INLAND WATER SURVEYING IN THE UNITED KINGDOM – A SHORT HISTORY

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A seminar was held at the Institute of Hydrology in October 1985 to celebrate the fiftieth anniversary of the formation of the Inland Water Survey. At the seminar Dr R. W. Herschy presented a paper reviewing the events which led up to the establishment of the INLAND WATER SURVEY and examined the development of hydrometric monitoring over the following thirty years. This article draws directly on material provided by Dr Herschy to document the evolution of the hydrometric networks in the United Kingdom. The impact of the 1963 Water Act, and subsequent legislation, is then considered with particular reference to the growth and contraction, of the gauging station network and contemporary developments in data acquisition and archiving practices.

Introduction

The prerequisite of planning based upon analyses of data is the availability of those data and the best data are those collected with the end use in view. In the development of water utilisation there was an increasingly obvious benefit to planners, engineers and users to be realised by the adequate provision of a fund of hydrological data to allow the assessment of water resources and their optimum apportionment to meet the demands for water.

The currently well-organised hydrometric data collection systems which allow the hydrological variables to be estimated with some precision give little indication of the earlier imbalances in surveying and measuring networks. A residual example may be found in the lack of nationwide coverage in the New Series 1:50,000 Geological Maps. The measurement of each of the hydrological components went through a similar gestation, in that they were initially effected by enthusiasts and volunteer services; these were later transferred to government agencies but the dates of takeover were very different.

The beginnings of formal hydrological records

Rainfall records were begun in 1729 and evaporation measurements in 1772. In 1860 G.J.Symons founded the British Rainfall Organisation and by 1880 there were more than 2200 gauges yielding records. By 1912 this figure had risen to about 5000, at which level it stabilised. In 1919 the British Rainfall Organisation was merged with the Meteorological Office, a department of the Air Ministry.

The Geological Society had been founded in 1807 and the Geological Survey in 1835. The records from wells and boreholes, initially seen as being of value to stratigraphy, became important with regard to water resources; this importance was reflected in the sections on water supply in the map sheet Memoirs, or in the County Water Supply Memoirs. In particular, monitoring of the water levels in the Chalk aquifer below London by Clutterbuck[1] (1850) highlighted the decline in water levels with aquifer development.

Systematic measurement of three components of the hydrological cycle were thus catered for in the 19th century. The fourth, continuous runoff measurement, was restricted to the Thames at Teddington and the Lee at Feildes Weir, despite international precedents for river flow monitoring set, for example, by Switzerland, Austria and the United States. Certainly, river gauging was not as straightforward as maintaining a raingauge, or as conveniently associated with water well drilling and mineral explorations as was groundwater. Neither was there a consistent and thoroughly dominant river water usage over the whole of the country to initiate a harmonised gauging scheme for its own interests. Indeed, gauging may well have been of most use as a conciliating tool, in settling disputes between conflicting interests; navigation and water mill usage, for example.

The general excellence of the rainfall survey added to frustration in that it allowed estimates of runoff to be made for use in river and reservoir engineering and thus proved a disincentive to more specific measurements.

Early proposals for a water resources survey

In the 19th century spurs or initiatives to set up gauging networks were provided by: a series of

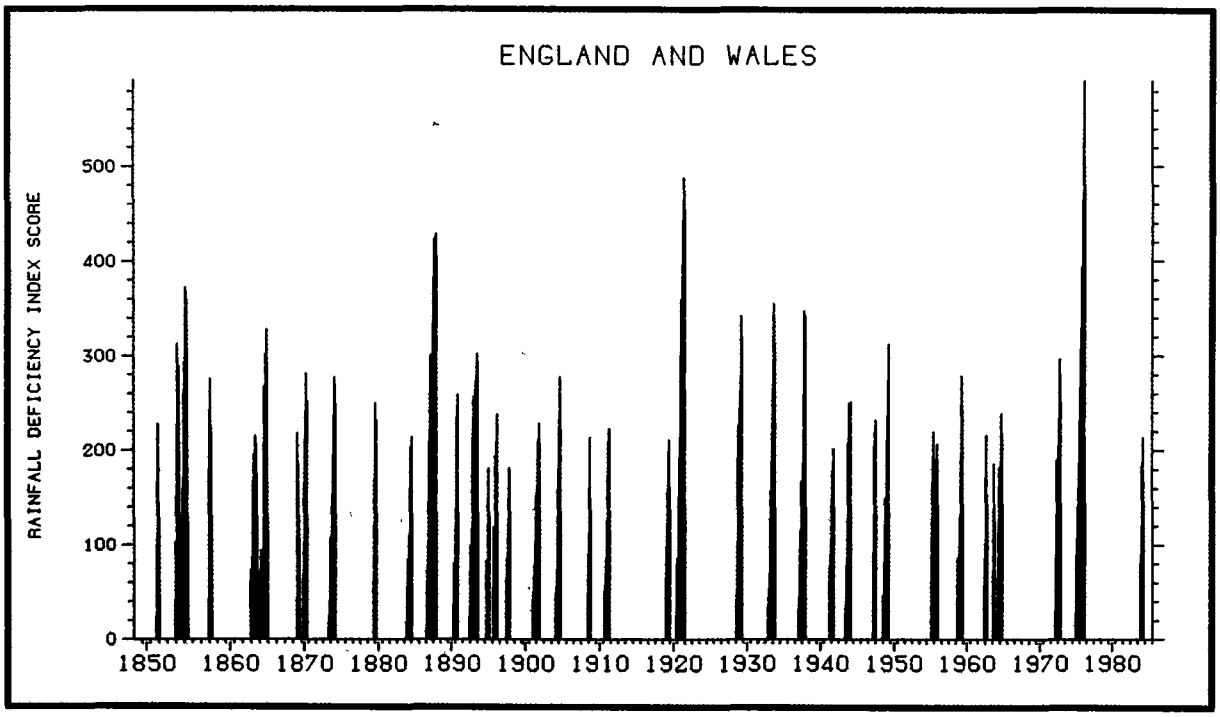


Figure 12. Rainfall deficiency index for England and Wales – based upon accumulated departures of monthly rainfall totals from the long term average. Details of the computations involved are given in 'The 1984 Drought' (see page 199).

significant droughts, particularly those which occurred in 1854–8 and 1887 (Figure 12); the publication by the Ordnance Survey of a catchment boundary map for England and Wales (subsequently editions for Ireland and Scotland were published); discussion, by the British Association for the Advancement of Science (British Association) in 1878, of hydrological measurements and the consequent suggestion for a hydrogeological survey of England[2]. Also in 1878, a paper was presented at the Royal Society of Arts in which runoff measurements from uplands were proposed[3]; C.E.De Rance published a book in 1882 which contained estimates of rainfall within the Ordnance Survey's river basins, delineated the major aquifers and described the quality and quantities associated with existing supplies[4]. The industrialisation of parts of Britain was leading to concern about pollution and River Pollution Prevention Acts of Parliament were enacted in 1876 and 1893 following Royal Commission Reports of 1865 and 1868; a Royal Commission on Sewage Disposal was set up in 1898.

