Hydrological Summary *for the United Kingdom*

October 2023

General

Despite some unseasonal autumn warmth, October was unsettled and exceptionally wet for large areas of the UK, with a train of Atlantic weather systems bringing heavy rainfall and severe impacts from flooding. Temperatures were near-average in Scotland but it was warm in the south, especially from the 7th-10th when temperatures of 25°C were recorded in south-east England. The October rainfall for the UK was 140% of average (the sixth wettest October since 1890) but it was the wettest on record in some regions of eastern Scotland, and among the wettest in parts of central and eastern England. Consequently, October river flows were largely above normal, and often notably or exceptionally high. Parts of east Anglia saw a marked hydrological recovery: some catchments that have seen persistent below-average flows until early autumn (e.g. the Waveney, Stringside) registered peak flows in October that were among the top three on record (for any month). Reservoir stocks increased in most northern impoundments and remain above average at the national scale. However, western areas saw near-average rainfall so there was little change in some reservoirs (Colliford, Roadford, Celyn & Briane) with persistent below-average stocks. Given the wet autumn soils, recharge was evident at the majority of boreholes and groundwater levels ranged from above normal to exceptionally high. The water resources position is favourable, but flood risk is elevated in many areas. The current Hydrological Outlook favours above normal flows over the coming months in eastern Britain, and October ended with the naming of another storm (Ciaran) that bought further flood impacts in early November.

Rainfall

The first ten days of October were mostly settled across southern Britain, and unseasonably warm after the 6th, under the influence of anticyclonic conditions. In contrast, Scotland was very wet due to the passage of several frontal systems, culminating in an 'atmospheric river' on the 6th-7th. Notable two-day rainfall totals were widespread, with 75-100mm across a large area of the Highlands and >150mm in some localities (e.g. 168mm at Kimelford, Argyll & Bute). From the 18th-21st, Storm Babet tracked northwards across the UK, bringing persistent heavy rainfall. The worst affected area was northeast Scotland, where exceptional daily totals were observed (e.g. 168mm at Waterside, Angus, on the 19th), but notable daily totals were also seen in central and eastern England (e.g. 61mm at Sheffield on the 20th; 48mm at Wattisham, Suffolk on the 19th). During this four-day period, large areas of northeast Britain, the Midlands and East Anglia exceeded the typical average rainfall for October as a whole, sometimes significantly. The rest of the month was unsettled and particularly wet at month-end in Northern Ireland. October rainfall totals were exceptional in many areas of central and eastern Britain: the North East Scotland and Tay regions saw their wettest October on record, while for other regions it was the second (Severn-Trent), third (Anglian and Northumbria) or fourth wettest (Northern Ireland), all since 1890. Some areas in these regions saw >250% of the October average rainfall. Only western areas saw near-average rainfall, and Solway was dry, registering 55% of average. The exceptional October adds to notable rainfall accumulations since late summer – away from western Scotland, July-October rainfall totals were significantly above average. Over a longer timeframe, Northern Ireland saw its wettest May-October since 1890.

River Flows

In northern Britain, river flows climbed rapidly in early October in response to repeated frontal incursions. Numerous Scottish index rivers saw their highest October daily mean flows on record on the 6th/7th and the Tay registered its third highest daily flow*, for any month (in a record from 1952). Further dramatic flow responses followed Storm Babet – by the 20th, there were nearly 250 flood warnings nationally. Many index rivers subsequently registered their highest October peak flows on record, while some saw peak flows ranking among the highest for any month: the Stringside registered a new maximum (in a record from 1965), while the Dove and Dover Beck (Midlands) saw their second highest peak flows (from 1962 and 1972). In Scotland the Helmsdale and Bervie saw their first and second highest daily mean flows* respectively (from 1975 and 1980). The month ended with further flood warnings, notably in Northern Ireland, where on the 31st the Lagan and Annacloy registered their second highest peak flows (records from 1972 and 1980). The October flooding, particularly from storm Babet, bought severe and widespread impacts. There were at least three fatalities (with others associated with the extreme weather more generally) and widespread property flooding. In Brechin, Angus, hundreds of properties were flooded, and reports indicate that over 1200 homes were flooded across Yorkshire, the east Midlands and East Anglia, while millions of pounds of crop damage was reported in Scotland. October mean flows were in the normal range along the west coast, but elsewhere were significantly above normal (the Coquet and Waveney saw four and five times the October average). New maximum October mean flows were registered in the Tay, Earn and Coquet (all with records >55 years), and the Ythan and Annacloy (with records from 1980). Outflows from Scotland were the highest on record for October (in a record from 1961). A similar picture is seen for the September-October average flows, with widespread notably and exceptionally high flows and new maxima for the Tay, Forth and Annacloy.

Soil Moisture and Groundwater

A wet October resulted in the majority of COSMOS-UK sites being above field capacity by the end of the month, with a few exceptions, mostly in southern England. Hence, recharge occurred at most Chalk sites, with some marked groundwater level increases – levels typically moved from normal to notably high. However, at more slowly-responding sites, such as Stonor Park, Redlands Hall and Therfield Rectory, levels remained in the normal range. In the Jurassic limestones, levels rose rapidly and at both Ampney Crucis and New Red Lion they moved to exceptionally high. Levels rose in the Magnesian Limestone at Brick House Farm and Aycliffe and moved from normal to above normal and notably high, respectively. Recharge was recorded at all Carboniferous Limestone sites. Although at Pant-y-Lladron levels remained in the normal range, Greenfield Garage and Alstonfield moved from the normal range to exceptionally high range, with levels at Alstonfield being the highest for October in a 50 year record. In the Permo-Triassic Sandstones at Skirwith, groundwater levels were stable and remained above normal. At Llanfair D.C. levels fluctuated but remained in the normal range at month-end. Whereas, at Bussels No.7a levels initially fell from notably high levels before rising slightly and ending above normal. Recharge started in the Upper Greensand at Lime Kiln Way and levels moved from normal to above normal. Recharge commenced in the Devonian sandstone at Feddan Junction and Easter Lathrisk, with levels respectively moving from exceptionally low and below normal to the normal range for both sites. Recharge was also recorded at Royalty Observatory (Fell Sandstone), but levels remained in the normal range.

**Highest Instantaneous Flows are unavailable for Scotland, and so daily mean flows are used as an alternative for flood event ranking.*

National Hydrological Monitoring Programme | UK Centre for Ecology & Hydrology | BGS British Geological Survey

Rainfall . . . Rainfall . . .

Met Office

Rainfall accumulations and return period estimates

Percentages are from the 1991-2020 average.

