HYDROLOGICAL SUMMARY FOR GREAT BRITAIN - SEPTEMBER 1990

Data for this review have been provided principally by the regional divisions of the National Rivers Authority (NRA) in England and Wales, the River Purification Boards in Scotland (RPBs) and by the Meteorological Office. The recent areal rainfall figures are derived from a restricted network of raingauges (particularly in Scotland) and a significant proportion of the river flow data may be subject to revision following reviews of the low flow stage-discharge relations.

For a fuller appreciation of the water resources implications, this hydrological review should be considered alongside assessments of the current reservoir storage and water demand situations in each region. A map is provided (Figure 4) to assist in the location of monitoring sites.

Summary

Cool and windy conditions signalled the end of the hot dry summer early in September. However, whilst in temperature terms an obvious transformation could be recognised, in relation to hydrological conditions the change - at least until the end of the month - was rather more apparent than real. Rainfall totals for September were low throughout most of Great Britain and, with soils exceptionally dry, the impact of the limited rainfall on runoff and recharge rates was negligible in those areas where the drought is most severe.

Provisional data indicate that the England and Wales rainfall total for March to September 1990 is the lowest (for those months) in the 220-year general rainfall series. By month-end, seven-month droughts of significant magnitude could be recognised in all regions of England and Wales and parts of eastern Scotland. In meteorological terms the droughts are very severe in lowland England and with high evaporative losses maintained through much of 1990 (especially in the spring) river flows and groundwater levels were very depressed in September. The remarkable contrast with the abundant rainfall through the preceding winter (in all but a few districts) finds expression in the rapid decline in regional rainfall deficiencies as the time-base is extended. On a water-year (October-September) basis rainfall is within the normal range in all regions - although not in parts of East Anglia and in some other areas - of England and Wales.

Spatial as well as temporal variability in rainfall has been considerable in the recent past. Water-year rainfall in Scotland is the highest in a record extending back to 1869 whilst long-term rainfall deficiencies still exist in eastern Britain, especially in the 22-30 month timeframe. This embraces two winter recharge periods and the drought is most severe in those eastern areas where the existing intense spring/summer drought is overlain on a long-term deficiency in rainfall. In such areas some river flows and groundwater levels are unprecedented and the water resources situation is fragile. Elsewhere flows (and groundwater levels) are substantially below average - and similar to September 1989 over wide areas - but above historical minima.

A decline in soil moisture deficits (SMDs) began in mid-month and accelerated through the first week of October. Some net reservoir replenishment and a little localised groundwater recharge have been recorded since late-September. If the current unsettled spell continues the seasonal upturn should occur rather earlier than in 1989 (and in 1988 in some areas). However, the very depressed nature of groundwater resources determines that above average rainfall through the winter will be essential to restore levels by the spring of 1991. In the eastern lowlands of England substantially above average rainfall will be required to satisfy SMDs and generate a recovery from the exceptionally low current levels.

Rainfall

Anticyclonic conditions dominated weather patterns throughout much of the first half of September. Rainfall was generally patchy in extent and limited in duration. In the lowlands, periods of up to 25 days, ending around mid-month, with only a trace of rainfall were reported - the latest in a series of dry sequences over the last 30 months or so. Frontal activity increased from mid-month and, from the 19th, widespread rainfall was experienced on a number of days. The weekend of the

29/30th was particularly wet with many areas recording over 20 mm. September rainfall exhibited large regional and local variations, partly a reflection of the amount of thundery activity. Broadly speaking, rainfall was above average in northern Scotland and in an area centred on the Cheshire Plain but below average through most of southern Britain. Less than half the average was recorded in a band extending from the East Midlands to the Sussex coast. Rainfall for the Thames and Anglia NRA regions, and some other lowland districts, has been below - often substantially - the average for each month since February and seven-month accumulations starting in March have been exceptionally modest.

Provisional data indicate that the minimum March to September rainfall total for England and Wales, established during the 1870 drought, was eclipsed this year. Considering any seven-month sequence, there have only been three drier periods (two in 1976, one in the 1921 drought) this century. By late-September a significant drought extended across most of southern Britain but regional variations in intensity were appreciable. Moderate (return periods in the range 20-50 years) to severe (50-100 years) seven-month droughts exist in northern England and the South West with extreme rainfall deficiencies (>100 years) in other regions. The drought is especially intense in the Anglia, Thames and Southern NRA regions. For the Thames catchment as a whole there is no precedent (in an areal rainfall record from 1883) for a March-September rainfall total of less than 190 mm.

The current drought in England and Wales follows directly on the wettest winter for seventy-five years. Throughout large tracts of southern Britain the December 1989 to February 1990 rainfall was almost twice that for the ensuing seven months. An obvious consequence is the steep decline in drought intensities for periods beyond seven-months. For all regions of the NRA, with the exception of Anglian, the 1990 rainfall totals, and the 1989/90 water-year totals, are within the normal range albeit mostly somewhat below average. This amelioration is far less pronounced along the eastern seaboard and the hydrological impact of the drought is currently most evident in those catchments, where long term rainfall deficiencies can still be recognised extending back to at least the autumn of 1988.

In Scotland, moderate spring/summer droughts may be recognised with persistent long-term deficits along the eastern coast. More remarkable though are the exceptionally wet conditions which have characterised western Scotland over much of the last year; typically only 2 months in 1990 have been below average. The provisional 1990 and water-year rainfall totals for the Clyde and Highland RPB areas are without modern parallel (though caution needs to be exercised due to the skeletal network upon which recent monthly rainfall totals are based). For Scotland as a whole the October-September rainfall total is the highest on record and the January-September figure exceeds the previous maximum by a very wide margin.

Evaporation and Soil Moisture Deficits (SMDs)

Whilst temperatures were a little below average in September, sunshine amounts were high in southern Britain and the windy conditions encouraged evaporation losses. MORECS data indicate that potential evaporation (PE) totals (for grass) for the 1989/90 water are the highest on record (in a series from 1961) throughout most of Great Britain. Actual evaporation (AE) totals (for grass) are similarly outstanding in much of western and northern Britain. In the English lowlands the inhibiting effect of long-standing high SMDs has resulted in far more moderate AE totals with very low annual figures typifying some eastern districts.

SMDs generally increased through the first half of September, declined moderately until near the month-end when some brisk reductions were reported. As of the 2nd October, field capacity had been reached throughout most of Scotland away from the eastern lowlands and parts of north-west England. In contrast, deficits in excess of 100 mm extend across much of central and southern England, and up the eastern seaboard to Northumbria. This high deficit zone includes the outcrop areas of the major aquifers in England. Typically, end-of-September deficits were 30-50 mm above average in these regions. Larger anomalies occur in parts of Wales and the South-West where field capacity is normally approached in October.

SMDs throughout much of southern and eastern Britain are the equivalent of 6-8 weeks average rainfall and, as in 1989, will serve to greatly moderate the hydrological impact of rainfall through the rest of the autumn.

River Flows

Whilst a modest increase in monthly runoff totals from August to September characterised rivers in Scotland and parts of northern England, in southern Britain the summer recessions continued into the autumn; by mid-September some exceptionally low daily flows were recorded. Subsequently, and especially over the weekend of the 29/30th, surface runoff boosted flow rates over wide areas although little impact on baseflow dominated rivers was evident.

September runoff totals were well below average in all regions; mean flows in the range 30-60% of the long term average typifying many catchments. It is rare for such notably low flows to extend across almost all of Great Britain. Runoff for September was not substantially different from that for August and, over large areas, equates closely to the corresponding figures for 1989. Runoff rates remain most depressed in eastern, central and southern England although some western streams draining less permeable catchments recorded notable low runoff totals also. The Dorset and Kent Stours each established new September minimum mean flows as did the Brue and the Yscir. For the Thames, the September mean flow (naturalised) is the lowest since 1949. Lower late summer/early autumn flows were, however, recorded in most areas during the droughts of 1976 (in the east), 1972 (western and northern Britain) and, often, in 1964 and 1959.

Return periods associated with the September mean flows encompass a wide range. For very high baseflow catchments (e.g. the Lud, Mimram and Itchen) the return periods are similar to those for August. In more responsive rivers some of the return periods are notably larger even where runoff increases (relative to the average) from August to September have been small. In part, this reflects the absence of recent autumn droughts, notwithstanding the low flows in some areas during 1988 and 1989. The 1984 and 1976 droughts were in rapid decline by September and many flow records do not include the 1964 and 1959 droughts which lasted until later in the year. As an illustration of the impact this can have, the return period for the September flow on the Kent Stour (see Table 4) reduces to about 25 years if an estimate of the 1959 discharge is incorporated in the analysis. Notwithstanding this caveat, the return periods testify to very severe hydrological droughts in parts of Yorkshire, East Anglia, Kent and Wessex.

