought conditions described in section 4.4. Simulations were conducted for the three scenarios described in section 4.5 ('Do Nothing', 'Drought Order Only' and 'Full In-Combination') to allow the changes in river flow under each scenario to be assessed. The aim of the assessment was to identify whether the River Severn Drought Order was a beneficial drought management option or not, and to identify any adverse impacts that could occur.

5.3.1. Aquator Modelling

The drought order was modelled in a water resource simulation programme called Aquator (version 3). The model covers the River Severn and Wye, routing an 88 year record of inflow sequences through the rivers and water supply network in accordance with existing licence constraints, to where it is needed based on demand profiles. The model contains public water supply and large private abstractions, discharges and the Environment Agency's Severn regulation system; code directs the model to maintain the prescribed flow at Bewdley by use of releases from Llyn Clywedog, Lake Vyrnwy water bank and the SGS (active phases 1-4).

In order to assess in combination impacts the Environment Agency modified the Severn & Wye PR09 Aquator model to include the Gloucester & Sharpness Canal abstraction and water company drought permits/orders. An average abstraction profile was manually imported into Aquator to model the potential impacts of the Gloucester & Sharpness Canal. Maximum abstraction from the Severn into the canal was modelled at 300 Ml/d (based on data up to 2010), but for full in combination assessment the 'worse case' maximum abstraction of 691 Ml/d was accounted for, with further work suggested to improve the conceptualisation and understanding for drought management in the future (refer to section 17 and Appendix T).

Water company drought permits for Severn Trent Water Ltd (STWL), South Staffordshire Water (SSW), Unities Utilities (UU) and Dŵr Cymru Welsh Water (DCWW) were included in the model by introducing specific code. Small permits/orders (typically <3Mld) on the River Wye were omitted due to limitations in model accuracy and the decision to focus effort to produce a good representation of the larger permits/orders.

For a complete write up of the water resource modelling and limitations in Aquator refer to Appendix E.

5.3.2. Hydrological Assessment Methods

A number of methods were used to present and interpret the modelled flow data at each of the eight assessment points. Hydrographs were produced for each scenario to assess the daily changes in flow and drought (critical low flow) duration. Flow duration curves (FDCs) were produced for comparison between the Aquator modelled flows, actual observed (gauged data) flow records, and CAMS Environmental Flow Indicators (Refer to Appendix F for an explanation of EFIs).

Flow duration curves are useful for illustrating the duration and magnitude of low flow/drought events (i.e. the rarity); however caution is needed when comparing different time periods as the results may be skewed. The observed FDCs (based on gauged data) were all based around the CAMS period 1990 to 2007 (18 years). The modelled data is based on a theoretical three year period (based on but not equivalent to flows observed in 1975 to 1977). The latter is a much shorter record and largely biased towards low flows, which needs to be understood when interpreting the results. Therefore, consideration of adverse impacts was largely based on the mid to low flows from each FDC, excluding the normal to higher flows which will have been skewed by the short time period used.

These modelling and assessment approaches provided the best certainty possible at the time of analysis, using the best available information and most up to date Aquator model and inflows.

5.3.3. Impact on Flows; Acute Drought Condition

Only the summary and conclusions are presented in this section, for the complete Hydrological assessment refer to Appendix I (Appendix J.1 to J.6 contain the supporting hydrographs, flow duration curves and a breakdown of the key regulation volumes and critical dates for the Acute scenario testing). It is important to emphasise the drought order scenarios being assessed are theoretical worse case situations. They were developed to assess the likely flow trends and identify the potential periods of drought order operation.

Figure 11 presents data from the furthest downstream River Severn assessment point, Lower Parting, and therefore includes cumulative impacts (from upstream) of all abstractions, plans and drought permits/orders. The hydrograph demonstrates the overall flow trend predicted along the majority of the River Severn; an initial flow depletion was predicted as the drought order was activated (compared to the 'Do Nothing' baseline), followed by a higher maintained flow than would be possible without operation of the drought order if the dry conditions continued.

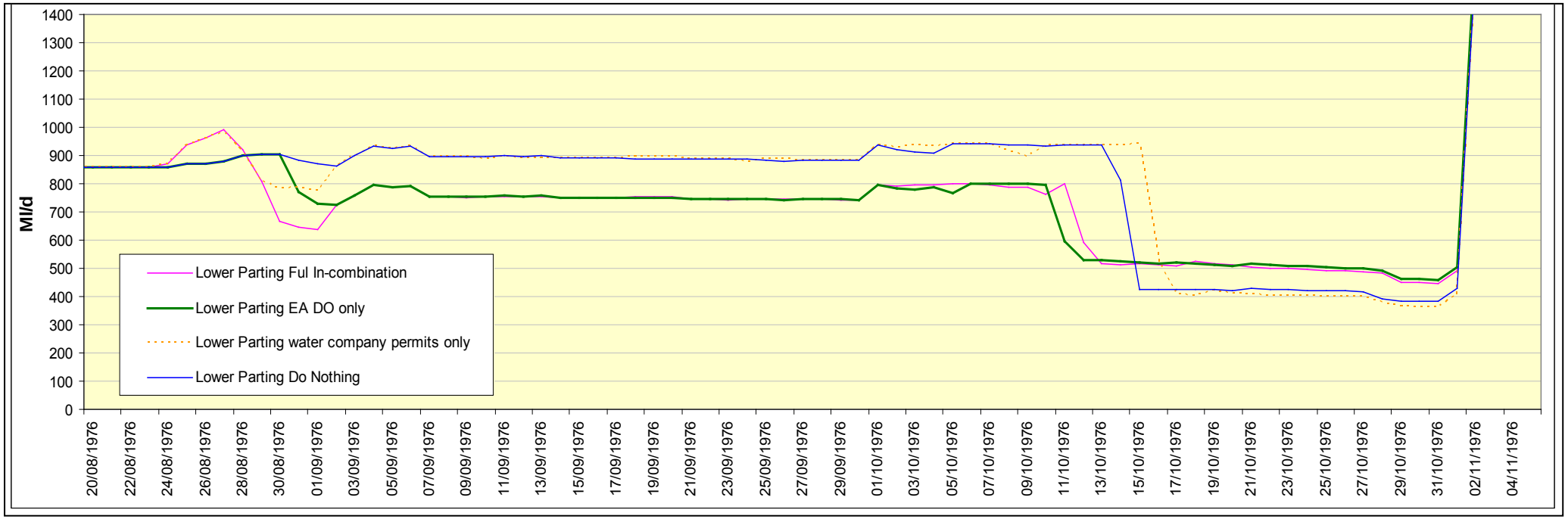

Figure 12: Lower Parting (Estuary inflows) Acute drought scenario 1976; 20 August to 5 November.

Figure 11: shows all the modelled impacts on flows at Lower parting, downstream of all the regulation inputs (Clywedog, Vyrnwy and SGS) and major abstractions, including the Gloucester & Sharpness Canal. The graph highlights the specific period of interest, when the Environment Agency drought order was modelled as being active.

Table 9 contains a summary of the modelled flow values under each scenario, the modelled drought Q30* values need to be viewed with additional caution due to the short (3 year) record of data used.

Table 9: Summary of Modelled Flow percentiles

Flow value	Acute Do Nothing Ml/d	Acute EA DO in isolation Ml/d	Acute Full In-combination Ml/d	Current flow Ml/d (G=Gauged, M=modelled**)	Naturalised flow Ml/d (D=decomposition, M=modelled**)
	(1975-1977)	(1975-1977)	(1975-1977)	(1990-2007)	(1990-2007)
Bryntail					
Q30*	163	163	163	176 G	216 D
Q95	18	18	18	18 G	19 D
Q99	9	18	9	18 G	-6 D
Q99.9	9	18	9	-	-59 D
Vyrnwy Weir					
Q30*	45	45	45	131 G	426 D
Q95	25	25	25	25 G	30 D
Q99	25	25	25	24 G	0 D
Q99.9	25	25	25	-	0 D
Buildwas					
Q30*	4978	4978	4978	5511 G	5646 D
Q95	1068	934	934	1030 G	742 D
Q99	551	635	623	919 G	527 D
Q99.9	513	586	573	-	527 D
Bewdley					
Q30*	4988	4982	4982	5470 G	6211 D
Q95	901	762	870	881 G	930 D
Q99	375	458	355	791 G	715 D
Q99.9	337	411	317	-	458 D
Saxon's Lode					
Q30*	7551	7551	7550	7992 G	8523 D
Q95	946	817	945	1327 G	1350 D
Q99	440	526	421	1167 G	1131 D
Q99.9	400	475	380	-	536 D
Deerhurst					
Q30*	9501	9501	9497	7992 G	8523 D
Q95	946	817	945	1327 G	1350 D
Q99	440	526	421	1167 G	1131 D
Q99.9	400	475	380	-	536 D
U/S Sharpness					
Q30*	1170	1033	1033	-	-
Q95	648	732	721	-	-
Q99	616	706	695	-	-
Q99.9	609	684	672	-	-

Flow value	Acute Do Nothing Ml/d	Acute EA DO in isolation Ml/d	Acute Full In-combination Ml/d	Current flow Ml/d (G=Gauged, M=modelled**)	Naturalised flow Ml/d (D=decomposition , M=modelled**)
	(1975-1977)	(1975-1977)	(1975-1977)	(1990-2007)	(1990-2007)
Lower Parting					
Q30*	983	893	914	9772 M	10213 M
Q95	370	735	729	1910 M	2056 M
Q99	319	729	718	1509 M	1564 M
Q99.9	304	528	523	1096 M	1123 M

*Modelled drought Q30 values need to be viewed with caution due to the short (3 year) record of data used.

***Modelled data using Low Flows Enterprise, a rainfall runoff model producing flow duration curves for a drainage basin (not time series data).*

Negative values within the calculated naturalised dataset are known errors associated with data quality.

5.3.3.1. Summary

The Acute drought condition represented a dry summer and winter (1975) preceding a summer drought (theoretical 1976) event. The modelled drought broke in November with the return of high rainfall. It is important to note the November rainfall created significant flow recovery; if the drought period were prolonged the duration of flow reduction would also have increased until regulation failure (all three sources exhausted) was reached. Similarly, if rainfall was to return earlier then regulation failure would be avoided and flow benefits of the River Severn Drought Order may not be observed (refer to the Chronic scenario).

The most difficult stretch to assess with confidence was the lower tidal Severn, from the channel bifurcation down to the Severn Estuary. Owing to the proximity to the Natura 2000 site and its importance for migratory fish and navigation, any impacts here could have the greatest significance to the catchment as a whole. The Canal & River Trust is currently exempt from needing an abstraction licence to operate its abstraction to the Gloucester & Sharpness Canal; therefore the Environment Agency has no legal powers to regulate this abstraction under routine conditions. Post drought reports from 1976 and 1989 indicated that large abstractions to the canal were taken during the peak of the droughts. In 1989 flows down the West channel dried up and were almost completely removed from the East channel, allowing only a few centimetres to pass over the Llanthony Weir. An Operating Agreement was created in 1998 to help safeguard the Severn Estuary, and assessments have shown that under routine flow regimes there is sufficient flow reaching the Estuary. The difficulty is managing a severe drought, which falls outside normal operation and would require close liaison and management between interested parties.

5.3.3.2. Do Nothing (Baseline)

An annual total of 166 regulation days and 70,220 Ml combined releases were modelled during the Acute Do Nothing scenario, with 152 days of continuous regulation; Llyn Clywedog provided 66% (46374 Ml), SGS 25% (17744 Ml) and Lake Vyrnwy 9% (6102 Ml) of the total resource.

SGS provided steady and continuous support, limited to a net of approximately 140 Ml/d. Once Llyn Clywedog became exhausted only the Lake Vyrnwy water bank contained large enough volumes to replace the 500+ Ml/d that regulation required to support the prescribed flow at Bewdley. However, the Lake Vyrnwy water bank is a short term resource when large releases are required and can only provide a temporary replacement to Llyn Clywedog. Modelling showed that during high regulation requirements, if Llyn Clywedog was exhausted and significant rainfall did not

arrive, the regulation system would begin to fail and flows decline. The speed and degree of failure and resultant flow crashes would vary according to the climatic conditions, abstraction demand and how much resource remained individually within the Lake Vyrnwy water bank and SGS licence.

Do Nothing modelled regulation failure to begin on 29 September, 16 days after Clywedog reached dead water. Once the Lake Vyrnwy water bank became exhausted, SGS also began to reach its 'individual' licence limits. In reality, SGS could be operated differently to utilise the group licence surplus (7756 Ml) more effectively, and/or the Environment Agency could consider applying the SGS Drought Order (separate report). It is important to note the additional daily quantities from SGS would be too small to prevent the eventual regulation failure, but early optimisation of the scheme could help delay a River Severn Drought Order application.

Significant flow impacts were observed at Bryntail, Bewdley, Saxon's Lode, Deerhurst and the lower River Severn (most notably Lower Parting, downstream of the Gloucester & Sharpness Canal abstraction). It can therefore be assumed a drought of this magnitude would put the most flow stress on the Upper Severn (dependant on reservoir operation), and from around Bewdley downstream. Flows around Bewdley were most likely to be affected at and downstream of the major abstractions points.

Bryntail identified significant flow impact; although the EFI (derived from natural flow) was not failed the local habitat and ecosystems would have adapted to rely on this residual flow. As Clywedog reaches dead water the 18.2 Ml/d compensation flow requirement can no longer be made between 27 September and 1 November, a total of 35 days. The model did not show flows drying up entirely at Bryntail, however in reality this is likely to occur immediately downstream of the dam under such a severe drought (i.e. little/no baseflow expected). It was unclear where flows would begin to buffer from tributary inputs, but with such a severe drought affecting the whole catchment it could be some distance downstream before significant flow returned.

Another consideration at Bryntail and downstream is the longer term affect on flow variation. Under Do Nothing, including the 35 days of little/no flow, there was a total of 306 continuous days (almost a full year) when only the compensation flow was released. The minimum compensation flow occurred because the reservoir would be intercepting all upstream runoff to refill, a vital process to prepare for the year ahead. The model showed September right through to the following July as being affected, in reality this period will vary according to how much and how quickly recharge is received.

From Bewdley, it can be expected the whole River Severn downstream would be affected to varying degrees by the natural drought event. As a result of the regulation system failing, flows were shown to fall approximately 500 Ml/d over 2 days. Flows crashed between 12 and 14 October, with depressions lasting between 19 and 22 days before natural recharge was modelled in early November. Bewdley predicted a daily minimum flow of 336 Ml/d, 182 Ml/d lower than ever recorded, Saxon's Lode predicted a daily minimum 399 Ml/d, 316 Ml/d below existing records and Deerhurst predicted a daily minimum 577 Ml/d, 398 Ml/d below existing records.

The minimum daily flow prediction at U/S Sharpness was 609Ml/d and 382Ml/d at Lower Parting, downstream of the Gloucester & Sharpness Canal abstraction. The variability of abstraction quantities and limited data make it difficult to assess whether flows could be reduced significantly further still. The lower section of the River Severn, around Lower Parting, was shown to be most at risk to likely significant effects from an Acute drought magnitude.

In reality, it is unclear what the minimum flows would be if the regulation system did fail. Aquator (version 3) has known problems with naturalised flows, and discharges are currently built into the background flows and cannot be altered. Therefore exact flow predictions need to be assessed with caution. However, the flow response is the important result for future planning. Should Llyn Clywedog fail, the remaining regulation support is short term and unlikely to cope. Minimum flows

will depend on climatic conditions and abstraction demands at the time of failure, but the River Severn flows can be expected to rapidly decline to baseflow rates until rainfall returns.

The degree of adverse impact resulting from significant flow impacts will depend on the duration of the event and demand management at the time. It is important to note that whilst satisfactory naturalised flows could not be extracted from Aquator at this time, once the flows crash they are effectively representing the baseflow expected in the absence of regulation support, flows maintained above this level are therefore in the best interest of supporting the environment.

5.3.3.3. Drought Order Only (River Severn Drought Order)

An annual total of 166 regulation days and 64,557 Ml combined releases were modelled during the Acute River Severn Drought Order scenario, with 153 days of continuous regulation; Clywedog provided 63% (40748 Ml), SGS 27% (17708 Ml) and Lake Vyrnwy 9% (6102 Ml) of the total resource.

Operating the River Severn Drought Order under the Acute condition caused the regulation system to begin failing 2-3 days earlier than the Do Nothing scenario. The drought order lowered the prescribed flow at Bewdley from 850 Ml/d to 730 Ml/d (over a 5 day mean), which only reduced regulation pressure on Llyn Clywedog by 120 Ml/d. Capping the releases at Clywedog at 300 Ml/d is necessary but created a regulation deficit to achieve 730 Ml/d at Bewdley, which Vyrnwy water bank and SGS supplemented earlier than under the Do Nothing scenario. The available resource remained the same so inevitably the regulation system began to fail slightly earlier as a result of Clywedog's reduced contribution.

The River Severn Drought Order prevented Clywedog from reaching dead water, which had various benefits to the whole Severn catchment. Avoiding dead water enabled the 18.2 Ml/d compensation flow to Bryntail to be made throughout, preventing 35 days of little/no flows for this section of watercourse. Due to the 11% storage saving, Clywedog refilled faster over the winter (exceeds 90% in April 1977) and therefore flow variation was returned in mid June, 49 days earlier than under Do Nothing.

Downstream, flows were reduced for between 45-48 days before the obvious flow benefits were observed. During this period, flows were reduced from Do Nothing by 139-142 Ml/d, equating to 13-15% flow reductions. Bryntail showed a significant improvement as discussed. Vyrnwy showed no change and Buildwas continued to show no significant flow impacts against the EFI. At Bewdley, no significant deterioration in flows beyond the unavoidable drought impacts were observed. Both Saxon's Lode and Deerhurst showed the initial flow reductions caused a small increase in the duration of Medium Risk EFI failure, related to the 140 Ml/d reduction in flows. At Lower Parting the EFI failure was assessed as High Risk and more prolonged than upstream, however operating the Severn Drought Order only created a minor increase in duration of this failure. It is difficult to assess whether the initial flow reductions (prior to any regulation failure) would be significant to the environment, and needs to be balanced against the subsequent flow gains it achieved.

Once the regulation system began to fail, the River Severn Drought Order showed clear benefits. Protecting the storage in Llyn Clywedog over the previous 45-48 days enabled small but continuous releases between 91-63 Ml/d (reduced per day according to remaining storage) to be made throughout the critical flow depression period. Under Do Nothing only small SGS releases were possible at this point. The regulation support Llyn Clywedog continued to provide was short term, but the Acute condition increased minimum flows by 72-75 Ml, and produced an average flow gain of 89-90 Ml/d.

Modelling supported the aim of the River Severn Drought Order. By operating the drought order and regulating to a lower flow target at Bewdley, Llyn Clywedog avoided reaching dead water and compensation flows at Bryntail were protected. The drought order did not prevent regulation system failure from occurring when the drought persisted, but did enable Clywedog to continue

providing regulation support at a reduced rate throughout the Acute drought. Subsequently higher flows were maintained during the worst period of the drought. Longer term, the River Severn Drought Order enabled the reservoir to refill faster, reducing the impacts on flow variation in the upper catchment and preparing the system for a subsequent drought/regulation season.

5.3.3.4. Full In-Combination

The River Severn is a very large and complex system of varying geology, topography, regulation, reservoirs, abstractions, transfers and discharges. It is not possible to accurately predict all these interactions in the exact sequence of events and magnitudes with the available tools, but for the purpose of impact assessment a worst case approach has been adopted. The model results from this scenario were very similar to the 'Drought Order Only' scenario, with timings and volumes varying slightly. In part this is likely to be due to the interactions between what the River Severn Drought Order enforces (e.g. restricting abstractors by 5%) and what the water company drought permits effectively take back/cancel out (i.e. increase abstraction).

An annual total of 166 regulation days and 64,022 Ml combined releases were modelled, with 152 days of continuous regulation; Clywedog provided 63% (40248 Ml), SGS 28% (17672 Ml) and Lake Vyrnwy 9% (6102 Ml) of the total resource.

Overall, initial flow reductions occurred for 1 day longer and reduced flows by 145-147 Ml/d, only 5-7 Ml/d more than the 'Drought Order Only' model. The flow gains achieved during the flow depression were reduced under the increased abstraction demands, ranging between 76-80 Ml/d, 10-13 Ml/d less than the 'Drought Order Only' model. Full In-combination still showed a minimum flow improvement of 60-64Ml compared to Do Nothing.

When compared to the 'Drought Order Only' model, minor additional impacts were observed at Saxon’s Lode and Deerhurst, where the duration of Medium Risk EFI failure slightly increased. However this additional increase, compared to the 'Drought Order Only' model, equated to 1 day and 7 Ml at both sites.

The most significant observation was the likely significant effects that could be created if abstraction for the Gloucester & Sharpness Canal were increased above the modelled 300Ml/d, which was already adding a significant stress to flows at this location. It is difficult to predict what abstraction might be required, but applying the worse case principle, the pumps can physically remove 691Ml/d from the River Severn. Post drought reports from 1976 and 1989 report high abstractions did occur and that flows were significantly impacted, reducing inflows to the Severn Estuary to nearly zero for short periods.

For the purposes of this assessment, owing to the unknowns and potential capacity for the Canal & River Trust to abstract, the 'Full In-Combination' impact is concluded as having a likely significant effect on the lower River Severn.

5.3.4. Impact on Water Levels; Acute Drought Condition

The impact of modelled flow reductions was investigated by using rating curves to convert the flow data into water levels. Rating curves identify the relationship between water level and flow; this requires continuous monitoring to establish a reliable equation. The assessment point at Lower Parting did not have a rating curve or enough recent gauged data to produce one for this investigation; it has therefore been flagged for the appropriate future monitoring.

In context to Severn regulation, a reduction of flow at Bewdley from 850 Ml/d to 730 Ml/d would reduce the water level from 6.81 meters to 6.36 meters. This 0.45m reduction represents a 7% change in total water level for this specific location. How it would impact the whole River Severn will depend on the channel dimensions and morphology at each location.

To investigate the modelled drought conditions, Q95, Q99 and Q99.9 flows (low to drought flows only) were compared against the Do Nothing baseline scenario to identify the impact. Table 10 summarises the results and provides the naturalised and gauged water levels for comparison. Green boxes show where no change against the Do Nothing baseline was identified, yellow boxes identified a reduction in levels and blue boxes an increase in water levels against the baseline.

The results showed the River Severn Drought Order, whether in combination with the water company drought orders or operating alone, was of benefit to water levels during the extreme low flow period.

In the upper catchment, at the Clywedog and Vyrnwy assessment points, the drought order either made no difference to water levels or increased them, reflecting how the drought order would enable the compensation flows to continue throughout a severe drought.

At the remaining 4 assessment points the water level at the equivalent Q95 flow was found to be lowest when operating the River Severn Drought Order. The decrease ranged from 0.93 meters at Buildwas to 0.12 meters at Deerhurst. The range of impact reflects the difference in channel dimensions that can be expected along a river of this size. At Buildwas the river channel becomes narrow and deep as it travels through the Ironbridge Gorge, comparing the water levels against the expected natural suggests even with the drought order in operation water levels could be 1.41 meters higher than naturally expected. However at Deerhurst, where the channel is much wider, a smaller impact on water levels was identified. No additional water level reductions were identified between the River Severn Drought Order scenarios and the Full In combination scenario's.

Looking at water levels at the equivalent Q99 and Q99.9 flows highlighted how the River Severn Drought Order would provide the benefit from prolonging Severn regulation releases during the extreme period of drought. Water levels were increased by between 0.12 meters at Deerhurst to 0.68 meters at Saxon's Lode, Bewdley and Buildwas. Under the Full In combination scenario water levels were increased above the Do Nothing by less. With the exception of Deerhurst, the benefit was often around 0.1 meters less, identifying the extra pressure that could result from the water companies operating their drought orders at the same time.

Table 10: Summary of Water Level data under the Acute scenario

	Acute Do Nothing (meters)	Acute EA DO in isolation (meters)	Acute Full In-combination (meters)	EA Naturalised 1990-2008 (meters)	Gauging Station observed 1990-2008 (meters)
Bryntail					
Q95	0.87	0.87	0.87	0.88	0.87
Q99	0.63	0.87 (+0.24)	0.87	0	0.86
Q99.9	0.61	0.87 (+0.26)	0.87	0	-
Vyrnwy Weir					
Q95	0.94	0.94	0.94	1.02	0.95
Q99	0.94	0.94	0.94	0	0.92
Q99.9	0.94	0.94	0.94	0	-
Buildwas					
Q95	10.70	9.77 (-0.93)	9.77	8.36	10.44
Q99	6.84	7.52 (+0.68)	7.43 (+0.59)	6.63	9.66
Q99.9	6.51	7.13 (+0.62)	7.02 (+0.51)	6.63	-
Bewdley					
Q95	6.98	6.48 (+0.50)	6.48	7.08	6.91
Q99	4.31	4.99 (+0.68)	4.90 (+0.59)	6.29	6.59
Q99.9	3.97	4.60 (+0.63)	4.50 (+0.53)	4.99	-
Saxon's Lode					
Q95	8.86	7.94 (-0.92)	7.94	11.58	11.43
Q99	5.09	5.77 (+0.68)	5.69 (+0.60)	10.13	10.37
Q99.9	4.76	5.37 (+0.61)	5.28 (+0.52)	5.85	-
Deerhurst					
Q95	5.96	5.84 (-0.12)	5.84	6.45	6.37
Q99	5.31	5.45 (+0.14)	5.44 (+0.13)	6.07	6.16
Q99.9	5.23	5.37 (+0.14)	5.35 (+0.12)	5.48	-

Water level changes could not be assessed at this time for Lower Parting. The river is generally wide in the lower sections, which would buffer smaller changes in flow. However the channel split at Gloucester and the amount of abstraction for the Gloucester & Sharpness Canal would also vary the impact in the lower tidal Severn.

To improve this analysis cross section survey work is needed to enable water levels and flows to be related to wetted perimeter and habitat characteristics. This will support a more detailed ecological assessment of water and flow changes in the future.

5.3.5. Impact on Flows; Chronic Drought Condition

The previous Acute drought condition attempted to model a prolonged one season drought, identifying the risk that significant rainfall could arrive earlier than modelled and prevent the flow benefits occurring. This raised the question of “what value would the River Severn Drought Order be if rainfall returned before regulation failure was reached? The Chronic condition was built to investigate this question. By introducing rainfall earlier in the existing Acute condition the flow benefits were removed in the first dry summer, the dry period was then extended over the critical winter recharge season to produce a more long term drought.

Only the summary and conclusions are presented in this section, for the complete Hydrological assessment refer to Appendix I (Appendix K.1 to K.6 contain the supporting hydrographs, flow duration curves and a breakdown of the key regulation volumes and critical dates for the Chronic drought condition testing). It is important to emphasise the drought order scenarios being assessed are theoretical worse case situations. They were developed to assess the likely flow trends and identify the potential periods of drought order operation.

Figure 12 presents data from the Lower Parting assessment point, which includes the cumulative impacts of all abstractions, plans and other drought permits/orders. The main focus of interpretation and graphing is the modelled 1977 year, the impacts and flow behaviour for the Chronic 1976 drought were very similar to the Acute drought condition, but with shorter duration low flow periods and no flow benefits being observed (to simulate the return of significant rainfall). Once again, the hydrograph demonstrates the overall flow trend observed along the majority of the River Severn, illustrating the initial flow depletion as the drought order is activated (compared to the 'Do Nothing' baseline), followed by a higher maintained flow than would be possible without the drought order. More crucially with the Chronic drought condition testing, by saving water from the previous year's drought order activation, flow could be maintained significantly higher during the chronic drought summer than if no drought order had been activated.

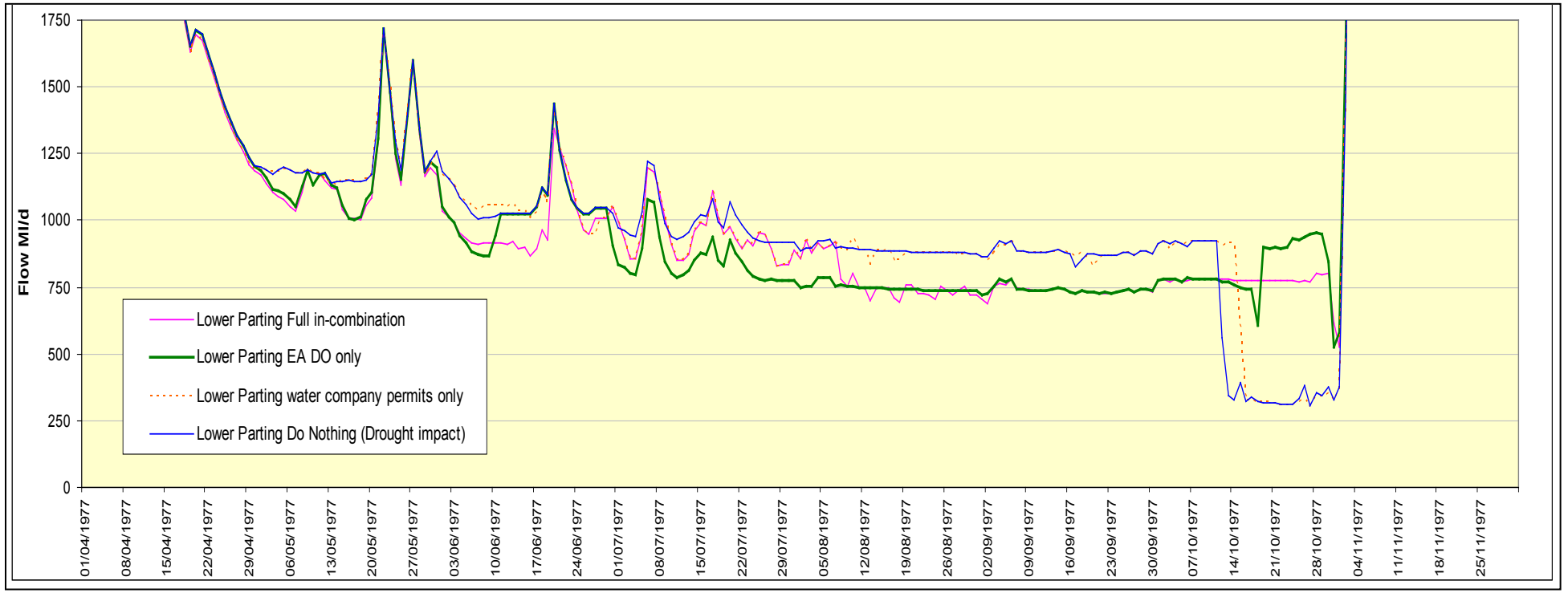

Figure 12: Lower Parting (Estuary inflows) Chronic Drought scenario 1977; 1 April to 1 December

Figure 12 shows all the modelled impacts on flows at Lower parting, downstream of all the regulation inputs (Clywedog, Vyrnwy and SGS) and major abstractions, including the Gloucester & Sharpness Canal abstraction. The graph highlights the specific period of interest, when the Environment Agency drought order was modelled as being active.

Within the Chronic modelling there were anomalies relating to when the Severn Drought Order was activated by Aquator, the results were therefore analysed in terms of general flow behaviour and trends, using judgement to suggest how the results might have differed if the drought order were operated more realistically. The 'Do Nothing' baseline was unaffected by this issue, as no drought orders or permits were operated. EFI testing was conducted but not analysed in detail as the duration of low flows under the Severn Drought Order operation were incorrect due to the modelling anomaly.

Table 11 contains some flow values for comparison, the drought scenario Q30 values need to be viewed with additional caution due to the short (3 year) record of data used.

Table 11: Summary of Modelled Chronic Flow percentiles

Flow value	Acute Do Nothing Ml/d	Acute EA DO in isolation Ml/d	Acute Full In-combination Ml/d	Current flow Ml/d (G=Gauged, M=modelled*)	Naturalised flow Ml/d (D=decomposition , M=modelled*)
	(1975-1977)	(1975-1977)	(1975-1977)	(1990-2007)	(1990-2007)
Bryntail					
Q30*	174	175	164	176 G	216 D
Q95	18	18	18	18 G	19 D
Q99	10	18	18	18 G	-6 D
Q99.9	9	18	18	-	-59 D
Vyrnwy Weir					
Q30*	45	45	45	131 G	426 D
Q95	25	25	25	25 G	30 D
Q99	20	25	25	24 G	-3 D
Q99.9	18	18	25	-	-228 D
Buildwas					
Q30*	3345	3345	3345	5511 G	5646 D
Q95	1067	934	931	1030 G	741 D
Q99	471	910	904	919 G	527 D
Q99.9	459	691	614	-	527 D
Bewdley					
Q30*	3250	3250	3250	5470 G	6211 D
Q95	895	762	761	881 G	930 D
Q99	304	745	732	791 G	715 D
Q99.9	289	521	444	-	458 D
Saxon's Lode					
Q30*	3938	3938	3938	7991 G	8523 D
Q95	939	804	799	1327 G	1350 D
Q99	344	791	781	1167 G	1131 D
Q99.9	328	551	511	-	536 D
Deerhurst					
Q30*	4418	4418	4421	9054 G	10079 D
Q95	1108	979	978	1571 G	1680 D
Q99	520	966	950	1317 G	1224 D
Q99.9	505	727	813	-	730 D

Flow value	Acute Do Nothing Ml/d	Acute EA DO in isolation Ml/d	Acute Full In-combination Ml/d	Current flow Ml/d (G=Gauged, M=modelled*)	Naturalised flow Ml/d (D=decomposition , M=modelled*)
	(1975-1977)	(1975-1977)	(1975-1977)	(1990-2007)	(1990-2007)
U/S Sharpness					
Q30*	1209	1117	1145	-	-
Q95	578	1005	997	-	-
Q99	547	1000	985	-	-
Q99.9	532	755	705	-	-
Lower Parting					
Q30*	983	893	914	9772 M	10213 M
Q95	370	735	729	1910 M	2056 M
Q99	319	729	718	1509 M	1564 M
Q99.9	304	528	523	1096 M	1123 M

*Modelled drought Q30 values need to be viewed with caution due to the short (3 year) record of data used.
**Modelled data using Low Flows Enterprise, a rainfall runoff model producing flow duration curves for a drainage basin (not time series data).*
Negative values within the calculated naturalised dataset are known errors associated with data quality.

