South West Wales River A

First Water Resources Survey: Report

South West Wales River Authority

Water Resources

A Study of the Resources, Demands and Future Development of Water Supplies in the area of the South West Wales River Authority

Penyfai House,
19 Penyfai Lane,
Furnace,
LLANELLI, Carms.

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Preface

The use and conservation of the water resources of Wales have previously been reported upon by the Welsh Advisory Water Committee which was appointed on the 7th February, 1958. Due to public opposition to the proposed selection of a reservoir site in Carmarthenshire a Working Party of Technical Advisers was set up in December 1961 to examine the costs and engineering aspects of alternative methods of providing major additional water supplies for the West Glamorgan area.

In February 1962 following the rejection of a Barrage Scheme, the Pembrokeshire County Council set up a Working Party to report on the most economic means of providing water to meet the needs of industry on both sides of the Milford Haven Estuary.

In May 1965 the Water Resources Board set up a Technical Committee to consider water demands and resources in South Wales with special reference to the proposal for transferring the function and ownership of the existing Usk and Cray Reservoirs owned and operated by the then County Borough of Swansea. At present these reservoirs are vested in the West Glamorgan Water Board.

In 1968 the Water Resources Board made known its intention to carry out a regional study of demands and resources to be known as the Wales and Midland Study. The Study has not yet been completed but it is expected that the report will be published in 1971.

The Water Resources Act of 1963 (henceforth called the 1963 Act) places an obligation on river authorities to carry out periodical surveys of water resources and demands and formulate proposals for action to meet deficiencies, that is, to produce Water Plans for their areas. Such plans have to be flexible having regard to changing circumstances. Section 14 of the 1963 Act prescribes the nature and contents of a Water Plan and ensures this flexibility by the statutory requirement for periodical review and amendment of such plans.

This document is the First Periodical Survey carried out by the South West Wales River Authority. The reports before mentioned have been used by way of reference and much additional information has been drawn from various sources, which is acknowledged. It is realised, however, that the document has its shortcomings particularly from the viewpoint of availability of long term records of rainfall and surface flows and kindred data upon which to base decisions. It does not represent a comprehensive survey of water resources within the Authority's Area (henceforth referred to as Area), though details of existing and potential demands upon those resources are given, and proposals for action in case the need arises either within or without the Area. The Authority believes that the document can make a contribution to an understanding of the comprehensive use and conservation of water resources within its Area and be of practical value to those wishing to use the resources.

In compliance with the request made by the Water Resources Board the measurements and quantities quoted in this report are presented in metric units. Conversion tables have been included as well as a list of definitions of technical terms used in the report.

Chapter 1 Field of Study

1.1 Terms of Reference

The Water Resources functions of River Authorities are defined by Section 4 of the Water Resources Act 1963 in which River Authorities are required to take all such action as they may consider necessary or as they may be directed to take for the purpose of conserving, redistributing or otherwise augmenting water resources in their area, of securing the proper use of water resources in their area, or transferring any of their water resources to the area of another River Authority.

The term Water Conservation is not defined in the 1963 Act but the following definition is given in the White Paper entitled Water Conservation England and Wales (Cmnd. 1693 April 1962) upon which the Act was based:

> "Water Conservation means the preservation, control and development of water resources (both surface and ground) whether by storage, including natural ground storage, prevention of pollution, or other means, so as to ensure that adequate and reliable supplies of water are made available for the purpose in the most suitable and economical way whilst safeguarding legitimate interests."

By Section 2 of the Act "water resources", in relation to any area, means water for the time being contained in any source of supply in that area, and "source of supply" means either:—

a. so much of any inland water, except a lake, pond or reservoir or one of a group of two or more such lakes, ponds or reservoirs, which does not discharge to any other inland water; and

b. any underground strata in that area whether the water is contained in any well, borehole or similar work or any excavation where the level of water in that excavation depends wholly or mainly on water entering it from that strata.

Part III of the Act describes the methods whereby a River Authority can make an assessment of water resources within their area and of related matters which will enable them to discharge their general duty under Section 4. Section 14 within Part III requires a River Authority to carry out a Periodical Survey as soon as possible after 1st April, 1965. The statutory requirements are:—

a. to carry out a survey of the water resources of their area, and of the existing demand, on the part of statutory water undertakers and other persons, for the supply of water from those resources, and to prepare a report setting out the results of the survey;

b. to prepare an estimate of the future demand, on the part of statutory water undertakers and other persons, for the period of 20 years from the date on which the survey is completed or such longer or shorter period from that date as the Water Resources Board may in any particular case direct; and

c. to formulate proposals as to action to be taken by the River Authority (whether by way of executing works or securing the execution of works by other persons or otherwise) for any of the purposes mentioned in Section 4 of the Act, including action for giving effect to any notice or advice given to them by the Water Resources Board under Section 12 of the Act.

Assessments made under Section 14 must be kept under review and such reviews must be undertaken at intervals of not more than seven years. That section places an obligation on the River Authority to consult the Water Resources Board in producing their survey report and copies must be sent to the Minister of Housing and Local Government, the Minister of Agriculture, Fisheries and Food and the Council of every County or County Borough Council any part of which is comprised in the River Authority area.

Whilst Section 14 prescribes that a forecast of future water demands should be made during a period of 20 years from the date on which the survey is completed, the Water Resources Board has already indicated that such a forecast should be related to the census years 1971, 1981 and 2001.

Section 12 of the Act places an obligation on the Water Resources Board to advise River Authorities with respect to the performance of their water conservation functions and to encourage and assist River Authorities in the formulation of plans as the Board might think necessary for augmenting water resources in a River Authority area by transferring water from another River Authority area. The special Study now being carried out by the Water Resources Board and entitled the Wales and Midland Study will no doubt produce proposals for the transfer of water from one River Authority area to another. This report, whilst bearing that matter in mind, does not specifically refer to any such proposals.

In formulating proposals as to action to be taken a River Authority is expressly required by Section 101 of the Act to take into account the desirability of conserving features of special scientific, architectural and historic interest and to have regard to the natural beauty of the countryside and to the desirability of preserving private rights of access to places of natural beauty. In the production of their periodical survey report a River Authority is also required to have particular regard to the duty of Statutory Water Undertakers to provide supplies of water for domestic purposes and for certain other public purposes such as extinguishing fires, and cleansing sewers, drains and highways.

1.2 Elements of Study

In order to assess the water resources of the area it is necessary to investigate the elements of the hydrological cycle as they operate in the area of study. This means the measurement of precipitation in its various forms, run-off, ground-water storage and evapotranspiration. It also entails taking into account any interferences with that cycle that are caused by man.

In this Area the records of rainfall are not considered to be of long duration for use in this survey except those from a very few stations. There are only five stations with

reliable records which operated over the period 1916–1950. The long term averages for stations with shorter records have been estimated by the Meteorological Office. It is only from 1951 onwards that the number of rainfall stations has increased and the coverage is still being extended. At present there are approximately 110 rainfall stations in operation giving a density of one station per 56 square kilometres.

The recording of river flows did not start until October 1957 when one station was established. Since the 1963 Act the hydrometric scheme has been extended and will continue to be extended for some years to come. At present there are 16 stations in operation from which records have been used. The number of stations will be increased ultimately to 23. Short term records are therefore available regarding the hydrological characteristics of the Area which allow an assessment of flow conditions which can be utilised for abstraction purposes. It is hoped after the publication of this survey to continue to obtain additional records by statistical methods so that more extensive data of rainfall and run-off will become available.

The measurement of evaporation is limited to five stations, the records of which are of short duration and do not cover very much of the Area. The hydrometric scheme envisages the establishment of more climatological stations so that a better coverage of the Area can be secured.

1.3 Expedients for Analysis

As mentioned in the previous section, it has not been possible to make use of very extensive records. It will be appreciated therefore that there is a severe shortage of the reliable information which would normally be required for comprehensive water resources planning.

In taking into consideration the records available no account has been taken of the effect on run-off of snow and ice conditions. These can have a marked effect on run-off in certain parts of the Area. Again, due to the lack of records of rainfall intensity and to the varied topographical effects on rainfall no account has been taken of isolated and intense storms.

No special account has been taken of the effects of various types of vegetation to be found in each catchment area, nor has any special allowance been made for the various types of rock formations.

Major abstractions from the catchment areas have been taken into account in the calculations. Whilst spray irrigation of agricultural crops particularly in the County of Pembrokeshire has been borne in mind, it must be noted that there are very many other unlicensed agricultural abstractions which, although of a minor individual nature, amount in total to a considerable quantity of water. It is considered that no useful purpose would be served by bringing these into account as they are so scattered throughout the area. Some figures, however, are included in Table 12.

The effects of sewage disposal have been taken into account as many of the gauging stations record the return of treated sewage. Major discharges of sewage in the area however, are direct to the sea and are thus lost to the water resources of the area. Two major cooling water abstractions by the Central Electricity Generating Board are returned to the sea. In other parts, some cooling water is returned to the water resources of the area.

The discharge of mine water from collieries either operating or disused has not been taken into consideration except where those discharges are already into watercourses which are being measured. There are numerous collieries in the area which have closed and where pumping has ceased. Whilst water will eventually find its way out of those collieries when the workings become flooded, at the same time the quality of water in any particular watercourse may become adversely affected and indeed polluted, thus making that particular source of supply unusable until the quality of the water is improved.

Section 19(5) of the 1963 Act refers to the determination of minimum acceptable flows (MAF). As no such flows have been determined within the Area, consideration must be given in the preparation of a programme for water development to certain interests such as public water supply, industry, navigation, fisheries, land drainage, irrigation, public health, amenity and recreational pursuits and any other lawful uses.

References

1. Report on the Water Resources of Wales (Welsh Advisory Water Committee, April 1961).
2. Report on Alternative Methods of Providing Major Additional Water Supplies for the West Glamorgan Area (West Glamorgan Water Supplies Working Party, December 1961).
3. Report of a Working Party on Water Supplies for Industry (Pembrokeshire County Council, 1st August 1962).
4. South West Wales Water Supply – Technical Committee on Water Resources in South Wales Interim Report (April 1966).
5. Water Resources Act, 1963.
6. Water Conservation, England and Wales (Cmnd. 1693 – April 1962).

Chapter 2 Survey of Water Resources

2.1 General Topography

(Maps 1 and 2)

The Authority's Area by virtue of Section 3 of the Water Resources Act, 1963 is defined by the South West Wales River Board Area Order 1950 and comprises the following:—

> "The area, the drainage of which is directed to the coast of the administrative Counties of Cardigan, Pembroke and Carmarthen and of the western part of the administrative County of Glamorgan, including the County Borough of Swansea, between the southern watershed of the river Dovey and the western watershed of the river Neath."

This embraces all of the geographical county of Pembroke, most of the counties of Carmarthen and Cardigan and parts of the counties of Glamorgan, Brecon and Montgomery. This area is shown on Map 1. The seaward boundaries of this area are further defined by the South West Wales River Authority (Seaward Boundaries of Area) Order 1964.

The Area is 6 264 km² and it is hilly though heights comparable to those of Central and North Wales are not found. The chief rivers are the Rheidol, the Ystwyth, the Aeron, the Teifi, the Nevern, the Gwaun, the Eastern and Western Cleddau, the Taf, the Towy, the Gwendraeth Fach and Fawr, the Loughor and the Tawe. The coastline is 510 km in length.

The population of the Area is estimated to be 568 120, most of it is in the industrialised south and south-east. In the rural districts of Pembrokeshire, Cardiganshire and Carmarthenshire, covering more than 80% of the total area, the density of population is nearly everwhere below 39 persons per km². At the other end of the scale the figure for the City of Swansea is 1 864 persons per km². In the west and south-west only five towns have populations of more than 7 000, namely, Milford Haven, Haverfordwest, Pembroke and Pembroke Dock, Carmarthen and Aberystwyth. The high moorland and plateau country of north Pembrokeshire, south Carmarthenshire and east Carmarthenshire and West Glamorgan contain urban areas such as Llanelli and the City of Swansea. Ribbons of development also extend along the lower slopes of the valleys of the Loughor, Amman and Tawe, but the hill tracts dividing these are very thinly populated.

The Area falls into three economic regions, namely, West Glamorgan and east Carmarthenshire, south Pembrokeshire (which is on the threshold of becoming a new industrial area) and the remainder, which is agricultural. Within these regions there are five hydrometric areas, (Table 1), namely:—

Hydrometric Area No. 59 – comprising rivers Tawe, Loughor and their tributaries.

Hydrometric Area No. 60 – comprising rivers Towy, Gwendraeth Fach and Fawr, Taf and their tributaries.

Hydrometric Area No. 61 – comprising rivers Nevern, Gwaun, Eastern and Western Cleddau, tributaries and coastal streams.

Hydrometric Area No. 62 – comprising river Teifi and tributaries.

Hydrometric Area No. 63 – comprising rivers Aeron, Wyre, Ystwyth, Rheidol and their tributaries.

2.1a General Morphology

The drainage of the Area is mainly consequent-superimposed and subsequent streams.

The original drainage was down dip slopes to the south-east, the direction of flow being altered by land movements so that the south-east flows became tributaries or reversed streams captured by strike-valley flows in the present south-westerly direction. It can be seen from the geology and ordnance survey maps that the majority of tributaries drain in a south-easterly direction into major south-west flowing rivers, leaving dry looking left banks. The better sites for dam construction tend to be those on the superimposed south-easterly/north-westerly streams.

Fault alignment is clearly shown in cases such as the upper part of the river Tawe, the middle of the Gwendraeth Fach and the upper part of the Ystwyth and lower Wyre, the trend being south-westerly.

Glaciation in two major directions to the south and to the east has created or enlarged gaps across the south-westerly watersheds offering ease of re-establishment of the original south-east pattern. Some of these gaps can be utilised where it is preferable to transfer water to the east or south-east, within the Area or to other Areas.

Some glacial gaps create difficulties in using the maximum storage in that it becomes necessary to construct subsidiary dams. There is, however, no lack of single-dam storage sites in most river systems.

Coastal planation in Pembrokeshire has created difficulties in the west and south where planes at about 60 m and 120 m severely limit the storage.

Three quarters of the land is over 120 m high rising steeply to a maximum height of 750 m; a similar proportion is impermeable rock, the areas of permeable rocks being almost the whole of HA 59, and the southern parts of HA 60 and 61. Springs provide localised supplies in all areas.

2.1b Topography – Hydrometric Area 59

HA 59 embraces that part of the Area which, both in the past and present, contains the bulk of the industries and population. Geologically it includes most of the Coal Measures and thus is subject to both deep and opencast mining.

The two main rivers are the river Tawe and the river Loughor. The Tawe rises at an altitude of about 600 m and the Loughor at 245 m. Both rivers fall quite rapidly in the early part of their journey to the sea; neither of these rivers is very long and both are contained in steep sided valleys.

Gower, although a part of this hydrometric area, can be considered as a separate entity. It is mostly residential as well as supporting a thriving agricultural industry. It is also a well-known holiday resort.

Llanelli and its immediate area is industrial and has a concentration of population. It lies within this hydrometric area but forms no part of any major river system.

In the industrial valleys and coastal area, the population is fairly concentrated as can be seen from the population map in section 3.1.

Except at the head waters of the river Tawe and its tributaries in the northern part of the hydrometric area there are good road communications.

The hydrometric area is 861 km^2; Table 1 contains details of the sub-catchments within this hydrometric area.

The primary gauging station on the river Tawe is at Ynystanglws (Map 6). The long term average (in future referred to as the average) rainfall above the station is 1 841 mm/a, *the long term average (in future referred to as average) potential evaporation (PE) above the station is 503 mm/a, and *the average daily flow (ADF) at the station is $836 \times 10^3 m^3/d$.

2.1c Topography – Hydrometric Area 60

This Area is the largest of the hydrometric areas being about 2 056 km^2 and containing two large rivers as well as about six medium sized rivers together with many small streams flowing direct into the river Towy.

a. River Towy The river Towy rises at an altitude of approximately 425 m in open hill country, sparsely populated and badly served by roads. The river bed and sides are very steep in the first 10 km from its sources, after which the gradient becomes a little flatter. By the year 1972 it is anticipated that the Llyn Brianne dam will be completed and a large freshwater lake will be formed above this point. Details of this reservoir appear in section 4.4.

Below the proposed dam the first of the large tributaries joins the river, namely the river Doethie which again rises in high open hilly country which is sparsely populated. The river Towy then flows in a much more gentle valley down to Llandovery where it is joined by other tributaries including the river Bran. Lower down the next major tributary of interest is the river Sawdde, flowing from the Llynyfan reservoir of the Llanelli and District Water Board. The river Sawdde rises at approximately 580 m and drains that part of the area with the highest rainfall which is in the order of 2 540 mm/a. Proceeding downstream from the junction of the Sawdde the next important tributary is the river Cothi which joins the river Towy a little above Nantgaredig Bridge and which in turn is just above the future point of abstraction for the West Glamorgan Water Board. This river rises at an altitude of approximately 335 m in open country, and flows through the Cothi valley collecting small tributaries on its way downstream. The valley is fairly well populated in small villages and has numerous farms, and is well served by roads.

The river Towy continues its journey to the sea in an open flat valley and at a short distance below the future abstraction point for the West Glamorgan Water Board near Nantgaredig Bridge the river becomes tidal. The main tributary in the tidal reaches is the river Gwili which joins the Towy a little above Carmarthen. The river then flows through Carmarthen and eventually discharges into Carmarthen Bay at Ferryside.

The catchment area of the river Towy and its tributaries, excluding the river Taf and the rivers Gwendraeth Fach and Fawr, is 1 335 km^2 (Table 1). It is an agricultural area and the towns within the area are mainly devoted to agricultural needs.

The primary gauging station on the river Towy is at Tycastell with another station at Dolauhirion (Map 6). The average rainfall varies between 1 756 mm/a above the Dolauhirion station to 1 572 mm/a above the Tycastell station. The average PE is taken as constant at 503 mm/a, and the ADF at Dolauhirion is $796 \times 10^3 m^3/d$ and at Tycastell it is $3\ 192 \times 10^3 m^3/d$.

b. River Taf This river rises at an altitude of approximately 200 m and flows in a southerly direction in a very narrow and steep valley in the early stages of its journey. It eventually meanders in a flat valley and flows through Whitland where it is joined by several smaller rivers all flowing in a southerly direction. The river, to the south of St. Clears, becomes tidal and eventually flows into the estuary of the river Towy at Laugharne and then into Carmarthen Bay.

Generally the river Taf catchment area is well served by roads. The northern part of the catchment is hilly but the southern part is much flatter. The whole of the area is agricultural, the emphasis being on cattle and sheep farming. The coastal region in the Pendine Sands area is a holiday resort.

The catchment area is 514 km^2 and includes the tributaries Dewi Fawr and Afon Cywyn (Table 1).

The primary gauging station on the river Taf is at Clog y Fran (Map 6).

The average rainfall above the Clog y Fran gauging station is 1 428 mm/a, the average PE is 503 mm/a and the ADF is $549 \times 10^3 m^3/d$.

The figures for the river Dewi Fawr above Glasfryn Ford (Map 6) are 1 478 mm/a and 514 mm/a respectively and the ADF is $106 \times 10^3 m^3/d$.

c. Rivers Gwendraeth Fach and Gwendraeth Fawr The Fach rises at an altitude of 200 m and the Fawr at 230 m; both rivers flow in a south-westerly direction. The valleys are fairly steep sided, that of the river Gwendraeth Fawr being near to the edge of the Carboniferous Limestone area. The catchments of the two rivers lie mainly in an agricultural area having numerous farms and being well served by roads. The rivers discharge into the river Towy estuary and then into Carmarthen Bay at Kidwelly. The total catchment area of both the rivers is 207 km^2 (Table 1).

The gauging station on the river Gwendraeth Fach at Pont Felin Gwendraeth is at present a temporary one, prior to the establishment of a permanent station as part of the Authority's hydrometric scheme. There is no gauging station on the river Gwendraeth Fawr.

The average rainfall of 1 386 mm/a, the average PE of 514 mm/a and the ADF of $170 \times 10^3 m^3/d$ refer to the temporary gauging station on the river Gwendraeth Fach.

**See Definitions and Abbreviations at end of Tables.*

2.1d Topography – Hydrometric Area 61

a. River Eastern Cleddau The Eastern Cleddau rises in the northern part of Pembrokeshire at an altitude of approximately 275 m, the upper area consists mainly of bracken with some rock outcropping. The land is poorly drained and the river is not very steep nor are the valley sides. The highest part of the catchment is approximately 535 m. The valley bottom remains fairly flat to the junction of the Afon Syfynwy. The Afon Syfynwy rises at an altitude of approximately 410 m in open country and feeds the Rosebush reservoir before flowing into the Llysyfran regulating reservoir which is now under construction. Details of this reservoir appear in section 4.4. The Afon Syfynwy is the most important tributary of the Eastern Cleddau.

The main river flows to Canaston Bridge weir which is the tidal limit. At Canaston Bridge weir the Pembrokeshire Water Board have a large pumping station and this station will be the point of abstraction for the regulated flow from the Llysyfran Scheme. The tidal river then flows to Picton Point and joins the Western Cleddau and becomes the Dau Cleddau before flowing into Milford Haven.

The catchment area of the river Eastern Cleddau is well served by roads. It has a considerable number of farms, dealing mostly in beef and dairy herds with sheep on the higher grounds; a few crops are grown in the catchment area, these being mainly feed-stuffs.

The catchment area of the river down to Picton Point is 237 km^2 (Table 1). The primary gauging station on the river Eastern Cleddau is near Canaston Bridge (Map 6). The average rainfall above the station is 1 461 mm/a, the average PE is 527 mm/a and the ADF is $468 \times 10^3 m^3/d$.

b. River Western Cleddau This river rises in open farmland at an altitude of approximately 120 m and flows first in a north-easterly direction before turning in a general southerly direction. It then flows in a steep sided valley to Wolf's Castle where it is joined by a major and important tributary, the Afon Anghof. From here the river, road and railway all follow a very steep sided and rocky valley for a few kilometres before the river enters a much wider valley, meandering downsteam to Haverfordwest. The river continues down to Picton Point, where it joins the river Eastern Cleddau. The two Cleddau rivers then proceed to the Milford Haven as the Dau Cleddau.

The remainder of HA 61 consists of various small rivers and streams flowing direct into the sea. The catchment area above Picton Point is 314 km^2 (Table 1). Generally the catchment of the river Western Cleddau consists of good agricultural land, well served by roads and having a considerable number of farms with mixed agriculture, including early potato growing, beef and dairy cattle, with sheep on the high land.

The primary gauging station on the river Western Cleddau is at Prendergast Mill (Map 6). The average rainfall above the station is 1 349 mm/a, the average PE is 527 mm/a and the ADF is $445 \times 10^3 m^3/d$.

2.1e Topography – Hydrometric Area 62

The river Teifi rises north of Strata Florida at an altitude of approximately 455 m; the area is hilly and consists of poor grazing land. In this area there are several small natural lakes which have been developed for water resources purposes. The river gradient is very steep until it reaches Tregaron Bog, a large swamp area. The river valley is then flat, the river meandering towards Lampeter, still flowing in a south westerly direction. Much of the high land is planted with soft woods and the lower land is agricultural. Below Lampeter the valley becomes broader and the surrounding hills not so high. In the region of Llandyssul the river bed and sides become rocky and steep, then again the river meanders its way to Newcastle Emlyn in a wide valley. At Cenarth Falls the bed and sides are rocky and steep. Below the Falls the valley becomes much flatter and wider and continues so to Cilgerran Gorge where the river is again confined between high cliffs. Here the river is affected by the tide; below the Gorge the tidal section is reached and the river then flows through the town of Cardigan and out into Cardigan Bay.

There are many tributaries of the river Teifi some of which are suitable as good regulating reservoir sites. There are several small woollen mills operating on such tributaries. The industries in the catchment are small but the area has a large influx of tourist traffic. The whole of the area is well served by roads and is primarily agricultural. The catchment area is 1 008 km^2 (Table 1).

The primary gauging station on the river Teifi is at Glan Teifi (Map 6); the average rainfall above the station is 1 389 mm/a, the average PE is 488 mm/a and the ADF is $2\ 207 \times 10^3 m^3/d$.

2.1f Topography – Hydrometric Area 63

a. River Rheidol The river Rheidol rises in the north of the Area and the flow is artificially controlled by the Cwm Rheidol hydro-electric power scheme. The river rises at an altitude of approximately 550 m in high, bleak, open country, sparsely populated. The top dam in the hydro-electric scheme is that at Nantymoch, the water then passing to the Dinas reservoir and eventually to the Cwm Rheidol power station. The power station tailwater joins the main river at Cwm Rheidol, the river having passed over the Devil's Bridge falls where the valley is exceptionally steep sided and the river falls very rapidly.

After passing the Cwm Rheidol power station outlet the river meanders its way in an open valley to Aberystwyth, where it discharges into Cardigan Bay.

Generally speaking, the area is well served by roads and supports a thriving agriculture, with forestry plantations on the higher land. There are numerous disused zinc and lead mines in the upper parts of the Rheidol valley.

The catchment area is 189 km^2 (Table 1). The primary gauging station on the river Rheidol is at Llanbadarn Fawr (Map 6). The average rainfall above the station is 1 784 mm/a, the average PE is 488 mm/a, and the ADF is $646 \times 10^3 m^3/d$. This latter figure is never maintained due to the retention of water in the reservoirs of the hydro-electric power scheme.

b. River Ystwyth The river Ystwyth rises at an altitude of about 470 m in high, open country. The river has a very steep gradient and flows in a narrow valley. The upper part of the valley is virtually uninhabited but there are several small villages in the middle and lower stretches of the river. There are adequate roads in the middle and lower reaches and the majority of the farms are situated here. There are several small tributaries flowing into the river Ystwyth but most of these are short, steep and flow in narrow valleys.