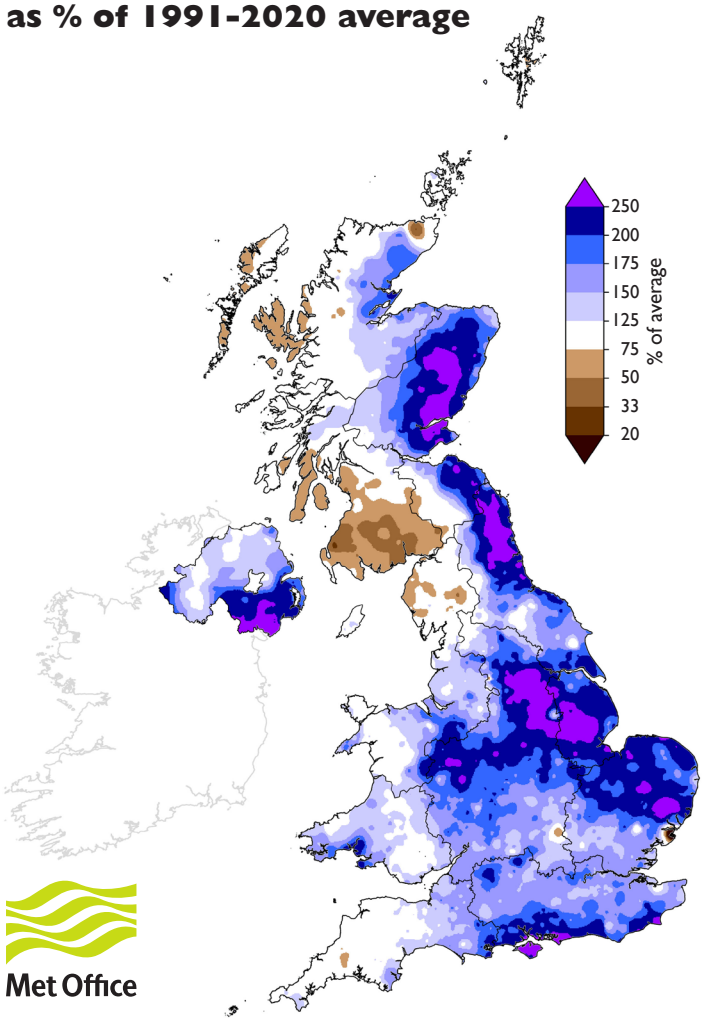
Region	Rainfall	Oct 2023	Sep23 – Oct23		Jul23 – Oct23		May23 – Oct23		Nov22 – Oct23	
				RP		*RP*		*RP*		*RP*
United Kingdom	mm	**172**	291		520		611		1265	
	%	**140**	136	10-20	133	40-60	114	5-10	109	10-20
England	mm	**147**	229		421		501		1024	
	%	**163**	144	10-20	141	30-50	119	5-10	118	15-25
Scotland	mm	**199**	367		624		733		1558	
	%	**118**	126	5-10	121	8-12	105	2-5	99	2-5
Wales	mm	**209**	364		661		742		1628	
	%	**132**	135	5-10	138	15-25	113	2-5	111	5-10
Northern Ireland	mm	**192**	337		649		770		1343	
	%	**168**	167	>100	166	>>100	141	>100	116	50-80
England & Wales	mm	**156**	247		454		534		1106	
	%	**156**	142	10-15	140	25-40	117	5-10	117	15-25
North West	mm	**151**	308		629		735		1440	
	%	**113**	128	5-10	140	15-25	120	5-10	112	10-20
Northumbria	mm	**171**	254		468		547		990	
	%	**196**	159	20-30	148	40-60	123	8-12	109	5-10
Severn-Trent	mm	**155**	229		397		480		924	
	%	**191**	158	20-30	142	25-40	118	5-10	115	8-12
Yorkshire	mm	**148**	232		454		524		993	
	%	**176**	150	10-20	151	40-60	123	8-12	114	8-12
Anglian	mm	**128**	185		322		389		738	
	%	**199**	158	20-30	138	10-20	116	5-10	117	8-12
Thames	mm	**124**	193		343		423		904	
	%	**158**	144	5-10	137	10-15	119	5-10	124	15-25
Southern	mm	**178**	232		385		447		1099	
	%	**189**	149	8-12	142	10-20	119	5-10	134	40-60
Wessex	mm	**158**	240		442		528		1177	
	%	**159**	145	8-12	147	30-50	126	8-12	130	50-80
South West	mm	**149**	257		507		599		1459	
	%	**109**	114	2-5	126	5-10	109	2-5	116	10-20
Welsh	mm	**203**	351		637		718		1572	
	%	**133**	135	5-10	137	15-25	113	2-5	112	8-12
Highland	mm	**214**	398		684		801		1737	
	%	**109**	116	2-5	117	5-10	102	2-5	94	2-5
North East	mm	**235**	338		528		622		1176	
	%	**194**	166	50-80	140	60-90	118	8-12	111	8-12
Tay	mm	**285**	445		691		779		1566	
	%	**190**	177	>100	151	>100	124	15-25	112	20-30
Forth	mm	**195**	329		546		638		1299	
	%	**149**	146	15-25	130	10-20	110	5-10	105	5-10
Tweed	mm	**157**	262		491		575		1137	
	%	**137**	135	8-12	131	10-20	111	2-5	105	5-10
Solway	mm	**95**	288		572		680		1561	
	%	**55**	99	2-5	108	2-5	95	2-5	99	2-5
Clyde	mm	**185**	395		687		825		1776	
	%	**92**	113	2-5	110	2-5	99	2-5	94	2-5

% = percentage of 1991-2020 average *RP = Return period*

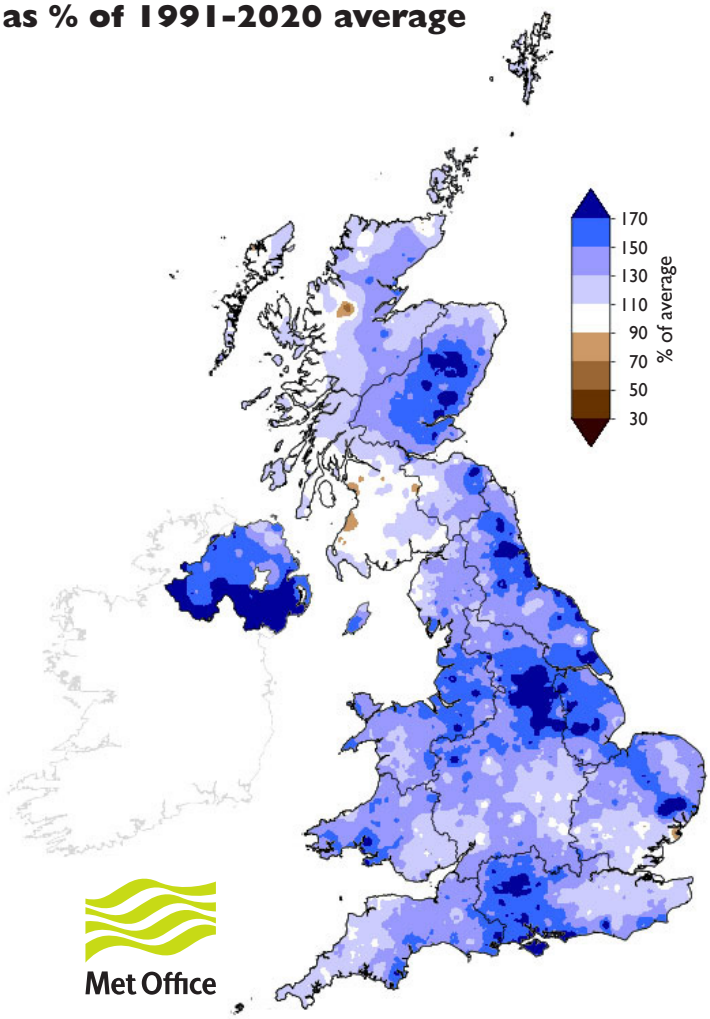
Important note: Figures in the above table may be quoted provided their source is acknowledged. Where appropriate, specific mention must be made of the uncertainties associated with the return period estimates. The RP estimates are based on data provided by the Met Office and reflect climatic variability since 1836; they also assume a stable climate. The quoted RPs relate to the specific timespans only; for the same timespans, but beginning in any month the RPs would be substantially shorter. The timespans featured do not purport to represent the critical periods for any particular water resource management zone. For hydrological or water resources assessments of drought severity, river flows and/or groundwater levels normally provide a better guide than return periods based on regional rainfall totals. Note that precipitation totals in winter months may be underestimated due to snowfall undercatch. All monthly rainfall totals since January 2023 are provisional. Source: Data from HadUK-Grid dataset at 1km resolution v1.2.0.0.

Rainfall . . . Rainfall . . .

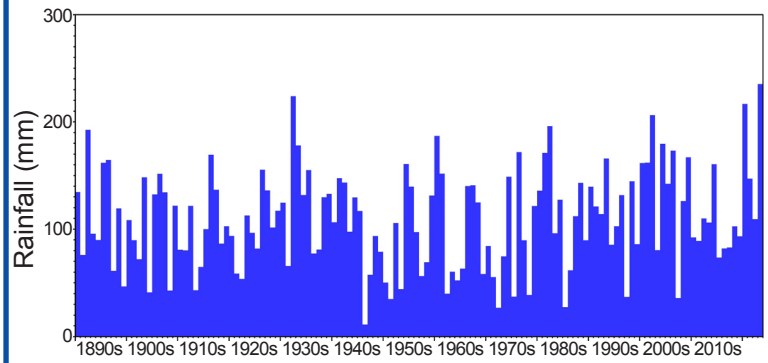
October 2023 rainfall
as % of 1991-2020 average



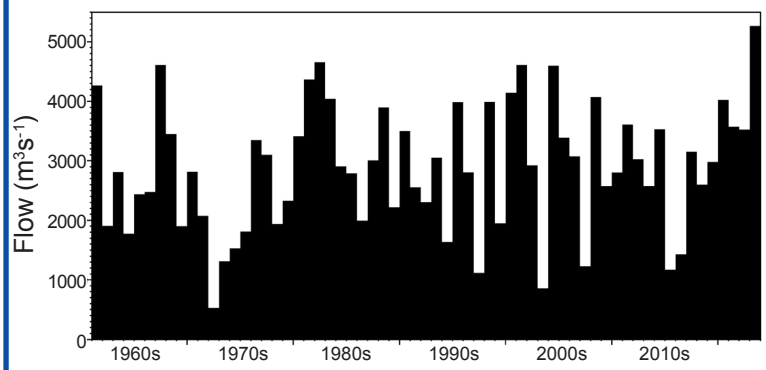
July 2023 - October 2023 rainfall
as % of 1991-2020 average