5.3.5.1. Summary

The Chronic drought scenario represented a dry summer and winter (1975) preceding a drought summer (1976), which triggered a River Severn Drought Order implementation but significant rainfall returned before true flow benefits were achieved. A second drought summer followed (1977). The main focus of the Chronic scenario is the second drought year (1977), and what impact applying a River Severn Drought Order in the first year without achieving flow benefits could have on a consecutive drought year.

The greatest uncertainty remains around the Gloucester & Sharpness Canal abstraction and its impact on the lower River Severn during a severe drought. The River Severn splits between U/S Sharpness and Lower Parting, with monitoring (between 1977-2007) indicating approximately 40% of flow goes down the East channel and 60% down the West channel. Low flows occurring due to the drought would become further divided (as the channel split) and flow velocity decreased encouraging siltation and saline intrusion. The degree of flow loss and subsequent impacts is unclear without more data/monitoring, however this stretch of the River Severn could potentially be at high risk during a severe drought and likely significant effects have been concluded as a precautionary measure.

5.3.5.2. Do Nothing (Baseline)

The Chronic scenario once again proved the importance of Llyn Clywedog as the primary source of Severn regulation water. Modelling showed that if Clywedog became exhausted, Lake Vyrnwy water bank could only offer a short term replacement for the large volumes of regulation water required. The SGS did not have enough capacity to replace the reservoir volumes. It also appears likely during such a drought, that Lake Vyrnwy storage would also become critically low and could pose another resource issue that would need careful management with the appropriate water company. The key message is that if Llyn Clywedog becomes exhausted the whole regulation system is likely to fail. Forward planning is needed during any event, considering the impact on the subsequent year if resources are drawn down too low.

The modelled 1976 drought event did not appear to have any significant flow impacts under Do Nothing, owing to the continued high releases made as part of normal regulation. This outcome would be unpredictable, if rainfall had not arrived, events would have followed the Acute condition, however on this occasion recharge was received and therefore no adverse flow impacts were observed along the Severn corridor. Significant flow impacts were observed during the modelled 1977 drought (Do Nothing) at Bryntail, Bewdley, Saxon's Lode and Deerhurst, the same locations identified in the Acute condition.

Bryntail was potentially at high risk of significant flow impact, as the 18.2 Ml/d compensation flow failed for 42 days between 18 September and 10 October. Modelling indicated a minimum flow of 9 Ml/d, however with no releases being made from the reservoir, the area immediately downstream of the dam is likely to become dry, extending downstream until significant natural baseflow returned.

During the modelled 1977 Vyrnwy Weir showed over 20 days (7 to 26 October) of irregular compensation flow failures, all below the minimum 25 Ml/d compensation flow. A minimum 17.46 Ml/d occurred on 25 October. It's unclear whether this is modelling error, although storage was at 14% and 7 continuous days recorded compensation flow failure.

From Bewdley, it can be expected the whole River Severn downstream would be affected to varying degrees by the naturally developing drought. If the regulation system failed, flows were found to fall up to 600 Ml over 2 days. Flows crashed between 8 and 11 October 1977, with depressions lasting between 21 and 24 days before natural recharge occurred in early November. Bewdley predicted a minimum flow of 289 Ml/d, 229 Ml/d lower than ever recorded, Saxon's Lode predicted a minimum 323 Ml/d, 392 Ml/d below existing records and Deerhurst predicted a minimum 499 Ml/d, 476 Ml/d below existing records. Greater uncertainty surrounded the lower River Severn as discussed; assuming a maximum 300 Ml/d abstraction to the Gloucester & Sharpness Canal, a minimum daily flow of 532Ml/d at U/S Sharpness and 304Ml/d at Lower Parting was modelled. The magnitude of predicted flow impact is certainly significant; the degree of adverse impact would depend on the duration of the event and sensitivity of the environment.

In reality, it is not possible to exactly predict what the minimum flows would be if the regulation system did fail and they should be viewed as advisory only. All drought events are unique with varying prevailing conditions and abstraction demands creating different responses to the same rainfall patterns. However, the flow behaviour is the important result for drought planning. Should Llyn Clywedog fail, the remaining regulation support is only short term. Once the regulation system goes into failure, minimum flows can be expected to rapidly decline to baseflow rates until rainfall returns, highlighting the need to operate the River Severn Drought Order.

5.3.5.3. Drought Order Only (River Severn Drought Order)

The modelled 1976 drought event and River Severn Drought Order operation appeared reliable and results could be used with reasonable confidence. Flow impacts for the modelled 1976 portion of the event were concluded to be the same as the Acute condition, but without the immediate flow gain being achieved.

During 1977 the model activated the River Severn Drought Order on and off on three different occasions, 24 February – 4 June, 24 June to 12 October and 24 October – 1 February, all which reduced the prescribed flow at Bewdley to the 730 Ml/d. The first two activations appeared to be false, as Clywedog storage was at 84% on both occasions, whilst the Drought Order in force curve would be crossed at 40%. The third activation on 24 October, although slightly late, was an accurate response to Llyn Clywedog storage.

It is unclear what the Aquator model was responding to on the false occasions. The system is complex and Aquator (version 3) was not designed to isolate the River Severn Drought Order for testing. A number of other triggers and linkages to system failures elsewhere could have caused these false activations.

As a result the 1977 flow results had to be assessed subjectively, making informed assumptions about how differently the flows would have responded if the River Severn Drought Order had only been activated on one occasion, likely during October. It is more likely the Do Nothing flows would be matched for longer leading into the critical flow period, drawing Llyn Clywedog storage down earlier in the regulation season as a result. Flows would then be lowered to maintain the Bewdley drought flow target (730 Ml/d 5 day mean) as modelled, continuing at this flow beyond the Do Nothing flow crash (as modelled). The high flows in mid October would be removed, instead maintaining the drought order prescribed flow. If the drought continued the regulation system would still inevitably fail, potentially sooner and to lower flows than currently modelled as less regulation water would be available due to higher flow maintenance earlier in the season (removing the false drought order activations).

Although the results could not be analysed in great detail owing to the modelling anomaly, the flow behaviour and trends were still valuable. By activating the River Severn Drought Order in 1976, although no flow benefits were immediately achieved 16% storage was saved at Clywedog. This enabled the reservoir to reach 96% capacity before regulation began in 1977, translating to longer regulation at 730Ml/d (5 day mean) after the Do Nothing model showed system failure and flow crashes. Modelling also suggested a greater protection of the minimum flows during any subsequent regulation failure, as Llyn Clywedog and SGS continued to have more resources than under Do Nothing.

With the exception of Bryntail, where compensation flows were protected with obvious benefits, significant flow impacts were difficult to conclude with certainty for 1977, due to the modelling issues. A precautionary approach was adopted, assuming a very similar impact as assessed under the Acute condition due to the reduced flows leading into the critical drought period (which are likely to be of similar duration), but with a greater flow benefit being achieved as the drought developed. Significant flow impacts were concluded at Saxon's Lode, Deerhurst and the lower River Severn (U/S Sharpness and Lower Parting).

Vyrnwy Weir response was similar to the Do Nothing model. The number of days when irregular compensation failure occurred was reduced, spread over 15 days (12 to 26 October). A minimum 17.46 Ml/d occurred on 25 October. Storage again reached 14% and flows failed on 7 consecutive days.

Modelling supports the aim of the River Severn Drought Order, and demonstrated the long term benefits its operation can create in a subsequent drought year. By operating the drought order in 1976, no flow benefits were immediately observed, but the reservoir storage saved was carried over into the subsequent regulation season (1977). This more long term saving was translated into preventing regulation system failure for longer than under Do nothing (opposite to Acute scenario), and potentially maintaining higher minimum flows during any subsequent regulation system failure, if the drought were to continue.

5.3.5.4. Full In-Combination

The modelled 1976 first year drought and River Severn Drought Order operation appear reliable and results could be used with reasonable confidence. Flow impacts for the 1976 portion of the event were concluded to be the same as predicted under the Acute drought condition, but without the immediate flow gain being achieved.

Modelling the River Severn Drought Order operation in the second year (1977) highlighted the same anomaly as discussed above, although the drought order only activated twice; 6 March – 13 June and 2 August – 9 November. On the March activation Llyn Clywedog storage was at 86%, and in August 58%, Bewdley flows illustrate the drought conditions were being operated, although high rainfall masks some operation. The August activation was still slightly premature, but appears more accurate.

Due to the similarities between the 'Drought Order Only' scenario results and the 'Full In-Combination' scenario results predicted under the Acute drought condition, and the suspect Chronic results, a very similar flow response to the 'Drought Order Only' scenario was assumed. By delaying the River Severn Drought Order activation to correspond with Clywedog storage more realistically, a very similar flow response to that produced by the Acute condition is expected. The duration of reduced flows leading into the critical period would be shortened, with the consequence of causing regulation failure slightly earlier than modelled, but still later than Do Nothing.

The main area of uncertainty was again around the Lower Parting assessment point and associated with the abstraction to the Gloucester & Sharpness Canal. Owing to the variability of abstraction quantity and splitting of the channel, there is the potential for significant detrimental impacts as modelled flows have already reached a record minimum by this location. The precautionary worst case principle was applied and likely significant effects concluded for the lower River Severn (mainly from the channel bifurcation to Lower Parting).

Due to the modelling issues significant flow impacts were difficult to conclude with certainty at other locations for 1977. No flow impact was concluded at Vyrnwy, as the compensation flow failure only occurred on 1 day. A precautionary approach was adopted to conclude a significant flow impact at Saxon's Lode and Deerhurst, where the duration of Medium Risk EFI failure could be slightly increased by operating the River Severn Drought Order, but the resulting flow benefits would be significant and clear.

5.3.6. Impact on Water Levels; Chronic Drought Scenario

To investigate the modelled drought conditions, Q95, Q99 and Q99.9 flows (low to drought flows only) were compared against the Do Nothing baseline scenario to identify the impact. Table 14 summarises the results and provides the naturalised and gauged water levels for comparison. Green boxes show where no change against the Do Nothing baseline was identified, yellow boxes identified a reduction in levels and blue boxes an increase in water levels against the baseline.

Similar trends were identified for the Chronic Condition as with the Acute Condition modelling, although more benefits were identified. As with the Acute modelling, the Chronic results showed the River Severn Drought Order, whether in combination with the water company drought orders or operating alone, was of benefit to water levels during the extreme low flow period.

More benefits were identified in the upper catchment, at the Clywedog and Vyrnwy assessment points. At the Q95 flow, water levels remained the same as the Do Nothing scenario. However, at Clywedog in particular, operating the River Severn Drought Order increased water levels by up to 0.24 meters. This reflects how the drought order protects Llyn Clywedog storage enough to enable compensation releases to continue throughout the drought period, and for longer under the Chronic Condition as the event is extended.

At the remaining 4 assessment points the water level at the equivalent Q95 flow was found to be lower under the River Severn Drought Order scenarios than the Do Nothing. The decrease ranged from 0.94 meters at Buildwas to 0.14 meters at Deerhurst, very similar to the Acute Condition modelling. However, some minor additional water level reductions were identified under the Full In combination scenario's, with an extra 0.02 meter decrease at Buildwas and 0.01 meter decrease at Saxon's Lode.

Table 12: Summary of Water Level data under the Chronic scenario

Flow value	Chronic Do Nothing (meters)	Chronic EA Drought Order only (meters)	Chronic Full In-combination (meters)	EA Naturalised 1990-2008 (meters)	Gauging Station observed 1990-2008 (meters)
Bryntail					
Q95	0.87	0.87	0.87	0.88	0.87
Q99	0.66	0.87 (+0.21)	0.87	0	0.86
Q99.9	0.63	0.87 (+0.24)	0.87	0	-
Vyrnwy Weir					
Q95	0.94	0.94	0.94	1.02	0.95
Q99	0.85	0.94 (+0.09)	0.94	0	0.92
Q99.9	0.81	0.81	0.94 (+0.13)	0	-
Buildwas					
Q95	10.69	9.77 (-0.92)	9.75 (-0.94)	8.36	10.44
Q99	6.14	9.60 (+3.46)	9.56 (+3.42)	6.63	9.66
Q99.9	6.04	7.97 (+1.93)	7.35 (+1.31)	6.63	-
Bewdley					
Q95	6.96	6.48 (-0.48)	6.48	7.08	6.91
Q99	3.68	6.42 (2.74)	6.36 (+2.68)	6.29	6.59
Q99.9	3.55	5.41 (+1.86)	4.88 (+1.33)	4.99	-
Saxon's Lode					
Q95	8.86	7.94 (-0.92)	7.94	11.58	11.43
Q99	5.09	5.77 (+0.68)	5.69 (+0.60)	10.13	10.37
Q99.9	4.76	5.37 (+0.61)	5.28 (+0.52)	5.85	-
Deerhurst					
Q95	5.96	5.82 (-0.14)	5.81 (-0.15)	6.45	6.37
Q99	5.12	5.80 (0.68)	5.78 (0.66)	6.07	6.16
Q99.9	5.09	5.48 (0.39)	5.61 (0.52)	5.48	-

As with the Acute modelling, water levels at the equivalent Q99 and Q99.9 flows highlighted how the River Severn Drought Order would provide benefit during the extreme period of drought. Results for the Chronic Condition showed greater overall benefits to water levels at Buildwas, Bewdley and Deerhurst than found under the Acute modelling. Water levels were increased by between 0.39 meters at Deerhurst and 3.46 meters at Buildwas.

Water level changes could not be investigated at the Lower Parting assessment point because there was not enough data to produce a rating curve. This requirement has been flagged in the monitoring programme and future work section, along with the need for cross section surveys and detailed investigation into the impacts on wetted perimeter and habitat characteristics.

5.3.7. Hydrology Conclusion

It is important to acknowledge the River Severn is a large and artificial system with respect to hydrology. Models are very important but cannot fully replicate reality; all results need to be considered with this in mind. The Aquator model is the best available tool we have at this time, but was not specifically designed to predict drought flows and demands. Deliberate error was built into the model to account for weather forecast and lag time difficulties encountered in real life, but how the Environment Agency operates the different regulation sources is likely to differ during a real event. The results are an indication of the potential worse case scenarios and help us identify important trends and problems to inform better drought management, they cannot provide the exact flows or timings that will be encountered.

It also needs to be understood the drought magnitudes created have not yet occurred (i.e. not on record), so all results and impacts are theoretical. Every drought event will be unique and produce different challenges. In particular, the exact timing and severity of a drought cannot be guaranteed.

The Do nothing models represent what could occur during droughts of these magnitudes, and all impacts have been assessed against improvements or deteriorations from this baseline. It needs to be remembered that droughts are natural events, and cannot be prevented only managed. Do Nothing is considered to represent what would occur if no drought management action was taken to protect water supplies or the environment.

Modelling has helped illustrate how robust the Severn regulation system is today, modelling pushed the system into very rare drought magnitudes in order to trigger the need for the Severn Drought Order. In reality, having three separate sources allows Clywedog to be rested early in the season if there is deemed to be a high regulation risk and the catchment is more likely to experience dry/drought conditions. All the actions available to the Environment Agency allow time to be ‘brought’ to prolong the resource available from Clywedog whilst recharge is awaited, lowering the probability of needing to utilise the drought order at present.

Real drought events have shown how the antecedent conditions at the commencement of the regulation season are the critical facture in whether a Drought Order will be required if dry weather persists. For the Midlands region, historic droughts have shown that two subsequent dry years are critical in reducing groundwater levels and therefore baseflows to rivers in the second year. Natural baseflow in the catchment is the primary driver for how much regulation support will be required in the absence of rainfall; low/below average baseflow will result in high regulation releases being required to supplement the deficit. Consistent releases of over 400 Ml/d can cause Clywedog to cross the SDO in a single season if dry weather persists, as shown by modelling and the 1976 drought event. In order for baseflow to have naturally receded to significantly low levels, a long term shortage of rainfall (i.e. drought event) needs to have occurred, likely to be of magnitude greater than a 1 in 20 year over more than 6 months for the whole River Severn catchment scale.

Once Clywedog is releasing large volumes in the absence of recharge, it is clear from real events (e.g. 1976) and modelling, that storage depletes quickly. Approximately 1% is lost per day when 500 Ml/d is released, which supports the original design and 100 day rule applied to Clywedog operation. With appropriate management, which could include a drought order under rare circumstances, Clywedog is likely to avoid dead water during a one season drought and maintain some level of regulation support. The recharge season immediately following a drought/high regulation season will be critical in determining how it performs if a second drought year follows. If the drought order was operated during the first drought year and sufficient recharge is received, the water saved in Llyn Clywedog could be critical in providing significant flow improvements above the drought baseline in the subsequent drought event, demonstrated by the Chronic scenario modelling.

Modelling has shown that with prolonged droughts and insufficient recharge, the regulation system could fail (i.e. individual licences/sources begin to run out of water) even with the Severn Drought Order in operation. Depending on remaining storage in Lake Vyrnwy water bank and the SGS, modelling suggests activating the Severn Drought Order could cause regulation system failure at the same time/earlier than if no action were taken (shown by Acute scenario), as pressure is diverted to the alternative sources earlier. However, even when this occurs and the Bewdley prescribed flow of 730 Ml/d (5 day mean) is failed, the water saved in Clywedog storage then enables a higher residual flow to be maintained than if the Severn Drought Order had not been activated.

Modelling has also identified the Severn Drought Order could be operated during a drought, without flow benefits being immediately achieved (refer to the Chronic scenario). The environmental cost would be to have created additional flow stress during an already stressed period. The Environment Agency acknowledges this is a risk that would always need to be assessed against long term weather forecasts, carefully balanced against the potential flow damage not operating the Severn Drought Order could allow to happen.

Modelling the Chronic scenario has helped to demonstrate that if the Severn Drought Order is operated during an event when recharge occurred before flow benefits were achieved, the resources saved one year could be critical in safeguarding against a consecutive drought or high regulation season the following year. Therefore, even though short term savings may not be translated into immediate flow benefits, the Severn Drought Order could have an important long term role and potentially be more beneficial in long term droughts than shorter acute events. Modelling suggested the storage savings made during the first Severn Drought Order year, could prevent or significantly delay regulation failure in the following drought.

Both the Acute and Chronic modelling identified a lack of conceptualisation and data around the Gloucester & Sharpness Canal abstraction and the relationship with Bristol Water abstraction from the canal. A maximum abstraction of 300Ml/d based on recent actual data was manually applied to the Aquator model, although post drought reports for 1976 and 1989 suggest abstraction to the canal increased to 680Ml/d for short periods, subsequently drying up inflows to the Estuary. The situation is further complicated by the channel bifurcation through Gloucester dividing flows approximately 60:40, with the canal abstraction taking from the smaller East channel. This poses a significant risk to the lower River Severn under the full in-combination scenario and needs further investigation and close liaison during a real event.

Real drought events (e.g. 1976) identify regulation beginning from April to early June, but reservoir storage and/or flows are not considered at significant risk until mid July onwards, when formal drought order applications were made. Variations of the Severn Drought Order typically came into force in early August through into September. Modelling identified that with the additional regulation resources now available, this risk is likely to be delayed towards the end of August/early September, although abstraction demand is an important factor.

The Severn Drought Order will reduce Severn corridor flows for a given period, but even under the rare drought magnitudes modelled, it prevents complete regulation failure at Clywedog. Ultimately the water saved early on enables the minimum flows to be increased along the whole Severn catchment when the regulation system goes into unavoidable failure as the drought continues. This reduces the severity of drought stress on flows during the most critical period. Importantly, the reduction in flow caused by the drought order prior to the obvious benefits, does not lower flows below the modelled baseflow (baseflows shown after regulation failure in Do Nothing scenario), and is therefore still maintaining an artificially elevated flow (above natural) benefit along the River Severn.

Forward planning is needed during any event, considering the impact on the subsequent year if resources are drawn down too low.

5.3.8. Limitations and Assumptions

The River Severn is the longest river in Great Britain, has the second largest tidal range in the world, and involves numerous complex abstractions and discharges as well as artificial flow regulation. Modelling the flow response of such a complex catchment made up of so many variables is very difficult with high confidence. This investigation can only provide a snapshot of potential impacts at a limited number of locations due to the scale of catchment being considered, it is acknowledged that local variation could be significant.

Modelling can only provide a somewhat black and white interpretation of a set of events. The reality is all drought events are unique and how we respond operationally will be different to a model, according to what information and confidence we have in forecasts at the time. The flow modelling should only be used as a guide for some possible worse case drought events to highlight the risks and help the Environment Agency better plan for drought and water resource management.

Droughts of these magnitudes have never occurred within our records of flows and rainfall, therefore cannot be calibrated with accuracy. Historic droughts and previous operation of the River Severn Drought Order does provide an initial baseline, but it must be acknowledged that water resource management and demand has changed since these events and the severity and length of these actual events has been increased. The results should be used as a guide to identify potential trends and highlight monitoring needs and potential remediation; however they cannot be used as a definitive prediction of how flows will behave.

Historic data are varied and flow records in particular rarely go back as far as the 1975-1976 event, particularly in the lower River Severn. Monitoring and methodologies have also changed since records began, making it very difficult to accurately compare datasets without accumulating further errors and uncertainty.

Aquator can model Severn regulation rigidly to meet the basic prescribed flow criteria at Bewdley, but in reality forecasts and travel times do not allow for such high accuracy. Parameters within Aquator were adjusted to build in some natural error, but sudden changes in releases from all regulation sources are still evident, but unlikely to occur in reality. The SGS in particular, is modelled to on off operate, where as in reality the resource requires preparation and then would be utilised as continuously as possible, stepping other resources back where needed, in order to increase operational efficiency and staff resources. These variations need to be acknowledged and understood when using the modelling results.

Flows from effluent returns is significantly different between Aquator and the water quality model SIMCAT (details in Appendix N) and needs to be investigated further to determine which model/method should be utilised for drought management and prediction in the future. Modelling identified that Aquators minimum flows were significantly lower (approximately half) in the lower River Severn/Severn Estuary inflows than SIMCAT could replicate. Further investigation identified that even if all natural runoff were switched off within SIMCAT, effluent alone would maintain flows significantly higher than Aquator was predicting. The greatest uncertainty was around the Severn Estuary inflows, and the worse case flows from Aquator were adopted in accordance with Habitats Regulations.

Modelling and interpretation clearly identified gaps in baseline drought data and a true understanding between how changes in flows would impact ecological flow and habitat requirements on the ground. Best available methods were adopted, but expert opinion had to be adopted regularly in the absence of clear flow targets and models to predict ecological impacts based on flow reductions for a regulated river.

In an attempt to provide an indication of possible impacts EFIs were used to provide a rough indication of significance. Risk bands were calculated by subtracting 10% per band from the

original EFI. Although the EFI methodology is widely used, the modelled drought scenarios only included three years of flow data from which to calculate flow duration curves. This produces a low flow biased FDC, skewing flows lower where as a longer period would have incorporated more higher range flows, likely reducing EFI failures. This limitation was taken into account when assessing the results where possible, but will have added to the uncertainty around concluding significant flow impacts on ecology.

Overall the highest uncertainty in flow data surrounds the lower tidal River Severn and Severn Estuary inflows, also the highest environmental risk area. A lack of continuous monitoring and the tidal influences makes it very difficult to determine what the full impacts could be.

5.4. Assessment of Impact on the Current Environment: Other Abstractors

Operation of the River Severn Drought Order would have a direct impact on the amount of water within the River Severn, and could therefore affect surface water abstractions. This section summarises the impacts on the main groups of abstractors (as defined in section 5.1.5) that could be impacted.

5.4.1. Water Companies

There is a genuine risk of conflicting interests between some of the water companies Drought Permits and the Environment Agency's Drought Order. A number of proposed Drought Permits/Orders that could impact upon the River Severn are identified within STWL's and SSW's Drought Plans. These permits seek to increase abstraction or decrease compensation releases along the River Severn and/or its tributaries. The River Severn Drought Order aims to reduce non-spray irrigation abstractions from the River Severn by 5% (with additional requests for reductions up to 20% if emergency storage is reached), to reduce pressure on the system whilst prescribed flows are reduced. These two primary objectives conflict, with STWL and SSW needing to put more strain on the River Severn and the Environment Agency attempting to mitigate the impacts of drought conditions.

Due to the complex interactions and size of the River Severn catchment, coupled with the unique behaviour of every drought event, the sequence of 'who would apply first' will alter according to demand and rainfall shortages. Modelling the worst case scenarios has shown that a chain reaction of applications is likely, following a wide scale and homogenous drought event such as the 1976 event. Assuming the abstraction quantities modelled remained the same, it is likely the River Severn Drought Order would not be the first drought permit or order to be activated, although the initial application could be made first. Higher abstraction demand and localised variations in rainfall would alter this sequence so predictions cannot be accurately made at this time.

The Environment Agency recognises that in extreme drought situations priority has to be given to ensuring that essential public water supplies can be met, whilst working together with water companies to minimise the effects of any resulting environmental damage. It is however important to note how the River Severn Drought Order does seek to prolong water for the benefit of water supply, therefore STWL's and SSW's drought permits/orders could be counterproductive. Full In-combination modelling showed the drought permit/orders did cause a small increase to the risk of regulation failure, reducing the amount of time that remaining sources lasted and creating lower minimum flows on the River Severn. In the event of conflict, water companies would apply directly to the Secretary of State or Welsh Assembly Government for a drought order on the grounds of Overriding Public Interest (OPI).

The Environment Agency and water companies will meet to discuss the potential conflicting nature of these permissions at an early stage during a drought. This will be important to ensure proper management of water resources on the River Severn during a drought and that all parties make appropriate, timely decisions. A meeting with key partners will be triggered when Severn Trent Water crosses its 'drought action trigger' curve at Elan Valley or the Llyn Clywedog reservoir 'alert' curve is crossed, whichever the sooner.

5.4.1.1. Potential impacts from the River Severn Drought Order

To provide an indication of potential impact regardless of whether the water companies applied and operated their own drought permits/orders, the assumption of a minimum 5% abstraction reduction was adopted for River Severn Drought Order assessment purposes. Due to the modelling parameters within Aquator, the generic period of the River Severn Drought Order operation was used and optional flexibility has been considered in the discussion below.

The first consideration for water companies would be the 100 day regulation restriction (section 2.2 contains details). This is not specifically related to the River Severn Drought Order and implications are outside the scope of this environmental assessment. However, it is important to note that the 100 day regulation restrictions would either already be in force, or likely to come into force soon after the River Severn Drought Order came into force. This is simply due to the nature of drought; for the River Severn Drought Order to be needed, high regulation demand would

already be present on the River Severn, drawing Llyn Clywedog storage down. It is expected that the 100 day restriction would come into force before the River Severn Drought Order was activated, but a drought order application could be made prior to the 100 day restriction.

For context, the Aquator Acute condition modelling produced 166 regulation days in total (basing a regulation day as releases from any of the 3 sources, Llyn Clywedog, Lake Vyrnwy water bank and/or the SGS), with 100 days regulation reached on 26 August for both the 'Do Nothing' and 'Drought Order Only' scenarios. In reality the SGS would be operated differently to how it is represented within Aquator (less on off activation and more continuous use), which should mean that in practice the 100 day restriction will occur after the drought order is activated (even though the modelling currently suggests the drought order would be activated 1 day before). Under the Chronic condition, 179 days of regulation were modelled for the 'Do Nothing' scenario, crossing the 100 day restriction on 12 August, whereas the Chronic 'Drought Order Only' scenario modelled 157 days regulation, crossing the 100 day restriction on 3 September.

Direct implications from the River Severn Drought Order relate to the 5% reductions imposed on activation, and the further reductions (up to 20%) that could be sought if storage at Llyn Clywedog crossed the 18% emergency storage curve. A 5% reduction in abstraction is generally considered achievable by most water companies and would not be expected to have a significant impact. Making larger reductions (up to 20%) associated with the emergency storage curve on Llyn Clywedog would be likely to have a significant impact.

There is a degree of flexibility around when restrictions could be relaxed (temporarily) and/or the drought order is fully removed, extensions are also possible within the last 28 days of the agreement. Therefore determining the exact impacts of the River Severn Drought Order from modelling is impractical.

With a worst case interpretation, the River Severn Drought Order can legally remain in force for between 6 months and a full year (if the maximum extension is sought) depending on the ongoing drought conditions. For the Acute condition Aquator operated the River Severn Drought Order for a total of 144 days from 25 August, for which the minimum 5% reduction would apply. The 18% emergency storage curve was crossed for a total 22 days between 15 October to 6 November. The impacts on water companies would alter according to current abstraction demands and whether or not the Environment Agency requested further abstraction reductions. Close discussions would be held with the water companies.

At the Environment Agency's discretion, flexibility within the River Severn Drought Order consists of the following measures:

- Consider withdrawing drought order application if storage rises above alert curve.
- Consider relaxing drought order conditions once storage rises 10% above enforce curve. *(Note: Drought order powers are in place for six months after date granted. Conditions could be implemented again without another application if storage subsequently drops below enforce curve).*
- Consider relaxing emergency storage drought order once storage rises 5% above emergency storage.

5.4.1.2. Bristol Water abstraction at Purton

Bristol Water's abstraction at Purton comes directly from the Gloucester & Sharpness Canal. The licence (18/54/20/138/C) is held by the Canal & River Trust and involves its own restrictions relating to tide heights and Severn Regulation. Due to its proximity to the Severn Estuary there is a risk of saline intrusion entering the canal and therefore impacting upon Bristol Water's abstraction. These risks are normally mitigated by the Canal & River Trust's operating agreement rules, all linked to tide heights and flows at Deerhurst. During a drought of the severity modelled under both Acute and Chronic conditions, the risk of saline intrusion up the lower tidal Severn is significantly increased. Therefore the risk of saline water entering the canal and affecting the

Purton abstraction is also increased. Reports identified that during the 1976 drought, salinity was reaching critical levels at Purton. The drought broke before action was needed, but the theoretical droughts modelled for the River Severn Drought Order extend the drought period and suggest potential problems for Bristol Water.

The River Severn Drought Order would reduce flows reaching the lower tidal Severn by approximately 120-140 Ml/d. In isolation these reductions would not be expected to create additional salinity concerns for Bristol Water, however in combination with other plans and drought permits/orders there is a greater potential for flows into the lower tidal Severn to become significantly derogated, with the Canal & River Trust potentially having to close the canal to navigation. Abstractions from the River Severn into the canal to support Bristol Water would be expected to continue, however the saline intrusion could be a concern.

A new abstraction cap of 300 Ml/d[25] will also be imposed on the Canal & River Trust when flows drop below 1200 Ml/d at Deerhurst, and the River Severn Drought Order is active. The Canal & River Trust has raised concerns that 300 Ml/d could pose a business risk to their operations and affect their confidence in supplying the Purton abstraction. The Environment Agency and the Canal & River Trust are working together to investigate what impacts the new restriction could have, if sufficient evidence can be provided to show a higher abstraction is justified, then the abstraction limit will be reviewed.

The main risk would develop if the drought persisted into regulation failure (which is a potential risk whether the drought order is activated or not), after which flows would suddenly fall to record lows. If regulation failure is ever reached, the River Severn Drought Order would provide a benefit to Bristol Water, as more water remains within the regulation system to provide support for longer. However saline intrusion is far more likely to be a problem after this point, although any impact would not be due to the drought order operation.

5.4.2. Agriculture

Before the River Severn Drought Order is implemented, Section 57 (S57) spray irrigation bans would be imposed. This would not be a direct consequence of the drought order itself, though it forms part of the preceding drought management process. Extensive Hands off Flow (HoF) restrictions would already be in force throughout the River Severn catchment (before the drought order is applied), so applying the Section 57 restrictions would be an extension commensurate with the wider seriousness of the developing drought. There would be a direct impact on the agricultural industry from S57 restrictions, mainly on the existing Licences of Right which normally avoid flow related restrictions and may be less prepared.

The River Severn Drought Order would lower flows along the River Severn for a longer period leading into a drought, than if no action were taken. The concern to spray irrigators is the risk of HoF's being triggered for longer periods as a consequence of these lower flows. Theoretically it would only be abstractors with HoF's set below the statutory prescribed flows at Bewdley (and equivalents at other gauges) that could be at risk of additional impact from the drought order. These licences are currently protected from restriction all year round, from normal to drought year (e.g. 1995/6) events, because their HoF triggers were set below the flow we have to maintain along the River Severn. The drought order would allow us to reduce this flow, and potentially trigger the lower HoF's. However, in reality the independent drought management procedure to seek S57 restrictions begins once Llyn Clywedog storage crosses the drought order 'application' curve (because it is a key indicator of drought severity in the Severn basin). This action would precede the River Severn Drought Order, which is not implemented until a second lower trigger curve is crossed at Llyn Clywedog. Therefore the impact on agriculture would result from the S57's and not the implementation of the River Severn Drought Order.

[25] Figure subject to change.

Data from the modelled Acute event (severe summer drought) showed that if the drought order were not implemented, the 'Do Nothing (Baseline)' scenario produced 233 days of potential S57 restrictions from 3 August to 23 March the following year. By operating the drought order, the 'Drought Order Only' scenario produced 206 days of potential S57 restrictions from 3 August to 25 February the following year. The 'Full In-Combination' scenario produced 201 days of potential S57 restrictions from 7 August to 24 February. This suggests the River Severn Drought Order would actually be of benefit to spray irrigators, by reducing the potential restriction period.

