UK Hydrological Review 2002

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Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

2002

UK HYDROLOGICAL REVIEW

This Hydrological Review, which also provides an overview of water resources status throughout 2002, is a reformatted version of the original commentary released as a web report in 2003. Some of the data featured in this report, particularly the more extreme flows, may have been subsequently revised.

The annual Hydrological Reviews are components in the National Hydrological Monitoring Programme (NHMP) which was instigated in 1988 and is undertaken jointly by the Centre for Ecology & Hydrology (CEH) and the British Geological Survey (BGS) – both are component bodies of the Natural Environment Research Council (NERC). The National River Flow Archive (maintained by CEH) and the National Groundwater Level Archive (maintained by BGS) provide the historical perspective within which to examine contemporary hydrological conditions.

A primary source of information for this review is the series of monthly UK Hydrological Summaries (for further details please visit: http://www.ceh.ac.uk/data/nrfa/nhmp/nhmp.html). The river flow and groundwater level data featured in the Hydrological Summaries – and utilised by many NHMP activities – have been provided by the Environment Agency (EA), Natural Resources Wales - Cyfoeth Naturiol Cymru, the Scottish Environment Protection Agency (SEPA) and their precursor organisations. For Northern Ireland, the hydrological data were sourced from the Rivers Agency and the Northern Ireland Environment Agency. The great majority of the reservoir level information has been provided by the Water Service Companies, the EA, Scottish Water and Northern Ireland Water (formerly Water Service). The generality of meteorological data, including the modelled assessments of evaporation and soil moisture deficits featured in the report, has been provided by the Met Office. To allow better spatial differentiation the monthly rainfall data for Britain are presented for the regional divisions of the precursor organisations of the EA and SEPA. The Met Office monthly rainfall series are Crown Copyright and may not be passed on to, or published by, any unauthorised person or organisation. The provision of the basic data, which provides the foundation both of this report and the wider activities of the NHMP, is gratefully acknowledged.

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For further information about the National Hydrological Monitoring Programme please visit: http://www.ceh.ac.uk/data/nrfa/nhmp/nhmp.html

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Hydrological Review of 2002

2002 Summary

Considering the UK as a whole, 2002 was another wet year - ranking 7th in the national rainfall series beginning in 1910 - and continuing a wet phase that began over the latter half of 1997. September was the only notably dry month whilst February, May-July and October/November were exceptionally wet - particularly in Northern Ireland which registered its wettest year in a 103-year series. Modest rainfall deficiencies did develop in parts of England and Wales in the early spring and early autumn but were insufficient to cause any significant water resources stress. In Scotland the temporal distribution of the rainfall was very unusual - exceptionally high rainfall accumulations characterised the January-July period but notable deficiencies began to build in the late summer across northern and some western catchments; the deficiencies were remarkably large by year-end.

2002 was another very warm year. The mean Central England Temperature was around 1.1°C above the 1961-90 average, making 2002 the fourth warmest year (after 1999, 1990, and 1949) in the 336-year CET series[1]. The combination of above average temperatures and above average rainfall (parts of northern and western Scotland excepted) contributed to relatively high actual evaporation totals - in the English Lowlands especially.

Nonetheless, water resources remained very healthy in most regions throughout the year. Drawdown releases were required (e.g. in February and December) in some major reservoirs to provide additional flood alleviation storage but overall stocks for England and Wales remained close to, or above, the monthly average throughout the year. Figure 1 shows the variation in overall stocks for a network of major reservoirs over the last eight years. Figure 2 compares the pattern of variation in 2002 with other recent years. As in the two preceding years, the seasonal decline in stocks began relatively late and overall stocks were close to capacity at year-end. Unsurprisingly therefore incidences of water supply stress were generally very localised - e.g. in January low reservoir levels in Silent Valley triggered appeals to moderate water use in Belfast; in July water was tankered to the Out Skerries (Shetlands) to augment dwindling stocks.

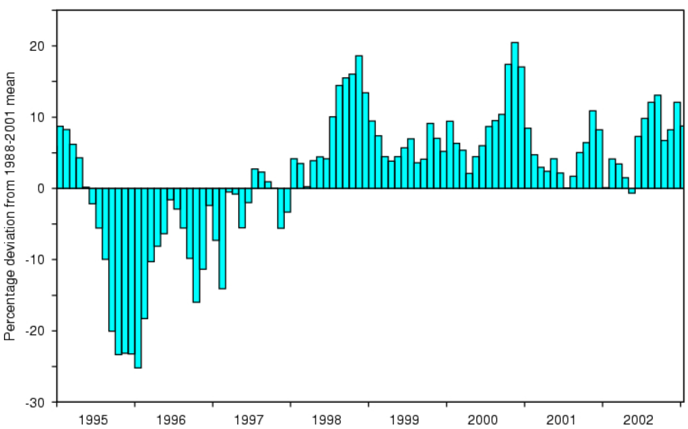


Figure 1 *A guide to England and Wales reservoir stocks 1995-2002.*

Data sources: Water Services Companies and the Environment Agency.

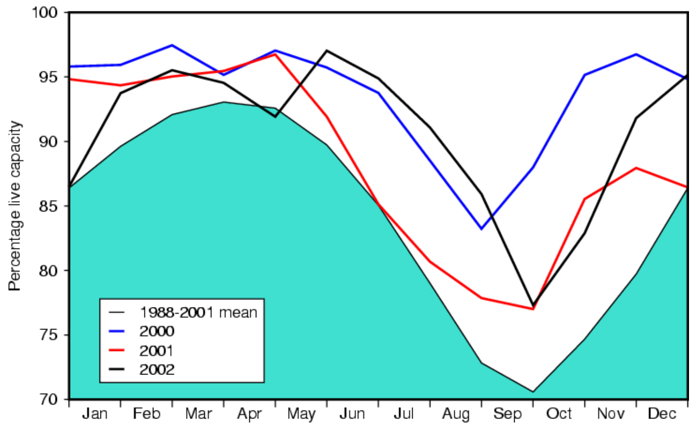


Figure 2 *Comparison between the within-year variation in overall reservoir stocks for England and Wales in recent years.*

Data sources: Water Services Companies and the Environment Agency.

A guide to the variation in annual runoff for England and Wales, Scotland and Northern Ireland based on outflows from representative networks of major river basins is shown on Figure 3. For England and Wales, runoff exceeded the average for the fifth successive year; clustering is a feature of the series but runoff over the 1998-2002 period is substantially greater than in any other 5-year sequence in the 42-year national series - long term rainfall data suggest that there is unlikely to be any close precedents in at least the last 227 years. Although runoff in many western and northern catchments was relatively depressed, the 2002 runoff total for Scotland was considerably above average - ranking third highest after 1990 and 2000. In Northern Ireland, where a province-wide gauging station network has operated only since the mid-1970s, the 2002 runoff was the highest on record by a considerable margin, and around 85% greater than the series minima established in 2001.

River flows remained above the seasonal average throughout much the greater part of 2002 in most regions. Moderate flooding was widespread in February and notable summer spates were common especially in northern Britain. Thunderstorms produced many locally severe flood events as rainfall intensities overwhelmed urban drainage capabilities (e.g. in Glasgow on July 30th) but continuing flow recessions through September - and very dry early autumn soils - seemed to foreshadow notably low October flows. In the event, a very wet episode beginning in the second

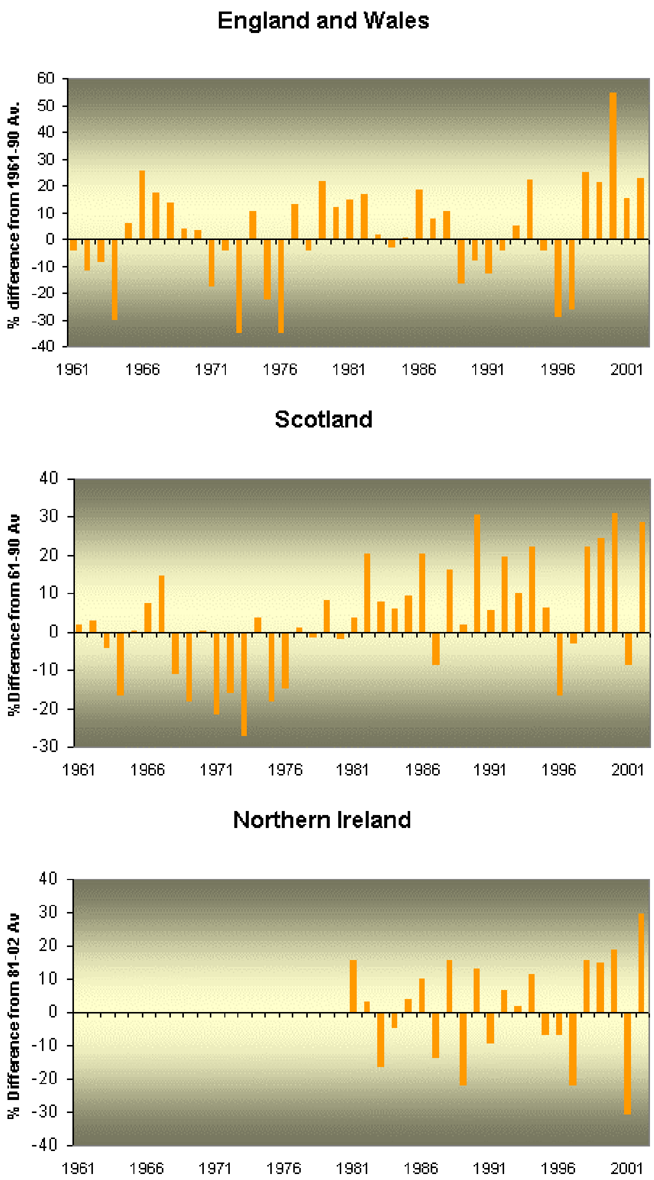


Figure 3 *Index of total runoff 1961-2002.*

week resulted in the focus of hydrological concern switching decisively from the threat of depressed runoff rates to the risk of widespread floodplain inundations. The flood risk remained high in the late autumn (severe flooding was experienced in north-east Scotland in November) and in December when floodplain inundations were common approaching year- end. The flooding culminated in early January 2003 when flows in some rivers in parts of central southern Britain were the highest since the snowmelt flood of March 1947.

As during the previous four years, 2002 was characterised by very healthy groundwater resources throughout most major aquifers. The legacy of very healthy groundwater replenishment over the 1998-2001 period helped ensure that groundwater levels in the majority of index wells and boreholes remained above average throughout the year and, by late-2002, levels had yet to decline below pre-2000 maxima in parts of the slow-responding Permo-Triassic sandstones. In the Chalk, and most other aquifers across southern Britain, levels during 2002 rarely approached the remarkable maxima of 2000 and 2001 but still generally exceeded the seasonal average. This despite very low rainfall during November and December 2001 providing little impetus to the seasonal recovery. Fortunately groundwater levels in early 2002 generally showed a continuing benefit from the abundant recharge in 2000/01 and, following sustained and heavy infiltration in January and February 2002, late-winter groundwater levels were significantly above average in most areas. Although the normal seasonal pattern in groundwater level behaviour was readily recognisable in 2002, the sustained rainfall through May and June served to usefully extend the 2001/02 recharge season, and a rapid seasonal recovery - a feature of a number of recent years - was underway by late October in most areas. Thus, moderately depressed levels in 2002 were largely restricted to a brief period in the early autumn. By year-end, levels were still rising and a heavy pulse of infiltration over the latter half of December triggered localised groundwater flooding (e.g. in parts of the Chilterns), echoing the situation in late 2000 (however, the dryness of the late winter of 2002/03 prevented any repetition of the sustained groundwater flooding experienced in 2001).

Rainfall over the 1998-2002 period was around 13% above the 1961-90 for the UK and eclipsed the previous highest 5-year rainfall total (1875-79) for England and Wales (in a record from 1766[2]). The last five years provide a remarkable contrast with the early and mid-1990s when drought episodes were both protracted and widespread, particularly in southern Britain. Over the same time period Scotland was subject to a number of damaging winter flood events. In large part these hydrological contrasts reflect the preferred tracks of Atlantic frontal systems crossing the British Isles. For lengthy periods over the recent past the high proportion of active depressions following abnormally southerly routes has brought sustained and heavy rainfall to the English Lowlands. Correspondingly, northern Scotland has been notably dry (as over the latter half of 2002). On many occasions the normally strong north-west to south-east rainfall gradient across the UK has been greatly moderated and even, for short periods (late-2002 included), reversed. This unusual synoptic backcloth has contributed to a recent extension in the range of recorded river flows and groundwater levels in many areas of the UK. The persistence of high flows has been especially notable, and record accumulated runoff totals (over a range of timeframes) have been registered for many spring-fed southern rivers.