There was continuing activity up until the outbreak of the First World War. Resource estimates from all major watersheds was urged by the Salmon Fisheries Committee in 1902[5]; in 1910 a Joint Select Committee of both Houses of Parliament recommended a survey of the water supply of the country. Subsequently Parliament required that Water Undertakings should submit returns as to their sources of supply and the volumes of water supplied. A circular was issued in 1914 by the Local Government Board and 2160 replies were received. The Royal Commission on Sewage Disposal in its 8th report (1912) recommended that effluent standards should be adjusted according to the character of the receiving watercourse[6]. Observations were made on various rivers during the enquiry, to assess the moderating effects of dilution and subsequent self cleansing, so the value of river flows recorded on a routine basis was recognised.

Gauging practice

Although any national effort was still not evident, some routine gaugings were already taking place. The technology was established. Current meters, of different designs, had been used in Italy and Germany since 1786. The 19th century had seen the development of hydraulic theory governing sharp edged and long based weirs, velocity distributions in open channels and stage-discharge relations. A paper by S.C.Chapman, a water supply engineer, in 1910 described runoff recording using weirs on South Dartmoor catchments[7]. Comparison of these data with raingauge data demonstrated seasonal, annual and geographical variations in catchment yield. The discussion brought out further examples of the value of continuous recording of rainfall and runoff for water supply undertakings. The Lee and Thames examples have already been cited but the most famous systematic river gauging using current meters was undoubtedly that on the River Garry by Captain W.N.McClean, not least as the work was funded by himself (see pages 49 to 54). This gauging was to cease in 1915 owing to the first World War. Other gauging results from Scotland[8] and the Derbyshire Derwent[9] reported at the Institution of

Civil Engineers in 1913 attracted comments from a bemused American engineer, Clemens Herschel, who asked "why Britons tied themselves in knots, measuring rainfall to deduce runoff, instead of measuring the latter directly?".

A manual called 'River Gauging' was published in 1917 by G.B.Kershaw, who was Technical Secretary to the Royal Commission on Sewage Disposal[10]. In 1920, the Department of Industrial and Scientific Research (DSIR) established a committee for river flow measurement. A significant natural event, the 1921 drought (see Figure 12), must have concentrated attention upon water resources and effluent dilution, but no formal survey was established. The DSIR committee's deliberations on river gauging bore fruit in 1922 and 1925 with publications on current metering[11] and gauging methods[12] respectively by M.A.Hogan, their Technical Secretary.

1920s survey pressure

In 1920, the Board of Trade set up the most relevant committee to that date, the Water Power Resources Committee, whose 2nd and 3rd reports (1920 and 1921)[13] proposed the setting up of a committee to compile records pertaining to the size and requirements of water resources and a rationale for allocating them, recognising that river gauging would be necessary to supplement existing information. W.S.Allard, subsequently to become Engineer in Charge of the Inland and Surface Water Surveys, believed the proposal that a committee should allocate water resources was too hot a political potato; the proposal was not acted upon[14].

The Institution of Water Engineers, at their 1921 annual general meeting, discussed survey matters; in 1927 W.N.McClean presented a paper on the River Garry measurements[15] and in 1929 he published an instructional booklet, 'Stream Flow and Underground Water Records'[16]. He also recommenced gauging the Garry.

The Ministry of Health, being the department concerned for the water supply industry, had an active Advisory Committee operating throughout the 1920s. This Committee, in considering the assessment of compensation water (that is, a statutory minimum flow maintained in a river below an impounding reservoir), were guided by the recommendations of the 1910 Select Committee in the use of stream gauging in the determination of catchment losses and variability. In 1928 the Minister of Health recommended the formation of Regional Water Committees to arbitrate in districts of multiple demand, recognising the paucity of information regarding surface supplies and the benefit to be realised by the collection of appropriate data by these committees.

In leaving the 1920s it appeared that the recommendations of the engineering profession, which was in the forefront of agitation for a survey, were going unheeded. The early part of the 1930s saw some significant legislation, a pertinent natural event – another severe drought – and the pooling of resources by the scientific and engineering fraternities to increase pressure on the government to formalise runoff measurement.

The 1930s; The British Association and the Institution of Water Engineers

Two relevant Acts of Parliament were passed in 1930: First, the Reservoirs (Safety Provisions) Act which had been presaged in 1865 by the recommendations of a Select Committee and spurred by dam failures at Dale Dyke (Sheffield) in 1864 and at Dolgarrog (Snowdonia) in 1925. In order to ensure adequate spillway design, continuous flow records from gathering grounds were deemed necessary, rather than relying on rainfall conversion to runoff. Second, the Land Drainage Act allowed for the setting up of joint committees concerned with individual or groups of river basins; the beginnings of river boards.

The British Association, in 1932, appointed a multidisciplinary committee, with McClean as secretary, to enquire into the structure and management of an Inland Water Survey. They reported the following year, concluding in a lengthy memorandum[17], that a systematic survey of water resources was urgently required and that "to be of maximum utility, should be conducted by a central organisation, preferably under a Government Department, independent of any interest in the administration, control or use of water". The memorandum discussed the requirements, structure and scope of a survey covering all aspects of inland waters, including rainfall, surface and ground waters, with submemoranda relating to water quality, amenity, navigation, fisheries, impoundments and power generation. So as to expedite the progress towards a survey the Institution of Civil Engineers was invited to assist in initiating one with private funds but in spite of much effort this aim was not achieved.