In reality the S57 restriction trigger curve will be used as a guide during a real event rather than a definitive start and stop trigger. When S57 restrictions would be enforced and lifted will vary with each drought event, although they will always be in force before the River Severn Drought Order is implemented. For context, it is more feasible that S57 restrictions would be lifted once sustained rainfall was experienced (it could be assumed that spray irrigation demand would also be reduced/removed at the same time). The modelled drought event ended at the beginning of November although storage in the reservoir takes several months to recover. However with the post drought rainfall modelled, by December S57 restrictions might have been lifted anyway. As the S57 restrictions were triggered at about the same time, whether the drought order was implemented or not, it is more likely the drought order benefits are associated with the recovery period, allowing S57's to be lifted more quickly as storage in the reservoir is better protected under drought order implementation. Therefore no additional negative impact on agriculture in the short term is concluded.

The longer-term benefit of operating the River Severn Drought Order, as shown by the Chronic condition modelling, is that Llyn Clywedog storage could be protected for a subsequent drought year. If storage could be protected by applying the drought order during an acute drought year, the probability of needing it in two consecutive years, even if the drought persisted, would be greatly reduced. Therefore the long term benefit could be the reduced risk of Section 57 restrictions being needed in two consecutive years, with obvious benefits for agriculture, industry and other abstractors.

The extent and nature of S57 restrictions will vary with each event, however worse case large scale crop failures could be expected where no alternative water supplies can be utilised. The risk to livestock should be limited to the natural deterioration of grazing/pasture land, as the restrictions only apply to spray irrigation licences, although some farmers may struggle to fill water troughs due to the drought conditions (not in connection with the River Severn Drought Order).

The Environment Agency would be openly engaging with the National Farmers Union (NFU), Farmers Union Wales (FUW) and agricultural industry wherever possible to warn of developing drought conditions and encourage farmers to plan ahead and make essential provisions should restrictions be absolutely necessary.

5.4.3. Canal & River Trust (formerly British Waterways) abstractions

5.4.3.1. Montgomery Canal

The Canal & River Trust abstraction from the River Severn for the Montgomery Canal at Newtown is exempt from (Water Resources Act 1991) licensing. Under the Montgomery Canal Agreement 1988, and the Operating Rules for the River Severn Resource/Supply System, flows entering the canal are restricted during periods of high River Severn regulation (section 5.1.5.3 contains details). The River Severn Drought Order conditions are included within the 1988 agreement and the Canal & River Trust would be expected to have appropriate plans in place.

Specifically related to the River Severn Drought Order, once the drought order is activated, the Canal & River Trust can abstract a maximum 115 Ml in 7 days at Newtown. Although the duration of a drought cannot be predicted, the Acute condition modelling results show this could exceed

140 days in any single year (whether in combination with other plans and permits or not) and is most likely to cause impacts from August onwards.

In addition, the 1988 agreement states that if Llyn Clywedog storage drops below 25%, then the Canal & River Trust must stop abstracting. The River Severn Drought Order Acute condition modelling indicated that Llyn Clywedog storage would be below 25% for a total of 76 days, between 16 September and 30 November. If the drought order were not operated then a greater impact would be felt, with a total of 120 days where abstraction would not be possible due to insufficient storage at Clywedog, between 2 September and 30 December. Under the Chronic drought condition, assuming a similar initial year, the second drought year was predicted to result in a further 15 days of 'no abstraction' restrictions under the River Severn Drought Order, whereas the 'Do Nothing' scenario could create a further 80 days of no abstraction.

It can therefore be concluded that the River Severn Drought Order would be of benefit to the Montgomery Canal abstraction, potentially lowering abstraction quantities for longer but reducing the potential period of no abstraction if Llyn Clywedog storage is allowed to fall below 25%.

5.4.3.2. Gloucester & Sharpness Canal

The Canal & River Trust abstraction from the River Severn at Gloucester (and the River Frome and Cam tributaries) for the Gloucester & Sharpness Canal is also exempt from licensing under the Water Resources Act 1991. The abstraction holds an added complication, with Bristol Water making a large abstraction directly from the canal at Purton for PWS. The Gloucester & Sharpness Canal abstraction at Gloucester is known to have a potentially significant impact on the lower tidal Severn and inflows to the Severn Estuary depending on tide heights and the volume of abstraction.

The Canal & River Trust and the Environment Agency entered into an Operating Agreement in 1998 regarding the safe environmental management of the canal, to help alleviate the known impacts and protect the Natura 2000 from derogation. Essentially the agreement restricted abstraction according to specific tide heights and flows at Deerhurst flow gauge, although it is important to note clause 7;

“Neither party shall be liable to the other under this Agreement for the failure to observe any of its obligations under this Agreement due to any cause beyond its reasonable control including without limitation any act of God, sudden or threatened loss of water from the Canal, drought, flood or major pollution.”

The Canal & River Trust also have their own internal Drought Plan (although there is no statutory requirement for the trust to produce one); this was not available for consideration during the impact assessment for the River Severn Drought Order but communication provided a flow trigger for consideration.

Due to the licence exemption, abstraction return data is not a legal requirement on the Canal & River Trust. The Environment Agency and Canal & River Trust meet annually to review operations against the agreement, abstraction data is provided to the Environment Agency. Data available at the time of modelling (up to 2010) was used to produce an average monthly abstraction profile (Table 13) for Aquator.

Table 13: Gloucester & Sharpness Canal average monthly abstraction profile

Month	Average abstraction (Ml/d)
January	60.3
February	132.5
March	89.7
April	180.7
May	165.8
June	199.8
July	252
August	280.5
September	296.9
October	239.6
November	190.6
December	109.8

Discussions and data made available by the Canal & River Trust following the dry period 2010-early 2011 has since highlighted these figures as not accurately reflecting the high demands during dry weather or the maximum potential abstractions (approximately 691 Ml/d) that the Canal & River Trust could legally take. The issue has been identified in the 'Further work recommendations' in section 17 and precautionary assumptions and historic evidence have been used to draw final conclusions on potential downstream impacts.

Aquator does not predict tidal movements and therefore assessing all the potential impacts on the canal abstraction is not possible with certainty. The Canal & River Trust currently consider closing the canal to navigation when flows at Deerhurst reach 1150 Ml/d or less, which can be used as a guide for the main impact on the canal abstraction. Using this as a basis, under the Acute 'Do Nothing' scenario the River Severn Drought Order modelling indicated a period of 106 days where flows were <1150 Ml/d at Deerhurst, from 2 July to 1 November. When compared with the 'Drought Order Only' scenario and the 'Full In-Combination', 38 of these days coincided with the activation of the River Severn Drought Order. Looking to a subsequent drought year in the Chronic condition identified another similar period of potential restrictions for both the 'Do Nothing' and 'Drought Order Only' scenarios. Owing to the consistency compared to the 'Do Nothing' scenarios and period of River Severn Drought Order operation, no additional canal closures would be caused as a result of activating the drought order.

It is understood that the canal closure trigger is for the Canal & River Trust's consideration only, and does not determine whether or when the canal will definitely be closed. The Environment Agency would actively encourage closing the canal for recreational use during severe drought conditions in the best interests of the environment and PWS.

The proposed new abstraction cap of 300 Ml/d (figure subject to change[26]), to be enforced when flows at Deerhurst drop below 1200 Ml/d, was tested. The Acute 'Do Nothing' scenario was used as a benchmark. No restrictions would have been enforced as the drought order was not active, however flows at Deerhurst dropped <1200 Ml/d for 131 days in total (modelled Jan 76-Jan77), 25 days more than 1150 Ml/d trigger. Under the 'Drought Order Only' and 'Full In-Combination' scenarios, there were 38 days when flows dropped <1200 Ml/d at Deerhurst and the drought order was active. When compared with the 1150 Ml/d flow trigger, the exact same 38 days were found

[26] The 300 Ml/d cap may be subject to change. The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operation of the Gloucester & Sharpness Canal and the Bristol Water abstraction it supports, which the Trust are investigating. If sufficient evidence is provided to show a higher abstraction is justified then the 300Ml/d limit will be reviewed.

to have triggered. It can be therefore be concluded that under these drought conditions, the Canal & River Trust abstraction from the River Severn was impacted for 38 days out of the year; all days which had already crossed the 1150 Ml/d Deerhurst trigger for potential canal closure and should therefore limit the magnitude of impact on the Canal & River Trust.

The complication of the Gloucester & Sharpness Canal abstraction relates to Bristol Water's reliance on the canal for its own PWS abstraction. The Purton licence entails its own tide height and regulation specific restrictions, which would naturally vary throughout the year. For both the Acute and Chronic drought conditions, abstraction for the Gloucester & Sharpness Canal was modelled with a continuous value for each month (based on Table 13). This should support the Bristol Water abstraction, although saline intrusion into the canal would be a private consideration for the water company to plan for.

With careful water management and the continued interception of several tributaries, the Environment Agency believe a 300 Ml/d restriction from the River Severn during drought order implementation, only when flows drop below 1200 Ml/d at Deerhurst, should still allow the Canal & River Trust to supply Bristol Water with enough water. The Canal & River Trust have raised concerns that 300 Ml/d may not be sufficient to meet all their obligations and therefore poses a risk to its operation of the canal. In respect of this concern the Environment Agency has committed to working with the Canal & River Trust, and if sufficient evidence can be provided to show a higher abstraction is justified then the abstraction limit will be reviewed.

5.5. Monitoring and Mitigation Options

Water resource specific monitoring and mitigation options are contained within the Hydrology technical report in Appendix I and incorporated into the overall mitigation programme in section 14 and monitoring section 15 respectively.

6. Water Quality

6.1. Baseline Environment Water Quality

The following sections provide a description of the chemical and nutrient quality of the River Severn, and how the baseline environment meets Water Framework Directive (WFD) requirements. For a full description of baseline water quality, including the historic use of General Quality Assessment (GQA) and how the monitoring sites previously used for GQA compare to the WFD sites, refer to Appendix L and M.

6.1.1. Water Quality Assessment Schemes

The Water Framework Directive (WFD) has introduced a new approach to assessing the whole water environment that will help direct action to where it is most needed and will tackle diffuse as well as point source issues.

The WFD water quality assessment uses a new tougher methodology based on a far wider range of assessments than the historic General Quality Assessment (GQA) classification. Unlike the GQA scheme, where only one monitoring point per stretch is used for assessment purposes, WFD water bodies can use multiple monitoring points in the water body catchment. Changes to the way water quality is assessed means that WFD results appear significantly different to the historic GQA data, care needs to be taken when comparing the two. For this report, WFD is the current method and forms the focus for assessment.

In the WFD classification scheme, physico-chemical elements are supporting elements. Only biological elements are recorded on the full scale, high to bad. Physico-chemical elements are not reported below moderate status. Table 14 gives the status of the physico-chemical elements for each River Severn water body. The status of each element will be in most cases calculated from a number of sample points within the water body.

Table 14: WFD Water Body Physico-Chemical Element Status

Water Body ID	Water Body Name	Ecological Status/Potential	Physico-Chemical Element Status
GB109054044790	R Severn – source to conf Afon Dulas	Moderate	Ammonia – High DO – High pH –High Phosphate – High Temp – High
GB109054049310	R Severn – conf Afon Dulas to conf R Camlad	Poor	Ammonia – High DO – High pH –High Phosphate – High Temp – High
GB109054049700	R Severn – conf R Camlad to conf Bele Bk	Moderate	Ammonia – High DO – High pH –High Phosphate – Moderate Temp – High

GB109054049142	R Severn – conf Bele Bk to conf Sundorne Bk	Moderate	Ammonia – High DO – High pH –High Phosphate – Good Temp – High
GB109054049141	R Severn – Sundorne Bk to conf M Wenlock-Farley Bk	Moderate	Ammonia – High DO – High pH –High Phosphate – Good Temp – High
GB109054049143	R Severn conf M Wenlock-Farley Bk to conf R Worfe	Moderate	Ammonia – High DO – High pH –High Phosphate – Moderate Temp – High
GB109054049145	R Severn – conf R Worfe to conf R Stour	Moderate	Ammonia – High DO – High pH –High Phosphate – Moderate Temp – High
GB109054049144	R Severn – conf R Stour to conf River Teme	Moderate	Ammonia – Good DO – High pH –High Phosphate – Poor Temp – High
GB109054039760	R Severn – conf R Teme to conf R Avon	Moderate	Ammonia – High DO – High pH –High Phosphate – Poor Temp – High
GB109054044404	R Severn – conf R Avon to conf Upper Parting	Moderate	Ammonia – High DO – High pH –High Phosphate – Poor Temp – High
GB109054032750	R Severn (E Channel) – Horsebere Bk to Severn Est	Moderate	Ammonia – High DO – Good pH –High Phosphate – Poor Temp - High

6.1.2. Water discharges

There are numerous sewage and other trade effluent discharges into the River Severn. All discharges of sewage and trade effluent require the consent of the Environment Agency. The consent limits are set on both the quantity and quality of the discharge according to the amount of water available to dilute the effluent at the point of discharge without causing significant deterioration in the quality of the watercourse. Also, the limits aim to ensure that the discharge does not compromise downstream uses of the river and that the resulting downstream water quality conforms to the relevant environmental quality standards.

The majority of industrial discharges that directly enter the Severn are not of sufficient size to present any threat to the receiving watercourse. One of the largest discharges is clean cooling water from the Ironbridge Power Station, where a volume of 16 Ml/d is consented for discharge. The power station is closed down for a six week period during the summer during which period there will be no abstraction or discharge. This has been taken into consideration by the Environment Agency during the development of the various drought order management scenarios.

The major sewage treatment work (STW) discharges to the River Severn are presented in Table 15 below. The Environment Agency reports that compliance with consent conditions is good and the most recent Catchment Abstraction Management Strategy (CAMS) for the River Severn does not identify any water quality issues directly associated with failure of consent conditions at sewage treatment works. However, STWs can have a significant impact during periods of low flow.

Table 15: Major Sewage Treatment Work Discharges to the River Severn (direct & indirect)

Name of discharge	Direct / Indirect	NGR	Consented Volume (M3/d)
Gloucester (Netheridge) STW	Direct	SO 80961594	42800
Worcester STW	Direct	SO 8449 5340	33000
Shrewsbury Monkmoor STW	Direct	SJ 5240 1357	20838
Coalport STW	Direct	SJ 7094 0134	17700
Malvern Barnards Green STW	Direct	SO 8009 4475	13400
Newtown Powys STW	Direct	SO 1380 9245	3700
Bridgnorth (Slads) STW	Direct	SO 7341 9104	2954
Coventry Finham STW	Indirect (via R Avon)	SP 3361 7379	115000
Roundhill STW	Indirect (via R Stour)	SO 8698 8365	59836
Barnhurst STW	Indirect (via Staff/Worcs)	SJ 9020 0176	47500
Warwick STW	Indirect (vu- R Avon)	SP 2777 6290	36000
Cheltenham Hayden STW	Indirect (via R Chelt)	SO 9060 2310	35000
Redditch Spernal STW	Indirect (via R Arrow)	SP 0846 6263	27500
Kidderminster STW	Indirect (via R Stour)	SO 8256 7375	26504
Stanley Downton (Stroud) STW	Indirect (via R Frome)	SO 7910 0480	24300
Telford Rushmoor STW	Indirect (via R Tern)	SJ 6130 1354	23523
Rugby Newbold STW	Indirect (via R Avon)	SP 4942 7635	21600
Stratford Milcote STW	Indirect (via R Avon)	SP 1805 5297	13110
Bromsgrove Fringe Green	Indirect (via R Salwarpe)	SO 9596 6834	11500
Lower Gornal STW	Indirect (via Bobs Bk)	SO 9030 9075	8500
Droitwich STW	Indirect (via R Salwarpe)	SO 8626 6166	7183
Coaley STW	Indirect (via R Cam)	SO 7562 0217	6680
Trescott STW	Indirect (via Smestow Bk)	SO 8549 9763	6460
Evesham STW	Indirect (via R Avon)	SP 0318 4467	5797
Tewkesbury STW	Indirect (via Mill Avon)	SO 8812 3186	5192
Oswestry Mile Oak STW	Indirect (via R Morda)	SJ 3024 2713	4890
Redditch Priest Bridge STW	Indirect (via Bow Bk)	SO 9926 5983	3576
Ludlow STW	Indirect (via R Teme)	SO 5163 7310	3500
Market Drayton STW	Indirect (via R Tern)	SJ 6685 3320	3400
Brockhampton STW	Indirect (via Hyde Bk)	SO 9462 2593	3360
Wombourne STW	Indirect (via Wom Bk)	SO 8575 9213	3289
Itchen Bank STW	Indirect (via R Itchen)	SP 4069 6281	2881
Blackminster STW	Indirect (via Badsey Bk)	SP 0661 4464	2756
Newport STW	Indirect (via Strine Bk)	SJ 7358 1924	2500
Tenbury Wells STW	Indirect (via R Teme)	SO 6044 6848	1247

Summer storms following periods of dry weather can cause catastrophic pollution and resultant fish kills, either through STWs stormwater overflows or through the flushing-out of urban pollution. Most of the large public sewerage systems have storm overflows that operate within the system or at the sewage treatment works at times of heavy rainfall. The majority of the overflows operate without causing nuisance, although it is reported that those situated in areas of high public amenity do give rise to some complaint. Pollution incidents associated with storm overflows are generally of short duration, but can have serious long term effects on the biological and aesthetic quality of the river.

STWs that serve a population in excess of 2000 people (or population equivalent) must also comply with the minimum standards required by the UWWTD.

As part of the water industry AMP, improvements have been delivered at a number of unsatisfactory continuous and intermittent discharges since 2000. These sewage works, and those planned for AMP 2010-2015, are summarised in Appendix L and M, Tables 12 to 14.

6.1.3. Physico-Chemical Water Quality

The WFD requires EU member states to formulate River Basin Management Plans (RBMPs) to deliver the objectives of the Directive. The River Severn RBMP divides the Severn into management catchments. The water qualities of these catchments are discussed in detail in Appendix L and M.

For most physico-chemical parameters, the River Severn is high quality. All of the River Severn WFD water bodies examined meet WFD high status for both temperature and pH. Dissolved oxygen achieves WFD high status for all water bodies except GB109054032750 River Severn (East Channel Horsbere Brook to Severn Estuary) where it drops to good status.

Ammonia concentrations in the river (Figure 13), although increasing from source (in a downstream direction), stay within the WFD good status standard of 0.3-0.6 mg/l (90%ile). Improvements at many of the sewage works within the Severn catchment have contributed to the overall reduction in ammonia concentrations since 1996.

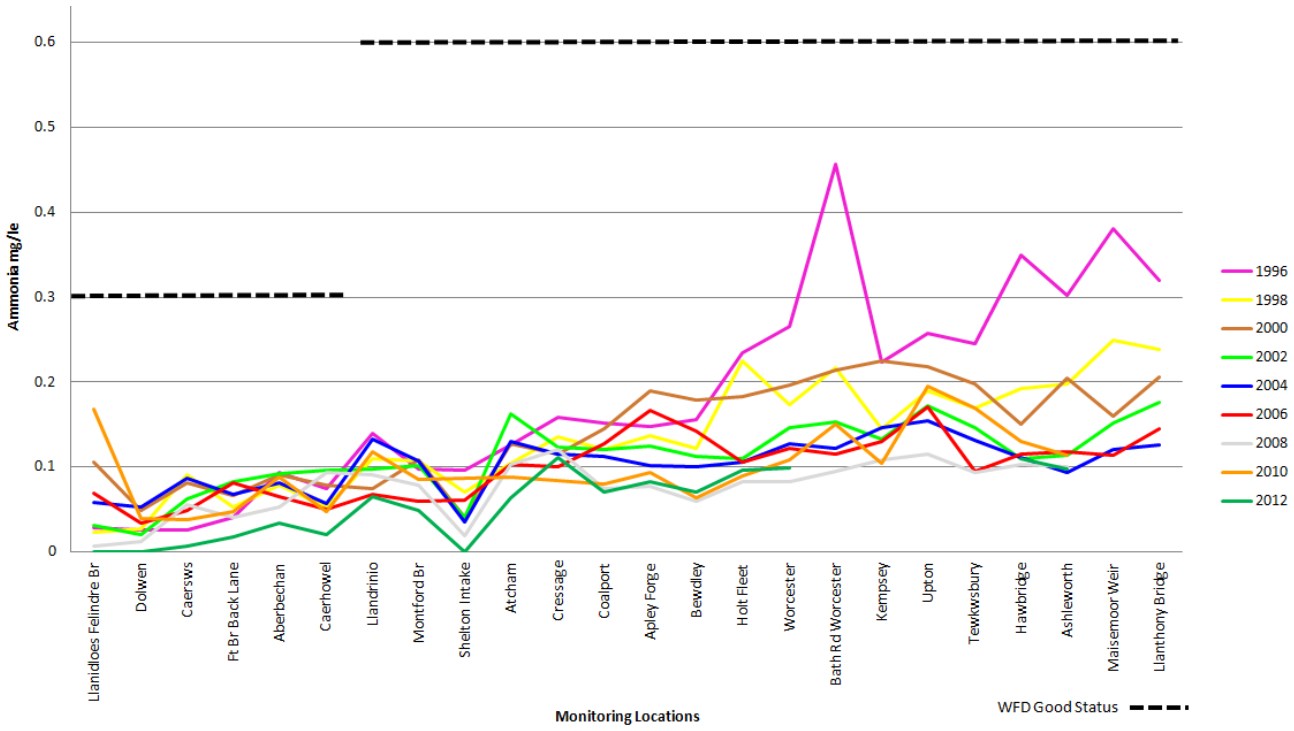

Figure 13: River Severn, Ammonia Annual 90 Percentile Concentrations 1996 to 2012

Phosphate concentrations show a general increasing trend with distance downstream. However, improvements at many sewage works within the River Severn catchment have contributed significantly to the overall reduction in phosphate concentrations since 1996. Even with these notable improvements, phosphate is the physico-chemical element contributing to WFD River Severn water body failures.

Apart from WFD water body GB109054049700 (River Severn, confluence River Camlad to confluence Bele Brook), phosphate concentrations are meeting WFD phosphate good status standard down to Atcham, which is above the Tern confluence. The moderate status of GB109054049700 is due to a single high orthophosphate result in September 2006; with this individual sample result removed, the water body would have achieved good status for phosphate. Subsequent annual means at this monitoring point are below the good status standard therefore it is likely that this will be a compliant parameter in the next RBMP classification. Below the Tern confluence, the WFD 0.12 mg/l good status standard is exceeded at all monitoring sites down to Llanthony Bridge up to 2010. Data from 2012 shows some improvement to Bewdley, however downstream of the confluence with the River Stour, concentrations are still in excess of the WFD standard for good status. This is examined in more detail in Appendix L and M.

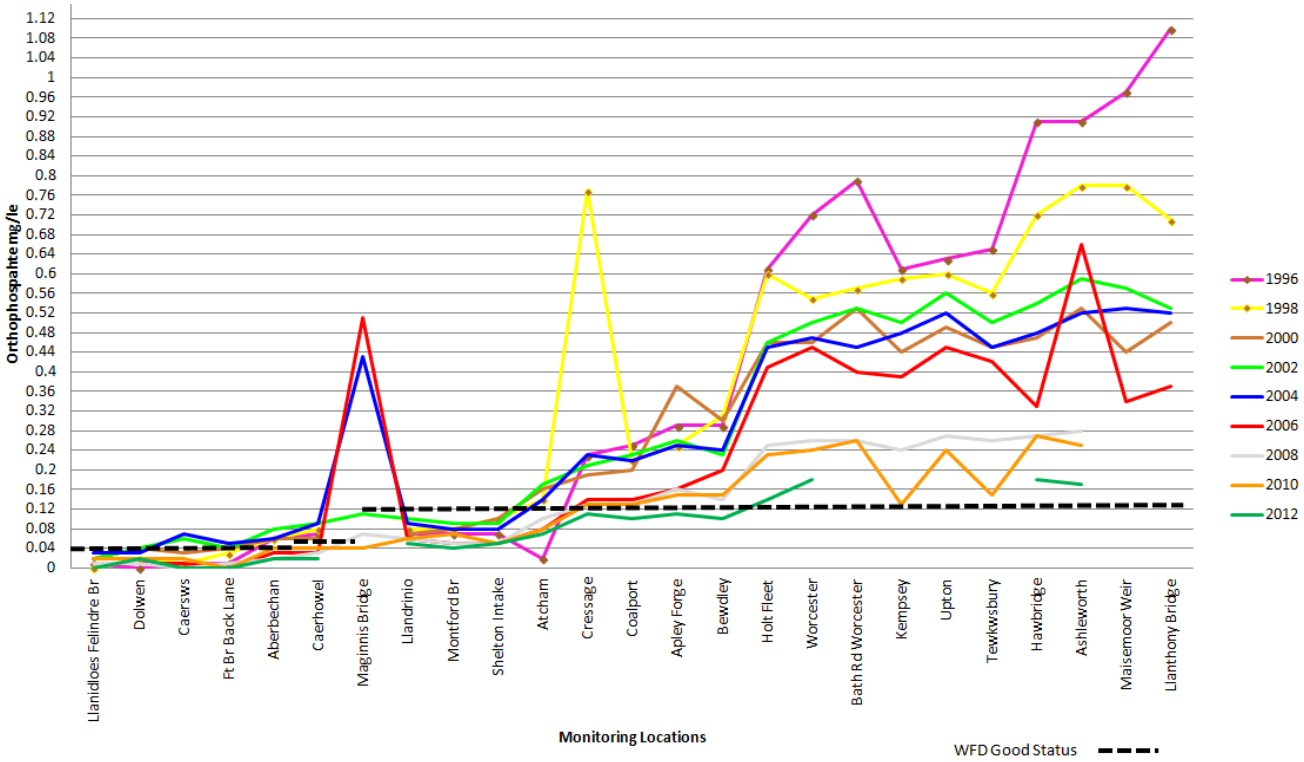

Figure 14: River Severn, Phosphate Annual Means 1996 to 2012

6.1.4. Nutrient Enrichment

As with ammonia and phosphate, nitrate concentrations show a general increasing trend with distance downstream, and overall concentrations have decreased, but not to the same extent. Nitrate is not used as a physico-chemical element in WFD classification and there is no associated environment quality standard.

Most of the east side of the River Severn catchment below Montford Bridge (and parts of the west side of the catchment) is designated as a Nitrate Vulnerable Zone (NVZ) (Figure 16) under the EC Nitrates Directive. This should contribute to on-going reductions in diffuse nitrate pollution, through restrictions in the use and storage of nitrate fertilisers for farms located within the NVZ.

A detailed assessment of water quality was carried out by the Environment Agency in relation to an unsuccessful proposal to designate a large proportion of the River Severn as a Sensitive Area (Eutrophic) under the E.C. Urban Waste Water Treatment Directive (UWWTD). The stretch under consideration was downstream of the Monkmoor Sewage Treatment Works (STW) to the tidal limit of the river at Maisemore, to the west of Gloucester. This report concluded that the River Severn becomes more eutrophic as the river flows downstream. Many of the STWs increase phosphate concentrations in the river but diffuse sources also contribute to nutrient enrichment, particularly in the upper parts of the Severn catchment.

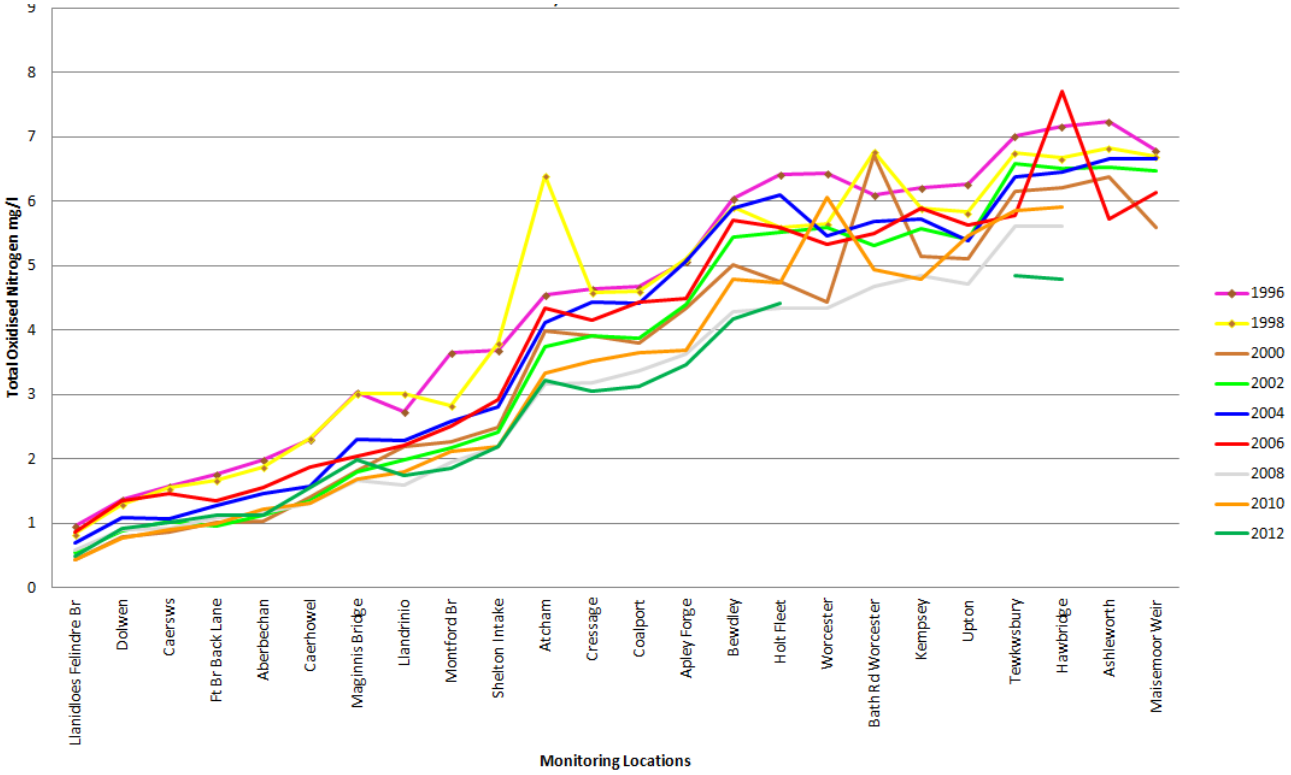

Figure 15: River Severn, TON Annual Means 1996 to 2012

As many of the River Severn tributaries are already designated as sensitive areas (eutrophic), there have been considerable improvements to the phosphate content of discharges from many of the larger sewage works, delivered as part of the water companies' Asset Management Plans (AMP). Other AMP drivers such as improvements to discharges impacting on SSSIs and Habitats Directive sites have also required reductions to phosphate concentrations in STW discharges.

Despite all these improvements and planned future reductions, phosphate concentrations will still exceed the WFD good status standards. The next (2015) RBMP will therefore have to address phosphate inputs from diffuse sources and investigate further options for reducing phosphate inputs to the river from point source discharges.

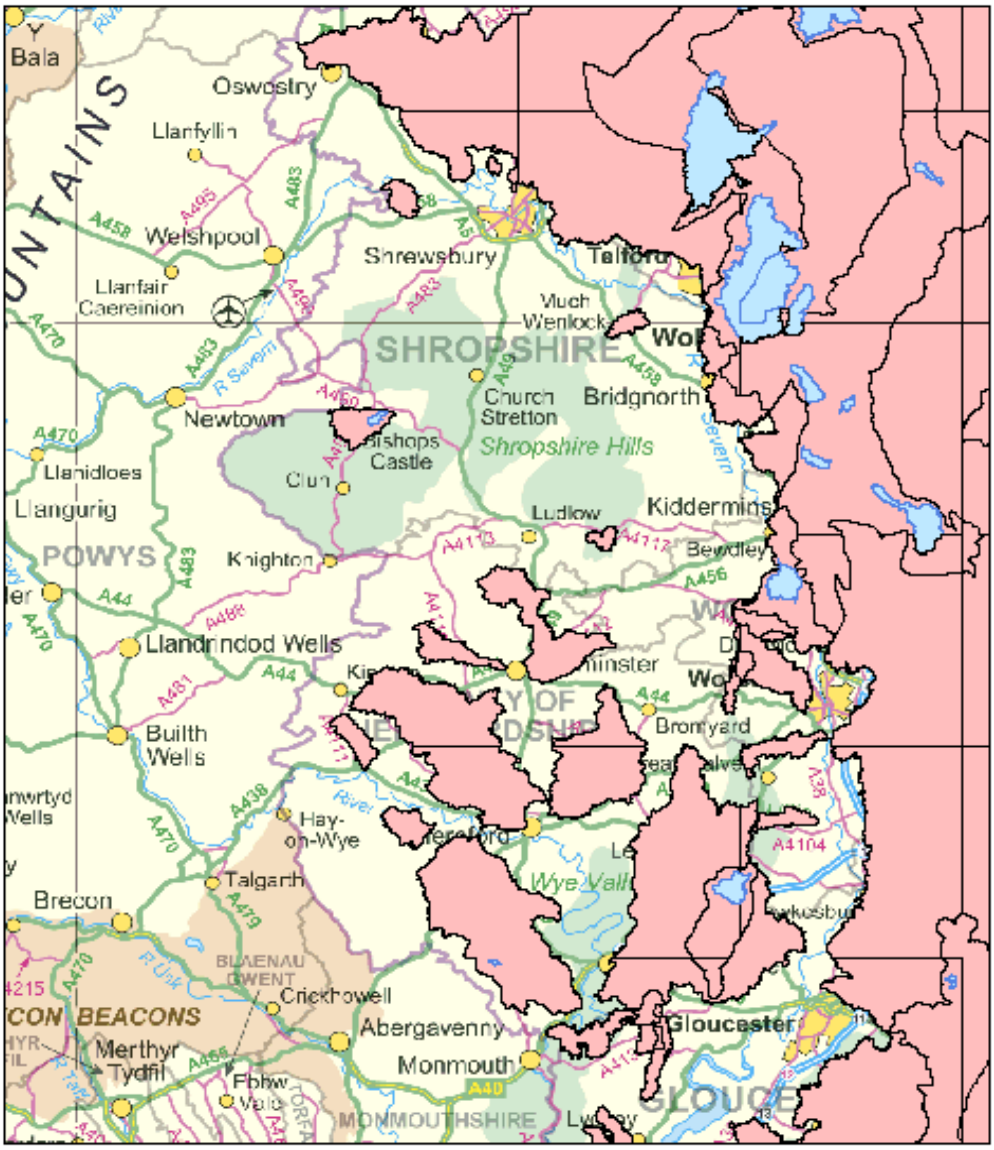

Figure 16: Nitrate Vulnerable Zones

6.2. Summary of Existing Drought Impacts

[Section to be completed when applying for a River Severn Drought Order]

6.3. Assessment of Impact on the Current Environment Water Quality

The complete SIMCAT Water Quality modelling and assessment write up is contained within Appendix O.