Some consistency may be recognised between the recent past and current climate change scenarios - above average temperatures and evaporative demands, and the preponderance of mild, wet winters

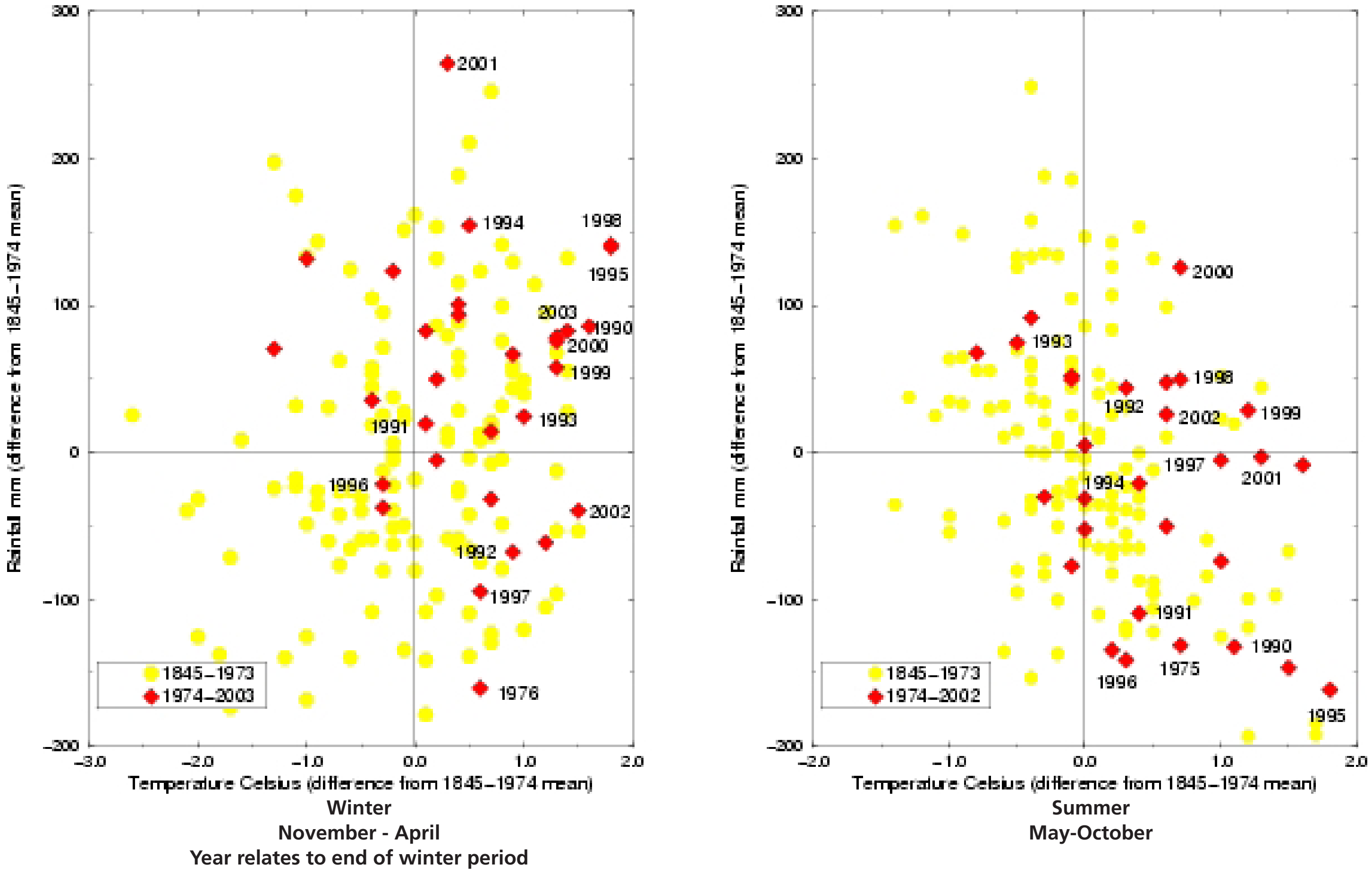


Figure 4 *England and Wales rainfall and temperature anomalies 1845-2002.*

Data sources: Central England Temperature series and monthly England and Wales precipitation CRU/Hadley Centre, UK Met Office.

in particular (see Figure 4). A tendency for a higher proportion of the UK rainfall to fall during the winter half-year (October-March) has also been a feature of the last 25 years, and continued in 2001/02. If this more distinct partitioning of rainfall within the year were to be become an enduring characteristic of the climate it would have important implications both for flood frequency and water resources. However, the complex interactions between rainfall, evaporation and soil moisture conditions implies that extrapolations from rainfall patterns to runoff and recharge patterns need to be undertaken with caution. Over the last five years in the English Lowlands for example, above average evaporative demands have, generally, coexisted with above average summer river flows. Importantly also, the UK climate is inherently very variable and, as has been demonstrated, very sensitive to minor shifts in the preferred tracks of rain-bearing low pressure systems. The hydrological volatility of the last 10-15 years also tends to be exaggerated by the relatively quiescent conditions of the previous 20 years - when major floods events were relatively rare, in southern Britain articularly.

Rainfall

The year in brief

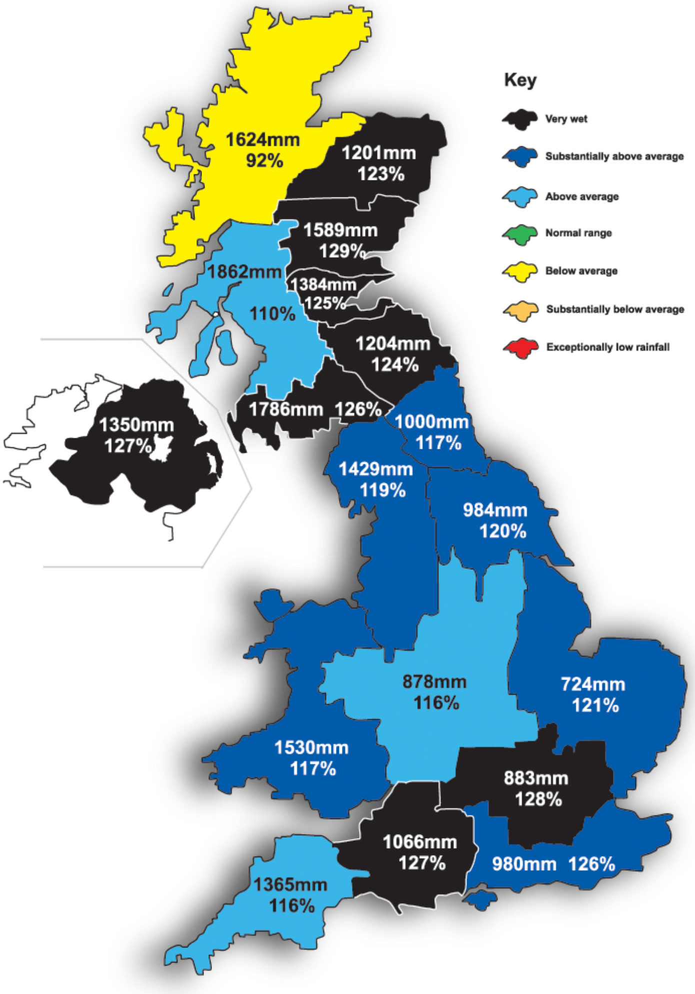
2002 regional rainfall totals for the UK, together with corresponding percentages of the 1961-90 average are shown on Figure 5; corresponding monthly and half-yearly figures are given in Table 1. In all regions apart from northern Scotland, rainfall exceeded the average - by a notable margin in many cases. England & Wales recorded its third wettest year, after 2000 and 1960, since 1903. Scotland was less outstanding but still 16th wettest in the same timeframe and, more notably, the Northern Ireland rainfall total was almost 50mm greater than the previous annual maximum. For the UK as a whole rainfall in 2002 was around 15% above average, the winter, summer and autumn each being well above average. Unusually, rainfall exceeded 120% of the 1961-90 average in five separate months - February was exceptionally wet. September was the only notably dry month at the national scale and apart from catchments in north west-Scotland (and the islands) no extended rainfall deficiencies developed.

In climatic terms the most notable feature of the rainfall distribution during 2002 was the unusual tracks followed by most rain-bearing frontal systems. As a consequence of synoptic patterns which for lengthy

Table 1 *2002 Rainfall in mm as a % of the 1961-90 average.*

Data source: UK Met Office.

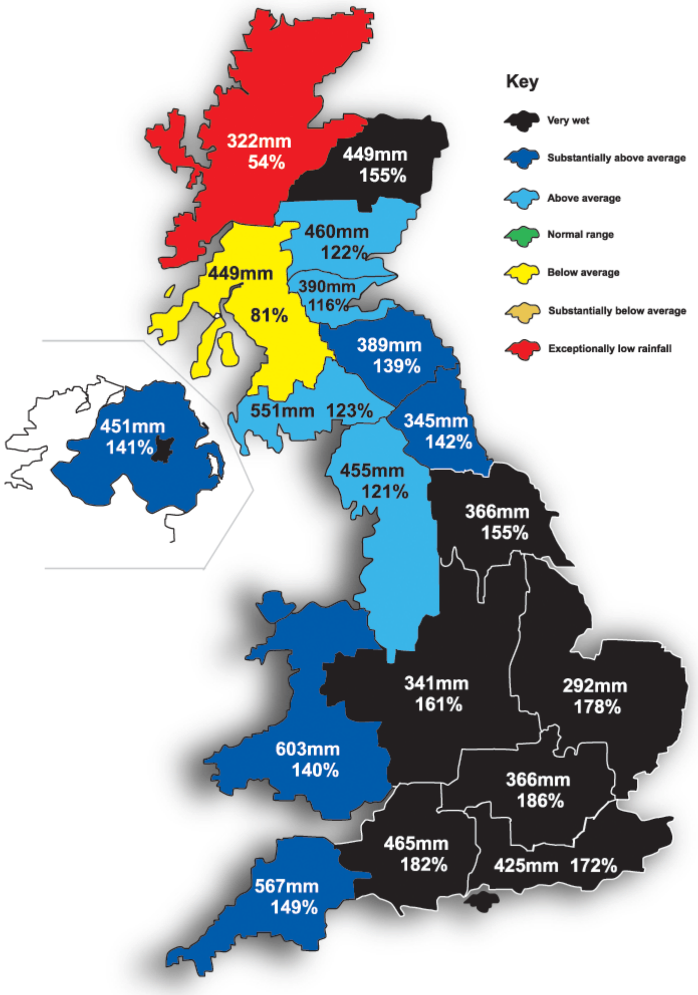
2002		J	F	M	A	M	J	J	A	S	O	N	D	Year	Oct-Mar 2001/02	Apr-Sep 2002
United Kingdom	mm	133	164	74	68	98	83	96	73	40	150	154	107	1240	700	458
	%	121	216	82	104	137	115	132	81	40	136	140	95	115	115	97
England and Wales	mm	94	129	49	53	91	55	81	67	35	134	150	130	1069	515	383
	%	107	205	68	89	143	84	131	88	46	158	167	138	119	105	95
Scotland	mm	210	231	124	89	106	131	125	87	48	173	157	69	1549	1069	585
	%	139	227	99	117	123	152	133	74	34	111	104	45	108	128	97
Northern Ireland	mm	125	162	66	101	133	113	103	56	41	189	178	85	1350	620	546
	%	112	207	75	158	187	159	154	61	41	167	173	82	127	104	118
North West	mm	131	222	61	83	122	100	102	102	53	169	146	139	1429	742	561
	%	108	285	64	116	163	123	119	95	46	132	119	112	119	111	105
Northumbrian	mm	82	137	54	39	67	79	79	85	33	134	105	107	1000	501	382
	%	97	232	77	70	109	131	121	105	46	176	122	131	117	110	96
Severn Trent	mm	63	109	35	45	72	42	85	56	30	124	110	107	878	400	330
	%	90	202	58	82	123	71	159	84	46	193	155	139	116	101	92
Yorkshire	mm	58	120	43	39	65	46	98	114	36	120	119	127	984	425	397
	%	73	207	63	65	109	77	166	154	53	164	149	153	120	96	105
Anglian	mm	44	55	35	32	57	33	88	57	32	91	102	99	724	290	298
	%	89	148	74	70	119	64	179	103	64	179	176	180	121	97	100
Thames	mm	71	85	43	44	80	51	76	42	26	97	147	122	883	384	319
	%	110	188	77	88	143	93	155	72	43	156	226	174	128	106	97
Southern	mm	84	94	46	38	89	54	69	40	43	84	188	153	980	429	331
	%	105	174	74	71	164	99	144	70	62	105	221	186	126	97	99
Wessex	mm	92	112	53	53	99	43	71	40	38	150	192	123	1066	477	345
	%	106	173	75	100	163	75	137	61	53	189	231	132	127	100	95
South West	mm	152	164	77	64	139	54	73	50	26	171	221	174	1365	692	406
	%	110	162	77	93	193	78	106	59	28	148	177	125	116	96	89
Welsh	mm	160	218	64	94	140	69	63	81	38	209	222	172	1530	839	485
	%	112	225	60	117	171	87	81	80	33	152	156	112	117	108	91
Highland	mm	261	284	165	106	96	135	140	67	48	153	129	40	1624	1299	591
	%	139	224	102	117	104	137	132	53	28	77	64	20	92	121	86
North East	mm	108	117	61	45	73	74	138	97	38	197	172	81	1201	594	465
	%	109	180	78	75	106	113	189	111	44	203	174	87	123	112	105
Tay	mm	214	207	114	67	133	129	127	106	32	194	176	91	1589	897	594
	%	148	218	105	108	160	177	165	113	28	149	145	71	129	124	118
Forth	mm	159	183	98	73	103	130	107	105	38	186	134	70	1384	733	555
	%	134	232	104	124	139	189	142	111	34	162	119	63	125	117	115
Clyde	mm	252	288	157	115	136	178	124	99	64	190	191	67	1862	1198	716
	%	133	244	107	137	150	191	113	74	36	99	106	38	110	119	104
Tweed	mm	130	168	65	61	76	92	105	81	37	184	113	92	1204	617	452
	%	130	250	82	107	107	142	143	92	42	194	121	99	124	117	102
Solway	mm	203	250	91	108	151	153	103	115	60	220	217	115	1786	933	691
	%	130	247	77	140	178	182	115	96	42	140	150	78	126	113	116
Western Isles; Orkney and Shetland	mm	188	185	104	73	53	105	84	50	47	58	99	54	1100	896	413
	%	149	220	103	117	90	172	120	58	39	43	75	42	95	127	90