October rainfall for North East Scotland



October outflows for Scotland



UK Hydrological Outlook

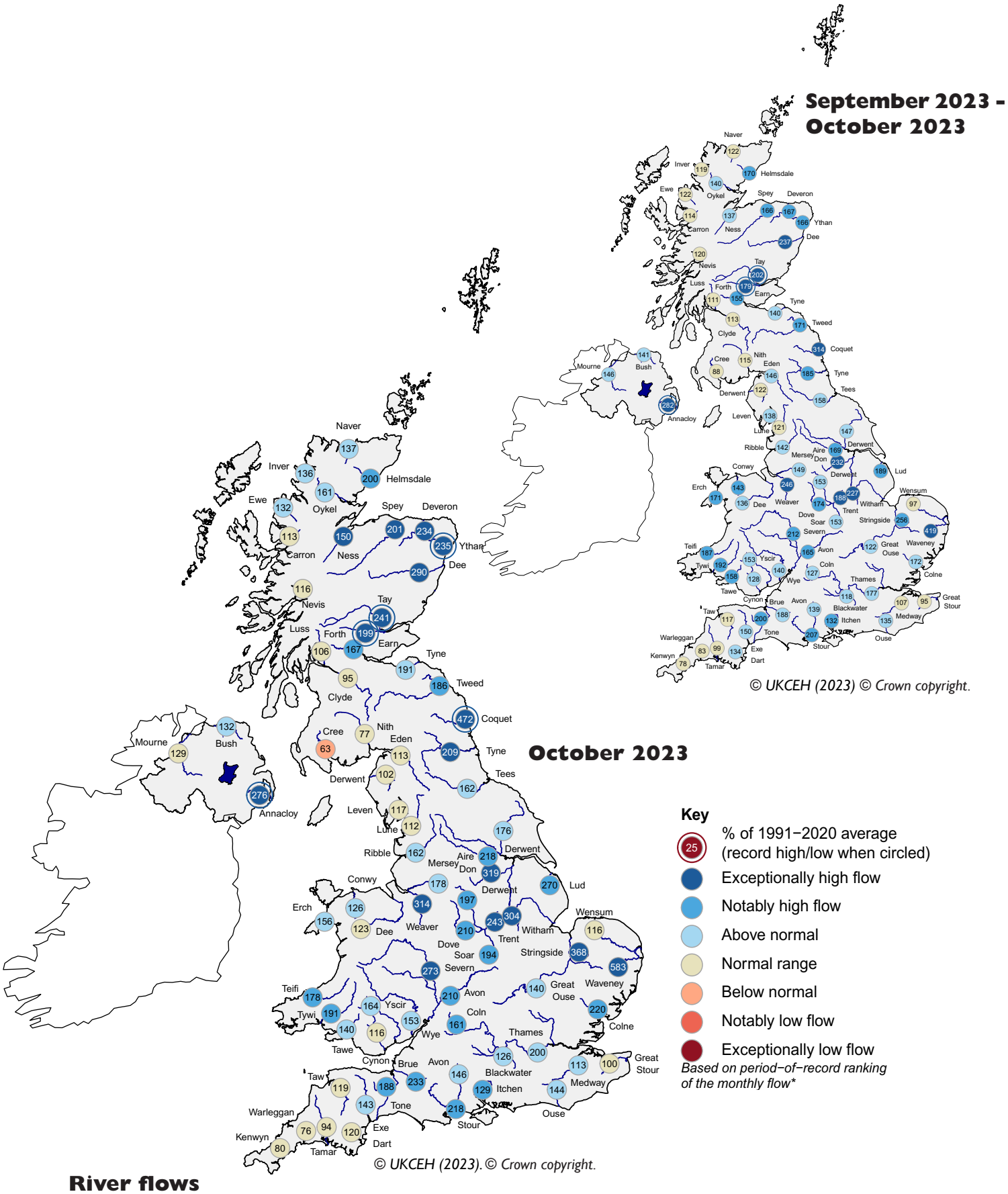
The Hydrological Outlook provides an insight into future hydrological conditions across the UK. Specifically it describes likely trajectories for river flows and groundwater levels on a monthly basis, with particular focus on the next three months.

The complete version of the Hydrological Outlook UK can be found at: www.hydoutuk.net/latest-outlook/

Period: **from November 2023**
Issued: **08.11.2023**
using data to the end of October 2023

The outlook for November and for November-January is for normal to above normal river flows on the eastern side of the country, and mostly normal for the western half, with the exception of some rivers in north-western Scotland where the flows are likely to be normal to below normal. For groundwater, the levels are likely to be above normal at most sites for the next three months.

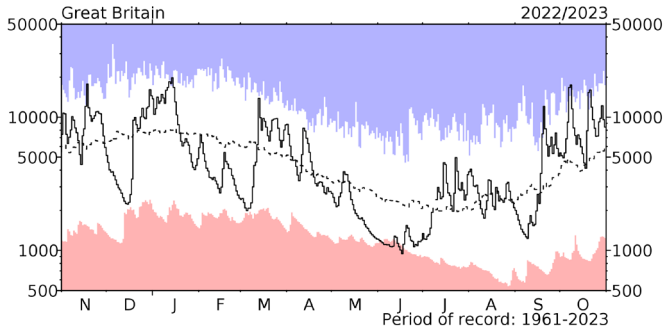
River flow . . . River flow . . .

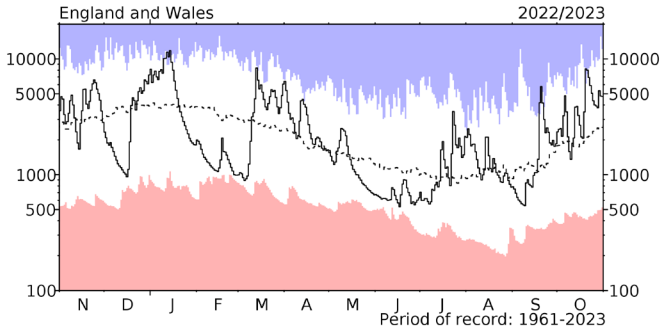


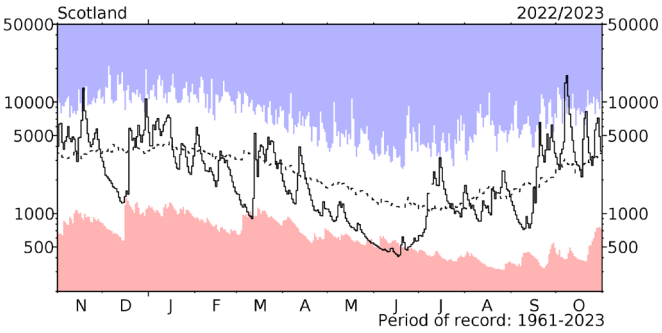
River flows

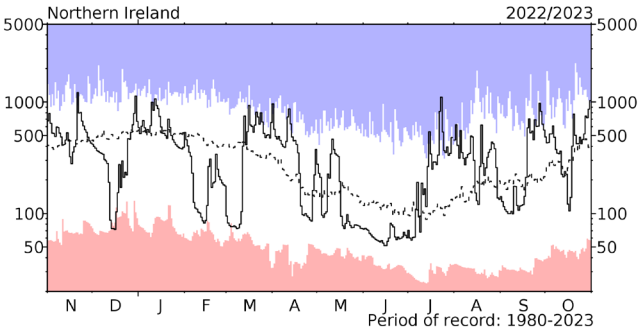
*Comparisons based on percentage flows alone can be misleading. A given percentage flow can represent extreme drought conditions in permeable catchments where flow patterns are relatively stable but be well within the normal range in impermeable catchments where the natural variation in flows is much greater. The categories of the spots are based on the full period-of-record data whereas the percentages are based on the 1991-2020 averaging period for consistency between rainfall and river flows. Percentages may be omitted where flows are under review.

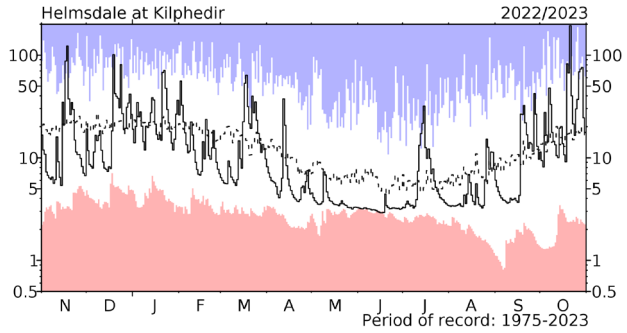
River flow . . . River flow . . .