6.3.1. SIMCAT overview

As the only current water quality modelling tool available that includes the River Severn corridor from source to estuary, including the ability to model the inputs from all tributaries and the flow control measures at Lake Vyrnwy and Llyn Clywedog reservoirs, the newly constructed River Severn River Basin District SIMCAT model represented the best option for assessing the Severn Drought Order options. SIMCAT cannot work as a water quality prediction tool for manually altered drought flows.

SIMCAT is a proven modelling tool for water quality planning and has been used by the Environment Agency for over 20 years. It has been developed as a software package that can represent point and diffuse source inputs as well as in-river decay. SIMCAT is used for the calculation of water quality statistics (usually mean and 90th percentiles) and for the determination of discharge consent conditions.

The model, rebuilt in 2009 using the most up to date data available, was deemed fit for purpose in terms of both quality and quantity calibration at the time of its completion. SIMCAT models are constructed using mean and standard deviation quality data and mean and 95% low flow data for flow.

The model operates on the relatively simple principles of mass balance calculations in which upstream loads and discharge loads are mixed to provide a downstream estimate of load, it is possible that it does not necessarily represent the best way of assessing extreme low flows as experienced during drought conditions. It is however the best suited water quality modelling tool available for a whole catchment assessment, and as such, the best available tool for the Severn Drought Order water quality assessment.

In terms of flow data, the model has been built on data provided from 57 flow gauges throughout the catchment and daily mean flow data provided by Severn Trent Water where available for the discharges included in the model. Where actual data was not available, the permitted discharge volumes were used.

Major abstractions are also included in the SIMCAT model where it was felt they had a significant impact upon the flows in the environment (29 sites in total). Where applicable, the appropriate hands-off flows can be incorporated in order to limit how much water can be taken from the environment at times of very low flow. The model, however, does not incorporate drought permit requirements at any features.

The water quality data used to build the final SIMCAT model came from a variety of sources including a total of 499 river quality sites, 334 sewage treatment works and 50 industrial discharge sites.

6.3.2. Water Quality Assessment Methods

To assess the impact of the operation of the River Severn Drought Order on water quality, an assessment of compliance against both Water Framework Directive (WFD) targets and Fundamental Intermittent Standards was carried out for phosphates, ammonia and biochemical oxygen demand (BOD). The relative standards for the various sections of the River Severn corridor can be found in Table 16. A comparative assessment of Total Oxidised Nitrogen was also included for reference.

Table 16: Water Framework Directive Targets and Fundamental Intermittent Standards

River Severn Stretch	Parameter	WFD Good (mg/l)	FIS 99%ile (mg/l)
Llanidloes Felindre Bridge to Caerhowell	Ammonia	0.3	0.6
Caerhowell to Llandrinio	Ammonia	0.6	0.6
Llandrinio to Gloucester	Ammonia	0.6	1.5
Llanidloes Felindre Bridge to Llandrinio	BOD	4	5
Llandrinio to Gloucester	BOD	5	9
Llanidloes Felindre Bridge to Aberbechan	Phosphate	0.04	n/a
Aberbechan to Gloucester	Phosphate	0.12	n/a

Results from the River Severn Drought Order Acute and Chronic conditions were plotted against the relevant assessment graphs to determine the relative impact in terms of water quality concentrations.

6.3.3. Impact on Water Quality: Acute Drought Condition

The complete SIMCAT Water Quality modelling technical report containing all graphs is contained in Appendix N. Findings have been summarised for the 'Drought Order Only' scenario, compared against the 'Do Nothing' scenario for the Acute drought condition. Refer to section 6.3.5 for the worst case scenario (substituted for the Full In-Combination scenario) summary of both Acute and Chronic conditions.

Under the acute drought condition the managed and reduced mean reservoir release from Clywedog results in a reduction in the mean flow throughout the river corridor whilst the increase in the released Q95 flow identified an improved situation along the same length of river.

Assessing the BOD and ammonia concentrations predicted only very limited areas of deterioration as a result of the drought order operation. Overall water quality under the 'Drought Order Only' scenario was predicted to improve compared with the unmanaged 'Do Nothing' scenario. The only areas of minor deterioration in either determinand were predicted to be:

- BOD - maximum 5% deterioration between Montford Bridge and Cross Houses on the River Severn;
- BOD - minor deterioration at Caerhowell on River Severn (1.5%); and
- ammonia – 25% increase in concentrations on the Afon Vyrnwy d/s of Llansantffraid.

At none of the above locations however, was the predicted deterioration great enough to cause any failure of WFD targets. In fact, no failures of the respective WFD target were predicted in either the 'Drought Order Only' or 'Do Nothing' scenarios.

The same two determinands (BOD and ammonia) were plotted as 99 percentiles; use of such high percentiles allows a direct application of the results to the extreme low flow and subsequent reduction in dilution predicted during the drought scenarios. For example, the 99 percentile effectively represents the concentrations which are exceeded for just 1% of the time or, the equivalent of just 3.65 days/year.

Although it is immediately evident that phosphate concentrations exceed WFD standards in both the 'Do Nothing' and 'Drought Order Only' scenarios, this is of low concern because WFD

compliance for phosphate along the River Severn corridor is currently less than good at all locations downstream of Cressage.

Results suggest there would be a significant length of new WFD failure for phosphate as a consequence of the unmanaged 'Do Nothing' scenario. Operation of the River Severn Drought Order was generally predicted to improve concentrations throughout the Severn catchment compared with the unmanaged 'Do Nothing' scenario.

The same can be said for Total Oxidised Nitrogen concentrations which were not predicted to deteriorate following commencement of the River Severn Drought Order.

6.3.4. Impact on Water Quality: Chronic Drought Condition

The SIMCAT Water Quality modelling technical report containing all graphs is contained in Appendix N. This section summarises the 'Drought Order Only' scenario against the 'Do Nothing' scenario under the Chronic drought condition. Refer to section 6.3.5 for the worst case scenario (substituted for the Full In-Combination scenario) summary of both Acute and Chronic conditions.

The Chronic condition comparison shows barely any difference in the Q95 flows (the River Severn Drought Order scenario effectively tracks the Do Nothing drought conditions) whereas the chronic mean flows show significant benefit from the River Severn Drought Order, through the sustained releases from both reservoirs into the second drought summer.

Consideration of the Chronic drought condition shows a very similar situation to that predicted under the Acute drought condition. No significant deterioration in any determinand at any point in the Severn or Vyrnwy catchments was predicted as a result of operation of the River Severn Drought Order.

This is of no real surprise given the increased flows modelled throughout the catchment as part of the 'Drought Order Only' scenario (in comparison with the 'Do Nothing' scenario) and the fact that operation of the drought order would result in greater mean and Q95 flows released from Llyn Clywedog and mean flows from Lake Vyrnwy.

As with the Acute drought condition, no new WFD failures were predicted for either BOD or ammonia as a result of the environment experiencing drought conditions ('Do Nothing' scenario). The same is true of the 99 percentile standard applicable to the River Severn corridor, the maximum concentrations predicted in the worst case scenario both largely remain below 3 mg/l and 0.3 mg/l for BOD and ammonia respectively (tightest applicable targets = 5 mg/l and 0.6 mg/l)

Not unexpectedly, achievement of WFD Good Status for phosphates is predicted to be harder to achieve during the modelled 'Do Nothing' scenario with a general increase in nutrient concentrations predicted across the board. As with the Acute drought condition however, the operation of the River Severn Drought Order is predicted to marginally improve the situation with increased dilution reducing both phosphate and Total Oxidised Nitrogen concentrations.

6.3.5. Impact on Water Quality: Worse Case testing (Full In Combination substitution) for Acute and Chronic drought conditions

Consideration of the zero natural flow scenario (representing conditions more extreme than the 'Full In-Combination' scenario) showed a similar situation for both ammonia and BOD under both Acute and Chronic drought conditions. Comparison with the previous work suggests that predicted concentrations for both determinands under this scenario were not particularly elevated and, as such, failures of the required WFD standards were not predicted for either the 'Do Nothing' or 'Drought Order Only' scenarios. This is reassuring considering the lack of natural dilution, even

when measured at the 99%ile (Table 17 and 18). The results indicate the application of the River Severn Drought Order improves the predicted water quality in comparison with the unmanaged 'Do Nothing' approach.

Table 17: BOD and Ammonia predicted concentrations for Acute zero natural flow scenario

		No Drought Order		River Severn Drought Order	
Flow Gauge Location	**FG Ref**	**BOD 99%ile (mg/l)**	**Ammonia 99%ile (mg/l)**	**BOD 99%ile (mg/l)**	**Ammonia 99%ile (mg/l)**
Bryntail	2109	1.6	0.05	1.6	0.05
Vyrnwy	2003	1.67	0.03	1.67	0.03
Buildwas	2134	2.13	0.36	1.84	0.31
Bewdley	2001	1.61	0.47	1.36	0.36
Saxons Lode	2032	2.32	0.45	2.1	0.38
Deerhurst	2057	2.28	0.39	2.17	0.36
Lower Parting		2.08	0.35	1.96	0.33

Table 18: BOD & Ammonia predicted concentrations for Chronic zero natural flow scenario

		No Drought Order		River Severn Drought Order	
Flow Gauge Location	**FG Ref**	**BOD 99%ile (mg/l)**	**Ammonia 99%ile (mg/l)**	**BOD 99%ile (mg/l)**	**Ammonia 99%ile (mg/l)**
Bryntail	2109	1.6	0.05	1.6	0.05
Vyrnwy	2003	1.67	0.03	1.67	0.03
Buildwas	2134	2.42	0.43	1.88	0.35
Bewdley	2001	1.73	0.48	1.42	0.37
Saxons Lode	2032	2.44	0.46	2.18	0.4
Deerhurst	2057	2.35	0.41	2.23	0.37
Lower Parting		2.12	0.36	2	0.33

The operation of the River Severn Drought Order was also predicted to improve water quality in terms of nutrient concentrations in the zero natural flow scenarios. Although maximum concentrations were predictably higher in this situation compared with the more realistic scenarios already discussed, it was noticeable in Tables 19 and 20 that concentrations reduced once revised regulation of the flows from Llyn Clywedog and Lake Vyrnwy were employed.

Table 19: Predicted nutrient concentrations for Acute zero natural flow scenario

		No Drought Order		Drought Order	
Flow Gauge Location	**FG Ref**	**Phosphate 99%ile (mg/l)**	**TON 99%ile (mg/l)**	**Phosphate 99%ile (mg/l)**	**TON 99%ile (mg/l)**
Bryntail	2109	0.06	1.07	0.06	1.07
Vyrnwy	2003	0.06	0.58	0.06	0.58
Buildwas	2134	1.39	7.14	1.27	5.93
Bewdley	2001	1.07	6.69	0.97	6.1
Saxons Lode	2032	1.69	12.95	1.6	11.73
Deerhurst	2057	1.21	15.73	1.17	15.01
Lower Parting		1.11	15.56	1.07	15.04

Table 20: Predicted nutrient concentrations for Chronic zero natural flow scenario

		No Drought Order		Drought Order	
Flow Gauge Location	**FG Ref**	**Phosphate 99%ile (mg/l)**	**TON 99%ile (mg/l)**	**Phosphate 99%ile (mg/l)**	**TON 99%ile (mg/l)**
Bryntail	2109	0.06	1.07	0.06	1.07
Vyrnwy	2003	0.06	0.58	0.06	0.58
Buildwas	2134	1.61	8.18	1.4	6.52
Bewdley	2001	1.21	7.4	1.05	6.6
Saxons Lode	2032	1.79	13.49	1.66	12.34
Deerhurst	2057	1.24	16.02	1.19	15.16
Lower Parting		1.14	16.06	1.09	15.28

6.3.6. Water Quality Conclusions

Some local areas of deterioration were predicted under the 'Do Nothing' scenario which are important to be aware of for drought management:

- Phosphate - Afon Vyrnwy d/s of Llansantffraid - 33% increase in concentrations - no resultant failure of WFD targets.
- BOD - Maximum of 5% deterioration between Montford Bridge and Cross Houses. Minor deterioration at Caerhowell on River Severn (1.5%) - no new WFD failures.
- Ammonia - Afon Vyrnwy d/s of Llansantffraid - 25% increase in concentrations - no resultant failure of WFD targets.
- Nitrogen - General deterioration in concentrations throughout the Vyrnwy catchment.

However results identified no new failures to achieve Water Framework Directive good status for ammonia or BOD for either the 'Do Nothing' or 'Drought Order Only' scenarios. Widespread phosphate failures persisted, but were present under normal conditions.

To test the extreme low flows predicted by the Water Resource model Aquator, 99 percentile water quality results were plotted against the appropriate standards. No failures of the 99% targets associated with the river reach classes imposed under the River Ecosystem Classification were identified.

Even under zero natural flow scenarios, maximum ammonia concentrations are predicted to equal 0.47 mg/l with BOD pollution topping out at 2.32 mg/l, both well within the WFD 90%ile standards. Nutrient concentrations continued to breach the required standards and were, indeed, elevated further without the benefit of any natural dilution flow for the treated effluent discharges.

No significant deterioration for any determinands at any point on the River Severn or Vyrnwy catchments was identified as a result of the River Severn Drought Order. Operation of the River Severn Drought Order resulted in a varying degree of improvement in water quality concentrations compared to the 'Do Nothing' situation under all the scenarios modelled. It can therefore be concluded that the River Severn Drought Order would be of benefit to the River Severn during a severe drought.

6.3.7. Limitations of the SIMCAT Modelling

Throughout the exercise to determine the impact of drought conditions on the water quality of the River Severn corridor and also the impact of managing the flows through implementation of the Severn Drought Order, it became obvious that the SIMCAT models at our disposal, although the best available tools, were not necessarily the right tools for drought impact assessment.

The verification exercise initially attempted to match SIMCAT predicted and theoretical Aquator observed drought flows at the various assessment points proved to be fraught with difficulty and was eventually abandoned in favour of a number of logical assumptions. This was predominantly due to the fact SIMCAT models are based on current day populations rather than those present at the time of the drought situations attempting to be matched (1976/77). However additional discrepancies between the SIMCAT and Aquator models relate to SIMCAT being unable to represent drought permit/order abstraction changes, and Aquator being unable to reduce discharges to better represent reduced storm runoff during real droughts. Therefore it became apparent that like for like flows were not being produced for comparison, but selecting which model was representing the most realistic flows was not possible in the project timescales. Therefore the precautionary worst case predictions produced by Aquator were used.

Modelling the full in-combination flows inside SIMCAT (in order to assess the water quality impacts) was abandoned as a result of the difficulties. Results would have been too inaccurate due to the assumptions being made and SIMCATS inability to model drought permit abstraction operations. A risk based decision was made to abandon this specific scenario as the Do Nothing scenario flows represented the worst case situation, while the Severn Drought Order scenario assessment would represent the main changes in flows and therefore water quality to be expected. By assessing the Do Nothing scenario water quality impacts, the worst case situation has been evaluated and the environmental report requirements satisfied.

Being a spatial rather than a temporal model, it also proved impossible to provide the data for ecological appraisal in the form that was required. Whereas the ecological impact would be best assessed using an indication of the varying ammonia and BOD concentrations at one location with time and flow (temporal model), SIMCAT was only able to provide a worst case scenario for the entire length of river with no immediate link to the flows at the corresponding time. In other words, an assumption had to be made that the 99th percentile value for each determinand represented the worst case scenario when, in fact, higher concentrations would be present for a maximum of 4 days in a year.

SIMCAT is also a tool more suited to representing more stable conditions and can struggle to represent prolonged, extreme events such as droughts. By its nature of representing mean and standard deviation statistical input, it is not inherently designed to predict environmental conditions in extreme, worst case scenarios.

Although a specific modelling tool cannot be recommended, any tool which is better suited at representing a temporal link between flow and pollutant concentration would probably be better suited to the tasks required in this water quality assessment.

The SIMCAT model itself could be improved by more sophisticated and numerous water quality and flow monitoring. Currently, the model is based upon the known input data, in other words measured data from flow gauges, water quality monitoring points, measured discharge volumes and quality. From this data, the model must make assumptions on the source of any errors that may occur following mixing of all the known data.

Without enhanced monitoring, much larger data sets encompassing all possible sources of pollution and diffuse flow inputs and highly detailed knowledge of the catchment, this calibration process can be fraught with problems. The SIMCAT models employed in this assessment have

been signed off and accepted as the best possible representation of the environment given the data available but it also has to be recognised that the model contains numerous locations where accurate representation of the environment was not possible. Calibration errors such as this can only successfully be rectified through the use of greater amounts of top quality monitoring of all potential sources of pollution and flow.

6.4. Monitoring and Mitigation Options

Based on the conclusion that water quality is not predicted to significantly deteriorate under the perceived worst case scenario of zero natural flows and that, under the same conditions, the predicted 99%ile quality remains within WFD concentration criteria for ammonia and BOD, there appears to be little benefit in employing mitigation measures for water quality in drought conditions.

With regards to phosphate and nitrogen, the drought is likely to cause a further increase in concentrations. As water quality standards are already breached and environmental damage is already likely to be occurring in non-drought conditions, continuation of the current regime of work to reduce nutrient enrichment is seen to be the best way forward with no further mitigation measures required.

Water quality specific monitoring options are contained within the Water Quality technical report in Appendix O and incorporated into the overall monitoring programme in section 15.

7. Ecology of the Severn Corridor

7.1. Baseline Environment: Macroinvertebrates and Macrophytes

This section provides a summary of the separate macrophytes and macroinvertebrate technical assessment, which is provided in Appendix O. Details of the methods used to carry out ecological assessments are included in the Appendix; these are based mainly on indices relating to the macroinvertebrate community, as this is a widely studied biological quality element with well-established indices of specific environmental pressures. The primary macroinvertebrate index used for this assessment is the LIFE (Lotic invertebrate Index for Flow Evaluation) score, which is based on the current velocity preferences of different taxa. A ratio of observed LIFE scores (O) to those expected (E) at a given site in the absence of human impact can be calculated to give an indication of impact. Also of value in assessing potential impacts of drought and low flow is the PSI (Proportion of Sediment-sensitive Invertebrates) score, as increased sedimentation is a common consequence of reduced flows. The BMWP (Biological Monitoring Working Party) score, indicating sensitivity to organic pollution, and its derivative the ASPT (Average Score per Taxon), were used to indicate responses of the fauna to reduced water quality.

Other ecological assessment has been carried out using River Habitat Survey (RHS), an assessment of physical habitat quality and measures of macrophyte assemblages. Water Framework Directive (WFD) status and classification has also been considered as part of the assessment.

7.1.1.1. General Impacts of Low Flows

Droughts can naturally have the following impacts on river channels:

- a reduction in the wetted width of the river, reducing the availability of habitat for invertebrates, and exposure of river bed sediments;
- reduced flow, leading to reduced mixing and oxygenation, which can be compounded during warmer periods, when oxygen solubility is reduced by increased water temperature;
- increased sedimentation, clogging invertebrate respiratory systems or smothering their food sources;
- exposure of stream margins and breakage of hydrological linkages to the channel edge;
- increased concentration of contaminants, exacerbating impacts of low water quality;
- an increase in algal blooms, which can smother other organisms and can cause large daily fluctuations in dissolved oxygen as they produce oxygen in the day and then use it up overnight; and
- in extreme cases, complete cessation of flow and formation of discrete pools, eliminating all species which require continuous flow.

Conversely, downstream of a regulating reservoir, drought conditions can lead to increased flow if higher compensation flows are released to mitigate reduction in inputs further downstream. Following cessation of a drought, natural flow variability may be suppressed downstream of a reservoir as water from high flow events is captured to replenish the reservoir; in consequence, sediment can build up, while less ecologically competitive species, which rely on periodic high flow events to ‘reset’ the community, can lose out to more competitive species.

Ecological resilience to flow stress is greater in more natural channels, due to the greater habitat diversity and substrate stability that provide more refugia for the invertebrates at extreme high and low flows.

There are two sources of information from which to predict impacts of droughts on the ecology of the River Severn:

- previous droughts, most notably in 1975-76, were intensively monitored, providing valuable information from which to predict future impacts; and
- modelling of potential impacts. As the Severn is regulated, no suitable model for ecological impacts is currently available, but effects upon flow determined by hydrological models can be used to provide predictions of likely impact on invertebrate assemblages.

During the 1975/76 drought period, water from Llyn Clywedog was used to provide flow for the Severn system. This resulted in higher than normal flows and lower temperatures during spring emergence and oviposition periods of aquatic insects. Conversely, it greatly reduced the level of the Llyn Clywedog, requiring a greater proportion of inflow to be retained in order to refill the reservoir. As a consequence, river flows were reduced for considerable periods even after rain returned, removing some of the natural flow variability along the river and leaving large areas of river bed exposed for long periods. Within the reservoir, silt build up increased and compensation water was taken from the bottom in order to remove this silt; its deposition in the Afon Clywedog, exacerbating the ecological problems.

7.1.1.2. Assessment of the River Severn

Water flow in the River Severn is regulated by two headwater reservoirs: Lake Vyrnwy on the Afon Vyrnwy and Llyn Clywedog on the Afon Clywedog. Therefore, to provide baseline information, two sources were used:

- Monitoring sites along the River Severn and its two main source tributaries: Afon Clywedog and Afon Vyrnwy. Several monitoring sites were chosen, each representing one of seven sections of the river, and each having a robust historical dataset. The exception to this is the most downstream section, for which no suitable macroinvertebrate data were available due to the methodology being unsuitable for this size of river and impacts of saline intrusion.
- Monitoring sites on two unregulated tributaries, the Afon Tanat and the River Teme were added as control points to compare the low flow responses on unsupported rivers.

Table 21 contains the ecological assessment sites and how they were paired up to the relevant River Severn Drought Order assessment point for this report.

Table 21: River Severn Drought Order ecological assessment points

Assessment Point	Watercourse	Invertebrate Site	Biosys ID	Grid reference
Clywedog (Bryntail)	Afon Clywedog	Caravan Park	49874	SN94000 85700
Vyrnwy(Vyrnwy weir)	Afon Vyrnwy	Dolanog	50350	SJ06780 12860
Buildwas	River Severn	Coalport	52795	SJ 70200 02100
Bewdley	River Severn	D/S Dowles Brook	52393	SO78000 76400
Saxons Loade	River Severn	Upton on Severn	47463	SO85050 40890
Deerhurst/Haw Bridge	River Severn	Hawbridge	51327	SO84500 27720
U/S Sharpness	n/a	n/a	n/a	n/a
Lower Parting	n/a	n/a	n/a	n/a
Control site	Tanat	Llanyblodwel	50766	SJ 24200 22900
Control site	Teme	Tenbury	48210	SO 59942 68511

The locations of these monitoring sites are shown in Figure 17.

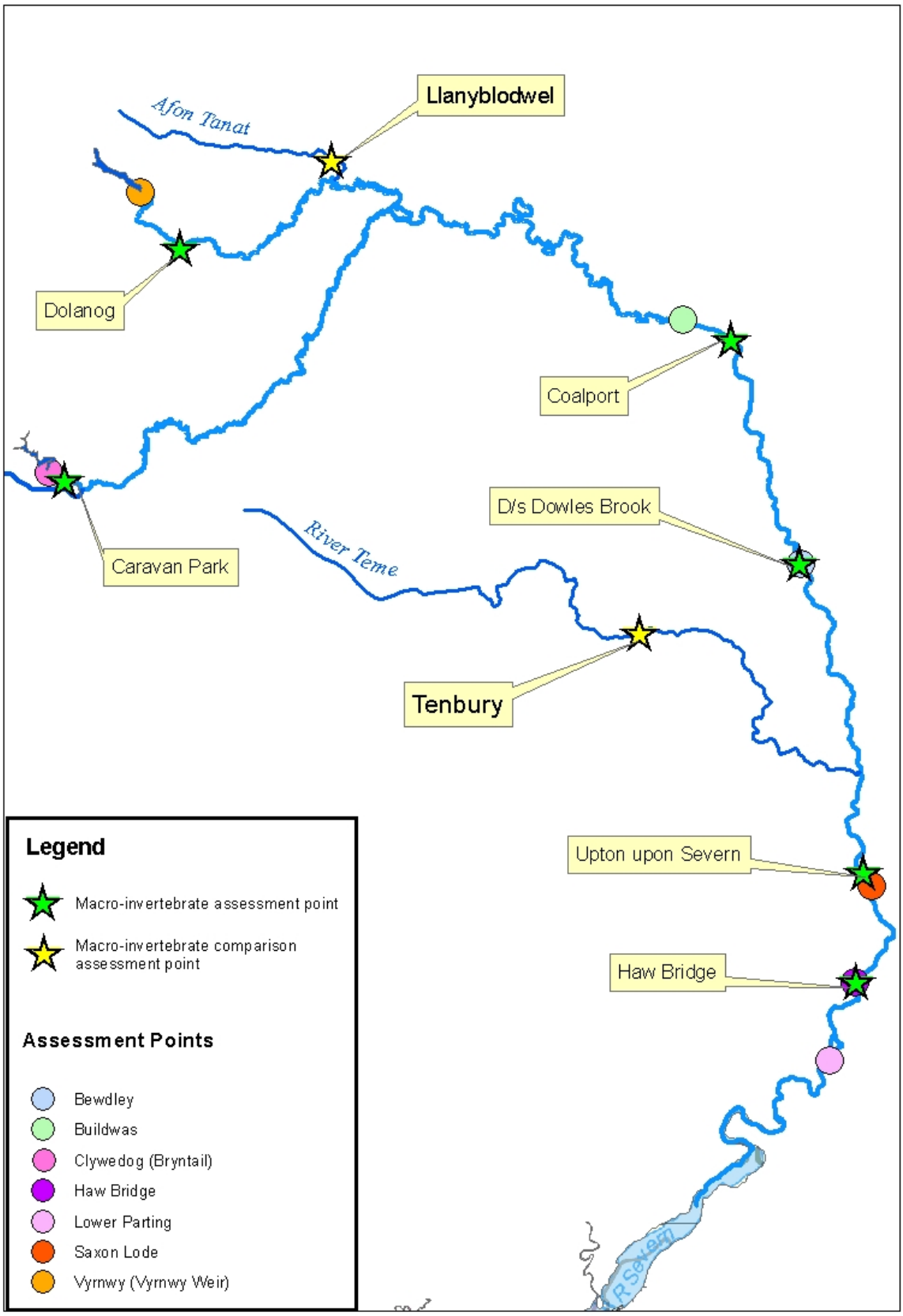

Figure 17: Macroinvertebrate sampling sites used in this report

7.1.1.3. Water Framework Directive Status

The majority of the water bodies on the River Severn, Afon Vyrnwy and Afon Clywedog have been designated as Heavily Modified Water Bodies (HMWBs) due to the regulation of river flows. No water body is considered to achieve higher than moderate potential, this is because until appropriate ecological mitigation measures are agreed/in place, the HMWB status limits the water body from achieving anything above moderate status.

Table 22: Water Framework Directive (WFD) status of water bodies on the Severn

Waterbody		Water Framework Directive Quality Elements					
Id number and Name	Overall Status/Potential	Physico-chemistry	Annex 8/10	Diatoms	Macrophytes	Invertebrates	Fish
GB109054049880 R Vyrnwy – Lake Vyrnwy to conf Afon Cownwy	MODERATE POTENTIAL	HIGH	MODERATE				
GB109054049720 Afon Vyrnwy – conf Afon Cownwy to Afon Banwy	MODERATE POTENTIAL	HIGH	MODERATE			HIGH	MODERATE
GB109054049850 Afon Vynwy – conf Afon Gam to conf Afon Tanat	MODERATE POTENTIAL	HIGH	MODERATE			MODERATE	HIGH
GB109054049800 Afon Vyrnwy – conf Afon Tanat to conf R Severn	MODERATE POTENTIAL	MODERATE	HIGH			GOOD	MODERATE
GB109054044760 Afon Clywedog – Clywedog dam to R Severn	MODERATE POTENTIAL	HIGH	MODERATE			GOOD	GOOD
GB109054044790 R Severn – source to conf Afon Dulas	MODERATE STATUS	HIGH	MODERATE	HIGH	HIGH	GOOD	GOOD
GB109054049310 R Severn – conf Afon Dulas to conf R Camlad	POOR POTENTIAL	HIGH	MODERATE	POOR		HIGH	POOR

GB109054049700 R Severn – conf R Camlad to conf Bele Bk	MODERATE POTENTIAL	MODERATE	HIGH			MODERATE	BAD
GB109054049142 R Severn - conf Bele Bk to conf Sundorne Bk	MODERATE POTENTIAL	GOOD	MODERATE		GOOD	MODERATE	POOR
GB109054049141 R Severn - Sundorne Bk to conf M Wenlock-Farley Bk	MODERATE POTENTIAL	GOOD	MODERATE			GOOD	BAD
GB109054049143 R Severn – M Wenlock-Farley BK to conf R Worfe	MODERATE POTENTIAL	MODERATE	MODERATE			GOOD	MODERATE
GB109054049145 R Severn - conf R Worfe to conf R Stour	MODERATE POTENTIAL	MODERATE	HIGH			GOOD	GOOD
GB109054049144 R Severn – conf R Stour to conf R Teme	MODERATE POTENTIAL	MODERATE	GOOD			MODERATE	MODERATE
GB109054039760 R Severn - conf R Teme to conf R Avon	MODERATE POTENTIAL	MODERATE	HIGH			POOR	
GB109054044404 R Severn - conf R Avon to conf Upper Parting	MODERATE POTENTIAL	MODERATE	MODERATE			POOR	
GB109054032750 R Severn (E Channel) - Horsebere Bk to Severn Est	MODERATE POTENTIAL	MODERATE	GOOD			POOR	

7.1.1.4. Physical Habitat

RHS's demonstrate increased incidence of heavily modified habitats and lower habitat quality assessment scores with increasing distance from source, demonstrating that there are fewer habitats and refugia available for macroinvertebrates and therefore probably reduced resilience to drought impacts.

7.1.1.5. Macrophytes

Submerged aquatic macrophytes are only present in any numbers on the River Severn upstream of Bewdley and on the Afon Vyrnwy. In general there is an increase in indicators of both increased nutrient status and reduced flow variation, reflecting the changing abiotic status of the river. The absence of macrophytes in the lower reaches of the Severn is an indication of the extent to which the channel has been physically modified. Limited data mean that it is not possible to determine whether periods of very low flow are having an effect on the macrophyte communities in the Severn, Clywedog and Vyrnwy.

7.1.1.6. Macroinvertebrates

Afon Clywedog
As part of the River Severn Regulation system, water releases are made from Llyn Clywedog reservoir during periods of low flow in order to maintain river flow further downstream (in the River Severn at Bewdley). As a consequence flows increase in the Afon Clywedog during periods of regulation. Data from six periods of summer flow release since 1989 generally showed a slight increase in LIFE O:E ratios, suggesting that flow-tolerant macroinvertebrates in this reach were benefiting from release of extra water. Number of taxa was generally low at this site, probably due to the unstable nature and the compacted substrate of the Afon Clywedog caused by releases of water from Llyn Clywedog. However, water quality indicators such as ASPT score highly, so poor water quality is unlikely to be a confounding factor.

The site does not generally suffer from siltation, although some build up is probable in spring before flow regulation releases begin, and there is evidence of a general increase in sediment at the monitoring site over time.

Afon Vyrnwy
The lowest LIFE scores for the Afon Vyrnwy at Dolanog were recorded in autumn of 1995 and 2004. This may reflect the low flow years 1995/6 and 2003 but there is a lack of data collected for this site in the years preceding these dates, making interpretation of the data unreliable. The lowest PSI score occurred in autumn 1996, suggesting a build up of fine sediment that may be a result of the low flows experienced during the previous year’s drought.

River Severn upper reach (sampling point at Coalport)
This site can be difficult to sample, particularly during higher flows, and this has resulted in data gaps that make interpretation difficult. However, there is evidence that there has been a general improvement in water quality since 2001; as poor water quality can compound drought effects, this improvement will have increased resilience of macroinvertebrate assemblages relative to previous low flow periods.

There is evidence of decline in LIFE scores and LIFE O:E following the low flows of 1995/96 and 2010/11, followed in the latter case by a recovery in LIFE by autumn 2012. The PSI scores suggest an increase in fine sediment build up as a consequence of the reduced flows during these historic drought periods.

River Severn upper middle reach (sampling point at Bewdley)
Data are available for this sampling point from the mid 1970s onwards. This reach shows a clear macroinvertebrate response to low flows, with reduced LIFE scores (demonstrating loss of species with high velocity requirements) in the 1975, 1989/90 1995/96, and 2010/11 drought periods. Where data are available, however, they show evidence of recovery the summer after these drought periods. The PSI results suggest that periods of low flow are marked by an increase in sedimentation.

River Severn lower middle reach (sampling point at Upton on Severn) and River Severn lower reach (sampling point at Hawbridge)
Sampling in these reaches is by dredging rather than kick-sampling, making comparison with sites in the upper catchment difficult. However, there are some important patterns in the data. There is little evidence of a invertebrate community response to reduced flows. Low PSI scores are recorded consistently; these may be partly due in the highly modified nature of the site, but also to the natural sedimentation that occurs in the lower reaches of the Severn. There is evidence of reduced water quality at Upton on Severn.