The rainfall figures are provisional for all regions; revised figures will be posted subsequently.

Figure 5 *Annual rainfall (provisional) for 2002 in mm and as a percentage of the 1961-90 average.*

Data source: UK Met Office.



The rainfall figures are provisional for all regions; revised figures will be posted subsequently.

Figure 6 *October-December 2002 regional rainfall totals (provisional) in mm and as a percentage of the 1961-90 average.*

Data source: UK Met Office.

periods favoured tracks across southern Britain parts of southern England registered October-December rainfall totals which approached the record figures established in 2000. Over the same timespan rainfall deficiencies in western and northern Scotland increased briskly. Following the second wettest January-July period in at least 40 years, the Highland region recorded five successive months with well below average rainfall. Over the August-December period precipitation was only around half the long term average; a remarkable deficiency in this part of the UK - the total was around 100mm less than the previous minimum for the Highland region in a series from 1961. Modest late summer/early autumn rainfall deficiencies were common across much of the country but these were rapidly made-up during an exceptional wet period from the second week of October. For England and Wales, the October-December rainfall was the third highest (after 2000 and 1929) in a series from 1766 - see Figure 6.

Rainfall - through the year

January

2002 began with high pressure dominating synoptic patterns; correspondingly precipitation was very limited and the sustained low temperatures resulted in frozen catchment conditions over wide areas. Following low rainfall totals in November and December 2001, winter rainfall deficiencies began to develop in much of southern Britain. However, synoptic patterns changed around mid-month allowing a mild westerly airflow to feed a succession of active frontal systems across the UK. As a result January rainfall totals in most western regions were well above average; by contrast some sheltered eastern catchments reported less than 60%.

February

As the cyclonic pattern continued through most of February many western areas experienced a number of damaging storms. A particularly active depression produced notable rainfall totals on the 1st - approximately 75mm was reported from Shap (Cumbria) - and regular pulses of rain continued through the month. Over a very unsettled six-week period 522mm was recorded at Bala (north Wales); this is the equivalent of around four months average winter rainfall and established a new 40-day maximum rainfall accumulation for the site. For the UK as a whole, February 2003 was the third wettest in a series from 1900. Nonetheless, the counterbalancing effect of the dry early winter meant that regional rainfall totals for December-February were mostly well within the normal range.

March

March was windy but mild, with notable rainfall early in the month; a 24-hr total of 93mm was reported for Sloy in the western Highlands on the 6th. Most of the frontal systems which crossed the country followed tracks remote from southern England where, in some central areas, fog-drip provided the only contribution to precipitation totals over periods of up to three weeks (extending into April). Northern Ireland registered its 7th successive March with below average rainfall. Notwithstanding substantial month-on-month variability, winter-half year rainfall totals were close to, or above, average in all regions - ensuring an encouraging water resources outlook.

April

April was an exceptionally mild and sunny month in most regions, with large spatial variations in rainfall amounts. The 100% rainfall isopleth broadly partitioned Britain between the wetter west, where some catchments reported >150% of average and the much drier east. In some areas a short but intense drought - at an important time for the farming community - was terminated by widespread rainfall on the 26th; in some central areas less than 5mm had been recorded over the previous seven weeks. The late-April rainfall was agriculturally very useful but too late to be hydrologically effective in eastern England where the dry April soils signalled the end of the 2001/02 recharge season.

May

In May a brief heat-wave in mid-month was more than counterbalanced by longer autumnal episodes during which many localities experienced a wide variety of precipitation types: rain, sleet, snow, hail and fog-drip. Notable storm totals (>50mm) were reported for Dawlish (Devon) and parts of County Down on 16/17th. May rainfall totals exhibited large spatial variations - a reflection of the showery and thundery nature of much of the rainfall, but most exposed western hills had a notably wet month. For the UK it was the second wettest May since 1986. Northern Ireland was particularly wet; rainfall was around 90% above the May average and contributed to the highest January-May rainfall total in a series from 1900.

June

Low pressure continued to dominate synoptic patterns in June - across northern regions especially. Scotland and Northern Ireland were very wet but June rainfall totals fell below 70% in parts of England where many lowland catchments were very dry after the initial week. For the UK as a whole, the combined May and June rainfall was the second highest since 1969. In Northern Ireland the wet phase continued; the May-June rainfall was the highest on record.

July

July was an exceptional month with large spatial and temporal variations in rainfall, lengthy dry spells in central England, and outstanding local storm rainfall totals across a range of timeframes. Approaching month-end the breakdown of a brief heat-wave triggered violent thunderstorms in many areas. On the 30th, 26.2mm fell in 15 minutes at Kirklees (Yorks), 103mm was reported in around 6 hrs at Charnwood Forest (Leics). The most severe local flooding was in Glasgow - triggered by a six-hour total of 61mm (including 38mm in a hour and a maximum intensity of 94.5mm/hr). A 3-hour total of 49mm at Leuchars (Fife) contributed to the wettest July in an 80-year rainfall series. Notwithstanding some dry interludes, July rainfall totals were well above average in most regions and the unsettled complexion to the late-spring/early summer weather patterns is reflected in the May-July rainfall - the wettest such period since 1958 for the UK (but 1968 and 1997 were only marginally drier). Exceptionally wet conditions extended across a broader timespan in Scotland and Northern Ireland which, respectively, reported their second highest and highest rainfall on record for the January-July period.

August

The extremely wet spell continued into August; for the rain-day ending on the 1st, Fylingdales (Yorks) registered 114.6mm and totals were outstanding throughout most of North-East England. Exceptional rainfall totals characterised wide areas for the week ending on the 5th. More locally, Olney (Bucks) reported 63mm on the 6th, an exceptional Figure for a lowland site. From the 13th, a rare (during the spring and summer of 2002) north-eastward extension of the Azores high pressure cell produced very dry and warm conditions. Northern Ireland recorded its driest August since 1995. The summer (June-August) rainfall total was appreciably above average for the UK as a whole and some of the driest (on average) catchments in eastern England reported their fifth summer in the last six with above average rainfall.

September

September was a very mild, sunny and dry month in most regions as anticyclonic conditions persisted in most regions. Most catchments reported lengthy dry sequences - but punctuated locally by some notably intense storm events, commonly associated with thunderstorms. On the 7/8th torrential rainfall (>90mm, including 61mm in 4 hours) caused severe flooding in Inverness (Highland). The following day Swanage (Dorset) reported a very exceptional 121.4mm (including 71mm in two hours) and rainfall totals exceeded 20mm over much of England and Wales. This widespread event heralded an extended dry spell, and many areas reported 27 or more days without significant rain in September. Scotland and Northern Ireland registered their driest and second driest September respectively in the last 30 years. More significantly, only in 1972 has the combined August/September rainfall been appreciably lower for the UK.

October

Rainfall deficiencies continued to build in early October - sequences of days without significant rainfall extended to 30 or more in parts of central England. However, from the 9th active frontal systems again tracked across the British Isles, heralding a very unsettled episode with damaging gales towards month end. The passage of several sequences of vigorous depressions produced exceptional 2-5 day rainfall totals: 120mm at Dunkeswell (Devon) on the 11-15th; 90mm in parts of the Grampian Region (22-23rd) and >130mm in the Mourne Mts, 20-22nd, heralding an outstandingly wet 7-day period in northern Ireland. Parts of northern and western Scotland - to the north of the favoured frontal tracks - had a dry month but most regions reported rainfall totals >150% of average. The third notably wet October in succession produced a dramatic change in the hydrological outlook, flood risk was significant in many areas by month end.

November

Continuing the synoptic theme established in October, November was a mild but stormy month as a succession of vigorous Atlantic low pressure systems crossed the British Isles. Dry days were rare - a few localities reported none (e.g. in parts of Northern Ireland) - and some 2-3 day rainfall accumulations were very exceptional. From the 15-17th orographic enhancement contributed to a remarkable 240mm total reported for Mulden (near Elgin), equivalent to around a quarter of the annual average, triggering severe flooding in the Grampian Region. Some exposed catchments in south-west Britain recorded more than 40% of average annual rainfall over the seven weeks from Oct 13th and the monthly total reached three times the October average for some locations in central southern England. At Wallingford (Oxon), November was among the four or five wettest months in the last 50 years. Consequently, autumn (September-November) rainfall totals were well above average in all regions apart from western and northern Scotland - in parts of the latter, rainfall was only a little above 50% of the 1961-90 average.

December

Apart from a calm interlude in mid month, resulting from a westerly extension of the Scandinavian high, active frontal systems were again very common in December. However the low pressure systems generally followed an even more southerly track. Much of Scotland was relatively dry, the north-west remarkably so - extending an exceptional rainfall deficiency which began in the late summer. The hydrological magnitude of this drought was emphasised by the December rainfall in some catchments in south-east England which reported monthly totals five times greater than that for some catchments in north-west Scotland - a rare circumstance. December rainfall totals were very high throughout most of southern Britain and a sequence of depressions over the final week, producing rainfall totals of 50-100mm over wide areas and triggering widespread flooding which continued into 2003.

Evaporation and Soil Moisture Deficits

Background

Over 40% of UK rainfall is accounted for by evaporative losses - but the proportion varies greatly from region to region, reaching around 80% in the driest parts of the English Lowlands. Evaporation may occur directly from open water surfaces, from the soil or as transpiration from plants. Potential evaporation (PE) is the maximum evaporation which would occur from a continuous vegetative cover amply supplied with moisture. PE losses exhibit a strong annual cycle, peaking normally in June or July; typically, only 10-20% of the annual PE loss occurs during the October-March period. Given normal rainfall, the increasing temperatures and accelerating evaporative demands through the spring lead to a progressive drying of the soil profile and the creation of what is termed a Soil Moisture Deficit (SMD). Eventually, the ability of transpiration to proceed at the potential rate is reduced as a result of the drying soil conditions, the ability of plants to take up water and the measures plants take to restrict transpiration under such conditions. Thus in the absence of favourable soil moisture conditions actual evaporation (AE) rates will fall below the corresponding PE rates, appreciably so during dry summers. When plant activity and evaporation rates slacken in the autumn, rainfall wets-up the soil profile once more - allowing runoff rates to increase and infiltration to groundwater to re-commence. Knowledge of the soil moisture status and evaporation rates are essential factors in understanding water resource variability.