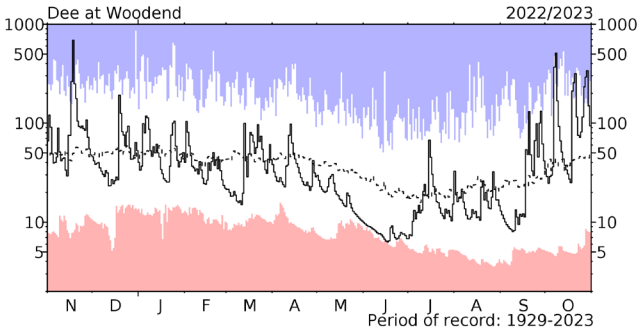


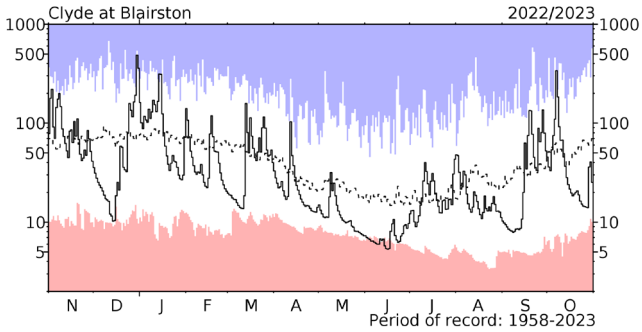


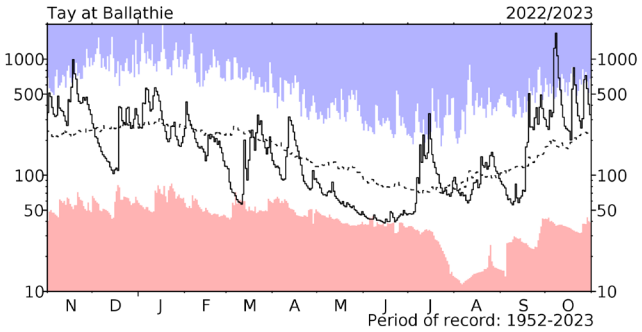


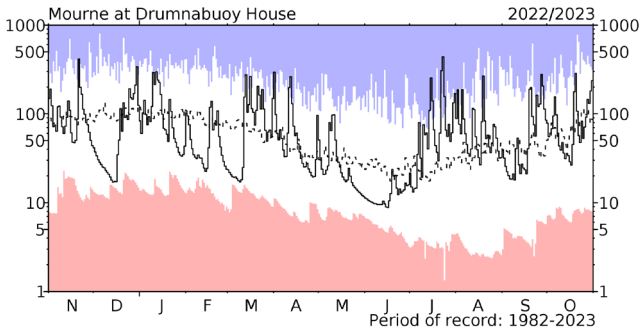


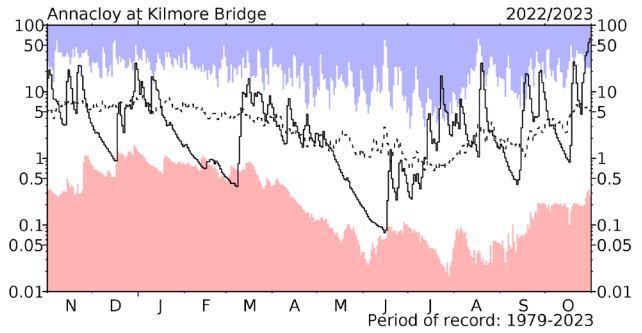








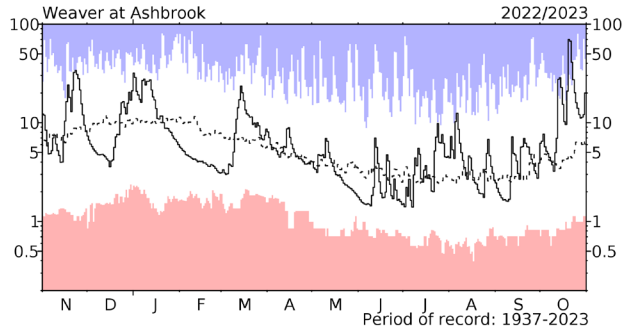


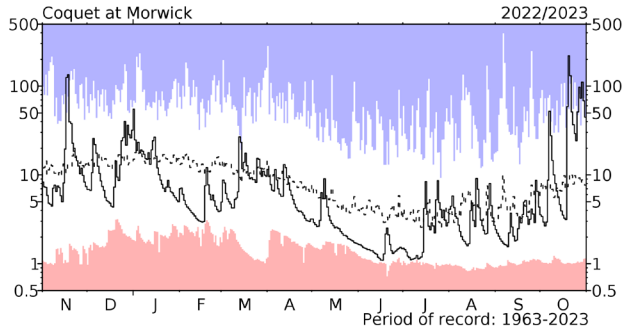


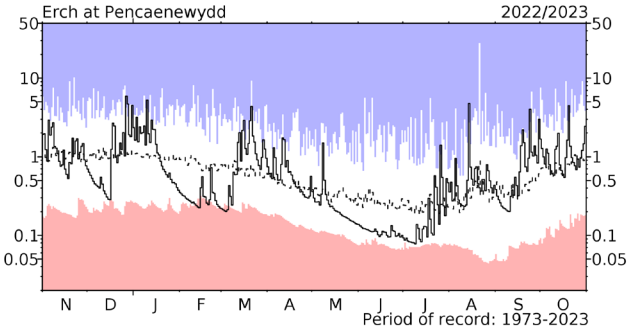
River flow hydrographs

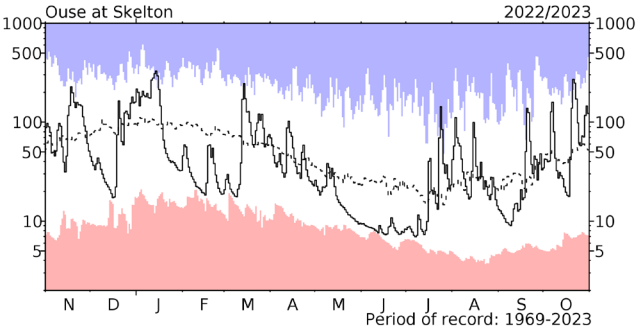
*The river flow hydrographs show the daily mean flows (measured in m^3s^{-1}) together with the maximum and minimum daily flows prior to November 2022 (shown by the shaded areas). Daily flows falling outside the maximum/minimum range are indicated where the bold trace enters the shaded areas. The dashed line represents the period-of-record average daily flow.

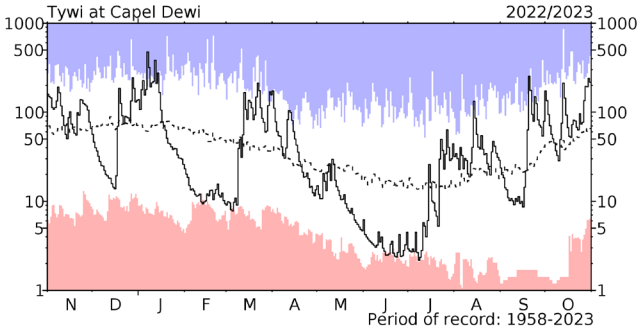
River flow . . . River flow . . .