The Political Dimension

At this stage, the interested professions had done all they could in achieving unity of purpose and support at the highest level; in June 1934 the British Association and the Institution of Civil Engineers made an application to the Rt Hon. Ramsay Macdonald M.P., the Prime Minister, to consider a survey for water resources assessment. This was at the height of the 1933–34 drought, perhaps a convenient concurrence of events. The application suggested the DSIR as the appropriate departmental agency to set up a special board to manage the water measurements and collect the data, stress throughout being laid on impartiality and independence. At the same time the 1933 Memorandum was submitted, along

with a request for the Prime Minister to receive a deputation to pursue the matter.

It is unlikely that the British Association's report of 1933 had gone unheeded; it certainly had relevance to the Ministry of Health. The reply from the Prime Minister to the request indicated which way the Civil Service advisors were thinking as, in the absence of the Prime Minister who was ordered to take a holiday on medical grounds, an appointment was made with Sir Hilton Young, the Minister of Health. The Minister, of course, requested a briefing and study of this indicates the lateral thinking practised by the administrators when considering an implementation of the British Association's request: a general water survey would serve no practical assistance to the development of the bulk of the water supply sources; if it were desired to go some way towards meeting the demands for a survey then Water Undertakings, Catchment Boards and Mine Owners might be persuaded to take the necessary measures to provide annual returns. The Ministry of Health, Ministry of Agriculture and the Geological Survey would undertake the collation of the data. No DSIR involvement was recommended. An alternative was to legislate to ensure the returns, but this was not favoured in the first instance. The DSIR showed condescending interest, it not being the sort of service falling within the Department's normal functions.

When the visiting engineers and scientists met the Minister, Sir Henry Maybury (President, Institution of Civil Engineers) introduced the deputation (Sir James Jeans, President, British Association, was indisposed) to him and to representatives of other Departments; the Ministries of Health (Scotland), of Agriculture, of Transport, the Scottish Office and the Electricity Commissioners were all involved. There was no DSIR representation. The results of the meeting reflected the Minister's brief. The then current drought was not considered to have any leverage and was dismissed as more a problem in evaluating whether higher insurance premiums were worth paying to insure against such a rare event than a justification for expenditure to collect data. The Engineering Inspectors of the Ministry of Health had been collecting information regarding sources and abstractions; The Geological Survey had collected data on subsurface waters; Catchment Boards were (theoretically) able to undertake the gauging of rivers and water statistics were already published in a Year Book issued by the British Waterworks Association. An extension and improvement of this machinery would be the best route forward and only if these proved ineffective would other means of proceeding be considered.

The deputation's disappointment was sharpened by scepticism regarding the likely quality, and consistency, of the proposed annual returns, serious doubts as to whether the mere fact of asking for data would, in itself, stimulate any improvement or extension of river gauging activities and the limited scientific content in the suggested programme. There was a realisation that the Geological Survey would have to be involved. Some internal minutes could be interpreted as being disparaging to other Departments or organisations; problems were anticipated with the DSIR as it was feared that the measures could be too practical to please the scientists. It is evident that unminuted discussions took place both within and perhaps outside of the ministry, and are therefore not held in the Public Records Office. As a result, Sir Hilton Young *was* persuaded to form a water committee to manage flow data.

Following an agreement by the Scottish Office to participate, Scottish representatives joined the proposed committee and its structure was settled by the beginning of December 1934. On the 6th, Lieutenant-Colonel Ackland-Troyte (Conservative, Tiverton) put a question in the House "To ask the Minister of Health whether he is in a position to announce further measures in connection with an Inland Water Survey?". In response, the Minister announced that a comprehensive Inland Water Survey should be undertaken for Great Britain. Information was to be secured from appropriate bodies and encouragement given where records were not kept. A Water Survey Committee, composed of members from outside of Government Departments would be appointed to advise on the survey and the progress of measures undertaken. Reviews and recommendations would feature in an annual report. In answer to further questions, the Minister replied that he did not believe any substantial government expenditure would be required. The willing of ends without the willing of means is a recurring theme in relation to the development of hydrometric survey in the United Kingdom. Despite misgivings about the effectiveness of the committee's remit it is notable that a mere six months elapsed between the initial approach to the Prime Minister and the statement of intent in Parliament; an intriguing contrast with the unproductive history of the previous sixty years.

The early years of the Survey

A reconnaisance of the data available from the various water undertakings was duly carried out during the first year of the Inland Water Survey and about 3000 replies to a comprehensive questionnaire were received. As may have been feared, the majority of the information was not amenable for conversion to runoff, related, as it was, to stages, compensation discharge or abstraction records. Those gauging locations which were in operation generally needed improving and to make the survey comprehensive a large number of new stations would be required.

Three Annual Reports were produced by the Inland Water Survey Committee before 1939, when the outbreak of war curtailed its activity[18]. Of the 28 gauges producing runoff records about two-thirds

were those of water supply undertakings gauging small upland streams and reservoir outfalls and these formed the bulk of the records published in the two Surface Water Year Books of 1935–36 and 1936–37 (see Table 6). Seven of the remaining stations were gauged by McClean. The Committee were of the opinion that the catchment boards were the appropriate bodies to install gauging schemes but, in spite of persuasion, river basin investigations and the potential attraction of grant aid, few catchment boards were prepared to follow the recommendations of a technical handbook published in 1936, called 'Memorandum on the Water Survey of a river system'[19]. It was evident that the Government's hope that reconnaisance and persuasion would promote the collection of resources data at little cost to the Exchequer was doomed and a statutory framework would be necessary to require the gauging of rivers.

The situation was no better in Scotland, although the Department of Agriculture and Fisheries for Scotland had made grant monies available for station installation (£500 in each of two years), but, given the problems of calibrating the larger rivers with inadequate equipment (e.g. no cableways or heavy sinkers for current metering), gauging was not carried out at the most advantageous sites.

The Groundwater Survey

A similar lack of a suitable statutory framework was affecting progress in the assessment of groundwater resources. Well records were supplied voluntarily by well sinkers or owners but related generally to construction and testing. Abstraction details could only be asked for and details of water level fluctuations were usually restricted to those wells in use for supply. Such sites are of limited value for monitoring purposes due to the effects of the pumping regime on the water table in the vicinity of the borehole. Lapsed production wells did provide genuine observation boreholes if observers could be found to measure them.

Post-war; progress and set backs

The obvious shortcomings in the Survey's effectiveness were discussed and considered during the war years. In 1942 the Institution of Civil Engineers published a report on the post-war development of a water resources survey[20]. It advocated a disinterested government department's control amongst other measures. The third report of the Central Advisory Committee of the Ministry of Health recommended the establishment of a network of River Boards, one of whose responsibilities would be systematic flow gauging[21]. Their wider duties would include land drainage, fisheries and pollution. The report highlighted the scarcity of data relating to flow and river quality.