Below Cwm Ystwyth the river flows in a westerly direction until it enters Cardigan Bay at Aberystwyth. There are numerous disused zinc and lead mines in the catchment.

The catchment area is 193 km² (Table 1). The primary gauging station on the river Ystwyth is at Pont Llolwyn (Map 6). The average rainfall above the station is 1 488 mm/a, the average PE is 488 mm/a and the ADF is $466 \times 10^3 m^3/d$.

c. River Aeron Another major river in this hydrometric area is the river Aeron which rises at Blaenpennal and flows in a westerly direction discharging into Cardigan Bay at the town of Aberaeron.

The catchment area is 162 km² (Table 1). No gauging station exists on the river Aeron although efforts have been made to establish one as part of the Authority's hydrometric scheme.

d. River Wyre The river Wyre is a short river and flows in a westerly direction discharging into Cardigan Bay to the south of Aberystwyth.

The catchment area is 56 km² (Table 1). The primary gauging station on the river Wyre is at Llanrhystyd (Map 6). The average rainfall above the station is 1 142 mm/a, the average PE is 500 mm/a, and the ADF is $98 \times 10^3 m^3/d$.

Generally speaking, the whole of this hydrometric area is well served by roads and is essentially an agricultural area with sheep and cattle as the main produce. In summer there is a very large influx of tourists. There appears to be little prospect of industrial development in this area except for the possible opening up of the disused mines. However, the tourist industry remains of paramount importance.

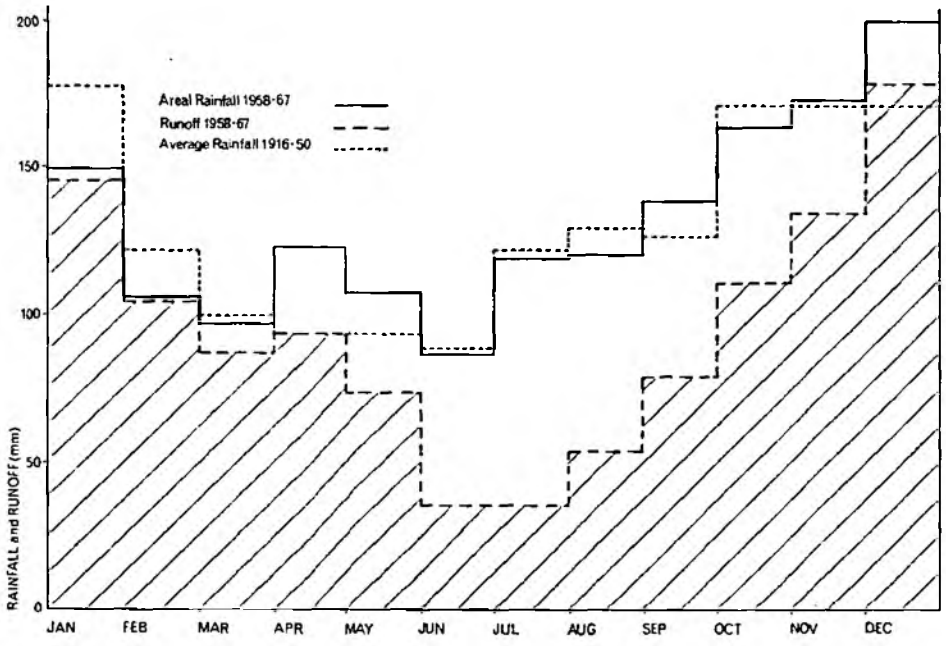
The total catchment area is 864 km² (Table 1).

2.2 Climate and Meteorology

Rainfall Published Meteorological Office records form the basis of the figures used in this Report. The very few local stations having long records (which include those of the Llanelli and District Water Board and the West Glamorgan Water Board) have been used in an attempt to put probabilities to the Area's dry seasons, which have not always followed country wide trends.

The rainfall is mainly orographic, the annual precipitation ranging from 1 000 mm/a in the south-west and coastal areas to more than 2 000 mm/a in the hill districts of the northern and western limits of the Area. Potential Evaporation (PE) is greatest in the south-west, so water resources, as available residual rainfall, are least in this area.

Fig. 2.2 R Towy at Nantgaredig



The pattern of precipitation is such that there is little seasonal difference in the monthly rainfall; on average less than 1½ times as much rain falls in the winter months (October to March) as in summer. Thus a normal summer is not noticeably dry. The average occurence of maximum and minimum monthly rainfall is in January and June respectively, but within the period of run-off records, winter has provided as many driest months as summer and account has to be taken of this when considering storage to maintain a river level for all year round abstraction. The seasonal distribution over the period of run-off records is shown in the accompanying graph of mean monthly rainfall and run-off at Nantgaredig on the river Towy. The river Towy is closely representative of all five type-river catchments. This pattern differs slightly from the long term distribution of rainfall.

In the long term, the four very wet months in all areas are October, November, December and January, with August also above average. The dry spell is clearly March, April, May and June. For seven months of the year rainfall is below the monthly mean. The earliest 'driest month of the year' in the Authority's river records is January, and the latest, September. Droughts often continue into part of October making this the driest part of the year. The driest twelve months in the Authority's records of run-off are December 1963 to November 1964, when the areal rainfall in the catchments of the rivers Tawe, Towy and Teifi was between 62% and 65% of the long-average rainfall.

Run-off and Rainfall in the year December 1963/November 1964 as a percentage of long-average rainfall

HA	59	60	61	62	63
River	Tawe	Towy	Eastern Cleddau	Teifi	Ystwyth
Rainfall	63·5%	65%	69·5%	62·5%	69·5%
Run-off	44·5%	38%	38·5%	38%	44·5%

This year approaches a dryness of between 1 and 2% severity. That is, the run-off may be expected to be so low only once in 50–100 years in the long average.

Point-rainfall records in HA 59 indicate that its 1% year exceeds 60% of the average rainfall and its rainfall percentages so far indicate a less severe regime than other areas within the Authority. Unfortunately the area lacks good storage to make use of this bonus.

It is stressed here that the long-term point-rainfall records are sparse and the above figures are indications being studied rather than conclusions reached.

The table below gives an indication of precipitation variation in each hydrometric area in type river valleys.

HA			59	60	61	62	63
Hill areas	Rainfall	mm	2 540	2 285	1 525	2 030	2 540
	PE	mm	444	442	527	444	444
Coast areas	Rainfall	mm	1 145	1 145	1 015	1 015	1 015
	PE	mm	552	559	559	552	552

Major storms appear generally to travel up valleys, i.e. from the south-west, but local storms are common in hill and coast areas and they can be extremely 'local' and intense.

Common rainfalls are in the order of 22 mm in 15–20 hours, with heavier falls of up to 175 mm in 50 hours in the east, up to 95 mm in 45 hours in the central area, and up to 55 mm in 45 hours in the south-west and west.

The areal rainfall over the period of river gauging records has been slightly above the long term average.

Evaporation and Soil Moisture Deficit Potential evaporation PE is that which may occur in given conditions of humidity, wind speed, solar radiation and air temperature, providing sufficient moisture is available to be evaporated.

If the moisture so evaporated is not replaced by rainfall, a soil moisture deficit develops. When this deficit reaches certain levels (currently assumed to be about 50 mm in bare soil, 75 mm in grass cover, 200 mm in wooded country), the rate of evaporation is reduced. This reduced or 'actual' evaporation (AE) is the loss normally used in estimating residual rainfall or gross available water resources. It is difficult to measure consistently, but records so far indicate that AE is so rarely less than PE in all our hydrometric areas that there may be very little error involved in calculating the gross dependable average residual flow as 'Rainfall – PE'.

Areal soil moisture deficit figures received from the Meteorological Office show that the length of deficiency is generally mid-May to October. From station records, the longest local deficiencies were in 1949 and 1964, when a deficiency was sustained for ten consecutive months. The earliest soil moisture deficit has been in January, the latest 'return to nil' was 30th November, 1964. Maximum deficiencies have most often occurred in July, but the greatest recorded deficiency was in October 1959, 116 mm at Abergorlech (HA 60). The areal pattern of deficiency is that the south and west coasts have the earliest and greatest deficiencies.

Residual Rainfall The residual rainfall available in each hydrometric area is shown below:—

HA	59	60	61	62	63
mm	1 100	913	700	790	858
ADF 1 000×10³m³/d	2·6	5·2	2·8	2·2	2·0

This represents the gross estimated available water, not necessarily the usable supply, since the storage and area of availability, e.g. sea-marshes, govern the amount extractable.

The residual rainfall has been estimated for all catchments shown in Table 1 and represents the gross estimated water resources in each catchment. Of the major catchments no difficulty is seen in storing the gross available water in the case of the rivers Towy, Teifi and Ystwyth. Of the others, the Tawe has geological and pollution difficulties; the river Eastern Cleddau is at present being fully developed: the Llysyfran Regulating Reservoir, when in operation, almost completes the development. The

river Western Cleddau is poorly provided with sizeable storage sites.

2.3 Run-off

The longest run-off records are for the rivers Tawe (HA 59), Towy (HA 60), and Teifi (HA 62). These all include the summer of 1959. Six stations include records for 1963/4 – one major river in each hydrometric area plus the river Cothi, a tributary of the river Towy. The accuracy of the low-flow gauging is at present under investigation. The lowest flows are of course those of September–October 1959, when for six weeks the mean daily flow was at or below 4%–5% of the ADF. The extreme flashiness of the rivers in this Area is clearly shown in the duration curves; the mode or commonest flow is well below the mean flow, as also is the median (i.e. flow level which 50% of all flows exceed).

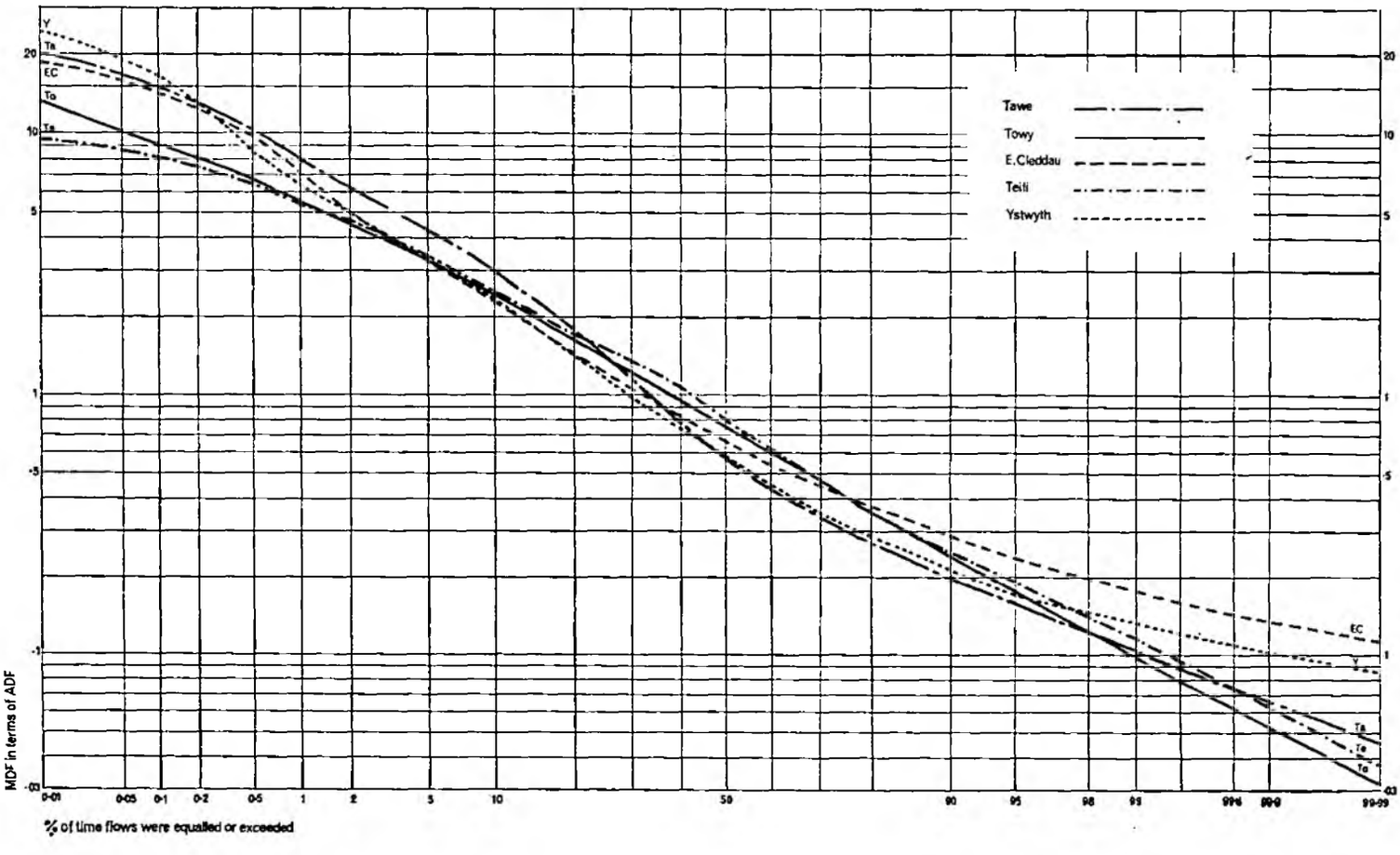
The duration curves indicate the percentage of time during which an abstraction of given amounts could take place without storage; with such flashy rivers it is obvious that the best usage will involve storage to equalise the low flow periods. However, local demands in most of the hydrometric areas are so small that some of them could rely on simple abstraction. Recession curves indicating more exactly the low flows to be expected are included at the end of Section 2.

The low modal flow indicates that the calculated ADFs are not average for the 'watercourse' and are not a good indication of minimum acceptable flows nor of the probable availability of water for abstraction, e.g. the ADF will be exceeded more often in permeable areas than in impermeable areas.

The gauging stations, present and proposed, are shown on Map 6. Initially processed data is presented only for one type catchment in each hydrometric area, since records are few.

The river Eastern Cleddau is not entirely typical of HA 61 in that it drains the steep and wet eastern side of a mostly flat and relatively dry peninsula. A comparison is given below of minimum flows in 1959 (a 1 in 200 dry summer) and 1964 (a 1 in 50 dry year in this Area).

Fig. 2.3 **Frequency Curves** for the 'type' rivers



Run-off in mm (% ADR shown in brackets)

	Tawe	Towy	Eastern Cleddau	Teifi	Ystwyth	Duration
Sept/Oct 1959	6(5·4)	4(5·6)	n.r	3(4)	n.r	6 weeks
Sept/Oct 1964	33(30)	25(29)	14(18)	15(20)	20(25)	5 weeks

Of these rivers, the Towy, the Teifi and the Ystwyth are on impermeable rocks and ground-water is not a factor. The river Tawe has mine water discharging into it, which boosts its low flows. Records on the river Eastern Cleddau are too short to allow comment on low flows. Effluent discharges are in general too small to make a significant alteration in low flows. The major ground-water abstractions are in the river Tawe valley. These also have negligible effect.

Low flows can occur at any time of year after a few rainless days, e.g. January 1963 monthly run-off was 17 mm on the river Tawe and this was well below the driest month of the driest year, 1964. Similar figures were obtained on the river Towy where mine water does not confuse the issue.

A list of average daily flows at each gauging station has been made from estimates of residual rainfall.

Average Daily Flows at Gauging Stations (listed in Table 3)
Derived from Average Daily Residual Rainfall

River and Gauging Station		Average rainfall mm/a	Average PE† mm/a	ADF $10^3 m^3/d$
Tawe	Ynystanglws	1 841*	503	836
Loughor	Tirydail	1 564	503	135
Towy	Dolauhirion	1 756	503	796
Bran	Llandovery	1 502	503	182
Sawdde	Felin y Cwm	1 748	503	276
Towy	Manoravon	1 610	503	1 704
Cothi	Felin Mynachdy	1 646*	503	933
Twrch	Farmers	1 727	475	71
Towy	Tycastell Farm	1 572*	503	3 192
Gwili	Glan Gwili	1 547	503	372
Taf	Clog y Fran	1 428	503	549
Dewi Fawr	Glasfryn Ford	1 478	514	106
Gwendraeth Fach	Pont Felin Gwendraeth	1 386	514	170
Gwaun	Cilrhedyn Bridge	1 414	527	76
Western Cleddau	Prendergast Mill	1 349	527	445
Eastern Cleddau	Caneston Bridge	1 461*	527	468
Teifi	Llanfair	1 467	488	1 464
Teifi	Glan Teifi	1 389*	488	2 207
‡Rheidol	Llanbadarn Fawr	1 784	488	646
Ystwyth	Pont Llolwyn	1 488*	488	466
Wyre	Llanrhystyd	1 142	500	98

**Meteorological Office estimate.*
The other figures are estimated from the 1/250 000 isohyet map and can only be approximate.
†County values, approximate.
‡This flow is affected by the presence of three hydro-electric power reservoirs on the river.

2.4 Ground-water

Map 8 shows the mainly impermeable nature of the Area. Only HA 59 is mostly of permeable rocks, and the high folding and faulting of these, plus surface and mine water pollution, make it unsuitable for large scale water development.

The succession of rocks and superficial deposits is as follows:—

Hydrometric Area	System	Type
All areas	Recent	Alluvium, blownsand, river and terrace gravels, and peat.
All areas	Pleistocene	Glacial sands and gravels and boulder clay.
59, (60), 61	Carboniferous – Coal Measures	Coal, sandstone, shale, grit and conglomerate.
	Millstone Grit	Sandstone, shale, grit, quartzite and conglomerate.
	Limestone	Limestone and shale.
(59), 60, 61	Old Red Sandstone	Marl, sandstone, cornstone and conglomerate
60, 61, 62, 63	Silurian	Shale, flags, mudstone, thin sandstone and conglomerate.
60, 61, 62, 63	Ordovician	Shale, flags, mudstone, sandstone, lava and tuffs.
61	Cambrian	Shale, flags, mudstone, sandstone and grit.
61	Pre-Cambrian	Plutonic igneous rocks, dykes, sills, lavas and tuffs.

(Brackets indicate hydrometric areas which have very little of the named rock system.)

The structure is of long folds in the Silurian and Ordovician systems running south and south-west and influencing the course of the major rivers Towy (Towy anticline) and Teifi (Teifi anticline). The Old Red Sandstone forms an eastern fringe to these folds and dips south and south-east. The Coal Measures form part of the South Wales Coal Basin and are highly folded in east–west axes at the outer (older) edge of the basin. This makes for difficulties in the use of Carboniferous Limestone and Millstone Grit as aquifers, but springs are common and dependable, though sometimes polluted. The whole Area is glaciated with patches of boulder clay and gravel cover, peat (notably Tregaron Bog at the head of the river Teifi) and deep glacial drift in the lower course of rivers. Faulting is mainly east–west in the major systems with additional north–south faults in the Coal Basin. Springs and wells occur in abundance on fault lines and at junctions between Old Red Sandstone and Carboniferous rocks. Pembrokeshire in particular makes much use of local springs.

The only major aquifer, in extent and yield, is the Pennant Sandstone of the Upper Coal Measures. This aquifer covers most of HA 59 but its yield is variable in quality due to the number of present and past coal mining operations; some use is made of it for industrial abstraction. The best prospects are thought to be in valleys of more than 60 m thickness of Pennant Sandstone. River gravels are a fairly good local source of water in the impermeable regions.

Yields There is not enough data for calculation of local yields, but the aquifers listed in Table 4 have been quoted at the following rates:—

Pennant and Millstone Grit:	up to 0·01 m^3/s.
Gravel:	up to 0·03 m^3/s.
Carboniferous Limestone:	up to 0·05 m^3/s.

2.5 Water Quality and Disposal of Effluents

Surface Waters Generally speaking the quality of surface water in the greater part of the Area is good, excepting that in the industrialised south-east and also

in the north-west where zinc and lead were formerly mined.

Samples of surface water are taken at fixed stations in most of the Authority's rivers and their locations are shown on Map 11 and a list of them is given in Table 15. One water quality monitoring station is operating on the river Tawe and others are under construction or planned.

In very general terms it may be said that most of the water in the Area is soft or moderately soft. There are, however, certain exceptions in the limestone areas and in Pembrokeshire where in certain localities the water has a total hardness of up to 250 mg/l as $CaCO_3$.

Except in relation to certain local problems and in the river Tawe, dilution of discharges is reasonably adequate and reuse of effluents is not considered to be an important aspect of the water economy of the Area.

Most of the major discharges of trade waste and sewage take place in the lower reaches or the estuaries of the rivers within the Area and the abstraction of water upstream could therefore bring about a serious deterioration in quality. It is therefore considered that these stretches are the most sensitive ones in the river systems.

The discharge of contaminated waters from underground from the coal mining industry and from the now defunct zinc and lead mines has an important bearing on water quality in the south-east and north-west of the Area. The progressive closure of coal mines may well cause some deterioration in water quality, though it is not known if this will become an important aspect of water pollution control in the Area.

The locations of the major discharges of sewage and trade effluents as well as the main discharges of mine water are shown on Map 12.

For the purposes of this survey, surface waters with a minimum summer flow in excess of 4·546 $10^3 m^3/d$ have been classified as follows:—

Class I Unpolluted rivers and those recovered from pollution These surface waters are normally those with a 5-day BOD less than 3 mg/l, well oxygenated and known to receive no discharges of toxic materials or suspended matter which affects the condition of the bed. Also included are those rivers which are indistinguishable biologically from those in the area which are unpolluted, but with a 5-day BOD marginally greater than 3 mg/l.

Class II Rivers of doubtful quality These are rivers not in Class I on the basis of BOD and with a substantially reduced dissolved oxygen content. The class also contains rivers known to have received significant toxic discharges which, however, cannot be proved to have affected fish or to have been removed by natural process. This class also includes those rivers receiving turbid discharges having an appreciable effect on the composition of the water or the character of the bed.

Class III Rivers of poor quality and requiring improvement as a matter of urgency This includes rivers with substantial BOD values, but not in excess of 12 mg/l, and having dissolved oxygen saturation values of less than 50% for considerable periods. The class also includes rivers containing toxic substances and those rivers which have been substantially changed in character by solids in suspension. Many rivers in this class have been the subject of substantiated complaints.

Class IV Grossly polluted rivers Rivers in this class have a BOD in excess of 12 mg/l, under average conditions. Also included in this class are those rivers known to be incapable of supporting fish life and rivers which are, except in conditions of exceptional drought, deoxygenated at any time. Also included are those rivers which are the source of offensive smells.

These classes of water quality are those which were used in the 1958 River Pollution Survey and are those which are currently being used in the 1969/70 River Pollution Survey. As mentioned above, the classes are not based on single criteria but represent a reasonable compromise of several, which collectively may be said to meet the general concepts of river pollution.

In very general terms, surface waters within Classes I and II are considered suitable for public water supply. This is, it should however be emphasised, from the point of view of quality criteria only, and in no way implies that such waters are in fact available for supply as there may be other factors involved which are dealt with elsewhere in this survey.

The various quality classes of surface waters are shown on the accompanying Map 12.

Hydrometric Area No. 59 The principal rivers in this hydrometric area are the Tawe and Loughor.

River Tawe The river lies in a highly industrialised valley, the main industries being open cast coal mining, the refining and smelting of metals and metal finishing. Only one deep mine is operational. The upper and middle reaches are relatively unpolluted receiving only discharges of treated sewage. The major effluents enter the river downstream of Pontardawe, and a number of effluents in tidal waters are untreated. In the upper and middle reaches the water is of good quality and lies within Class I. Considerable lengths downstream are, however, of poor quality. Two of the principal tributaries are also sub-standard. These are the river Upper Clydach which receives heavy discharges of matter in suspension and is placed in Class III and the Nantyfendrod which receives major discharges from the smelting industry and is placed in Class IV. Tidal waters are placed in Class III.

A number of minor tributaries are polluted and are the cause of local problems.

The Swansea Canal which is now used only for water supply purposes is in the main placed within Class I but a short stretch at the lower end is however, within Class III as at this point the canal receives an unsatisfactorily treated trade effluent. Consideration is now being given to the filling in of the canal.

The dilution of effluents in the lower reaches of the river Tawe is by no means adequate, and at low flows the

total volume of waste waters is roughly equal to the flow of water.

Within the catchment, surface waters may be said to be moderately soft with an average hardness of around 100 mg/l as $CaCO_3$.

River Loughor Most of the catchment lies in a rural area, though the valley of a major tributary the river Amman, and the river Loughor downstream of Ammanford is more urban in character. With the exception of certain tributaries, most of the surface water in the catchment lies within Class I. The lower reaches and tidal waters, however, are heavily polluted by untreated sewage, and major tributaries in the south-east of the catchment namely the rivers Lliw and Llan are of poor quality as they receive untreated sewage and unsatisfactorily treated discharges of trade effluent. The water in the middle and lower compartments of the estuary, as well as certain streams entering the estuary, are also of poor quality, again owing to the discharge of sub-standard trade effluents and untreated sewage.

The main river Loughor upstream is slightly hard in character whilst the remaining waters within the catchment are moderately soft.

Hydrometric Area No. 60 This is a very extensive area, the principal rivers being the Gwendraeth Fach, Gwendraeth Fawr, Towy and Taf.

River Gwendraeth Fawr The valley of the river Gwendraeth Fawr is relatively highly industrialised, the main industries being associated with the mining and preparation of coal – both deep mined and open-cast. The river receives a large number of discharges of coal mining and washing waste waters as well as a number of treated sewage effluents.

The upper reaches of the river are unpolluted, and are placed within Class I. From Cwm Mawr downstream to Pontyates the river receives a number of discharges of sewage and trade wastes and is within Class II. A minor tributary, the Afon Hafren is grossly polluted by coal mining and washery effluents and is placed within Class IV. This tributary is the principal cause of the poor quality (Class III) of the main stream to tidal waters.

