Water Quality Management Plan

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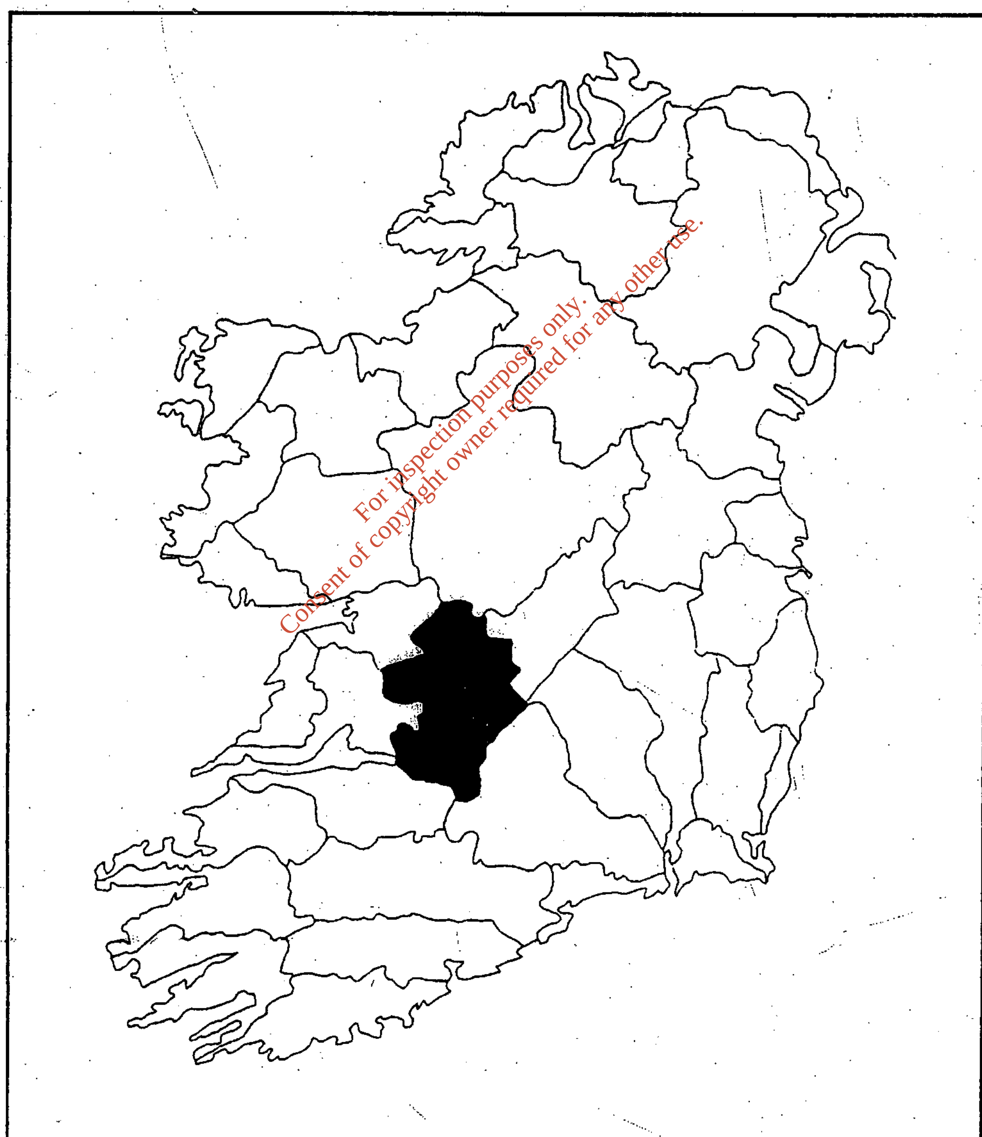
for the

LOWER SHANNON CATCHMENT



Clare County Council, Galway County Council, Limerick Corporation,
Limerick County Council, Tipperary (N.R.) County Council.

Water Quality Management Plan

for the

LOWER SHANNON CATCHMENT

Prepared in accordance with Section 15

of the

Local Government (Water Pollution) Act, 1977.

March 1990

Clare County Council, Galway County Council, Limerick Corporation,
Limerick County Council, Tipperary (N.R.) County Council.

This document is based on Volume 1 of a five volume draft report prepared by An Foras Forbartha at the request of the local authorities involved. The titles of the five volumes, some of which are referred to in this document, are as follows:

Volume 1, Main Report
Volume 2, Summary of Water Resources
Volume 3, Abstractions and Discharges
Volume 4, Beneficial Uses and Water Quality Criteria
Volume 5, Water Quality

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CHAPTER ONE

GENERAL INTRODUCTION

INTRODUCTION

1.1 Urban population growth and rapid industrial development all over the world during the past century have led to very great increases in the quantitative demand for water, on the one hand, and increased water pollution on the other. The problems of water quantity and water quality have, in the past, often been treated as two separate fields but it is now widely recognised that they are closely linked. The increased amount of sewage, industrial and agricultural wastes discharged into surface waters, coupled with the increased demand for water, has made it necessary in recent years for many countries to adopt comprehensive measures for quality improvement not only as a public health measure but also as a means of increasing water supplies and assisting economic growth. Generally, it is becoming increasingly necessary to view water as an economic resource, available in limited quantities and with a variety of competing uses.

1.2 Since 1971, the decline in the population of Ireland has been arrested and in the period 1961 to 1981 the population has increased from 2.82M to 3.44M. This population growth has been accompanied by a rapid decline in the rural, and a rapid expansion in the urban populations. In the same period this population growth has been accompanied by a very substantial increase in industrial activity and by an intensification of agriculture.

1.3 All of these developments over the last 20 years have led to the discharge of greater quantities of waste to rivers, lakes, estuaries and coastal areas. In recent times, public opinion has become increasingly aware that water pollution problems exist throughout the country and nowadays virtually no week goes by without some reference to water pollut being made in the national and provincial press. The introduction of th Local Government (Water Pollution) Act, 1977 was a recognition by the Oireachtas that new initiatives were required to control and abate water pollution. Section 15 of this Act provides for the preparation of water quality management plans. Plans prepared under Section 15 shall contain such objectives as the prevention and abatement of pollution of the waters and such other provisions as appear to the local authority to be necessary The Act also provides that such plans, when made, shall be furnished by the local authority to the Minister for the Environment, the Minister f Fisheries, adjoining local authorities, sanitary authorities and to releva boards of conservators (Fisheries Boards) in the functional area of that authority.