Accumulated runoff totals are very low for periods of up to 7 months, especially so in the 4-6 month timeframe. The summer half-year (April to September) runoff totals rank in the lowest three or four on record for many catchments - at least where record lengths are less than 30 years. Unprecedented summer runoff totals were recorded on the Dee (Grampian), South Tyne and the Severn (where the effects of river regulation temper the significance of the data presented in Table 3). Very low summer flows characterised responsive western catchments (e.g. the Eden and Cynon) and lowland rivers with substantial baseflows. Long return periods, in excess of 25 years, are associated with the April-September runoff totals for a range of lowland rivers and some others, notably the Yorkshire Derwent.

Clear evidence of the extraordinary transformation in hydrological conditions around the end of the winter may be found in the accumulated runoff totals for 1990 as a whole. Spate conditions in January and, particularly, February counterbalance the spring/summer drought in most regions and the mean flows for 1990 fall within the normal range in all but central and southern England and northwards along the eastern seaboard. For some Scottish rivers - notably the Tay and Clyde - and a few in north-west England, the nine-month runoff is the highest on record. A similar picture emerges from the tabulation for the water-year. However, only a relatively moderate amelioration in the drought's magnitude is evident in some eastern rivers especially those draining permeable catchments. Twelve-month accumulations are amongst the lowest on record for a number of eastern catchments and modest for some further inland (the Trent and Brue being examples) and, generally, longer term accumulations provide further evidence of a very persistent runoff deficiency. The Trent, Coln, Stour (Kent) and Itchen are among those rivers for which runoff has been below average for at least 20 months in the last two years. It is 23 months since an above

average flow was registered on the Lud and 24 on the Derwent (Yorks) and the Whiteadder.

The river flow response to the recent unsettled spell has been determined largely by the rainfall amounts and the prevailing soil moisture conditions. Flooding occurred in Scotland early in October but in southern England the moderate surface runoff was not the precursor of any general seasonal upturn.

Groundwater

With the continuation of low rainfall in September, there has been little, if any, significant recharge to any aquifer in England and Wales. The recessions which commenced in most areas in February have continued largely unabated. By the end of September, levels were well below average in all aquifers (some monitoring sites excepted) and, generally, a little below those recorded at the same time during the 1989 drought. Throughout the major aquifers, water-tables stood at their lowest September levels since 1976 and in some eastern units groundwater levels were unprecedented.

Groundwater levels are affected not merely by the recharge of the winter months - modest in 1989/90 along the eastern seaboard - but also by the depth of the recession during the previous summer and autumn. For example, at the Fairfields site (East Anglia Chalk - not featured on Figure 3), the sustained recession of 1989 was followed by only a limited rise in groundwater levels and the summer recession of 1990 commenced from a level that was already below the seasonal mean and, by September had reached a level approaching the minimum recorded value.

The severity of the drought situation is emphasised by the fact that groundwater levels are everywhere (with one or two isolated exceptions) below the seasonal means for September, and often well below this, even approaching or below the minimum recorded values. The most severely affected area is within the Chalk outcrop of Yorkshire, where the levels at the Dalton Holme site are unprecedentedly low. South of the Humber, at Little Brocklesby (Lincolnshire Chalk), the situation is but little better with levels at their lowest since 1976. Continuing southwards, in the coastal aquifers (Fairfield and Little Bucket Farm) groundwater levels are seriously depressed, and this state of affairs is continued along the south coast - albeit somewhat moderated. Only at the Lime Kiln Way site are levels, although in recession, above the seasonal mean; this may in part reflect the exceptionally high peak level registered in the early spring. Inland, the observation well at Rockley is nearly dry, Ampney Crucis close to the minimum recorded level for September and the New red Lion, Peggy Ellerton and Llanfair sites all well below the seasonal means.

The relatively high rainfall during late-September has not yet caused an end to the overall recession although local and very moderate water-table responses have been reported for fissured aquifer units in some areas (e.g. parts of the Sussex coast). Some upturn may be recognisable in October as the infiltration associated with the late-September/early-October rainfall reaches the water-table but this will herald no general recovery in the absence of further substantial autumn rainfall.

Following the extreme 1976 drought, winter rainfall was generally some 50% above average over the aquifer outcrop areas, resulting in dramatic recoveries in groundwater levels. If similar precipitation occurs over the winter of 1990-91, groundwater levels will recover equally rapidly. If, however, the precipitation is of equal magnitude to the winter of 1988-89, then the recessions in the summer of 1991 will, generally, start from unprecedentedly low levels and the water resources outlook will be a matter of concern. Although the rainfall of the winter of 1989-90 was high in most districts, it was concentrated into very short periods, notably late-January and February, and the dramatic rise in groundwater levels registered in western and central aquifer units was followed in most cases by an equally dramatic fall. With regard to water resources the very early onset of recessions - at a time when levels are normally still rising - counteracted much of the benefit associated with the heavy recharge early in the year.

TABLE 1 1989/90 RAINFALL AS A PERCENTAGE OF THE 1941-70 AVERAGE

		Aug 1989	Sep	Oct	Nov	Dec	Jan 1990	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
England and	mm	58	41	98	61	134	133	142	23	38	25	70	35	49	53
Wales	%	65	49	118	63	149	154	219	39	66	37	115	47	54	64
NRA REGIONS															
North West	mm	116	29	145	84	100	196	187	47	52	49	97	55	70	84
	%	93	24	123	69	83	175	231	65	68	60	117	53	55	68
Northumbria	mm	77	20	71	35	75	111	133	33	28	51	68	40	57	53
	%	76	25	95	37	100	139	202	63	51	80	111	52	56	66
Severn Trent	mm	44	38	82	52	135	107	110	21	30	19	62	29	39	49
	%	54	57	126	66	193	155	208	40	58	30	111	44	48	73
Yorkshire	mm	41	20	77	45	98	118	112	24	24	29	83	34	61	42
	%	46	28	112	51	132	153	175	45	43	48	143	48	68	58
Anglia	mm	35	30	41	36	98	52	74	15	36	16	45	22	30	31
	%	55	58	79	58	185	101	177	38	90	34	92	39	47	59
Thames	mm	44	28	65	37	141	91	114	12	35	7	46	15	34	34
	%	63	45	102	51	214	147	242	26	76	13	88	25	49	55
Southern	mm	29	37	79	50	142	121	135	6	43	11	59	12	32	37
	%	40	52	101	53	175	159	238	12	90	20	118	21	45	51
Wessex	mm	43	49	101	58	165	124	157	15	35	13	63	30	42	53
	%	52	62	123	60	183	147	265	26	65	19	117	49	51	67
South West	mm	62	107	148	100	196	195	238	25	47	24	98	58	61	72
	%	61	103	131	75	145	151	264	30	66	29	151	69	60	69
Welsh	mm	91	62	180	109	199	240	214	37	45	33	94	48	62	82
	%	76	50	140	76	137	176	223	43	52	36	115	50	52	66
Scotland	mm	184	96	187	60	96	250	291	247	97	55	124	67	119	143
	%	143	70	126	42	62	182	280	268	108	60	135	60	92	104
RIVER PURIFICATION BOARDS															
Highland	mm	222	118	258	79	109	293	364	395	136	57	137	94	161	205
	%	150	75	139	47	56	179	274	346	119	55	125	74	109	130
North-East	mm	84	57	87	29	54	103	145	87	44	48	108	47	78	89
	%	79	66	90	28	53	114	195	140	72	62	154	51	73	102
Tay	mm	140	83	136	51	86	236	249	186	60	43	122	40	74	82
	%	119	72	111	43	64	200	270	227	80	45	147	39	63	71
Forth	mm	144	69	112	39	79	220	221	134	55	39	119	50	80	60
	%	124	64	106	36	72	222	287	194	81	46	159	51	69	56
Tweed	mm	113	47	68	30	78	166	180	53	31	46	101	54	61	58
	%	99	51	77	29	87	179	260	91	51	61	149	61	54	62
Solway	mm	176	77	145	59	119	250	282	97	71	77	120	76	106	86
	%	135	51	101	41	79	179	303	107	81	84	133	69	82	57
Clyde	mm	252	120	244	73	107	316	343	290	127	58	134	96	149	119
	%	177	69	133	44	58	196	304	276	123	60	130	74	105	68

Note: September figures for England and Wales for 1990 are based upon MORECS figures supplied by the Meteorological Office

Scottish RPB data for September 1990 are estimated from the isohyetal map of September rainfall in the MORECS bulletin. The Scottish national value was provided by the London Weather Centre.