The estuary which is a common estuary with the river Gwendraeth Fach is of good quality.

The water in the main stream is slightly hard in character with an average hardness as $CaCO_3$ of 110–120 mg/l.

River Gwendraeth Fach There are few significant discharges of waste waters in the area and the surface waters within the catchment are of good quality and within Class I. They are moderately hard in character.

River Towy The whole of the catchment above tidal limits, of this, the largest river in the Area, flows through country of a rural character and with very minor exceptions, waters are of good quality and placed within Class I. The Nant-y-Bai, a minor tributary at Rhandirmwyn is polluted by zinc and lead wastes from a derelict mine and is fishless. This stream, however, has no measurable effect upon the main river. There are a number of other derelict mines in the upper reaches, but they could not be said to cause serious pollution affecting water resources.

The effluents discharging into fresh water in the catchment are restricted to discharges of treated sewage, and there is one fairly large discharge of treated milk waste into the river Bran at Langadog. In addition, there are very minor discharges of trade wastes elsewhere in the catchment but they have no significant effect on water quality.

In the upper reaches the water is distinctly acidic in reaction and pH values as low as 4·8–5·0 have been recorded.

Routine sampling indicates that the water in the catchment is soft with hardness in terms of $CaCO_3$ of between 20 and 40 mg/l.

In tidal waters, in the vicinity of Carmarthen, a marked deterioration takes place and the estuary downstream to its mouth at Ferryside is placed within Class II. This deterioration is caused by the entry of major discharges of untreated and partially treated sewage as well as untreated milk waste. Treatment of these effluents is, however, being undertaken and a progressive improvement in quality can be anticipated.

Tidal waters therefore represent the most sensitive part of the catchment from the point of view of water pollution control and any proposal to abstract significant volumes upstream with consequent reduction of dilution in the estuary will have to take this factor into account.

River Taf The whole of the catchment, other than near the confluence of the river Gronw, is of good quality receiving only discharges of sewage, most of them treated. A major milk effluent enters the river Gronw just above its confluence with the river Taf at Whitland and a short stretch of the rivers Gronw and Taf is in Class II.

Water in the catchment is soft or moderately soft with a hardness of 40–70 mg/l as $CaCO_3$.

Hydrometric Area No. 61 The main rivers in this area are the rivers Eastern and Western Cleddau which have a common estuary forming the Dau Cleddau before flowing into Milford Haven. In addition there are a number of smaller rivers including the Ritec, Gwaun and Nevern and also a large number of minor streams.

River Ritec This is a small stream reaching the coast at Tenby. The lower reaches are not satisfactory as they receive a discharge of untreated sewage in tidal waters. At high tide backing up of the water can take place with resulting deterioration in quality. The remainder of the catchment is of good quality though serious local problems, caused by the discharge of farm effluents, occur in the Knightson Brook.

Water in the river is slightly hard.

River Eastern Cleddau The waters in this catchment are of good quality and placed within Class I. Local problems are however caused by the discharge of unsatisfactorily treated sewage but these have no significant effect upon the quality of water in the main river or principal tributaries.

The water is soft in character with a total hardness of 25–50 mg/l as $CaCO_3$.

River Western Cleddau The whole of the catchment above tidal limits is of good quality though as in the case of the river Eastern Cleddau, certain minor tributaries are seriously polluted by discharges of sewage, farm and trade effluents. A marked deterioration, however, occurs in the upper estuary due to the discharge of partially treated sewage effluent from the town of Haverfordwest. The lower reaches of Merlins Brook, a tributary entering tidal waters, is also polluted and is placed within Class II. At low flows the dilution of effluent in the upper estuary is not great and therefore, as in the case of the rivers Towy and Tawe, any further significant abstractions upstream could have serious effects on the quality of tidal waters. There is little prospect of any improvement in conditions in the foreseeable future.

Water in the catchment is soft having a hardness of around 40 mg/l as $CaCO_3$.

The Dau Cleddau or Milford Haven The body of water known as Milford Haven is probably a drowned river valley or ria and forms the common estuary of the rivers Eastern and Western Cleddau. It has now become highly industrialised with substantial discharges of effluent from three oil refineries and smaller discharges from an oil terminal. In addition a power station of considerable size is near completion on the south shore and this will result in the discharge of 69·36 m^3/s of heated effluent into the waters of the Haven. A very large number of tankers enter the Haven to discharge oil at the refineries and at the oil terminal, and large numbers of spillages, some of them serious, occur annually.

Sewage is discharged untreated at a number of points on the shores of the Haven and there are smaller discharges of treated sewage.

Apart from oil spillages, and in the vicinity of certain of the outfalls, the waters of the Haven at present appear chemically to be of good quality and for the purposes of this survey are placed within Class I. It is not anticipated that the discharge of heated effluent from the power station will cause a serious deterioration in quality. Further comprehensive investigations of the quality of the Haven and its capacity to receive effluents are currently under consideration.

The remaining rivers in the hydrometric area are generally of good quality apart from local problems.

The river Gwaun receives very few discharges apart from a relatively small discharge of untreated sewage in tidal waters and some farm discharges. The water is soft in character.

The river Nevern is also unpolluted, and as in the case of the river Gwaun, the water is soft in character.

Hydrometric Area No. 62 This area includes the river Teifi, a major river entering the sea at Cardigan. The whole of the catchment above tidal waters excepting for certain tributaries is of good quality and placed within Class I. Discharges are restricted to, in the main, fully treated sewage, treated milk wastes, discharges from small woollen factories, a small number of derelict zinc and lead mines and farms.

Three of the zinc and lead mines in the upper reaches cause some local pollution though this is not measurable in the main river. Unfortunately investigations are currently under way at two of the mines with a view possibly to restart mining.

There are two additional derelict mines in the Teifi Valley namely Glogfach and Glogfawr which, however, are drained into the valley of the river Ystwyth.

The river Brennig at Tregaron is seriously polluted by the discharge of untreated sewage from the village and part is placed within Class IV. Untreated sewage is also discharged from the town of Cardigan and from St. Dogmaels and waters in that part of the estuary are placed within Class II. It is, however, anticipated that remedial measures will be undertaken at all the above, and that therefore an improvement to Class I can be expected in these areas.

Waters in the whole of the river Teifi catchment are soft or very soft with a hardness as $CaCO_3$ of 15–40 mg/l.

Hydrometric Area No. 63 The principal rivers in this area are the Aeron, Ystwyth, Rheidol and Clarach. In addition there are a large number of minor streams flowing to the coast of Cardigan Bay.

The river Aeron and other minor streams flowing to the coast south of Aberystwyth are all of good quality and discharges are restricted to treated sewage and one discharge of milk effluent. There are a number of discharges of untreated sewage but most of these are on the coast and appear to have no substantial effect upon the water resources in the area.

Generally speaking, waters in this area are soft with a hardness as $CaCO_3$ of 20–50 mg/l.

The rivers in the north of the hydrometric area namely the Ystwyth, Rheidol and Clarach are of special interest, as in their catchments there are very large numbers of now derelict metalliferous mines.

These mines (of which there are also small numbers in the catchments of the rivers Teifi and Towy) were first recorded as causing pollution as early as 1568. All of them ceased working after the first World War, though serious pollution has been caused by certain of them in the intervening years and they remain the source of significant pollution in the three rivers concerned.

At many of them adit waters, more or less seriously contaminated by zinc and lead, are discharged to surface waters. In others, pollution is caused by surface water running over dumps of oxidising zinc and lead wastes.

River Ystwyth The river is seriously polluted by a number of mines in the valley. In the upper reaches it receives wastes from the Cwm Ystwyth Mine, and from Cwm Ystwyth to the confluence with the river Cell the waters of the main river are placed within Class IV.

From the river Cell downstream to the confluence with the river Creuddyn they are placed within Class III. There

is then a continued improvement and the main river from the confluence of the Afon Adal to the sea is within Class I. A number of tributaries, namely the Frongoch stream, the river Cell and the river Magwr which carry mine wastes are also placed within Class IV.

It is noted that those waters within the catchment placed within Class IV are, as far as can be ascertained, fishless.

There appears to have been a small degree of improvement in the quality of the waters in the catchment since the 1920's due probably to the stabilisation of mine dumps. This improvement, however, is of a minor nature and is by no means as well marked as that which occurred In the catchment of the river Rheidol.

Other discharges in the catchment are mainly treated sewage, and agricultural effluents.

River Rheidol As mentioned elsewhere in this survey, the waters of the river Rheidol are harnessed for the production of electricity and the flow down the main stream is therefore more restricted than it would have been under natural conditions. Dilution of waste waters from metalliferous mines has in some instances been as a consequence reduced, and in one case measures to treat adit waters by absorption on limestone chippings have been undertaken.

As in the case of the river Ystwyth, the main pollution problems are those caused by the metalliferous mines, of which a very large number were at one time working in this catchment. Two tributaries namely the rivers Tuen and Llywernog are placed within Class IV and are fishless whilst a considerable proportion of the main river between the confluence of the rivers Castell and Melindwr is placed within Class III.

There is substantial evidence that the main river Rheidol unlike the river Ystwyth is improving in quality and as will be seen in Section 3.5 a healthy salmon and trout fishery exists in the catchment. Apart from the discharges from the zinc and lead mines, other discharges include a small number of treated sewage effluents and the discharge of screened but otherwise untreated sewage from the town of Aberystwyth.

River Clarach As in the case of the rivers Ystwyth and Rheidol, the main pollution problems are associated with metalliferous mining. A substantial proportion of the main river and a number of tributaries are placed within Class III and it is noted that a major part of the Afon Silo, and the Nant Symlog and Nant Erfyn are fishless.

Discharge of unsatisfactorily treated sewage from caravan sites in the lower reaches near the estuary contributes to the poor quality occurring there (Class II).

In all three rivers waters are soft or very soft with a hardness of around 20–35 mg/l as $CaCO_3$. In the upper reaches of the rivers, total hardness as low as 10 mg/l have been recorded.

It should be noted that with few exceptions the main problems associated with the metalliferous mines are now caused by zinc rather than lead. Very few analyses out of many hundreds carried out on waters in the catchment have revealed the presence of significant quantities of lead. In view of the differences in the maximum allowable concentration of zinc as opposed to lead in drinking water, this fact could be of considerable consequence as far as future utilisation of the waters within the three catchments are concerned.

Underground Waters As mentioned elsewhere, underground water does not constitute an important part of the water resources of South West Wales. Most of the licensed abstractions occur in HA 59, as a substantial proportion of the remainder of the area is covered by the South West Wales River Authority (Exceptions from Control) Order, 1965.

Most of the abstractions from underground sources appear to be for industrial purposes, though there are exceptions. Some abstractions are in river gravels and there is some evidence that the quality of water so abstracted does not differ significantly from surface water in the nearby rivers.

A limited amount of work has been carried out on the quality of underground waters in the various aquifers in the Area. It should, however, be emphasised that the information so obtained is not necessarily typical for all waters in the aquifer under consideration, and in fact, the quality of water from a single source may not itself be constant.

One of the notable features of the quality of ground waters in the Area is the remarkably low ionic content as compared with underground waters in other parts of the country. This is referred to also by Ineson (1967) in a comprehensive paper on ground water conditions in the South Wales Coalfield.

Calcium, sodium and magnesium are the principal cations present in most waters, whilst the anions are sulphate, chloride and bicarbonate (referred to in the analyses as 'carbonate' – though present as the bicarbonate ion). In addition, particularly in waters from the Coal Measures, iron and manganese have been found to be present.

No attempt has been made to classify the ground waters on the basis of the dominant cations and anions present, as it is considered that to do this would require far more sampling at a greater number of stations. It would also be outside the scope of the present survey.

In that part of the South Wales Coalfield within the Area, most of the pits have now closed and in many instances pumping of water from underground has ceased. At some of these sites there appears to be no overflow. At others the discharge of underground water has continued. No information is yet available on the changes, if any, in quality of underground waters which have occurred or may occur as a consequence of the colliery closures.

Some of the mine waters are acidic in reaction and may contain appreciable quantities of iron and manganese as well as matter in suspension. In order therefore to utilise

these potential supplies (based on quality criteria only), treatment would be necessary for the removal of iron, manganese and suspended matter and for the correction of acidity. This is discussed in some detail by Ineson (1967).

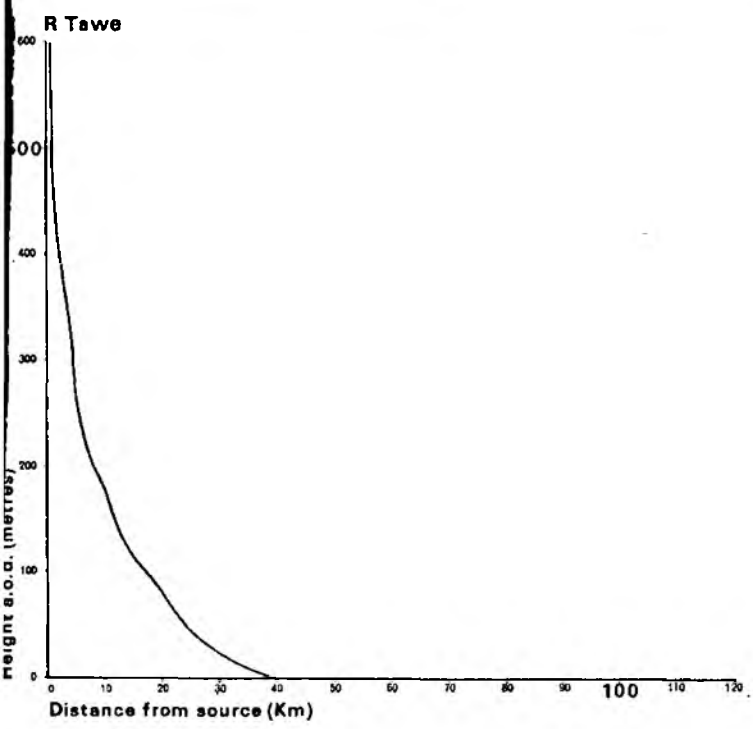
In the north of the Area, rather special circumstances obtain due to the now defunct mining of non-ferrous metals. As mentioned previously, many surface waters are consequently contaminated by zinc and lead in solution by discharges from mine adits.

The analytical information in Table 16 relates to the quality of underground waters from a number of sources in various aquifers within the Area.

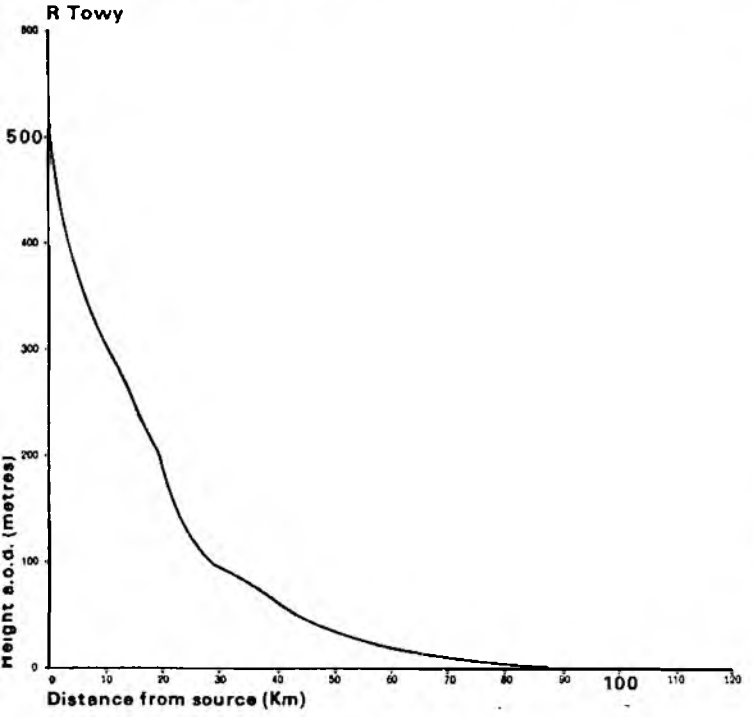
References

1. Eric H. Brown (1960): The Relief and Drainage of Wales.
2. British Regional Geology: South Wales (2nd Edition).
3. O. T. Jones: The Glacial and Post-glacial History of the Lower Teifi Valley.
4. Manual of British Water Engineering Practice: 3rd Edition 1961 (Hydrogeology).
5. Ineson, J. (1967): Ground Water Conditions in the Coal Measures of the South Wales Coalfield. Water Supply Papers of the Geological Survey of Great Britain Hydrogeological Report No. 3 NERC.

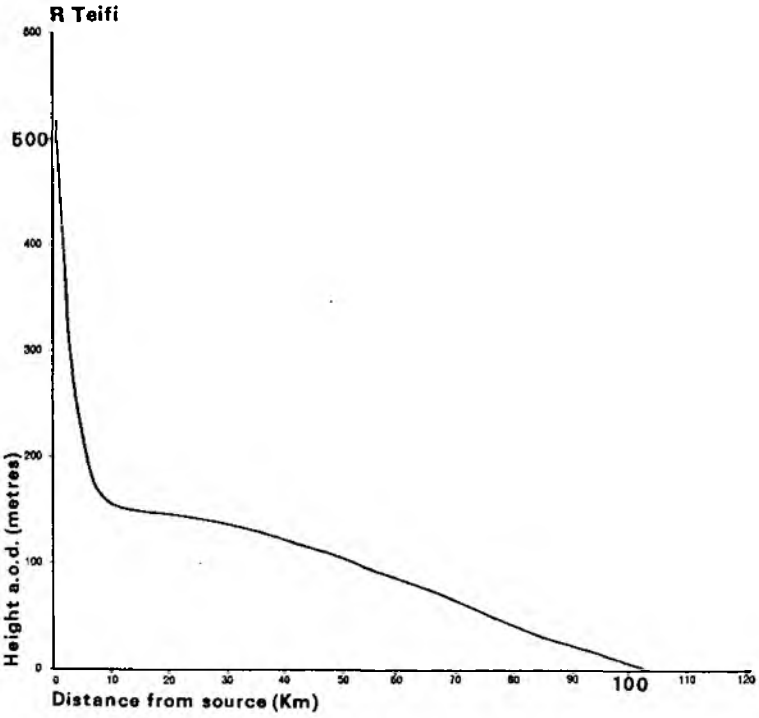
R Tawe



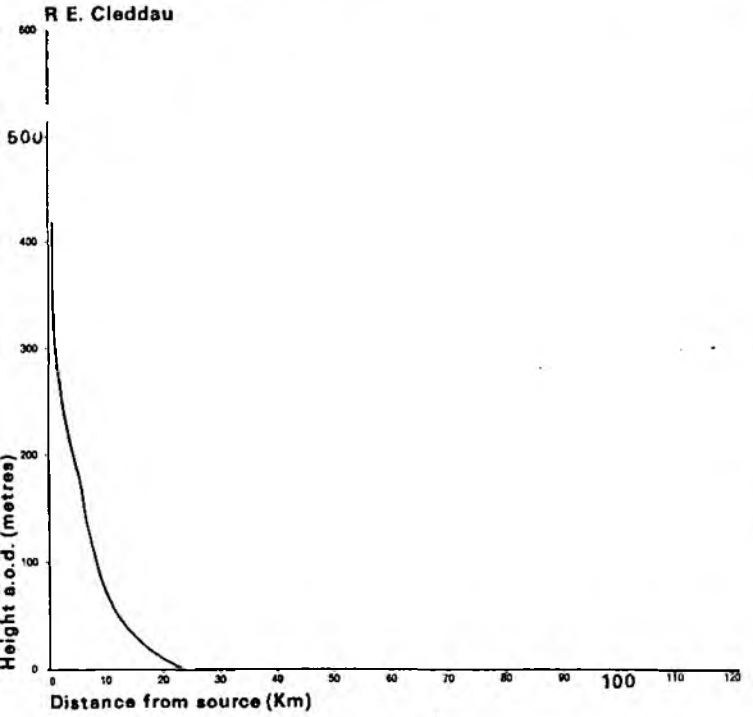
R Towy



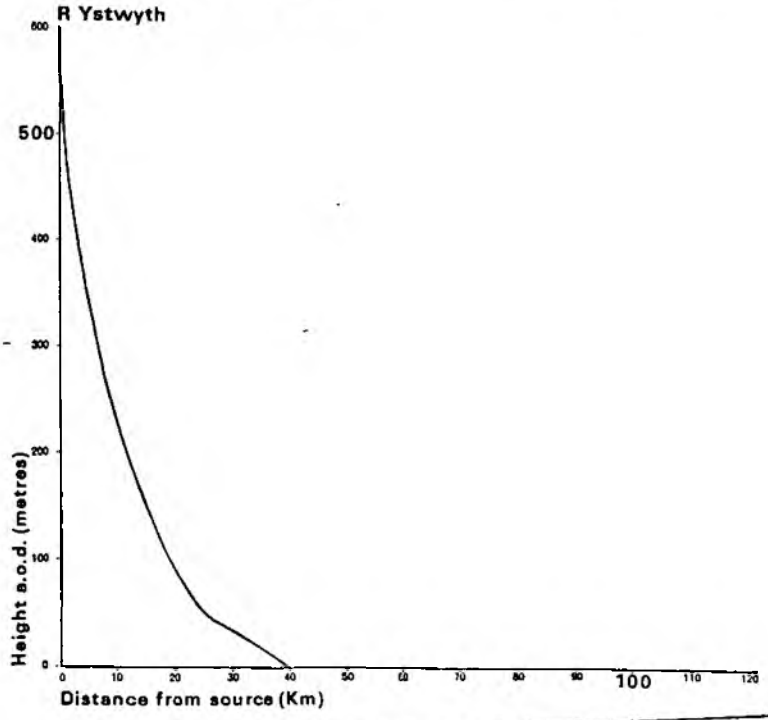
R Teifi



R E. Cleddau



R Ystwyth



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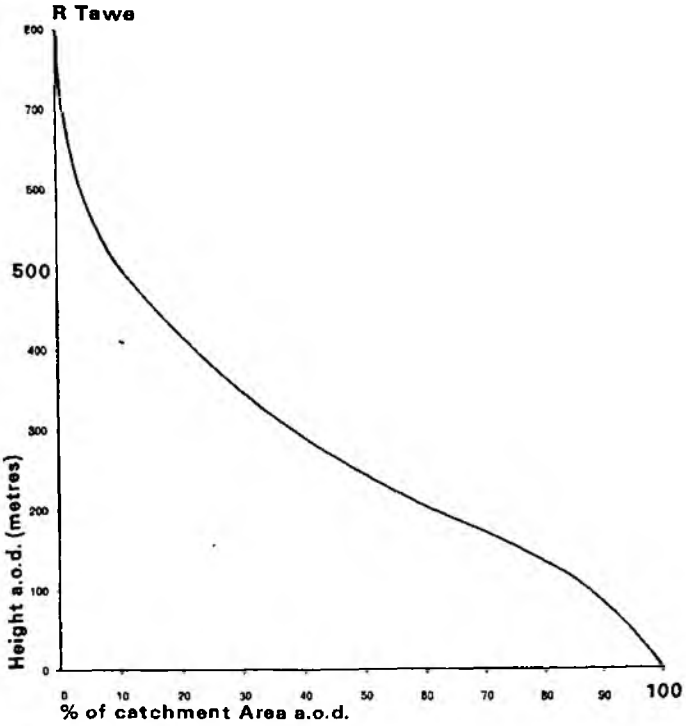