Reference sites - River Tanat and River Teme
Both reference sites have diverse instream habitats which ensure that the macroinvertebrate community is resilient to the effects of low flow. Both sites show invertebrate response to variation in flow, but neither shows evidence of major changes due to severely reduced flow. The greatest impact on macroinvertebrates is following a second year of low flows, after which the time taken to recover is extended.

7.2. Baseline Environment: Fish of the Severn Corridor

This section provides a summary of the separate fish technical assessment, which is provided in Appendix O. Severn Estuary fish populations and their migration into the River Severn corridor have been investigated in more detail for the HRA. To save repetition this information is largely provided within the Habitats Regulations Assessment report in Annex 1; however for completeness the fish HRA technical report has also been included as Appendix U within this report.

A range of habitats is present in the Severn catchment, from high gradient, nutrient poor upland water courses, to lowland, low gradient, nutrient rich conditions, and the system supports a correspondingly broad range of fish species. The River Severn is a designated fishery under the EC Freshwater Fish Directive (2006/44/EC) (due to be repealed by the Water Framework Directive in December 2013). A salmonid fishery extends upstream from the Shrewsbury weir and encompasses the Afon Vyrnwy, while a cyprinid fishery extends downstream of the Shrewsbury weir to Saxons Lode near Tewkesbury.

7.2.1. Fish species of Conservation Importance

Twaite shad is an Annex II and V species under the Habitats Directive and is a primary feature of the Severn Estuary SAC. Twaite shad are anadromous and migrate from the Severn Estuary to the River Severn to spawn, although the upstream extent of twaite shad movement is restricted by the weir at Diglis. Allis shad have been recorded in the River Severn but do not spawn in the catchment.

River and sea lamprey are also anadromous Annex II species (river lamprey is also listed under Annex V of the Habitats Directive) and are designated features of the SAC. Shad and lamprey species are also notable sub-features of the ‘Estuaries’ SAC feature. In addition, three other species are notable sub-features: Atlantic salmon (Annex II species), sea trout and European eel

(eel are also protected under the Severn Estuary Eel Management Plan). Each of these species is listed under the UK BAP.

The main migration periods for these species within the Severn catchment are indicated below:

- Adult twaite shad tend to migrate upstream between April and June with spent adults migrating downstream in June and August, and juveniles moving downstream to the estuary in August/September.
- Migration of adult sea lamprey to the River Severn usually occurs in April to June, with the adult river lamprey tending to migrate upstream during low autumn flows (August to December). Sea lamprey often travel up the Severn as far as Shrewsbury and have been known to get as far as Newtown. Juvenile migration downstream occurs between October and February for both species.
- The main salmon runs up the River Severn are in spring (entering May to July and spawning in late autumn/early winter) and autumn (entering late September to early December and spawning in autumn/early winter). Salmon can migrate up the Severn to just above Llanidloes, encompassing the regulated section of the River Severn.
- Glass eels mainly enter the Severn Estuary between February and April. The migration of elvers in the River Severn is limited by the presence of weirs and by flood defence works in the lower and tidal reaches.
- Sea trout tend to migrate from the sea to the River Severn in October, and they generally utilise gravels in the lower reaches of the river for spawning.

7.2.1.1. Population Assessment Methods

A combination of electrofishing in the narrower reaches of the Severn and hydroacoustic survey in the wider and deeper areas has provided fish population data for the Severn catchment. In addition, rod catch data were available for salmon and sea trout, while a database of catches from angling matches provided information for coarse fish species. Creel census data has also been collected which monitors catches by individual anglers at fishing hotspots along the River Severn

Data were also available from three types of fish counter in the catchment: a resistivity counter at Carreghofa on the Afon Tanat; a Vaki counter on the River Teme at Ashford; and a video camera system with motion detection on the River Severn at Shrewsbury.

7.2.1.2. Fisheries Baseline Environment

Creel catch records from summer 2004 around Shrewsbury and Bridgnorth indicated that chub and barbel were the main species caught in summer while roach and dace dominated the catch in winter. Putcher catch data across the period 1951 – 2012 has indicated a decrease in salmon catches from the 1980s onwards although there is potential for this to be influenced by variation in the number of licences allocated over this period. A decrease in salmon catch is also evident for Lave net and to a lesser extent Draft net catches over the same period.

Rod catches for the period 1951 – 2012 have fluctuated considerably across years. Since the late 1980s, however, the overall general trend has been a decrease in catch. The Salmon Action Plan (SAP) for the River Severn published in 2003 provided conservation targets for egg deposition rates for salmon, and this target has not been reached for seven of the last ten years. The conservation target has been lowered recently, however, and based on this revised figure the Severn has fallen short of the target for four of the last ten years.

Comprehensive data-sets are available for 0+ salmon on the Afon Tanat and Rhiew from 2002 - 2010. No significant correlation between egg deposition rates and numbers of juvenile salmon is apparent. Declines in salmon numbers are most evident at Pedair-fford and Glan Hafren on the Afon Tanat, while no clear trends are apparent at any of the sites on the Afon Rhiew.

The main long term dataset available for the fish counters is from the Afon Tanat at Carreghofa which indicates that since 2006 there has been a gradual decline in the number of adult salmon recorded moving upstream. A comparison of upcounts against flow indicates salmon at the site demonstrate a tendency to move upstream during a period following high flows. In contrast to the salmon catch and counter data, there is no clear trend in redd (salmon nest) counts for the period 1975 to 2004, or any apparent relationships between counts during 'wet' or 'dry' years.

Electric fishing has been used for initial WFD classifications although it should be noted that the surveys have not fully adhered to WFD methodologies. Data for salmonid surveys indicate that salmon spawn in the main River Severn as far downstream as Bewdley. These surveys also indicate there is a considerable amount of inter-year and inter-site variation in the number of coarse fish individuals and the types of species present. Overall, roach, gudgeon, dace and bleak are generally the species most commonly recorded.

Hydroacoustic surveys conducted in the middle and lower sections of the River Severn have indicated fish densities are generally high in localised areas, particularly at the bottom of weirs. Overall, however, a national programme of these surveys has indicated that fish densities in the Severn are low when compared with other UK rivers.

7.3. Summary of Existing Drought Impacts

[Section to be completed when applying for a River Severn Drought Order]

7.4. Assessment of Impact on the Current Environment: Macroinvertebrates & Macrophytes

The main aim of this report is to separate the impacts of the River Severn drought order on the ecology of the River Severn from the impacts of the 'Do Nothing' scenario i.e. allowing the natural drought event to take its course, resulting in a potential complete loss of flows in the upper reaches of the Severn. There are three possible scenarios under a future drought episode, 'Do Nothing', 'Drought Order Only' and 'Full In-Combination', as defined in section 4.5. Each of these was modelled under two drought conditions, Acute and Chronic, as defined in section 4.4.

7.4.1. Assessment Methods

Of the four ecological indicators used in WFD classification (benthic macroinvertebrates, diatoms, macrophytes and fish), fish are considered in section 7.5, while macrophytes and diatoms were considered unsuitable for assessment. Therefore, this assessment considers potential impacts of the River Severn drought order on ecology with respect to macroinvertebrates only.

At present it is not possible to use the DRIED UP (Distinguishing the Relative Importance of Environmental Data Underpinning flow Pressure assessment) model to assess the potential impacts of the River Severn drought order because it is a regulated river. However, by looking at available historical invertebrate data (including data from historical low flow periods) it is possible to suggest what may happen to macroinvertebrates under the different scenarios, using the hydrological modelling described in section 5.3.

Note that the impacts predicted below only relate to the Afon Vyrnwy, the Afon Clywedog and the two upstream sections of the Severn itself (upper reach and upper middle reach based on data gathered at Coalport and Bewdley respectively). In the lower sections the invertebrate community

appears not to be responding to variations in flow based on historical data, but this may be because the sampling methods required at these sites are not compatible with the use of LIFE and PSI scoring methods.

7.4.2. Impact on Macrophytes

Due to the lack of existing data it was not possible to accurately determine to what extent periods of very low flow would impact on the macrophyte communities along the River Severn, Afon Clywedog and Afon Vyrnwy; and diatoms are generally not considered to be appropriate for use in drought monitoring and assessment.

7.4.3. Impact on Macroinvertebrates: Acute Drought Condition

Under the 'Do Nothing' scenario, upstream reaches were predicted to undergo severe declines in flow, and historic data suggest that the macroinvertebrate fauna would be affected, with a decline in flow-sensitive species (reduced LIFE scores) considered likely. Compensation flows were predicted to fail on the Afon Clywedog in late September and for 35 days flows of less than 10 Ml/d were predicted. Based on the hydrological modelling, this river and the Afon Vyrnwy were predicted to experience narrowing of the wetted channel and exposure of sediments. Following the drought there was predicted to be an extended period (at least 170 days) with no flow variation while the reservoirs refilled. It is considered likely that this would lead to sediment build up, dominance by more competitive species, and disruption of life cycles. Further downstream, exposure of as much as 50% of the river bed was predicted; at Coalport, the flow was predicted to remain at 1100 Ml/d for nearly 2 months but then was predicted to reduce to below 600 Ml/d towards the end of October. At Bewdley, river flow was predicted to fall even lower during the autumn, with a minimum flow of 336 Ml/d predicted.

Operation of the River Severn Drought Order would bring forward flow reduction in the Afon Clywedog by a month, but would ensure compensation flows continued for longer, thereby reducing the impact on macroinvertebrates. Following the end of the drought, loss of flow variation was predicted to occur for 224 days (whilst the reservoir refilled), 82 days fewer than under the 'Do Nothing' scenario, allowing the invertebrate community to recover more quickly. No change in flow relative to the 'Do Nothing' scenario was predicted on the Afon Vyrnwy as a result of application of the drought order. At Coalport river flows were predicted to drop by approximately 200 Ml/d during August and September, but were still predicted to be higher than naturalised. The River Severn Drought Order was predicted to provide a flow benefit for approximately 20 days in the latter half of October. Further downstream, flows were predicted to be maintained at 730 Ml/d, there was no evidence of significant deterioration based on historical data, and flows were predicted to be higher than under the 'Do Nothing' scenario, until the start of the modelled rainfall at the beginning of November. Reductions in water quality were a confounding feature of the 1976 drought, but improvements since this time are expected to reduce this potential issue in future drought events.

On the Afon Clywedog, the effects of the 'Full In-Combination' scenario are predicted not to differ from that of the 'Drought Order Only' scenario, but in the Afon Vyrnwy the hydrological modelling predicted that the length of time post-drought without flow variation would increase by 24 days. The greatest impacts on the Afon Vyrnwy would be expected closer to the dam.

7.4.4. Impact on Macroinvertebrates: Chronic Drought Condition

Under the 'Do Nothing' scenario, continuous low flows were predicted to have a dramatic impact on macroinvertebrates, with severe decline in low flow sensitive taxa. In the upstream reaches, flow failure was considered a strong possibility, and the length of time over which the impacts occur would have a consequent impact upon recovery times. Further downstream at Coalport and

Bewdley, no significant flow failure was predicted but low flows were still predicted to cause a major impact.

Operation of the River Severn Drought Order was predicted to reduce impacts on the Afon Clywedog and Afon Vyrnwy, as there would be no compensation flow failure and there would also be a reduction in the length of post-drought time without flow variation. Further downstream at Coalport and Bewdley, no significant flow failures were predicted and a flow benefit was predicted to occur in the latter part of autumn.

Although it is difficult to anticipate precisely, the 'Full In-Combination' scenario is anticipated not to have much additional impact on macroinvertebrates relative to the 'Drought Order Only' scenario, either upstream or downstream.

7.4.5. Macroinvertebrate Conclusions

The biological data assessed within this report suggests that in the upper and middle reaches of the River Severn, invertebrate assemblages respond to changes in flow. The available historical data indicate that flow sensitive ecology has been affected by low flows/drought events in the past. Reductions in LIFE scores in relation to the 1975/76, 1989/90 and1995/96 and 2010/11 droughts were detected and therefore it is probable that in the 'Drought Order Only' scenario (Acute and Chronic), the reduction in the amount of water used for regulation would have a negative impact on the macroinvertebrate community. Nevertheless, evidence from historical data suggests that macroinvertebrate assemblages will recover relatively quickly following drought. However, it must be remembered that the proposed drought order would be used to prolong the length of time water is available for regulation of the River Severn. If the drought order was not applied (i.e. the 'Do Nothing' scenario), there would be a much greater deterioration in the invertebrate community and the length of time taken for the ecology to fully recover from the effects of a drought would be greatly increased.

Further work on the understanding of how flows impact the ecology of rivers and new tools will hopefully become available that will allow us to calculate the impact of modelled flows. The new DRIED UP (Distinguishing the Relative Importance of Environmental Data Underpinning flow Pressure assessment) model is not suitable for use on regulated rivers to predict ecological response to altered flow at present, but work is on- going in this area and it is hoped in future it will be possible to use a modelling approach on the regulated Severn.

7.4.6. Limitations and Assumptions

The main limitation on the predictions given here is the patchy nature of the biological data available. The lower reach has no data that could be used, while two of the other reaches have macroinvertebrate data that are not comparable, in terms of collection method, with those from upstream. The need for further monitoring in the lower River Severn has been identified in Appendix S and airlift sampling methods are already being trailed.

At the time of this investigation river channel cross sectional data (e.g. depth, width, wetted perimeter etc) was not available at the required locations. Specific channel dimensions would allow the potential changes to in-river habitats to more quantifiably assessed, showing the direct impact that lowering water levels could have on the wetted perimeter or how much reduced flows might reduce velocity. This omission has been highlighted in the future work recommendations section 17 and the need for cross section surveys at the ecological assessment sites has been included in the monitoring programme in section 15.

A key assumption is that the macroinvertebrate community will respond to droughts, in this heavily regulated river system, in the same way as is predicted for rivers with more natural flow; this is

largely borne out by the historical data available. The need for better prediction models, calibrated to regulated rivers such as the Severn, has been highlighted in the future work recommendations section 17.

A second assumption is that there has been no deterioration in water quality impacts on drought-stressed invertebrates since intensive data were last collected in the 1970s. Again, this is believed to be a valid assumption as evidence points to an improvement in water quality since this period.

7.5. Assessment of Impact on the Current Environment: Fish of the Severn Corridor

7.5.1. Assessment Methods

As part of the overall assessment, flows have been modelled at a range of locations (assessment points) for potential acute (one year) and chronic (two year) drought conditions. The assessment points were: Clywedog, Vyrnwy, Buildwas, Bewdley, Saxons Lode, Haw Bridge/Deerhurst, and Lower Parting.

The main approach was to look at hydrographs depicting the modelled flow at these locations under three scenarios:

- Do Nothing (baseline) scenario
- Drought Order Only
- Full In-Combination

It should be noted that when considering potential effects on fish, the 'Drought Order Only' scenario and 'Full In-Combination' scenario were so similar that they were considered to effectively be the same.

An assessment was then undertaken as to whether the flow was lower under the 'Drought Order Only' scenario or other scenarios (in particular the 'Do Nothing' Scenario) and what impacts there could potentially be on fish.

The assessment also consider the modelled flow in relation to the Environmental Flow Indicator (refer to Appendix F) values used within the water resources CAM process.

For the twaite shad assessment, data were available for Saxons Lode indicating flows considered to be acceptable for this species for the period May to October (the acceptable flow ranged from 847 to 1426 Ml/d) (Review of Consents reference). Considerations for salmon, lamprey and elver were mainly based on whether the migration of individuals would be restricted. In addition, for the coarse fish assessments the potential for weirs and very shallow riffles to form potential barriers during low flows was considered.

Other aspects taken into account during the assessment, where appropriate, included the potential effects of low flow on water temperature and dissolved oxygen levels, and the potential effects of decreases in wetted width increasing susceptibility to predation e.g. by cormorants and goosander and leading to increases in competition for food and spawning areas.

7.5.2. Impact on Severn Corridor Fish: Acute Drought Condition

Clywedog
Under the 1976 Do Nothing scenario dead water was predicted for a period of 35 days (slack water was not predicted under the Drought Order only scenario). In addition, the flow was predicted to fall below a critical level of 70Ml/d (determined from a PHABSIM assessment) for 397 days under the Do Nothing scenario, while under the Drought Order only and Full in-combination scenarios the flow was predicted to fall below 70Ml/d for 305 and 295 days respectively. Overall, the significance of impact under the Drought Order only and Full in-combination scenarios was considered to be minor.

Vyrnwy
The Afon Vyrnwy site is dominated by salmonids. Having a drought order in place was predicted to make a negligible difference to flows when compared to the 'Do Nothing' scenario. As the low flows between November to April could potentially limit migration of Atlantic salmon to the upper sections of the Vyrnwy the significance of impact with the 'Drought Order Only' and 'Full In-Combination' scenarios was considered to be minor.

Buildwas
This site on the River Severn is dominated by coarse fish, but used by migratory Atlantic salmon, eels and lamprey. Negligible differences in flow were predicted between the 'Drought Order Only' and 'Do Nothing' scenarios and flow remained above the EFI level. Available fish habitat may be reduced at the Ironbridge Gorge as the river changes form, however, overall the impact under the Drought Order only and Full in-combination scenarios was considered to be negligible.

Bewdley
This site is dominated by coarse fish with a number of riffles used by spawning salmonids. Under the Do Nothing scenario flows were predicted to reduce to an average 368Ml/d for 22 days (from 12th October), which is below the High Risk EFI level (refer to Appendix I). With the 'Drought Order Only' and 'Full In-Combination' scenarios, river flows were predicted to drop slightly earlier in the year and remain at a higher level than predicted under the Do Nothing scenario. The reduced ability of Atlantic salmon to migrate past fish passes and weirs due to reduced flows would make them more prone to predation and angling pressure. Overall, the significance of impact with the Drought Order only and Full in-combination scenarios was considered to be minor.

Saxons Lode
Under the Drought Order only and Full in-combination scenarios, river flows were predicted to be around the 'acceptable' level for shad at Saxons Lode for August flows (acceptable level of 847Ml/d), but were predicted to be lower than the acceptable level in September (acceptable level of 1054Ml/d). The decrease in flow in October, however, was predicted to be more extreme under the Do Nothing scenario and could impact twaite shad that have not migrated down to the estuary. Coarse fish fry within this section could benefit from enhanced growth due to the predicted low flows. Overall, the significance of impact under the Drought Order only and Full in-combination scenarios was considered to be minor.

Haw Bridge/Deerhurst
Under the 1976 Do Nothing scenario at Haw Bridge/Deerhurst the flow was predicted to drop considerably on the 13th October for 19 days and was also predicted to drop below the High Risk EFI. Under the Drought Order only and Full in-combination scenarios the flow was predicted to be near the Medium Risk EFI level. The predicted reductions in flow are not expected to occur at critical times for most fish species in this section of the River Severn and overall the significance of impact under the Drought Order only and Full in-combination scenarios was considered to be minor.

Lower Parting
This section is within the tidal range of the estuary. High tides combined with low flows can lead to saline intrusion into the watercourse, an increase in suspended solids and low dissolved oxygen levels. It has been recommended that a critical flow of 1800Ml/d at Haw Bridge is required to maintain critical levels for these parameters, however, this flow is not attained for 19% of the period 1975 to 1979 under all scenarios which could result in fish mortality (mainly of salmon). There is a large decrease in flow in October under all scenarios (the decrease in flow is reduced under the Drought Order only and Full in-combination scenarios) which may be detrimental to salmon and river lamprey waiting to migrate upstream and any shad that are still in the upper estuary. The significance of impact under the Drought Order only and Full in-combination scenarios was considered to be moderate.

7.5.3. Impact on Severn Corridor Fish: Chronic Drought Condition

Clywedog
Low flows are predicted over the winter months between the first and second year of the chronic scenario (1976-1977). This could limit the dispersal of salmon spawning in the upper Severn due to insufficient flows to stimulate movement up the catchment.

During the second year under the Do Nothing scenario an extensive period of slack water was predicted in October which could cause substantial fish kills and this is prevented under the DO and Full in-combination scenarios for which a far greater flow was predicted to be maintained for a much longer period. At Dolwen the flow was predicted to fall below 70Ml/d (1975-79) for 469 days under the Do Nothing scenario, while under the Drought Order only and Full in combination scenarios the flows were predicted to fall below 70Ml/d for 413 and 389 days respectively, which is considered to be an improvement for salmon. Overall, however, the significance of impact under the Drought Order only and Full in-combination scenarios was considered to be moderate.

Other assessment sites
For each of the other sites specific variations and considerations were noted, however, the assessment of impact significance under the Drought Order only and Full in-combination scenarios was considered to be the same as described above for the acute scenario.

At the River Vyrnwy site in the second year near the end of the drought under both the Do Northing Scenario and the DO scenario there are 20 days of irregular flows which could impact the fish population due to both change in flow and fluctuating temperatures. It is considered that salmonids could benefit from the cooler water but it could be detrimental to the coarse fish. At Buildwas flow remain above the EFI for all management options.

Under the Do Nothing scenario at Bewdley the flow falls to an average flow of 289 Ml/d for about a month in October 1977 which could lead to the drying out of riffle sections and thereby have an impact on salmonids. Under the DO scenario the fall in flow occurs much later in the year, is less extreme (fall to ~520 Ml/d), and lasts for a period of ~3-4 days. With the DO in place and under the Full in-combination scenario, however, flows from July 1977 onwards are lower than under the Do Nothing scenario which could prevent salmon from negotiating fish passes leaving them more prone to predation and angling pressure.

At Saxons Lode under the Do Nothing scenario flow falls to an average of 428 Ml/d for 22 days from the 10th October, whereas under the DO and Full in-combination scenario the decrease in flow is to ~530 Ml/d and lasts for a few days. As for Bewdley, flows from July onwards are lower under the DO and Full in-combination scenarios which could have an impact on adult salmonid upstream movement. The impacts at Haw Bridge/Deerhurst are expected to be similar to those at Saxon’s Lode although modelling for 1977 suggests there could be saline intrusion in October due to the low flows.

A large drop in flow is predicted in October 1977 under the Do Nothing scenario which could cause considerable problems for fish in the upper estuary waiting for autumn high flows due to potential saline intrusion and low oxygen levels. This is avoided under the DO and Full in-combination scenarios, however, with these in place flow is modelled to decrease from July 1977 onwards which could lead to freshwater flows into the estuary being too low to prevent saline intrusion and oxygen level sags which have the potential to be detrimental to fish within the upper estuary.

7.5.4. Fish Conclusions

The closest events in recent history to these modelled scenarios were the droughts of 1976 and 1989, when the River Severn Drought order was operated (refer to Appendix B). During the droughts of 1976 and 1989 water regulation releases were found to mainly benefit the upper Severn and had little effect on the lower river and estuary in which serious problems were recorded.

Twaite shad
During drought events of similar magnitude to the 1976 and 1989 events the main concern would be related to shad within the upper estuary in the late autumn under the Do Nothing scenario. Under this scenario, freshwater flows were predicted to be very low meaning that saline intrusion and reduced oxygen levels could cause distress.
River flows are also predicted to be lower during early summer under the Drought Order only scenario in comparison with the Do Nothing Scenario which could limit upstream migration of adult shad.

Sea and river lamprey
Sea and river lamprey are not expected to be significantly impacted under any of the different modelled scenarios. River lamprey migration could potentially be slightly delayed; however, as this species they can migrate between August and April such a delay is unlikely to be detrimental.

Atlantic salmon
Regulation releases under the Drought Order only and Full in-combination scenarios would be generally beneficial to salmonids. There could still be problems with salmon mortality in the upper estuary due to low oxygen levels.

European eel
Although baseline drought conditions might impact the movement of elvers upstream it is considered that the various drought management scenarios assessed would not have a significant impact on the eel population.

Sea trout
Adult sea trout in the upper estuary waiting to migrate upstream could potentially be impacted by low flows under all scenarios.

Overall
In the event of an acute and especially a chronic drought it is considered that under the Do Nothing scenario there would be a significant adverse impact on the fish population of the River Severn, especially in the upper sections of the catchment at Clywedog and within the estuary.

Under the Drought Order only and Full in-combination scenarios, river flows in the upper catchment were not predicted to fall to the extremely low levels predicted under the Do Nothing scenario. It is considered that implementation of the River Severn Drought Order would be beneficial to the fish population in the upper River Severn although further downstream, and in particular near the estuary, the benefits will be greatly reduced.

7.5.5. Limitations and Assumptions

The main difficulty in quantifying the impacts on fish was limited baseline data, specifically relevant to low flows and drought conditions. This issue relates to both the difficulty with monitoring larger sections of the River Severn and the routine timing of annual sampling. Quite often when suitable comparison flows occur, the annual monitoring programmes do not have a scheduled sample to take and therefore the opportunity to gather information has been lost.

The difficulty with monitoring larger sections of the River Severn, and particularly the Severn Estuary, is you cannot guarantee you are catching a representative sample of species present. Fish may avoid sampling nets or not be present at the sampling location on the day of monitoring; however they are known to be present because of information/data collected from anglers and sites like the Oldbury Power station screens. However older data collection sites and methods are no longer consistent with WFD standards, and as with Oldbury Power station, sites are closing down and the sampling opportunities are decreasing.

The need for more specific low flow data, in the lower tidal Severn and upper estuary in particular, has been included in the monitoring programme (section 15.2 and Appendix S) and further work recommendation sections.

7.6. Invasive Non Native Species

Plants, aquatic life forms and animals that have been introduced to a place where they do not naturally occur are known as non-native species. Many of these live in the UK without causing a problem but a few become what's called invasive, resulting in damage to our environment, leisure and economy.

Invasive species upset the balance of the ecosystem as they may be bigger, faster growing or more aggressive than our native species. They also have fewer natural predators, diseases or parasites to control numbers. Our native species are often unable to compete and the invasive species increasingly take over.

Invasive non-native species (INNS) in our watercourses pose a threat to biodiversity, increase flood risk, affect the state of our water environment and cost the British economy by impacting on tourism and industry.

The Non-Native Species Secretariat (NNSS) is an organisation with responsibility for helping to coordinate a preventative approach to invasive non-native species in Great Britain, providing tools and information to help meet the challenge. NNSS is funded by Defra and the Welsh and Scottish Governments. The Environment Agency works in partnership with NNSS to promote what they do and to develop our own approaches to managing invasive non-natives in the course of our day to day duties.

7.6.1. Priority Invasive Non Native Species

Spread of INNS is an ever increasing problem in the United Kingdom, especially with the added pressure of climate change. The Environment Agency's top ten priority Invasive Non Native Species (INNS) are;

1. Killer Shrimp – *Dikerogammarus villosus*
2. Water Primrose – *Ludwigia grandiflora*

3. Floating Pennywort – *Hydrocotyle ranunculoides*
4. American Signal Crayfish – *Pacifasticus leniusculus*
5. Topmouth Gudgeon - *Pseudorasbora parva*
6. Giant Hogweed – *Heracleum mantegazzianum*
7. Japanese Knotweed – *Fallopia japonica*
8. Himalayan Balsam - *Impatiens glandulifera*
9. Mink – *Mustela vison*
10. Parrot's Feather – *Myriophyllum aquaticum*

All of the top ten INNS have been found in the Severn River Basin District.

7.6.2. Assessment of Invasive Non Native Species

The top ten INNS have been considered in relation to the River Severn Drought Order operations;

1. Killer Shrimp – at present these have not been found in the River Severn itself, although its 'cousin' *Dikerogammarus haemobaphes* has now been recorded in the River Severn (Tewkesbury to Worcester) and the Gloucester & Sharpness Canal. The most likely spread of these invasive shrimps would be through water users (e.g. anglers and boat traffic) and the application of the River Severn Drought Order is unlikely to impact their spread. The natural spread of the shrimps upstream would possibly increase due to lower flows but any obstructions like navigation weirs would be more difficult for them to be able to pass.
2. Water primrose – all known populations of the water primrose in the Severn catchment are in still water environments that are not directly connected to the River Severn. Therefore the application of the River Severn Drought Order is unlikely to impact this species.
3. Floating pennywort – the only known populations of floating pennywort in the Severn catchment have been found in canals and ponds that are not directly linked with the River Severn. Therefore the application of the River Severn Drought Order is unlikely to impact this species.
4. American signal crayfish – the signal crayfish has been found throughout the Severn catchment and is the main reason for the decline in our native white clawed crayfish. It is unlikely that the implementation of the River Severn Drought Order would impact the further spread of this invasive crayfish.
5. Topmouth gudgeon – two populations of top mouth gudgeon have been recorded within the Severn catchment. Both of these are in offline pools. Therefore the application of the River Severn Drought Order is unlikely to impact this species.
6. Giant hogweed – this poisonous invasive plant has been recorded at numerous locations throughout the Severn catchment. However, records in connection with the River Severn are not known. Therefore the application of the River Severn Drought Order is unlikely to impact this species.
7. Japanese knotweed – this plant is throughout the whole of the Severn catchment. During drought periods river levels would be lower and due to habitats being stressed there is potential for larger growths of Japanese knotweed. This plant spreads through vegetative reproduction and often high flows increase this. The changes from the implementation of the Severn Drought Order are unlikely to alter the spread of Japanese knotweed.
8. Himalayan balsam – this is another plant that is spread throughout the catchment. During drought periods river levels would be lower and due to habitats being stressed there is potential for larger growths of Himalayan balsam. Unlike Japanese knotweed this plant spreads through seed dispersal, but also high flows do improve dispersion. The changes to flows from the implementation of the Severn Drought Order are unlikely to alter the spread of this species.

9. Mink – this animal continues to be spread throughout the Severn. During times of drought fish will become stranded in pools and so therefore will be easier to catch by predators such as mink. On the main River Severn this should not happen but wetted width would decrease and so predation is likely to still increase. The application of the Severn Drought Order will maintain flows for longer and so decrease the problems of predation that would happen in the higher reaches of the Severn.
10. Parrots feather – The only populations of this plant within the Severn catchment have been in offline pools and canals. Therefore the application of the River Severn Drought Order is unlikely to impact this species

7.6.3. Invasive Non Native Species conclusion

With specific regard to the area covered by the River Severn Drought Order, only American signal crayfish, giant hogweed, Japanese knotweed, Himalayan balsam and mink are likely to be problematic. Considering the individual reproduction and dispersion methods for each of these species the majority of them did not identify an increased risk through the River Severn Drought Order implementation.

Mink were the only species that may benefit from isolated predation opportunities experienced during a natural drought event. However modelling found although the River Severn Drought Order would initially lower water levels and flows along the main River Severn corridor, the Acute and Chronic Conditions both showed that if the drought persisted, higher flows and water levels would be supported than under the Do Nothing (Baseline) scenario. Therefore additional protection would be provided to fish and other vulnerable species under the River Severn Drought Order implementation, helping to reduce the benefit to mink. Any adverse impacts would be temporary and have no prolonged adverse impact; therefore no adverse impact is concluded.

7.7. Monitoring and Mitigation Options

Ecology specific monitoring and mitigation options are contained within the Ecology technical report in Appendix O, Fish technical reports in Appendix P and U, and incorporated into the overall mitigation programme in section 14 and monitoring section 15 respectively.

INNS have not been specifically considered for monitoring purposes due to the conclusion of no impact. Routine work and monitoring to target INNS will continue, but is not within the remit of this environmental report.

8. Designated sites connected to the River Severn

The River Severn Drought Order could have an impact, whether positive or negative, via primary or secondary pathways (refer to section 4.1). Any sites which are in hydraulic continuity with the main River Severn could potentially be impacted and therefore needed considering as part of this environmental report.

Hydraulic continuity means a site is connected to the main River Severn by some form of water pathway. For example this could be a tributary river, a drainage ditch or a canal, which would allow species to move from the main River Severn into the site and vice versa. It can include wetland sites which are directly connected to the River Severn, or within flood plains along the banks.

8.1. Sites in Hydraulic Continuity with the River Severn

There are numerous designated sites within the River Severn catchment, this environmental report has identified all those sites which have the potential to be impacted because they are in hydraulic continuity with the River Severn. These sites are listed in the table in Appendix A.

8.2. Assessment Method

The sites were initially screened to test what the main flow parameter was, identifying the type of water levels that would be important to the health of the site. For example, sites that relied on flood water would not be impacted by the River Severn Drought Order, as the natural weather phenomena driving a drought would exclude these sites anyway. The screening identified which sites were reliant on normal to low flows, and sites with clear impact pathways were identified (red font in the table in Appendix A) and taken forward into the Habitat Regulation Assessment process for greater scrutiny.

In summary, the geological sites are unlikely to be affected by the River Severn Drought Order as they are not dependent on water. They are more likely to be eroded/damaged by flooding events arising from prolonged or heavy rainfall events. Geological sites were therefore screened out as not impacted by the River Severn Drought Order.

Many sites were found to be dependent on/benefit from being flooded, and were therefore unlikely to be affected by the River Severn Drought Order, which would be impacting flows below the sites needs. During drought conditions evaporation would be expected to exceed precipitation so those sites in hydrological continuity with the river would be more significantly impacted by natural weather conditions. Regulation of the river guarantees continued water supply to sites along the main River Severn (in channel) which places them at significant advantage over neighbouring catchments that are routinely impacted by natural low flows.

Application of the River Severn Drought Order should be beneficial in ensuring the continuation of flows throughout the worst period of a long term drought. Evidence to oppose these conclusions, along with site specific water level and minimum flow requirements would be required for individual sites if further investigation was requested.

8.3. HRA Screening Conclusions

From the sites identified in Appendix A, 13 relevant sites were taken through the Habitat's Regulation Assessment (HRA) screening process on the basis that they were in direct hydraulic connectivity with the River Severn, were linked to the Severn Estuary or were a species which migrated through the estuary. These sites are all listed in Table 23.