TABLE 2 RAINFALL RETURN PERIOD ESTIMATES

		MAR - SEP 90 Est Return Period, years		JAN - SEP 90 Est Return Period, years		OCT 89 - SEP 90 Est Return Period, years		NOV 88 - SEP 90 Est Return Period, years	
England and	mm	293		568		861		1479	
Wales	% LTA	60	100-150	88	5	94	<2	85	20
NRA REGIONS									
North West	mm	453		836		1165		2096	
	% LTA	68	30-40	97	2-5	96	2-5	90	5-10
Northumbria	mm	330		574		755		1308	
	% LTA	67	30-50	90	2-5	86	5-10	78	60-90
Severn Trent	mm	249		466		735		1264	
	% LTA	57	100-150	83	5-10	95	2-5	85	10-20
Yorkshire	mm	297		527		747		1294	
	% LTA	65	40-60	88	2-5	90	2-5	81	30-40
Anglia	mm	195		322		497		920	
	% LTA	56	150-200	73	20-30	81	10-15	79	40-60
Thames	mm	183		388		631		1077	
	% LTA	47	>200	77	10	90	2-5	80	30-40
Southern	mm	200		457		728		1175	
	% LTA	49	>200	84	5	92	2-5	78	40-50
Wessex	mm	251		531		855		1396	
	% LTA	55	100-120	89	2-5	98	<2	84	10-20
South West	mm	385		818		1262		2053	
	% LTA	65	30-40	101	<2	106	2-5	90	5-10
Welsh	mm	401		854		1342		2278	
	% LTA	59	100-120	93	2-5	101	<2	90	5-10
Scotland	mm	852		1393		1736		3140	
	% LTA	115	5-10	142	>>200	121	40-60	116	40-60
RIVER PURIFICATION BOARDS									
Highland	mm	1185		1843		2289		4164	
	% LTA	136	90-110	157	>>200	133	>>200	128	>>200
North-East	mm	501		749		919		1618	
	% LTA	90	2-5	104	2-5	90	2-5	83	40-50
Tay	mm	607		1091		1364		2466	
	% LTA	91	2-5	124	10-20	109	2-5	103	2-5
Forth	mm	537		977		1207		2191	
	% LTA	87	5	123	15-20	108	2-5	103	2-5
Tweed	mm	404		750		926		1650	
	% LTA	72	20-30	104	2-5	92	2-5	86	10-20
Solway	mm	633		1165		1488		2589	
	% LTA	84	5-10	118	5-10	104	2-5	99	2
Clyde	mm	973		1632		2056		3738	
	% LTA	114	5	145	>>200	123	30-40	119	40-50

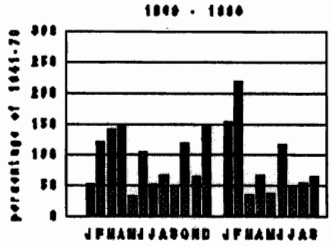
Return period assessments are based on tables provided by the Meteorological Office*. These assume a start in a specified month; return periods for a start in any month may be expected to be an order of magnitude less. "Wet" return periods underlined.

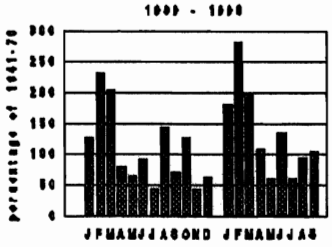
The tables reflect rainfall totals over the period 1911-70 only and the estimate assumes a sensibly stable climate.

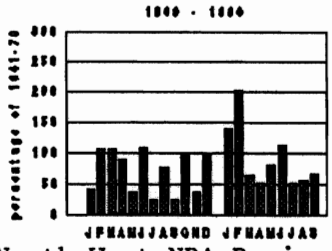
The September 1990 RPB values are estimated from the isopleth map within the September summary published in the Met. Office's MORECS bulletin.

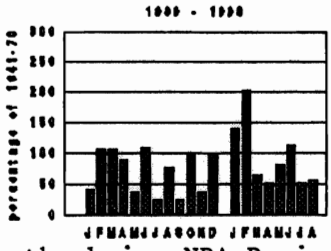
* Tabony, R C, 1977, The Variability of long duration rainfall over Great Britain, Scientific Paper No. 37, Meteorological Office (HMSO).

FIGURE 1. MONTHLY RAINFALL FOR 1989 – 1990 AS A PERCENTAGE OF THE 1941 – 1970 AVERAGE FOR ENGLAND AND WALES, SCOTLAND, AND THE NRA REGIONS


England and Wales


Scotland


North West NRA Region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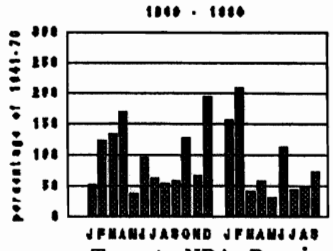
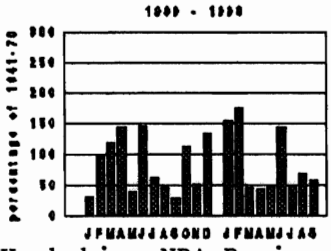
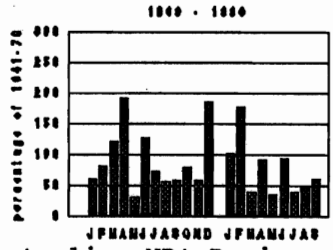

Severn-Trent NRA Region


Yorkshire NRA Region


Anglian NRA Region

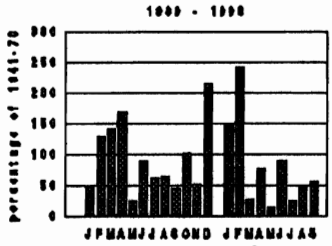
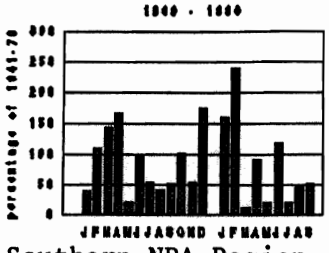

Thames NRA Region

FIGURE 1 (continued)



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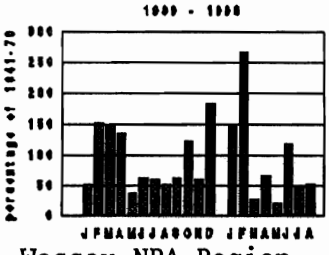
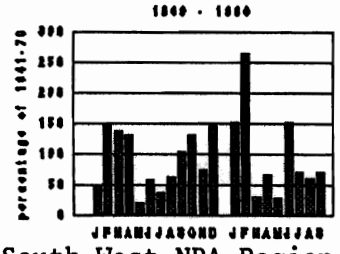
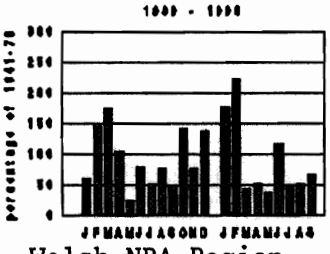