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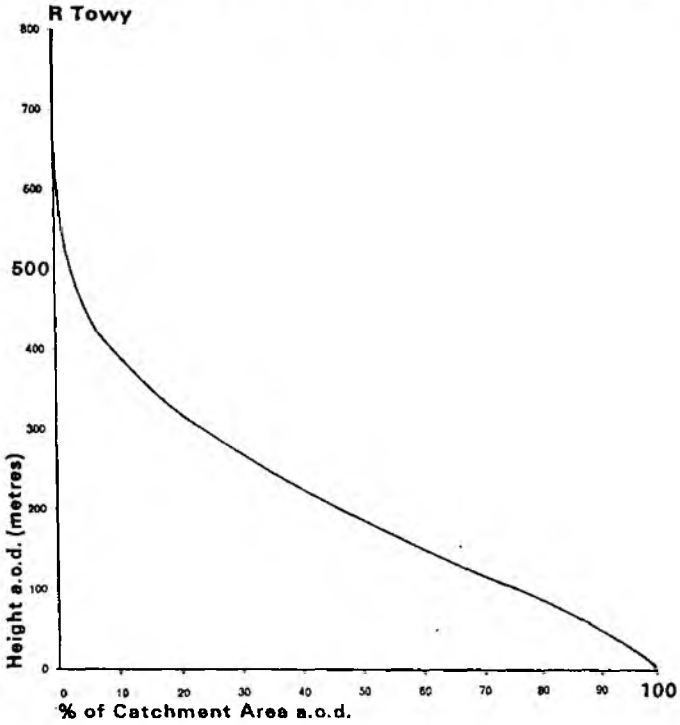
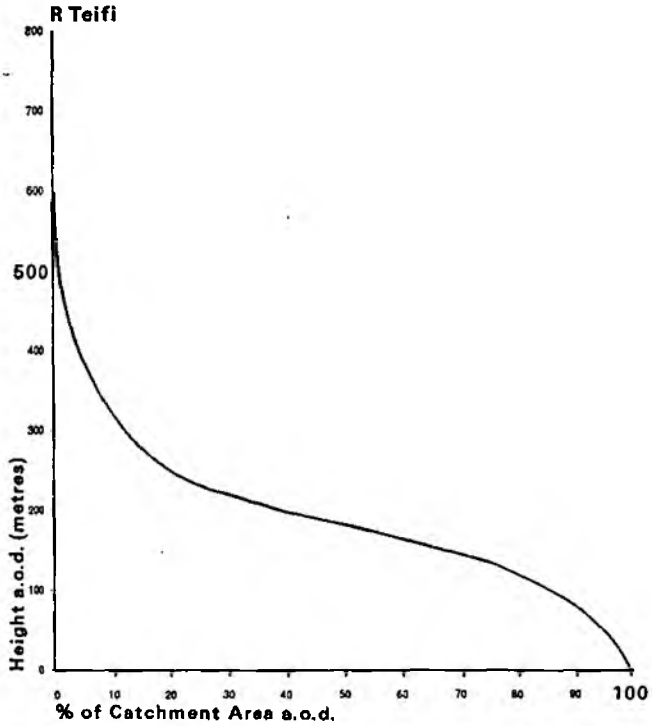
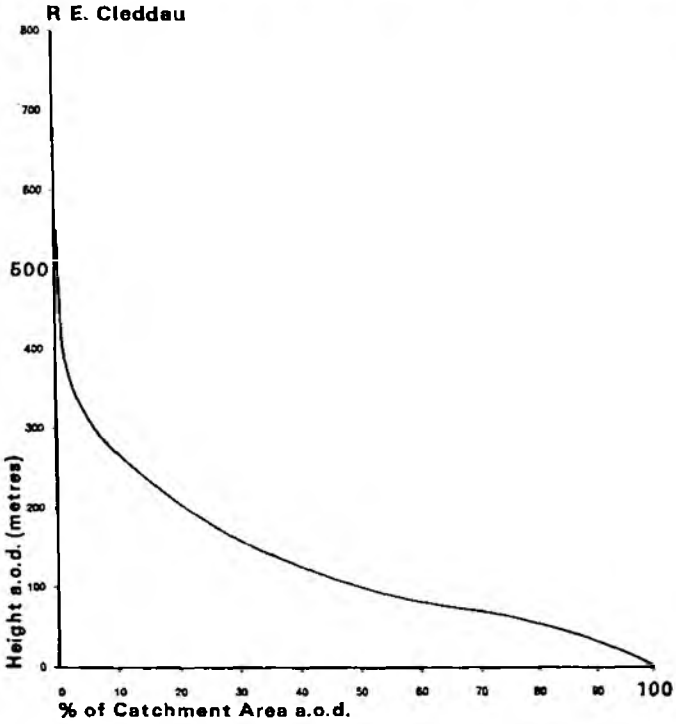


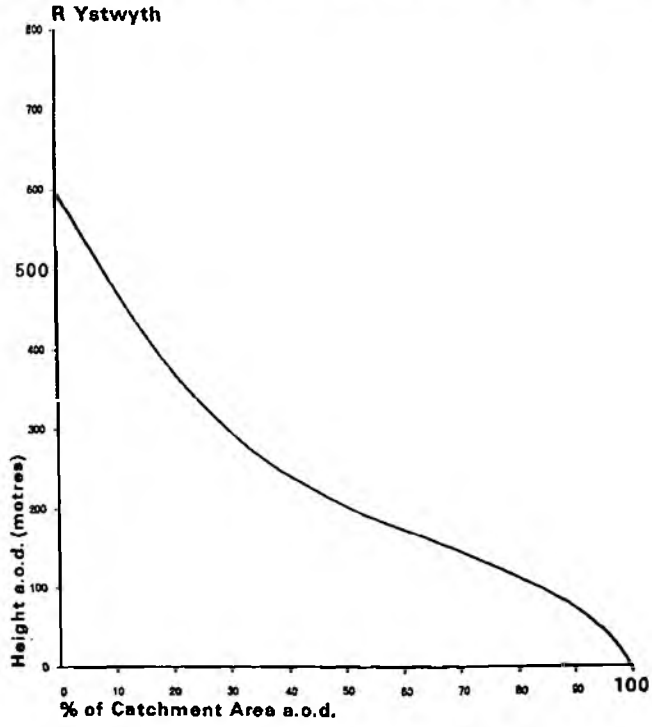
R Teifi



R E. Cleddau

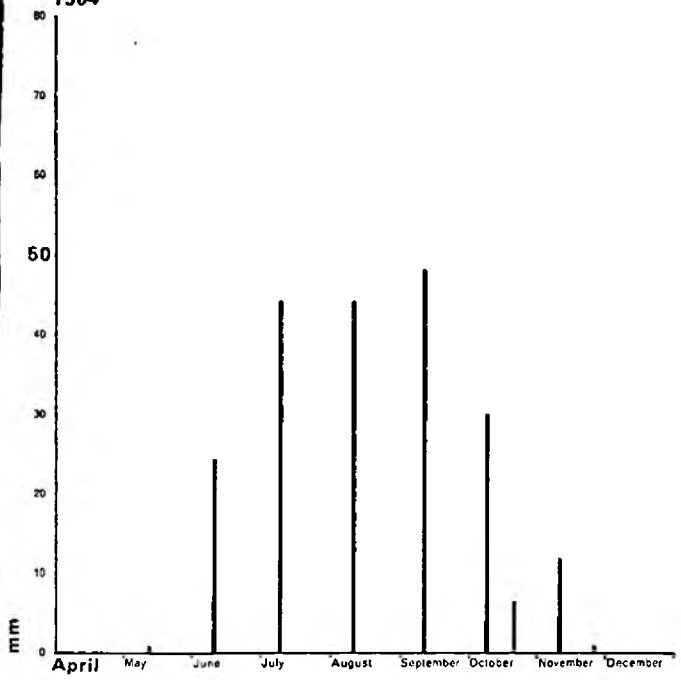


R Ystwyth

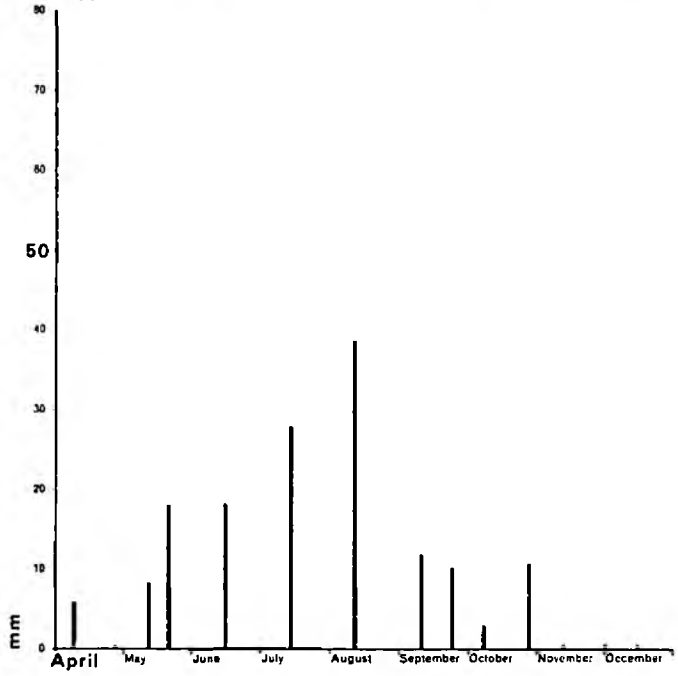


Areal Soil Moisture Deficits within the period of record (Section 2.2)

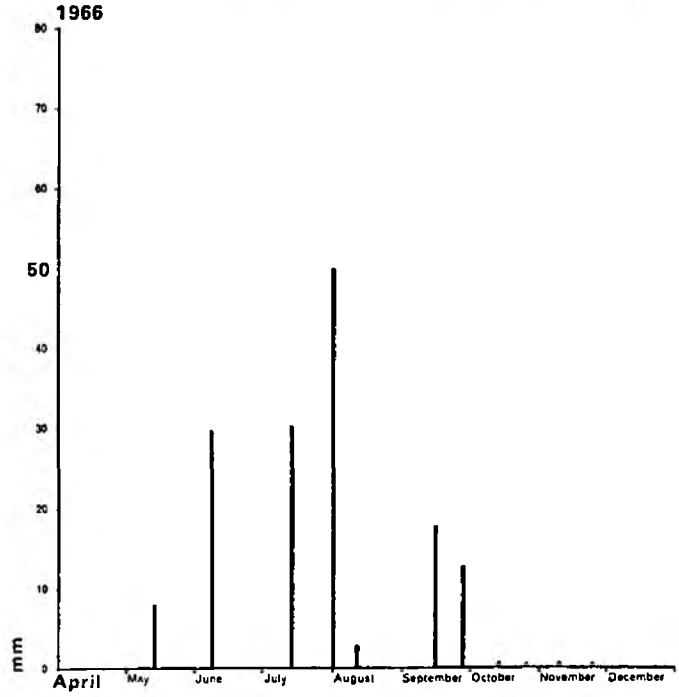
1964



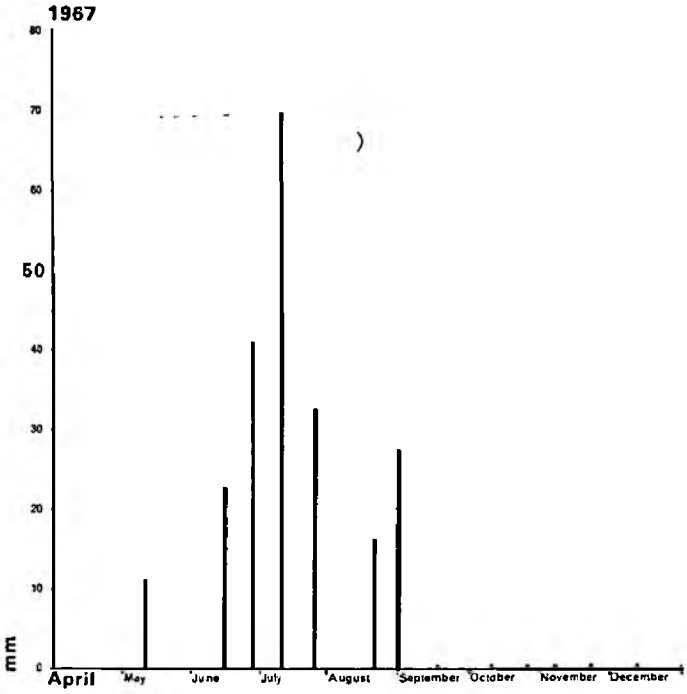
1965



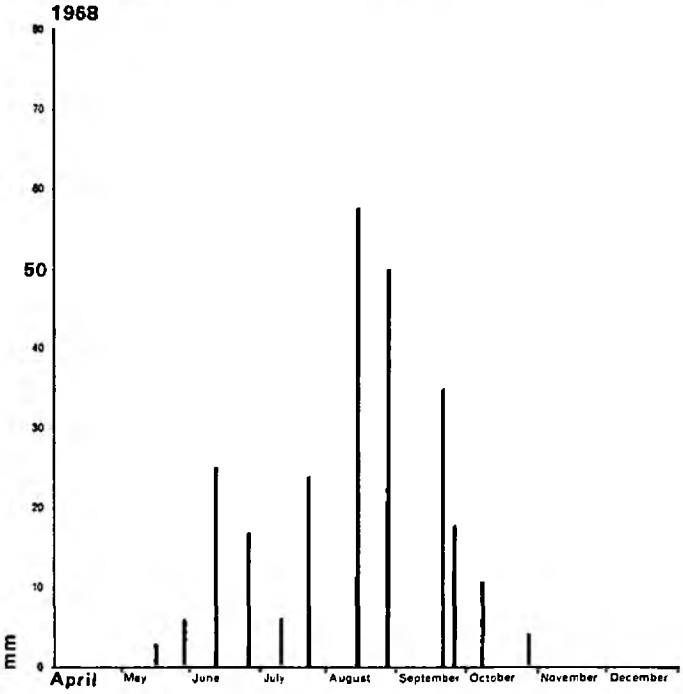
1966



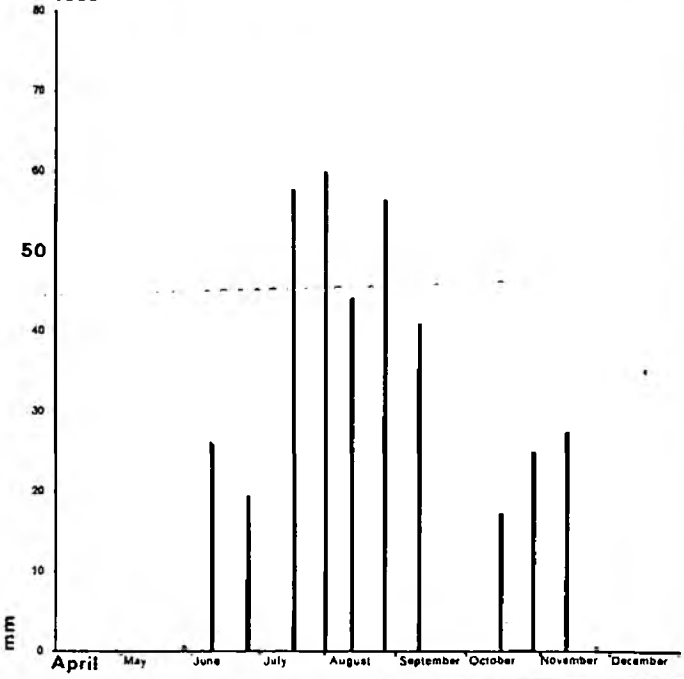
1967



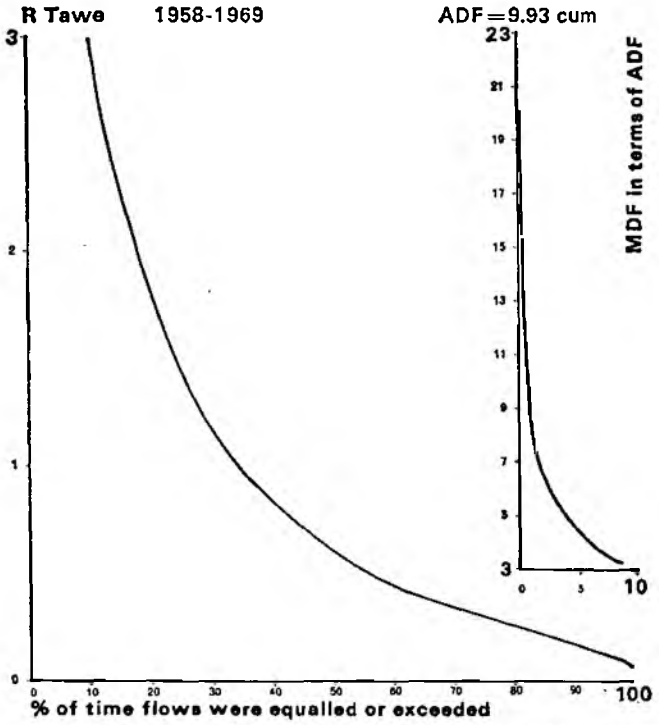
1968

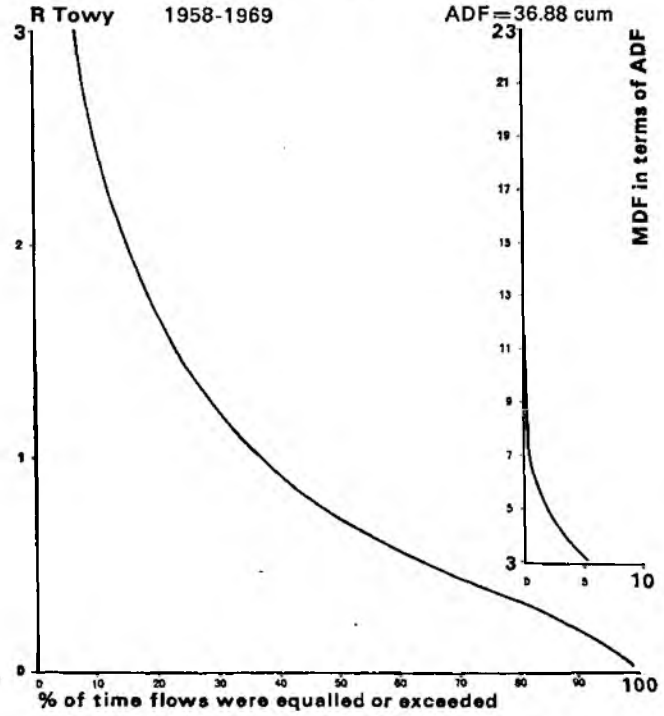


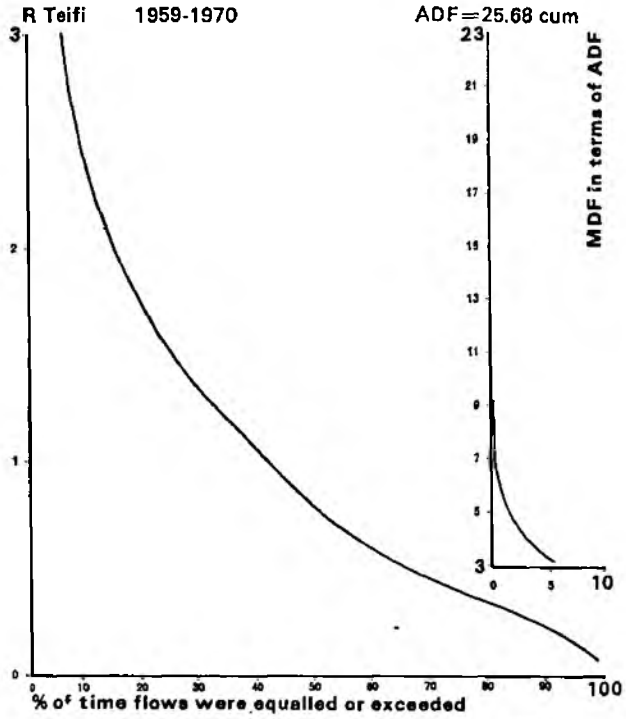
1969

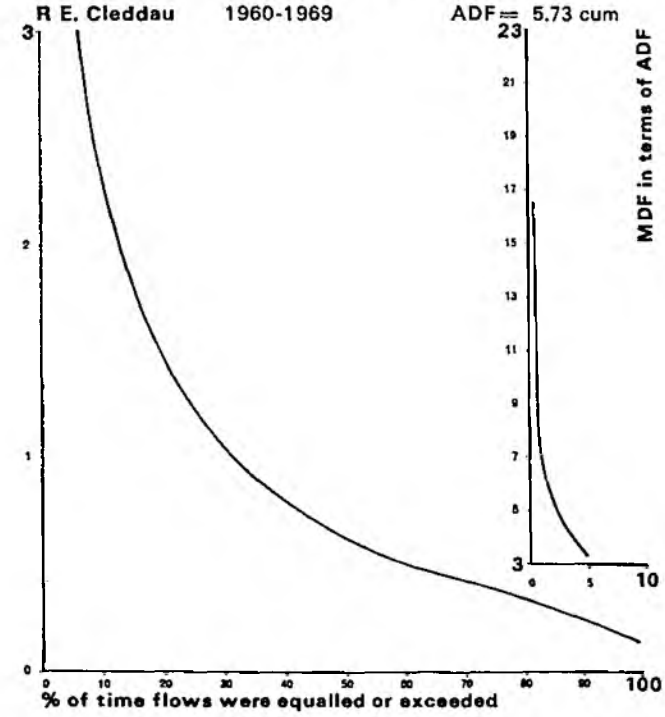


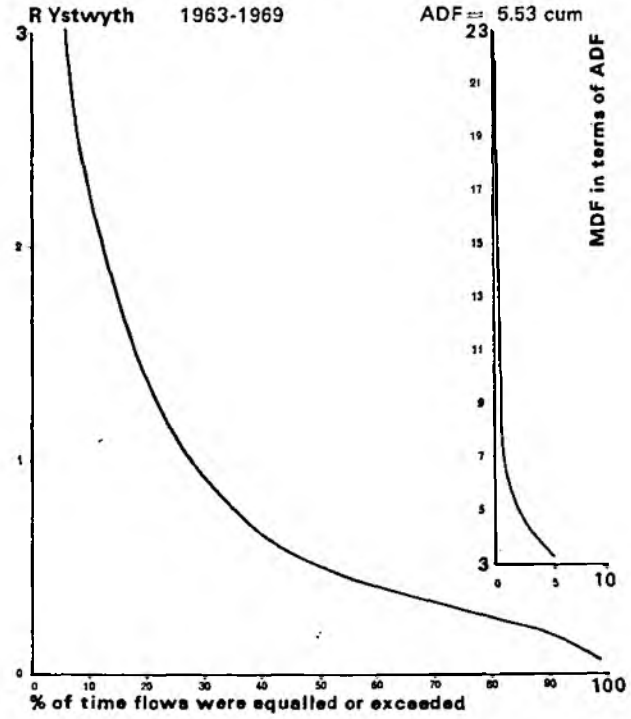
Duration Curves for the 'type' rivers within the period of record (Section 2.2)







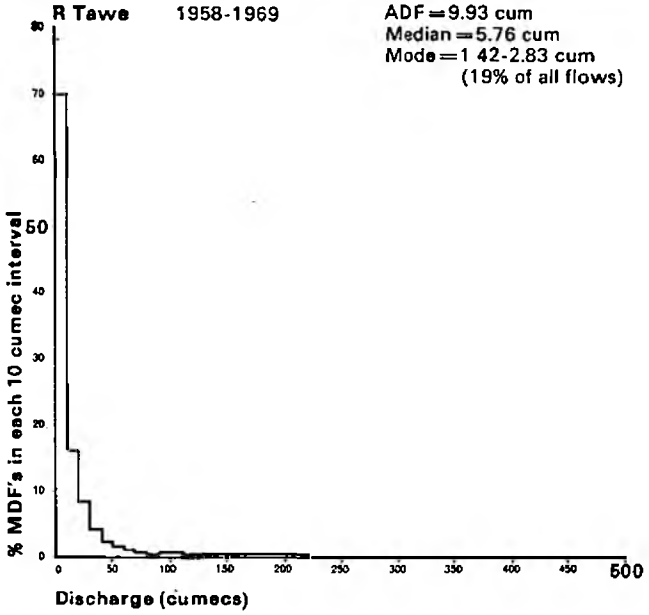




Histograms of Mean Daily Flows for the 'type' rivers within the period of record (Section 2.3)

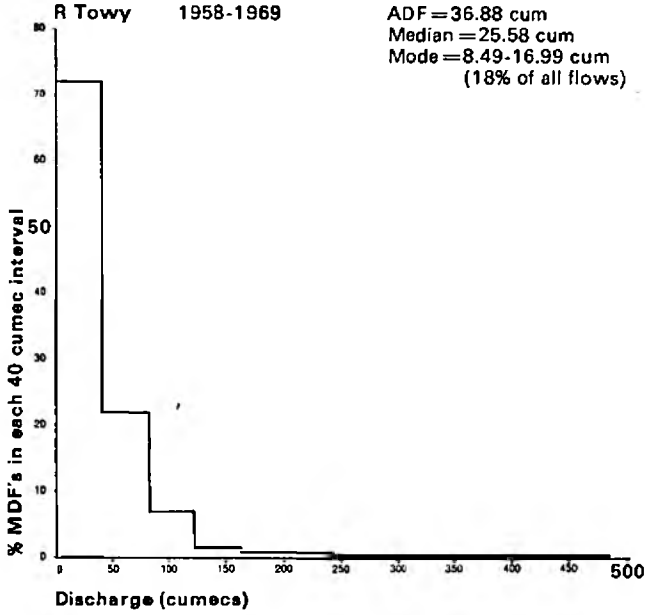
R Tawe 1958-1969

ADF = 9.93 cum
Median = 5.76 cum
Mode = 1 42-2.83 cum
(19% of all flows)



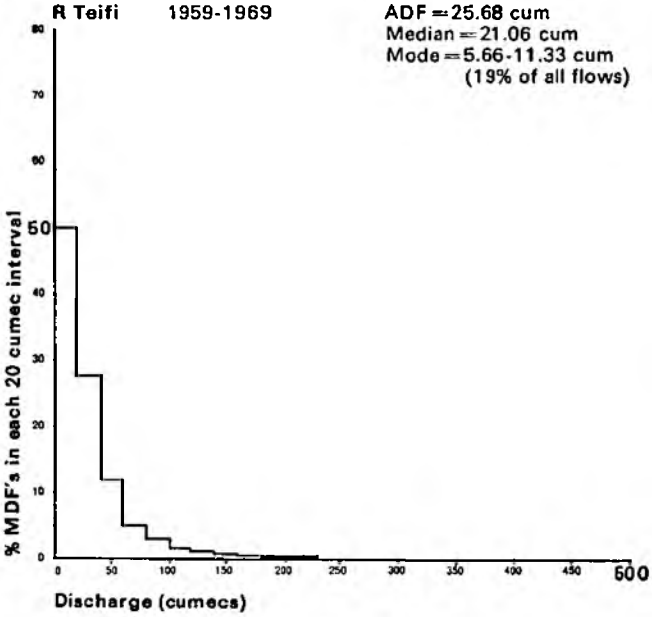
R Towy 1958-1969

ADF = 36.88 cum
Median = 25.58 cum
Mode = 8.49-16.99 cum
(18% of all flows)