Potential and actual evaporation losses

2002 added a further year to an exceptionally warm cluster. During the last 15 years, only in 1996 have annual mean temperatures fallen below the 1961-90 average and, over the 1998- 2002, period the Central England Temperature exceeded the average by almost 0.7°C. Relative to the average, January, February, March, November and December 2002 were each very mild months but temperatures during the May-July period - when evaporative demands are normally at their greatest - were close to the 1961-90 average. As a consequence potential evaporation (PE) losses were generally within the normal range across most of Great Britain, and appreciably below the annual totals for a number of recent years. Annual PE totals and corresponding percentages of the 1961-90 average, computed using the Met Office Rainfall and Evaporation Calculation System (MORECS[3]) methodology, and assuming a grass cover, are shown on Figure 7. As usual, the maximum PE losses - in excess of 600mm - are found in southern Britain, coastal areas of East Anglia in particular, whilst totals of less than 500mm characterise much of the Scottish Highlands. Relative to the 1961-90 average the range of spatial variation is much narrower with annual totals generally falling in the 95-105% range; larger positive PE anomalies were mostly confined to coastal areas where wind can be a particularly influential factor.

Annual Actual Evaporation losses are normally appreciably below the corresponding PE totals across much of the UK - in an average year the shortfall is around 80-110mm across large parts of the English Lowlands. However in 2002, above average rainfall during the late spring and early summer allowed transpiration to continue almost unhindered and AE losses closely approached PE losses until the late summer. Although AE losses fell below average in the Welsh mountains and Scottish Highlands, the generally modest shortfall of AE relative to PE losses resulted in AE totals for 2002 being above average throughout much of the country (see Figure 8). AE losses were particularly notable across the English Lowlands where the 2002 losses typically rank amongst the highest 10 in the 42-year MORECS series. Over wide areas, annual losses were between 500 and 600mm, equivalent to more than 80% of the rainfall in many eastern lowland catchments. Above average AE losses have been a recurring feature over the 1998-2002 period for much of the English Lowlands; taken together, mean AE losses over the five years are around 15% greater than the 1961-90 average across large parts of southern and eastern England.

Soil moisture deficits

The development and decay of soil moisture deficits (SMDs) over the 1998-2002 period is illustrated on Figure 9 for six representative MORECS squares; the SMD values relate to the end of each month and assume a grass cover. Monthly PE and AE totals are also shown together with the differences in the annual PE and AE totals. Taken together, the 1998-2002 period contrasts markedly with the preceding five years - when maximum SMDs were generally greater and soils remained notably dry for longer periods. In 2002, SMDs began to build across eastern and southern Britain during April but the steep increase which commonly marks the acceleration of evaporation rates in the late spring failed to materialise - May rainfall was well above average in almost all regions. More substantial SMD increases occurred in June but as a consequence of the sustained July rainfall, soils were their wettest since 1991 in many areas of southern Britain at month end. However, contrary to the normal pattern, SMDs then increased through the late summer and early autumn. Maximum deficits during 2002 were commonly registered in late September/ early October (see Figure 10) when SMDs were well above average across most of Britain and exceeded 100mm throughout much of the English Lowlands. In the driest eastern catchments, SMDs were the equivalent of around 10-12 weeks average rainfall (allowing for evaporation losses). Normally such dry soils would substantially delay the seasonal recovery in river flows and groundwater levels. In the event however, the second wettest October and November since 1974 across much of southern Britain ensured that the deficits were eliminated over a much shorter timespan. By the late autumn almost all catchments were at, or closely approaching, saturation - allowing runoff and recharge rates to pick up smartly even in eastern England.

River Flows

The year in brief

As in the preceding two years, many new runoff records - mostly over lengthy timespans - were established in 2002. Although notable localised - mostly urban - flood events were common, the frequency of widespread floodplain inundations was relatively modest given the preponderance of wet months and the length of time most catchments were close to saturation. However, spates were common in most river basins and high flows were maintained over substantial periods. These episodes are reflected in Figure 11 which illustrates 2002 runoff totals - expressed as a percentage of the period of record average - for a network of index gauging stations throughout the UK. Annual runoff totals were depressed in north- west Scotland, where the River Carron reported its second lowest annual mean flow in a 24-year record. This region was however very atypical of the UK as a whole. A significant proportion of rivers in eastern Scotland and in Northern Ireland (where flow records generally begin in the 1970s) established new maximum annual runoff totals; in the

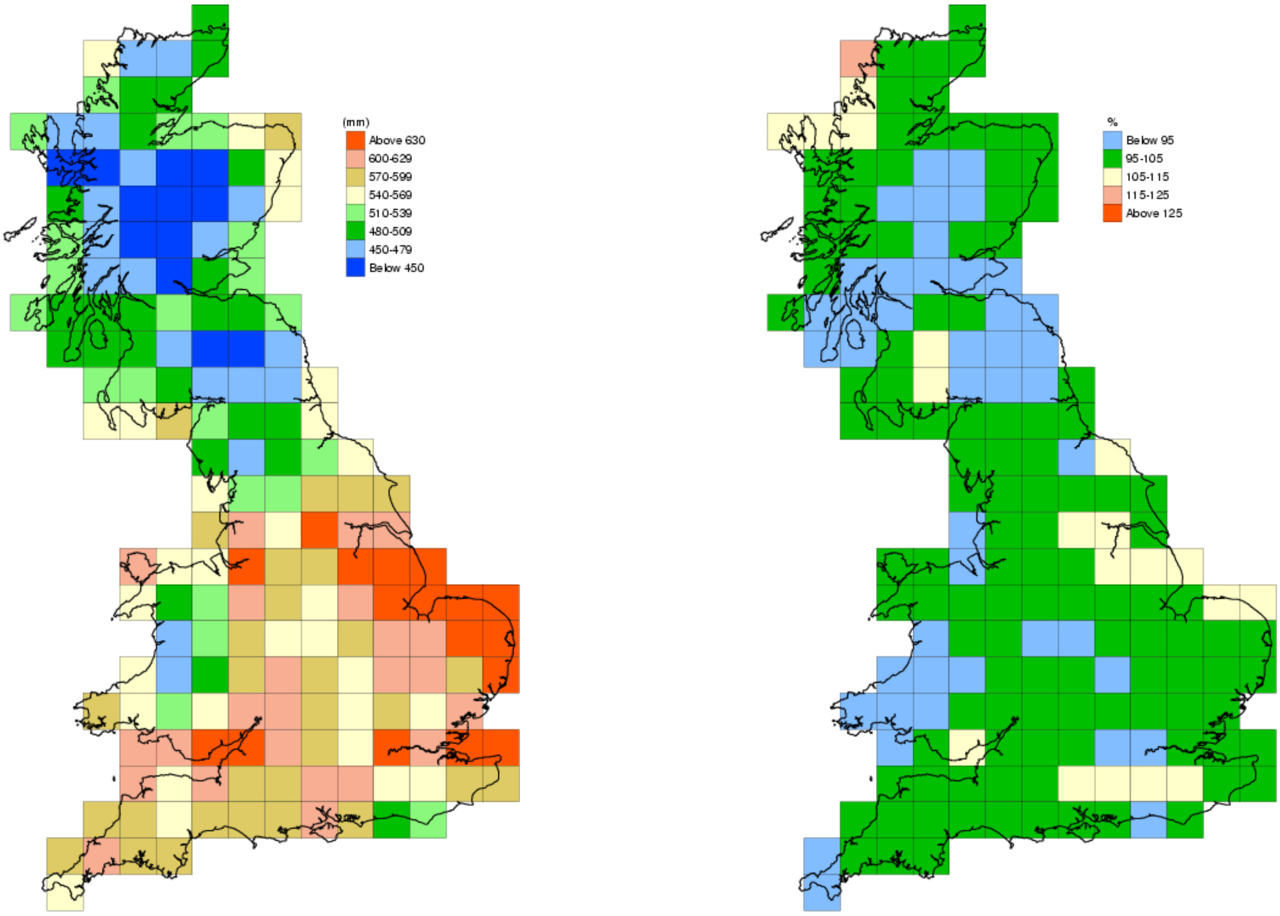


Figure 7 *Potential evaporation totals for 2002 in mm and as a percentage of the 1961-90 average.*

Data source: MORECS.

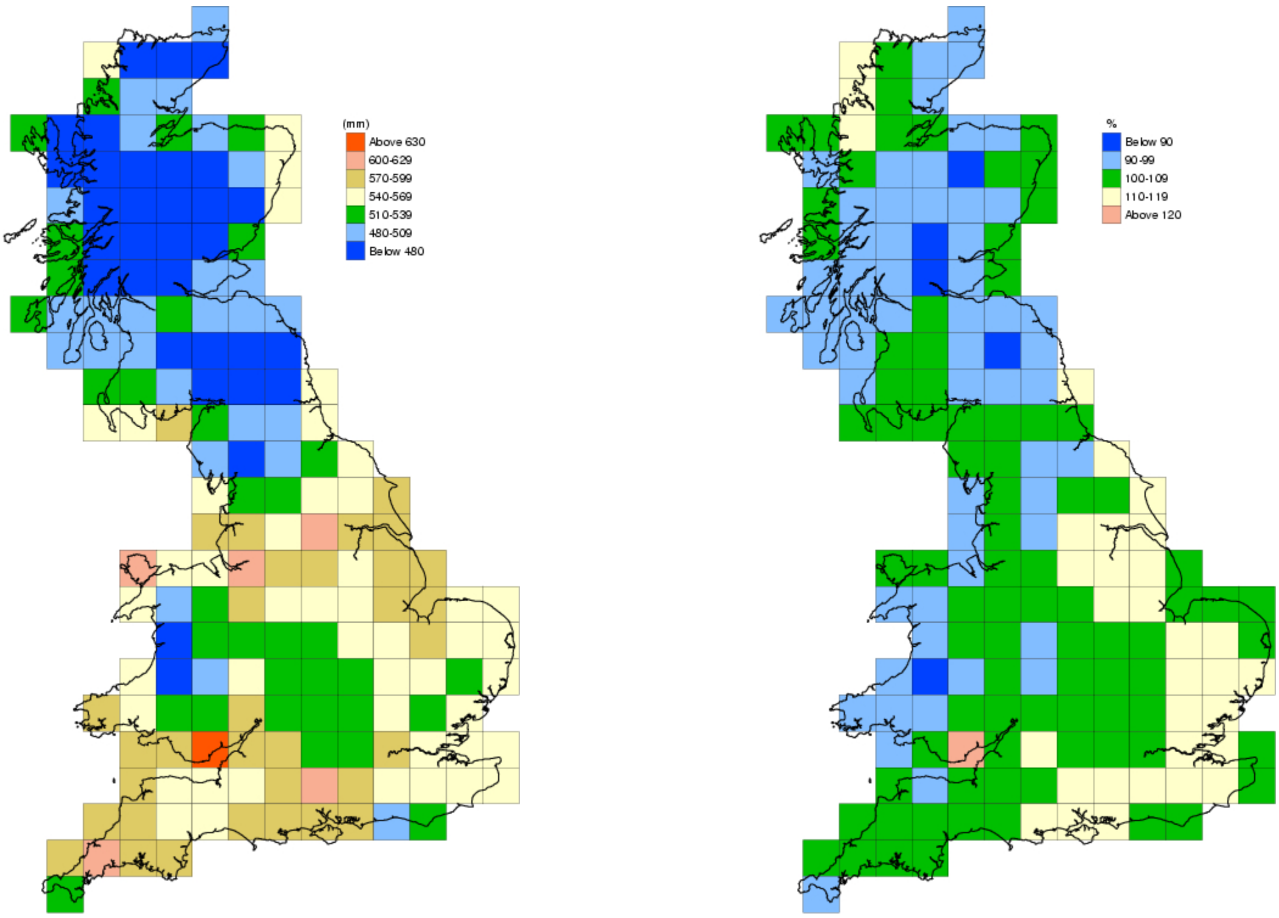


Figure 8 *Actual evaporation totals for 2002 in mm and as a percentage of the 1961-90 average.*

Data source: MORECS.