Acts of Parliament, 1945 and 1948

In 1944 a White Paper was issued, entitled, 'A National Water Policy'[22]. Fortuitously or otherwise this also coincided with a severe drought but the proposals in the White Paper were the most encouraging then seen, containing the sentence: "The Government consider that collection and collation of scientific records of the flow of rivers and of information regarding the quality of water and the behaviour of underground water sources should be resumed and pressed on with vigour as soon as circumstances permit." "The task of the survey would be to make available ...to all who needed it, information as to the yield, behaviour and quality of the country's water resources."

The reversion to a normal Parliament after the war did not deflect commitment to the White Paper and in 1945 the Water Act was passed. This gave responsibility for conservation and proper use of water resources to the Ministry of Housing and Local Government. The Water Act was notable for its effects regarding groundwater; well sinkers were obliged to notify the DSIR of the details of the drilling and testing operations and abstractors could be required to keep and provide records of water taken. The proposals of the White Paper relating to river boards had to wait three years for the River Boards Act, 1948 but then, for the first time, a statutory framework required schemes for systematic flow gauging to be drawn up and implemented.

North of the border it was incumbent upon the Secretary of State to collect, prepare and publish data relating to water resources as detailed in The Water Act (Scotland), 1946; the work on the ground was carried out by the Department of Agriculture and Fisheries for Scotland, water supply authorities and the North of Scotland Hydroelectric Board. The evaluation of the power generating capacity of Scottish rivers by the NSHEB had yielded data from the more remote, high rainfall, high relief areas; no other land use would have provided such a motivation. Many of the gauges did not prove to be permanent as inundation or regulation by the power generating schemes overtook them.

The seedling of the Institute of Hydrology was planted in 1948 with the establishment, within the DSIR, of the Hydraulics Research Station, which was then available for experimentation on hydrometric problems.

The Surface Water Survey Committee

The Inland Water Survey Committee was resurrected in January 1950 with activities confined to surface water surveying but with the brief, much as before, to review progress and advise through annual reports. Their fifth report recognised the widening extent of water usage and that planning and the reconciliation of multiple usage would be best served

by rapid implementation of river board gauging networks[23]. An annual publication of water statistics was deemed essential. These points may have been covered in the legislation but at this time the formation of the River Boards was not complete and the Committee would not allow these objectives to lapse for lack of promotion. A sub-committee of the Surface Water Survey recommended that a specific surveying organisation should be provided for Scotland.

At the end of 1951 a retrospective Surface Water Year Book covering the years 1937–45 was published (see Table 6). The contents of this are instructive, for it shows how little progress had been made to that time in actually producing widespread, usable flow records. It contained the records from 52 stations, 38 of which were river gauging stations. Six gauges were in Scotland (McClean's) and 14 were in the catchments of the Wye and the Nene!

Further legislation was passed for Scotland in 1951, the Rivers (Prevention of Pollution – Scotland) Act, which made provision for the setting up of River Purification Boards. Permissive powers were given to these boards to survey and gauge their rivers and this was reflected in the differing approaches to gauging in the early days of their existence.

Suspension of the Surface Water Survey

Progress towards a comprehensive national network received a setback when, in 1952, the Survey was suspended and gauging station construction discontinued due to national economy measures. Allard, in a footnote to his review paper, rightly compares the White Paper's exhortation "pressed on with vigour" with this reverse[14]. The parallel between civil service commitment in 1934 to the setting up of the Inland Water Survey may be seen with his observation that implementation of policy may depend upon the individual, interested civil servants. He advanced the mock commandment "Thou shalt not kill, yet needst not strive officiously to keep alive"!

As may be imagined, there was a considerable outcry from the deprived parties, who perceived this as a false economy and who lobbied throughout the period of suspension. Other water interests from supply, fisheries and disposal protested similarly and the scientific community weighed in with pressure from the Hydrological Sub-Committee of the Royal Society. Allard was a senior member of this group, which had contacts at a high level within Government. Allard was on good terms with the River Board chairmen and no doubt impressed upon them the desirability of maintaining the collection of data where facilities allowed.

Resurrection

The Central Advisory Water Committee was revived on the 1st October 1954 and a sub-committee on the Information on Water Resources set up. The Surface Water Survey was restaffed and recommenced their active role. The engineer in charge of the Survey at the Ministry of Housing and Local Government was A. Gerard Boulton. One of the first achievements was the publication of the data for 1945–53 (see Table 6). Reports were made for 81 stations and the rather more interventionist role of the Department of Agriculture and Fisheries in Scotland led to their significantly increasing their representation to 22 stations.

Progress was made in the submission of networks; by 1956, 27 of the 34 River Boards had submitted plans for approval. A map of the gauging stations whose flow records were presented in the 1954–55 Surface Water Year Book is shown in Figure 13. The aim was to establish a network of about 400 primary stations but steady progress towards that aim was all that could be hoped for. The Surface Water Year Books (see Table 6) were showing the fruits of collation from various sources; for instance, the Meterological Office began supplying monthly catchment areal rainfall data, and the long term analogues for the period 1881–1915.

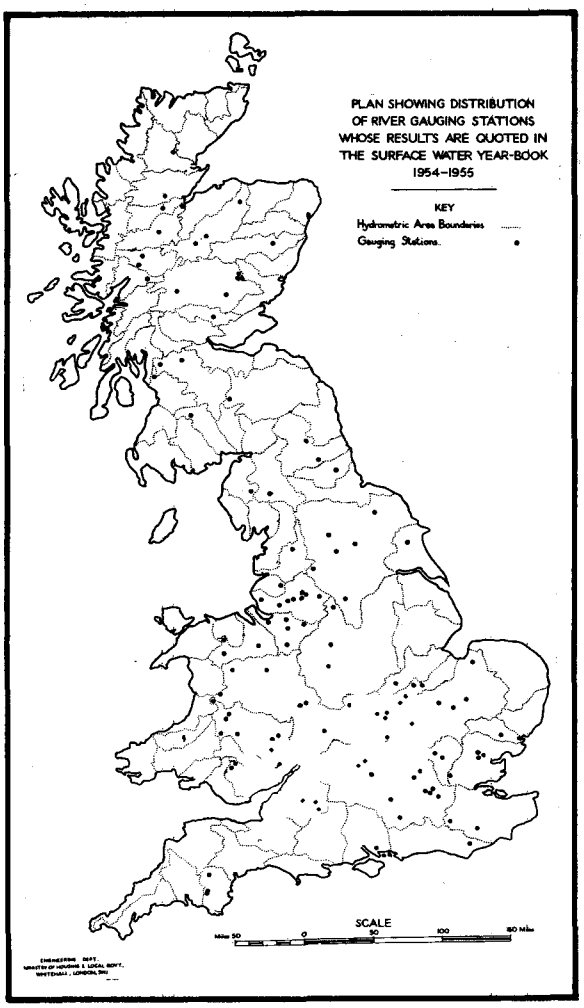


Figure 13. The gauging station network in 1955.