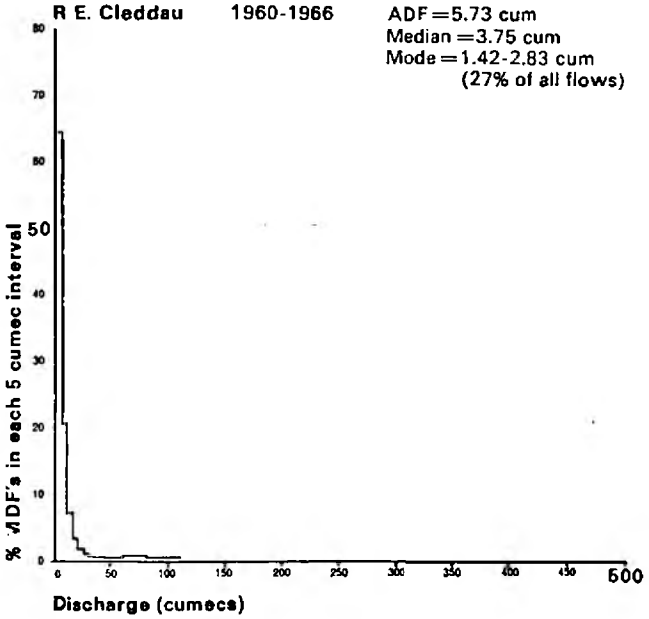
R Teifi 1959-1969

ADF = 25.68 cum
Median = 21.06 cum
Mode = 5.66-11.33 cum
(19% of all flows)



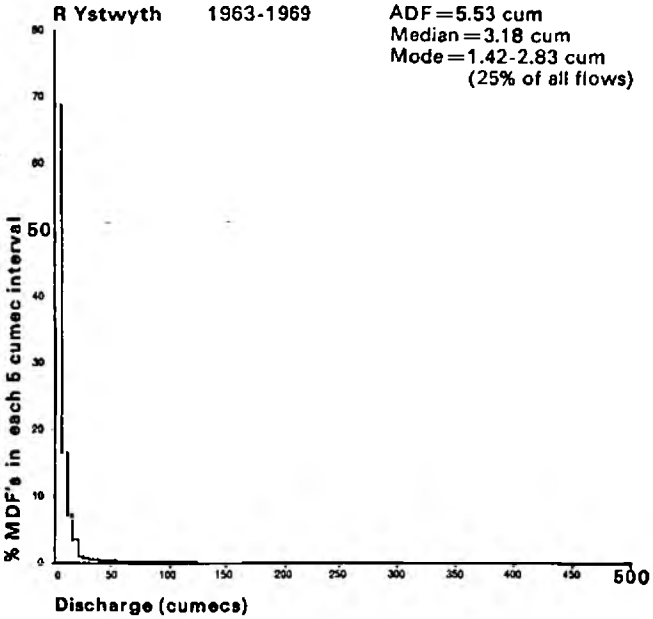
R E. Cleddau 1960-1966

ADF = 5.73 cum
Median = 3.75 cum
Mode = 1.42-2.83 cum
(27% of all flows)

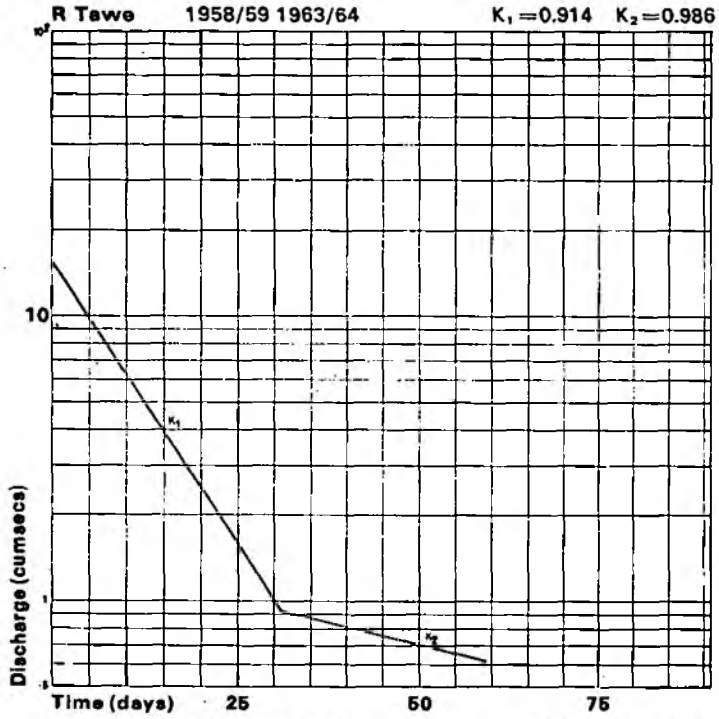


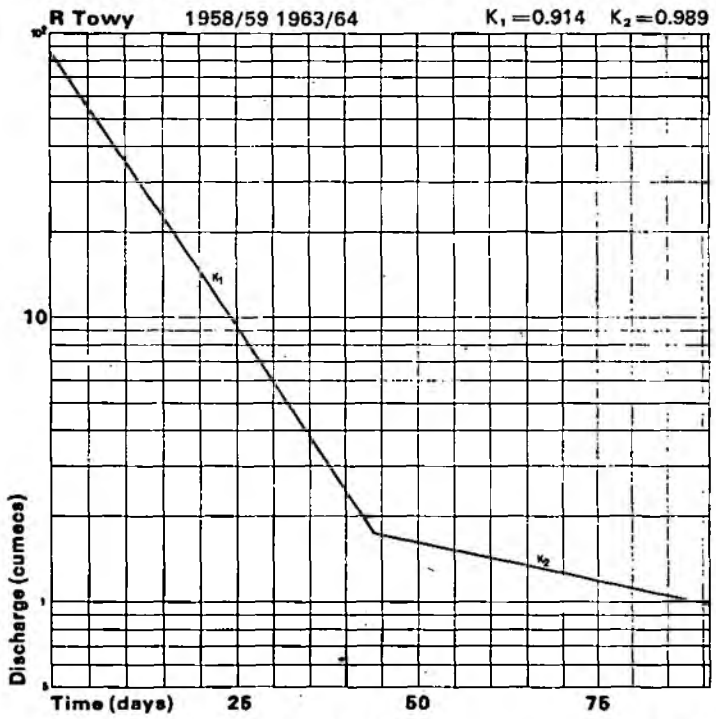
R Ystwyth 1963-1969

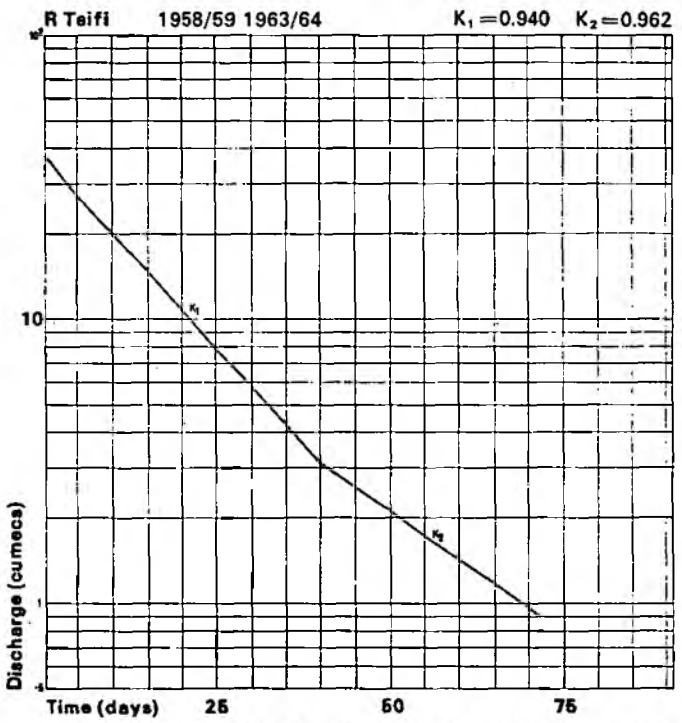
ADF = 5.53 cum
Median = 3.18 cum
Mode = 1.42-2.83 cum
(25% of all flows)

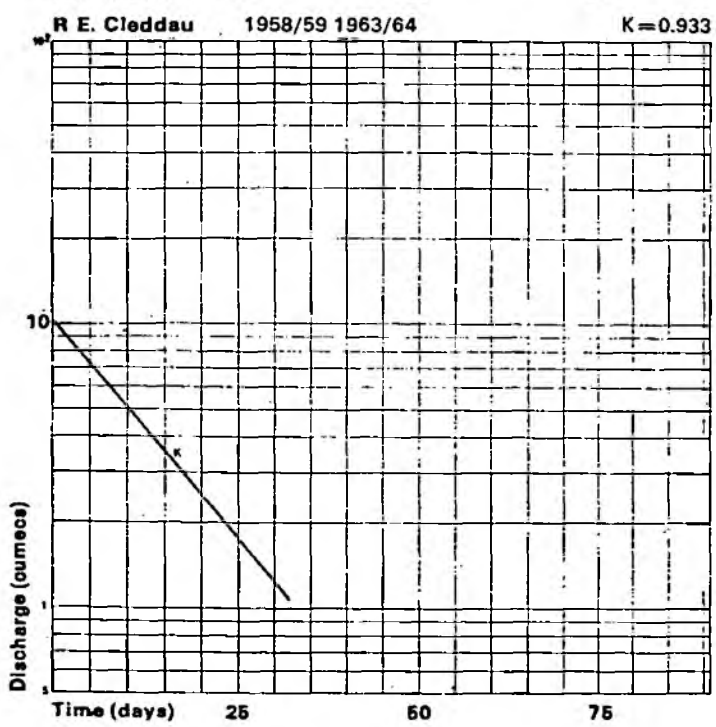


Baseflow Recession Curves for the 'type' rivers based on dry years (Section 2.3)









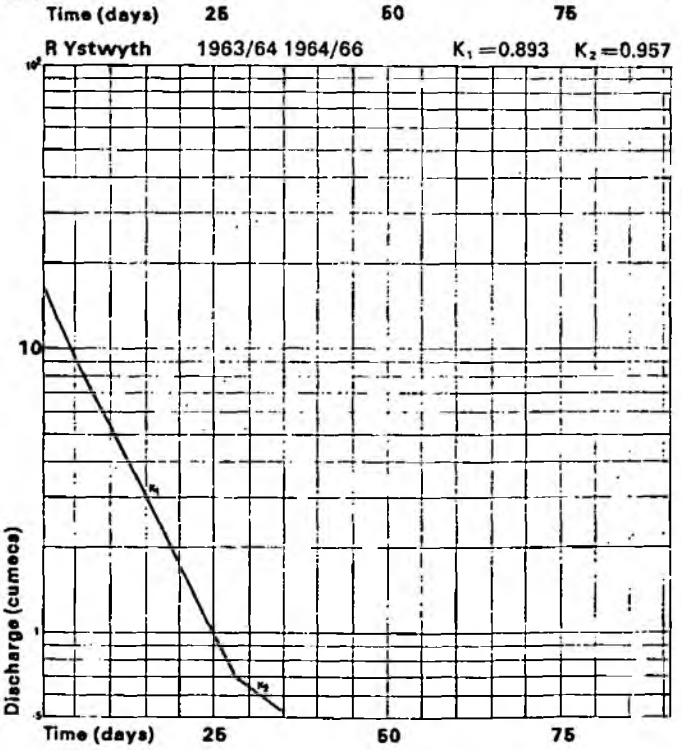
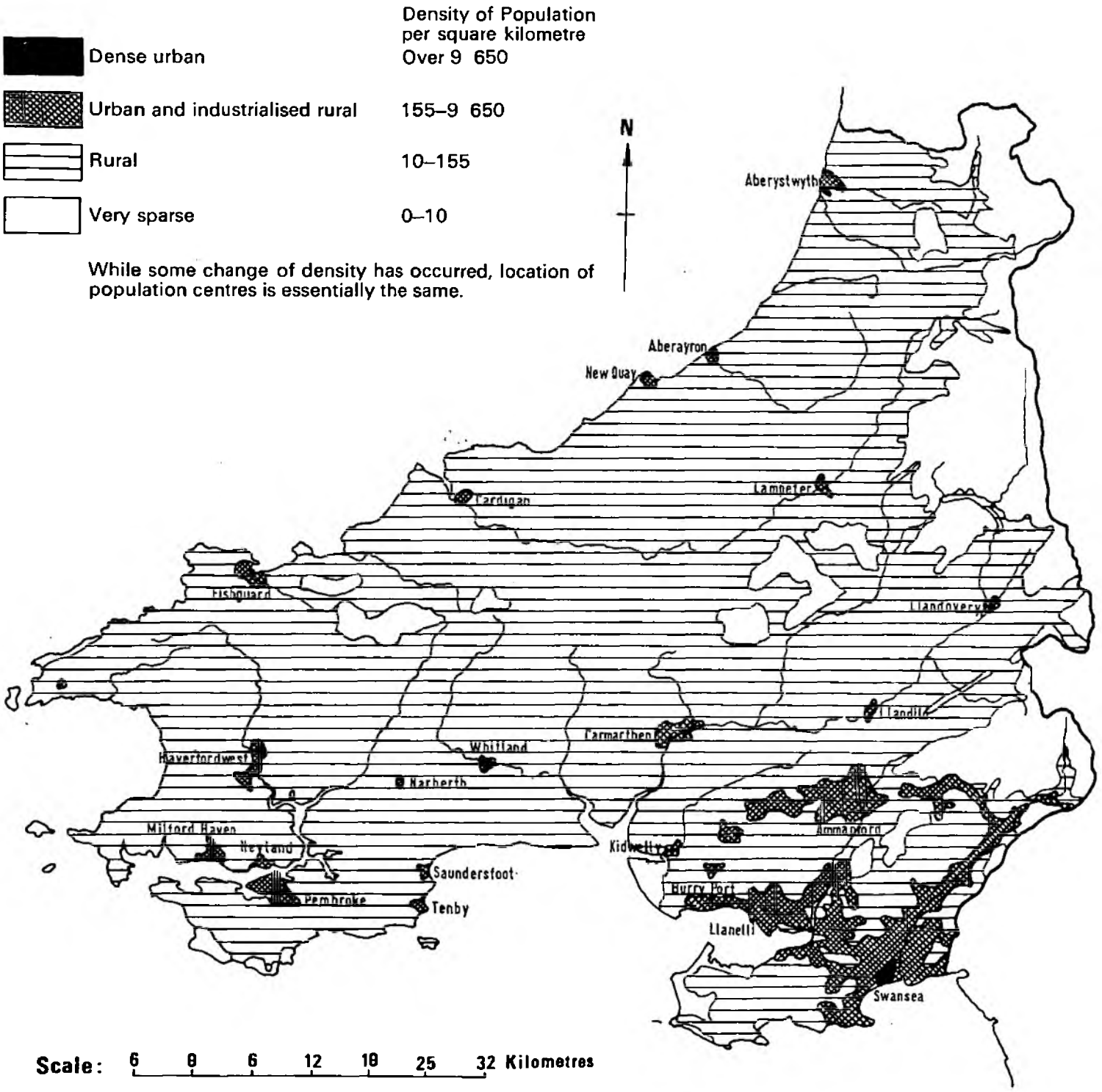


Fig. 3.1 **Population Density** (MOHLG 1951 Census)



Chapter 3 Existing Water Use

3.1 Population and Industries

The Area can broadly be divided into three economic regions, the south-east region, Milford Haven region and the remainder of the area.

Population The population within the Area is 568 120. Apart from the concentration of population in the vicinity of the large towns (see Fig. 3.1) the rest of the Area is by comparison sparsely populated: the population of the various county councils is listed below.

The figures are those quoted in the Municipal Year Book for 1968.

Glamorgan County Council (Part)	241 300
Carmarthenshire County Council	165 650
Pembrokeshire County Council	97 060
Cardiganshire County Council (Part)	53 410
Breconshire County Council (Part)	10 600
Montgomeryshire County Council (Part) – allow	100

The figure for Montgomeryshire is purely an estimate as the very small part of that County Council's area in the Area is in the hills and consists of isolated farms.

The following figures of population are those for the County Borough of Swansea (now the City of Swansea) and the non-County Boroughs and are in numerical order:—

Swansea County Borough	170 600
Llanelli	28 730
Pembroke	13 480
Carmarthen	12 880
Aberystwyth	9 900
Haverfordwest	9 300
Tenby	4 530
Cardigan	3 850
Lampeter	2 080
Llandovery	1 990

Gower is expanding as a residential and tourist area but due to its narrow roads and restricted development area it is unlikely that there will be any major expansion.

The counties of Pembrokeshire, Cardiganshire and, to a lesser degree, Carmarthenshire, are tourist areas and have a large increase in population during the holiday seasons which inflates water demands.

In Table 5 the population distribution has been taken on a water undertaking basis (Map 5) rather than on a catchment basis, the former giving a more useful indication than the latter. It will be noted that four zones have been used:—

Zone 1 being the area served by the Pembrokeshire Water Board including a very small part of the county of Carmarthen.

Zone 2 is the area served by the present Cardiganshire Water Board plus the area served by the Newcastle Emlyn Rural District Council and by the Newcastle Emlyn Urban District Council.

Zone 3 has been assumed to include the area of West Glamorgan Water Board within the Authority's boundary, also the areas of Llanelli and District Water Board, Loughor Joint Water Board, Cwmamman Urban District Council, Llandovery Borough Council, Llandeilo Urban, Llandeilo Rural, Carmarthen Borough and Carmarthen Rural. These areas have been grouped together (in Zone 3) as they depend upon the river Towy catchment for their future development.

Zone 4 is also dependent upon the river Towy catchment for its future development but excludes the area of the West Glamorgan Water Board.

The part of the Area within the administrative boundary of the Radnorshire and North Breconshire Water Board and that of the Montgomeryshire Water Board has not been considered in this report.

Industries In the south-east region there is evidence of old established industries such as smelting, mining, manufacture of tinplate and iron and steel. The copper, tinplate, iron and steel industries were all concentrated around the coal fields giving highly industrial and populated areas, which in most cases were in the valleys or very near to the coast. The main centres are the Swansea Valley, the Amman and Loughor Valleys and the coastal area of Llanelli. Copper has now completely ceased as an industry as has iron; however, the tinplate industry has been modernised and concentrated into two major plants, the steel for these plants coming from outside the area. The only remaining steel produced is that required for specialised purposes and is a small quantity when compared with the major modern plants. There are many light industries operating in the area as well as a major car components factory using locally produced tinplate, but these light industries although making use of local labour are not great users of water and do not materially affect the consumption. There are very few coal mines in operation at the moment, those that are in existence are either run by the National Coal Board or the Opencast Executive or under private licence. Although the deep mines have a possible life beyond the 1980's, this life is unlikely to extend to the end of the century: the two major collieries being at Abernant and Cynheidre. Although around 1·016 million metric tons of coal still pass through Swansea Docks, some of this is from outside the area of consideration; in the heyday of the mining industry as much as 2·032 million metric tons passed through the docks in the southern part of the Area.

The second region namely that of Milford Haven has a great potential as a deep water berth. The Haven is well suited to accommodate the largest type of ore carriers and tankers (as evidenced by three refineries and a marine terminal). There is also the likelihood of petro-chemical industries and a new refinery being attracted to the region. There is a high percentage of unemployment in the area and this again is an attraction to the establishment of new industries.

The Central Electricity Generating Board have under construction a major power station, with the prospect of extension, in the Haven area. This again should be an incentive to the petro-chemical industry and other users of electric power.

The remaining region of the Authority's Area is agricultural, being mostly made up of small farms of dairy and beef cattle, with sheep on the higher ground. The county of Pembrokeshire is also a producer of early potatoes and certain other vegetables and it is considered likely that more vegetables will be grown in this area in the coming years.

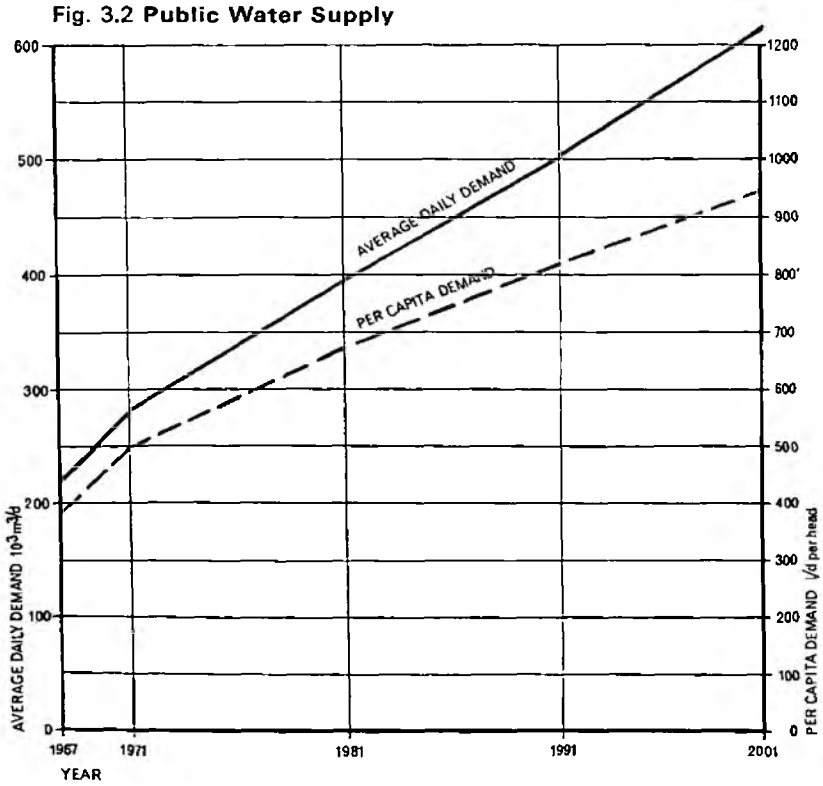
From this brief outline of population and industrial and agricultural activity in these regions, it would appear that there is little likelihood of major or sudden expansion in population or industries requiring large quantities of water. However, in arriving at figures for future demands for industries, ample allowance has been made to cater for an influx of light industries as it is considered expedient to have water available at very short notice in order to satisfy any prospective industrialist wishing to come to the area.

3.2 Public Water Supply

In Table 10 will be found a list of the various water boards, their existing daily demands and those up to the period 2001. Also in the table will be found the various reliable yields of resources, the export and imports of bulk supplies (Tables 10a and 10b) and lastly the apparent overall deficiencies or surplus up to the year 2001 (Table 10c).

The various water undertakings in this table have been listed as they exist at 1st April, 1970 but it is anticipated, as mentioned in Section 3.1 that there may be reorganisation of these undertakings and only three or four major boards may remain. These boards are shown in Table 5.

Fig. 3.2 **Public Water Supply**



The per capita consumption of water in this Area as a whole is higher than in any other Welsh river authority area or the border authorities (see Fig. 3.2). The reason for this high figure which amounts to 0·963 m^3/hd/d, in the year 2001, is due to the high level of supply of raw water to industries by water boards. The Llanelli and District Water Board use one reservoir solely for the supply of raw water to a major steel industry. The Pembrokeshire Water Board have agreements with various refineries in the Milford Haven area to supply raw water and substantial quantities of potable water are supplied by the West Glamorgan Water Board for industrial use. A diagram shows these per capita demands.

Map 5 shows the various water board areas, the transfers of water, the reservoirs and main distribution systems.

By far the greater part of the water supplies in this Area come from surface water and only a very small quantity is from underground sources (Tables 6 and 7). The supply to the town of Llandovery is from boreholes in the Towy river gravels, and can be considered as river water. The various underground supplies in Gower, in the County of Carmarthen, of the Pembrokeshire Water Board and the major ones in the County of Cardigan are shown on Map 8.

At 1st April, 1970 small quantities of water are being moved either into or out of the Area (Tables 10a and 10b). These small imports and exports have been taken into account in preparing Table 10. The bulk of the water supplies for Swansea are imported from the Usk River Authority and come from two reservoirs, the Usk and the Cray, the quantity being in the order of $68{\cdot}20 \times 10^3 m^3$/d. By far the greater part of this quantity is discharged to sea in the form of sewage; a small part being discharged to the river Tawe catchment area. Small quantities are exported to the Glamorgan River Authority area (Table 10b). Again these quantities have been adjusted in Table 10. Llanelli and District Water Board imports water from HA 60 into HA 59 but this of course is an export-import within the Area and does not appear in Tables 10a and 10b. The greater proportion of this water is discharged direct to the sea either as sewage effluent or by industry.

The Pembrokeshire Water Board exports water from HA 61 to HA 60 and a very small amount to HA 62; these transfers are insignificant. Very small quantities are moved around between areas 60 and 62 and between areas 62 and 63 but again these are of no significance.

Water is imported from the Gwynedd River Authority area into the Central Electricity Generating Board's Cwm Rheidol hydro-electric power system. In times of very high water levels in the Nantymoch reservoir a proportion of the water flows back into the Gwynedd River Authority area. No account nor measurement is made of this small quantity.

Water is also moved into this Area from the Gwynedd River Authority area by the Cardiganshire Water Board but again the quantity is exceedingly small and has no effect upon the water resources of that area but has been accounted for in Tables 10 and 10a.

It will be seen in Chapter 4 (Surface Storage), that there is a considerable quantity of water available for export to other areas but that for economic reasons it is anticipated that only a limited number of areas would be suitable for export of major quantities to other Authorities' areas.

The following list of major water supply reservoirs are in operation (Map 5).

Hydrometric Area	Location	Owner	Type	Auth. Abst. $10^3 m^3/d$
59	Upper Lliw	West Glamorgan Water Board	C	18·68
59	Lower Lliw	West Glamorgan Water Board	C	
59	Upper Lliedi	Llanelli and District Water Board	C+P	C=18·37 P=27·66
59	Lower Lliedi	Llanelli and District Water Board	C+P	C=19·04 P= 7·01
60	Llynyfan Fach	Llanelli and District Water Board	C	7·73
60	Cwmtawel	Carmarthen Borough	C+P	2·30 (Combined)
61	Rosebush	Pembrokeshire Water Board	C+P	16·19 (Combined)
62	Teifi Pools	Cardiganshire Water Board	C	4·51
62	Egnant	Cardiganshire Water Board	C	2·43
63	Llyn Llygad Rheidol	Cardiganshire Water Board	C	2·55

3.3 Direct Industrial Use

In the consideration of industries the Central Electricity Generating Board has been treated separately in Table 11 as the quantities of water concerned are very large and of a special nature, much of the abstraction being from estuaries or directly returned to the source after abstraction.