Wessex NRA Region

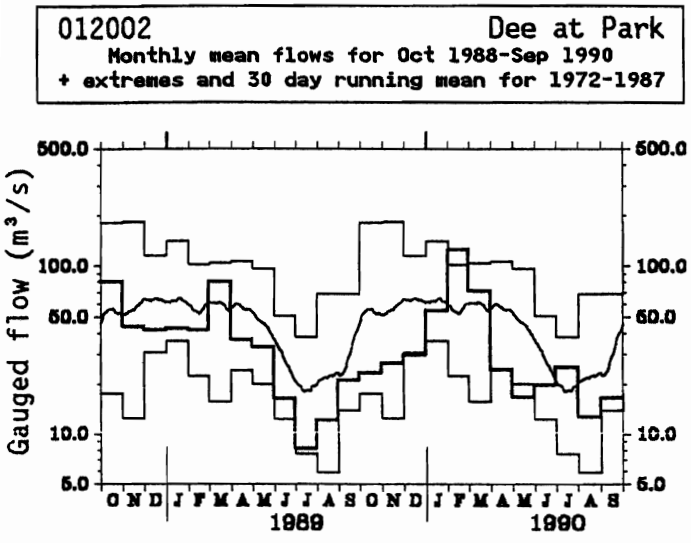


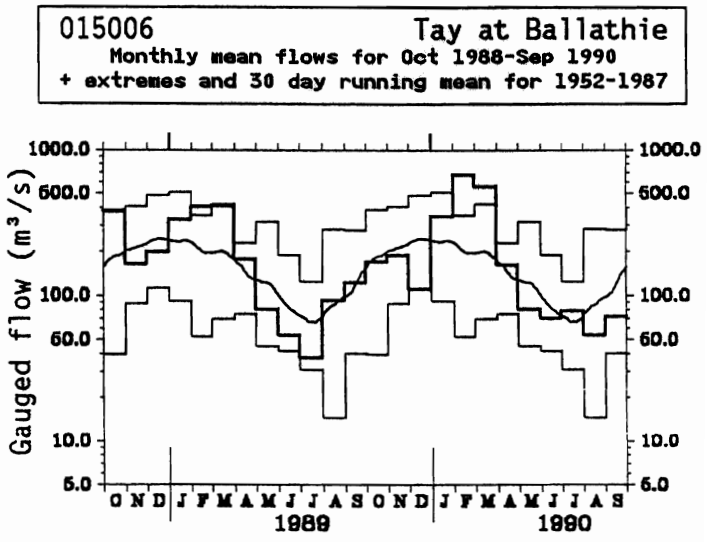
South West NRA Region

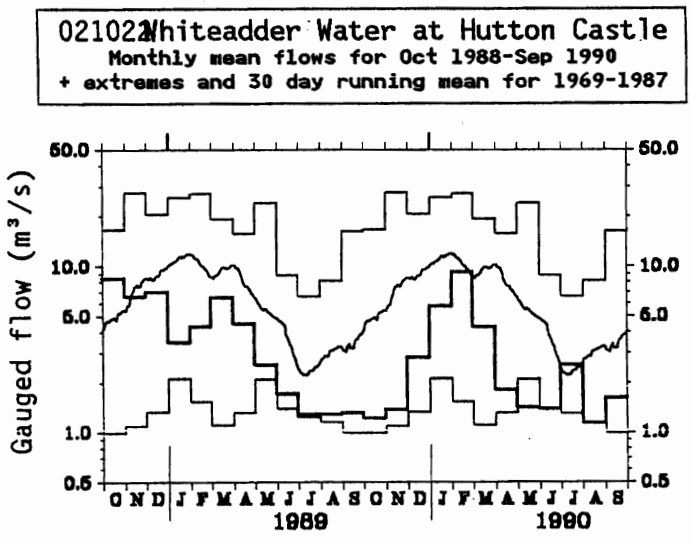


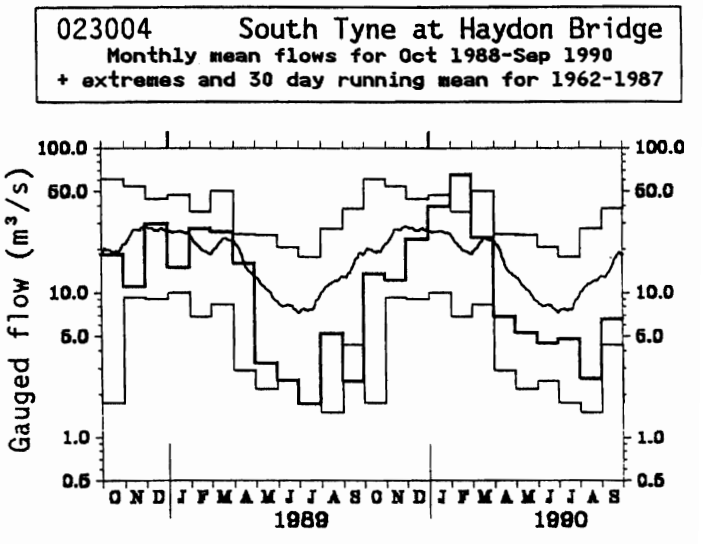
Welsh NRA Region

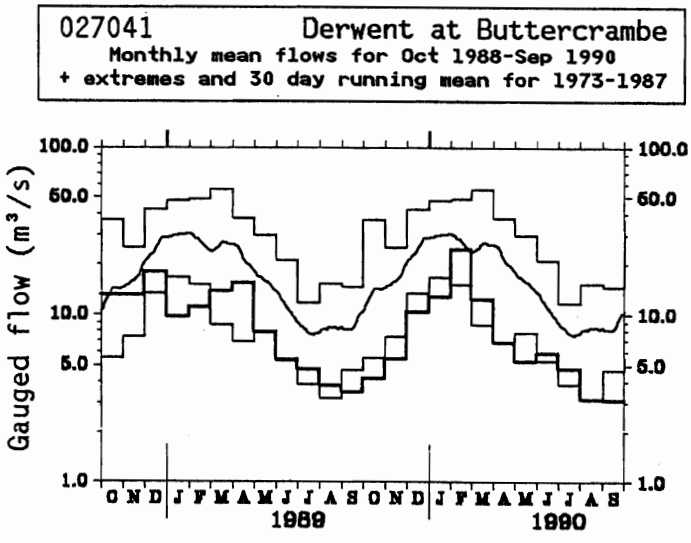
FIGURE 2 MONTHLY RIVER FLOW HYDROGRAPHS

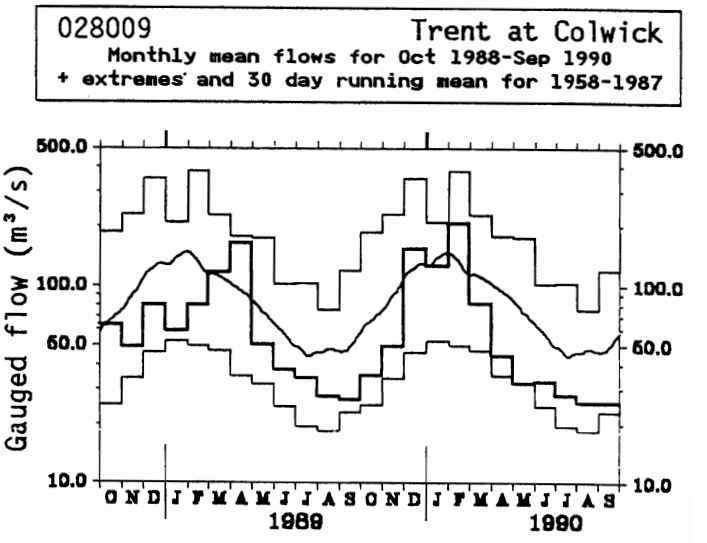






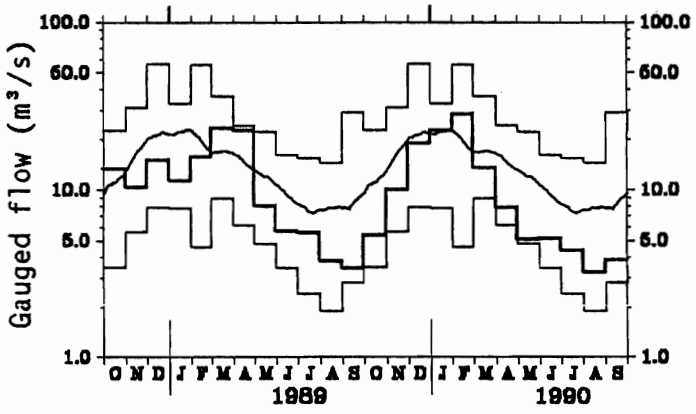






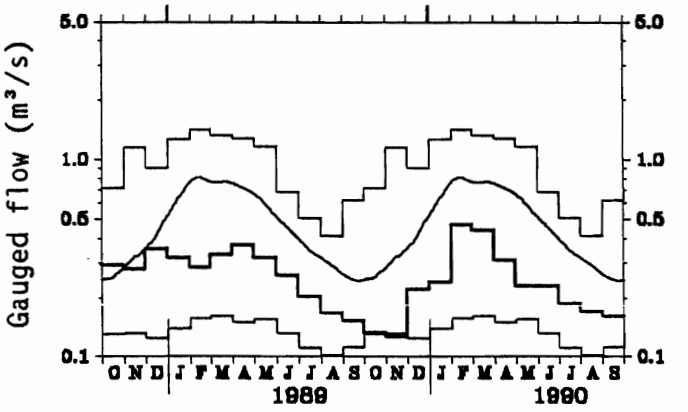
028018 Dove at Marston on Dove

Monthly mean flows for Oct 1988-Sep 1990
+ extremes and 30 day running mean for 1961-1987



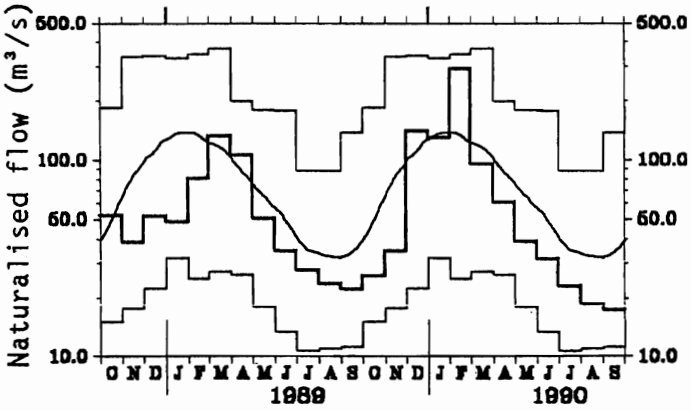
029003 Lud at Louth

Monthly mean flows for Oct 1988-Sep 1990
+ extremes and 30 day running mean for 1968-1987