THE CONCEPT OF WATER QUALITY MANAGEMENT

1.4 Water is used for many beneficial purposes, some which involve changes in quality and some which do not. These uses include abstractions to meet the needs of public supplies, industry and agriculture and the in situ uses associated with recreation and commercial and sport fishing. The controlled disposal of wastes, arising from domestic, industrial and agricultural sources, is another important use, even though it is a potential constraint on the foregoing uses. These various water uses and associated factors are inter-related, often complex, sometimes conflicting and they cannot be managed properly as a whole without adopting a comprehensive approach or without the availability of a wide variety of data and basic information.

1.5 Water quality management strives for fish and wildlife propagation rather than merely ensuring their survival. It emphasises prevention of pollution and conservation of water quality as well as the improvement in quality that can be obtained through identification and correction of existing water pollution problems. The implementation of a water quality management plan will therefore ensure an acceptable quality of water for a specific use at the time and place where it is needed.

1.6 The studies deemed necessary for the preparation of a water quality management plan include economic and demographic investigations to project the place and time of future water needs, the quantity and type of wastes likely to be produced and the locations at which such wastes will be discharged. As well as their deoxygenating capacity and acute toxicity, the chronic toxicity and other cumulative adverse effects of wastes singly or in combination with other wastes need to be determined. Desirable water quality for fish propagation is determined in contrast to the quality needed merely to ensure survival.

1.7 To be effective, water quality management must be based on a knowledge of the basic principles governing hydraulic and hydrological phenomena and natural decay and assimilation of pollution, both manmade and natural. It involves the prediction of what will happen when and where additional amounts of manmade wastes are contributed as a result of population growth and industrial and agricultural expansion. It is only when these fundamental data and information are collected, collated and analysed that it is possible to plan for the comprehensive management of water quality in a river catchment and to develop the controls which will adequately protect waters from pollution and provide for the maximum range of water uses. Therefore, a water quality management plan provides for continuous data collection and updating, as well as ongoing monitoring at critical points so that problems are identified and control actions put in motion.

OBJECTIVES OF THE WATER QUALITY MANAGEMENT PLAN

1.8 The overall objective of a water quality management plan for the Lower Shannon Catchment is to ensure in the future an acceptable quality of water for specific uses at the time and place where it is needed. In particular, the main objectives to be achieved by the Plan are to ensure that the quality of the waters in the catchment is maintained in a satisfactory condition and where necessary improved, thereby:

(i) safeguarding public health,

(ii) catering for the abstraction of increasing quantities of water for domestic, industrial and agricultural purposes,

(iii) catering for the needs of commercial and game fisheries,

(iv) catering for the relevant water based amenities and recreational requirements.

Other vital objectives of the draft Plan are to identify the control measures deemed necessary in relation to the satisfactory treatment and disposal of sewage and industrial effluents and also to identify the priorities for investment in public and private (industrial) wastewater treatment.

METHODOLOGY ADOPTED IN PREPARING DRAFT PLAN

1.9 In order to meet the objectives of the draft Plan as outlined in paragraph 1.8 the following methodology was adopted in preparing the Draft Plan:

(i) All the available basic data on water quality and water quantity were collated. These included data available from local authority records, the Office of Public Works, the Electricity Supply Board, and from An Foras Forbartha.

(ii) The above basic data were compiled and examined in detail. The characteristic elements which determine water quality in specific lakes and along the main river channels, and tributaries were selected.

(iii) The beneficial water uses (existing and future) to be protected within the catchment were identified.

(iv) The desired water quality conditions deemed necessary to support the various beneficial uses were defined. In doing this, reference was made to data and information from various international sources, EEC Directives, Memorandum No.1 and the general water quality conditions pertaining in the catchment.

(v) Estimates of the assimilative capacity of rivers and lakes in the catchment were computed and the maximum permissible waste loads that can be discharged to these at key locations were determined.

(vi) Estimates of the existing generated waste loads, at present discharged to surface waters in the catchment (in some instances after treatment), were compiled. Projections of the generated waste loads for the next twenty years were also computed.

(vii) Estimates of the water quality conditions likely to arise in lake waters and at selected key locations along the rivers as a result of the existing and projected waste loads were computed.

(viii) A number of options in relation to the treatment of existing and future waste water discharges in the catchment were identified and, where appropriate, the reserve capacities of the receiving waters were estimated in relation to these options.

(ix) The waters at present overloaded by waste discharges were identified and the remedial actions deemed necesssary to rectify these problems are discussed.

(x) In relation to the projected waste loads the measures that should be adopted in relation to treatment are outlined as is the general procedure that should be adopted for the laying down of effluent quality standards.

(xi) The main priorities for capital investment in both public and private wastewater treatment facilities have been identified.

MAIN ELEMENTS OF DRAFT PLAN

1.10 It is evident that the key problem in relation to the successful preparation and subsequent implementation of a water quality management plan for the catchment concerns the availability of a wide variety of basic data. The framework for data collection particularly in relation to water quality and water quantity should be ongoing so that water quality management plans once prepared can be revised and refined on a regular basis.

1,11 While much data and information were collected for the preparation of the draft water quality management plan for the Lower Shannon Catchment there are many gaps in the data available, particularly in relation to hydrometric data, water quality data and to waste loads. The various gaps which exist are highlighted in Chapter 10.

The draft Plan includes recommendations on an action programme which will ensure that all the necessary basic data are collected on an ongoing basis to facilitate updating, revision, refinement and implementation of the present draft plan.

SCOPE OF DRAFT PLAN

1.12 The Draft Water Quality Management Plan for the Lower Shannon Catchment covers the main Shannon River and its principal tributaries from the upper limit of the tidal reach at Limerick to Portumna and includes Lough Derg and its main feeder streams. The estuarine part of the river downstream of Limerick has already been the subject of a separate "Draft Water Quality Plan for the Shannon Estuary". A draft plan is also being prepared for the Upper Shannon Catchment upstream of Portumna. It is proposed to exclude from the draft Plan a number of small streams and drains for which no specific beneficial use has been identified. While it is recognised that waste discharges to all waters in the catchment area under consideration will be subject to control, the exclusion of these small streams from the draft Plan is considered to be necessary on practical grounds, because it might not be possible or necessary to maintain the selected water quality standards. In these streams, the main concern will be the prevention of public nuisance and the carry over of pollution to larger streams. The waters of the Lower Shannon River Catchment included in the Plan are approximately indicated on Map 1 in the pocket at the back of this volume. The official Plan map is available for inspection at the offices of each of the local authorities involved and the schedule appended herein (p. 145) gives the grid references to the terminal points shown in that map.