In HA 59 there are industries using water abstracted from the Swansea Canal (British Waterways Board) as well as from the river Tawe direct. The Canal is fed from the river Tawe at Panteg Weir and the water is returned to the river Tawe just above Swansea in the tidal part of the river.

The Canal within the boundary of the City of Swansea is to be filled in sometime in 1970/71 and the abstractions within this area are being directed to the river Tawe.

The major abstractors are as follows :—

1. National Coal Board : Coal washing, the water being recirculated.
2. British Rail : Various uses.
3. Swansea Canal (British Waterways Board) : Licences are issued to the British Waterways Board for each of the abstractions from the Canal.
4. International Nickel Company : Cooling and processing. Abstractions are from the Canal as well as from the river direct.
5. British Steel Corporation : Cooling and in the manufacture and process of iron and steel.
6. International Smelting Corporation : Process water.
7. Aladdin Industries Ltd : Cooling and process water.

Outside the Tawe valley but still within HA 59 there are several abstractors such as :—

1. BP Llandarcy : Refining purposes.
2. Imperial Metals (Kynoch) : Cooling and manufacture.
3. Mettoy Toy Factory : (not yet in use).
4. Imperial Aluminium : Cooling.
5. The Tennant Canal Company : Like the Swansea Canal it is not navigational but used for water supply purposes.
6. Llanelli Steel Company : Cooling water.

There are a number of lesser abstractions such as those made by the ice and cold storage companies, laundries, breweries and small industries, and these have not been listed : some being from underground sources.

Consultations have taken place with the Confederation of British Industry and various Planning Authorities. Apart from light industries, which in most cases take their water direct from the water undertakings, there is no evidence to suggest that industrial demands will vary greatly and there are no indications of a need for major supplies above the general increase of about 4% per annum, compound.

Water taken from the Swansea Canal is discharged after use to the river; the discharge from certain of the abstractions from the Canal is returned in a chemically polluted state but is re-used lower down the river Tawe after being diluted with the normal river discharge. In the larger factories water is used for several processes and it is difficult to break down the quantities into separate uses; the factories even vary their use according to the time of year. Certain factories can generate their own electricity and during this time the water is used mostly for cooling purposes with the result that it is exceedingly difficult to divide the abstraction into various uses, and to say what water is returned as there are often several outlets from one factory and the water is also re-used within the factory before being returned to the river system.

In **HA 60** there are few industries, the main one being the production of milk products; there is some coal washing in the Gwendraeth Valley. In the Carmarthen area the Unigate Creameries abstract water from the Towy river for use in the manufacture of milk products. There are also direct abstractions for other milk product factories such as the Co-operative Society plant at Llangadog : the major part of the water is returned to the river Bran.

There is little indication of any great expansion in this type of industry or in any other industrial development in HA 60. A licence was issued to one abstractor at Pembrey as a licence of right, but so far no water has been used from the licensed source. Bearing in mind the proposal to transfer an Artillery proving range to Pembrey, more water may be required.

The large oil refineries at Milford Haven in **HA 61** do not themselves carry out any major direct abstractions; agreements were made when the refineries first moved to Milford Haven with the public water undertaking that raw water would be supplied to the refineries for their various processes and as all the water is being so supplied it is not considered in this section. Should the petro-chemical industry move into this area, then there is the likelihood that increased quantities of water would be required, but again this may be supplied by the water undertaking in that area. So far, it is not possible to say if there will be any influx of such plants.

The other major users of water are mineral companies for sand and gravel washing where the water is re-used and only that part contained in the transported material is lost to the catchment, this quantity being in the order of 5% of the load by weight.

British Rail also have small abstractions in this Area but the figures of consumption are being reduced considerably and in many cases licences are being revoked.

HA 62 has few industries, the major ones being those operated by the Unigate Creameries for the manufacture of milk products. Abstractions for this purpose are not large and in many cases the water is returned to the same source. Several woollen mills use water as a means of power but again this is only a by-passing of part of the river. There is also, in this area, a small amount of gravel washing.

There is little prospect of any major industrial development in this hydrometric area thus it is unlikely that any major abstractions will take place.

In **HA 63** there is little or no industrial abstraction except for sand and gravel washing. British Rail have various isolated abstractions but these are of little or no consequence and are slowly being abandoned. The Milk Marketing Board have an abstraction in the area but again this is very small.

The only foreseeable increase in direct abstraction could be for mining and the processing of lead, zinc, etc.

Exploration is taking place at the moment and if the old industries are revived then it may well be that industrial water will be required in such processing but at present there is no real evidence of the need for large quantities of water.

In the case of the Central Electricity Generating Board, a major use of water takes place at Nantymoch for the generation of hydro-electric power. The scheme operates in the river Rheidol catchment area and consists of two major dams together with small ancillary dams and adits. The quantity licensed at the lowest point in the river system is in the order of 22 $400 \times 10^3 m^3/a$ and most of this water is used during the winter period. A very small quantity of water is obtained from the Gwynedd River Authority area and taken into the Nantymoch Reservoir and at times of very high level of the reservoir, water can return to the Gwynedd River Authority area, but these transfers are not considered of any value. The Cardiganshire Water Board have a right to a small quantity of water from the Rheidol catchment area but this quantity only amounts to some 1 $400 \times 10^3 m^3/a$ which has no effect on the generation of electricity.

A major abstractor of water will be the power station now being constructed by the Central Electricity Generating Board near Pembroke Dock on the Milford Haven estuary. Water will be abstracted direct from a part of the estuary for cooling purposes and discharged at a point further seawards but still near to the point of abstraction.

There are other old and small power stations which are being closed down, and by December 1970 the abstraction for use at these stations will no longer be taking place.

3.4 Use for Agriculture

The atlas of Long Term Irrigation Needs for England and Wales issued by the Ministry of Agriculture, Fisheries and Food has been studied but it is thought that it does not give a detailed enough indication of the requirements for this area which consists of very many small irrigation plots scattered around Pembrokeshire, mostly towards the coastal belt. Nor does it take into account the local variation in rainfall. However, it has been possible to obtain a fairly concise account of present and future trends in agricultural water needs. At present, as stated previously, most of the irrigation takes place in the County of Pembrokeshire and is for early potatoes. There are approximately 3 237 hectares under cultivation of which approximately 1 619 hectares are irrigated at irregular intervals. It is possible that there could be a maximum potential of 2 023 hectares under irrigation. It is exceedingly difficult to forecast agricultural policies as so much is dependent upon imports, and also the ever changing political situation regarding agriculture generally. It is unlikely that more than 20% of the irrigators will take up double cropping.

It is not considered likely that the irrigation of grass lands will increase beyond the 1 619 hectares already irrigated, the area being under a rotation of grass land and early potatoes.

In view of the distance of the Pembrokeshire area from any large wholesale market it is unlikely that there will be a vast increase in vegetable growing. However, the canning of meat and vegetables, especially potatoes is being encouraged and is likely to increase in the future. This would result in an increase in the area under irrigation and the need for minor conservation works to ensure water being available at critical times. Table 12 shows the present and future demands up to the year 2001.

There is only a small amount of horticulture taking place in the Pembrokeshire area at the moment and it has no marked effect on water resources. This condition is most probably due to the distance to any major area of large population.

There is a tendency for farmers generally in Carmarthenshire, Cardiganshire and the borders of Pembrokeshire to increase the size of their herds and change the farming pattern to large operating units; these would require irrigation to support the aim of two cows per hectare which is already being achieved in certain parts of Carmarthenshire without irrigation. It is possible that stock will increase between 3% and 5% per annum in this area. In 20 years it is anticipated that the stock figures for Pembrokeshire should have nearly doubled.

In this Area abstractors using water for dairy purposes and for watering sheep and cattle are not required to produce figures of quantities abstracted, but when licences are issued we have always requested abstractors to notify the Authority from time to time of the number of cattle on the farm, and by using the standard requirements of 136 l/d per cow, which includes washing and cooling of milk, it is possible to obtain some idea of the amount of water being abstracted. An allowance of 45 l/d has been made for other beasts and a figure of 11 l/d for sheep, the allowance for pigs has been taken as 13 l/d. These licensed quantities only relate to underground supplies which are subject to licensing and do not take into account the remainder of the abstractions from both underground and surface water which were not subject to licensing. It is believed that there are in the order of 18 000 separate farms, very many of which may rear either cattle or sheep or both with the result that there is a considerable amount of water unaccounted for, which could be in the order of $60 \times 10^3 m^3/d$.

Approximate Figures of Livestock for 1966

(Number in thousands)

	Cards	Carms	Pembs	Glam	Totals
Sheep and Lambs	506	441	185	38	1 170·0
Pigs	17	22	32	2·3	73·4
Cattle	109	184	151	21	465·0
Totals	632·0	647·0	368·0	61·4	1 708·4

NB The figures for Glamorganshire are based on a proportion of the County figure with adjustments.

3.5 Fisheries

The extent and value of the fisheries The salmon and trout (including migratory) fisheries in the Area are important commercially and from a recreational point of

view. Coarse fish occur in a few lakes and ponds, but no well developed fishery exists.

The most important fishing rivers in the Area are the Towy (including the Cothi), the Teifi, the Taf and Rheidol, Eastern Cleddau, Western Cleddau, Nevern and Loughor. Other rivers such as the Ystwyth and Tawe which are recovering from pollution also provide fishing of a reasonable quality and in fact migratory fish occur in most rivers and streams within the Area, except minor grossly polluted water-courses, and those stretches of rivers above obstructions impassable to migratory fish. Commercial (net) fisheries for salmon and sea trout are to be found on the rivers Towy, Teifi, Taf, Eastern Cleddau, Western Cleddau and Nevern, as well as in certain areas of the sea and sea coast.

The ten year average (1960–1969) salmon catch for nets is 1 568 fish/a, and the similar figure for rod and line is 1 898 fish/a. The latter figure is based on only 14% of anglers' returns and the actual catch is probably of the order of twice the declared catch. Similarly there is evidence that the declared commercial catch is an underestimate. The combined average commercial and rod catch of 3 466 salmon can therefore probably be doubled. The **direct** value of this salmon catch is of the order of £40 000.

The ten year average (1960–1969) sea trout catch for nets is 3 403 fish and the average weight of the fish caught is between 1·5–2 kg. This declared catch is, as in the case of salmon, an underestimate of the true catch. Details of sea trout catches are not required from anglers, but the annual catch by rod and line is very large. In 1968, for instance, 530 anglers volunteered details of their sea trout catch as 7 810 fish in that season. It is known that very many individual anglers catch 100–150 sea trout in a season. The total catch must therefore run into many thousands of fish. The weight of the individual sea trout caught by anglers varies from less than 0·5 kg in the case of whitling, to 7·5–10 kg particularly in the catchment of the river Towy. The heaviest sea trout recorded in recent years was a 10 kg fish caught in the river Eastern Cleddau.

No information is available with regard to brown trout catches within the Area. For various reasons, trout in the rivers are small in size (except in the upper and middle reaches of the river Teifi), though the annual catch probably amounts to many thousands. Some lakes and reservoirs provide reasonably good brown trout fishing.

The present rod and line licensing system has been in existence for five years and the average annual numbers of licences sold during this period are 7 730 season and 4 423 weekly migratory fishing licences, 4 985 children's licences and 146 brown trout licences. This means that the average number of anglers fishing within the Area during this period was 17 284.

The number of men engaged in commercial salmon and trout fishing in 1969 was 56 licence holders and 136 endorsees or servants. Many of these men are fully employed during the season on this commercial fishing.

In 1969, the River Authority derived an income of £23 926 from the sale of rod licences and £715 from the sale of net licences.

The total value of assessed fisheries (part only of the Area is assessed) was £11 748 in 1968. The rate imposed by the Authority was 12½p in the £1 (15p as from September 1st, 1970). Certain severed fisheries are liable to local authority rates in addition.

There are approximately 50 angling clubs in the Authority's Area and these and numerous riparian owners derive an income from the sale of fishing permits.

It is clear from the foregoing that fishing in the Area is of very great importance, and in addition to those interests directly connected with it, it is of prime importance to the tourist and hotel industries, fishing tackle shops, etc.

The actual value of the fishery, in terms of money, is difficult to assess. It is, however, notable that very high prices have been paid in recent years for only moderate fisheries.

Apart from the obvious tangible benefits, the fisheries afford recreational facilities for many thousands of people in the Area. In addition the maintenance of healthy fish populations is an important aspect of conservation. The value placed on this can clearly not be translated into monetary terms.

Effects of water abstraction It is an established fact that water abstraction can adversely affect fisheries in a variety of ways whether it is taken directly or by the construction of conventional reservoirs or regulating reservoirs. This is particularly true of anadromous species such as the salmon and sea trout which migrate into fresh water to spawn. The following paragraphs indicate the ways abstractions may exert their effects upon the fisheries.

Water abstractions may reduce the water available for the adequate dilution of effluents to a critical level, especially during dry weather. This is of particular importance in certain estuaries in South West Wales and this is referred to in some detail in Section 2.5 where it is noted that many of the estuaries are the most sensitive parts of the rivers.

A deterioration due to the abstraction of water upstream could kill fish moving through the estuary in either direction, or deter fish from moving. Smolts moving downstream in spring are in a sensitive condition physiologically and their ability or otherwise to pass through substandard quality water is probably one of the most important factors affecting the migratory fish populations in polluted rivers.

Enough water must be left in the river to permit the production, feeding and growth of immature migratory fish and brown trout. Critical factors are the areas of river bed remaining covered at low flows and the depth of the water.

Sufficient water must remain flowing to allow the migrations upstream of salmon and sea trout and there must be sufficient depth for the fish to swim in. The minimum flow required to allow upstream migration is not known and appears in any case to vary somewhat

according to the size of the fish and the species. There is some evidence that sea trout will move under lower flow conditions than salmon. Fish counting stations are clearly essential if accurate information with regard to this is to be obtained, and the River Authority is considering the installation of a Sonar Counter on the river Towy near Nantgaredig. Limited visual observations (admittedly of doubtful accuracy) during one season appeared to show that fish movement was most evident in the lower river Towy at flows between 15·79 m^3/s and 42·09 m^3/s. Further investigations are clearly called for. There is no evidence that the recirculation of saline water encourages fish movement.

Even higher flows appear to be necessary for the capture of adult salmon. In the river Teifi, the combined results for five years (1964–1968) indicate an optimum flow for salmon angling success of between 28·32 m^3/s and 33·96 m^3/s, whereas the average of the mean daily flows during the angling season was 20·11 m^3/s. In the river Towy, the average of six years results indicates an optimum flow for angling success of between 39·65 m^3/s and 45·28 m^3/s. (South West Wales River Authority Annual Reports 1967/68 and 1968/69.)

The effects of the construction of dams The construction of dams, in addition to affecting the fisheries by reducing or otherwise altering the flow in the river downstream, may render inaccessible spawning gravel and feeding grounds previously used by adult and juvenile salmon and/or sea trout.

Gravel suitable for spawning occurs widely within the Area, particularly in the upper reaches of the most productive rivers. It is, however, by no means confined to the upper reaches.

Fishery protection measures Possible damage to the fishery can, provided that certain conditions are fulfilled, be mitigated in a number of ways.

Where relatively low dams are constructed, a fish ladder or lock can be included to pass adult upstream migrants over the dam and onto spawning and feeding grounds (for the progeny) above. It is important, however, that descending smolts can find their way downstream and out of the reservoir. If this does not happen they apparently, in some instances, lose their urge to migrate. Predation of smolts in reservoirs can also be an important factor (Mills 1964).

Where higher dams are proposed (in excess of 50–70 m) a fish pass may not be practicable, and the upstream migrants could then be trapped below the dam and transported to the river above. In view of the problems associated with the downstream movement of smolts and referred to above, the trapping and manual transport of smolts downstream would be advantageous.

An alternative to the above would be the trapping of upstream migrants, their transport to a fish hatchery, and the production of eggs and/or fry which would then be planted out in the feeding grounds remaining above the reservoir. The movement of smolts downstream would be either by natural passage through the reservoir or by trapping and transport.

In the event of no spawning gravel and feeding grounds for the juvenile stages remaining above the reservoir, the trapping of adult migrants and the production of smolts at a hatchery and smolt rearing station would probably be the best method which could be adopted to compensate the fishery. Alternative possibilities would include the utilisation of virgin streams in the same catchment (if they exist) by the construction of a fish pass, or the planting of eggs and/or fry in the unused stream concerned.

Measures to protect fisheries must normally be taken at major intake works to prevent fish being sucked into the actual intake. This is normally done by the installation of screens which exclude smolts and other immature stages. A maximum velocity through the screens is also specified to avoid fish being swept against screens and killed.

The quality of water discharged from a reservoir to the river downstream has also to be considered, as when water is drawn from the hypolimnion it is often deficient in dissolved oxygen. This can usually be avoided by drawing water from near the reservoir surface or by aeration at or after discharge.

Fishery protection schemes In this Area there are examples of three large scale fishery protection schemes associated with major abstraction or diversion works. In each instance, the capital cost of the works is relatively high, and in the cases of Llysyfran and Brianne, the running costs constitute substantial items of expenditure.

Rheidol Hydro-electric Scheme (CEGB) Fishery protection works include a Borland fish lock built into the dam of the lowest reservoir at Cwm Rheidol. This enables upstream migrants to pass into the reservoir. The reservoir drowned quite valuable spawning and feeding grounds, so a fish ladder has been constructed upstream at Rheidol falls. This allows the passage of migratory fish onto spawning and feeding grounds previously inaccessible. Some minor difficulties have been experienced in connection with the passage of smolts out of the Cwm Rheidol Reservoir, but it appears that most pass safely through the Borland Lock and the turbines.

The compensation flows below the Nant-y-Moch and Dinas reservoirs (the other two reservoirs associated with the Hydro-electric Scheme) and the prescribed minimum flow downstream of the Cwm Rheidol reservoir, were all fixed bearing in mind the needs of the fisheries, both migratory and non migratory.

Llysyfran Regulating Reservoir (Pembrokeshire Water Board) This reservoir (due to be completed in late 1970) will drown spawning gravel used both by salmon and sea trout in the Afon Syfynwy (a tributary of the river Eastern Cleddau). Feeding ground for immature salmonids have also disappeared. A fish pass would serve no useful purpose as no spawning or feeding grounds will remain above the reservoir site. The scheme adopted therefore includes the trapping of upstream migrants and the production of smolts at a hatchery and smolt rearing

station. These are then placed in the catchment of the river Eastern Cleddau.

Llyn Brianne Regulating Reservoir (West Glamorgan Water Board) This reservoir and associated works are under construction in the upper reaches of the river Towy. The height of the dam precludes a fish pass and in any case, the size of the reservoir and the discharge from it would present serious difficulties to the passage of smolts. Ample spawning and feeding grounds will remain above the reservoir and therefore a trapping and transport scheme has been devised and is now operational. This involves the trapping of upstream migrants downstream of the dam site and their transport to spawning grounds upstream. Kelts and smolts are then trapped in two smolt traps and transported to the Towy downstream of the dam.

In this scheme and in the Llysyfran Scheme, the compensation flows below the reservoirs and the prescribed flows downstream of the intake have been fixed after due regard has been had to the fishery requirements.

In both cases also, measures have been taken at the intakes to prevent damage to fish by screening, and by limiting the velocities of flow through the screens.

Potential reservoir and storage sites It is outside the scope of the present survey to comment in detail on each of the potential reservoir or storage sites listed in 4.4. Each will obviously have to be the subject of careful consideration at the appropriate time.

It is, however, clear that many of them would be damaging to fisheries and therefore fishery protection schemes would have to be included as part of any proposal or proposals ultimately put forward.

3.6 Other Water Uses

Some of the existing demands for water have been mentioned in Section 3.3 namely, the British Waterways Board (Swansea Canal) who have a feeder from the river Tawe at Panteg Weir, the canal proceeding towards Swansea. There are also canal feeders on the upper and lower Clydach rivers, tributaries of the river Tawe. It is therefore necessary that these existing sources of supply to the canal should not be used for other purposes as there are times when the canal is unable to supply all the needs of the various abstractors in the lower reaches.

A similar condition arises with regard to the Tennant Canal which draws approximately 13 $640 \times 10^3 m^3/d$ from the Crymlyn Bog; this quantity is consistent with the rainfall over the very small catchment of the bog. There are already in existence, small dams and abstractions in the catchment area and it would not be possible to increase these abstractions without affecting the flow in the Tennant Canal. There is a connection between the canal and Swansea docks but it is in a poor condition and could only operate at high flows. This canal flows into the area of the Glamorgan River Authority and water flows both ways according to tidal conditions.

Milling is carried out mostly in Carmarthenshire and Cardiganshire with a little in Pembrokeshire. Here the water is used to drive machinery for the production of power both for corn milling and for the manufacture of wool products. The water is all returned to the river, the only detriment being the depletion in flow for a short length but in the dry season this could be serious as it affects pollution and/or fishery interests.

There is a growing demand, although small, for licences to abstract water for the operation of fish farms but this does not and never should affect the water resources in any area as the water is not 'lost' but only 'used' as in the case of water mills.

In Haverfordwest, proposals are being considered for the provision of water for emergency use in the fire fighting at a petrol storage depot. Water is also stored in the Crymlyn Bog area for fire fighting at the Llandarcy Oil Refinery.

3.7 General Amenity

All of the Pembrokeshire National Park and part of the Brecon Beacons National Park is within the Area. In addition there are certain Nature Reserves and sites of special scientific interest; all these are shown on Map 10.

Most of the rivers flow through areas of scenic beauty and offer recreation in the form of fishing, and some of them are used for canoeing.

It is the policy of the Authority to encourage the proper use of water for recreational purposes. The Authority believes that the construction of reservoirs, which in their case will be chiefly in the upland areas, even within National Parks should not detract from the general beauty of the area, but would provide additional recreational facilities and even enhance the scenic beauty of those upland areas.

Reference

1. Mills, D. H. (1964). The ecology of the young stages of the Atlantic Salmon in the River Bran (Ross-shire). Department of Agriculture & Fisheries Research 32.

Chapter 4 Future Development

4.1 Estimated Gross Needs

Public Water Supply Table 10 shows the various demands for the year 1967, 1971, 1981 and 2001. The method of extrapolation from past records has been used by the various water undertakings for many years and past experience has shown this to be the most reliable guide. If figures using litres per head per day and estimates of future population in various areas are used, very little difference is made in the final results.

It has not been found necessary to assume a large increase in demand to meet any influx of population. At the present there is a certain amount of unemployment in the Area and it is not thought that any industries that are brought to the Area to solve the unemployment problem would involve an increase in water consumption as the majority of the employment would be given to people already in the Area.

In the case of the small water undertaking the demands are exceedingly small and in some cases show no increase whatsoever. Even in the cases where slight increases occur between one period and the other no great significance is attached to these figures, for the reason that the undertakings are very small, with a rural population and located in an area which is not likely to benefit from new industries; in fact it is probably not out of place to say that such rural areas are losing some of their population to the more industrialised centres, thus these constant figures would appear to be justified.

In the case of the Cardiganshire Water Board and the West Glamorgan Water Board a certain quantity of water leaves the Area and some is also brought into the Area. The Cardiganshire Water Board have a pipeline from the Nantymoch catchment taking water to a reservoir in the Gwynedd River Authority area; water is supplied locally, and approximately $1{\cdot}82 \times 10^3 m^3/d$ is imported into the Area (see Table 10a).

The West Glamorgan Water Board, at 1st April 1970, imports $65{\cdot}91 \times 10^3 m^3/d$ of water from the Usk River Authority but the demand figures refer solely to that part of the West Glamorgan Water Board area within the boundary of the Area.

No account has been taken of any possibility of large quantities of water being supplied to areas outside this Area, although discussions are taking place at present on this subject.

Direct Industrial Use In the south-east region and in the Milford Haven region the public water supply undertakings are supplying large quantities of water direct to industry. In the case of the Pembrokeshire Water Board raw water is supplied to the oil refineries in the Haven and the Llanelli and District Water Board have one reservoir devoted solely to the supply of raw water to a tinplate works. These quantities have of course been taken into account in the figures supplied by the various water undertakings.

In the case of direct abstractions it is much more difficult to estimate and make provision for industrial expansion. The returns submitted under Section 114 of the 1963 Act have not been available for a long enough period to establish any trend, and even if available, it would be exceedingly difficult to give a very reliable forecast as so much would depend upon the trend in the establishment of new industries. A considerable number of light industries has been established within the Area, but these are not large users of water and rely upon public water undertakings. It appears that there is little likelihood of very large industries requiring direct abstraction being established in the Area.

It is not anticipated that there will be an increase in demand for industrial water for use by the Central Electricity Generating Board, as at the present moment the power stations are being decreased in number. Only larger stations which use water from estuaries are predicted and such abstraction of water does not have any effect on the water resources of the Area. The hydro-electric power scheme at Cwm Rheidol does not include plans for increased generation of power.

Spray irrigation demands have been estimated as accurately as possible. It is not easy to see the trends in spray irrigation in this Area as a great deal depends upon the nature of the crop to be irrigated; the chief crops at present are early potatoes with a small amount of grass land for beef cattle. Some increase of demand has been allowed for, but as so much depends on agricultural policy in the future, it is not possible to base any estimates on a prescribed formula.

To summarise, it can be said that using all the data available, provision has been made for all foreseeable demands. It is considered that these demand figures should provide ample room for a reasonable expansion in domestic demands, direct industrial use (which includes cooling water for electricity production) and also water for spray irrigation.

Other Uses There is no reason to expect an increase in this category.