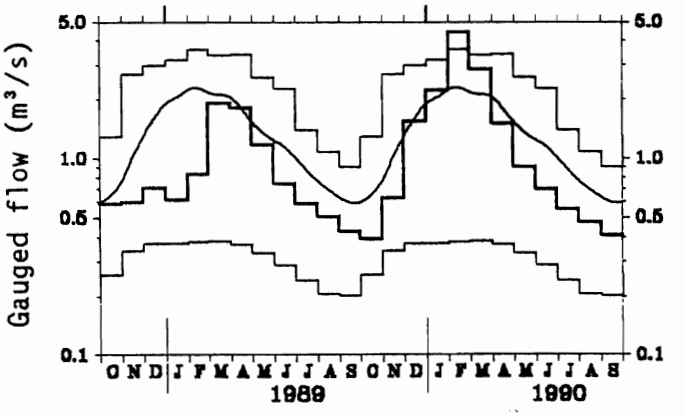
039001 Thames at Kingston

Monthly mean flows for Oct 1988-Sep 1990
+ extremes and 30 day running mean for 1883-1987



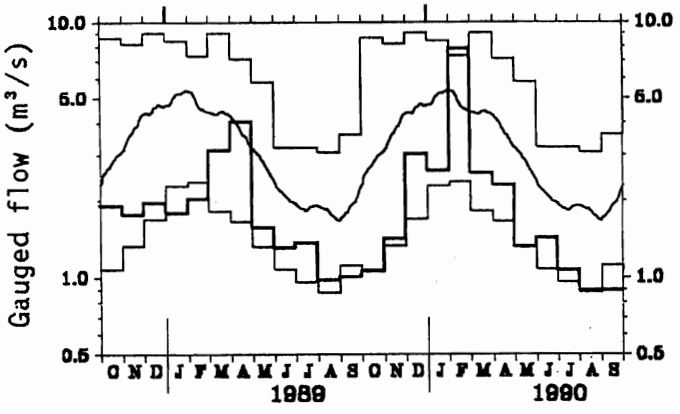
039020 Coln at Bibury

Monthly mean flows for Oct 1988-Sep 1990
+ extremes and 30 day running mean for 1963-1987



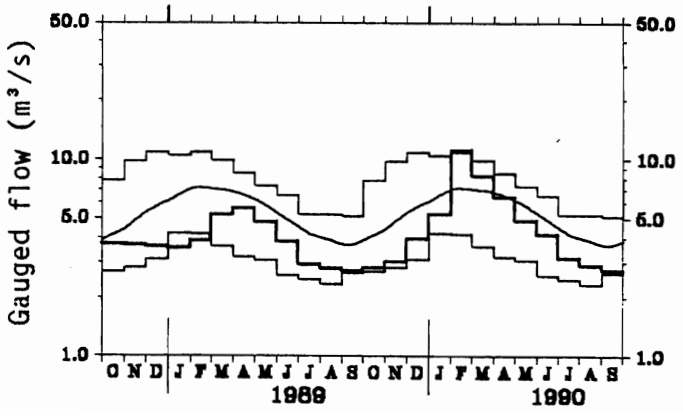
040011 Great Stour at Horton

Monthly mean flows for Oct 1988-Sep 1990
+ extremes and 30 day running mean for 1964-1987



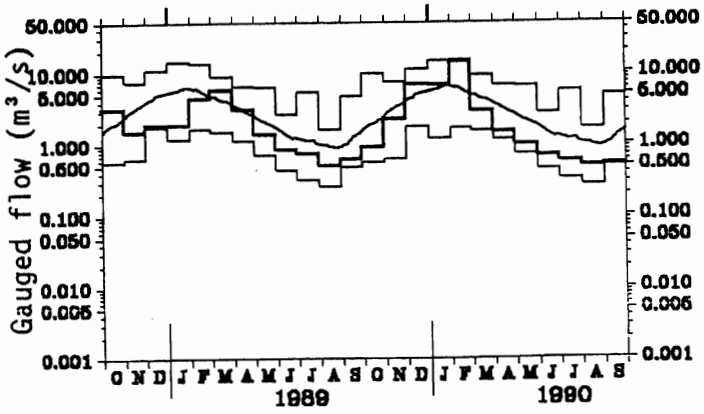
042010 Itchen at Highbridge+Allbrook

Monthly mean flows for Oct 1988-Sep 1990
+ extremes and 30 day running mean for 1958-1987



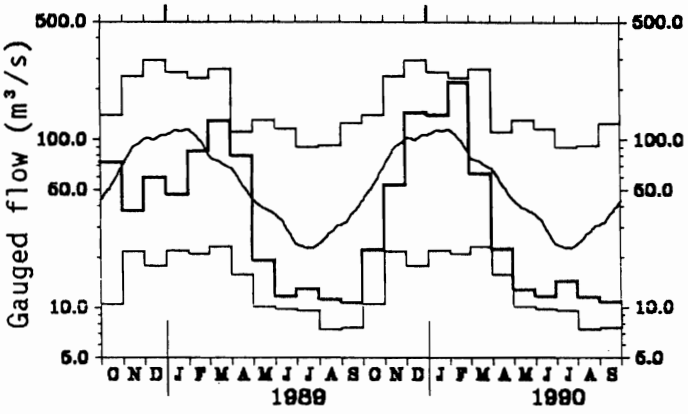
052005 Tone at Bishops Hull

Monthly mean flows for Oct 1988-Sep 1990
+ extremes and 30 day running mean for 1961-1987



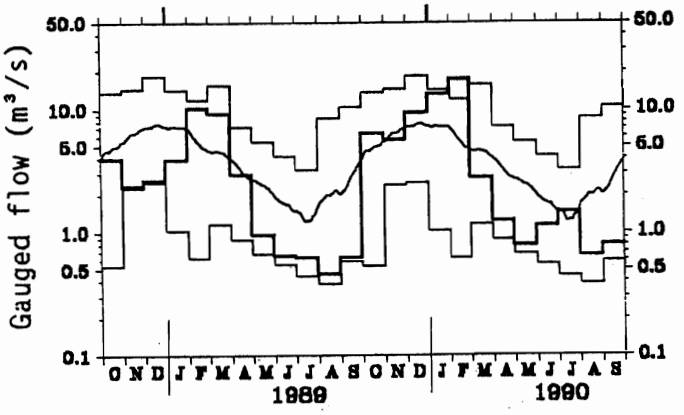
054001 Severn at Bewdley

Monthly mean flows for Oct 1988-Sep 1990
+ extremes and 30 day running mean for 1921-1987



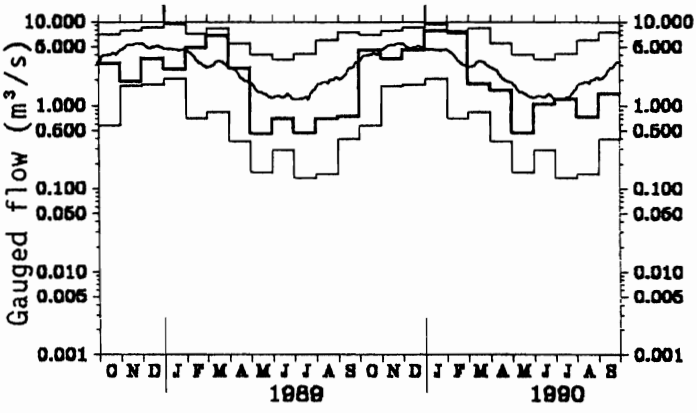
057004 Cynon at Abercynon

Monthly mean flows for Oct 1988-Sep 1990
+ extremes and 30 day running mean for 1957-1987



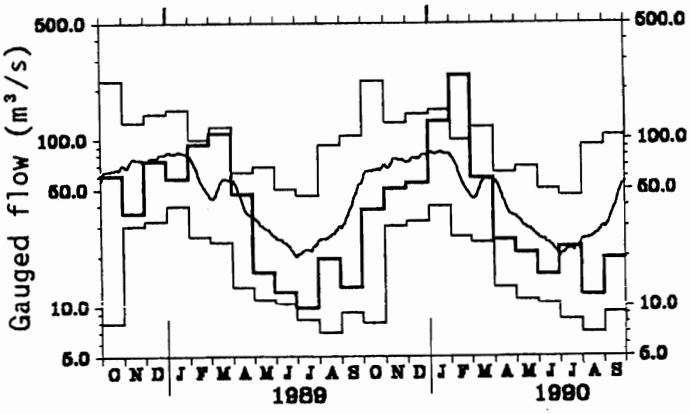
067018 Dee at New Inn

Monthly mean flows for Oct 1988-Sep 1990
+ extremes and 30 day running mean for 1969-1987



076007 Eden at Sheepmount

Monthly mean flows for Oct 1988-Sep 1990
+ extremes and 30 day running mean for 1967-1987



084013 Clyde at Daldowie

Monthly mean flows for Oct 1988-Sep 1990
+ extremes and 30 day running mean for 1963-1987