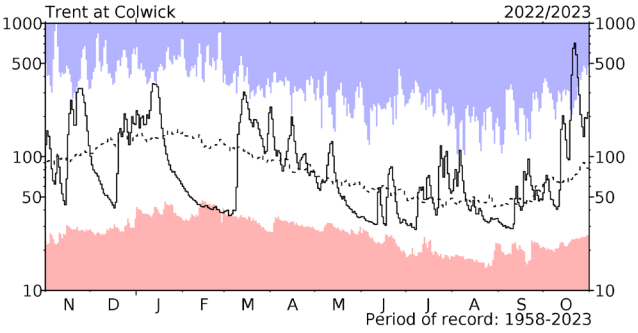


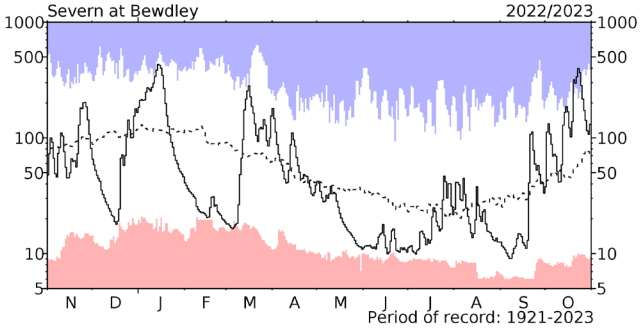


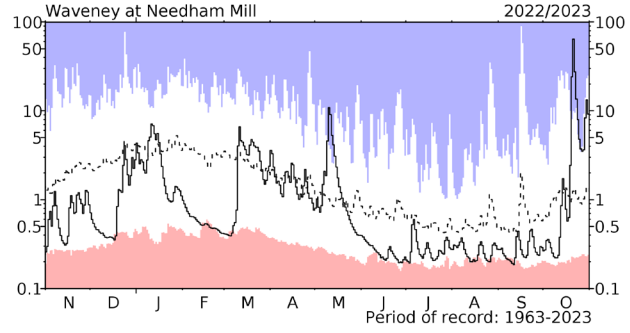


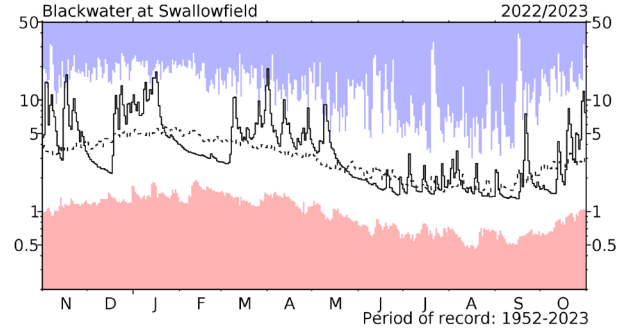


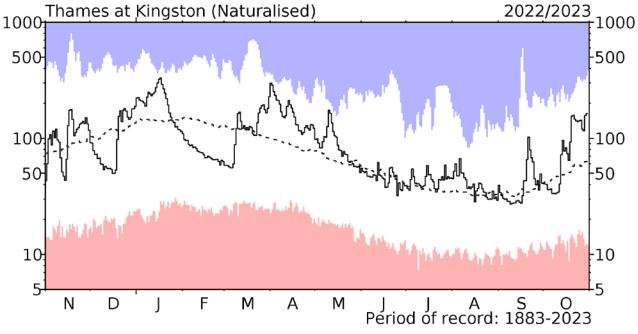


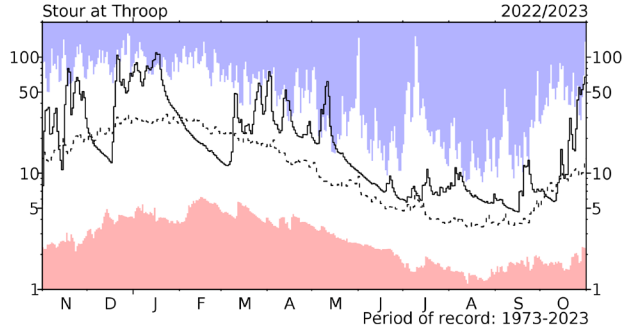


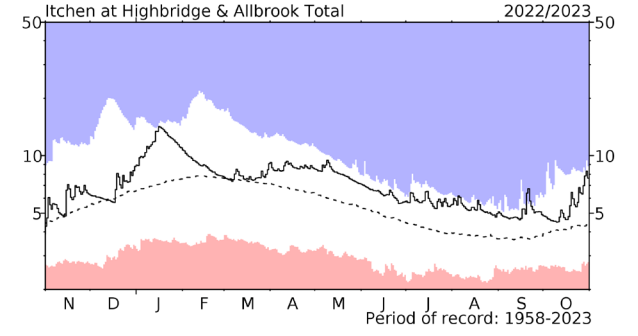




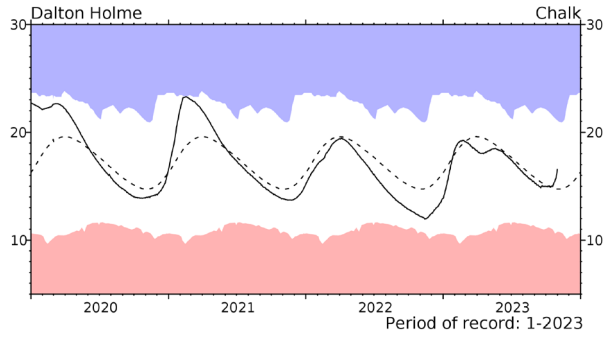


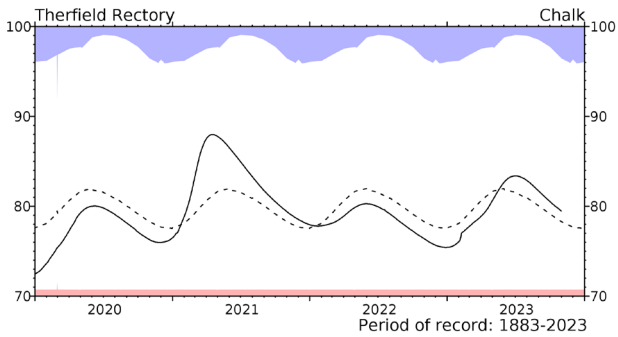


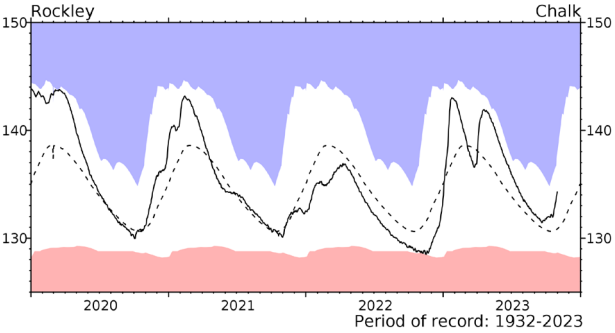


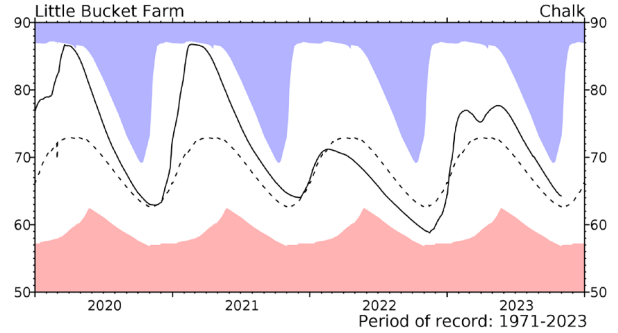


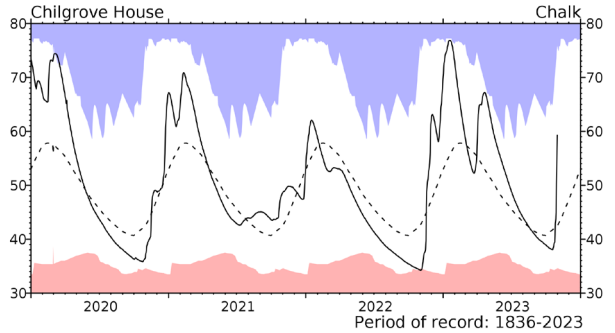
Groundwater…Groundwater

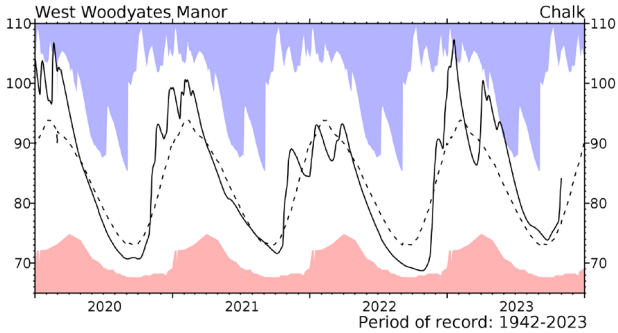


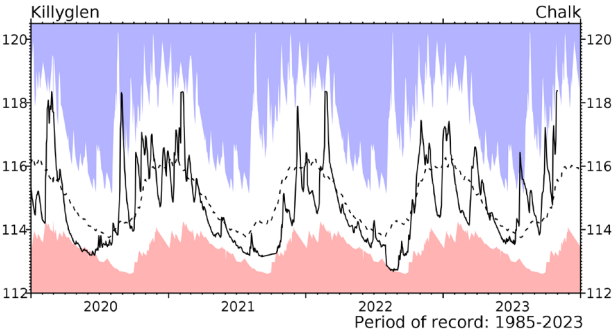


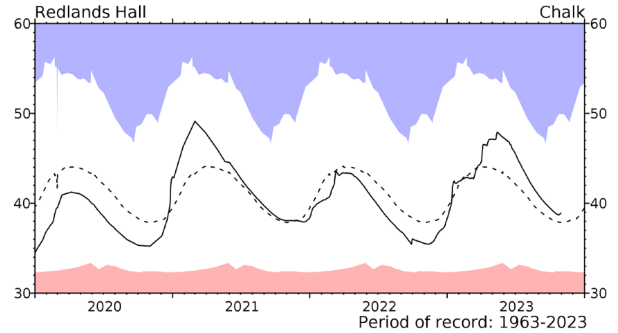


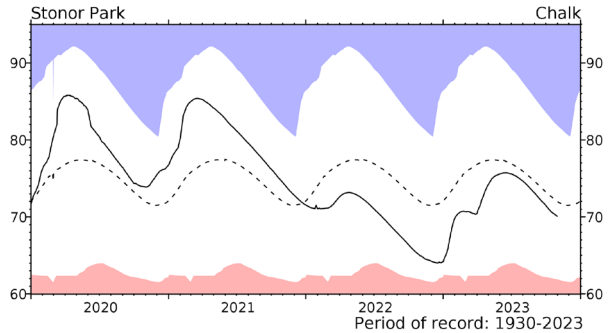


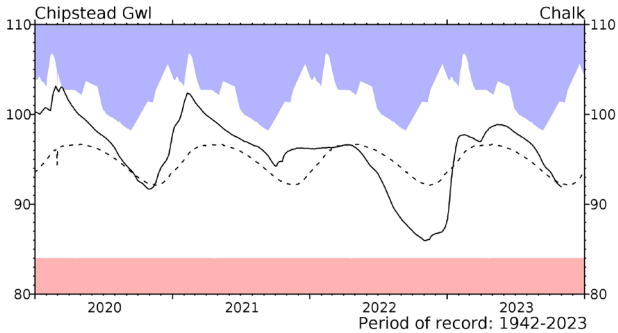






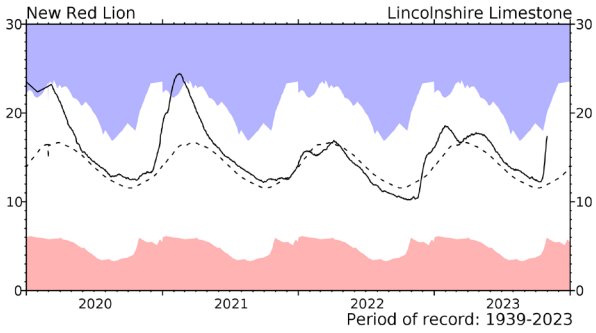


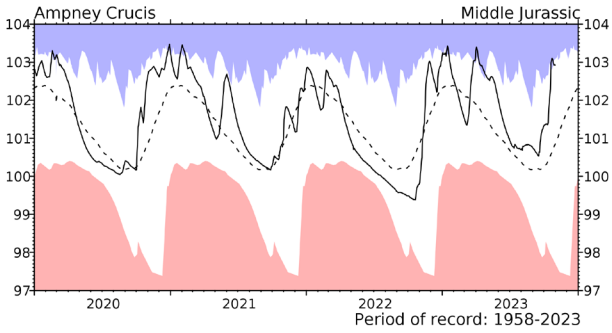