CHAPTER TWO

THE LOWER SHANNON CATCHMENT

INTRODUCTION

2.1 The Lower Shannon catchment includes that portion of the Shannon river which extends from Portumna at the upstream end to the upper limit of the tidal reach at Limerick, including Lough Derg. The Shannon river rises in the Cuilcagh Mountains in County Cavan and flows southwards through Lough Allen, Lough Ree and Lough Derg draining the central lowlying plain of Ireland. Downstream of Lough Derg the river flows southwards to Limerick and west through the Shannon Estuary to the Atlantic Ocean. The total area of the Shannon catchment is approximately 11,700 km^2. The area of the Lower Shannon river catchment covered by this Plan is approximately 2943 km^2. The Lower Shannon catchment includes portions of counties Clare, Limerick, Tipperary (N.R.), Galway, Offaly and Tipperary (S.R.), and is shown in Figure 2.1 together with the other hydrometric areas in the Country.

THE LOWER SHANNON

2.2 The Lower Shannon river is shown in Figure 2.2 and the main feature of this section of the river is Lough Derg having a surface area of 117.5 km^2 approximately. The lake is elongated in the nort east/south west direction; on the north western side the lake includes parts of counties Galway and Clare and on the south eastern side parts of counties Offaly, Tipperary (N.R.), Limerick and Tipperary (S.R.). Topographically the catchment can be divided into two areas; these comprise the lowlands of south east Galway, north west Tipperary and east Limerick, and the uplands, which include Slieve Bernagh and Slieve Aughty to the west of the lake Slieve Ava, Slieve Felim, Keeper Hill, Silvermines, Mother Mountain and the Devil's Bit to the east.

2.3 Downstream of Lough Derg the water level in the lake is controlled to provide storage for the hydro-electric development of Ardnacrusha, for flood control, and for navigational purposes in the lake. The main control is at the weir in Parteen which is about 6 km downstream of Killaloe. Downstream of Parteen weir the flow in the old River Shannon channel is normally limited to compensation water flow only (10 m^3/s), the remainder of the flow is discharged to the headrace canal of the Ardnacrusha

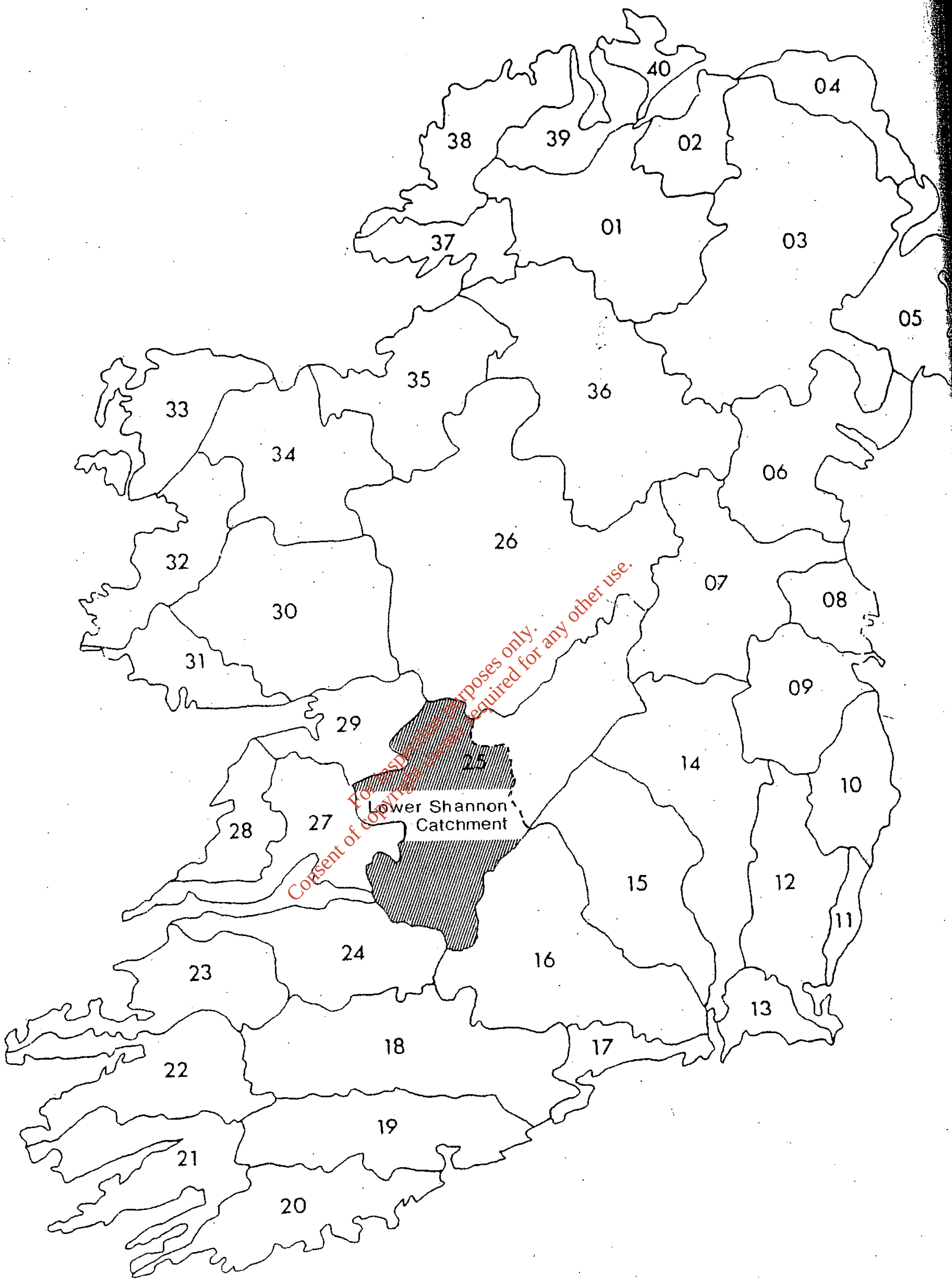
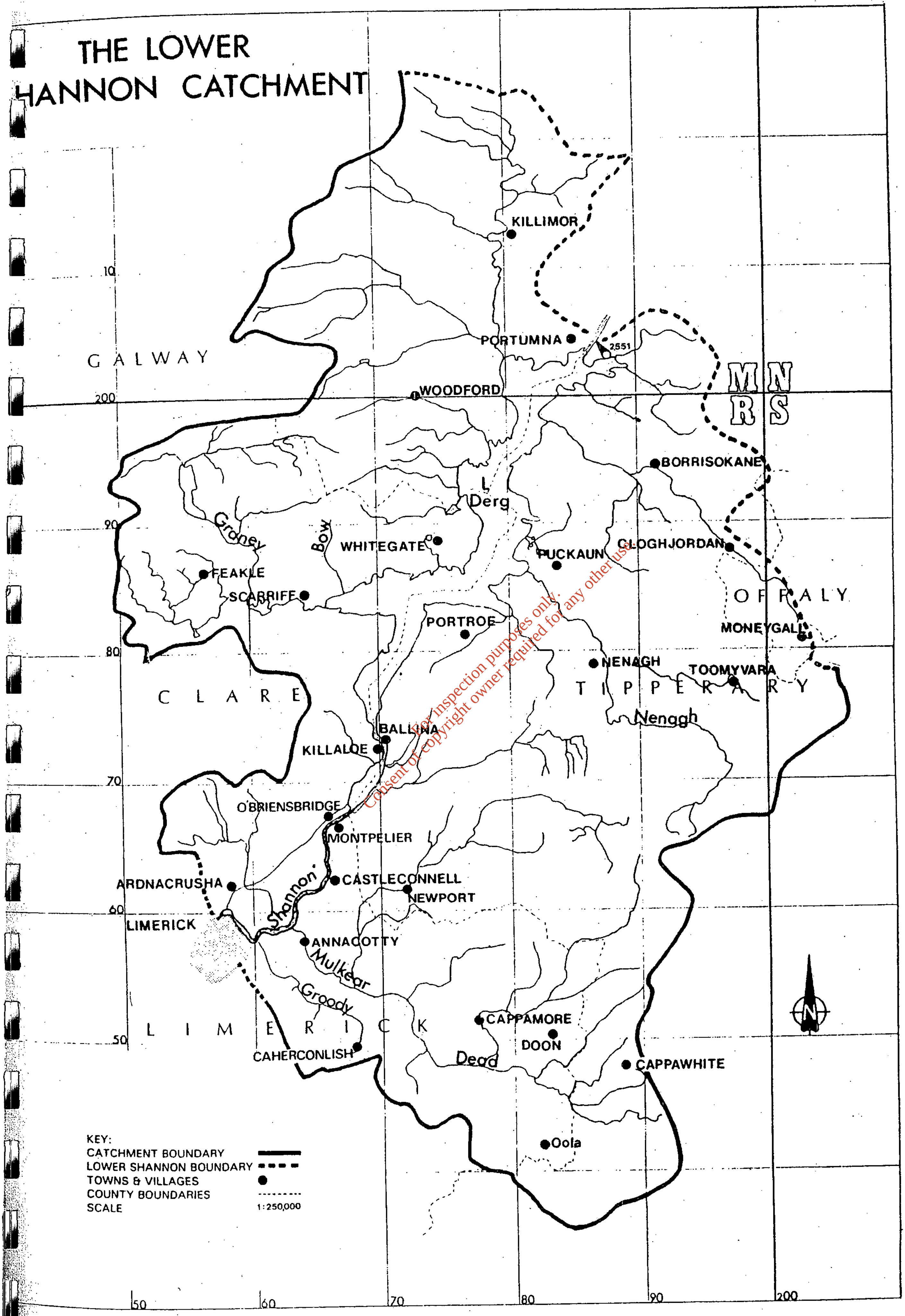