The Central Advisory Water Committee recommendations

The subcommittee of the Central Advisory Water Committee on Information on Water Resources submitted their report in December 1959[24]. This reviewed the measurement and collection of all data related to the hydrological cycle. By this time all the River Boards had submitted schemes for rainfall and stream gauging or had satisfactory schemes in operation. River Boards were expected to proceed with the implementation once schemes had been approved. The Surface Water Survey needed to be satisfied of the accuracy of any derived record before allowing publication of data. The report stated that more than 100,000 well records were in existence and that the rate of increase was about 2000 each year. It was noted that, although the evaluation of the catchment areal rainfall values for more than 100 river gauges put a severe tax on the Meterological Office's rainfall section, it should continue as most of the flow records were, at that time, short. The existing or proposed arrangements for the collection, interpretation and publishing of information broadly met the known need. The recommendations included the determination of the extent of hydrological research and to co-ordinate it; improvements were hoped for with regard to the collection of precipitation and groundwater data; vigorous action should be taken to set up the remainder of the flow gauges within the next 2 or 3 years; bodies with a legitimate interest should have access to the outline gauging schemes; and that hydrological data should be presented on the common basis of river basin areas.

Running in parallel was another sub-committee of the Central Advisory Water Committee, that of The Growing Demand for Water. This group produced three reports, the first of which estimated that the increase in demand between 1955 and 1965 would be of the order of 25 per cent and that new measures for the control and development of water resources might be required[25,26,27]. The final report concluded that new authorities were needed to plan and implement the ordered development of resources and that the new bodies, 'river authorities', should be responsible for conservation, land drainage, and flood control and would supersede the River Boards. Existing and future abstractions of surface or ground waters should be subject to licence and thus provide revenue. A central authority should oversee the river authorities and promote an active policy for the conservation and proper use of resources and co-ordinate any regional planning. Subsequently a White Paper was issued in 1962 entitled 'Water Conservation in England and Wales' which incorporated these recommendations[28].

The Water Resources Act 1963

River Authorities were duly formed after the Water Resources Act 1963 was passed. The role of the Surface Water Survey became a function of the new authority, the Water Resources Board. Hydrometric schemes were to be prepared and submitted for approval by the Water Resources Board; section 15 of the Act relating to measuring rainfall, evaporation and surface water and section 18 similarly for groundwater. Grant aid for capital works was permitted under section 89 and research under section 90 of the Act.

At the time of the formation of the River Authorities the number of gauging stations in operation (as reflected by the 1963–64 Surface Water Year Book) was 295 in England and Wales and 69 in Scotland. There were more stations commissioned but their calibration was incomplete.

This Act gave the most tremendous impetus to river gauging. The Water Resources Board 2nd Annual Report (1965) gave the number of operational gauging stations as 410 in England and Wales[29]. An inference of this larger number of stations was a growing workload in processing data to flows, and utilising the flows thereafter. Following United States Geological Survey practice, punched tape recorders were recommended as recording instruments, and initially the Meterological Office's computer at Bracknell was used to process the data, after a translation process had been completed at the Water Resources Board. A case was made for a Water Resources Board computer to carry out this processing work.

The following year, under section 15 of the Act, Hydrometric Schemes were submitted to the Water Resources Board for approval. The approximate numbers of stations proposed in the completed networks would be: 5000 rainfall; 600 evaporation; 1500 flow; 400 quality monitoring. New style Surface Water Year Books were proposed, which would be generated within the computer and the output photographed and printed.

The International Hydrological Decade 1965-1974

The implementation of the 1963 Act coincided pertinently with two events: first, the Science and Technology Act in 1965 saw the dissolution of the DSIR and the formation of the Natural Environment Research Council (NERC), which had the power to grant funds for hydrological research. The Hydrological Research Unit, located with the Hydraulics Research Station near Wallingford, was transformed into the Institute of Hydrology. Second, the International Hydrological Decade commenced in 1965. Member countries of UNESCO agreed to support a long term international co-operative effort in hydrology. Many items of the 50 or so which were in the

programme were already covered by some British agencies. Research programmes were identified for about 50 catchments, some to accord with the establishment of experimental and representative basins[30]. Of the latter, some would be incorporated into River Authority hydrometric schemes; others – and the experimental basins – would be associated with the Institute of Hydrology, university departments and other agencies. Five of these proposals were in Scotland and three in Northern Ireland.

Implementation of the Hydrometric Schemes proceeded at a slower pace than was hoped. By 1970, the 7th Annual report of the Water Resources Board reported that many River Authorities had begun to reappraise their networks, reducing the planned numbers and selecting sites which they hoped would be representative of more than one area[31]. Other considerations, such as operational requirements associated with river abstractions, regulation and flood prediction, were of growing significance. To reflect this, the gauging proposals could also be considered under section 89 of the Agriculture Act, 1970, related to flood warning schemes. Formal revisions of the schemes were ordered. The revisions would, however, have been able to take into account the prospects of gauging at sites using the newer methods of ultrasonic and electromagnetic flow gauging, which allowed measurements at sites where conventional methods of gauging were inappropriate. The research into these methods was promoted by the Water Resources Board under section 90 of the 1963 Act.

The situation in Scotland

The expansion of the gauging network in Scotland followed a different course and was not so directly connected with enabling legislation. In 1959 a government Inter-Departmental Committee was set up with the following brief: 'To examine the arrangements for river surveying and gauging in Scotland and to make recommendations on the need for co-ordinating and extending the work and on the co-ordination and publishing of the information provided by it'. The Committee had representatives from the Department of Health, Department of Agriculture and Fisheries, the Scottish Home Department and the North of Scotland Hydroelectric Board. The River Purification Boards and the Scottish Council (Development and Industry) were involved in the discussions. The Committee reported in 1961, deciding that the most appropriate framework would be a central organisation with central funding[32]. The proposed network would be of 77 primary and 140 secondary stations.