4.2 Redeployment of Existing Resources

There are within the Area certain conventional reservoirs. They were built some distance from the main distribution area and the water mains supply water along their length. If these reservoirs were to be used as regulation reservoirs, it would be necessary, in most cases, to pump the water back up valleys to supply the higher areas. Therefore, there is little or no value in the conversion of these reservoirs to regulating reservoirs as the cost involved in extra pumping would exceed the benefit to supplies.

A typical example of the difficulty in the change of use of reservoirs is that of the Usk and Cray reservoirs, which belong to the West Glamorgan Water Board and are located in the Usk River Authority area. These reservoirs would be most useful to the regulation of the river Usk and would meet the deficiency in the Usk Authority area for a limited period. However, the question of cost comes into this problem as a supply to the higher level of the West Glamorgan Water Board area from the Nantgaredig abstraction on the river Towy would entail pumping

against a head of approximately 122 m with two separate pipelines approximately 19 km long. To do this it would be necessary to pump an extra quantity at Nantgaredig and re-pump up the Swansea Valley and along the area supplied by the Usk pipeline, thus entailing a continuing high cost for the sake of a regulated supply to the river Usk for a limited period before further new works are built.

To get the greatest benefit from a regulating scheme the abstraction is better placed in the lower reaches of a river as the catchment area is greater. Even if the abstraction takes place in the middle reaches there would, in the above cases, still be a considerable area of high land to be supplied and at an increased cost; so it is not considered to be of any benefit to use existing conventional reservoirs for regulating purposes.

4.3 Estimate of Net Needs

Net abstraction is that water lost to a specific section of stream under consideration. At one end of the scale water may be used for milling and similar purposes where all the water is passed down a leat, used and then returned to the main stream without any loss; the middle of the scale includes water used for cooling purposes where evaporation takes place, or in the manufacturing process where water is partly lost, such as brewing and similar processes; the other end of the scale embraces water lost completely to the catchment and includes such uses as spray irrigation and public water supply or industry where the resultant effluent is discharged direct to the sea.

The above factors have been taken into consideration in arriving at the net requirements for the specified periods of time.

It is assumed in assessing net requirements from underground sources that all water abstractions are net, there being no return of the water to underground strata.

With the type of rivers under review it is not thought to be of any practical use to prepare residual flow diagrams for the main rivers, as the major abstractions, which are in most cases for domestic water supply purposes, discharge their effluents direct to the sea. In the case of major power station abstractions which are on the coast, these would not be shown on any residual diagrams.

Agricultural needs have been estimated on the assumption that there is a complete loss to the stream and the factor of 'one' has been used in the tables.

4.4 Potential Surface Storage

This section of the survey deals purely with the physical factors and takes no account of sociological, agricultural, amenity or any other interest; it is a practical survey of water resources. With new methods of desalination, the acceptance of estuarine barrages, the reuse of sewage effluent and the possible flattening off of demand curves, the whole question of meeting demands may have altered by the time decisions are required on individual proposals and their impact on affected localities.

In view of the large number of sites listed, it is not considered that these should have any effect on land value or the use of land as it is evident that all the sites would not be required, and, as will be seen from the report, the foreseeable need for additional development within the Area does not arise until the period approximately 1991 to 2001, and even then only the deficiencies of Pembrokeshire have to be met.

Alternative pumped storage and gravity diversions are available in many cases to avoid flooding of productive valleys, but at a greater cost.

Estuarine barrages have not been included in the list of potential surface storage as the need for the same in this Area is not fully accepted.

In the preparation of Table 14 a standard method of yield calculation has been adopted to enable sites to be compared. This has been necessary due to the brevity of hydrological data.

Direct supply reservoir yields quoted are gross and include compensation flows, or where a regulating reservoir is quoted in the same catchment they include any allowance required for regulation.

Regulating reservoir yields quoted are average yields for the development of a river basin to 30% of the ADF at the abstraction point. Thus the first reservoir constructed in a system may have an underestimated yield, and the second reservoir's yield could be overestimated.

The following two regulating reservoirs were under construction on 1st April, 1970 (Map 5).

Hydrometric Area	Location	Water Board	Type	Yields at Abst. Point $10^3 m^3/d$	Remarks
60	(i) Llyn Brianne	West Glamorgan Water Board	R	386·418	Stage I
61	(ii) Llysyfran	Pembrokeshire Water Board	R	85·200	Stage I
				135·200	Stage II

Notes: (i) *The abstraction point is just below Nantgaredig. Stage II is shown in Table 14.*
(ii) *The abstraction point is at Canaston Bridge.*

4.5 Potential Ground Water Storage

It will have been noted from earlier sections of the survey that there is ample surface water and that the geology of the Area is such that no major ground water resources exist. The most likely source is in HA 59 and then most of the water is polluted, but could be used for selected purposes in small quantities.

In view of the proposed development of surface water in the Area it is not proposed to investigate nor to develop the ground water resources at present.

The problem of assessing the storage would involve a high cost and expert opinion and this is not considered necessary unless specifically required.

4.6 Potential Yields

This section has been combined with Section 4.4 in so far as reservoir yields are concerned as well as storage. It will be seen from the list of reservoirs (Table 14) that sites have been selected on each river and yields have been shown against these various sites, both for normal regulation and for direct supply.

Only sites yielding at least $68{\cdot}5 \times 10^3 m^3/d$ have been listed in this first survey.

Chapter 5 Programme for Augmenting Future Resources

Bearing in mind the net demands for domestic and industrial needs it is apparent that these needs can be met from within the Area and can be obtained from works already in progress, or proposed, with the exception of a deficiency in Pembrokeshire of $53{\cdot}2 \times 10^3 m^3/d$ by the year 2001.

Examining the deficiencies of each undertaking in the specified years the following picture emerges:—

1971

a. Newcastle Emlyn Rural District Council will have a deficiency of 450 m^3/d; this can be found from local sources or can be supplied by the Cardiganshire Water Board. The quantity is so very small as to be of no consequence.

b. The West Glamorgan Water Board will have a deficiency of $86{\cdot}80 \times 10^3 m^3/d$. This deficiency occurs prior to the completion of the Llyn Brianne regulating scheme and assumes that the Usk and Cray reservoirs have been transferred to the Usk River Authority. In fact, at the time of writing, this transfer has not taken place; thus the deficiency could be reduced to $18{\cdot}2 \times 10^3 m^3/d$. No means are readily available to meet this deficiency except by local economy in the use of water or by above average rainfall.

1981

a. Cardiganshire Water Board at this time will have a deficiency of $2{\cdot}27 \times 10^3 m^3/d$; but it is anticipated that by this date two schemes will have come into operation, thus eliminating the deficiency and in fact creating a surplus of $9 \times 10^3 m^3/d$.

b. Llanelli and District Water Board will have at this time a deficiency of $6{\cdot}82 \times 10^3 m^3/d$ and this quantity could be taken from the river Towy as part of the $68{\cdot}20 \times 10^3 m^3/d$ reserve in the Llyn Brianne regulating scheme, referred to by the Secretary of State for Wales in letter reference LA 3495/9770 dated 7th June 1968.

c. At this date the Loughor Joint Water Board will have a deficiency of 910 m^3/d, but this very small quantity could be met from the West Glamorgan Water Board's supply or local sources. The quantity is insignificant.

d. Newcastle Emlyn Rural District Council at this time will have a deficiency of $1{\cdot}82 \times 10^3/d$ and it is anticipated that this could be met by the Cardiganshire Water Board.

2001

a. At this date the Cardiganshire Water Board will have a deficiency of $11{\cdot}36 \times 10^3 m^3/d$, but when the new works are carried out as stated previously, this deficiency will be eliminated.

b. Carmarthen Borough Council will have at this time a deficiency of $4{\cdot}09 \times 10^3 m^3/d$ which could be taken from the river Towy as part of the $68{\cdot}20 \times 10^3 m^3/d$ reserve in the Llyn Brianne regulating scheme, referred to by the Secretary of State for Wales in letter reference LA 3495/9770 dated 7th June 1968.

c. Llandovery Borough Council will have a deficiency of 455 m^3/d at this time which could be met by increasing the abstractions from the river gravels at Llandovery without having any adverse effect on the flow in the river.

d. Llanelli and District Water Board will at this time have a deficiency of $34{\cdot}10 \times 10^3 m^3/d$ which could again be taken from the river Towy.

e. Loughor Joint Water Board at this date will have a deficiency of $4{\cdot}55 \times 10^3 m^3/d$ which could be met by agreement with the West Glamorgan Water Board or from local sources.

f. Newcastle Emlyn Rural District Council will have at this date a deficiency of $6{\cdot}36 \times 10^3 m^3/d$ which could be met by the Cardiganshire Water Board or from local sources.

g. The Pembrokeshire Water Board will at this date have a deficiency of $53{\cdot}2 \times 10^3 m^3/d$ which could be met by constructing a regulating reservoir at Wolf's Castle with an abstraction point at Crow Hill on the river Western Cleddau. This site would be the most economic way of providing the required quantity. An alternative scheme would entail further use of the Eastern Cleddau with supporting storage. This is being investigated.

Chapter 6 Summary and Recommendations

Summary

By reference to the previous chapters and to the various diagrams and maps it will be observed that there is ample rainfall over the Authority's area and the run-off is sufficient to supply the internal needs up to and beyond the year 2001.

The works already in course of construction, such as the Llyn Brianne regulating reservoir for the West Glamorgan Water Board and the Llysyfran regulating reservoir for the Pembrokeshire Water Board include provisions for raising the dams and thus increasing the storage. In the case of the Llyn Brianne reservoir this will be sufficient to the year 2001, but as regards the Pembrokeshire Water Board area, it will be necessary to find an additional $53{\cdot}2 \times 10^3 m^3/d$ before the year 2001.

The area in the north-west, that is roughly the area of the Cardiganshire Water Board, already has schemes prepared which will meet the needs of that area up to the year 2001.

Recommendations

The following recommendations are made as a guide to assist the statutory water undertakings to meet their deficiencies.

a. Newcastle Emlyn Rural District Council should apply to the Cardiganshire Water Board for an increased supply.

b. Carmarthen Borough Council should apply to the West Glamorgan Water Board for a supply from the Towy Brianne reservation of $68{\cdot}2 \times 10^3 m^3/d$ to meet any of their deficiencies.

c. The Llanelli and District Water Board should apply to the West Glamorgan Water Board for a supply from the Towy Brianne reservation of $68{\cdot}2 \times 10^3 m^3/d$ to meet their deficiencies.

d. The Loughor Joint Water Board should apply to the West Glamorgan Water Board for the small quantity required or if this proposal is found to be unacceptable then the supply could possibly be augmented from local sources.

e. Consultations should take place with the Pembrokeshire Water Board and investigations commenced with regard to the question of supplying the deficiency in Pembrokeshire. The outcome could be a regulating reservoir on the river Western Cleddau with the point of abstraction at Crow Hill, or use of a tidal barrier on the river Eastern Cleddau, or alternatively the construction of a reservoir outside the Cleddau group, the water being transferred to the river Eastern Cleddau and abstracted at Canaston Bridge.

f. Consideration should be given to the carrying out of a hydrological investigation into the various potential regulating reservoirs listed in section 4.4 when required.

g. Measures should be taken to secure substantial improvements in the quality of effluents discharging into the lower reaches and estuaries of certain rivers within the Area. In this context, particular reference is made to the rivers Loughor, Towy, Western Cleddau and Teifi.

h. The work already undertaken with regard to the control of pollution from metalliferous mines in the catchments of the rivers Rheidol and Ystwyth should be continued, and wherever practicable, further improvements be brought about. The position in connection with the possible explorations for minerals in the upper reaches of the rivers Towy and Teifi should be kept under close surveillance.

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Conversion Factors

British Units	Br/Met Units		Metric Units
0·0394 inches	1	mm	25·4 millimetres
3·281 feet	1	m	0·3048 metres
0·6214 mile	1	km	1·609 kilometres
10·764 sq feet	1	m^2	0·0929 sq metres
0·3861 sq miles	1	km^2	2·59 sq kilometres
35·315 cubic feet	1	m^3	0·0283 cubic metres
0·220 gallons	1	l	4·546 litres
0·00022 mgd	1	m^3/day	4 546·1 cubic metres/day
19·005 mgd	1	m^3/s	0·0526 cumec
35·315 cusecs	1	m^3/s	0·0283 cumec
0·0353 cusecs	1	l/s	28·317 litres per sec
0·0915 cusec/sq mile	1	l/s km^2	10·933 litres/sec km^2
0·143 cusec/1 000 acres	1	l/s km^2	6·997 litres/sec km^2
0·984 UK ton	1	t	1·016 tonne (1 000 kg)
2·471 acres	1	ha	0·405 hectares (100 km^2)
0·0008 acre feet	1	m^3	1 233·500 cubic metres
0·00025 acre	1	m^2	4 046·9 sq metres

Each thousand is represented by a space – eg 2 124

Tables

TABLE 1
Hydrometric Areas and Catchment Details

Hydrometric Area No.	Name	Catchment No.	Name	Av Areal Rainfall mm over catchment	Residual mm over catchment	Area km²
59	River Tawe Group	1	Tawe	1 769	1 266	246
		2	Loughor	1 631	1 128	262
		3	Llanelli Area	1 311	797	72
		4	Gower and Area	1 235	721	262
		5	Crymlyn Bog	1 165	613	19
			Total			**861**
60	River Towy Group	1	Towy above Cothi	1 559	1 056	753
		2	Cothi	1 640	1 137	306
		3	Lower Towy and Gwili	1 446	932	276
		4	Upper Taf	1 404	901	279
		5	Dewi Fawr	1 463	949	99
		6	Lower Taf and Cywyn	1 371	857	136
		7	Gwendraeth Fawr and Fach	1 320	806	207
			Total			**2 056**
61	Rivers Eastern and Western Cleddau Group	1	Nevern and Gwaun	1 289	762	219
		2	St. David's Head Coastal	1 141	614	189
		3	Western Cleddau	1 313	786	314
		4	Eastern Cleddau	1 431	904	237
		5	Milford Haven Coastal	1 078	519	155
		6	Tenby Coastal	1 155	596	364
			Total			**1 478**
62	River Teifi Group	1	Upper Teifi	1 552	1 064	314
		2	Middle Teifi	1 328	840	390
		3	Lower Teifi	1 176	688	304
			Total			**1 008**
63	North Cardiganshire Group	1	Rheidol	1 760	1 272	189
		2	Bow Street Coastal	1 144	656	57
		3	Ystwyth	1 435	947	193
		4	Wyre Coastal	1 140	652	136
		5	Aeron	1 284	796	162
		6	New Quay Coastal	1 128	576	127
			Total			**864**
			Grand Total			**6 267**

TABLE 2
Monthly Rainfall and Evaporation in a Dry Year:—1963/64 – mm

	River Tawe Catchment or Sub-catchment 59/1			River Towy Catchment or Sub-catchment 60/1 and 60/3			River E. Cleddau Catchment or Sub-catchment 61/4			River Teifi Catchment or Sub-catchment 62/1/2/3			River Ystwyth Catchment or Sub-catchment 63/3		
	Rainfall	Evapn	Residual	Rainfall	Evapn	Residual	Rainfall	Evapn	Residual	Rainfall	Evapn	Residual	Rainfall	Evapn	Residual
October	122	1	121	94	0	94	114	3	111	86	0	86	102	0	102
November	328	9	319	244	9	235	267	11	256	231	9	222	229	9	220
December	58	29	29	46	30	16	51	32	19	28	29	−1	25	29	−4
January	35	20	15	33	24	9	35	24	11	36	23	13	58	23	35
February	61	5	56	53	8	45	48	10	38	38	7	31	43	7	36
March	107	0	107	94	0	94	107	3	104	76	0	76	71	0	71
Winter Total	**711**	**64**	**647**	**564**	**71**	**493**	**622**	**83**	**539**	**495**	**68**	**427**	**528**	**68**	**460**
April	109	53	56	84	49	35	86	48	38	61	50	11	66	50	16
May	117	77	40	91	75	16	109	73	36	76	75	1	81	75	6
June	79	80	−1	74	71	3	94	71	23	71	67	4	68	67	1
July	137	89	48	97	83	14	112	81	31	92	77	15	140	77	63
August	99	83	16	94	77	17	92	76	16	94	75	19	135	75	60
September	74	64	10	86	51	35	43	62	−19	53	51	2	61	51	10
Summer Total	**615**	**446**	**169**	**526**	**406**	**120**	**536**	**411**	**126**	**447**	**395**	**52**	**551**	**395**	**156**
Year	**1 326**	**510**	**816**	**1 090**	**477**	**613**	**1 158**	**494**	**664**	**942**	**463**	**479**	**1 079**	**463**	**616**

Note: Evapn is long term county average PE for winter term, slightly adjusted, and 1964 county values for summer term.

TABLE 3
River Flow Records

Catchment or Sub-catchment No.	Name	Name of river and Gauging Station	National Grid Reference of Gauging Station	Records Available From	To	Period of low flows From	To	Drainage Area down to Gauging Station (km²)	Average Discharge (m³/s)	mm over catchment	Extreme Discharges Highest and Date (m³/s)	Lowest and Date (m³/s)	Remarks eg Accuracy of Gauging Station, etc
59/1	R Tawe Group	R Tawe Ynystanglws	SS 685998	Oct 57	Present			228	12·370	5	27.2.67 323·848	Sep/ Oct 59 0·453	Unstable bed. Rating subject to change.
59/2	R Tawe Group	R. Loughor Tirydail	SN 624127	Oct 68	Present			46·4			New Station		Weir control – Good.
60/1	R Towy Group	R Towy Dolauhirion	SN 762362	Oct 68	Present			232			New Station		Rock control – Good.
60/1	R Towy Group	R Bran Llandovery	SN 771343	Oct 68	Present			66·8			New Station		Appears to be reliable.
60/1	R Towy Group	R Sawdde Felin y Cwm	SN 712266	Oct 70				81					Flat "V" Weir under construction.
60/1	R Towy Group	R Towy Manoravon	SN 656239	Oct 68	Present			562			New Station		Reliable up to bank full.
60/2	R Towy Group	R Cothi Felin Mynachdy	SN 508224	Oct 61	Present			298	12·271	4	12.12.64 274·710	9 Jul 62 0·651	Rock bed and sides. Good.
60/2	R Towy Group	R Twrch Farmers	SN 650440	Oct 70				20·7					Current meter station under construction.
60/3	R Towy Group	R Towy Tycastell Farm	SN 491204	Oct 58	Present			1 090	43·925	3	3.2.60 577·740	Sep/ Oct 59 1·189	Unstable bed. Flat "V" Weir under construction.
60/3	R Towy Group	R Gwili Glan Gwili	SN 431220	Oct 68	Present	Since Records Commenced		130			New Station		Appears to be reliable.
60/4	R Towy Group	River Taf Clog y Fran	SN 238160	Oct 65	Present			217	7·726	3	18.12.65 27.2.67 61·739	Aug/ Sep 68 1·189	Stable bed. Overspill at very high flows.
60/5	R Towy Group	R Dewi Fawr Glasfryn Ford	SN 290175	Oct 68	Present			40·1			New Station		Ford control good.
60/7	R Towy Group	R Gwendraeth Fach Pont Felin Gwendraeth	SN 418103	Oct 70				71·2					Not yet constructed.
61/1	R Nevern Group	R Gwaun Cilrhedyn Bridge	SN 005349	Oct 68	Present			31·3			New Station		Appears to be reliable.
61/3	R Cleddau Group	R Western Cleddau Prendergast Mill	SM 954177	Oct 65	Present			198	6·137	3	27.2.67 5.11.67 51·827	29–31 Aug 68 0·623	Stage affected by very high tides. Proposed to move point of stage measurement.
61/4	R Cleddau Group	R Eastern Cleddau Canaston Bridge	SN 072153	Oct 60	Present			183	6·106	3	12.12.64 199·377	6–9 Jul 62 2 Aug 62 0·651	Stage affected by downstream shoaling. Rating subject to change.
62/2	R Teifi Group	R Teifi Llanfair	SN 433406	Oct 70				546					Current meter station under construction.
62/3	R Teifi Group	R Teifi Glan Teifi	SN 244416	Oct 59	Present			894	31·025	3	19.12.65 259·700	1–8 Oct 59 0·920	Reliable, subject to seasonal weed clearing.
63/1	R Ystwyth Group	R Rheidol Llanbadarn Fawr	SN 601804	Oct 65	Present			182	9·657	5	17.12.65 145·285	7–11 Aug 68 1·246	No assessment of natural flow, owing to complex CEGB Scheme.
63/3	R Ystwyth Group	R Ystwyth Pont Llolwyn	SN 591774	Apr 63	Present			170	5·451	3	12.12.64 210·422	29 Aug–1 Sep 68 0·255	Stable bed. Cableway extended to facilitate measurement of high flows.
63/4	R Ystwyth Group	R Wyre Llanrhystyd	SN 542698	Oct 68	Present			55·9			New Station		Ford control – Good.

Note: Eastern Cleddau. Average and Extreme Discharges based on period of records to 30th September, 1966 only. In all other cases to 30th September, 1968.

TABLE 4
Theoretical Ground-Water Resources (Simplified)

Ground-water unit: Hydrometric sub-catchment	Aquifer	Area of outcrop of aquifer (km^2)
59/1	d^6	100
	d^3	19
	d^4	48
59/2	d^6	89
	A	31
	d^3	2
	d^4	24
59/3	d^6	42
	A	10
59/4	d^6	84
	A	17
	d^3	66
	d^4	28
59/5	d^6	8
	A	4
60/1	A	45
	d^3	12
	d^4	17
60/2	A	12
60/3	A	17
60/4	A	20
60/5	A	5
60/6	A	6
60/7	d^6	5
	A	20
	d^3	12
	d^4	29
61/1	A	4
61/2	A	2
61/3	A	11
	d^4	22
61/4	A	8
	d^3	1
	d^4	5
61/5	d^6	4
61/6	A	8
	d^3	99
	d^4	48
62/1	A	15
62/2	A	11
62/3	A	6
63/1	A	1
63/3	A	1
63/5	A	8

Key: d^6 *Pennant Sandstone*
d^4 *Millstone Grit*
d^3 *Carboniferous Limestone*
A *River gravels and alluvium.*

Notes: 1. Superficial deposits include glacial gravels, sands, boulder clay, and peat and alluvium.
2. Built up areas are very small in relation to the rest of the catchment areas.

TABLE 6
Population and Area Statistics

Zone No.	Water Undertakings	Area km^2	Population 1 000's	
1	Pembrokeshire Water Board	1 590	97	
	Zone Total	**1 590**	**97**	
2	Cardiganshire Water Board	1 792	(i)W51	S100
	Newcastle Emlyn RDC	335	8	
	Newcastle Emlyn UDC	1	1	
	Zone Total	**2 128**	**W60**	**S109**
3	West Glamorgan Water Board	1 008	(i)256	
	Loughor Joint Water Board	117	14	
	Llanelli and District Water Board	235	78	
	Cwmamman UDC	4	5	
	Llandovery BC	4	2	
	Llandeilo UDC	10	2	
	Llandeilo RDC	907	16	
	Carmarthen BC	21	13	
	Carmarthen RDC	699	28	
	Zone Total	**3 005**	**414**	
4	Loughor Joint Water Board	117	16	
	Llanelli and District Water Board	235	78	
	Cwmamman UDC	4	5	
	Llandovery BC	4	2	
	Llandeilo UDC	10	2	
	Llandeilo RDC	907	12	
	Carmarthen BC	21	12·8	
	Carmarthen RDC	699	21·3	
	Zone Total	**1 997**	**149·1**	

W=Winter
S=Summer
(i) *Estimation of population within the River Authority boundary.*

TABLE 6
Licensed Surface-Water Abstraction on 30th September 1968

No.	Catchment Name	Public Supply $10^3m^3/d$	Industry $10^3m^3/d$	Agriculture $10^3m^3/d$	Miscellaneous $10^3m^3/d$	Total Licensed Abstraction $10^3m^3/d$
59	River Tawe Group	57·692	247·773	0·101	0·023	305·589
60	River Towy Group	385·651	18·148	0·029	Nil	403·828
61	River Cleddau Group	171·318	4 910·131	2·913	Nil	5 084·362
62	River Teifi	9·224	1·832	0·016	1·179	12·251
63	North Cardiganshire Group	2·688	604·274	0·003	0·157	607·122
	Totals	**626·573**	**5 782·158**	**3·062**	**1·359**	**6 413·152**

TABLE 7
Licensed Ground-Water Abstraction on 30th September 1968

No.	Catchment Name	Public Supply $10^3m^3/d$	Industry $10^3m^3/d$	Agriculture $10^3m^3/d$	Miscellaneous $10^3m^3/d$	Total Licensed Abstraction $10^3m^3/d$
59	River Tawe Group	9·128	3·717	0·365	0·004	13·214
60	River Towy Group	3·438	4·713	0·984	Nil	9·135
61	River Cleddau Group	Nil	Nil	0·002	Nil	0·002
62	River Teifi	0·269	Nil	0·230	0·007	0·506
63	North Cardiganshire Group	Nil	0·068	0·072	Nil	0·140
	Totals	**12·835**	**8·498**	**1·653**	**0·011**	**22·997**

TABLE 8
Public Water Supply: Simple Balance of Resources and Demands – $10^3m^3/d$

Zone	Average Demands 1967	1971	1981	2001	Net Resources	Apparent overall Deficiencies (–) or Surpluses (+) on Total Authorised Resources 1971 +	1971 –	1981 +	1981 –	2001 +	2001 –
1	47·28	79·55	126·37	198·19	145·01	65·46	—	18·64	—	—	53·18
2	12·73	16·82	22·28	35·91	29·55	12·73	—	7·27	—	—	6·36
3	153·17	186·37	246·83	376·83	498·68	—	(1) 64·10	251·85	—	121·85	—
Totals	**213·18**	**282·74**	**395·48**	**610·93**	**673·24**	**78·19**	**(1) 64·10**	**277·76**	—	**121·85**	**59·54**
4	60·44	70·91	93·18	134·54	93·65	22·74	—	0·47	—	—	40·89

Note: The composition of the zones is given in Section 3.1 and in Table 5.
(1) Llyn Brianne abstraction is licensed and appears in Net Resources but as it will not be in operation until 1972 it is shown as a deficiency for 1971.