FIG 2.1 HYDROMETRIC AREAS



THE LOWER SHANNON CATCHMENT
GALWAY
CLARE
LIMERICK
TIPPERARY
OFFALY
KILLIMOR
PORTUMNA
WOODFORD
BORRISOKANE
L. Derg
WHITEGATE
PUCKAUN
CLOGHJORDAN
FEAKLE
SCARRIFF
Graney
Bow
PORTROE
MONEYGALL
NENAGH
TOOMYVARA
Nenagh
BALLINA
KILLALOE
O'BRIENSBRIDGE
MONTPELIER
ARDNACRUSHA
CASTLECONNELL
NEWPORT
Shannon
LIMERICK
ANNACOTTY
Mulkear
Groody
CAPPAMORE
DOON
CAHERCONLISH
Dead
CAPPAWHITE
Oola
MN
RS
2,551
N
10
200
90
80
70
60
50
50
60
70
80
90
200
KEY:
CATCHMENT BOUNDARY
LOWER SHANNON BOUNDARY
TOWNS & VILLAGES
COUNTY BOUNDARIES
SCALE 1:250,000

power station. The flow through the power station varies from a maximum of 400 m³/s to a minimum of 1 m³/s. This minimum flow is formed by the combined discharge through the auxiliary turbine and fish pass when the power station is off load. The principal tributaries discharging to Lough Derg include the Killimor, the Nenagh, the Ballyfinboy and the Graney rivers. Downstream of Parteen the compensation flow in the old River Shannon channel is augmented by the Mulkear, Kilmastulla and the Groody rivers.

RAINFALL

2.4 Rainfall data are collected at a large number of stations in and around the periphery of the catchment. These data are useful as a means of assessing the magnitude of the resource in terms of the long average run-off at various points on the river. The map of isohyets of long average rainfall in the Lower Shannon (Figure 2.3) which was supplied by the Meteorological Service shows that the long average rainfall varies from about 1600 mm/annum in the Silvermines to below 900 mm/annum in the northern portion of Tipperary (N.R.). On the basis of data supplied by the Meteorological Service and having regard to evapotranspiration losses in the catchment, the long average river flow in the river Shannon at Portumna was estimated to be 163 m³/s, and at Killaloe, 188 m³/s.

RESOURCES

2.5 In order to make an accurate assessment of the magnitude of the surface water resources of a catchment, reliable hydrometric records must be available at strategic locations on the river for a number of years. At Killaloe, a hydrometric record of water level in the river has been maintained for a period of 46 years and the results of an analysis of these records show that the long average run-off at Killaloe was 173.4 m³/s in the record period. Discrepancies in the results between those calculated from the hydrometric records and those estimated from rainfall records (para.2.4) can only be reconciled when the quality and availability of the records are improved with time.