A pragmatic course was followed, however, as the River Purification Boards were intent on developing their gauging networks. At a meeting in 1963 with all interested parties, a programme for the construction of 80 stations by the end of the following year was presented; grant aid was expected to be provided. The River Purification Boards did not encompass all of Scotland; areas to the north of the Great Glen Fault had more local arrangements for the implementation of the 1951 Act. Subsequently a Working Party reconsidered the Inter-Departmental Committee recommendations and advocated that the committee's proposed network should form a basis for Scottish gauging but should be flexibly applied[33]; in the areas of the 6 southernmost River Purification Boards, the boards' programmes for stations could be assumed to meet the national need. Elsewhere the Department of Agriculture and Fisheries would deal with the network stations. Studies or investigations into data processing and publications were recommended.

A Joint Committee on River Survey and Gauging was set up in 1965, comprising the Department of Agriculture and Fisheries, Scottish Development Department (SDD), the River Purification Boards and the Institution of Water Engineers. It reported later that year, recommending the use of punched tape recorders, metrication and arguing for Scottish data processing[34]. The latter was not realised as use was made of the Water Resources Board's processing facilities. The SDD began to offer grant aid towards network station construction costs in return for the River Purification Boards taking over the SDD stations in their areas.

With the River Purification Boards and the SDD busy constructing stations, progress with the network was steady, from about 78 in 1966 to 100 in 1970 and 130 in 1974.

The situation in Northern Ireland

Northern Ireland was the last country in the United Kingdom to collect the full range of hydrological data. Before 1945 virtually no hydrometric work on rivers was undertaken; one gauge recording level only. Subsequently some thin-plate weirs were installed for purposes of monitoring certain individual public water supply sources. These data were not routinely collated. A chart record was begun on the Lower Bann and this and other staff gauge records throughout the Province are held by the Department of Agriculture (Northern Ireland). There was some catchment activity which involved data collection for most of the hydrological variables in three areas which were listed in the programme for the International Hydrological Decade. The earliest flow measurement station for hydrometric purposes was constructed in 1969 on the River Lagan in anticipation of an Act of Parliament (passed as the Water Act – Northern Ireland, 1972) which placed the duties of promoting conservation and cleanliness with the Department of the Environment (Northern Ireland). The DOE(NI) is now responsible for all aspects of water and sewage, environmental pollution and water research; urban and arterial drainage

and the provision of facilities for recreation are the responsibility of the Department of Agriculture.

Currently, the bulk of the gauging stations are velocity-area stations; these number a little more than 50. There are few structures; these total about 10.

Integrated basin management; the 1973 Water Act

Wider consideration of water conservation and usage had been under review in England and Wales by the Central Advisory Water Committee since 1969, in the light of a Royal Commission report on Local Government. The Committee reported in April 1971 (The Future Management of Water in England and Wales)[35] and their main recommendations, presaged by Water Resources Board submissions to the Central Advisory Water Committee published in the Seventh Annual Report[31], were that further integration of the Water Industry was desirable, incorporating supply, disposal, river management, planning and co-ordination. Large regional bodies would take on these roles, overseen by a national body. A Government Circular published in December 1971 indicated their interpretation of the Central Advisory Water Committee Report[36]; 10 Regional Water Authorities would be set up in England and Wales but no national Authority; a central body to represent the industry to government and provide central services would be set up. Nothing specifically related to hydrometry was included in the Circular other than could be inferred by the need for data to service the long term review plans the regional water authorities were to make. These proposals were incorporated into the Water Act 1973.

Reviewing the early results of the necessary involvement of computers in hydrological data processing and dissemination it may be said that it did not yield altogether satisfactory results. Whilst allowing greater processing accuracy for a much increased network size, the archive produced was, by today's standards, inflexible and difficult to access and manipulate. The existence of a central archive served to reduce the priority attached to the prompt publication of data and the availability of yearbooks grew evermore behind the collection of flow data; many fewer basic flow values were presented, the emphasis switching to catalogues of gauges and summaries of retrievals. This did not find universal favour with data users. On the other hand, the 1960s and the early 1970s probably saw the most diligent hydrometry practised, with good staffing levels and enthusiastic and committed workforces and organisations.

The Water Resources Board had overseen the inauguration of a computer based national archive, designed initially by the Surface Water Survey, the logical extension of which was the data processing facility provided for River Authorities and River

TABLE 6 NATIONAL RIVER FLOW DATA PUBLICATIONS

Edition	Series title	Years covered	Publication date	Organisation	Publisher
1	The Surface Water Yearbook	1935/36	1938	Inland Water Survey	H.M.S.O.
2	of Great Britain	1936/37	1939	»	»
3	»	1937/45	1952	»	»
4	»	1945/53	1955	»	»
5	»	1953/54	1956	Surface Water Survey	»
6	»	1954/55	1957	»	»
7	»	1955/56	1958	»	»
8	»	1956/57	1959	»	»
9	»	1957/58	1959	»	»
10	»	1958/59	1960	»	»
11	»	1959/60	1961	»	»
12	»	1960/61	1962	»	»
13	»	1961/62	1963	»	»
14	»	1962/63	1965	Water Resources Board	»
15	»	1963/63	1966	»	»
16	»	1964/65	1968	»	»
17	»	1965/66	1971	»	»
18	»	1966/70	1974	»	»
19	Surface Water: UK	1971/73	1978	DOE-Water Data Unit	»
20	»	1974/76	1982	»	»
21	»	1977/80	1983	DOE-WDU and IH	»
22	Hydrological data: UK*	1981	1985	Institute of Hydrology	NERC
23	»	1982	1985	»	»
24	»	1983	1986	»	»
25	»	1984	1986	»	»
26	»	1985	1987	»	»

*These publications also contain data relating to groundwater.

Purification Boards. Although never responsible for all the machine processed data, the central processing service continued for 15 years, being taken over by the Department of the Environment's Water Data Unit after the 1973 Act. At the time of its dissolution, the Water Data Unit maintained national archives of river flow, groundwater levels in observation boreholes and water quality (The Harmonised Monitoring Archive), the first time that such a range of data was managed by, and available through, a single agency.