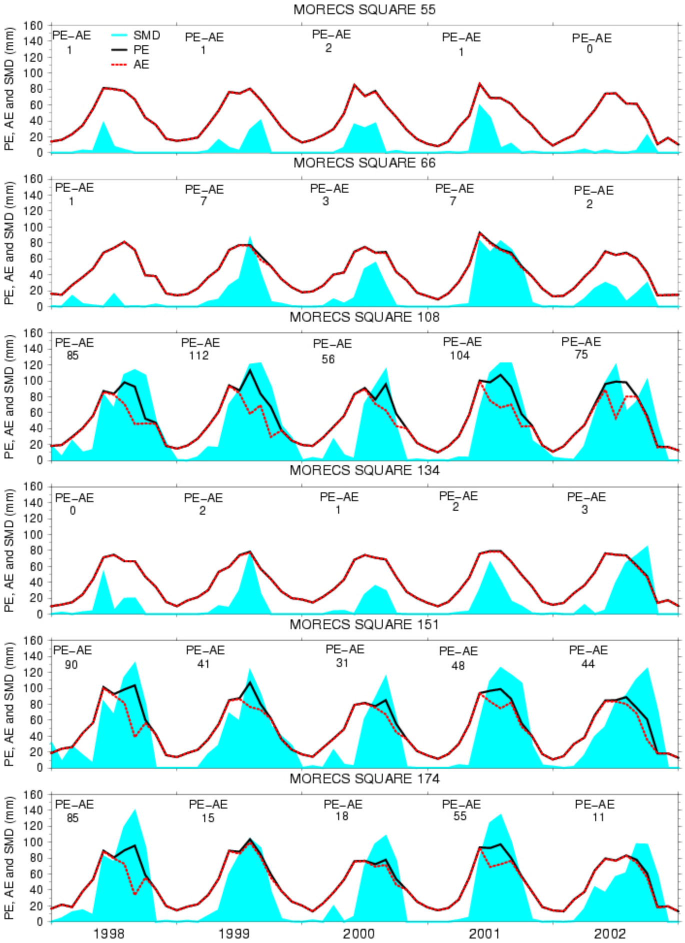


Figure 9a *The variation in potential evaporation, actual evaporation and soil moisture deficits for six MORECS squares 1998-2002.*

Data source: MORECS.

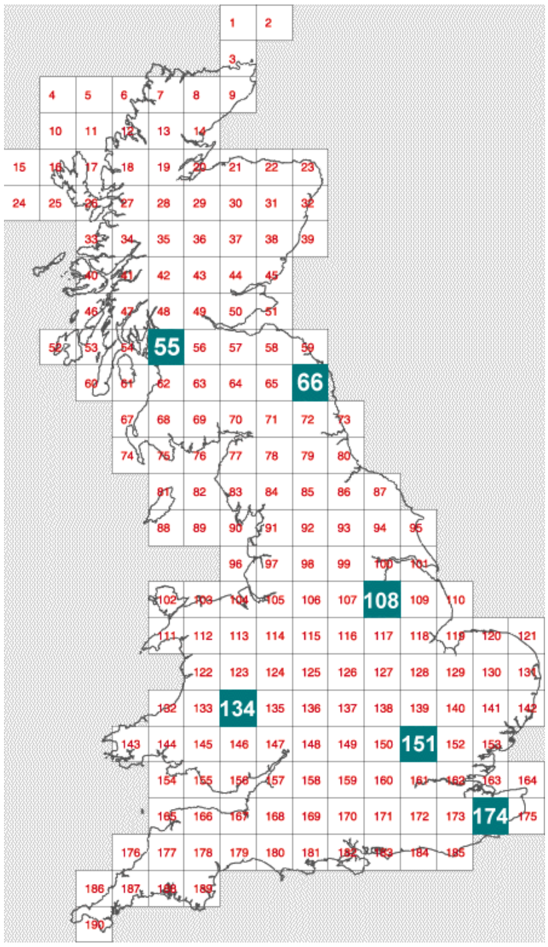


Figure 9b *MORECS Location Map: the location of the 40km squares and their associated reference numbers.*

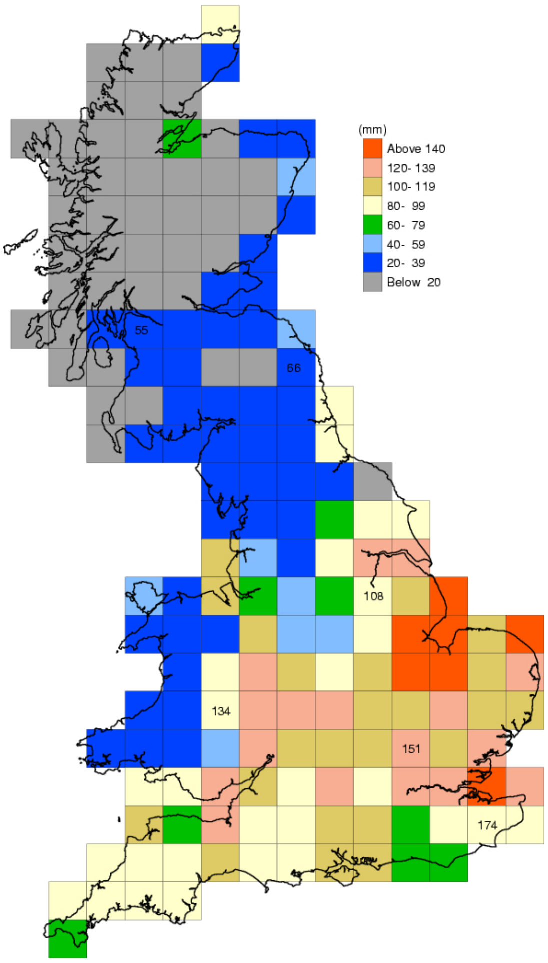


Figure 10 *Soil Moisture Deficits at the end of September 2002.*

Data source: MORECS.

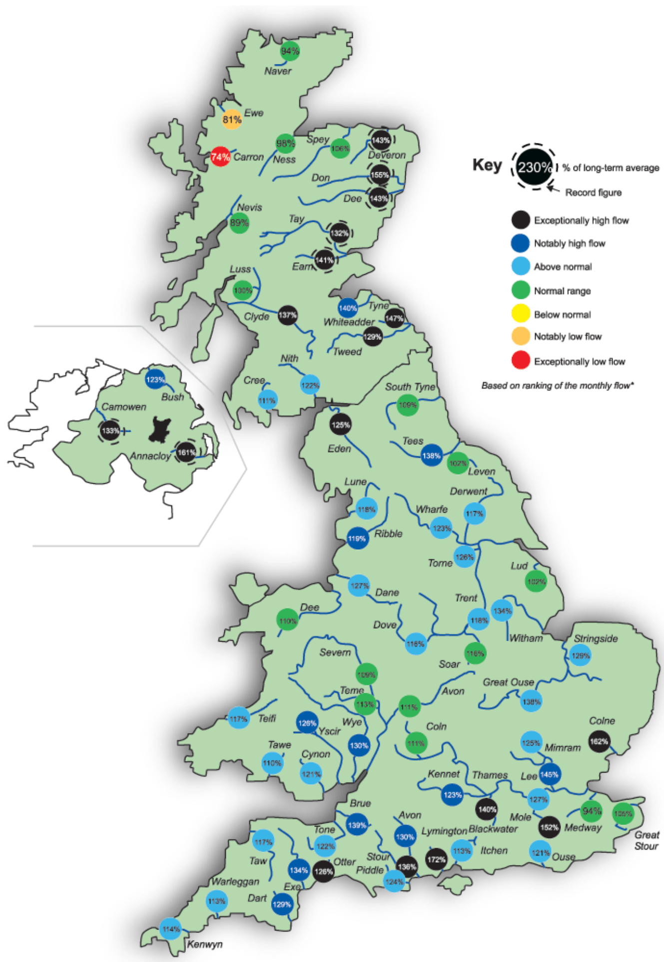


Figure 11 *2002 runoff totals as a percentage of the previous average.*

Data sources: Environment Agency/Scottish Environment proection Agency/ Rivers Agency.

case of the River Annacloy the previous maxima was exceeded by >25%. Mean flows were also notably high in many catchments in southern England; some spring-fed rivers registered significantly above average monthly flows throughout the year.

Figure 12 shows daily flow hydrographs for 20 index gauging stations throughout the UK; the 2002 hydrographs are illustrated by the solid trace and the shaded envelopes illustrate the maximum and minimum daily flows over the preceding record. The year began with seasonally depressed flows across much of the UK but, thereafter, only brief approaches were made to the low flow envelope (e.g in April and early October). The unusually high frequency of, mostly minor, spates in the late spring and early summer of 2002 resulted in the normal seasonal flow contrasts being less evident than in a typical year. High flows, with significant flooding, were common in February and over the last three months of the year; an exceptionally severe event afflicted parts of eastern Scotland in November. Localised flooding was frequent in the summer and autumn, particularly in urban areas where drainage systems were overwhelmed during intense storms. Minimum flows during 2002 were generally experienced in the early autumn and, with the exception of rivers in north-west Scotland, were typically very healthy - substantially greater than those which characterised the 1989-1997 period. For the third successive year, river flow patterns across the UK departed significantly from those experienced in a typical year. The unusual nature of the 2002 flow patterns is evident from the flow duration curves featured in Figure 13. These curves allow the proportion of time that river flows are above, or below, any given threshold to be identified - they also provide a means of comparing the regime for a particular year with that for the previous record. The 2002 duration curves confirm the notable regional contrasts in runoff patterns. Flows in rivers throughout north-west Scotland were generally depressed throughout the full flow range whereas in eastern Scotland flows were atypically high; this was true of many rivers in Northern Ireland and some draining impermeable catchments in the English Lowlands also. The 2002 duration curves for rivers in northern England, Wales and the South-West were more representative of the normal regime but many spring-fed rivers in eastern and southern England, which in any case are characterised by stable regimes, registered an exceptionally modest range of flows. Away from rivers in northern Scotland, a feature of most flow duration curves is the degree by which the 95% exceedance flow (a commonly used index of low flows) was greater than the long term average, confirming the transient nature of depressed runoff rates in the summer and autumn of 2002.

River flows - through the year

January

Following lengthy recessions in December 2001, freezing weather conditions in early January further reduced runoff rates and resulted in flows approaching monthly minima in many rivers across the country (from the Tay to the Lymington). The influx of a mild westerly airflow during the second week was accompanied by a dramatic increase in runoff rates in impermeable catchments. Spates were common towards month end and storms on the 26-28th resulted in widespread flood alerts (>100 across England and Wales). However, January runoff totals were well below average in most impermeable lowland catchments. In Northern Ireland, the River Annacloy registered a ninth successive month with below average flows, establishing a new May-January runoff minimum - the wide margin by which the previous minimum was eclipsed provides a guide to the limited replenishment of the Silent Valley reservoirs over the period beginning in the spring of 2001.

February

February began with many fluvial and tidal flood warnings in operation, and bankfull - or higher - flows were common throughout the month. Fortunately, the rapid passage of most frontal systems helped to moderate the risk of severe flooding. The ability of the natural drainage network to cope with sustained high runoff was also well demonstrated. Nonetheless, significant flooding was experienced in some locations (e.g. Monmouth) and floodplain inundations were particularly common in mid-month. In a broad zone from South Wales to the Southern Uplands many rivers registered flows around the mean annual flood level on four or more occasions in the month. Correspondingly, gauging stations establishing new maximum February runoff totals showed a very wide distribution; runoff for the River Dee (north Wales) eclipsed the November 2000 total to establish a new single-month record in a series from 1937.

March

Most rivers were in brisk recession in early March, with an associated reduction in flood risk. In Scotland, flows recovered smartly in the second week and short-lived spates were common in mid-month across southern England before recessions became re-established. Runoff totals were within the normal range in almost all index catchments but mostly lower in rivers draining impermeable catchments than those where groundwater makes a major contribution to river flow. Winter half-year (October 2001-March 2002) runoff totals were generally also well within the normal range but substantially above average in many Scottish catchments - for the sixth successive year in some cases.