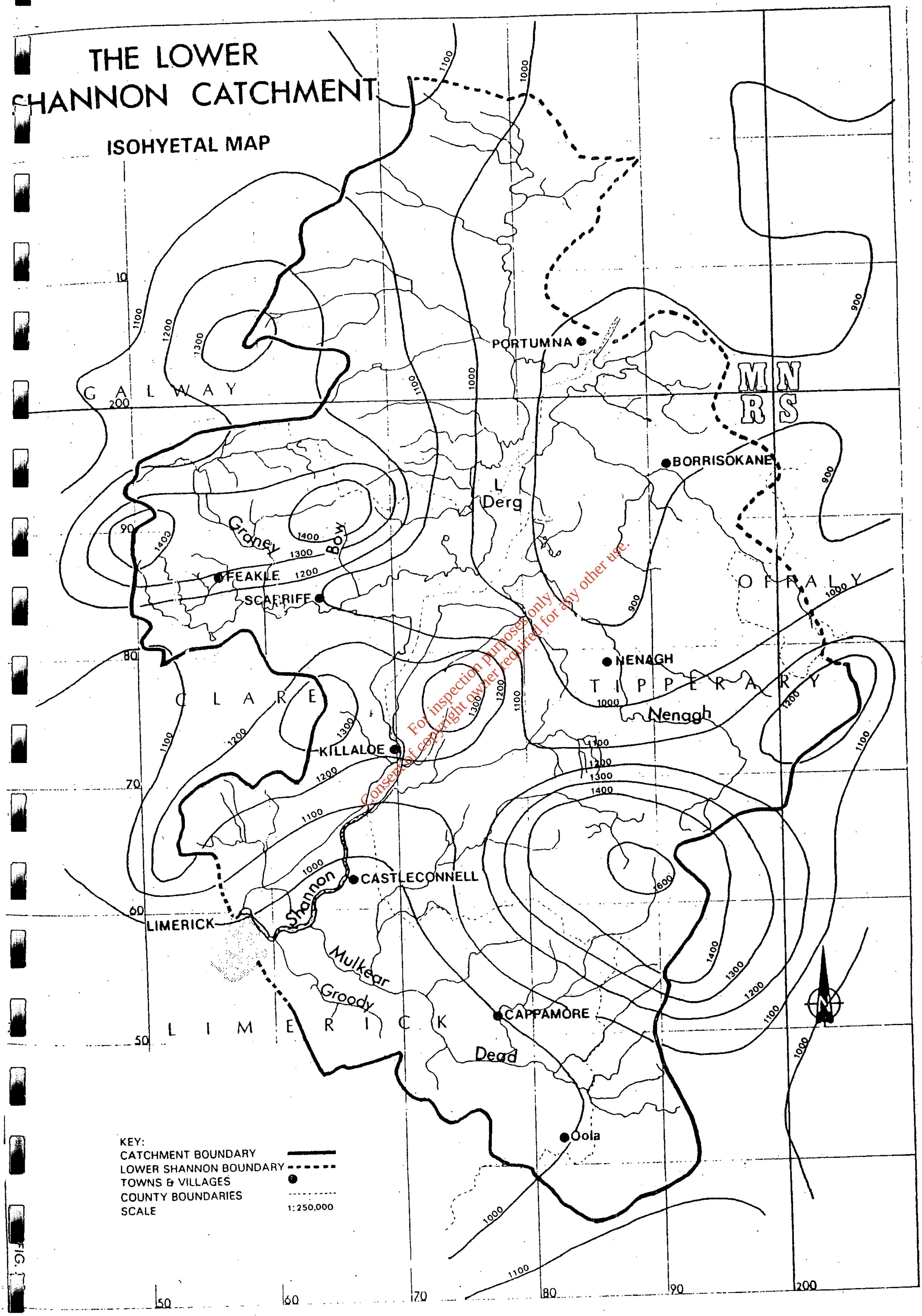
2.6 The long average run-off from a river catchment gives an overall assessment of the magnitude of the resources. In considering the abstraction of water from rivers or streams however or in considering the magnitude of the resource for water quality management purpose other flow criteria have to be considered. When planning the abstraction of water from a river or stream, it is necessary to know the dry weather flow (DWF). This is defined as the minimum flow that might be expected to occur with a frequency of occurrence of once in fifty years. For water quality management purposes, the general practice is to adopt the 95 percentile flow as being the lowest flow for which water quality standards for organic biogradable waste should be adhered to. This is a relatively low flow and corresponds to the flow in the river which is equalled or exceeded for 95% of the time. It is a statistical figure and requires records of flows in a river over a number of years before it can be reliably established.

2.7 A detailed examination and analysis of all the records available from gauging stations in the catchment, together with actual flow measurements was carried out, and the results of this are reported in Volume 2.- "Summary of Water Resources". As a result of this analysis the magnitude of the resource in terms of the estimated 95 percentile flow and the estimated dry weather flow at strategic locations on the main river and on some of the tributaries and feeder rivers to Lough Derg were quantified and these results are set out in Table 2.1.

TABLE 2.1

Estimated Ninety Five percentile and Dry Weather Flows at Towns in the Lower Shannon Catchment

TOWN	RIVER	CATCHMENT AREA (km^2)	ESTIMATED 95 PERCENTILE FLOW (m^3/s)	ESTIMATED D.W.F. (m^3/s)
Portumna	Shannon	8,856	23.6	7.2
Borrisokane	Ballyfinboy	95	0.06	0.03
Nenagh	Nenagh	143	0.35	0.19
Cloghjordan	Ballyfinboy Trib.	47	0.028	0.014
Cappamore	Bilboa	116	0.60	0.29
Annacotty	Mulkear	646	2.04	0.97
Limerick (part of)	Groody	57	0.06	0.03
Scarriff	Graney	279	0.47	0.22
Killimor	Kilcrow Trib.	123	0.04	0.02
Limerick	Shannon	11,800	--	12.24


THE LOWER SHANNON CATCHMENT
ISOHYETAL MAP
GALWAY
CLARE
LIMERICK
TIPPERARY
OFFALY
PORTUMNA
BORRISOKANE
L Derg
Graney
Bow
FEAKLE
SCARRIFF
NENAGH
Nenagh
KILLALOE
CASTLECONNELL
LIMERICK
Shannon
Mulkear
Groody
CAPPAMORE
Dead
Oola
M N
R S
1400
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1600
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2.8 The dry weather flows as quoted above in Table 2.1 are derived from an examination of the charts from water level records at gauging stations on the various rivers and from actual flow measurements carried out in recognised drought periods in 1969, 1972, 1976 and 1984. The dry weather flow quoted for the head of the estuary at Limerick is based on the dry weather flow in the Shannon, which includes the flow over the Parteen weir (10 m^3/s) and the flow through the Ardnacrusha Power Station (1.0 m^3/s) together with the dry weather flow in the Kilmastulla (0.16 m^3/s), the Mulkear (1.02 m^3/s), the Blackwater (0.03 m^3/s) and the Groody (0.03 m^3/s) rivers. The estimated 95 percentile flows as quoted in Table 2.1 at other locations in the catchment are based on records processed by the Office of Public Works from their own river gauging stations and similar records from Electricity Supply and local authority gauging stations which were processed by An Foras Forbartha. The estimated 95 percentile flows and the dry weather flows as quoted above can be taken as being reasonably accurate for water quality management and for planning purposes. These estimates, however, should be kept under review and refined as more detailed and more accurate long term records become available.

LOUGH DERG

2.9 Lough Derg, having a surface area of some 117.5 km^2 is the largest lake on the river Shannon system. The water level in the lake is controlled at an almost constant level to facilitate power generation at Ardnacrusha, and for flood control and for navigational purposes in the lake and in the Shannon river upstream of Portumna. The total volume of water in the lake is estimated to be 887 x $10^6 m^3$ at an average depth of 7.55 m, this provides approximately 59 days storage to the long average run-off from the Shannon.