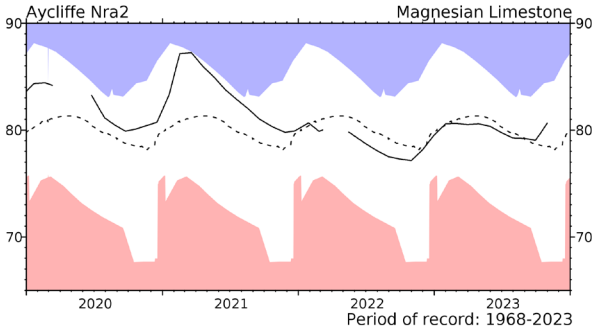


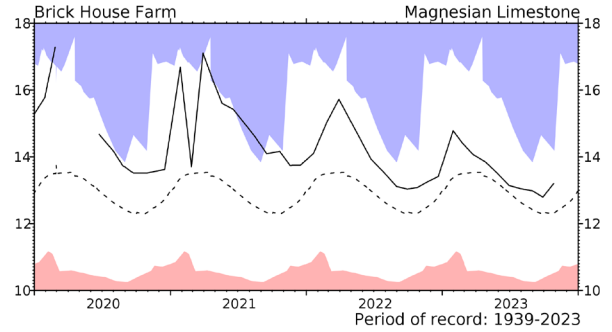
Groundwater levels (measured in metres above ordnance datum) normally rise and fall with the seasons, reaching a peak in the spring following replenishment through the winter (when evaporation losses are low and soil moist). They decline through the summer and early autumn. This seasonal variation is much reduced when the aquifer is confined below overlying impermeable strata. The monthly mean and the highest and lowest levels recorded for each month are calculated with data from the start of the record to the end of 2019. Note that most groundwater levels are not measured continuously and, for some index wells, the greater frequency of contemporary measurements may, in itself, contribute to an increased range of variation.