Table 23: HRA screened sites in Hydraulic continuity with the River Severn

Site	Designation	Relationship to River Severn	Risk of Likely Significant Effect (LSE)
Berwyn and South Clwyd Mountains	SAC	Headwaters of the Afon Vyrnwy which provides a component of the River Severn regulation	No
Berwyns	SPA	Headwaters of the Afon Vyrnwy which provides a component of the River Severn regulation	No
Montgomery canal	SAC	In direct hydraulic connectivity with the River Severn as it is fed by water taken from River Severn and River Tanat. This is allowed under an Act of Parliament not an abstraction	No
River Clun	SAC	In direct connectivity with the River Teme which is a major tributary of the River Severn. Salmon which are a feature of the Severn Estuary are a feature of the Freshwater Pearl Mussel life cycle.	No
Downton Gorge	SAC	River Teme which is a major tributary of the River Severn flows through this site. Salmon migrate up the River Teme to get to the River Clun where they are a feature of the Freshwater Pearl Mussel life cycle	No
Walmore Common	SAC	In direct hydraulic connectivity with the River Severn via ditches	No
Walmore Common	Ramsar	In direct hydraulic connectivity with the River Severn via ditches	No
Severn Estuary	SAC	In direct hydraulic connectivity with the River Severn	Yes
Severn Estuary	SPA	In direct hydraulic connectivity with the River Severn	No
Severn Estuary	Ramsar	In direct hydraulic connectivity with the River Severn	Yes
River Wye	SAC	Although not linked to the River Severn are linked to the Severn Estuary	No
River Usk	SAC	Although not linked to the River Severn are linked to the Severn Estuary	No
River Tywi	SAC	CCW requested the inclusion in relation to migratory fish and the Severn Estuary	No

The majority of sites were concluded as not being negatively impacted by the River Severn Drought Order, and/or receiving benefits from its operation. The HRA screening did identify potential impacts for further investigation as follows:

- for the Severn Estuary SAC overall estuarine feature it was uncertain whether there was a likely significant effect, either alone or in combination; and
- for the Severn Estuary SAC and Ramsar site there was likely to be a significant effect on the fisheries feature of the site.

The HRA screening results led to an Appropriate Assessment being carried out for the estuarine and fisheries features of the Severn Estuary SAC and Ramsar. Further detail can be found in the Severn Estuary section 9.

The Habitat's Regulation Assessment (including the Screening and Appropriate Assessments) produced for the Severn Estuary Natura 2000 site, and other potentially impacted sites can be found in full in Annex 1.

9. The Severn Estuary

The Severn Estuary is protected by the Habitat's Directive (Directive 92/43/EEC on the conservation of Natural Habitat's and Wild Flora and Fauna), Birds Directive (Directive 79/409/EEC on the protection of wild birds) and Ramsar Convention 1971 (Internationally important wetlands, afforded the same protection as SPAs and SACs by UK Government) legislation.

The Environment Agency and Natural Resources Wales are both a 'competent authority' under Regulation 7(1) of the Conservation of Habitats and Species Regulations 2010 (SI No. 2010/490), commonly referred to as the Habitat's Regulations. Under Regulation 9(5) it states 'a competent authority must have regard to the requirements of the Habitat's Directive when exercising any of its functions.' In accordance with the legislation, a Habitat's Regulations Assessment (HRA) for the modelled Drought Order scenarios (alone and in combination) has been carried out for all the relevant sites along the River Severn. Natural England and the Countryside Council for Wales (now part of Natural Resources Wales) have been consulted throughout.

Now that Natural Resources Wales has been formed, it has a second role in safeguarding the Severn Estuary. Natural Resources Wales will now also be a statutory consultee under the Habitats Regulations (similar to Natural England). Functional separation between these sections of Natural Resources Wales will ensure transparent and rigorous scrutiny of the HRA proposals.

To save duplication, this section only contains some background information on the Severn Estuary and a summary of the HRA assessment conclusions and mitigation options. For more detail please refer to the complete **'Habitat's Regulations Assessment (River Severn Drought Order)'** report in Annex 1.

9.1. Baseline Environment

The Severn Estuary is the largest example of a coastal plain estuary in the United Kingdom and one of the largest estuaries in Europe, shown in Figure 18. The overall area of the estuary covered by European and International conservation designations is 73,715.4 ha of which roughly two thirds is composed of subtidal habitats (stable sandbanks and shifting sediments of gravel, sand and mud) and one third is composed of intertidal habitats (tide washed mud and sand, salt marshes and rocky shores).

The estuary lies in the broad Severn Vale, with most of the sediments on the margins of the estuary having accumulated since the last ice age. It has been a focus for human activity, a location for settlement, a source of food, water and raw materials and a gateway for trading and exploration. As well as supporting the cities of Cardiff, Bristol, Newport and Gloucester, major industries are sited around the Estuary's shores including modern port installations, chemical processing companies and nuclear power stations. Aggregate extraction also occurs within the estuary.

Alongside all these competing activities, the Estuary also supports a wide array of habitats and species of international importance for nature conservation. A number of habitats and species have also been recognised through the designation of several Sites of Special Scientific Interest (most notably, the Upper Severn Estuary, Severn Estuary and Bridgwater Bay SSSIs in the 1980's) which underpin the European and International designations.

The Severn Estuary is designated on the basis that the immense tidal range (the second highest in the world) and classic funnel shape make the Severn Estuary unique in Britain and very rare worldwide. The intertidal zone of mudflats, sand banks, rocky platforms and salt marsh is one of the largest and most important in Britain. The estuarine fauna includes: internationally important populations of waterfowl; invertebrate populations of considerable interest; and large populations

of migratory fish, including the nationally rare and endangered Allis Shad *Alosa alosa*. The SSSI forms the major part of a larger area of estuarine habitat, which includes the Upper Severn Estuary, the Taf/Ely Estuary and Bridgwater Bay. The estuary also has a diverse geological setting and a wide range of geomorphological features especially sediment deposits.

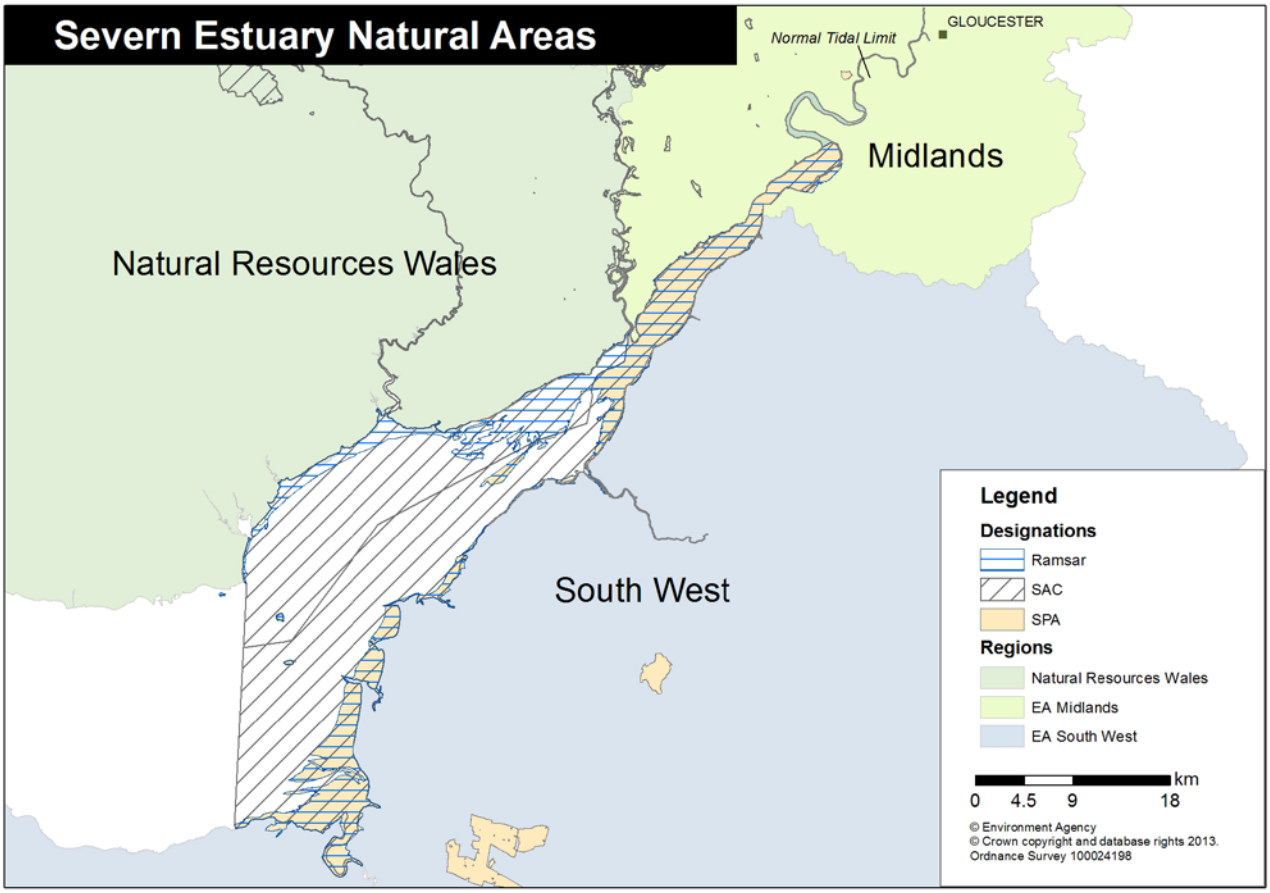

Figure 18: Severn Estuary Natura 2000 site

Table 24 shows the wide range of nature conservation features for which the estuary is valued and the interrelationship of these features by designation. This table outlines features of European and International importance in their own right and others of national importance for which the Severn Estuary has been designated as a Site of Special Scientific Interest (SSSI) but which form an intrinsic part of the Severn ecosystem and therefore contribute to the overarching “estuary” feature of the SAC and Ramsar Site.

Table 24: Summary of Notified features of each designation:

Feature	SAC	SPA	Ramsar Site	SSSI (Nationally important feature)
Estuary	Yes	*Supporting habitat to designated bird interests*	Yes	Yes
Subtidal sandbanks	Yes	No – outside boundary of SPA	No – outside boundary of Ramsar Site	No– outside boundary of SSSI
Intertidal Mud and Sand	Yes	Supporting habitat to designated bird interests	*Component of Ramsar "estuaries" feature and supporting habitat to designated bird interests*	Yes
Atlantic salt meadow / salt marshes	Yes	*Supporting habitat to designated bird interests*	*Component of Ramsar "estuaries" feature and supporting habitat to designated bird interests*	Yes
Reefs	Yes	No	*Intertidal Sabellaria contiguous with subtidal reefs is a component of the hard substrates subfeature of the Ramsar "estuaries" feature*	No – outside boundary of SSSI
Migratory fish (river & sea lamprey & Twaite shad)	Yes	No	Yes	Yes
Migratory fish (salmon, eel, sea trout and Allis Shad)	*Part of notable species sub-feature of estuary feature*	No	Yes	Yes
Assemblage of fish species (>100 species)	*Notable species sub-feature of estuary feature*	No	*Notable species sub-feature of estuary features*	Yes
Internationally important populations of migratory bird species	*Notable species sub-feature of estuary feature*	Yes	Yes Internationally important populations of waterfowl	Yes
Internationally important populations of wintering bird	*Notable species sub-feature of estuary feature Yes*	Yes		Yes

species				
Assemblage of nationally important populations of waterfowl	*Notable species sub-feature of estuary feature*	Yes	Yes	Yes
Hard substrate habitats (Rocky shores)	*Notable species sub-feature of estuary feature*	*Supporting habitat to designated bird interests*	*Component of Ramsar "estuaries" feature and supporting habitat to designated bird interests*	Yes
Freshwater grazing marsh / Neutral grassland	No	*Supporting habitat to designated bird interests within SPA but outside European Marine Site* **and therefore not addressed in this Regulation 33 advice document**		Yes (currently England only)

9.2. Summary of Existing Drought Impacts

[Section to be completed when applying for a River Severn Drought Order]

9.3. Assessment of Impact on the Current Environment: Severn Estuary

As a 'competent authority' under Regulation 7(1) of the Conservation of Habitats and Species Regulations 2010, under Regulation 9(5) we "must have regard to the requirements of the Habitats Directive when exercising any of its functions", which includes activities authorised by a drought order. It is therefore necessary for the Environment Agency to undertake a Habitats Regulations Assessment (HRA) for this Drought Order. The HRA tests whether the impacts identified as arising from a permit/order, project or plan are likely to have a significant effect on European sites.

9.3.1. Assessment Method: HRA Screening

For the River Severn Drought Order HRA screening was conducted to identify the likely impact of the Acute and Chronic drought conditions (and subsequent scenarios) on the relevant European sites and determine whether they are likely to be significant. This process identifies those sites and features of the sites where an Appropriate Assessment of the drought option is required. The River Severn Drought Order HRA screening identified;

- for the Severn Estuary SAC overall estuarine feature it was uncertain whether there was a likely significant effect, either alone or in combination.
- for the Severn Estuary SAC and Ramsar site there was likely to be a significant effect on the fisheries feature of the site.

The screening results determined an Appropriate Assessment was required for the estuarine and fisheries features of the Severn Estuary SAC and Ramsar. The Appropriate Assessment document includes the sites and designated features, determines whether there is the potential for likely significant effects or whether significant effect is uncertain and needs further investigation.

The **'Habitat's Regulations Assessment (River Severn Drought Order)'** is available in Annex 1 as a separate report and contains all the relevant site information, HRA screening and appropriate assessment work for the Habitat Directive sites and the Severn Estuary.

9.3.2. Severn Estuary HRA Findings: Drought Order Only scenarios

In Section 4.1.1.1 of the Severn Estuary SAC, SPA and Ramsar Site: Regulation 33 Advice from CCW and Natural England, June 2009 it states that 'A failure to meet these conditions, which is entirely a result of natural process will not constitute unfavourable condition, but may trigger a review of the definition of favourable condition.' The Regulation 33 advice recognises variable weather conditions, tidal surges and the fact that estuaries are dynamic systems and that particular communities can have short term disappearances or crashes.

Drought is a natural event and will cause low flows that result in various effects, having a particularly adverse effect on fish migration. The impacts on the designated migratory fish was identified under all three scenarios; the extreme natural drought ('Do Nothing (baseline)'), 'Drought Order Only' and Full In-Combination scenarios. Fish passage was identified as the major issue and unlikely to be improved without the removal of barriers to migration. The impact on migratory fish was identified for the 'Do Nothing' scenario, although the River Severn Drought Order provided benefits the failure was still found to be likely under the ' Drought Order Only' and 'Full In-Combination' scenarios. As the initial 'Do Nothing' failure was a result of the natural drought process and not the operation of the River Severn Drought Order (WFD Article 4.6, refer to section 10) it should be short term and therefore would not constitute the migratory fish feature being in unfavourable condition.

During previous drought events, prior to the implementation of the River Severn Drought Order, fish mortalities were recorded in the Severn Estuary and lower tidal Severn. Water quality has significantly improved at Netheridge STWs (Appendix Q and R) since these droughts, and modelling found the implementation of the River Severn Drought Order in conjunction with these improvements should reduce the risk of fish mortalities resulting from water quality issues. This will help support any migratory fish waiting in the Severn Estuary and reduce the risks that have been recorded during previous droughts. Implementation of the River Severn Drought Order was also found to provide resilience should there be an ongoing drought, better supporting fish migration in subsequent years, which could support a faster recovery of fish species during post drought years.

For the 'Drought Order Only' scenarios under both the Acute and Chronic Conditions it was concluded the baseline drought conditions caused the adverse effect on the migratory fish while implementation of the River Severn Drought Order would lessen or minimise the impacts. **Therefore it was concluded that implementation of the River Severn Drought Order alone (Drought Order Only scenarios), did not have an adverse effect on the designated migratory fish features of the Severn Estuary SAC and Ramsar.**

9.3.3. Severn Estuary HRA Findings: Full-In-Combination scenarios

The potential impact of the Canal & River Trust abstraction for the Gloucester & Sharpness Canal is large; depending on when and how much is abstracted from the River Severn at Gloucester. This abstraction remains exempt from licensing under the Water Resources Act 1991, although an Operating Agreement (1998) between the Environment Agency and CRT largely safeguards the Severn Estuary during normal regulation years. Clause 7 of the Operating Agreement does exclude severe drought conditions, during which the Gloucester & Sharpness Canal could abstract up to 691Ml/d. There are reasons why the maximum amount might not be abstracted, such as siltation and saline intrusion on high tides (Bristol Water abstract from the canal) but there is the

potential at low tides for the rate of pumping to be at its maximum, leaving very little freshwater in the lower tidal Severn (as recorded in reports from the 1976 and 1984 droughts).

All the drought scenario modelling accounted for the Gloucester & Sharpness Canal to abstract up to a maximum 300 Ml/d. For the 'Full In-Combination' assessment it was necessary to account for the precautionary worst case abstractions (maximum abstraction up to 691 Ml/d) when concluding the potential environmental impacts.

Under the 'Do Nothing (Baseline)' scenarios there would theoretically be times when no freshwater flow was entering the lower tidal Severn: the repercussions on the fish fauna could be damaging. At high tides saline intrusion would increase and pose a greater risk to the environment, however higher saline intrusion would also halt abstraction into the canal. Low tides and flows cause increased sediment deposition, any fish trapped in pools would be at risk from rapidly rising water temperature, lowering dissolved oxygen and predation. The HRA found that operating the River Severn Drought Order ('Drought Order Only') did protect higher minimum freshwater inflows than the 'Do Nothing (Baseline)' scenario, although flows would still be low and harm to fish likely, the drought order could provide a benefit during the critical periods. However if the Gloucester & Sharpness Canal abstraction were to take the maximum amount, benefits from the River Severn Drought Order would be neutralised as flows could be reduced to a few centimetres over Maisemore and Llanthony weir, as recorded in the 1976 and 1984 droughts.

The HRA found Gloucester & Sharpness Canal abstractions around the potential maximum 691 Ml/d, could have the potential to have an adverse effect on the migratory fish features of the Severn Estuary SAC and Ramsar site alone, and in combination with the River Severn Drought Order and water company drought orders. The sensitivity around what exact flow and water level conditions would start causing a problem is very difficult to determine without more data.

The HRA therefore concluded that Full In-Combination operation of the River Severn Drought Order could have an adverse effect on the migratory fish features of the Severn Estuary SAC and Ramsar site. These adverse effects will be particularly experienced by migratory fish in relation to their passage through the lower tidal Severn.

9.4. Mitigation Requirement

This Appropriate Assessment determines whether, in view of the European site's conservation objectives, the implementation of a River Severn Drought Order 'either alone or in combination with other plans or projects' would have an adverse effect on the integrity of the site. Where adverse effects are identified, which cannot be avoided or mitigated for, alternative options or solutions must be considered.

If it is not possible to identify mitigation or alternatives, consideration should be given to whether the sites host priority habitats/species, and if there are important human health/safety considerations 'imperative reasons of overriding public interest' (IROPI). If Imperative Reasons of Overriding Public Interest (IROPI) are determined, then compensatory measures must be designed, assessed and put in place, prior to the commencement of the plan. This is not considered a standard part of the process and will only be carried out in exceptional circumstances.

9.4.1. Mitigation of the Gloucester & Sharpness Canal abstraction under Full-In-Combination scenarios

As a competent authority under the Habitat's Directive we have to either mitigate against potential environmental harm, or apply for the River Severn Drought Order on the grounds of Imperative Reasons of Overriding Public Interest. The most appropriate option to balance water needs and

the requirements of the Habitat's Directive was found to be limiting the abstraction to the Gloucester & Sharpness Canal.

The HRA concluded a Gloucester & Sharpness Canal abstraction of 300 Ml/d in combination with the River Severn Drought Order and water company drought permits/orders is not predicted to cause a likely significant effect on the designated Severn Estuary and its features. The designated Severn Estuary (and features) is 35km downstream of the canal abstraction and the major influences on the habitat and species are from tidal movements. There are no reports of the designated Severn Estuary being impacted during the 1975-1976 droughts, however following the 1989 drought it was concluded that residual outflows into the Severn Estuary are sensitive to the Gloucester & Sharpness Canal pumping rate during periods of low river flow.

Because the Habitats Regulations Assessment was able to conclude a maximum abstraction of 300 Ml/d to the canal (Full In-combination) was unlikely to cause harm to the Natura 2000 site designations, applications for this Drought Order will therefore now include an abstraction cap of 300 Ml/d on the Canal & River Trust, when flows at Deerhurst drop below 1200 Ml/d. If the Drought Order is granted, the conditions set would become legally enforceable. This action should successfully mitigate any potential harm to the Natura 2000 site and satisfy the Habitat Directive requirements.

The Environment Agency views the restriction as aiming to protect environmental needs whilst still allowing the Canal & River Trust enough water to meet its main obligations. The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to its operation of the canal. The Environment Agency recognises this risk and have committed to working with the Canal & River Trust to investigate their concerns further. If sufficient evidence can be provided to show a higher abstraction is justified, then the Environment Agency is committed to reviewing the restriction volume appropriately in the future.

9.5. Severn Estuary Conclusions

As a drought progresses flows get lower and to be in a situation where a River Severn Drought Order is being applied for, flows will already be impacted by drought, especially where the channel splits around Gloucester. It should be noted that it is not the effects of the drought that is being assessed but the effects of implementing options considered in the River Severn Drought Order.

The modelling undertaken for the HRA and historic drought reports from the 1975/6 and 1984 droughts as well as anecdotal evidence found the lowest flows were experienced in the Lower Tidal Severn (especially around Gloucester). Implementation of the River Severn Drought Order alone was unlikely to cause likely significant effects on the overarching designated estuary feature, sub features or supporting habitats. In particular modelling demonstrated that WFD targets were unlikely to be failed during low flows.

As well as being the stretch of river experiencing the lowest flows, the Lower Tidal Severn was particularly vulnerable due to the combination of low flows and saline intrusion associated with Spring and Neap tides, another natural event. The combination of low flow and increased salinity has led to dissolved oxygen lags resulting in fish mortalities in the past. However despite the improvements in water quality (Appendix Q and R), which have greatly reduced the risk, migratory fish are still vulnerable given the reduction of flow that can occur, potentially leaving them stranded in pools and at the periphery of the river. They would be at even greater risk if the drought was accompanied by high temperatures as ponded areas or fringes of the river would dry out more quickly and the temperature of the water rise. Besides the risk of fish kills, low flows could also impact on their migration up or down the river, which has been discussed in the Appropriate Assessment.

The Gloucester & Sharpness Canal abstraction was assessed during the Review of Consents (RoC) Stage 3 process[27], to determine whether it had a significant effect on freshwater flows from the Severn into the Estuary. Both influenced (current observed) and natural flows were found to be above 'Good ecological status,' and therefore concluded as providing sufficient flows into the estuary. The work on migratory fish also concluded that none of the abstractions (including this one) had an impact on the integrity on shad and lamprey alone or in-combination. It is important to note the RoC did not cover the impacts of lowering the regulation flows for drought management; the work conducted for the River Severn Drought Order environmental report builds on the RoC process to investigate severe drought scenarios.

An Operating Agreement (1998) between the Environment Agency and the Canal & River Trust largely safeguards the Severn Estuary during normal regulation years. Clause 7 of the Operating Agreement however excludes drought conditions, during which the Gloucester & Sharpness Canal could legally abstract up to 691Ml/d. The Canal & River Trust remain committed to making best endeavours to meet the obligations set out in the Operating Agreement. The impact on the Severn Estuary and migratory fish would vary according to when and how much water is abstracted from the River Severn at Gloucester.

It is recognised that sufficient abstraction for the Gloucester & Sharpness Canal is needed to support Bristol Waters PWS abstraction at Purton (from the canal), however the ability to abstract 691 Ml/d remains a potential risk and could also be considered to negate the benefits intended by implementing the River Severn Drought Order.

Through the River Severn Drought Order modelling and historic drought information that has become available since RoC, the potential effects of the Gloucester & Sharpness Canal abstraction during severe low flows has been fully realised. The maximum abstraction of 300 Ml/d in combination with the River Severn Drought Order and water company drought orders should not cause a likely significant effect on the designated estuary and its features. This abstraction does have the potential to take quantities of up to 691 Ml/d and during heavy abstraction and low flows it has been known to significantly reduce flows during previous droughts, occasionally almost to zero at the weirs in Gloucester. Therefore it certainly has the potential to have an adverse effect on the Lower Tidal Severn and the migratory fish, analysis also suggest the designated estuary could be put at risk.

The HRA Appropriate Assessment concludes that while the natural drought could be impacting fish migration, no additional likely significant effects should result because of operating the River Severn Drought Order. Water quality has improved in the lower tidal Severn enough to ensure fish should not be harmed by the 'Drought Order Only' scenarios, even if the fish are delayed or fail to migrate as a natural consequence of the drought.

The 'Full In-Combination' assessment concluded there was the potential for likely significant effects on the Severn Estuary SAC and migratory fish, if the Canal & River Trust abstracted around the potential maximum 691 Ml/d. As a competent authority under the Habitat's Directive we have to either mitigate against potential environmental harm, or apply for the River Severn Drought Order on the grounds of Imperative Reasons of Overriding Public Interest.

The most appropriate option to balance water needs and the requirements of the Habitat's Directive was found to be limiting the abstraction to the Gloucester & Sharpness Canal. Because the Habitats Regulations Assessment was able to conclude a maximum abstraction of 300 Ml/d to the canal (Full In-combination) was unlikely to cause harm to the Natura 2000 site designations, applications for this Drought Order will therefore now include an abstraction cap of 300 Ml/d on the

[27] The initial summary provided during external consultation stated the Gloucester & Sharpness Canal abstraction had not been assessed during RoC. A more thorough investigation of the audit reports forming the RoC process identified the abstraction was in fact considered and investigated as far as possible at the time.

Canal & River Trust, when flows at Deerhurst drop below 1200 Ml/d. If the Drought Order is granted, the conditions set would become legally enforceable. This action should successfully mitigate any potential harm to the Natura 2000 site and satisfy the Habitat Directive requirements.

The Environment Agency views the restriction as aiming to protect environmental needs whilst still allowing the Canal & River Trust enough water to meet its main obligations. The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operations. The Environment Agency recognises this risk and have committed to working with the Canal & River Trust to investigate their concerns further. If sufficient evidence can be provided to show a higher abstraction is justified, then the Environment Agency is committed to reviewing the restriction volume appropriately in the future.

9.6. Limitations and Assumptions

Uncertainty remains around the Gloucester & Sharpness Canal abstraction volumes and timings, which introduces uncertainty within the assessments. The precautionary worst case situation has been adopted to ensure the impacts are fully considered in line with the Habitat's Directive; however it is important to note that a maximum abstraction of 691 Ml/d is unlikely to be taken by the Canal & River Trust during a drought. The Canal & River Trust have their own statutory obligations to protect the environment and an internal Drought Plan with advisory trigger for closing the canal to navigation.

The appropriate assessment was carried out using the specific Acute and Chronic drought conditions; however the exact timing of a real drought may be different to what has been outlined in this assessment.

It is important to note the models used are based on daily flows, and cannot account for tidal variations. These impacts have been considered outside of the drought flow model (Aquator) but again the timing and exact magnitudes coinciding with low flows cannot be guaranteed. All droughts will be different.

9.7. Monitoring and Mitigation

The process of carrying out this appropriate assessment has identified gaps in our knowledge and how additional monitoring would contribute to the overall understanding of the Lower Tidal Severn and the Severn Estuary. During low flow conditions it is vital that we have base line data against which monitoring undertaken during a drought can be assessed. It is also necessary to undertake post-drought monitoring so that the recovery of habitats and species can be assessed. It is only by obtaining this whole suite of data that the whole process of a drought and its impacts can be fully assessed and understood. Estuary specific monitoring options are contained within the HRA report in Annex 1 and incorporated into the overall monitoring programme in section 15.

10. Water Framework Directive

The European Water Framework Directive (WFD) came into force in December 2000 and became part of UK law in December 2003. WFD is a key piece of European legislation, rewriting existing water legislation into an overarching programme to deliver long-term protection of the water environment and improve the quality of all waters and associated wetlands. It takes an approach to managing water called River Basin Management Planning, looking at the water and wildlife within the wider ecosystem. It covers estuaries, coastal waters, groundwater and lakes as well as rivers and monitoring is risk-based, focusing where there is likely to be a problem.

The Environment Agency is the principal protector of the water environment in England and Natural Resources Wales is the principal protector of the water environment in Wales. We are designated by the Department for Environment, Food and Rural Affairs (Defra) and the Welsh Government as the 'Competent Authorities' for implementing the Directive.

The Water Framework Directive requires EU member states to ensure ‘no deterioration’ in the ecological status of waterbodies and to achieve their Good Ecological Status by 2015 (Good Ecological Potential in the case of waterbodies categorised as Heavily Modified).

For surface waters it proposes achieving this through a number of different environmental objectives:

- Prevent deterioration in status for water bodies
- Aim to achieve good ecological and good surface water chemical status in water bodies by 2015
- For water bodies that are designated as artificial or heavily modified, aim to achieve good ecological potential by 2015
- Comply with objectives and standards for protected areas where relevant
- Reduce pollution from priority substances and cease discharges, emissions and losses of priority hazardous substances.

Extreme natural events such as drought are recognised within WFD. Article 4.6 allows for a temporary deterioration as a 'result of circumstances of natural cause which are exceptional or could not reasonably have been foreseen, in particular extreme floods and prolonged droughts.' These give rise to situations which cause us to make use of the water environment in ways that result in its deterioration of status (e.g. by supplying the public with drinking water during prolonged drought; by pollutants washed into the water environment by floods).

When concluding impacts on WFD for this assessment, consideration needs to be made as to whether the impacts are caused by the natural drought event, whether the impacts are temporary, or whether the waterbody will recover quickly and without the need for restoration measures.

10.1. Water Framework Directive Baseline Environment

There are eleven WFD River Water bodies along the main River Severn from source to the tidal limit, one River Water body along on the Afon Clywedog, four River Water bodies along the River Vyrnwy and two Lake Waterbody's at the source of these main rivers. The relevant waterbodies are listed in Table 25.

Table 25: River Severn Water Bodies

Water Body ID	Water Body Name
GB30937446	Llyn Clywedog
GB109054044760	Afon Clywedog - Clywedog Dam to R Severn
GB109054044790	R Severn - source to conf Afon Dulas
GB109054049310	R Severn - conf Afon Dulas to conf R Camlad
GB109054049700	R Severn - conf R Camlad to conf Bele Bk
GB109054049142	R Severn - conf Bele Bk to conf Sundorne Bk
GB109054049141	R Severn - Sundorne Bk to conf M Wenlock-Farley Bk
GB109054049143	R Severn conf M Wenlock-Farley Bk to conf R Worfe
GB109054049145	R Severn - conf R Worfe to conf R Stour
GB109054049144	R Severn - conf R Stour to conf River Teme
GB109054039760	R Severn - conf R Teme to conf R Avon
GB109054044404	R Severn - conf R Avon to conf Upper Parting
GB109054032750	R Severn (E Channel) - Horsebere Bk to Severn Est
GB30935568	Lake Vyrnwy / Llyn Efyrnwy
GB109054049880	R Vyrnwy - Lake Vyrnwy to conf Afon Cownwy
GB109054049720	Afon Vyrnwy - conf Afon Cownwy to conf Afon Banwy
GB109054049850	Afon Vyrnwy - conf Afon Gam to Afon Tanat
GB109054049800	Afon Vyrnwy - conf Afon Tanat to conf R Severn

The Directive sets a target of aiming to achieve at least 'good status/potential' in all waters. For surface waters, good status is a statement of 'overall status', and has an ecological and a chemical component. Good ecological status is measured on the scale high, good, moderate, poor and bad. Physico-chemical elements are a supporting element in the classification of ecological status. Chemical status is measured as good or fail. Good ecological status applies to natural water bodies, and is defined as a slight variation from undisturbed natural conditions. Figure 19 below shows how status is determined for surface waters.

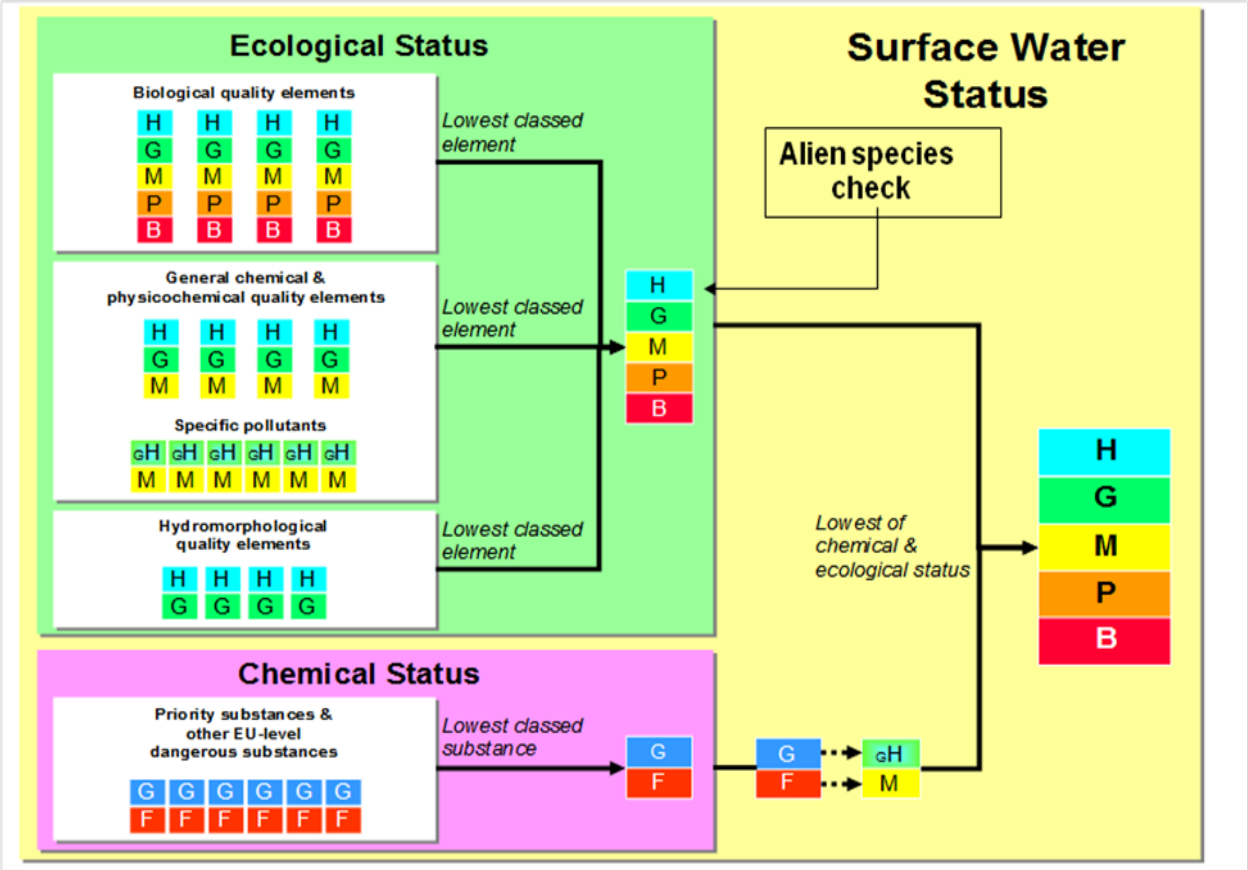

Figure 19: How to determine Ecological status for the Water Framework Directive

Each component has several different elements. These are measured against specific standards and targets developed by the Water Framework Directive UK Technical Advisory Group (UKTAG) and the European Union.