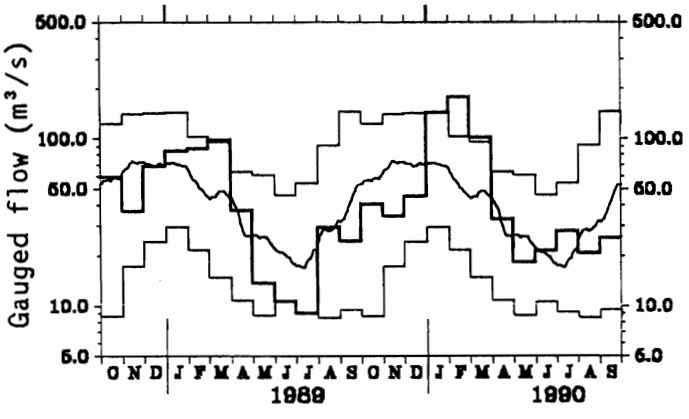


TABLE 3 RUNOFF AS MM. AND AS A PERCENTAGE OF THE PERIOD OF RECORD AVERAGE WITH SELECTED PERIODS RANKED IN THE RECORD

River/ Station name	Apr 1990	May	Jun	Jul	Aug	Sep 1990		4/90 to 9/90		1/90 to 9/90		10/89 to 9/90		11/88 to 9/90	
	mm %LT	mm %LT	mm %LT	mm %LT	mm %LT	mm %LT	rank /yrs	mm %LT	rank /yrs	mm %LT	rank /yrs	mm %LT	rank /yrs	mm %LT	rank /yrs
Dee at Park	34 43	24 37	28 75	37 134	18 55	23 54	4 /18	164 59	1 /18	511 96	7 /18	626 78	2 /17	1164 77	2 /17
Tay at Ballathie	91 110	47 67	40 89	46 116	31 60	41 58	10 /38	295 82	8 /38	1176 158	38 /38	1446 129	37 /38	2620 123	37 /37
South Tyne at Haydon Bridge	24 44	19 52	16 58	17 58	9 22	23 44	5 /27	107 45	1 /27	540 110	18 /27	714 95	10 /27	1201 83	4 /25
Whiteadder Water at Hutton Castle	20 36	17 44	11 44	34 127	6 37	8 50	6 /22	52 41	1 /21	149 53	3 /21	178 45	2 /20	388 48	1 /18
Derwent at Buttercrambe	11 33	9 35	10 59	8 60	5 36	5 38	1 /17	48 43	1 /17	128 52	2 /17	161 48	1 /17	336 51	1 /16
Trent at Colwick	15 45	11 43	11 57	10 62	9 53	9 53	2 /32	66 53	2 /32	207 80	3 /32	292 81	6 /32	546 78	2 /31
Dove at Marston on Dove	23 53	15 42	15 57	13 57	10 43	11 45	5 /28	88 51	2 /28	275 78	3 /28	378 75	2 /28	749 77	3 /26
Lud at Louth	15 45	11 39	11 53	9 54	8 58	8 70	4 /23	61 51	4 /22	115 52	4 /22	138 51	3 /22	282 54	2 /21
Bedford Ouse at Bedford	10 49	6 45	5 61	4 67	3 58	3 60	20 /58	30 53	12 /58	156 98	29 /58	221 102	30 /57	408 95	25 /56
Mimram at Panshanger Park	12 94	10 81	8 73	7 72	6 67	5 62	4 /38	48 77	6 /38	88 89	12 /38	109 87	10 /37	210 86	7 /36
Thames at Kingston (natr.)	16 71	10 57	8 63	6 63	5 57	5 56	11 /108	50 63	19 /108	182 100	53 /108	236 96	47 /107	398 83	28 /106
Coln at Bibury	36 83	23 69	17 63	14 66	12 71	10 70	2 /27	111 72	4 /27	338 107	15 /27	402 102	10 /27	646 83	6 /26
Mole at Kinnersley Manor	22 63	14 52	18 100	18 141	12 79	12 68	12 /17	89 72	4 /17	352 115	12 /16	462 100	10 /15	779 88	2 /13
Great Stour at Horton	17 62	10 46	11 70	8 56	7 51	7 50	1 /26	60 57	2 /24	155 72	4 /24	197 66	4 /23	356 61	1 /21
Ouse at Gold Bridge	20 58	10 40	9 58	9 89	8 72	9 61	13 /31	65 60	2 /30	281 104	15 /29	335 85	9 /29	537 71	2 /27
Itchen at Highbridge+Allbrook	46 98	36 84	30 86	23 75	21 74	20 76	3 /32	177 85	5 /32	351 98	14 /32	423 91	7 /32	732 81	2 /31
Stour at Throop Mill	22 63	15 63	10 63	6 53	5 47	4 33	1 /18	63 59	3 /18	332 119	15 /18	430 108	11 /17	669 87	4 /16
Tone at Bishops Hull	19 48	13 46	9 50	8 51	6 48	7 45	2 /30	61 48	2 /30	357 105	16 /29	490 103	15 /29	789 85	4 /28
Brue at Lovington	12 39	8 34	7 46	5 30	5 32	4 26	1 /26	42 37	2 /26	270 91	8 /26	390 90	6 /26	676 80	2 /25
Severn at Bewdley	13 41	8 33	7 40	9 63	7 40	6 27	6 /70	51 40	1 /70	297 98	31 /69	432 96	30 /69	736 85	11 /68
Teme at Knightsford Bridge	16 45	12 56	10 70	9 109	7 80	7 83	10 /21	62 65	4 /21	307 115	15 /20	427 114	17 /20	631 87	5 /19
Cynon at Abercynon	30 39	20 33	28 69	37 109	16 32	19 28	5 /32	150 46	2 /32	944 122	27 /32	1480 119	28 /32	2320 98	14 /30
Dee at New Inn	73 70	23 33	50 85	59 87	36 38	66 48	6 /22	308 58	4 /21	1130 101	11 /21	1755 97	9 /21	2997 87	4 /20
Lune at Caton	43 58	28 56	15 37	68 132	12 17	36 41	6 /28	202 55	4 /28	843 118	22 /28	1149 102	14 /26	2015 94	9 /24
Eden at Sheepmount	28 60	24 73	17 66	26 95	14 45	22 50	6 /20	132 64	2 /20	603 134	20 /20	768 111	13 /19	1322 103	9 /17
Clyde at Daldowie	45 109	26 74	29 110	39 146	29 71	35 60	10 /27	203 89	11 /27	770 159	27 /27	937 124	25 /27	1622 113	22 /26

Notes (i) Values based on gauged flow data unless flagged (natr.), when naturalised data have been used.
(ii) Values are ranked so that lowest runoff as rank 1;
(iii) %LT means percentage of long term average from the start of the record to 1989. For the long periods (at the right of this table), the end date for the long term is 1990.

TABLE 4 RIVER FLOW RETURN PERIODS

River	Station Name	First Year of Rec.	Mean September Flow	1990 September Flow	Return Period (in years)	Base Flow Index [b]
Dee	Park	1972	29.5	16.5	5-10	0.54
Coquet	Rothbury	1972	2.8	0.72	25	0.48
Wharfe	Flint Mill	1937	13.5	3.85	10-25	0.39
Derwent	Buttercrambe (Yorks)	1973	8.1	3.08	25	0.68
Trent	Colwick	1959	49.5	25.6	25	0.64
Dove	Marston on Dove	1961	8.3	3.84	5-10	0.60
Lud	Louth	1968	0.24	0.16	5-10	0.90
Witham	Claypole Mill	1959	0.71	0.39	5-10	0.67
Welland	Ashley	1970	0.29	0.11	50-100	0.41
Mimram	Panshanger Park	1952	0.42	0.27	10	0.94
Kennet	Theale	1961	5.3	3.31	25	0.87
Coln	Bibury	1963	0.59	0.41	10-25	0.94
Great Stour	Horton	1964	1.8	0.89	50	0.69
Itchen	Highbridge	1958	3.6	2.75	10-25	0.97
Brue	Lovington	1964	0.77	0.22	50-100	0.47
Taw	Umberleigh	1958	7.8	1.64	10	0.42
Severn	Bendley	1921	36.5	10.8	10-25	0.53
Yscir	Pontaryscir	1972	1.3	0.25	10-25	0.47
Eden	Sheepmount	1967	38.4	19.25	5	0.50

Note (i) The stations featured are drawn from those areas where the hydrological drought is currently most severe

Note (ii) The precision of low flow measurement may be affected by gauge sensitivity and, further, by uncertainties in summer stage discharge relations which are generally addressed retrospectively. The pattern of water utilisation in certain catchments, particularly regulation and/or augmentation at low flows, plus the the influence of abstractions and the discharge of sewage effluent, means some return periods need to be treated with especial care.