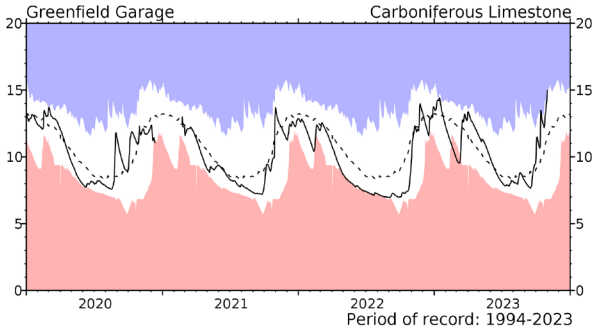
Groundwater… Groundwater

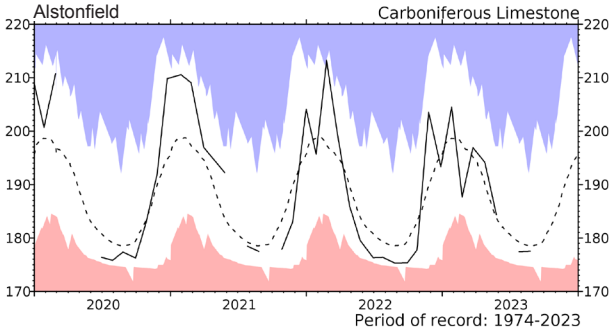


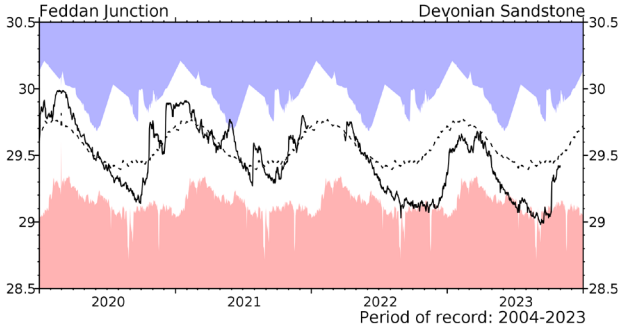


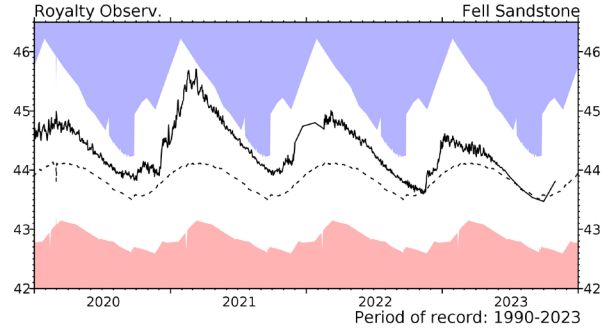


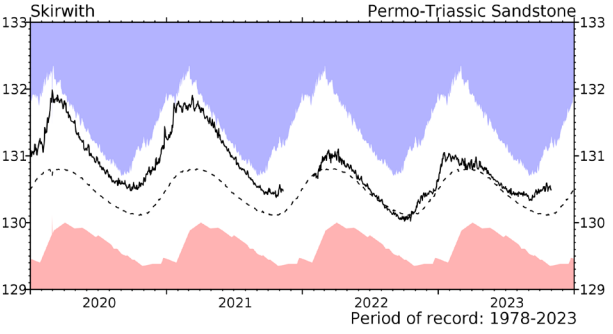


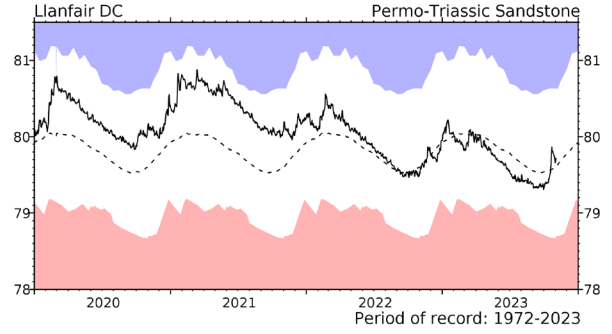


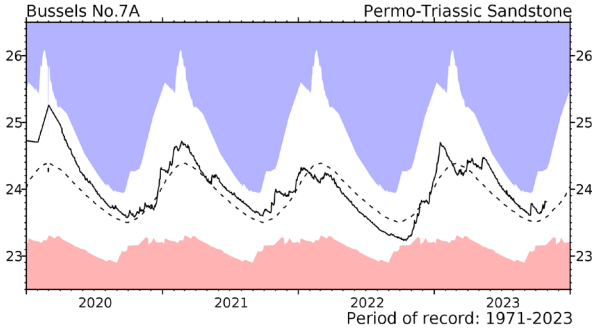


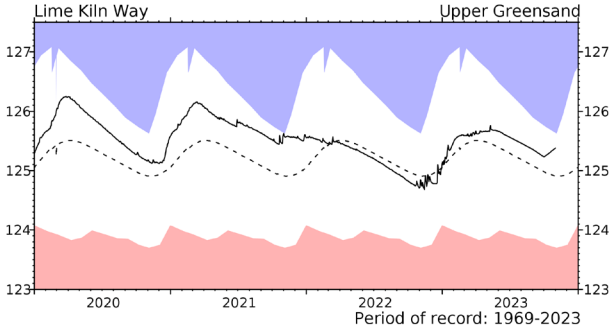


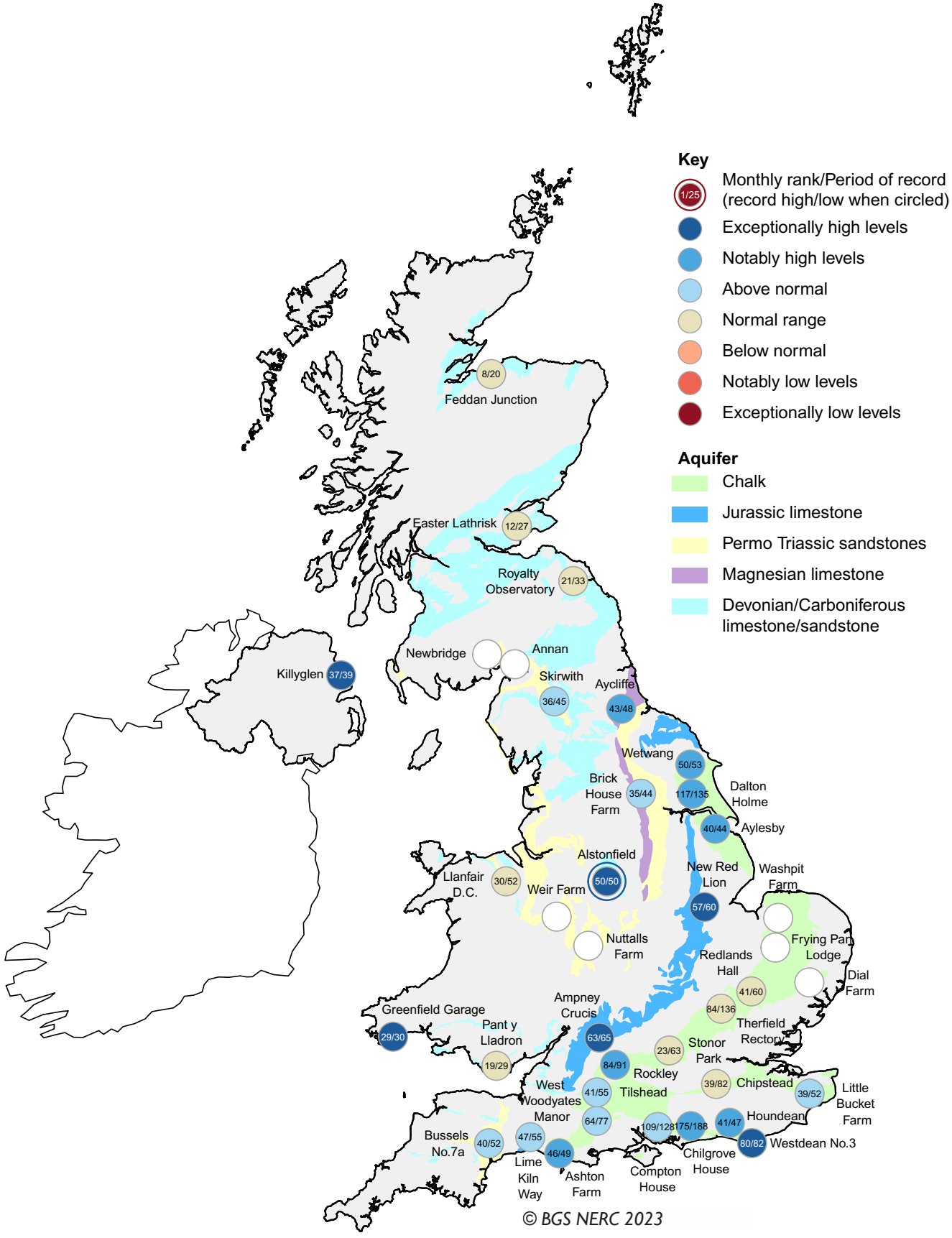










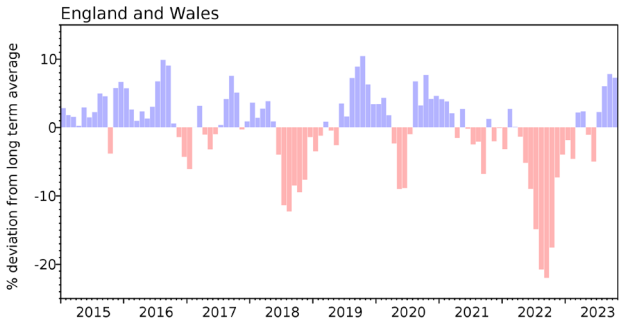


Groundwater levels - October 2023

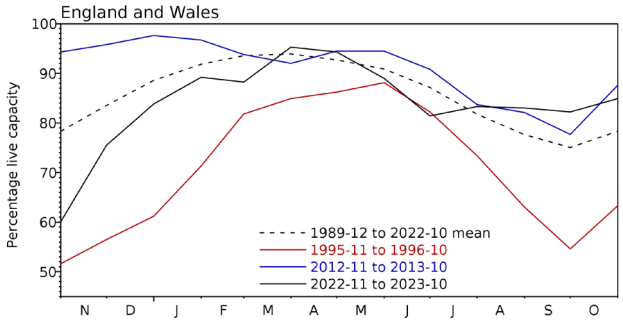
The calculation of ranking has been modified from that used in summaries published prior to October 2012. It is now based on a comparison between the most recent level and levels for the same date during previous years of record. Where appropriate, levels for earlier years may have been interpolated. The rankings are designed as a qualitative indicator, and ranks at extreme levels, and when levels are changing rapidly, need to be interpreted with caution.

Reservoirs . . . Reservoirs . . .

Guide to the variation in overall reservoir stocks for England and Wales



Comparison between overall reservoir stocks for England and Wales in recent years



Percentage live capacity of selected reservoirs at end of month

Area	Reservoir		Capacity (Ml)	2023 Aug	2023 Sep	2023 Oct	Oct Anom.	Min Oct	Year* of min	2022 Oct	Diff 23-22
North West	N Command Zone	•	124929	73	76	80	11	33	2003	62	19
	Vyrnwy		55146	97	95	100	23	25	1995	55	45
Northumbrian	Teesdale	•	87936	87	98	100	23	33	1995	71	29
	Kielder		(199175)	85	85	85	-1	63	1989	86	-1
Severn-Trent	Clywedog		49936	97	89	85	7	38	1995	54	30
	Derwent Valley	•	46692	79	71	93	24	15	1995	52	41
Yorkshire	Washburn	•	23373	82	81	93	23	15	1995	42	50
	Bradford Supply	•	40942	76	74	99	26	16	1995	41	57
Anglian	Grafham		(55490)	93	90	85	2	44	1997	57	28
	Rutland		(116580)	87	85	85	6	59	1995	69	16
Thames	London	•	202828	96	94	91	14	46	1996	60	31
	Farmoor	•	13822	99	96	91	3	43	2003	70	21
Southern	Bewl		31000	82	71	67	7	33	1990	43	24
	Ardingly		4685	62	46	44	-20	15	2003	26	18
Wessex	Clatworthy		5662	68	75	81	19	14	2003	24	57
	Bristol	•	(38666)	78	71	78	15	24	1990	44	34
South West	Colliford		28540	56	52	52	-16	15	2022	15	36
	Roadford		34500	55	54	55	-14	18	1995	34	21
	Wimbleball		21320	73	74	83	19	18	2022	18	65
	Stithians		4967	61	56	57	0	14	2022	14	43
Welsh	Celyn & Brenig	•	131155	68	67	67	-16	48	1989	58	9
	Brianne		62140	100	100	100	7	57	1995	83	17
	Big Five	•	69762	73	71	78	2	38	2003	52	26
	Elan Valley	•	99106	78	85	96	12	37	1995	51	45
Scotland(E)	Edinburgh/Mid-Lothian	•	97223	89	92	95	14	48	2003	86	9
	East Lothian	•	9317	92	91	100	15	38	2003	72	28
Scotland(W)	Loch Katrine	•	110326	84	93	88	1	40	2003	96	-8
	Daer		22494	84	89	85	-6	42	2003	94	-9
	Loch Thom		10721	59	73	91	2	63	2020	97	-6
Northern	Total+	•	56800	97	99	99	18	39	1995	84	16
Ireland	Silent Valley	•	20634	99	100	100	22	34	1995	83	17