The recent past

The regional water authorities (henceforth 'Water Authorities') created in England and Wales under the 1973 Act were under no specific obligation to gauge rivers. They were obliged to furnish data on request to the Secretary of State to allow him to collate and publish information relating to water demand and resources. In practice, the Water Authorities continued to gauge rivers for their own, generally operational, convenience. It is difficult to assess the progress of hydrometry in isolation following the setting up of the Water Authorities. There is little doubt that it had a less protected status than in the days following the 1948 and 1963 Acts. Other contributary factors include first, the irresistible move towards 'multi-functionalism' in the Water Authorities which generally infers a shared, instead of a dedicated, workforce to undertake monitoring and maintenance work and second, the incorporation of the supply and disposal functions which had far inferior measuring networks for the assessment of water movement, with the result that resources were shifted towards improving their measurement procedures.

Data processing slowly became the province of the Water Authorities and the River Purification Boards; this was hastened finally when the DOE Water Data Unit was disbanded. The stewardship of the national flow archive was passed to the Institute of Hydrology who have redesigned the annual publications (the successors to the Surface Water Year Books and Surface Water: United Kingdom volumes) and are reducing the lag between data receipt and publication. Details of the full series of national river flow data publications are summarised in Table 6.

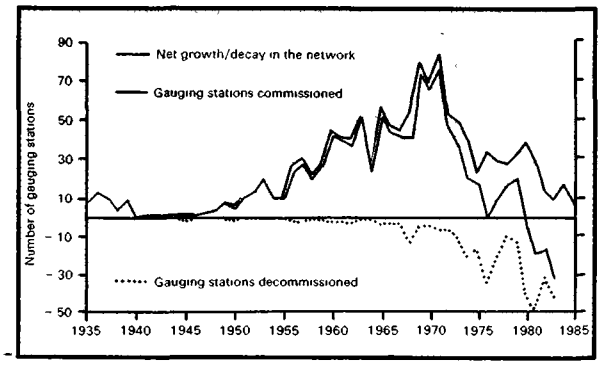
The 1983 Water Act primarily affected the management of and representation on the boards of the Water Authorities. Manpower has been severely squeezed since that time following tighter budgetary constraints and networks have taken their share of cuts, often in successive cycles of pruning. The contraction in the gauging networks (see Figure 14) is related to both the excision of stations deemed superfluous or performing poorly and a practical response to a lower financial input; where the dividing line exists between these reasons is debatable. Certainly, a number of stations operated primarily for strategic planning or research purposes have been closed, to the regret of the data users.

One mitigating element has been the contribution of microcomputers, logging systems and telemetry in transforming the potential for data capture and transmission. The use of such technology has allowed the continued operation of gauging sites which would have closed through lack of manpower. The field hydrometry may have suffered, however, with less frequent site visits and a less fastidious approach to the maintenance of stage-discharge relations.

The 50th anniversary of the Inland Water Survey and the current situation

Figure 14 presents the numbers of stations producing sensibly continuous records of daily mean flows as stations whose records begin and those which cease in any one year. The geographical spread of gauging stations in 1985 is depicted in Figure 15. It may be seen that, although during the 1980s there has been a net fall in the gauged network, new stations have continued to be installed, many as replacements for less sensitive gauges, others as fulfilments of a long term aim, perhaps making use of the wider applicability of the newer technologies, and others as a response to an operational demand. There has certainly been an increase in the numbers of restricted range stations, generally gauging lower flows, which do not have their data featured in the national archive. There is a continuum from these through to primary 'network' stations as it is likely that there is some variation in the interpretation of 'full range' in different parts of the country, according to the degree of containment of high flows and sensitivity at low flows.

The situation in Scotland is different, as few gauges have been closed. The network density in Scotland is significantly lower than in England and Wales, particularly in the remote areas (see Figure 15), where it continues to be developed. The interest in acid rain studies has undoubtedly promoted increased catchment based research.



Where the number of gauging stations commissioned equates to the growth of the network', the black line has been suppressed.

Figure 14. The growth and contraction of the United Kingdom gauging station network.

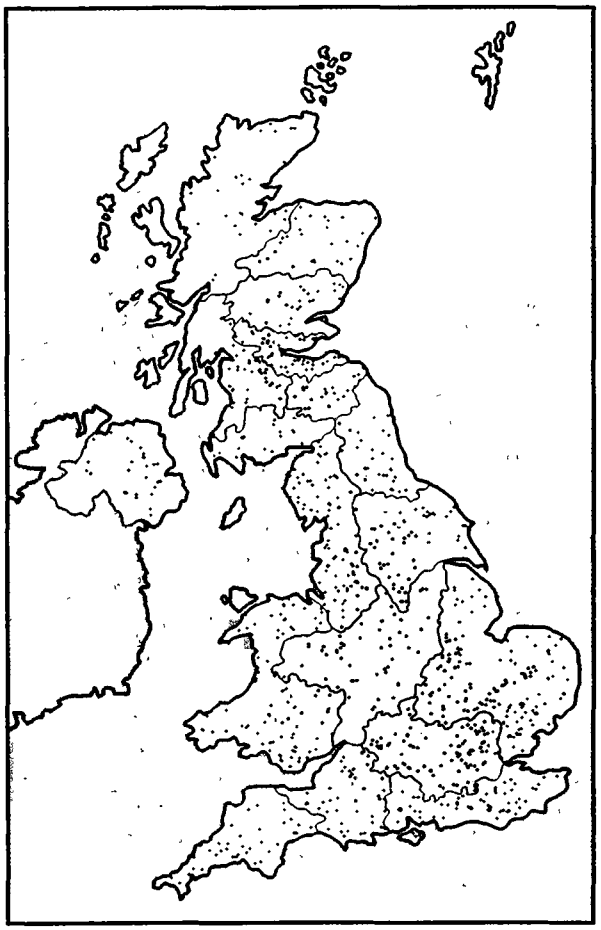


Figure 15. The gauging station network in 1985.