HYDROGEOLOGY

2.10 Information on aquifers in the catchment and a hydrogeological map of the Lower Shannon were made available by the Groundwater Section, Geological Survey Office and details are given in Volume 2. The Devonian sandstones which occur on the flanks of the upland areas would, if their hydrogeological properties are similar to Devonian sandstones elsewhere, provide aquifers. The Carboniferous bedrock where they are composed of fissured limestones and sandstones contain groundwater. The limestone in the Nenagh to Borrisokane area, to the east of Limerick City and the limestones directly to the North of the Silvermines are aquifers. The volcanics near Palls Green may contain groundwater but because of their limited extent they would only constitute a local aquifer. There are extensive sand and gravel deposits in southeast Galway and to the north-east of Nenagh which could constitute an important groundwater resource but little is known of their groundwater characteristics. The known abstractions from these deposits are very small.

POPULATION TRENDS

2.11 In 1966 the population of the Lower Shannon catchment (Portumna to Limerick but excluding Limerick City) was of the order of 66,000. Fifteen years later, in 1981, this population had increased to 78,500. Based on a simple straight line relationship the above trend would indicate a population increase of about 830 persons (or 1.3%), per year. If this trend were to have continued the existing (1986) catchment population would be of the order of 100,000. Table No. 2.2 sets out the population trends for those portions of the various counties within the Lower Shannon catchment from 1966 to 1981. Population increases have occurred in all county regions within the catchment except the region of Co. Galway: this had a decrease of 3% in population between 1966 and 1981. The regions of the catchment which show maximum growth rates are those around Limerick city and those within and around Nenagh. It is within these areas that the greatest industrial development and the consequent increased water demands and wastewater discharges will occur.

2.12 Significant population increase will also occur at the existing towns, villages and other population centres, within the catchment. Table No. 2.3 sets out the population trends, from 1966 to 1981, at all the towns and villages within the catchment for which there are data available from the 'Census of Population', Vol. 1. Based on these trends, the Table also gives the estimated population at each settlement for the year 2006. It is evident, from the population totals of Tables No. 2.2 and 2.3, that there is a marked move of population to the existing settlements: in 1966 the total population within settlements was about 19% of the catchment population; in 1971 it increased to 21% in 1979 and 1981 it increased further to 23%. The population estimates for the year 2006 would indicate a further increase in this figure, to about 26%.

TABLE NO. 2.2

Populations in the Lower Shannon Catchment

Part of County within Catchment	1966	1971	1979	1981	% Change 1966 to 1981
Galway	10,508	10,229	10.132	10,159	-3%
Offaly	739	701	768	783	+6%
Tipperary (North)	28,528	29,413	32,288	32,540	+14%
Tipperary (South)	4,205	3,949	4,172	4,254	+1%
Clare	9,052	9,331	11,493	12,211	+35%
Limerick	13,012	13,775	17,124	18,473	+42%
Totals	66,044	67,398	75,977	78,420	

AGRICULTURAL AND INDUSTRIAL ACTIVITY

2.13 The quality of agricultural land in the area of the Lower Shannon is mixed. In the upland areas, east and west of Lough Derg the terrain is mainly rugged, boggy moorland where some grazing by sheep occurs. In the lowlands, grass production and dairy farming predominate and in association with this silage making is carried out on farms in the lowland areas east and west of Lough Derg. Some intensive farming occurs in the area but this is not extensive. Agricultural activity in the area could constitute a potential threat to water quality, in particular in areas where intensive farm enterprises exist, where land spreading of farm wastes is carried out and in areas where silage is made. Forestry activities and peat harvesting operations are other activities which could potentially constitute a threat to water quality in rivers and lakes in the area. There is a wide variety of industrial activity established in the area which includes food and dairy products, engineering, timber and timber products. The principal industrial organic waste generators are in the dairy and food processing sections. The area is characterised by a large number of milk collection stations which service the large co-operative creameries in the region.

TABLE NO 2.3

Population Trends at Settlements in the Lower Shannon Catchment

Settlement	Population for years shown				
	1966	1971	1979	1981	Estimated 2006
Nenagh	4,635	5,174	5,827	5,871	8,500
Castletroy/Monaleen	-	-	-	4,000	10,000
Borrisokane	751	769	859	847	1,120
Moneygall	296	282	333	326	380
Toomevara	244	274	375	427	730
Newport	563	618	777	797	1,190
Cappawhite	311	305	363	406	560
Cappamore	556	595	658	755	1,090
Doon	385	393	456	419	470
Castleconnell	521	592	779	1,053	1,940
Caherconlish	361	345	492	505	740
Annacotty	-	255	344	402	770
Ballina	319	336	424	451	670
Killalce	816	906	975	1,022	1,360
Feakle	-	103	178	188	400
Scarriff	564	666	823	873	1,390
O'Briensbridge/Mount-pelier	234	237	346	360	570
Woodford	193	198	256	243	320
Portumna	878	917	1,161	1,118	1,500
Killimor	201	225	199	226	270
Portroe	-	118	289	322	830
Puckaun	-	57	234	253	350
Whitegate	-	109	185	193	400
Oola	360	348	378	401	470
Cloghjordan	463	480	474	478	500
Totals	12,651	14,302	17,185	21,936	36,520

FUTURE INDUSTRIAL DEVELOPMENT

2.14 In order to support the projected growth in population in the area over the next twenty years, considerable industrial development and expansion will be necessary to create new employment. Employment in the agricultural sector declined between 1971 and 1979 and it is not envisaged that this trend will be reversed. New employment opportunities must, therefore, be found in manufacturing and other productive activities and also in the services sector. It is difficult to anticipate what kind of new industry will be attracted to the area in the future; it is reasonable however to assume that some of this new industry will represent either an expansion of existing activities or new industry based on the agricultural activities or the natural resources of the region. Estimates are made later in the report (Chapter 7) of the future waste loads likely to arise as a result of population growth and future industrial development in the Lower Shannon catchment.

ADDITIONAL DATA REQUIREMENTS

2.15 The existing hydrometric data base in particular in relation to low flow is such that it is not always possible to be precise when giving flow rates especially during periods of low flow. As Water Quality Management Plans are adopted and put into operation more precise information will be required on flows in the upper reaches of some rivers in relation to effluent disposal and the abstraction of water to meet future demands. Four rivers have been identified in the Lower Shannon where additional hydrometric gauging stations should be provided, these include, the Graney, Cahir (tributary of Graney), Groody, and Newport rivers and a water level recorder should also be sited on Lough Graney. Staff gauges should be erected at eight further sites in the catchment where partial records should be obtained. Surface and groundwater constitute a single hydrological system and as such should be managed in order to prevent pollution and depletion. There is little information available on groundwater behaviour in the area of the Lower Shannon. To overcome this, a scheme should be prepared for the collection of data on groundwater which would, in particular, monitor the variation in groundwater levels in areas which are identified as aquifers.