( ) figures in parentheses relate to gross storage

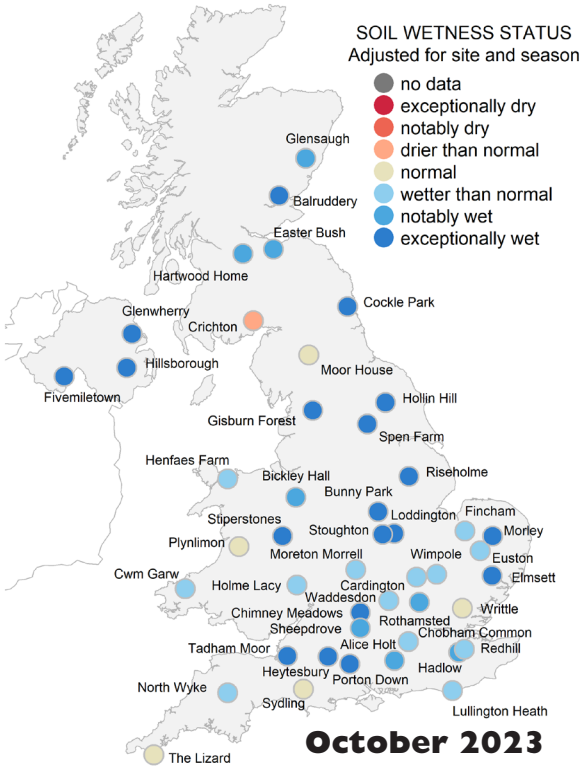
• denotes reservoir groups

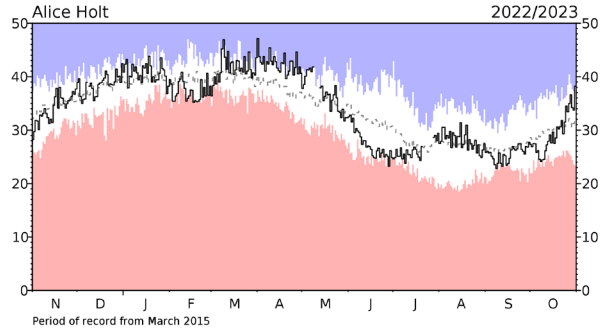
*last occurrence

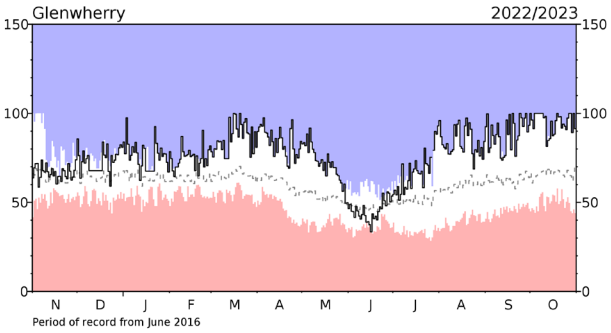
+ excludes Lough Neagh

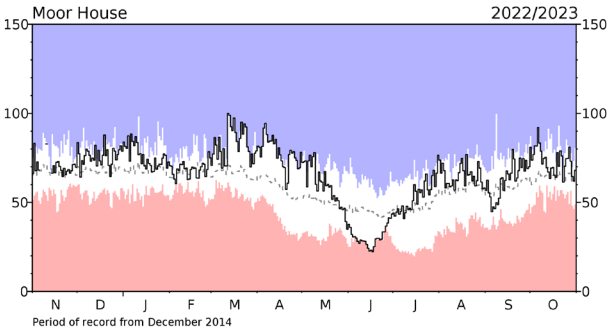
Details of the individual reservoirs in each of the groupings listed above are available on request. The percentages given in the Average and Minimum storage columns relate to the 1988-2012 period except for West of Scotland and Northern Ireland where data commence in the mid-1990s. In some gravity-fed reservoirs (e.g. Clywedog) stocks are kept below capacity during the winter to provide scope for flood attenuation purposes. Monthly figures may be artificially low due to routine maintenance or turbidity effects in feeder rivers.

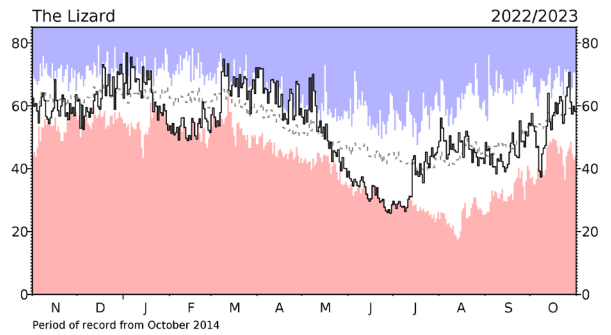
Soil Moisture . . . Soil Moisture

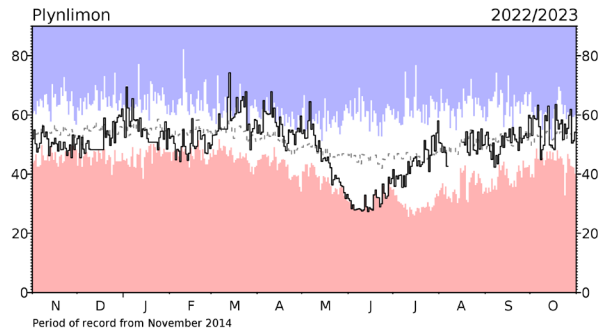












A wet October has resulted in the majority of COSMOS-UK sites being above field capacity by the end of the month.

At the end of the month, soil moisture was above field capacity for most COSMOS-UK sites. Eight sites were just below field capacity, seven in Southern England. Alice Holt, under tree cover, was approaching saturation towards the end of October. Except for June, some sites have been saturated for most of the year (e.g. Fivemiletown, Gisburn, Glensaugh and Glenwherry), whereas other places such as Tadham Moor, Moor House, Crichton, Plynlimon and The Lizard fluctuated between normal and near-saturated conditions throughout the month.

Soil moisture data

These data are from UKCEH's COSMOS-UK network. The time series graphs show volumetric water content as a percentage in black together with the maximum and minimum daily values for the period-of-record of the sites. The dashed line represents the period-of-record mean VWC. For more information visit cosmos.ceh.ac.uk.

NHMP

The National Hydrological Monitoring Programme (NHMP) was started in 1988 and is undertaken jointly by the UK Centre for Ecology & Hydrology (UKCEH) and the British Geological Survey (BGS). The NHMP aims to provide an authoritative voice on hydrological conditions throughout the UK, to place them in a historical context and, over time, identify and interpret any emerging hydrological trends. Hydrological analysis and interpretation within the Programme is based on the data holdings of the National River Flow Archive (NRFA; maintained by UKCEH) and National Groundwater Level Archive (NGLA; maintained by BGS), including rainfall, river flows, borehole levels, and reservoir stocks.

The Hydrological Summary is supported by the Natural Environment Research Council award number NE/R016429/1 as part of the UK-SCAPE programme delivering National Capability.

Data Sources

The NHMP depends on the active cooperation of many data suppliers. This cooperation is gratefully acknowledged. A location map of all sites used in the Hydrological Summary can be found on the NHMP website. River flow and groundwater level data are provided by the Environment Agency (EA), Natural Resources Wales - Cyfoeth Naturiol Cymru (NRW), the Scottish Environment Protection Agency (SEPA) and, for Northern Ireland, the Department for Infrastructure - Rivers and the Northern Ireland Environment Agency. In all cases the data are subject to revision following validation (high flow and low flow data in particular may be subject to significant revision).

Details of reservoir stocks are provided by the Water Service Companies, the EA, Scottish Water and Northern Ireland Water.

The Hydrological Summary and other NHMP outputs may also refer to and/or map soil moisture data for the UK. These data are provided by the Meteorological Office Rainfall and Evaporation Calculation System (MORECS). MORECS provides estimates of monthly soil moisture deficit in the form of averages over 40 x 40 km grid squares over Great Britain and Northern Ireland. The monthly time series of data extends back to 1961.

Rainfall data are provided by the Met Office. To allow better spatial differentiation the rainfall data for Britain are presented for the regional divisions of the precursor organisations of the EA, NRW and SEPA. The areal rainfall figures have been produced by the Met Office National Climate Information Centre (NCIC), and are based on the HadUK-Grid 1km resolution gridded data from rain gauges. The majority of the full rain gauge network across the UK is operated by the EA, NRW, SEPA and Northern Ireland Water; supplementary rain gauges are operated by the Met Office. The Met Office NCIC monthly rainfall series extend back to 1836 and form the official source of UK areal rainfall statistics which have been adopted by the NHMP. The gridding technique used is described in Hollis, 2019 available at https://doi.org/10.1002/gdj3.78

Long-term averages are based on the period 1991-2020 and are derived from the monthly areal series.

The regional figures for the current month in the hydrological summaries are based on a limited rain gauge network so these (and the associated return periods) should be regarded as a guide only.

The monthly rainfall figures are provided by the Met Office NCIC and are Crown Copyright and may not be passed on to, or published by, any unauthorised person or organisation.

For further details on rainfall or MORECS data, please contact the Met Office:

Tel: 0370 900 0100
Email: enquiries@metoffice.gov.uk

Enquiries

Enquiries should be directed to the NHMP:

Tel: 01491 692599
Email: nhmp@ceh.ac.uk

A full catalogue of past Hydrological Summaries can be accessed and downloaded at:

http://nrfa.ceh.ac.uk/monthly-hydrological-summary-uk

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