Those catchments which were set up under the aegis of the IHD have had a variable history. The Water Authorities should not be the sole targets for those who complain of the cessation of gauging on the more esoteric catchments, that is of small, well instrumented, unmodified, homogeneous headwater or flat lowland catchments, and highly urbanised catchments or those undergoing urbanisation. Some gauges have been transferred from universities and government agencies to, and operated by, the River Authorities and subsequently the Water Authorities. Some have been transferred in the reverse direction. With a few exceptions the burdens of routine data collection and particularly maintenance have proved too costly for research orientated organisations. The inability to promote successful research applications for successive or continuing use of data from these catchments has been a factor. Coupled with the lack of central direction to oblige Water Authorities to continue operations on such catchments, either by the provision of funds or by the stated requirement for the data by the Secretary of State, these factors have inevitably led to the majority being closed.

A catchment size distribution in 1985 is depicted together with some historical distributions in Figure 16. The infilling of the network by gauges on smaller catchments after the establishment of gauges on the major tributaries may be seen by reference to the

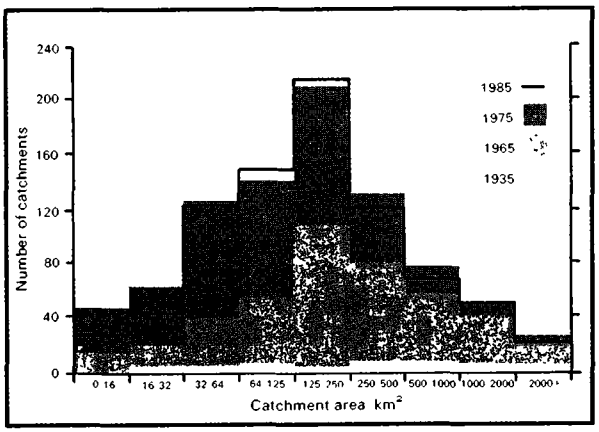


Figure 16. Distribution of catchment sizes for gauging stations on the national surface water archive.

1965 and 1975 traces. A second important feature is the recent reduction of numbers at the lower end of the size range.

The distribution of record lengths is shown in Figure 17. In international terms the United Kingdom has a relatively dense current network. This reflects the great heterogeneity of the British Isles, with its long coastline, many small river basins and diverse climate, geology and land use. The UK is less well blessed in terms of the length of flow records – the arithmetical mean is 16 years and there are only 12 stations whose records exceed 50 years, probably too few to give a good historical perspective to regional flow regimes.

In these cost conscious days, the question will be repeatedly asked, cannot the gauging density be reduced, as we have sufficient data to allow models to estimate flows in the majority of watercourses by extension or prediction from fewer, key stations. A number of points may be made here. First, can we be satisfied that the data we have collected would allow us to characterise or anticipate future changes in the flow regimes within the United Kingdom? Second, with the growing importance of environmental monitoring, does the nature and scope of the flow

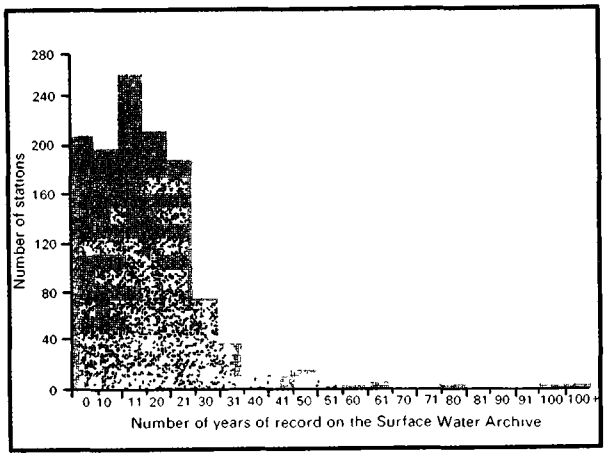


Figure 17. Distribution of record lengths for gauging stations on the national surface water archive.

record allow accurate and appropriate enhancements to chemical or biological data to clarify our understanding of waterbourne pollution and its impact? Third, should we consider that a network of flow gauges, designed primarily to evaluate water resources, and now a service component for operational management, fully meets the requirements of the wider community outside the Water Authorities?

In the earliest days of the survey there was always a desirable objective for the enhancement of the monitoring network. The developing industrial usage, the increase in domestic consumption, the satisfying of conflicting demands all pointed initially to a water resources interest; gauging was necessary to see how much water was there. After the second World War when there was a great push towards increased agricultural production, land drainage became increasingly important. The 1960s saw the emphasis return to water resources and the effective completion of a basic network. With the implementation of some of the larger resource schemes in the 1970s, interest grew in water quality and pollution control; blending of water from different sources before distribution began to be more widely practised and the Control of Pollution Act 1974 promised wider powers to effect improvements to water quality.

It is hoped that the network will remain relatively stable for the forseeable future. In the 1980s the needs for hydrometric data are broadening, particularly in relation to environmental issues. The improvements to river quality, recognised in the 1970s, have in many areas been halted or reversed; acid rain studies have already been mentioned by reference to Scotland; in England, nitrates and other contaminants in water may provide a similar impetus for increased or more specific monitoring. The value of a good network is that it could provide the flexibility to service the varying data needs of the differing interests.

Conclusion

The collection, assembly and provision of hydrological data records should not be taken for granted as the history of the last 100 years has seen oft changing fortunes and varying degrees of commitment by governments for surveying. We have been bequeathed a considerable heritage by the Inland Water Survey and its successors. The Government's proposals, published in July 1987, relating to the creation of a National Rivers Authority provide an unprecedented opportunity for building on this heritage. A greater measure of co-ordination between local data acquisition practices and national archiving activities may be anticipated; this can only bring increased benefits to a wide community of data users. The gauging station network, the associated hydrometric archives and the systems necessary to exploit them represent very substantial public investments. They, like the water itself, may be regarded as an important resource; it is incumbent upon policy makers and planners, as well as interested engineers and scientists, continually to state their requirements for maintaining such investments, for we have great historical precedents for their use.

Footnote

In addition to the material provided by Dr R.W.Herschy, the compilation of this review was rendered easier by reference to a number of articles which the interested reader may wish to pursue; W.S.Allard's paper (ref. 14) is important because of his close involvement with both the Inland Water Survey and the Surface Water Survey. It contains some anecdotal material. The British Association's Memorandum of 1933 (ref. 17) is a comprehensive review of what was hoped for from a survey and provides a good bibliography of early material. Invaluable guidance for the situation in Scotland was provided by a paper by S.C.Agnew and T.D.Macdonald presented to the Institution of Water Engineers and Scientists (Scottish Section) on 17 November 1977. Mr P.E.Holland supplied the information for Northern Ireland.

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