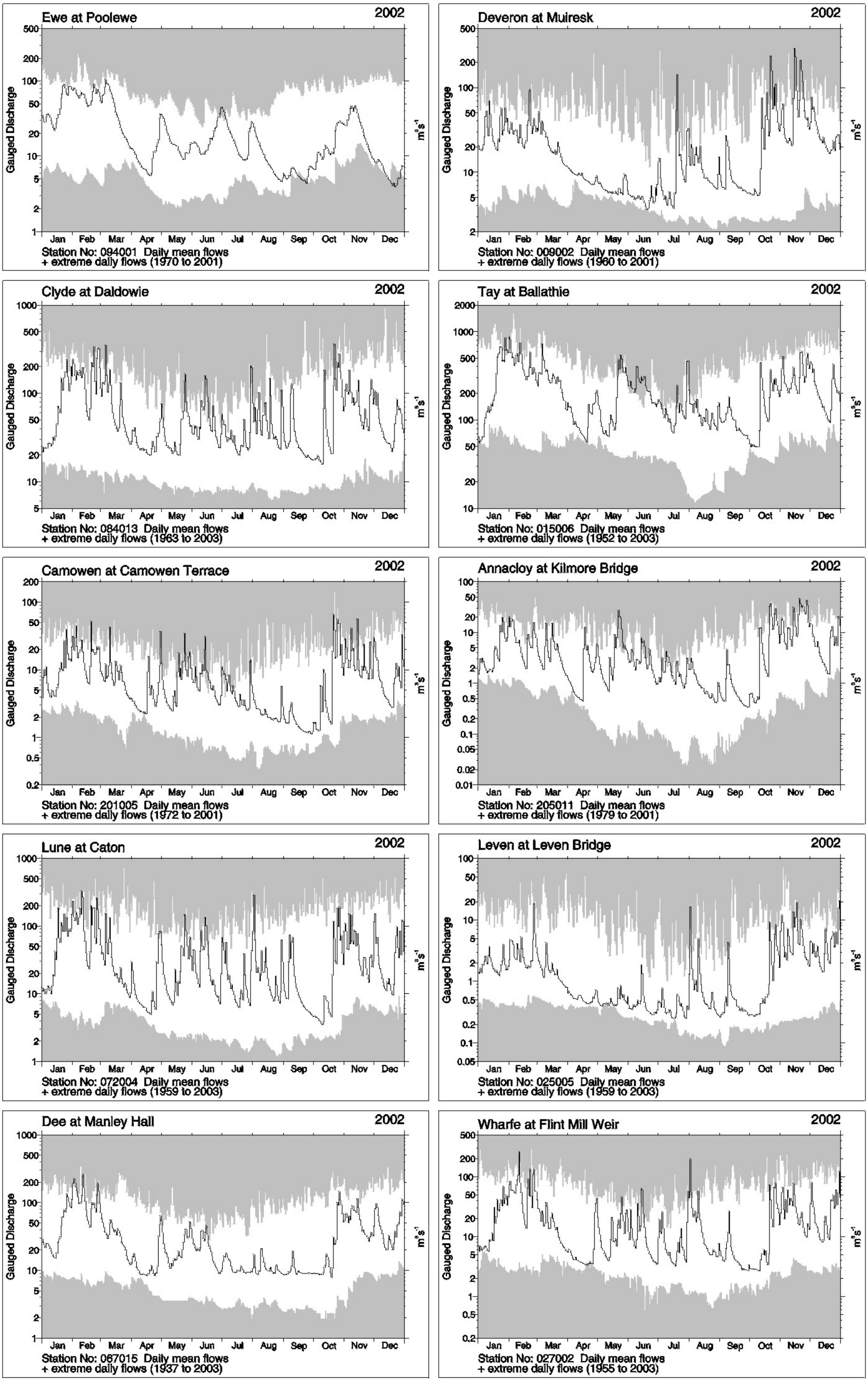


Figure 12 *Daily river flow hydrographs for 2002.*

Data sources: Environment Agency/Scottish Environment Protection Agency/Rivers Agency.

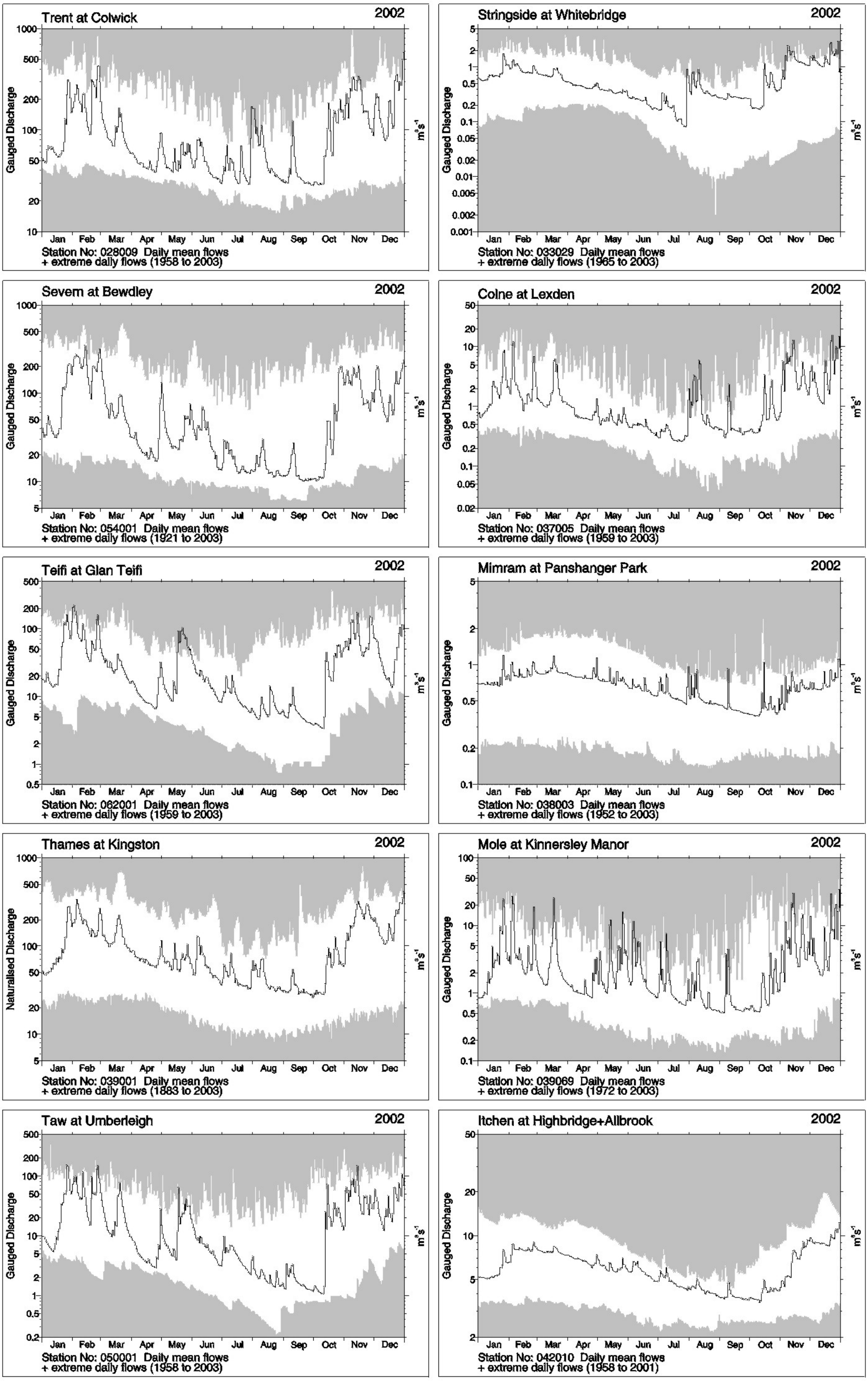


Figure 12 *(Contd.).*

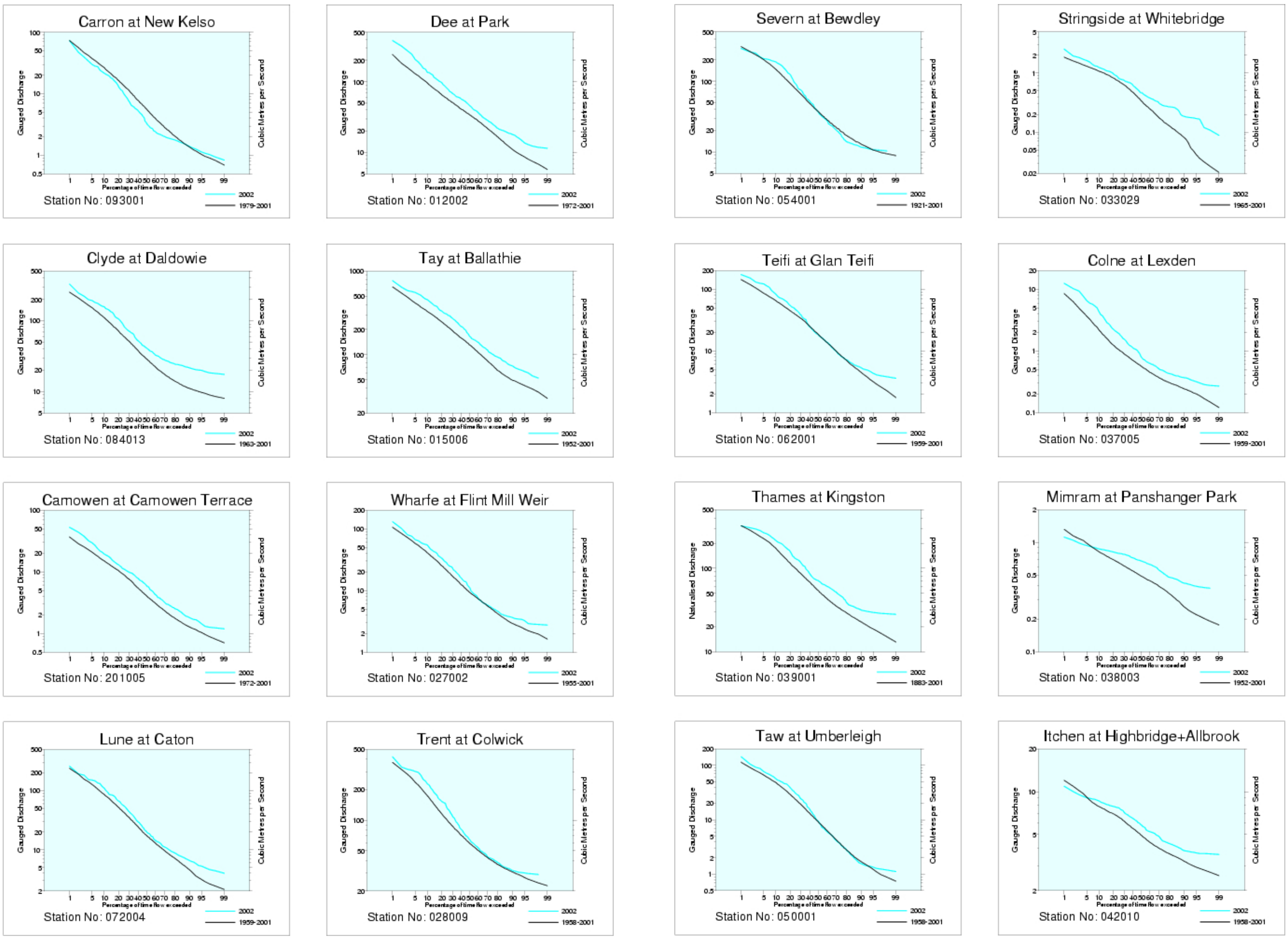


Figure 13 *Flow duration curves for 2002 (in blue) and the preceding record.*

Data sources: Environment Agency/Scottish Environment Protection Agency/Rivers Agency.

April

The early spring recessions continued into April and although interrupted by spates in mid-month (e.g. in Northern Ireland), monthly minimum flows were approached over wide areas as flow patterns showed similarities to the sustained recessions experienced in the spring of 1997. Heavy late-April rainfall produced a very brisk recovery in many catchments - triggering modest floodplain inundations (e.g. in South Wales). Notwithstanding this upturn, April runoff totals were mostly well below average, notably so on the River Spey (at the Boat of Garten gauging station) which reported its lowest April flow since 1981.

May

Aside from those rivers primarily reliant on groundwater, most rivers registered a very wide range of flows in May, but spatial variations in runoff totals were rather more marked than in April. Notably high flows were reported at the beginning and during the third week of the month for many western rivers. The Dart, Teifi and Yscir were amongst a significant number establishing new maximum flows for May. The associated modest floodplain inundations were complemented by significant urban flooding caused by intense storm events (e.g. in Belfast and Swansea). May runoff totals were unprecedented for a few rivers in south-western Britain but depressed in a zone from the Humber to the Forth estuary - the River Leven (Cleveland) reported its lowest May runoff since 1960.

June

June witnessed outstanding runoff totals in many catchments in Scotland and Northern Ireland where especially high flows - for the early summer - were recorded in mid-month. The River Camowen established a new maximum June flow on the 14th; the following day the Clyde recorded its highest June flow since 1966. Flooding was generally very modest but thunderstorms resulted in some significant local - mostly urban - flooding (e.g. Belfast on the 22nd). Many rivers, including the Camowen, Nith, Tay and Mole, established new maximum June runoff totals but in a zone from Cleveland to the East Midlands mean flows were depressed - only around 50% of the June average for the River Torne.

July

Most July runoff totals were within the normal range but moderate floodplain inundations were again common (significant flooding occurred on the River Etherow at Glossop) and the River Tay and River Clyde - both with flow records of >40 years - reported their highest July flows (on the 30th). Of greater significance in terms of their impact were a series of intense rainfall events - often with heavy surface runoff and, in Scotland especially, landslides - transport disruption was severe and extensive. Flash floods afflicted Belfast again on the 12th, Nottingham on the 20th, and the Pennines and Scotland on the 30th. Evacuation of residents from stricken areas was necessary (e.g. Lincoln, the Trossachs, and Glasgow where a major event caused 500 residential properties were inundated and required an estimated 200 people to be evacuated).