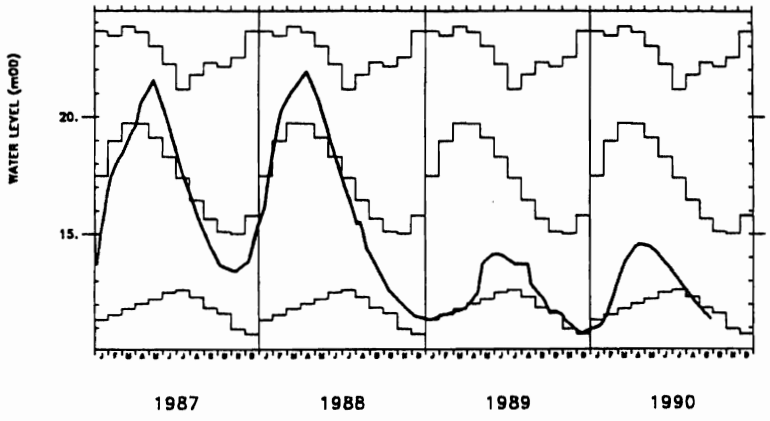
b The base flow index is an indicator of what proportion of the the hydrograph is represented by base flow following a hydrograph separation exercise on the whole record. The lower the index, the lower the base flow contribution and the more responsive the catchment is to rainfall.
See: Low Flow Studies, 1980 NERC