Some surface water bodies are designated as ‘artificial’ or ‘heavily modified’ because they have been created or modified for a particular use such as water supply, flood protection, navigation or urban infrastructure. By definition, artificial and heavily modified water bodies are not able to achieve natural conditions. Instead the classification and objectives for these water bodies, and the biology they represent, are measured against ‘ecological potential’ rather than status. Whilst good ecological status is defined as a slight variation from undisturbed natural conditions in natural water bodies, artificial and heavily modified water bodies are unable to achieve natural conditions. Instead, artificial and heavily modified water bodies have a target to achieve good ecological potential, which recognises their important uses, whilst making sure ecology is protected as far as possible. Ecological potential is also measured on the scale high, good, moderate, poor and bad. The chemical status of these water bodies is measured in the same way as for natural water bodies. **All the River Severn water bodies downstream of the confluence with the Afon Dulas are classed as heavily modified.**

Classification uses a principle of ‘one out, all out’ which means that the poorest individual result drives the overall classification. It reports on over thirty measures, grouped into ecological status (including biology and ‘elements’ such as phosphate and pH) and chemical status. A summary of compliance with good overall status/potential (correct as of April 2013) is shown in Table 26.

Table 26: Compliance with WFD Objectives

Water Body ID	Water Body Name	Overall Status/Potential	Overall Status/Potential (2012 interim classification)
GB30937446	Llyn Clywedog	Moderate	Moderate (Potential)
GB109054044760	Afon Clywedog - Clywedog Dam to R Severn	Moderate (Potential)	Moderate (Potential)
GB109054044790	R Severn – source to conf Afon Dulas	Moderate	Moderate (Status)
GB109054049310	R Severn – conf Afon Dulas to conf R Camlad	Poor (Potential)	Moderate (Potential)
GB109054049700	R Severn – conf R Camlad to conf Bele Bk	Moderate (Potential)	Poor (Potential)
GB109054049142	R Severn – conf Bele Bk to conf Sundorne Bk	Moderate (Potential)	Moderate (Potential)
GB109054049141	R Severn – Sundorne Bk to conf M Wenlock-Farley Bk	Moderate (Potential)	Moderate (Potential)
GB109054049143	R Severn conf M Wenlock-Farley Bk to conf R Worfe	Moderate (Potential)	Moderate (Potential)
GB109054049145	R Severn – conf R Worfe to conf R Stour	Moderate (Potential)	Moderate (Potential)
GB109054049144	R Severn – conf R Stour to conf River Teme	Moderate (Potential)	Moderate (Potential)
GB109054039760	R Severn – conf R Teme to conf R Avon	Moderate (Potential)	Moderate (Potential)
GB109054044404	R Severn – conf R Avon to conf Upper Parting	Moderate (Potential)	Moderate (Potential)
GB109054032750	R Severn (E Channel) – Horsbere Bk to Severn Est	Moderate (Potential)	Moderate (Potential)
GB30935568	Lake Vyrnwy / Llyn Efyrnwy	Moderate (Potential)	Moderate (Potential)
GB109054049880	R Vyrnwy - Lake Vyrnwy to conf Afon Cownwy	Moderate (Potential)	Moderate (Potential)
GB109054049720	Afon Vyrnwy - conf Afon Cownwy to conf Afon Banwy	Moderate (Potential)	Moderate (Potential)
GB109054049850	Afon Vyrnwy - conf Afon Gam to Afon Tanat	Moderate (Potential)	Moderate (Potential)
GB109054049800	Afon Vyrnwy - conf Afon Tanat to conf R Severn	Moderate (Potential)	Moderate (Potential)

United Utilities is currently working with Natural Resources Wales and the EA on the Afon Cownwy AMP5 investigation, reviewing reservoir operations for Lake Vyrnwy with the aim of helping to achieve Good Ecological Potential.

10.2. Assessment of Impact on WFD Status

Assessment of the River Severn Drought Order impacts against WFD compliance has been carried out within the water quality (section 6.3) and ecology (7.4 and 7.5) sections of this report. For more detail refer to the relevant chapters and appendices. An overall conclusion is presented within this section.

10.3. Impact on WFD Status Conclusion

Temporary deterioration of WFD status is a natural consequence of prolonged drought events, as stated by Article 4.6 of the Directive.

The River Severn Drought Order is an Environment Agency mitigation measure intended to manage deterioration of WFD designations during severe natural drought events. The drought order is expected to support essential public water supply abstraction in a sustainable manner during the severest of droughts, whilst benefiting the environment by protecting against significant flow failure should resources in Llyn Clywedog be exhausted.

Historic drought events provide evidence (Appendix B) that lowering prescribed flows at Bewdley down to 545 Ml/d during the 1976 drought order operation, still maintained flows higher than would naturally have been occurring at Bewdley, and at least the same as would have naturally occurred at Haw Bridge.

Modelling indicated that flows and water quality would deteriorate below local WFD targets as part of the natural drought process, regardless of whether the River Severn Drought Order was operated or not. While the Severn Drought Order could marginally increase the duration of impact on flows and therefore the environment in the short term, the long term gains are clearly beneficial to the environment and WFD objectives. No additional WFD water quality failures are predicted during the River Severn Drought Order operation and all flow and subsequent ecological impacts are expected to be short term with a quick recovery in line with the natural event.

The impacts of the River Severn Drought Order are therefore considered to come under Article 4.6 of the Water Framework Directive, allowing for temporary deterioration as a 'result of circumstances of natural cause which are exceptional or could not reasonably have been foreseen, in particular extreme floods and prolonged droughts.'

The in combination assessment has to consider the impact of maximum abstraction from the Gloucester & Sharpness Canal (details in section 5.4.3.2). If abstraction were maintained at a maximum 300 Ml/d, the same conclusion would apply. If abstractions were to be higher, there could be potential for ecological impacts to exceed those expected from the natural drought event, more investigation work would be needed.

For more detailed discussions and evidence refer to the individual impact assessment sections.

11. Archaeological and Cultural Heritage

11.1. Baseline Environment

The River Severn passes through a landscape exceptionally rich in archaeological sites and historic buildings. The physical evidence of past human activity covers every period, from the Palaeolithic to the modern; many of the key sites lie within the floodplain of the river. The management of this unique resource is undertaken at several levels – by international treaty, statutory protection, government guidance, registers and local plan policies.

The cultural resource of the River Severn is very fragile, and once lost it cannot be restored. Much remains unknown about the scale of survival, especially in the lower river where alluvium has covered numerous sites of importance. The concentration of known prehistoric sites in the upper Severn is greater for two reasons: there has been less deposition owing to the more active nature of the river in the upland zone; and aerial photography has been able to identify sites which have been buried under shallow deposits. In the middle and lower sections of the river, medieval and post-medieval sites assume a greater importance as a result of the use of the river as a communications route and the development of settlement and industry. Prehistoric sites are likely to be as important in these lower parts of the river, but they remain undiscovered.

11.1.1. World Heritage Sites

The UK Government, as a signatory to the World Heritage Convention, has undertaken to protect and conserve a number of sites which have been designated as of World Heritage significance. There is no special legislation for the protection of World Heritage Sites in the UK. In fact emphasis is placed upon the existing framework of protection, with the use of management plans linked to planning policies. PPG 15, Planning and the Historic Environment, identifies World Heritage Site status as a material consideration in the planning process.

The study area includes one World Heritage Site, the Ironbridge Gorge, which comprises the Coalbrookdale, Ironbridge, Jackfield and Coalport Conservation Areas, and includes within this several Scheduled Ancient Monuments and many Listed Buildings. The River Severn passes through the World Heritage site for a distance of some 4 km.

11.1.2. Scheduled Ancient Monuments

Scheduled Ancient Monuments (SAMs) are those monuments which are considered to be of national importance. While their designation goes back to 1882, the current legislation that covers their management is the Ancient Monuments and Archaeological Areas Act 1979. This restricts works to a designated monument, and consent has to be sought from the Secretary of State for Culture, Media and Sports (or in Wales, by the Secretary of State for Wales), on advice provided by English Heritage and Cadw. Works includes: activities such as excavation, dumping, repair and deliberate flooding, but does not include the current land use of the monument. SAMs receive protection through the national planning system in the form of planning guidance (including PPG 16, Archaeology and Planning, regional planning guidance and planning policies).

Within the study area there are a number of SAMs including the first iron bridge ever built, located at Ironbridge, and also SAMs associated with battlefield sites in Shrewsbury.

11.1.3. Listed Buildings

The Secretary of State for the Environment is required to compile lists of buildings of special architectural or historic interest, for the guidance of local planning authorities in the exercise of their own planning functions under the Town and Country Planning Act 1971 and as revised in Section 1 of the Planning (Listed Buildings and Conservation Area) Act 1990. The principles of selection for the lists were drawn up by the Historic Buildings and Monuments Commission (HBMC) (formerly the Historic Buildings Council) and approved by the Secretary of State.

Within the study area, there are a very large number of listed buildings, especially in the historic urban centres of Gloucester, Tewkesbury, Worcester, Bridgnorth, Shrewsbury and in Telford, Coalport and Ironbridge.

11.1.4. Conservation Areas

The designation of conservation areas has also been developed over a number of years, but most recently through the Planning (Listed Buildings and Conservation Areas) Act 1990. The management and conservation of these areas is guided by national policy, PPG 15, regional and local planning policy. The primary aim of Conservation Areas is to protect the built environment and the settings of listed buildings.

Within the study area most of the historic centres have been designated conservation areas, which include the river and its banks. Historic centres include Gloucester, Worcester, Shrewsbury and the smaller towns, through to the Central Marches Bridgnorth, Upton on Severn, Bewdley, Stourport and many villages.

The objective of this environmental assessment is to assess the potential impacts imposed by the River Severn Drought Order. The primary aim of Conservation Areas is to protect the built environment and the settings of buildings within it. Imposing a drought order would not significantly impact upon the architectural setting. However it is accepted that there may be adverse impacts for plants shrubs and trees through shortage of water. However, this would be temporary and not significant for the long term therefore no further assessment has been undertaken.

11.1.5. Register of Historic Parks and Gardens

This register is maintained by English Heritage (and in Wales by Cadw), to provide a listing of important parks and gardens. It has no statutory status. However in PPG 15, registration is considered to be a material consideration in the planning process. Most local plans contain policies for historic landscapes, parks and gardens.

Parks and Gardens in England and Wales have always been subject to variation in weather and sometimes these variations are extreme (1976 summer drought and the winter of 1962). Implementation of a River Severn Drought Order would not affect the architectural layout and landscape design of a Parkland or Garden. It is accepted that there may be adverse impacts for plants shrubs and trees however this would be temporary and not significant for the long term well being of the Parks and Gardens and therefore no further assessment has been undertaken.

11.1.6. Register of Battlefields

A register is maintained by English Heritage to provide a listing of important battlefields. It has no statutory status. However in PPG 15, their designation is considered to be a material consideration in the planning process. Within the study area there are three battlefield sites: at Shrewsbury, Worcester and Tewkesbury.

Historic Battlefield Sites in England and Wales have always been subject to variation in weather and sometimes these variations are extreme (1976 summer drought and the winter of 1962). Imposition of a River Severn Drought Order would not affect the geographical position or indeed its historic merit. It is accepted that there may be adverse impacts on the landscape setting (i.e. lack of water for plants shrubs and trees) However, this would be temporary and not significant for the long term well being of the Battlefield Site and therefore no further assessment has been undertaken.

11.1.7. County Sites and Monument Records

The county-based Sites and Monument Records (SMRs) provide a non-statutory inventory of archaeological sites (and in some cases, listed buildings). The record has been built up, over a number of years, from the National Monuments Record.

The coverage of the study area includes independently maintained SMRs for Clwyd/Powys, Shropshire, Hereford and Worcester and Gloucestershire.

The existence of a site on the SMR does not in itself provide for its protection or management. However, it can provide a first indication of potential archaeological interest, where development is proposed and with appropriate consultation protection of such sites can be provided through the planning process, through Planning Policy Guidance. In fact PPG 16 Archaeology and Planning confirms that archaeology is a material planning matter.

In some cases organizations (mainly the private utilities) which have exemptions from the planning process have undertaken to consult the SMR and agree voluntary mitigation where necessary. The Water Act Code of Conduct and the Water Recourses Code of Practice emphasise the need to establish and maintain channels of Liaison and Consultation with all the appropriate consultee's (including archaeological) bodies, statutory and non-statutory, and landowners.

The Conservation Guidelines for Drainage Authorities, 1991 set out the statutory obligations of the former NRA and the Internal Drainage Boards (IDBs) which includes having regard to protecting and conserving buildings and sites of archaeology, architectural or historic importance.

11.1.8. Landscape

The River Severn flows through some of the UK's most attractive and protected landscapes. The Shropshire Hills in the north and the Malvern Hills and Cotswolds in the south are noted as areas of Outstanding National Beauty (AONB) and the area around Telford is noted as a World Heritage Site. Many of the cities and towns of the region have attractive protected conservation areas and lie within the River Severn corridor, or front on to it. The river corridor itself contributes to that attractiveness.

In 1998 and 2001, as a first step towards raising the profile of historic landscapes in Wales, Cadw, CCW and ICOMOS (UK) (International Council on Monuments and Sites) published the Register of Landscapes of Historic Interest in Wales. This is an advisory but non-statutory document

highlighting what are considered to be the best examples of different types of historic landscape in Wales. The Maesmawr character area of the Caersws Basin features the fieldscape along the River Severn and the floodplain. The Trehelig-gro character area of the Vale of centres on a timber framed cottage on the bank of the Severn which was the site of a ferry and ford across the river.

The River Severn has always been subject to variation in weather and sometimes these variations are extreme (e.g. 1976 summer drought). During high rainfall events river flow can increase significantly. High flow causes erosion by over topping or breaking through river banks, which can transform the landscape. Implementing the River Severn Drought Order is intended to protect and maintain flows at a lower rate. It is accepted that lack of rainfall during drought may have an adverse impact on the landscape (contemporary and historic) setting through a lack of rainwater for plants shrubs and trees. However, this would not be an effect related specifically to a drought order and therefore no further assessment has been undertaken.

11.2. Summary of Existing Drought Impacts

[Section to be completed when applying for a River Severn Drought Order]

11.3. Assessment of Impact on the Current Environment: Archaeology and Cultural Heritage

The potential effects of a natural drought on cultural heritage have been summarised as (Coles, 1995):

"a rapid fall in water levels, with the consequent desiccation of bogs and fens, increased fire risk, increased fire growth and increased activity of burrowing animals. In times of drought it is also likely that rainfall recharge of the aquifer will decrease leading perhaps to drying out of spring fed fens, particularly if conditions are exacerbated by over abstraction. None of this is good for archaeological sites and organic material will be particularly vulnerable under a regime of increased fluctuation between flood and drought."

11.3.1. Lowering of the Water Table through Reduced River Flow

Archaeologists would consider that the drying out of waterlogged sites is the most severe problem associated with drought conditions. It is often very difficult to monitor loss, and in extreme conditions all trace of these organic materials will disappear from the soil. Examples of lost evidence of past human activity includes environmental material (such as macro plant remains and wood, insects and pollen) used to reconstruct past climates, and past economic activity; and artefacts made of wood, bone, leather and textiles. Organic materials survive in the ground where they are protected from micro-organisms. Drying out allows oxygen and thus micro-organisms to come in contact with the materials, and decay rapidly follows: Experiments suggest that materials that have survived over 2000 years may decay within months. A particularly damaging situation is where wet and dry conditions exist, with seasonal fluctuations.

The scale of waterlogged preservation within the river floodplain is unknown. Excavations at Shrewsbury Abbey in the 1980s identified waterlogged medieval deposits, and it can be assumed that the other riverside abbeys contain a similar degree of waterlogged preservation. Examples would include Tewkesbury, Buildwas and Alberbury (all, except Alberbury are SAMs). Features include mills; drains (and their organic fills) and fishponds. The major Roman urban/military sites of Caersws, Wroxeter, Worcester and Gloucester, although for the most part dry, have areas of

potential waterlogging, especially in the base of ditches and on riverside features such as wharves and bridges. The motte and bailey castles in Powys which are close to the river will have waterlogged deposits in their ditch fills.

Fish weirs were a particular feature on the Severn in Shropshire. These were wooden and wicker structures and the bases probably survive in the waterlogged conditions. Reduced river flow could result in the loss of these structures.

The general lowering of the water table could also affect the stability of the foundations of listed buildings, of which there are many hundreds within the study area. Underpinning of these buildings would then be needed, and this would have a further damaging effect on the below-ground archaeology associated with these structures.

11.3.2. Changes in River Flow

The course of the river has changed considerably over the last 10,000 years, especially in the upper and middle sections of the River Severn and Afon Vyrnwy. This is visible from preserved palaeochannels, representing very substantial changes in the river courses during the period of the formation of the archaeological record. The middle sections of these rivers are still actively migrating (Lewin 1992), and this causes potential erosion and loss of archaeological sites which were once some distance from the river, but at the same time protecting others by covering them with alluvium. While this is a natural process, the present regulated flows will affect the rate of loss compared with that in the pre-regulated river. Broadly, low flows are to be preferred, and will cause the river banks to erode less; floods create major loss and, on occasions, new channels can develop.

Historic riverside structures such as wharves, weirs and bridges are also vulnerable to river flow changes. Here the effect is complicated, because a period of low flow may cause the structures to dry out and any organic component to decay, thus destabilising them. Bridges and bridge piers are particularly vulnerable in this respect.

11.4. Conclusion

The natural drought event represented by the Do Nothing scenarios, under both the Acute and Chronic Conditions, could dry out some archaeological features and increase the risk of fires. However many features detailed would also benefit from lower flows. Modelling found the River Severn Drought Order would initially lower water levels and flows along the main River Severn corridor. The Acute and Chronic Conditions both showed that if the drought persisted, higher flows and water levels would be supported than under the Do Nothing (Baseline) scenario. Therefore a benefit would be provided to those features that are considered more sensitive to low flows. Any adverse impacts would be temporary and have no prolonged adverse impact; therefore no adverse impact is concluded.

11.5. Monitoring and Mitigation Options

The Environment Agency has an established environmental monitoring network within the river Severn catchment. On the conclusion of no adverse impact, no additional monitoring is recommended.

12. Navigation and Recreation

12.1. Baseline Environment

12.1.1. Llyn Clywedog Reservoir

It is understood that Llyn Clywedog Sailing Club has boats moored in the water and stored on the bankside between March and October. The Club's launching facilities are also used by Powys Education Centre which has an outdoor centre at the reservoir.

The reservoir is drawn-down during the summer to support the River Severn, which is the reservoir's primary function. During a normal summer the reservoir operates above 70% full. In dry summers, the level may drop and a drought order may be sought in line with drought order curves (Figure 5) in order to conserve water in the reservoir.

Historic data from the sailing club indicated that access to the water benefits from an old road; part of the infrastructure of the valley prior to flooding which provides an extension to the club's launching ramp. This allows access across the mud to the retreating water's edge in most summer circumstances, (including previous droughts). It is only in very extreme circumstances that use for sailing is ceased. This did occur in 1989, when water levels dropped so low that sailing ceased in August rather than continuing through to October.

The effect of severe depletion of the water resource has an impact on access to the water for recreational use. A vast expanse of mud is exposed by extensive drawdown, which creates difficulty for water users in reaching the water's edge. In addition, a much smaller body of water leads to problems of limited space for users and produces unusual wind conditions (Llyn Clywedog Sailing Club, pers. com.).

12.1.2. Lake Vyrnwy Reservoir

Lake Vyrnwy itself offers a variety of water sport and fishing opportunities, while the combined area attracts tourists throughout the year. The reservoir was created principally to provide water supplies to the North West, and is drawn down throughout the year. A smaller portion of the water is retained solely for supporting downstream watercourses and primarily the River Severn.

It is understood that Bethania Adventure provides canoeing, kayaking, sailing and windsurfing opportunities to tourists, and allows private boat launches from its facilities. No information was found which relates volumes and levels in Lake Vyrnwy reservoir to recreational use at the time of writing this report. However, as with Llyn Clywedog, it is likely that a severe depletion of the water levels would have an impact on access to the water for recreational use.

Lake Vyrnwy's 1,100 acres remains the world's second oldest manmade trout fishery, with fly fishing dating back to 1818. Lake Vyrnwy Hotel and Spa have exclusive fishing rights over the reservoir, with year round fishing reported for wild brown and stocked brown and rainbow trout.

12.1.3. Upper Catchment

The majority of boating in the upper catchment is canoe (both Indian canoes and kayaks) and raft-based (used during raft races). Following the construction of the Llyn Clywedog reservoir, river regulation releases maintain higher river levels during summer, which benefits water based

activities. It is less beneficial for coarse fishing as releases can flush sediment down the river, increasing turbidity, smothering eggs and having a cooling effect. Low water levels and higher water temperatures tend to increase coarse fishing success, so drought can have beneficial effects, unless it is so severe that fish mortality occurs. High water levels are necessary for salmonids to move up the river to spawn, but regulated water does not necessarily achieve this as successfully as a fall of fresh rain.

The specific Montgomery Canal abstractions in Powys are covered in sections 5.1.5.3 and 5.4.3.

12.1.4. Middle Catchment

More commercial boating and rowing activity is associated with the middle catchment, as well as competitive angling. Previous work by the Environment Agency identified a number of sites between Buildwas and Bewdley where certain reaches of the river could become unnavigable at times of low flow, although the river is not navigable upstream of Stourport. Below Stourport the character of the river changes owing to the locks and weirs and these, together the additional input of the River Stour, help to maintain higher water levels.

12.1.5. Lower Catchment

The river downstream of Stourport is within the Canal & River Trust navigation control; locks and weirs help to maintain water levels at the crest height of the weirs.

Far greater use of the river by vessels occurs in the lower catchment. As well as canoes and kayaks, the river is used by narrow boats, powered craft and cruisers, and ocean going yachts and commercial barges still carry grain between Gloucester Dock and Tewkesbury. These all have different water depth requirements: narrow boats need 0.6 m of water while the cruisers, large yachts and commercial barges need 1.8 to 2.1 m. The Canal & River Trust are required to maintain a navigable depth of 2.4 m[28] in the River Severn, which is normally achieved by dredging. This is costly and has an adverse impact on the environment through sedimentation, the Environment Agency advice against dredging during low flows because the environment is more vulnerable during these conditions.

During the drought of 1995, commercial vessels and larger sea-going craft did experience considerable difficulty in travelling between Gloucester and Tewkesbury, because in some sections of the river only approximately 1.44m of water depth was available (Source: Inland Waterways Association, pers. comm.). The River Severn Drought Order was not in operation during 1995, which provides a useful comparison of how natural low flows and drought conditions can create the initial impacts on navigation.

As water levels fall, the effective width of the river is reduced and this can make the passing of boats in mid-stream more difficult. Risk of grounding, of keel damage or risk of collision with other vessels all increase if water levels fall severely. As water levels fall, the minimum level between Stourport (in the middle catchment) and Gloucester is set by the numerous weirs, which only allow the water level to fall to the weir crown height, below which there is no flow.

The specific Gloucester & Sharpness Canal abstraction from the River Severn is covered in sections 5.1.5.3 and 5.4.3.

With regard to fisheries and angling, past degradation of fish habitat has occurred, owing to the construction of weirs and the use of the river for navigation purposes. Coarse fishing takes place

[28] navigable depths are currently (2013) under review and maybe subject to change.

throughout the lower catchment, but low flows have been identified as a problem at various locations. More details can be found in the Fish Technical report in Appendix P.

12.2. Summary of Existing Drought Impacts

[Section to be completed when applying for a River Severn Drought Order]

12.3. Assessment of Impact on the Current Environment: Navigation and Recreation

Impacts on the abstractions for the Montgomery canal in Powys, and the Gloucester & Sharpness Canal in Gloucestershire can be found in section 5.4.3.

12.3.1. Impact on Llyn Clywedog Reservoir

No information exists which relates volumes and levels in the reservoir to recreational use. Assessment is based on historic information from discussion with Llyn Clywedog Sailing Club.

Sailing and boating activities should largely be able to continue through the drought until late in the summer (late August). The modelled River Severn Drought Order conserves water resources within Llyn Clywedog by 11% total storage, allowing sailing to continue for longer than if no action were taken ('Do Nothing' scenario). Under the 'Do Nothing' scenario, the water resource in the reservoir would continue to diminish into dead water (<5%), making it no longer possible to sail if the drought continued long enough.

Implementation of the River Severn Drought Order would clearly have a positive impact by conserving water resources and prolonging the extent of the sailing season on Llyn Clywedog. In addition, the recovery time (reservoir refill) is reduced by applying the drought order, subsequently reducing the duration of drought impact on the sailing club and helping to protect against a second year of impact.

12.3.2. Impact on Lake Vyrnwy Reservoir

No information was found which relates volumes and levels in Lake Vyrnwy reservoir to recreational use at the time of writing this report. However the River Severn Drought Order would not increase the maximum quantity of water released from the reservoir compared to normal operation. The Vyrnwy waterbank would be fully utilised, but this is in accordance with normal regulation years. Levels within Lake Vyrnwy would be lowered as a result of the drought and high public water supply demands, but this drought order does not seek to amend the quantities used. No impact was concluded on recreational use of Lake Vyrnwy.

12.3.3. Impact on River Severn Navigation

The main impact upon water based recreation in the main river from severe drought is the effect on water levels (i.e. water depth) and channel width. This directly affects access down the river for boats. Low water levels during the summer have caused problems for large vessels, in particular the commercial barges, with concern directed towards the quantity of water abstraction (an Environment Agency function) and frequency of dredging (a Canal & River Trust function). During

1995 commercial vessels experienced considerable difficulty in navigating between Gloucester and Tewkesbury with a water depth of only approximately 1.44 m in places (Source: Canal & River Trust, pers. comm.).

Navigation along the River Severn from the middle to lower catchment could be significantly impacted by the lowered water levels from the River Severn Drought Order preceding any regulation failure, making passage over weirs and through locks limited according to the drought severity. The level of impact is likely to vary locally and be exasperated by in combination abstractions, making it impractical to quantify at the River Severn catchment scale. Taking a worst case precautionary approach, navigation by the majority of vessels could largely be prevented until high rainfall events raise water levels.

The exact duration of a future drought cannot be predicted and will depend on rainfall patterns; modelling work estimated flow depressions could last for approximately 70 days (between August and October), with approximately 20 days of severe flow depression (resulting from regulation failure) where navigation is almost certainly unlikely. However, if the River Severn Drought Order were not operated then more severe flow depressions would result after regulation failure. Realistically the impact from the River Severn Drought Order for consideration is the lead-in time, prior to regulation failure, where flows are lowered by approximately 120-140 Ml/d from Buildwas downstream. This period was modelled as approximately 45 days starting at the end of August, but every event will be different.

Data is not currently available to assess the local impacts of lowering water levels at every lock and weir along the River Severn, so a precautionary assumption of there being no navigation possible for boats has been adopted.

12.3.4. Impact on Angling

Section 7.5 contains the conclusions for fish species within the River Severn while the Habitats Regulation Assessment report considers the Estuary fish species and migration in greater detail. Please refer to this section and report for detail.

With regard specifically to angling, falling water levels are likely to have a beneficial effect upon fish catches initially. However as the drought persists, as shown by the Acute and Chronic Conditions, adverse effects upon fish survival are likely (section 7.5 contains details). Analysis showed that flows and water levels during the critical periods would be lowest in the 'Do Nothing' scenarios. Operating the River Severn Drought Order in both the 'Drought Order Only' and 'Full In-Combination' scenarios provided benefits to fish by increasing water levels and flows, which should also benefit angling interests.

In the lower catchment in particular, where locks and weirs are extensive, water levels could fall below the weir crest height and effectively prevent flow. This can then have adverse effects upon water quality and fish movements, resulting in elevated stress and potentially mortality. At such times, if it is considered that angling is leading to further stress to fish it may be necessary to introduce a temporary cessation of fishing activities. Although this would have a temporary negative impact on angling interests, it would benefit fish populations and recovery rates, which would be of benefit to angling in the longer term.

13. Summary of Impacts

The environmental report has used the water resource model Aquator to predict potential changes in River flows that may result from operating the River Severn Drought Order. Two magnitudes of drought were modelled, an 'Acute Condition' and a 'Chronic Condition,' to investigate the potential impacts from a short and a long term drought event. Within each drought condition, a further three scenarios was created to investigate the direct, indirect and potential cumulative impacts from the River Severn Drought Order operation.

The 'Do Nothing (Baseline)' scenario tested what could happen if the River Severn Drought Order was not used, providing the baseline drought conditions/impacts for testing the other scenarios against. The 'Drought Order only' scenario tested the operation of the River Severn Drought Order and normal abstractions and discharges, while the 'Full In-Combination' scenario tested the potential cumulative impacts of all the water company drought orders and the maximum potential abstraction for the Gloucester & Sharpness Canal on top of the River Severn Drought Order operation.

The results from the flow modelling have been used to assess potential impacts on the following receptors;

- Hydrology and water resources (including impacts on other abstractors)
- Water quality
- Ecology (Macroinvertebrates and fish populations, recruitment and migration)
- Designated sites connected to the River Severn
- The Severn Estuary
- Archaeological and cultural heritage
- Navigation and recreation

Individual technical reports and impact conclusions were produced for the Hydrology, Water quality, Macroinvertebrates and Fish receptors, which can be found in Appendices I, L, O and P respectively. All the designated sites in connection to the River Severn were considered and screened in Appendix A, and a separate Habitats Regulation Assessment was conducted for the Severn Estuary (Annex 1). All these documents have been summarised within the relevant sections of this environmental report.

The individual assessments have investigated whether the River Severn Drought Order could have a positive or negative impact on the environment and water users under the Acute and Chronic Conditions. The assessments also discussed how the impacts would change as the drought developed and whether the impacts were likely to be temporary or permanent. The ecological assessments also discussed what could happen if a drought order application/implementation occurred at a different time of the year, and/or if adverse weather or high temperatures also coincided.

Section 4 details the method used to summarise the individual assessments into an overall risk category. This method has been applied to the two reservoirs, original eight assessment points, the Severn Estuary (due to its significance) and the two watercourses identified as potentially being indirectly (Secondary Path) at risk.

13.1. Summary of potential risk

Table 27 summarises the results of the original environmental assessments, assuming the Gloucester & Sharpness Canal abstraction could reach a maximum of 691 Ml/d under the Full In-Combination scenarios. A final summary of potential risk, accounting for mitigation options, is provided in section 13.2.

Table 27: Summary of Potential Risk

Site Name	Do Nothing (baseline)	Drought Order Only	Full In-Combination*
Llyn Clywedog reservoir	High Risk	Low Risk/Benefit	Low Risk/Benefit
Lake Vyrnwy reservoir	Low Risk/Benefit	Low Risk/Benefit	Low Risk/Benefit
Clywedog AP	High Risk	Low Risk/Benefit	Low Risk/Benefit
Vyrnwy AP	Low Risk/Benefit	Low Risk/Benefit	Low Risk/Benefit
Buildwas AP	Medium Risk	Low Risk/Benefit	Low Risk/Benefit
Bewdley AP	Medium Risk	Medium Risk	Medium Risk
Saxons Loade AP	Medium Risk	Medium Risk	Medium Risk
Deerhurst/Haw Bridge AP	Medium Risk	Medium Risk	Medium Risk
U/S Sharpness AP	Medium Risk	Medium Risk	Medium Risk
Lower Parting AP	High Risk	Medium Risk	High Risk
Severn Estuary	High Risk	Low Risk/Benefit	Medium Risk
Tenbury control point (River Teme)	Potential Indirect Risk	Potential Indirect Risk	Potential Indirect Risk
Llanyblodwell control point (River Tanat)	Potential Indirect Risk	Potential Indirect Risk	Potential Indirect Risk

** Full In-Combination summary assuming the Gloucester & Sharpness Canal abstraction could reach a maximum of 691 Ml/d.*

The potential risk categories for the 'Do Nothing (baseline)' and 'Full In-Combination' potential risks have also been summarised into Figures 20 and 21. These maps help to illustrate where the environment is most at risk during an Acute or Chronic magnitude drought.