August

Other than at the very local scale, it is unusual for flood risk to extend into August but in 2002 rivers draining the Pennines and North York Moors were very vulnerable to further rainfall. The Wharfe reported its highest August flow on the 2nd and, in Scarborough, intense storm runoff caused a caravan park to be evacuated. Localised flooding also occurred in Perth and Pitlochry on the 6th. To the south, thunderstorms generated severe localised flooding and substantial transport disruption - on the 7th the rail network in London was badly affected. In many eastern catchments August runoff totals were amongst the highest three or four on record. By contrast, runoff was depressed in much of Wales and western Scotland - where the River Carron reported its second lowest August total. Away from such areas, summer (June-August) runoff totals were well above average - for the fourth or fifth year in succession in many lowland catchments.

September

The late summer recessions resumed in September after significant spates during the second week - on the 8th, the Mimram recorded its highest September flow since 1975. River flows generally remained in-bank but some locally significant flooding did occur as a consequence of intense storms overwhelming urban drainage capacities e.g. at Swanage, Inverness, Burntisland (Fife); landslides were triggered and transport disruption was again substantial. Of wider hydrological significance were the depressed flows reported at month-end - across much of southern Britain flows were at their lowest since 1996 or 1997 and new September minima were established in a number of western rivers, including the Cynon and Ewe.

October

In many catchments flows continued to decline in early October. On the 10th, the River Tawe (South Wales) recorded its lowest October flow since the 1959 drought. But thereafter - again echoing the 1959 drought - river flow recoveries were dramatic with moderate flooding in south-western Britain in the following week. In parts of western Scotland, the recovery was insufficient to prevent a new October runoff minimum being established on the River Carron. To the east however, the recovery was dramatic culminating around the 22nd when all three gauging stations on the Don eclipsed previous maxima, as did the River Tweed at Sprouston; flooding affected Eyemouth. Inundation of agricultural land was very widespread and many rivers in the English Lowlands - most of which respond much more slowly than rivers draining the western hills - were close to bankfull.

November

The continuing passage of active frontal systems further increased the risk of flooding in November which was characterised by sustained high flows in most river basins away from north-west Scotland. Severe flooding affected the South-West peninsular around the 14th (e.g. at St Ives and Newquay) by which time flood warnings applied across a broad swathe of England and parts of Scotland. On the 15/16th many rivers draining to the Moray Firth overtopped their banks - the Lossie exceeded its previous maximum in a 44-year record, resulting in severe flooding; evacuations were required in Elgin and Moray. The following week the maximum flows established on the River Don in October were eclipsed - further flooding occurred in Brechin and other parts of Aberdeenshire. Rivers establishing new November runoff maxima displayed a wide distribution - including the Annacloy, Kenwyn and Kennet (which, like other chalk rivers, benefited substantially from increasing baseflows as groundwater levels rose).

December

December was a month of stark regional contrasts in runoff patterns. New December runoff minima were established in many catchments in northern Scotland where mean flows were typically 10%-30% of the monthly average. Flows fell below previous December minima in mid-month on the River Ewe where the accumulated deficiency for the August-December period was, remarkably, more than 20% below the previous minimum in a 32-year record. By contrast, in much of southern Britain, the English Lowlands especially, flows were well above average and, as further sustained rainfall fell on saturated catchments, flood warnings were increasingly frequent from mid-month; by early January 2003 around 300 were in operation. On the 28/29th December flooding occurred at many flood-prone localities (from Elvington in North Yorks to Yalding in Kent) and further rainfall at year-end heralded the most extensive flooding since 1947 in a few areas - e.g. the middle reaches of the Thames.

Groundwater

The year in brief

Rainfall over the outcrop areas of most major aquifers during 2002 was generally 15-30% above the 1961-90 average. Because of the non-linear relation between rainfall and groundwater replenishment, this implies that recharge to some eastern aquifer units was more than 50% above the annual mean. This, together with the notable high recharge over the 1997-2001 period, helped ensure that in almost all areas groundwater levels were above the seasonal average throughout most of 2002.

In 2001 the seasonal recovery in groundwater levels began later in the autumn than is normal, and replenishment to the major aquifers was modest until the middle of January 2002. Thereafter however, infiltration was heavy and the wet spring served to extend the recharge season into May (and, in some areas, the early summer). The unusually late recharge episode helped to maintain generally healthy groundwater levels through the summer but with very dry soil conditions in September the autumn recover in groundwater levels was expected to be sluggish. In the event, infiltration rates were remarkably high by late October and regular heavy pulses of recharge fuelled a very steep rise in levels through the late autumn; some parallels could be drawn with the dramatic recovery of autumn 2000. Infiltration was especially abundant over the last two weeks of 2002 and although the heavy pulse of recharge had not all reached the water-table by the end of December, localised groundwater flooding triggered concern that early 2003 could witness a repetition of the early-2001 groundwater flooding in southern Britain.

Figure 14 shows 1998-2002 groundwater level hydrographs for a selection of index wells and boreholes throughout the UK. Five-year plots have been used because groundwater levels in many areas show considerable persistence - reflecting groundwater replenishment over a number of recharge seasons. The groundwater level trace is shown together with the monthly maximum and minimum levels for the pre-1997 record. The normal seasonal variation in levels is clearly evident in the hydrographs for most monitoring sites in the Chalk, limestone and in the more responsive Permo-Triassic sandstones units. The spring maxima were generally within the normal range in the Chalk and limestone aquifers - albeit well below the 2001 peaks. In the generally much slower-responding Permo-Triassic sandstones outcrops of the Midlands and northern England, levels continued to reflect the exceptional recharge over the autumn and winter of 2000/01 and for some index wells levels remained above pre-2000 maxima throughout 2002. Such aquifer units aside, minimum levels during 2002 were generally healthy (at Redbank, groundwater abstraction has a significant affect) and the steep rise in water-tables towards year end resulted in notably high groundwater levels across most outcrop areas (see Figure 15). Overall groundwater resources were very healthy entering 2003.

The majority of observation wells and boreholes for which data are held on the National Groundwater Level Archive monitor the natural variation in levels. However, in parts of the UK groundwater levels have been influenced, sometimes over very long periods, by pumping for water supply or other purposes. As a consequence, some local or regional water-tables have become substantially depressed. For instance, contemporary levels at a number of boreholes in the Permo-Triassic sandstones of the Midlands are indicative of a significant regional decline. In London, increasing groundwater abstraction through the nineteenth and the first half of the twentieth centuries led to a 70-metre decline in groundwater levels in the Trafalgar Square borehole. Since the 1950s, a much reduced abstraction rate has resulted in a recovery of around 30 metres; levels rose by 1-2 metres a year through the early 1990s (Figure 16). Level data for the 1998-2002 period are under review but 2003 data confirm that control measures (principally abstraction by Thames Water instigated in the late 1990s) have reversed the increase - other wells in central London confirm a decline in levels since around 1999. Rising groundwater levels have also been reported from other conurbations; leakage from water mains is considered a significant factor in some cases. The implications of rising groundwater levels extend beyond the potential improvement in water resources that the rise represents. Groundwater quality may be adversely affected as levels approach the surface and a number of geotechnical problems may result, for instance the flooding of tunnels and foundations.

Groundwater levels - through the year

January

Groundwater levels began 2002 within the normal early-winter range in most major aquifers, albeit well above average in much of the eastern Chalk and still close to seasonal maxima in much of the slower-responding Permo-Triassic sandstones outcrops. Generally, the distribution of rain in the first half of January did not favour the major aquifers but, thereafter, successive pulses of moderate intensity rainfall produced abundant late-January infiltration.

February

Sustained rainfall and near-saturated soil conditions in February were conducive to further very substantial groundwater replenishment - infiltration across much of the South-East was 200-300% of the monthly average. This fuelled a brisk increase in groundwater

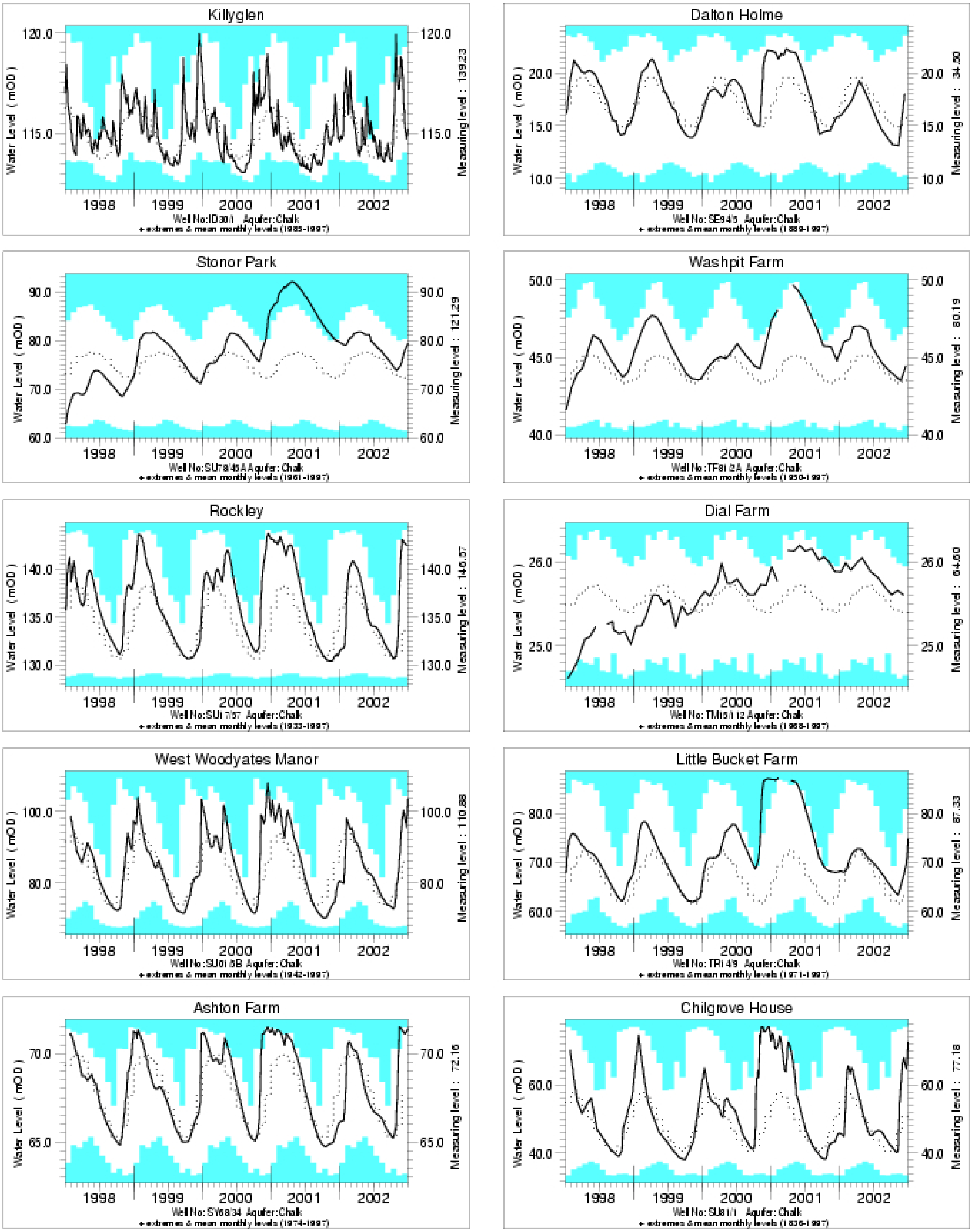


Figure 14 *Groundwater level hydrographs 1998-2002.*

Data sources: Environment Agency/Scottish Environment Protection Agency/Rivers Agency.