FIGURE 3 GROUNDWATER HYDROGRAPHS

Site name: DALTON HOLME

National grid reference: SE 9851 4530 Well number: SE94/5

Aquifer: CHALK AND UPPER GREENSAND Measuring level: 33.50

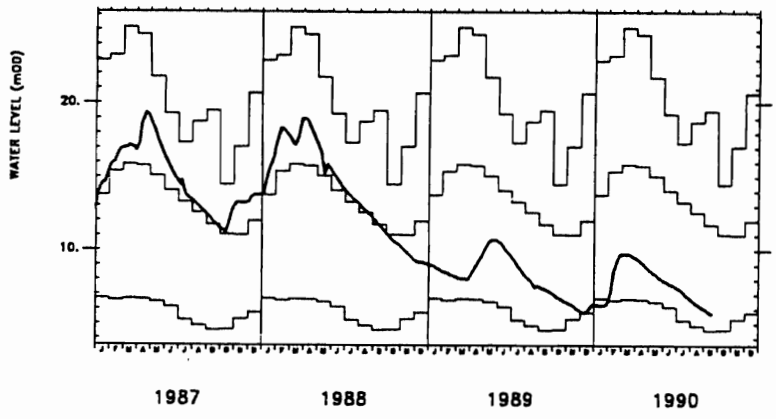


Max, Min and Mean values calculated from years 1988 TO 1989

Site name: LITTLE BROCKLESBY

National grid reference: TA 1371 0888 Well number: TA10/40

Aquifer: CHALK AND UPPER GREENSAND Measuring level: 44.33

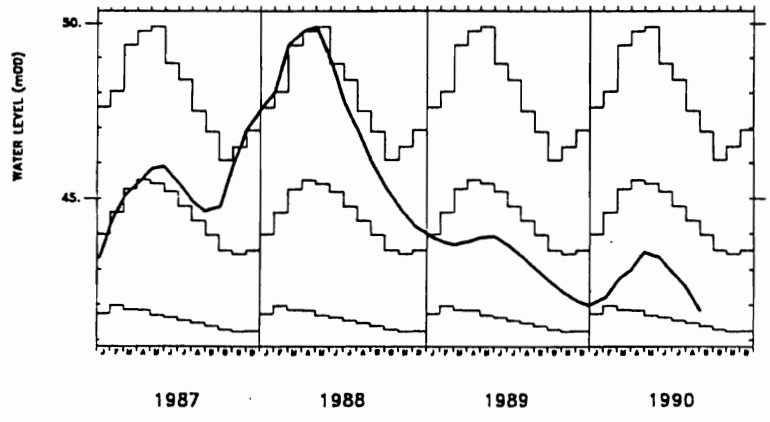


Max, Min and Mean values calculated from years 1926 TO 1988

Site name: WASHPIT FARM

National grid reference: TF 8138 1980 Well number: TF81/2

Aquifer: CHALK AND UPPER GREENSAND Measuring level: 80.20



Max, Min and Mean values calculated from years 1950 TO 1988

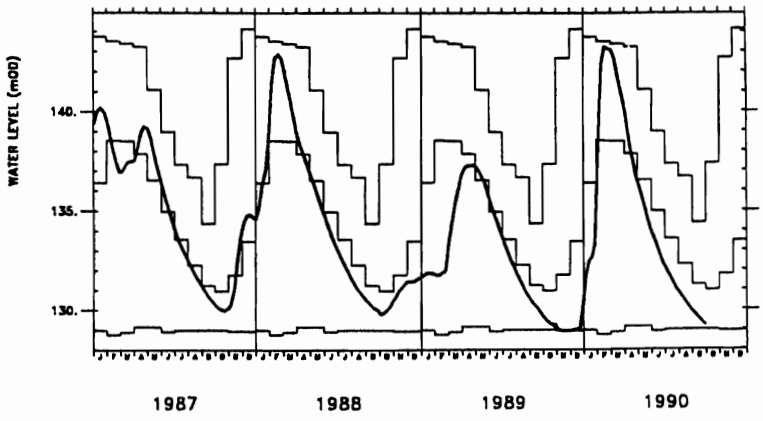
Site name: ROCKLEY

National grid reference: SU 1655 7174

Well number: SU17/37

Aquifer: CHALK AND UPPER GREENSAND

Measuring level: 148.38



Max, Min and Mean values calculated from years 1958 TO 1989

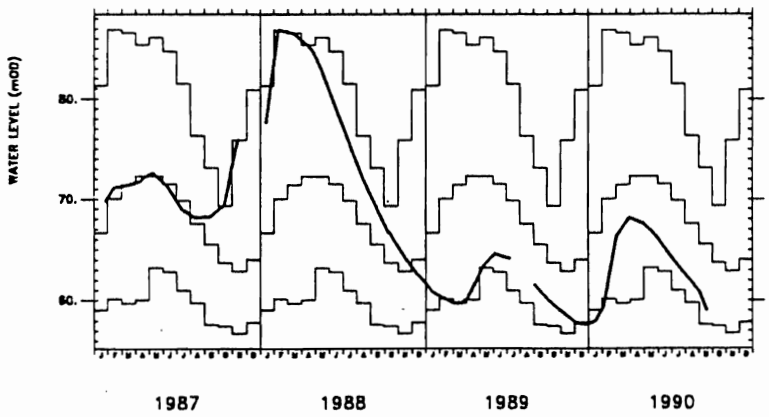
Site name: LITTLE BUCKET FARM,WALTHAM

National grid reference: TR 1225 4880

Well number: TR14/9

Aquifer: CHALK AND UPPER GREENSAND

Measuring level: 87.33



Max, Min and Mean values calculated from years 1971 TO 1989

A break in the data line indicates a recording interval of greater than 8 weeks

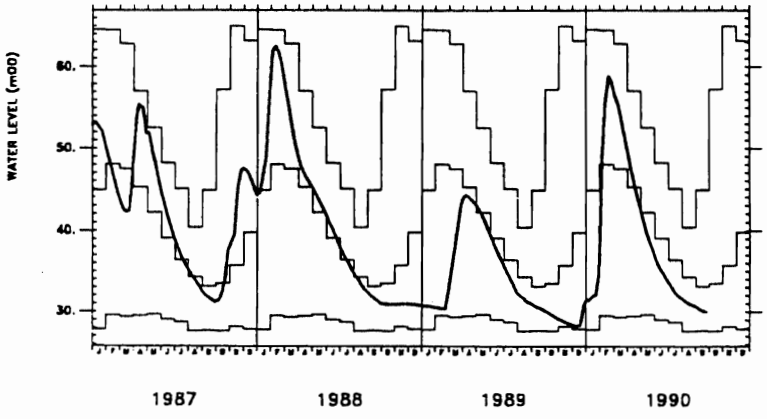
Site name: COMPTON HOUSE

National grid reference: SU 7755 1480

Well number: SU71/23

Aquifer: CHALK AND UPPER GREENSAND

Measuring level: 81.37



Max, Min and Mean values calculated from years 1884 TO 1988

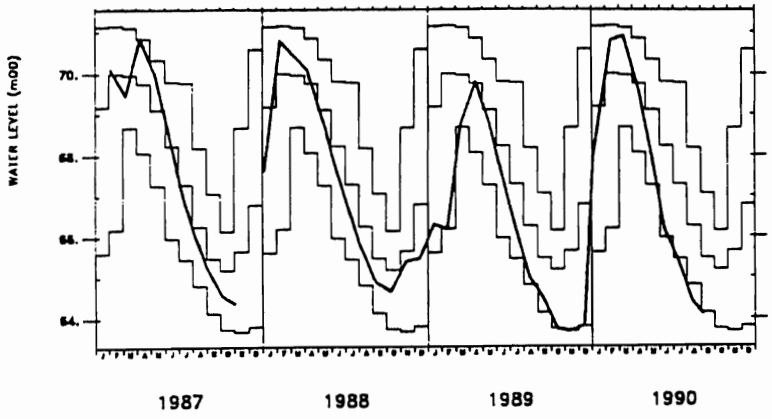
Site name: ASHTON FARM

National grid reference: SY 6620 8810

Aquifer: CHALK AND UPPER GREENSAND

Well number: SY58/34

Measuring level: 72.16



Max, Min and Mean values calculated from years 1977 TO 1988

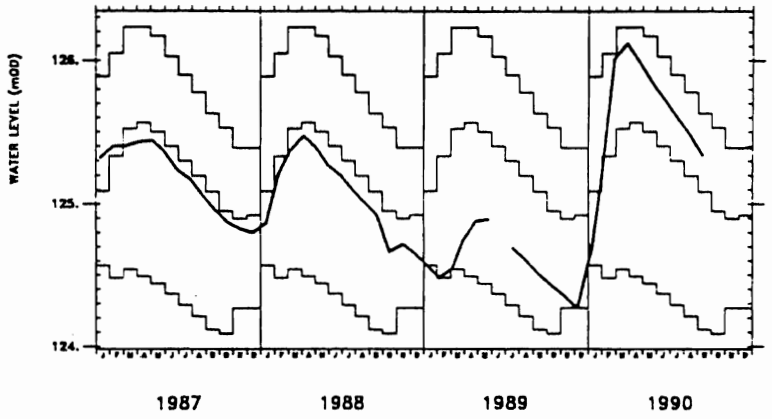
Site name: LIME KILN WAY

National grid reference: ST 3763 0867

Aquifer: CHALK AND UPPER GREENSAND

Well number: ST30/7

Measuring level: 130.19



max, min and mean values calculated from years 1969 TO 1988

A break in the data line indicates a recording interval of greater than 6 months

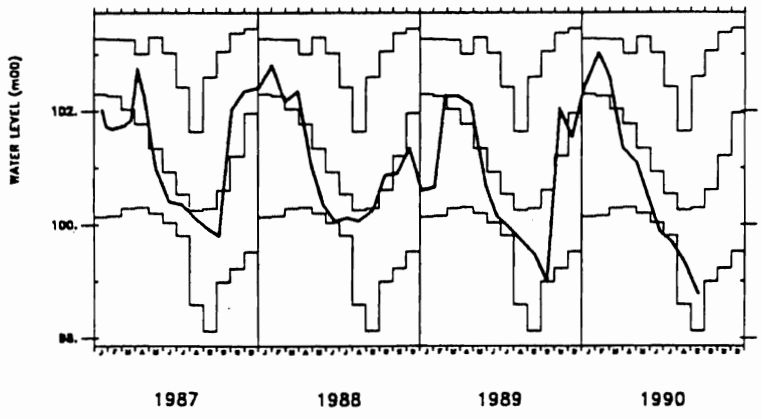
Site name: AMPNEY CRUCIS

National grid reference: SP 0585 0190

Aquifer: MIDDLE JURASSIC

Well number: SP00/82

Measuring level: 109.70

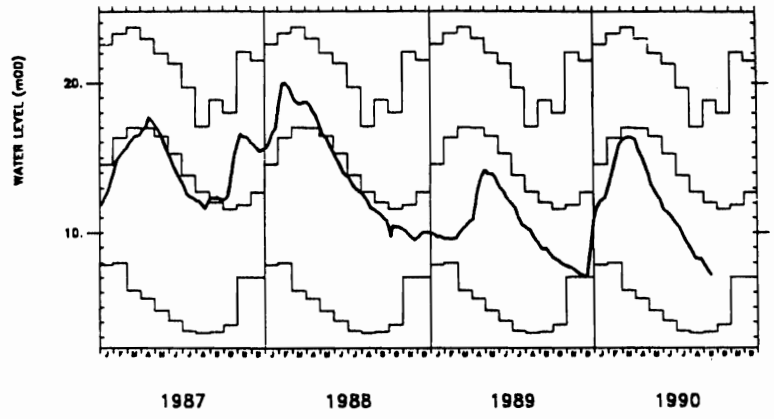


Max, Min and Mean values calculated from years 1958 TO 1988

Site name: NEW RED LION

National grid reference: TF 0885 3034 | Well number: TF03/37

Aquifer: LINCOLNSHIRE LIMESTONE | Measuring level: 33.82

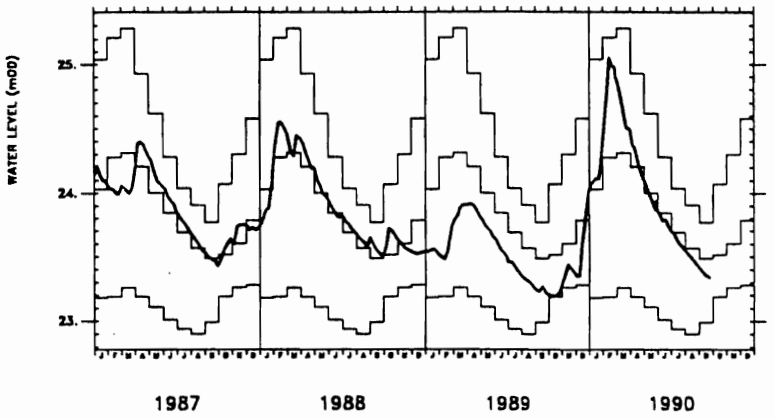


Max, Min and Mean values calculated from years 1954 TO 1988

Site name: BUSSELS NO.7A

National grid reference: SX 9528 9672 | Well number: SX99/378

Aquifer: PERMO-TRIASSIC SANDSTONE | Measuring level: 28.07

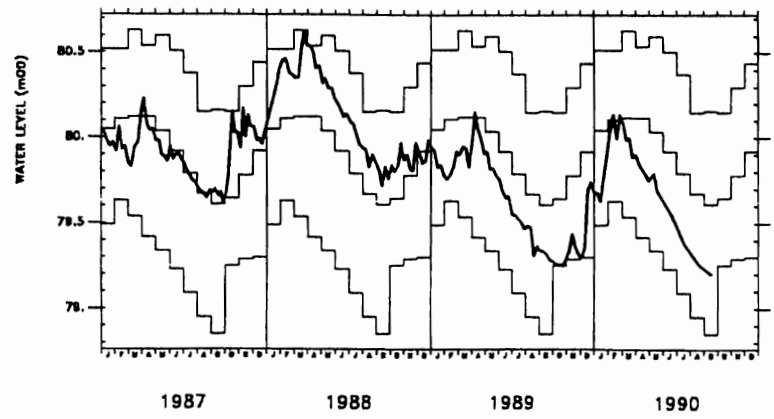


Max, Min and Mean values calculated from years 1972 TO 1988

Site name: LLANFAIR DC

National grid reference: SJ 1374 5556 | Well number: SJ15/15

Aquifer: PERMO-TRIASSIC SANDSTONE | Measuring level: 82.00



Max, Min and Mean values calculated from years 1972 TO 1989

TABLE 5 A COMPARISON OF SEPTEMBER GROUNDWATER LEVELS: 1990 AND 1976

Borehole	Aquifer	First year of record	Av. Sept level	Sept 1976		Sept 1990		No. of years of record with Sept levels <1990
				Day	level	Day	level	
Dalton Holme	C & U.G.	1889	15.67	25	11.87	27	11.38	none
L. Brocklesby	"	1926	11.72	24	4.56	20	5.69	1
Washpit Farm	"	1950	43.98	1	41.70	3	41.85	2
Rockley	"	1933	131.06	26	128.97	27	129.30	5
Compton House	"	1894	33.11	30	27.72	25	29.98	3
L. Bucket Farm	"	1971	65.56	30	57.64	20	58.96	1
Limekiln Way	"	1969	125.09	15	124.12	12	125.34	16
Fairfields	"	1974	23.04	24	22.37	10	22.24	1
Ashton Farm	"	1977	65.28	24	63.23	6	4.10	1
New Red Lion	L.L.	1964	12.03	28	3.68	19	7.21	1
Llanfair D.C.	PTS	1972	79.61	1	78.85	17	79.20	1
Bussels 7A	"	1972	23.49	28	23.09	25	23.34	3
Ampney Crucis	M.J.	1958	100.29	15	98.12	19	98.78	1

C & U.G. Chalk and Upper Greensand;
L.L. Lincolnshire Limestone
PTS Permo-Triassic Sandstones
M.J. Middle Jurassic Limestone

FIGURE 4 LOCATION MAP OF GAUGING STATIONS AND GROUNDWATER INDEX WELLS