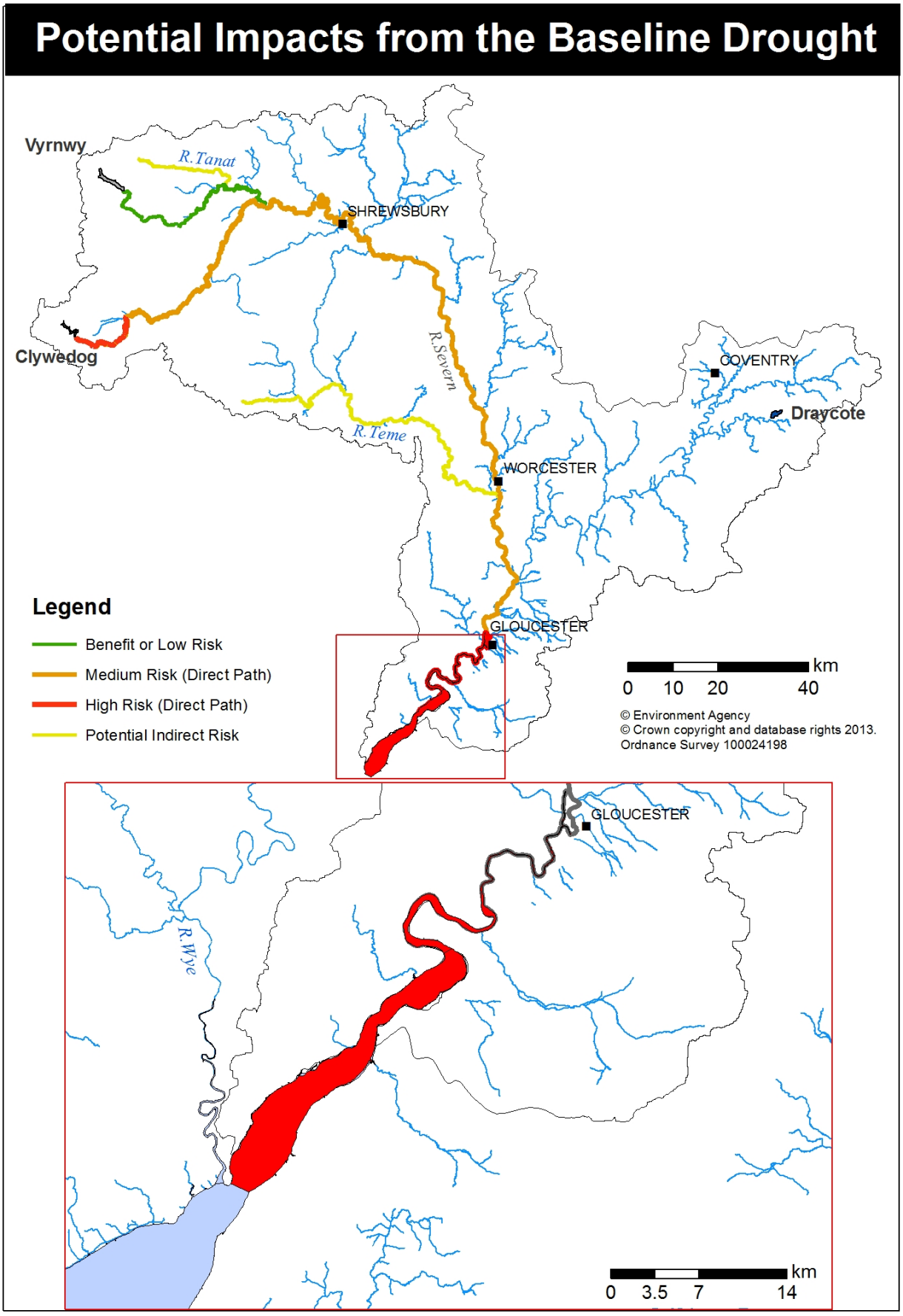

Figure 20: Potential Impacts from the baseline (Do Nothing (baseline) scenario) drought

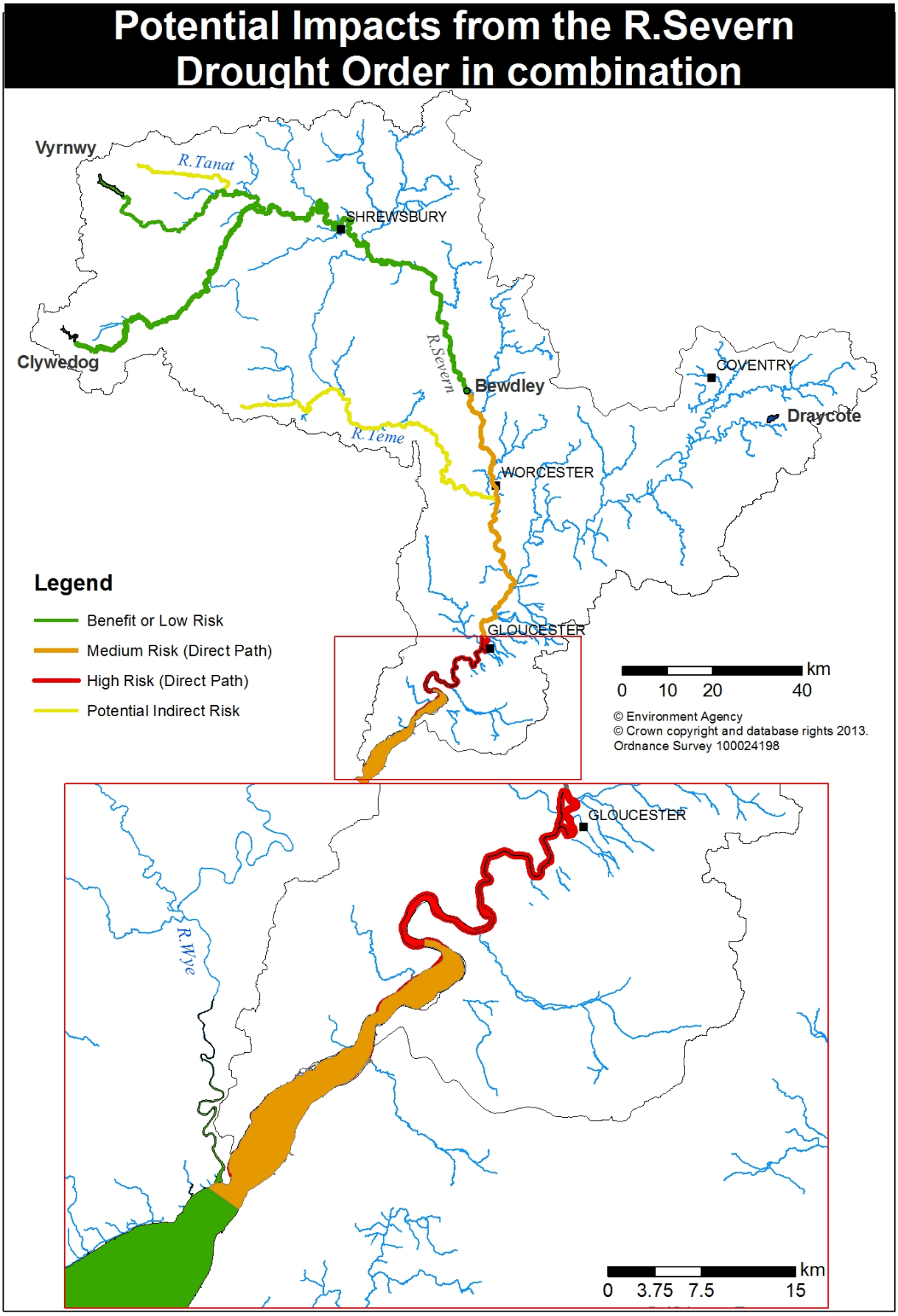

Figure 21: Potential Impacts from the River Severn Drought Order Full In-Combination with water company drought permits and the Gloucester & Sharpness Canal abstraction at maximum 691 Ml/d abstraction.

13.2. Summary of potential risk post mitigation measure

The environmental assessments identified the Full In-Combination scenarios (for Acute and Chronic Conditions) posed a high risk to the Lower Tidal Severn and a medium risk to the Severn Estuary Natura 2000 site (summarised in section 13.1). As a competent authority under the Habitat's Directive, we have to consider ways to mitigate against potential environmental harm or prove grounds of Imperative Reasons of Overriding Public Interest.

The conclusions within this report identified the biggest uncertainty and risk was posed by the potential for the Canal & River Trust to abstract up to 691 Ml/d. The most appropriate option to balance water abstraction needs and the requirements of the Habitat's Directive was found to be limiting the abstraction to the Gloucester & Sharpness Canal, as part of the drought order application.

The Habitats Regulations Assessment used historic data and reports from previous drought order events, alongside current data analysis tools, methods and expert knowledge to assess the potential impacts. Existing data enabled the assessment of an abstraction to the Gloucester & Sharpness Canal up to 300 Ml/d to be concluded as not having a likely significant effect on the Natura 2000 site and its designated species. Historic evidence was used to assess the potential impact of the canal abstracting close to the 691 Ml/d maximum for short periods, concluding a significant impact could result. Insufficient data and evidence to justify further investigation to date has prevented sensitivity testing of abstraction volumes between these values.

The initial draft environmental reports went out to public consultation during the summer of 2013 identifying a potential in combination impact on the Natura 2000 site, and that further collaborative work was needed to resolve this issue. Consultation representations received through this process (contained in Appendix V) expressed concern with this outstanding issue, highlighting that until a mitigation option was identified the River Severn Drought Order should not be used in combination or we would be in breach of the Habitats Regulations 2010.

Leaving the River Severn without a drought order option in the interim posed an unacceptable risk to the people and environment which rely on the water. Based on the Habitats Regulations Assessment work, a new abstraction cap of 300 Ml/d (figure subject to change) will form part of the application for a River Severn Drought Order. The abstraction cap from the River Severn to the Gloucester & Sharpness Canal, will only apply when flows at Deerhurst gauge fall below 1200 Ml/d and the River Severn Drought Order is active.

Because our consultation draft reports did not include this abstraction cap condition, the Canal & River Trust did not have an opportunity to respond to the impact in their consultation representation. We have been in discussions and held a meeting with the Canal & River Trust since the official consultation period closed to enable them to submit a more informed representation, and to identify future work. The Canal & River Trust raised concerns that 300 Ml/d could pose a risk to their operation of the canal and their confidence in being able to supply water to Bristol Water for its Purton abstraction. The Canal & River Trust have also expressed concern that their abstraction would be disproportionately restricted under the River Severn Drought Order when compared to conditions applied to the other abstractors. Appendix V contains the Canal & River Trusts responses, alongside all the representations we received.

The Environment Agency have committed to working with the Canal & River Trust to investigate their concerns further. If sufficient evidence can be provided to show a higher abstraction is justified, the Environment Agency is committed to reviewing the restriction volume in the future.

Based on the new Gloucester & Sharpness Canal abstraction cap being in force when a River Severn Drought Order is active, the potential risk under the Full In-Combination scenarios was re-assessed. Table 28 summarises these results.

Table 28: Summary of Potential Risk post mitigation measure

Site Name	Do Nothing (baseline)	Drought Order Only	Full In-Combination*
Llyn Clywedog reservoir	High Risk	Low Risk/Benefit	Low Risk/Benefit
Lake Vyrnwy reservoir	Low Risk/Benefit	Low Risk/Benefit	Low Risk/Benefit
Clywedog AP	High Risk	Low Risk/Benefit	Low Risk/Benefit
Vyrnwy AP	Low Risk/Benefit	Low Risk/Benefit	Low Risk/Benefit
Buildwas AP	Medium Risk	Low Risk/Benefit	Low Risk/Benefit
Bewdley AP	Medium Risk	Medium Risk	Medium Risk
Saxons Loade AP	Medium Risk	Medium Risk	Medium Risk
Deerhurst/Haw Bridge AP	Medium Risk	Medium Risk	Medium Risk
U/S Sharpness AP	Medium Risk	Medium Risk	Medium Risk
Lower Parting AP	High Risk	Medium Risk	Medium Risk*
Severn Estuary	High Risk	Low Risk/Benefit	Low Risk/Benefit*
Tenbury control point (River Teme)	Potential Indirect Risk	Potential Indirect Risk	Potential Indirect Risk
Llanyblodwell control point (River Tanat)	Potential Indirect Risk	Potential Indirect Risk	Potential Indirect Risk

**Improvements achieved through the abstraction cap on the Gloucester & Sharpness Canal.*

As shown in Table 28, a higher certainty could be used to conclude the Severn Estuary would no longer be at medium risk of impact, and the risk to the Lower Tidal Severn was reduced from high to medium risk. With the Gloucester & Sharpness Canal restriction measure in force, the Habitat Directive requirements are satisfied under the Full In-combination scenarios. The Natura 2000 site and species would benefit from the prolonged regulation period enabled by the River Severn Drought Order implementation, providing greater protection than under the 'Do Nothing (Baseline)' scenarios.

13.3. Limitations

A number of limitations encountered during the individual assessments have been identified within each relevant section. These have been used to produce the list of future work recommendations listed in Appendix T; however the most urgent recommendations are contained in section 17.

A common difficulty was a lack of predictive models specifically designed for drought purposes. Most models had to be manually manipulated to produce theoretical drought conditions, rather than allowing 'what if' queries to be run to provide a more intuitive function. The artificial nature of the River Severn and complex interactions of abstractions and regulation releases on this scale also made it difficult to model drought impacts with high certainty, particularly as all drought events will be different. The drought conditions modelled provide a steer on the potential worse case eventualities, but all droughts are different and we cannot guarantee the exact timings and magnitudes of future droughts.

Due to limited baseline drought data, uncertainty remains around the magnitude of impact which could be experienced along the River Severn in response to the River Severn Drought Order. The last drought order operation was in 1989. Sampling methods, designations, data records, water quality requirements and basic abstractions and discharges (due to population changes) have all changed considerably in the last twenty years. Specific low flow and drought order monitoring has been identified in this report as a result, however until a drought order is operated we cannot collect the most relevant data needed to improve the certainty.

Uncertainty remains around the dry weather and drought operations of the Gloucester & Sharpness Canal. The Canal & River Trust remain exempt from abstraction licensing for the routine abstractions to this canal. The abstraction from the River Severn can range from 0 to almost 700 Ml/d on a daily basis under normal operation, varying with tide heights and navigation demands. The new drought order restriction will allow the Environment Agency to work with the Canal & River Trust to regulate these abstractions during a drought order implementation, a measure which has improved the certainty around the impact conclusions made. Work is ongoing to refine the abstraction volume and improve the conceptualisation of this section of the River Severn.

14. Mitigation Options

This section identifies potential options the Environment Agency will consider to help alleviate environmental stress during a River Severn Drought Order magnitude event. The mitigation options aim to delay the need for the River Severn Drought Order activation, provide greater flexibility within the regulation system and/or reduce environmental impacts in the reaches identified as medium to high risk.

The options have been divided into actions the Environment Agency could achieve in isolation, and options that could be achieved through collaborative and partnership working. For more generic drought management strategies please refer to the Environment Agency Midlands Drought Plan http://www.environment-agency.gov.uk/homeandleisure/drought/136954.aspx.

14.1. Environment Agency Mitigation Options

During River Severn Drought Order operation there are options which the Environment Agency could independently act upon to help remediate any resulting negative environmental impacts. The option/s taken will vary according to the unique nature of each drought event, weather forecasts and the resources present at the time.

The identified options include;

1. **Fish rescues.** Careful consideration would be needed in deciding where to release stranded fish. The River Severn is supported by regulation and therefore expected to be experiencing less drought stress than more natural catchments.
2. **Temporary actions to make fish passes, weirs and in channel structures passable to migratory fish.** Consideration would be taken in deciding whether upstream and tributary flows were sufficient to support onward fish movement and/or spawning before taking action.
3. **Temporary restrictions/cessations of fishing activities to reduce stress.**
4. **Consider directing resources into bringing new or inactive boreholes/phases of the SGS online.** Water quality and ecological considerations would be needed before taking action.
5. **Apply for a SGS Drought Order to provide additional support to Llyn Clywedog** (as part of the River Severn Drought Order or individually according to need). This would only be beneficial if the individual annual licences or rolling 5 year licence were being approached. During the Aquator modelling for this report, the SGS annual licence quantities were found to be a limiting factor. In a real event, rather than cutting back this regulatory support an application could be made for the SGS Drought Order (refer to Annex 2). The order seeks to permit an increase to the annual and five year volume licence limits to meet an extreme and prolonged drought period, similar to that modelled under the Chronic condition within this report. If granted this drought order could provide prolonged support to the River Severn and take some strain off Llyn Clywedog and Lake Vyrnwy water bank storage.
6. **Seek additional reductions from abstractors of up to 20% if Llyn Clywedog reservoir reaches emergency storage.** Some water companies may be able to rely on supplies other than the River Severn (i.e. rest their Severn abstraction through transfers). Each drought is different and conditions elsewhere could be worse than in the Severn catchment. Scope for reducing demand on the Severn may be restricted by priorities elsewhere and this option is unlikely to be achievable in a large scale drought event.
7. **Targeted restocking programmes.** A post drought management option to help impacted species recover and re-colonise the River Severn, for e.g. Salmon.
8. **Increased flexible monitoring at locations not identified in the monitoring programme**. The Monitoring programme should not be used as a rigid or limiting document, additional monitoring may be needed as localised issues arise.

14.2. Collaborative Mitigation Options

During a River Severn Drought Order operation there are options which the Environment Agency could consider in cooperation or joint management with other organisations/bodies. These options would not solely be within the gift of the Environment Agency and would require close working and communication through the River Severn Drought Management Group.

The identified options include;

1. **Work collaboratively through the River Severn Drought Management Group, with all the in combination water users, to deliver joined up mitigation options.** For example, options could involve water companies having capacity for flexibility within their supplies to divert demand to less affected sources, or more short term changes in operation to elevate localised issues. Communication will be critical and the group would need to be mobilised early in the drought process.
2. **Consider approaching United Utilities for an 'overdraft' on the Lake Vyrnwy water bank**. This would only be beneficial if there were sufficient excess storage in Lake Vyrnwy, and if UU were able to spare the water to the River Severn catchment at low risk to their own public water supply.
3. **Explore the option for emergency augmentation to the lower tidal Severn and Estuary by utilising Chelmarsh bankside storage for abstraction.** If SSW can reduce abstraction pressure on the River Severn and use Lake Vyrnwy water bank releases to refill Chelmarsh, very short term (days to a week only) remediation maybe available for critical periods/issues. This would only be beneficial in emergency situations, when sufficient storage is available in the Lake Vyrnwy water bank to repay Chelmarsh. This emergency option would be short term (days to a week only) and incur additional costs to the Environment Agency, who would need to pay SSW for the water.

15. Environment Monitoring Programme

The ‘Drought permits and drought orders’ guidance (2011) identifies the need for a robust monitoring programme to support any drought order application. The monitoring programme ensures evidence will be collected to identify and enable the mitigation of drought impacts.

The Environment Agency recognises it is vital to collect baseline data both during normal and low flow conditions, enabling River Severn Drought Order specific monitoring to be compared against a proven benchmark to help quantify any impact. It is also necessary to undertake post-drought monitoring to assess the extent and rate of habitat and specie recovery so we can better understand any long term implications.

This recommended monitoring programme only contains sites specific to assessing the River Severn Drought Order, however the EA (and other bodies/organisations) have an extensive monitoring network, in addition to the sites listed, and all available data would be used during a real event. For example, WFD monitoring data and reports, Severn Estuary monitoring (6 yearly Habitat’s Directive programme) programme etc.

15.1. Data monitoring limitations

Due to the significant size of the River Severn catchment, and area of potential impact from the River Severn Drought Order, it is challenging to design a specific monitoring programme that is not too large to be feasible, or too sparse to be useful. The proposed monitoring programme represents a range of monitoring at the key assessment locations (conditions will vary locally between these targeted sites), however the programme application may need to be flexible and discussions will need to be held between the organisations with potential in combination impacts on the River Severn.

Due to the large area and tidal variations within the Severn Estuary, monitoring baseline conditions in the Estuary is very challenging. For example, surveying fish at specific locations only provides a snap shot picture of what species were caught on that day according to the environmental conditions at that time. Various fish species may avoid the monitoring nets, or simply be located elsewhere within the Severn Estuary and therefore be excluded.

Various Severn Estuary monitoring options and techniques were considered for this project. For transitional fish, the conclusion is to increase the frequency of baseline monitoring over the next 5 years, at 3 existing locations, to help understand more about transitional fish behaviour within the Severn Estuary, and how they may be impacted by low flows/drought. Macrophyte surveys were considered inappropriate for the Estuary due to the absence of significant vegetation. Diatom surveys were also considered for the Upper Estuary (already conducted in the middle and lower section), however due to the dynamic nature of the system along this section the results are unlikely to be conclusive or helpful in understanding the ecosystems response to low flows/drought. Invertebrate surveys were also considered unfeasible for the lower Severn, some deep water surveys have been proposed and will be trialled at Haw Bridge, but the size and dynamic nature of the upper Severn Estuary make it unlikely results would be conclusive for this project.

15.2. Monitoring Programme

All the proposed River Severn Drought Order monitoring sites and requirements are listed in Appendix S, starting in the uppermost catchment and working downstream towards the Severn Estuary. It is recommended that gap analysis and collaborative work be carried out with in-combination organisations, and the Environmental Report be updated periodically to ensure it is kept up to date. The monitoring programme should retain a degree of flexibility to cope with the dynamic nature of droughts, additional routine or one-off monitoring could be warranted according to each event.

All '**baseline**' monitoring specific to the River Severn Drought Order is required to collect a benchmark of the aquatic environment and ecology in the River Severn over a normal range of flow conditions. These data can then be used alongside low flow/drought evidence to determine the impact of natural drought, any additional impacts from operating the River Severn Drought Order, and help assess what the minimum flow requirements are for the River Severn. The baseline monitoring will be included in the Environment Agency's annual work programme, highlighting the River Severn Drought Order as a key driver[29].

The '**low flow**' specific monitoring is required to collect data for naturally developing drought conditions prior to a River Severn Drought Order application, building a representative benchmark for comparison. The data will inform decisions on when an application may be required and provide evidence to help separate natural drought impacts from those caused solely by the River Severn Drought Order (alone or in combination with other plans and/or permits). The low flow specific monitoring will be included within the Midlands Drought Plan, linked to appropriate triggers.

The '**River Severn Drought Order**' monitoring will be triggered by the activation of the River Severn Drought Order conditions. The data collected will allow the state of the environment to be regularly monitored and compared against both the baseline and low flow data, to help assess the impacts associated with operation of the River Severn Drought Order. Monitoring can also be used to help target any mitigation options available at the time. The River Severn Drought Order specific monitoring will be identified in the Midlands Drought Plan.

'**Post low flow/natural drought and/or Severn Drought Order**' specific monitoring is required to monitor the recovery time following both a natural low flow/drought event, and the use of the River Severn Drought Order. Monitoring after a natural event will provide the baseline evidence crucial for comparison against River Severn Drought Order operation. This would enable assessment to distinguish between what would have occurred even if the drought order were not operated, helping to isolate the drought order specific impacts which then need managing appropriately. Both sets of monitoring will also provide evidence on the long term implications of drought events. The Post low flow/natural drought and/or Severn Drought Order specific monitoring will also be identified in the Midlands Drought Plan.

Refer to Appendix S for the proposed River Severn Drought Order monitoring programme.

[29] Drivers describe the justification for monitoring and support the financial investment required.

16. Conclusion

The River Severn Drought Order is the Environment Agency's final option to manage the development of a severe drought event, encompassing a dual purpose of protecting public water supply and the environment along the River Severn. It aims to extend the length of time regulation releases can be made in the absence of significant rainfall by carefully managing remaining storage in Llyn Clywedog reservoir. If we did not apply for the drought order, we would risk running out of water for Severn regulation.

In the short term the River Severn Drought Order alone will lower flows and water levels along the full length of the River Severn, in order to make water in Llyn Clywedog reservoir last longer to safeguard against continuing drought. During this initial period no new flow benefits would be provided along the River Severn and the river environment and wildlife could be placed under additional stress compared to normal regulation years (i.e. not drought years), although no Water Framework Directive failures would be expected as a result. It is only because flows along the River Severn are maintained artificially high to support abstraction that stress may occur from the reduced water levels; flows along the majority of the River Severn should not fall significantly below what is expected to naturally occur under these drought conditions.

Assessment found that if the drought continued, water supply from Llyn Clywedog reservoir would run out. Significant detrimental impacts would then be experienced along the whole River Severn as compensation releases stopped and no specific flow could be maintained at Bewdley. Operating the River Severn Drought Order would preserve supplies in Llyn Clywedog for longer, so even beyond the point when a prescribed flow at Bewdley can no longer be maintained (regulation failure), higher flows and water levels would be maintained than if the Drought Order were not operated. This would benefit all river users and the environment by preventing the upper River Severn catchment below Llyn Clywedog from drying up and maintaining higher flows and levels throughout the River Severn.

In the long term, the River Severn Drought Order would conserve storage in Llyn Clywedog reservoir to benefit people and the environment in subsequent years. Reservoir refill would be accelerated by reducing the amount of time and rainfall needed to restock the reservoir in time for the following year's regulation season. This would greatly reduce the impacts of a further dry winter and drought summer on the River Severn. More water would be available for a subsequent dry (i.e. high regulation) year and potentially prevent the need for a second River Severn Drought Order application. This could enable normal regulation to continue throughout a second drought summer, maintaining flows significantly higher than would naturally occur to provide significant benefits for the environment and people.

The impacts caused by the River Severn Drought Order alone are all predicted to be temporary and not cause any new failures under the Water Framework Directive when compared to baseline drought conditions. Once normal rainfall returns, the environment should improve naturally and recover within one to three years, consistent with the expected natural drought recovery period.

The assessments carried out for this report identified the main risk as likely to occur under the 'Full In-Combination' scenario, which included the effects of water company Drought Permits/Orders, and particularly the potentially high abstractions by the Canal & River Trust for the Gloucester & Sharpness Canal. Under this scenario, flows and water levels from Bewdley onwards became more significantly impacted, illustrating where the larger water company abstractions are located. The lower tidal Severn became particularly at risk to adverse impacts from the natural channel split at Gloucester, largely dependent on the quantity of abstraction taken from the River Severn for the Gloucester & Sharpness Canal, which can vary significantly. However, once the new abstraction

cap[30] was applied to the canal abstraction, a higher certainty could be used to conclude the Severn Estuary would no longer be at medium risk of impact, and the risk to the Lower Tidal Severn was reduced from high to medium risk. All impacts will vary according to the time of year (e.g. Spring tides, fish migration season) and other environmental conditions (e.g. temperature) and severity of the individual drought event.

The overall conclusion is that the Environment Agency's River Severn Drought Order represents a sustainable use of water resources and attempts to appropriately balance the requirements of people and the environment; potentially conflicting uses during a severe drought event. Operating in isolation it should not cause a significant additional risk to ecology when compared to the natural drought conditions. Operating in combination with other water abstractors there is the potential for environmental damage beyond the natural drought conditions in the lower tidal Severn, therefore the Environment Agency has introduced an abstraction cap on the Gloucester & Sharpness Canal to reduce the risk to acceptable levels. The Environment Agency and the Canal & River Trust are continuing to work together to refine the restriction details.

[30] The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operations. If sufficient evidence can be provided to show a higher abstraction is justified, then the abstraction volume will be reviewed in the future.

17. Further Work Recommendations

In order to improve the environmental assessment of the River Severn Drought Order, a number of recommendations for future work were collated into Appendix T. The list below only includes the recommendations considered to be achievable in the short to medium term, or those which are critical and will need addressing in preparation for any future assessment or collaborative working.

1. **Deliver the Monitoring Programme -** the monitoring programme includes existing and new monitoring recommendations to support a River Severn Drought Order application. Without baseline and appropriate event monitoring, impacts cannot be accurately assessed.
2. **Work with the Canal & River Trust to resolve the outstanding concerns around the abstraction restriction on the Gloucester & Sharpness Canal** - The Canal & River Trust has raised concerns that 300 Ml/d could pose a business risk to their operations. The Environment Agency and the Canal & River Trust are continuing to work together to resolve these concerns. If sufficient evidence can be provided to show a higher abstraction is justified, then the abstraction volume will be reviewed in the future.
3. **Future monitoring should include cross sections of the river at specific sites to quantify impacts on habitat from changing water levels** - future monitoring should include cross sections of the river at specific sites with reference to flows/levels in order to predict the effect of the altering flows on the wetted area and the exposure of substrate and sediments at those sites.
4. **Get reservoir storage levels prior to 1990 entered into WISKI (data archive)** - need to capture important historic droughts electronically to improve the speed and ease of future drought analysis. The Environment Agency currently only holds some hard copy graphs and would need to identify where the data can be sourced from.
5. **Explore options to increase/improve ecological (including fish) monitoring in the lower tidal Severn and the Severn Estuary** - this report and supporting HRA report highlighted the gaps in information and knowledge, both internally and externally in relation to understanding what the Severn Estuary environment currently is, and quantifying the freshwater inflow and water level requirements needed to support the designated features and species. More monitoring and assessment is needed to improve our understanding of the Severn Estuary, and also the lower tidal Severn where routine monitoring techniques are not practical.
6. **Develop specific shad monitoring** - as recommended by Hillman, Cowx & Harvey (2003):
    - Juvenile density (represented by catch per unit effort, CPUE). Micromesh seine netting is the most appropriate sampling method to assess juvenile shad in the lower river/upper estuary
    - Adult run size. Fish counters should be used to monitor the time and approximate size of adult spawning migration.
7. **Improve monitoring and understanding of Salmonid sites** - most impact expected on salmon therefore consider;
    - Electric fishing on Severn (above Dolwen), Afon Clywedog and Afon Vyrnwy (quantitative). Also timed surveys on riffles further down the Severn to estimate juvenile salmon distribution
    - Habscore all quantitative sites at an appropriate frequency
    - Use fish counter data from Shrewsbury to assess annual salmon migration (and other fish movements)
    - Fry sampling on main River Severn (netting) to assess coarse fish population

8. **Update the River Severn Estuary residual flow study (written in 1992)** - need to establish the current freshwater inflow targets based on the existing abstractions and discharges. This would inform a stronger Habitat Regulation Assessment and enable more quantifiable flow targets and restrictions to be set for the protection of the Natura 2000 site. Information/work which may support this;
    - Obtain any monitoring data on conductivity (salinity) and turbidity (suspended solids)
    - Time series data and vertical profiles on the levels of Dissolved Oxygen at various locations in the tidal River Severn during low river flows is needed to assess the impact of the current discharge from Gloucester (Netheridge) STW.
    - The benthic ecology of the tidal River Severn and the upper part of the SAC needs to be assessed in detail, using available information. If necessary, this information could be supplemented by some survey transects looking at seasonal variations in the upper Estuary, which would provide some data on the response of the benthic ecology to changes in river flows.
    - In the long-term, a numerical model of the upper reaches of the Severn Estuary, looking at saline intrusion and the up-estuary transport of suspended sediments could be developed, to allow actual flow and tidal conditions to be modelled.
9. **Integrate water quality and water resource modelling to ensure continuity in drought/low flow testing** - need to better understand the difference between the current water resource and water quality models and find ways to better integrate their ability to represent and test low flows/drought impacts.
10. **Develop hydro-ecological prediction/assessment tools capable of assessing regulated rivers** - ensure appropriate prediction tools are tested on regulated rivers to improve the confidence and use for assessing the River Severn catchment.
11. **Improve conceptualisation of the River Severn within the Aquator model** - specifically to;
    - Test and adopt the most up to date version of Aquator and background flow data.
    - Test the naturalised flow data against the Environment Agency's own datasets.
    - Improve representation of SSW and DCWW abstractions.
    - Explore how non-water company abstraction is represented (e.g. agriculture) and how flexibly it can be managed.
    - Explore how discharges are represented and how flexibly they can be isolated and adjusted to better represent dry weather/drought conditions.
    - Improve the conceptualisation of flows and impacts between Bewdley and the Severn Estuary.
    - Improve the conceptualisation of the Gloucester & Sharpness Canal abstraction, developing average dry year and maximum abstraction profiles.
    - Explore modelling additional demand saving levels.
    - Explore whether channel splits can be incorporated.
12. **Integrate the River Severn and SGS Drought Order modelling work and environmental reports** - future modelling and assessment work needs to be more aligned and jointly produced where possible to improve consistency.
13. **Work collaboratively on any future in combination Drought Order modelling work** - to save duplication, resource and improve partnership working, future updates to the in combination modelling work for this environmental report need to be conducted with the relevant water companies and the Canal & River Trust.
14. **Test the River Severn Drought Order for climate change** - test the resilience and return period of the River Severn Drought Order under the UKCP09 projections.
15. **Produce a Strategic Environmental Assessment** - external consultation responses highlighted and SEA as a valuable addition to the reports already produced.

18. Future Considerations

During external consultation (summer 2013) a number of comments were received containing useful additional information. Future changes in operations that could impact the River Severn catchment or new guidance that may inform impact assessments. While this information could not be used for this report, it may need to be considered for the programmed updates, and is therefore included for reference below;

- In 2012 United Utilities commissioned a new 55km bi-directional pipe called the West-East link to improve resilience. This allows up to 100 Ml/d of water to be transferred in either direction between Cheshire/Merseyside and Manchester. This needs to be considered in relation to the potential impact on Lake Vyrnwy, and whether the mitigation option to request an 'overdraft' from Lake Vyrnwy for Severn regulation will remain viable.
- As part of the Water Resources Management Plan process, all water companies have been encouraged to discuss options for water trading. Any new options need to be considered in regards to the potential impact on RSDO levels of service and any additional drought permit/order options that may rely on the Severn catchment.
- The 'River flow for good ecological potential' (June 2013) by the WFD Technical Advisory Group (TAG) was out in draft for consultation at the time of publication. This document should be considered for future updates of the RSDO reports.
- The Review of Consents on the River Wye will result in some abstraction licence changes. These changes will need to be considered in relation to the potential Full In-combination effects.
- Proposals to restore the Cotswold canals (includes the Stroudwater canal and the Thames and Severn canal) involve connecting the Gloucester & Sharpness Canal to the Cotswolds canals at Saul Junction. Need to consider in relation to the future removal of abstraction exemptions and how this could potentially alter the in-combination pressures on the River Severn.

Consider changes in water company drought permit/orders, including new options and changes in the triggers used in the Full in-combination modelling. E.g. United Utilities drought permit triggers have changed since the 2009 Drought Plan used for this report.

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