TABLE 9
Summary of Actuel and Licensed Ground-Water Abstraction – $10^3m^3/d$

Ground-water unit Hydrometric Area	Aquifer	Total actual abstraction (part estimation)	Total Licensed abstraction (from Table No. 7)
59	Pennant Sst and Carb Lst	2·50	13·214
60	River gravels, with some Pennant Sst, Carb Lst and Millstone Grit	2·39	9·135
61	River gravels, with some Carb Lst and Millstone Grit	Nil	0·002
62	River gravels	0·025	0·506
63	River gravels	Nil (quantity too small)	0·140

Note: As the Area has an abundance of surface water, and poor aquifers, this table is only an indication of the licensed and used ground-water quantities in the various aquifers and is thus not a true balance.

TABLE 10
Public Water Supply: Demands and Resources – $10^3m^3/d$

Undertaking	Average Daily Demands 1967	1971	1981	2001	Reliable Yield of Resources Auth	Bulk Supplies +	Bulk Supplies −	Net	Apparent Overall Deficiencies (−) or Surpluses (+) on Net Resources 1971 +	1971 −	1981	2001 −	2001 +	2001 −
Column No.	1	2	3	4	5	6	7	8 (5+6 −7)	9 (8−2)	10 (8−2)	11 (8−3)	12 (8−3)	13 (8−4)	14 (8−4)
Cardiganshire WB (i)	10·91	14·55	18·64	27·73	27·73 (iv)	—	—	27·73	13·18	—	9·09	—	—	—
Carmarthen BC	3·18	4·55	9·09	13·64	9·55	—	—	9·55	5·00	—	0·45	—	—	4·09
Carmarthen RDC	4·09	4·55	5·45	9·09	4·09	5·45	—	9·55	5·00	—	4·09	—	0·45	—
Cwmamman UDC	0·91	1·36	1·36	1·82	1·82	—	—	1·82	0·45	—	0·45	—	—	—
Llandeilo RDC	3·64	3·64	4·55	5·91	0·91	6·82	—	7·73	4·09	—	3·18	—	1·82	—
Llandeilo UDC	0·45	0·45	0·45	0·45	0·45	—	—	0·45	—	—	—	—	—	—
Llandovery BC	0·45	0·45	0·91	1·36	0·91	—	—	0·91	0·45	—	—	—	—	0·45
Llanelli and District WB	42·27	50·00	63·64	90·91	65·00	—	8·18	56·82	6·82	—	—	6·82	—	34·09
Loughor Joint WB	5·45	5·91	7·73	11·36	6·82	—	—	6·82	0·91	—	—	0·91	—	4·55
Newcastle Emlyn RDC	1·82	2·27	3·64	8·18	1·82	—	—	1·82	—	0·45	—	1·82	—	6·36
Pembrokeshire WB (ii)	47·28	79·55	126·37	198·19	146·37	—	1·36	145·01	34·09	—	18·64	—	—	53·18
West Glamorgan WB (iii)	92·73	115·46	153·65	242·29	408·21	—	3·18	405·03	—	86·82	251·38	—	162·74	—
Totals	**213·18**	**282·74**	**395·48**	**610·93**	**673·68**	**12·27**	**12·72**	**673·24**	**69·99**	**87·27**	**287·28**	**9·55**	**165·01**	**102·72**

TABLES 10a, 10b, 10c

	Average Daily Transfers – $10^3m^3/d$ 1971	1981	2001
a. Imports			
Cardiganshire WB transfer from the Gwynedd RA area	1·82	1·36	0·91
West Glamorgan WB transfer from the Usk RA area	65·91	65·91	65·91
Totals	**67·73**	**67·27**	**66·82**
b. Exports			
West Glamorgan WB transfer to the Glamorgan RA area	Nil	57·73	105·46
c. Effective Deficiencies	22·73	Nil	68·18

Notes: (i) *The import from the Gwynedd River Authority area is shown in Table 10a but does not appear in Table 10.*
(ii) *The second stage of this Llysyfran Regulating Reservoir Scheme has been taken into account in the table although no abstraction licence has been approved.*
(iii) *The figures do not take into account the import from the Usk and Cray Reservoirs which is shown in Table 10a nor the export to the Glamorgan River Authority area shown in Table 10b.*
(iv) *The authorised yield of 27·73 × $10^3m^3/d$ includes works for which an abstraction licence has been approved.*
The Newcastle Emlyn Urban District Council has been omitted from the table as the quantities are so small.

TABLE 11
Direct Industrial Demands – $10^3m^3/d$

	Gross Demands Current	1981	2001	Authorised Abstraction	Factor Net/Gross	Net Abstraction	Net Demands Current	1981	2001	Nominal Net Deficiencies Current	1981	2001
Column No.	1	2	3	4	5	6	7	8	9	10	11	12
Industry – cooling		—	—	69·5	—	—	—	—	—	Nil	Nil	Nil
– other than cooling		—	—	55·0	—	—	—	—	—	—	—	—
CEGB – direct cooling	—	—	—	—	—	—	—	—	—	—	—	—
– evaporation	—	—	—	—	—	—	—	—	—	—	—	—
– hydro power	618·3	618·3	618·3	618·3	—	—	—	—	—	—	—	—
Total: (Non-tidal)		—	—	—	—	—	—	—	—	Nil	Nil	Nil
CEGB – direct cooling (tidal)	168·2	4 973·4	4 973·4	5 141·6	—	—	—	—	—	—	—	—

Gross Demands – the average daily quantity of water abstracted from the source.
Authorised Abstraction – the average daily quantity of water licensed, or permitted, to be abstracted from the source.
Factor net/gross – the ratio of the quantity of water not returned to the resources of the area to the quantity of water abstracted.
Net Abstraction – Authorised abstraction × Factor Net/Gross.
Net Demands – Gross Demands × Factor Net/Gross (ie the quantity not available for re-use).
Deficiencies – Excess of Net Demand over Authorised Net Abstraction.

TABLE 12
Direct Agricultural Demands – $10^3 m^3/d$

		Gross Demands 1967	1971	1981	2001	Auth Abst	Factor Net/Gr	Net Abst	Net Demands 1967	1971	1981	2001	Nominal Net Deficiencies 1971	1981	2001
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Agriculture – normal	(i)	60·0	65·0	75·0	100·0	—	—	—	—	—	—	—	—	—	—
Spray irrigation	(ii)	4·5	9·1	18·2	22·7	4·5	1	4·5	4·5	9·1	18·2	22·7	4·5	13·6	18·2
Total		**64·5**	**74·1**	**93·2**	**122·7**	**4·5**	**1**	**4·5**	**4·5**	**9·1**	**18·2**	**22·7**	**4·5**	**13·6**	**18·2**

Gross Demands – the average daily quantity of water abstracted from the source.
Authorised Abstraction – the average daily quantity of water licensed, or permitted, to be abstracted from the source.
Factor Net/Gross – the ratio of the quantity of water not returned to the resources of the area to the quantity of water abstracted.
Net Abstraction – Authorised abstraction × Factor Net/Gross.
Net Demands – Gross Demands × Factor Net/Gross (ie the quantity not available for re-use).
Deficiencies – Excess of Net Demand over Authorised Net Abstraction.
(i) *No details of 'Agriculture – normal' demands available as licences not issued for this class of water use in this Authority's Area but an estimate has been made using the Ministry of Agriculture, Fisheries and Food figures for animal consumption.*
(ii) *The quantities under 'Spray irrigation' are obtained by dividing the annual quantity authorised by 365 days.*

TABLE 13
Public Water Supplies in Zones – $10^3 m^3/d$

		Available Potable		Available Raw		
Zone	Water Board	Surface	Ground	Surface	Ground	Totals
1	Pembrokeshire Water Board	140·177	—	31·141	—	171·318
	Zone Total	**140·177**	**—**	**31·141**	**—**	**171·318**
2	Cardiganshire Water Board	11·468	0·213	—	—	11·681
	Newcastle Emlyn RDC	0·500	—	—	—	0·500
	Zone Totals	**11·968**	**0·213**	—	—	12·181
3	West Glamorgan Water Board	348·192	8·783	—	—	356·975
	Loughor Joint Water Board	6·819	—	—	—	6·819
	Llanelli and District WB	55·023	1·194	26·049	0·227	82·493
	Cwmamman UDC	—	1·133	—	—	1·133
	Llandovery BC	—	0·668	—	—	0·668
	Llandeilo UDC	—	0·909	—	—	0·909
	Llandeilo RDC	0·274	0·274	—	—	0·548
	Carmarthen BC	4·123	—	—	—	4·123
	Carmarthen RDC	0·894	1·347	—	—	2·241
	Zone Totals	**415·325**	**14·308**	**26·049**	**0·227**	**455·909**
	Totals Available	**567·470**	**14·521**	**57·190**	**0·227**	**639·408**
4	Loughor Joint Water Board	6·819	—	—	—	6·819
	Llanelli and District WB	55·023	1·194	26·049	0·227	82·493
	Cwmamman UDC	—	1·133	—	—	1·133
	Llandovery BC	—	0·668	—	—	0·668
	Llandeilo UDC	—	0·909	—	—	0·909
	Llandeilo RDC	0·274	0·274	—	—	0·548
	Carmarthen BC	4·123	—	—	—	4·123
	Carmarthen RDC	0·894	1·347	—	—	2·241
	Zone Totals	**67·133**	**5·525**	**26·049**	**0·227**	**98·934**

Notes: (1) Zone 3 assumes that the West Glamorgan Water Board will take over the supplies in the county of Carmarthen, excluding Newcastle Emlyn RDC.
(2) Zone 4 assumes that a new Water Board would be created to take over those supplies in the County of Carmarthen, again excluding Newcastle Emlyn RDC.
(3) Quantities will not agree with those given in Tables 8 and 10 as in the latter tables other considerations have been taken into account.
(4) Newcastle Emlyn UDC has been omitted as the quantities are insignificant.

TABLE 14
List of Reservoir Sites

Hyd Area No.	River	Remarks	Reservoir Type	Yields x $10^3 m^3/d$ From Storage	Maximum of Catchment above Point of Abstraction
59	Tawe			Nil	
60	Towy Brianne	Extra yield by raising dam	R	85	
	Doethie		R	305	
	Gwenffrwd		R	70	
	Gwydderig		R	235	
	Bran (Sawdde)		R	100	
	Sawdde 1		R	100	
	Sawdde 2		R	375	
	Dulais		R	170	
	Twrch		R	245	
	Cothi 1		R	70	
	Cothi 2a		R	125	
	Cothi 2b		R	165	
	Clydach		R	120	
	Cothi 3		R	695	955 (Towy Basin)
	Duad		R	70	
	Gwili 1		R	110	
	Gwili 2		DS	240	110
	Gwendraeth Fach	either	DS	70	
	Gwendraeth Fach	or	R	70	70
	Taf 1		R	165	
	Taf 2		DS	220	
	Gronw		R	80	
	Dowi Fawr		R	70	
	Cynin		R	130	165 (Taf Basin)
	Cywyn 1		R	60	
	Cywyn 2		DS	90	60
61	Nevern		DS	120	
	Gwaun		DS	65	
	Anghof		R	145	145 (W. Cleddau Basin)
62	Teifi		R	340	
	Clotwr		R	185	
	Ceri		R	155	
	Cych		R	235	665 (Teifi Basin)
63	Ystwyth		R	160	155

R = *Regulating*
DS = *Direct Supply*

'Maximum yield of catchment' refers to development to 30% ADF regulating, measured at abstraction point, which is taken to be about the tidal limit.

TABLE 15
List of Sampling Stations

River Tawe

Station No.	Map Ref	Location
1(H)	SN 797 101	Ystradgynlais Road Bridge
2(H)	SN 775 103	Twrch at Lower Cwmtwrch
3(H)	SN 687 007	Footbridge to 'Cae Sewerage' Clydach
4(H)	SN 685 998	Ynystanglws Gauging Station
5(H)	SS 676 977	Morriston Road Bridge
6(H)	SS 669 967	Nant-y-Fendrod
7(H)	SS 668 960	Landore Bridge
8(H)	SS 663 933	New Cut Bridge, Swansea

River Loughor

Station No.	Map Ref	Location
45	SN 713 138	River Amman, Brynamman Road Bridge
9(H)	SN 634 118	River Amman, Pontamman Road Bridge
10(H)	SN 620 119	Penybanc Road Bridge
46	SN 622 105	Pantyffynnon Road Bridge
11(H)	SN 588 042	Pontardulais Road Bridge
47	SS 561 982	Loughor Bridge
48	SS 579 971	Lliw at Island Farm Bridge

River Towy

Station No.	Map Ref	Location
14(H)	SN 789 480	Iron Bridge at Rhandirmwyn
57	SN 783 362	River Bran near Llandovery
58	SN 761 348	Llandovery Road Bridge
15(H)	SN 694 288	Llangadog Road Bridge
59	SN 695 286	River Bran at Llangadog
16(H)	SN 656 239	Manoravon, near Pumping Station
60	SN 627 220	Llandeilo Road Bridge
61	SN 553 202	Dryslwyn Road Bridge
17(H)	SN 588 225	Cothi – Gauging Station at Felinmynachdy
18(H)	SN 491 204	Nantgaredig Gauging Station
62	SN 433 210	Gwili at Abergwili Road Bridge
63	SN 414 199	'Aberystwyth' Railway Bridge at Carmarthen
19(H)	SN 398 166	Below Green Castle

River Taf

Station No.	Map Ref	Location
20(H)	SN 156 201	Llanfallteg Bridge
64	SN 201 163	River Gronw below United Dairies, Whitland
21(H)	SN 202 162	Trevaughan
22(H)	SN 238 161	Clog-y-fran Gauging Station
65	SN 282 154	Dewi Fawr – Cynin below St Clears
23(H)	SN 284 143	Taf below St Clears
66	SN 324 178	Afon Cywyn – Pontnewydd, Bancyfelin

River Eastern Cleddau

Station No.	Map Ref	Location
24(H)	SN 038 242	Afon Syfynwy at Llysyfran
25(H)	SN 106 233	Llwyndwr Bridge
67	SN 092 204	Llandre Bridge
26(H)	SN 072 153	Canaston Gauging Station

River Western Cleddau

Station No.	Map Ref	Location
27(H)	SM 961 230	Treffgarne Bridge
28(H)	SM 954 176	Prendergast Gauging Station
68	SM 955 157	New Bridge, Haverfordwest
69	SM 959 148	Merlins Brook, Haroldstone Bridge, Haverfordwest
70	SM 979 152	Railway Bridge, Haverfordwest
29(H)	SM 969 141	Uzmaston

River Teifi

Station No.	Map Ref.	Location
71	SN 730 665	Pontrhydfendigaid Road Bridge
31(H)	SN 670 612	Tregaron (Pont Einon)
32(H)	SN 580 477	Lampeter Road Bridge
33(H)	SN 476 416	Maesycrugiau Bridge
72	SN 3555 4010	Henllan Bridge
34(H)	SN 244 416	Glan Teifi

River Ystwyth

Station No.	Map Ref	Location
36(H)	SN 828 754	Esgair-wen Bridge
37(H)	SN 800 743	Hen-Barc below Cwm-Ystwyth Mine
73	SN 742 727	Pontrhyd-y-groes Bridge
74	SN 734 729	Frongoch Stream above confluence with Afon Cell
75	SN 736 729	Afon Cell – 25 yards below confluence with Frongoch
76	SN 715 720	Footbridge Grogwinion Mine
38(H)	SN 688 716	Llanafan Bridge
77	SN 666 738	Afon Magwr near Abermagwr Bridge
39(H)	SN 624 754	Llanilar Bridge
78	SN 591 777	Pont Llolwyn Gauging Station
79	SN 579 807	Bridge near Pier

River Rheidol

Station No.	Map Ref	Location
40(H)	SN 749 808	Ponterwyd Bridge
80	SN 741 806	Afon Llywernog
81	SN 767 812	Afon Castell below diversion to Dinas Reservoir
82	SN 737 786	Afon Tuen near Ystumtuen School
41(H)	SN 743 770	Afon Mynach near Devil's Bridge
83	SN 688 815	Afon Melindwr below Bridge to Goginan Mine
84	SN 731 781	Above Cwm Rheidol Mine
85	SN 727 782	Below Cwm Rheidol Mine
42(H)	SN 712 788	Above Rheidol Falls
86	SN 644 804	Below confluence with Melindwr
43(H)	SN 594 813	Penybont Bridge
88	SN 583 813	Trefechan Bridge

River Dafen

Station No.	Map Ref	Location
49	SN 532 026	Lethri Road Bridge, Felinfoel
50	SN 529 013	Above Nuffield Works outfall
51	SN 528 011	Maescanner Road Bridge
52	SN 525 004	Halfway Road Bridge
53	SS 522 991	Above Railway Culvert near Trostre Works
54	SS 510 986	Scour Pond at Great Western Dock

River Gwendraeth Fach

Station No.	Map Ref	Location
13(H)	SN 420 087	Old Tinplate Works

River Gwendraeth Fawr

Station No.	Map Ref	Location
12(H)	SN 434 059	Pont Spwdwr, Kidwelly
55	SN 501 112	Pontyberem
56	SN 469 084	Pontyates

River Gwaun

Station No.	Map Ref	Location
30(H)	SN 005 349	Cilrhedyn Bridge

River Aaron

Station No.	Map Ref	Location
35(H)	SN 466 610	Aberaeron

Notes re Table 15:
Sampling Stations with suffix H *are those adopted for the assessment of river water quality for the Hydrometric Scheme.*
Numbered stations are other locations where sampling will be continued though not necessarily to the same frequency as at the hydrometric stations.

TABLE 16
Underground Waters – Analyses

The results are expressed as milligrams per litre except where otherwise stated.
ND – *none detected by approved method.*

Abercrave Colliery*
SN 826 120 Lower Coal Series

pH value	6·7
Carbonate hardness	120
Total dissolved solids	240
Carbonate	110
Sulphate	26
Chloride	12
Calcium	27
Magnesium	18
Sodium	39
Alkalinity	183

Pentremawr Colliery, Pontyberem
SN 494 104 Lower Coal Series

pH value	8·2
Free and Saline Ammonia	ND
Albuminoid Ammonia	ND
Nitrites	ND
Nitrates	ND
Permanganate value (4 hours)	0·24
Total dissolved solids	500
Sulphate	20
Chloride	10
Calcium	105
Magnesium	80
Total hardness	185

Morlais Colliery, Llangennech
SN 573 023 Lower Coal Series

pH value	8·1
Free and Saline Ammonia	ND
Albuminoid Ammonia	ND
Nitrites	0·16
Nitrates	0·008
Permanganate value (4 hours)	1·27
Total dissolved solids	800
Sulphate	470
Chloride	120
Calcium	170
Magnesium	155
Iron	8
Total hardness	325

Graig Merthyr Colliery
SN 624 024 Lower Coal Series through Pennant Sandstone

pH value	6·9
Permanganate value (4 hours)	0·32
Total dissolved solids	104
Sulphate	ND
Chloride	12
Calcium	ND
Magnesium	40
Total hardness	40
Free CO_2	6·2

Cwmgorse Colliery
SN 701 110 Lower Coal Series through Pennant Sandstone

pH value	7·9
Permanganate value (4 hours)	0·89
Total dissolved solids	606
Sulphate	355
Chloride	6
Calcium	128
Magnesium	186
Iron	ND
Total hardness	314
Free CO_2	6

Adit discharging at Middle Hill Farm, near Hook, Pembrokeshire
SM 957 119 Lower Coal Series

pH value	6·1
Total dissolved solids	214
Sulphate	29
Chloride	27
Calcium	11
Magnesium	31
Total hardness	88
Electrical conductivity (micromhos/cm)	330
Iron	29
Manganese	1·6
Dissolved oxygen	0·7

Felinfoel Brewery Well, Llanelli
SN 518 021 Pennant Sandstone

	*	†
pH value	6·9	6·6
Total dissolved solids	176	—
Sulphate	17	—
Chloride	21	24
Magnesium	9	—
Calcium	23	—
Total hardness	97	87
Iron	—	3·2
Manganese	—	0·3
Electrical conductivity (micromhos/cm)	—	265

Six Pit, Llansamlet
SS 680 969 Lower Coal Series through Pennant Sandstone

pH value	5·9
Iron	25
Manganese	1·7
Soluble Lead	ND
Total hardness	219
Soluble Zinc	10
Electrical Conductivity (micromhos/cm)	610

Felindref Springs – Llanelli Water Board
SN 460 122 Carboniferous Limestone through Millstone Grit

pH value	7·52
Total dissolved solids	250
Permanganate value (4 hours)	0·15
Chloride	12
Total hardness	220

Capel Sul Springs – Llanelli Water Board
SN 406 074 Old Red Sandstone

pH value	7·5
Total dissolved solids	220
Permanganate value (4 hours)	ND
Chloride	26
Total hardness	166
Iron	0·04
Manganese	ND

Llanelli Ice and Cold Storage Limited, Well
SN 506 995 Pennant Sandstone

pH value	8·2
Chloride	109
Iron	2·08
Manganese	0·25
Total hardness	276
Electrical Conductivity (micromhos/cm)	800

Messrs Eastwoods Limited, Pembrey
SN 411 039 Pennant Sandstone through superficial deposits

pH value	8·3
Chloride	422
Iron	33
Manganese	0·3
Total hardness	246
Electrical Conductivity (micromhos/cm)	3 000

Unigate Creameries – Pensarn, Carmarthen
SN 414 198 Silurian

pH value	7·0
Chloride	47
Iron	5·8
Manganese	0·8
Total hardness	20

Borehole at Milton Springs
SN 041 029 Carboniferous Limestone

pH value	7·5
Permanganate value (4 hours)	ND
Chloride	28
Iron	ND
Manganese	ND
Total hardness	265
Total solids in solution	320

Penwallis, Fishguard
SM 959 365 Acid Igneous intrusion in Ordovician

pH value	6·8
Permanganate value (4 hours)	1·2
Chloride	19
Iron	ND
Manganese	ND
Total hardness	46
Total solids in solution	90

Ritec Springs (Pembrokeshire Water Board)
SN 118 008 Carboniferous Limestone

pH value	7·7
Total dissolved solids	439
Sulphate	27
Chloride	43
Calcium	33
Magnesium	13
Iron	ND
Manganese	ND
Total hardness	203
Electrical Conductivity (micromhos/cm)	530
Dissolved Oxygen	4·4

Cwm Ystwyth Village Supply (Cardiganshire Water Board)
SN 788 741 Silurian

pH value	7·4
Total dissolved solids	150
Chloride	6
Calcium	11
Magnesium	3·4
Iron	ND
Manganese	ND
Lead	ND
Zinc	ND
Total hardness	72
Electrical Conductivity (micromhos/cm)	154
Dissolved Oxygen	9·4

Adit Waters – defunct metalliferous mines
Average Analytical Data 1970

Esgair Fraith Mine
Adit water
SN 742 912 Ordovician

pH	Max 7·5	Min 6·4	
Lead	Max ND	Av ND	Min ND
Zinc	Max 1·08	Av 0·81	Min 0·18

Rheidol Mine
Adit No. 6
SN 730 782 Silurian

pH	Max 4·0	Min 2·8	
Lead	Max 2·1	Av 0·96	Min ND
Zinc	Max 125	Av 29	Min 13·7

Cwm Ystwyth Mine
Adit No. 2
SN 803 744 Silurian

pH	Max 6·7	Min 6·3	
Lead	Max 0·37	Av 0·07	Min ND
Zinc	Max 410	Av 98	Min 25

Frongoch Mine
Adit water
SN 724 746 Silurian

pH	Max 5·3	Min 5·0	
Lead	Max 8·0	Av 3·0	Min ND
Zinc	Max 118	Av 104	Min 75

* After Ineson (1967)
† River Authority 10th June, 1970

Definitions and Abbreviations

AE – actual evaporation.
ADF—theoretical average daily flow, from 'average rainfall—PE'.
ADR – average daily residual rainfall.
average rainfall – this refers to the long-term average – 1916–1950.
average potential evaporation – this is an average based on 15 years – 1950–1964.
areal rainfall – the estimated rainfall over an area.
Area – refers to the South West Wales River Authority Area.
area – refers to a local area within the Authority Area, or any outside area.
C – conventional reservoir – depending on its catchment area only and supplying water all the year round.
C+P – conventional reservoir plus pumped storage – as above but supplemented by pumping.
HA – hydrometric area.
MAF – Minimum Acceptable Flow.
MDF – mean daily flow – the average of the recorded flows during a 24-hour period.
mean – arithmetic average.
median – middle value of a set of numbers arranged in order of magnitude.
mode – commonest occurrence.
PE – potential evaporation – PE has been used to cover all forms of loss by evaporation.
R – regulating reservoir – a reservoir used to augment yield at an abstraction point during dry periods.
residual rainfall – measured rainfall minus estimated evaporation.
1963 Act – The Water Resources Act, 1963.
Welsh names – There are various spellings (including anglicised forms) in common use. The following are of interest in connection with this report:

Rivers in	*Commonest use*	*Other spellings*
HA 59	Loughor	*Llwchwr
60	*Cywyn	Cywin
	Towy	*Tywi
61	Nevern	Nyfer, Nefern
	Solva	Solfach
	*Syfynwy	Syfni
62	*Teifi	Teify, Tivy

* Generally agreed as 'correct Welsh'.

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