2.16 Rainfall is another element of the hydrological cycle for which the existing data base could be improved. The feasibility of improving the collection of rainfall data, particularly at high altitudes, should be investigated in conjunction with the Meteorological Service of the Department of Communications.

CHAPTER THREE

WATER QUALITY

INTRODUCTION

3.1 An account of water quality in the Lower Shannon (i.e. from Portumna Bridge to Corbally Weir), in its principal tributaries and in Lough Derg and its feeder streams is presented in detail in Volume 5 of this report. This chapter summarises the main points made in that account.

3.2 The data upon which the account is based have been generated by the biological and physicochemical surveys of An Foras Forbartha and by the physicochemical investigations of the Regional Water Laboratories in Kilkenny and Castlebar, of Clare and Limerick County Councils and of Limerick Corporation.

3.3 For the rivers the biological investigations in many cases extend over the period 1971 to 1986; the physicochemical data refer to the period 1979-80 to 1985, the bulk of the measurements being made in the years 1983-85. The limnological investigations of Lough Derg were carried out by A.F.F. over the years 1972 to 1984.

3.4 The assessments of river and lake quality appearing in the report are primarily based on biological data which are supplemented by physicochemical information. The benthic macroinvertebrate community structure forms the basis of the quality assessment of rivers and streams; in lakes the planktonic algae are the primary indicators of trophic status and water quality.

3.5 Toxic pollution by mine tailings leachate is known to affect two river systems in the sub-catchment viz. the Kilmastulla (Silvermines) and the Lisduff (Tynagh Mines) systems but in the main the most widespread type of pollution encountered is that originating from the discharge of organic biodegradable wastes of all types. Such wastes may cause deoxygenation during active decay and eutrophication or nutrient enrichment on mineralisation. The characteristic end result is seen in the excessive development of weed and/or algal growths in rivers and lakes.

3.6 The following sections deal, in turn, with the assessments of water quality in the rivers and streams in the catchment and in Lough Derg. A general consideration of assessment methods is also presented in each case.

RIVERS AND STREAMS

Quality Assessment : General

3.7 Reliable assessment of water quality in rivers and streams req the complementary data generated by both biological and physicochemi surveys. The structure of the biological communities resident at a particular location in a river or stream gives an integrated picture average conditions at that particular point whilst the physicochemica surveys provide precise, quantitative data necessary for the accurate elucidation of pollutant concentration or other constituent concentra This topic is discussed in detail in an Appendix to Volume 5. In thi report the assessments of water quality in the rivers and streams of t catchment have been based primarily on the biological data for two rea firstly, because of the reliability of the biological data in reflecti average conditions, particularly in the highly critical summer/autumn period when the surveys are normally carried out and, secondly, because frequency of physicochemical sampling has been generally less than adeq for this purpose.

Quality Assessment : Biological

3.8 The assessment procedure is described in detail in Volume 5 but, briefly, it is based on the varying reactions to pollution of the differ elements of the macroinvertebrate fauna. This fauna consists largely of the immature, aquatic stages of aerial insects together with various crustaceans (shrimps and the like), molluscs (snails, mussels etc.), oligochaetes (worms) and other organisms, all of which are easily observed and identified in the field without the aid of microscopes. The fact tha characteristic assemblages of macroinvertebrates (communities) tend to develop in similar environmental conditions forms the basis of biological assessment procedures. For example, a characteristic faunal community is typically to be found in clean, unpolluted riffle areas (shallow, fast-flowing areas) of streams and characteristic well documented changes occur to this community in conditions of slight, moderate or serious organic pollution. These facts have led to the development of various assessment procedures, some of which employ biotic indices in order to simply convey the biological information to non-biologists. Such a scheme is employed here; this scheme identifies five arbitrary levels of water quality as follows:

Q5	Good Quality
Q4	Fair Quality
Q3	Doubtful Quality
Q2	Poor Quality
Q1	Bad Quality

The intermediate ratings Q4-5, 3-4, 2-3 and 1-2 are also used, thus effectively extending the scale to a nine point system. In the interests of simplicity, however, quality data can be compressed into a three class system as under:

Class A :	Unpolluted	(Q5, 4-5 and 4)
Class B :	Slightly polluted Moderately polluted	(Q3-4) (Q3 and 2-3)
Class C :	Seriously polluted	(Q2, 1-2 and 1)

3.9 Class A waters, because they are unpolluted, are unlikely to give rise to problems in relation to their existing and/or potential beneficial uses and are regarded, therefore, as being in a "satisfactory" condition. Waters classified as B and C are likely to have an adverse effect on beneficial uses to a lesser or greater extent and are, thus, in an "unsatisfactory" condition. For example, in Class B waters the excessive growths of aquatic weeds and algae - the characteristic end product of excessive nutrient input - interfere with such beneficial uses as abstractions, fisheries or amenity value. Increased intensity of plant photosynthesis and respiration in such reaches may lead to marked diurnal variations of dissolved oxygen, the minimum values usually occurring just before dawn, sometimes being low enough to stress or even kill fish. Rivers and streams subject to such excessive plant growth are regarded as being eutrophic to a greater or lesser extent and such conditions are typically encountered in the reaches downstream of lakes, in recovery zones of seriously or moderately polluted rivers and streams and in situations of slight or moderate organic pollution from either point or non-point sources.

3.10 In seriously polluted (Class C) reaches the presence of large concentrations of organic waste whether settled or in suspension may exert such a demand for oxygen (B.O.D.) that dissolved oxygen levels become depleted to the point where fish and other aquatic life may be eliminated. In certain instances the development of the slime organism *Sphaerotilus* (sewage fungus) may reach nuisance proportions. Serious depletion of dissolved oxygen can also arise in reaches affected by low B.O.D. but high nutrient content effluents due to respiration of abnormally dense growths of filamentous algae and/or higher plants which typically develop in such reaches.