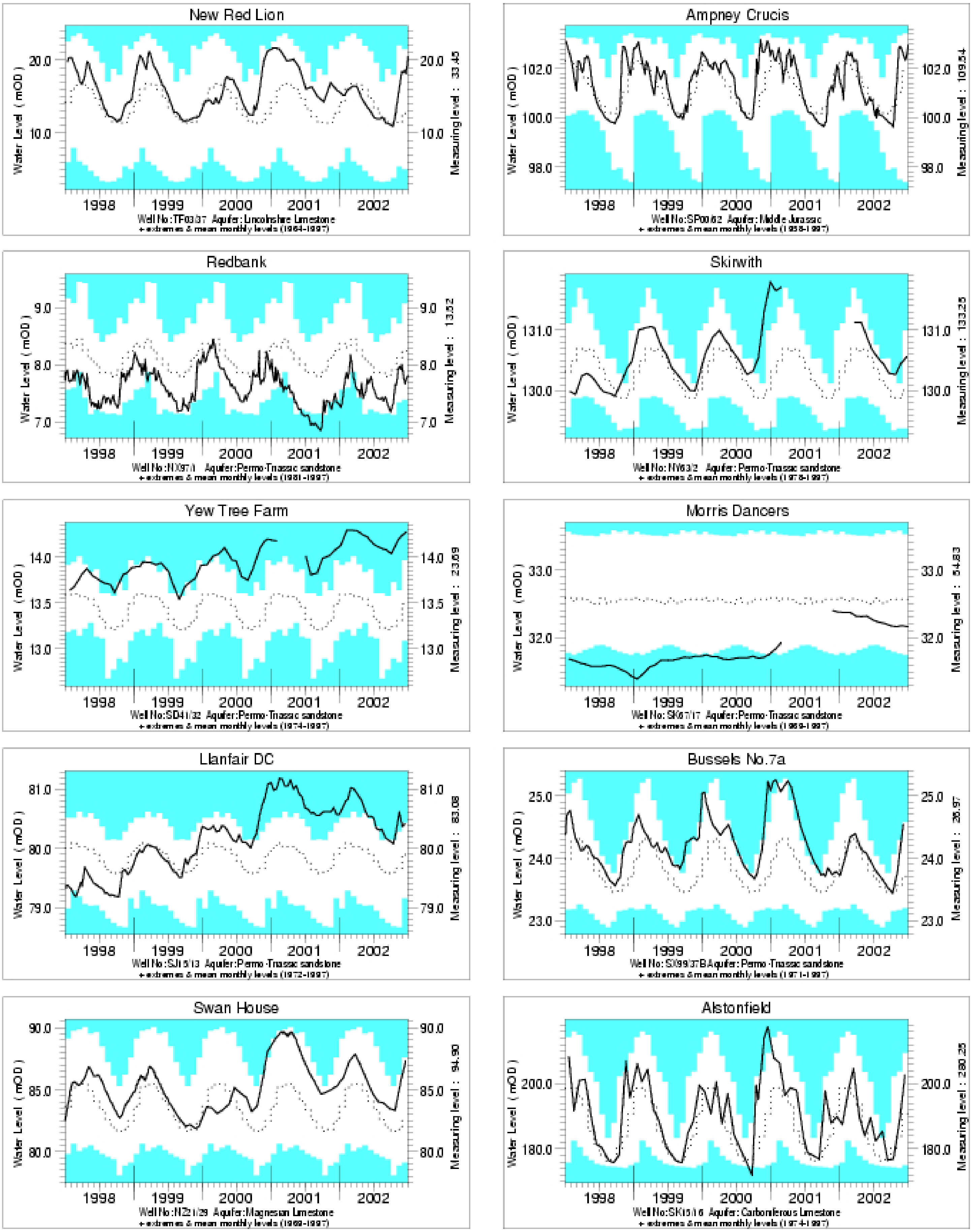
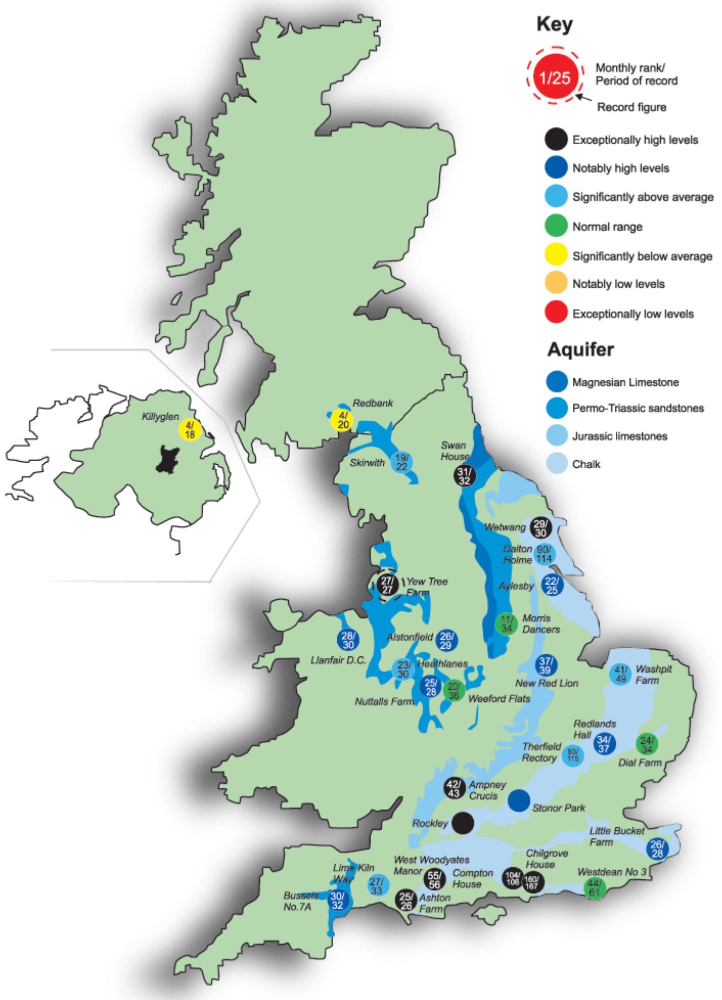


Figure 14 *(Contd.)*



The rankings are based on a comparison between the average level in the featured month (but often only single readings are available and the average levels in each corresponding month on record. They need to be interpreted with caution especially when groundwate levels are changing rapidly or when comparing wells with very different periods of record. Rankings may be omitted where they are considered misleading. (Note: Redbank is affected by groundwater abstraction)

Figure 15 *The ranking of December 2002 groundwater levels for a selection of observational wells and boreholes.*

Data sources: Environment Agency/Scottish Environment Protection Agency/ Rivers Agency.

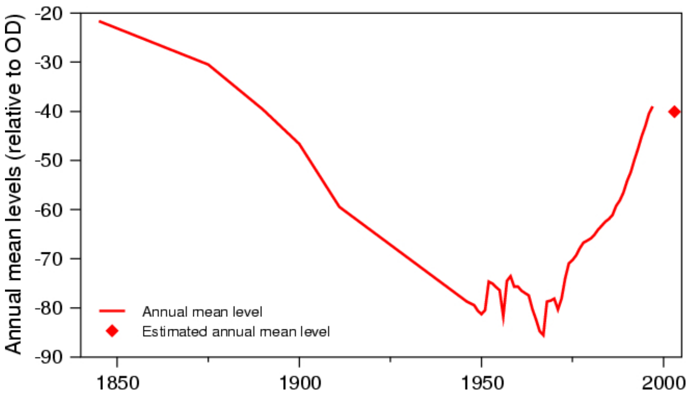


Figure 16 *Annual mean groundwater levels for the Trafalgar Square borehole.*

Data source: Environment Agency

levels and a corresponding increase in spring outflows. Levels throughout most of the Chalk were well above average but still considerably below the outstanding maxima registered during 2000/01. New February maximum levels were reported in the Permo-Triassic sandstones for a number of western index wells and boreholes (e.g. Yew Tree Farm); this reflects both the late-winter rainfall and the abundant recharge over the three preceding winters.

March

Many index wells register their highest levels in the late winter and early spring. This pattern was followed in the faster-responding aquifer units in 2002, but the mild and windy conditions during March encouraged seasonally high evaporative demands and infiltration rates during the latter half of the month were modest. With natural outflows (from springs and seepages) exceeding recharge, groundwater levels began to fall in some index boreholes (e.g. Rockley and West Woodyates in the Chalk); the seasonal decline began from typical spring maxima across much of the country.

April

In April, high temperatures combined with record sunshine hours (in some areas) produced evaporative demands more than 25% above the monthly average. Steep increases in soil moisture deficits confirmed the termination of the recharge season in many eastern aquifer units. Groundwater levels were in steep decline in all but the slowest-responding wells and boreholes. Nonetheless, April mean groundwater levels throughout most of the Chalk and the limestone aquifers were close to, or a little above, the spring average. This was also true of most minor aquifers (e.g. the Norfolk Drift and Essex Gravels).

May

May rainfall totals were well above average across most aquifer outcrop areas in southern Britain. Unusually, end-of-month soil moisture deficits were lower than in mid-April. This provided the opportunity for some seasonally late infiltration in several areas (e.g. the North Downs) and some modest local increases in levels were reported (e.g. in the Jurassic Limestone of the Cotswolds) but this did not materially change the hydrogeological outlook - May was characterised by a typical late-spring recession. Despite this decline, levels in the Permo-Triassic sandstone outcrops in the Midlands, north Wales and northern England commonly remained close to, or above, pre-2000 maxima.

June

Accelerating evaporative demands and the associated dry lowland soils ensured that infiltration during June was restricted to intense local storm events and had minimal impact on overall resources. Groundwater levels declined steadily through the month in almost all index wells and boreholes. Generalising broadly, levels in the Chalk exceeded the monthly average in the more easterly outcrops but were well within the normal summer range elswhere. A similar picture characterised the limestone aquifers but the Permo-Triassic sandstones present a less spatially coherent picture - June levels were around average in the South-West but still seasonally very high in the Midlands and northern England.

July

Soil moisture deficits were unusually low across the outcrop areas of most major aquifers in July - but still sufficient to restrict infiltration to very localised (and modest) pulses following sustained storm rainfall (e.g. at Chilgrove in the South Downs). Predictably, the early summer situation was replicated as recessions continued with groundwater levels mostly well within the normal summer range (parts of the Permo-Triassic sandstones remaining an exception).

August

As usual in August aquifer recharge was minimal - confined to localities where heavy rainfall coincided with a thin soil cover. In broad terms, the rainfall patterns favoured the major aquifer outcrop areas - but served to moderate soil moisture deficits rather than arrest the seasonal recession in groundwater levels. After a period of two years or more with seasonally high levels, water-tables in much of the Chalk closely approached the average. The same is true of most minor aquifers (e.g. the Suffolk Crag). By contrast, levels in parts of the Permo-Triassic sandstones remained close to, or above, pre-2000 maxima (e.g. at Llanfair DC). Overall groundwater resources for the late summer were healthy.

September

Contrary to the normal seasonal pattern, soil moisture deficits increased through the latter half of September and by month-end were above average across most of the UK - raising the prospect that the autumn recovery in recharge rates would be delayed. As usual in September groundwater levels generally exhibited little change from the late summer. Levels in the great majority of index wells and boreholes in the Chalk and limestone aquifers (and most minor aquifers also) remained close to the long term average for the early autumn. In the Permo-Triassic sandstones levels had generally returned to within the pre-2000 band of variation.

October

Following a dry start, rainfall over the five weeks from October 9th was between two and four times the average across most of the major aquifer outcrops. This produced a very steep decline in soil moisture deficits - allowing infiltration to recommence by early November in all but the most easterly aquifer units. Brisk groundwater level recoveries were reported from the more responsive aquifers (e.g. the Jurassic Limestone and south-western Chalk) but levels continued to decline in some deeper Chalk wells where the lag between infiltration and water-table response can be several months (e.g. at Therfield).

November

In most aquifer outcrop areas November rainfall totals were in the 150-250% range, resulting in abundant infiltration - exceeding four times the November average in some, mostly southern, areas (including the Chilterns). As this substantial pulse of recharge reached the water-tables, the 2002 seasonal recoveries gathered momentum. Rapid rises in groundwater levels were reported in the Chalk - e.g. at Rockley and Ashton Farm where a new maximum November level was recorded. November levels were also well above average in most limestone aquifers, notably so in the Lincolnshire Limestone. The much higher storage in the Permo-Triassic sandstones made for a more sluggish recovery but levels were rising in most outcrop areas, and generally above, to well above, the late-autumn average.

December

Once again, rainfall patterns favoured the major outcrop areas during December. With soils saturated and evaporative demands modest, the rainfall was particularly hydrologically effective. Some localities in the eastern Chalk registered over three times the average infiltration for December. More significantly in relation to overall groundwater resources, three-month recharge totals were, in some areas, comparable with the record figures registered over the last three months of 2000. Correspondingly, groundwater recoveries accelerated - at Chilgrove levels had risen 35 m from their 2002 minimum and were close to the surface at year-end; overflowing wells and boreholes were reported from a few localities (e.g. the Chilterns). Entering 2003 overall groundwater resources were exceptionally healthy but the threat of extensive groundwater flooding was very real (in the event, much drier conditions from early January 2003 rapidly moderated the groundwater flood risk).

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Location Map

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