3.11 There are no formal standards for the biological quality of freshwaters based on the diversity of the benthic fauna. However, the response of these organisms to organic pollution are well understood and show a basic similarity over a wide geographical area. A large number of arbitrary schemes of water quality assessment have been devised in Europe and the U.S., particularly in the last twenty years, but these all incorporate the basic idea of loss of diversity as pollution increases. In a series of technical exercises carried out in West Germany, Great Britain and Italy in 1975, 1977 and 1978 the biological water quality assessment procedures employed by the various environmental agencies throughout the E.E.C. were tested and compared. Teams from each participating nation employed their own particular techniques and procedures to assess water quality in a wide range of pollution conditions in the Main River - Germany, the Trent River - England and the Po River - Italy. A team of biologists (including the authors) from the Water Resources Division of An Foras Forbartha represented Ireland in this series of exercises. Results show that there is a high degree of concordance between the various techniques and assessment procedures employed throughout the E.E.C. and that water quality may be reliably assessed, even in unfamiliar situations, by macroinvertebrate biological assessment methods.

Quality Assessment : Physicochemical

3.12 Physicochemical data may be assessed in the light of guidelines, recommendations and standards, whether laid down by law or otherwise. At the present time the primary standards which are best used for this purpose are contained in the Directives of the E.E.C. One of these in particular, concerning the quality of water for freshwater fisheries (C.E.C., 1978)[1], is relevant in the present context, as is a set of guidelines issued by a technical committee set up to assist the Minister for the Environment (Technical Committee on Effluent and Water Quality Standards, 1978). To

[1]While this applies only to waters designated for the purposes of the Directive the limits specified are a general indication of the conditions required in fishery waters. It should be noted that, to date, there has been no designation of rivers in the Lower Shannon Catchment for the purpose of the Freshwater Fish Directive.

assist in the interpretation of the tabulated physicochemical results, these standards and guidelines, for three of the principal quality characteristics defined above, are set out in Table 3.1.

3.13 The reliability which may be placed on the representativeness of physicochemical data obtained from grab-sampling surveys, in respect particularly of the variations of water quality parameters in polluted reaches, is dependent on the frequency of sampling. In general, where water quality assessments are to be made on the basis of physicochemical data alone, monthly sampling would be a minimum requirement and in many cases a full evaluation might require weekly or even twice weekly sampling. A more detailed discussion of this topic is given in Volume 5. While the frequency of sampling in many of the rivers considered here has been less than monthly this drawback is compensated for by the availability of complementary biological data in most cases and by the pooling of data for several years. Thus, an acceptable degree of reliability may be placed on the general assessment of water quality at each point considered and on the ranges, at least, of the values recorded for each physicochemical parameter as being representative of the true ranges.

Lower Shannon : River/Stream Quality Status

3.14 Thirty-five rivers and streams have been surveyed in connection with this report either biologically (all 35 rivers) or physicochemically (24 of the 35 rivers). A water quality classification of those rivers surveyed biologically is presented in Table 3.2. This table shows that of the total channel length (360 km) surveyed biologically, some 80 per cent (288 km) is classed as generally unpolluted (Class A), approximately 19.5 per cent (70.5 km) as being in Class B, that is, either slightly polluted (12.5%; 45 km) or moderately polluted (7%; 25.5 km), and just 0.5 per cent (1.0 km) as subject to serious, chronic pollution (Class C).

3.15 Rivers assessed as remaining generally free of significant pollution include the Mulkear and its tributaries the Annagh, Bilboa and Newport Rivers, and also the Cappagh and Woodford Rivers. However, there is some evidence to suggest that the Mulkear itself may be subject to intermittent pollution at

TABLE 3.1

Standards for 3 parameters of water quality for freshwaters which are used or intended to be used as salmonid and/or cyprinid fisheries.
Sources: Council of the European Communities, Directive No. 78/659/EEC, (C.E.C., 1978) and the Technical Committee on Effluent and Water Quality Standards, (1978). Values shown are maxima in all cases except for Dissolved Oxygen where values are minima.
≮ = not less than. ≯ = not greater than. 'G' values are guideline values. 'I' values are mandatory values.

Parameter	SALMONID FISHERY WATERS		CYPRINID[1] FISHERY WATERS	
	Technical Committee	C.E.C.	Technical Committee	C.E.C.
Dissolved Oxygen (D.O.)	≮ 9 mg/ℓ in 50% of samples ≮ 6 mg/ℓ in 95% of samples ≮ 4 mg/ℓ in any sample	'G' Values: ≮ 9 mg/ℓ in 50% of samples ≮ 7 mg/ℓ in 100% of samples 'I' Values: ≮ 9 mg/ℓ in 50% of samples	≮ 7 mg/ℓ in 50% of samples ≮ 4 mg/ℓ in 95% of samples ≮ 3 mg/ℓ in any sample	'G' Values: ≮ 8 mg/ℓ in 50% of samples ≮ 5 mg/ℓ in 100% of samples 'I' Values: ≮ 7 mg/ℓ in 50% of samples
(B.O.D.)	≯ 4 mg/ℓ in any sample	'G' Values only: ≯ 3 mg/ℓ in 95% of samples	≯ 5 mg/ℓ in any sample	'G' Values only: ≯ 6 mg/ℓ in 95% of samples
Ammonia	≯ 0.016 mg/ℓ N (un-ionised)	'G' Values: ≯ 0.004 mg/ℓ N (un-ionised) ≯ 0.03 mg/ℓ N (Total) (in 95% of samples) 'I' Values: ≯ 0.02 mg/ℓ N (un-ionised) ≯ 0.8 mg/ℓ N (Total) (in 95% of samples)	≯ 0.02 mg/ℓ N (Un-ionised)	'G' Values: ≯ 0.004 mg/ℓ N (un-ionised) ≯ 0.16 mg/ℓ N (Total) 'I' Values: ≯ 0.02 mg/ℓ N (un-ionised) ≯ 0.8 mg/ℓ N (Total) (in 95% of samples

[1] Includes fish such as perch and pike as well as the true cyprinids (bream, rudd, roach, etc.).

TABLE 3.2

Rivers and Streams of the Lower Shannon Catchment showing Year of most recent Biological Survey, the Length of Channel in three Biological Quality Classes, and the Total Surveyed Length. Distances are rounded to nearest 0.5 kilometre.

RIVER	Year of Biolog. Survey	Channel Length [km] in Quality Class A [Q5,4-5,4] No Pollution	B [Q3-4] Slight Pollution	B [Q3,2-3] Moderate Pollution	C [Q2,1-2,1] Serious Pollution	Total Surveyed Channel Length [km]
Annacarriga	1984	1.0	–	–	–	1.0
Annagh	1983	19.0	–	–	–	19.0
Ardcloony	1984	0.5	–	–	–	0.5
Ballintotty	1986	3.0	5.5	1.0	–	9.5
Ballyfinboy	1984	17.5	3.0	3.0	–	23.5
Ballyteige	1984	1.5	–	–	–	1.5
Barnacullia	1986	–	–	1.5	–	1.5
Bilboa	1983	11.0	–	–	–	11.0
Blackwater [Clare]	1986	9.0	–	1.0	–	10.0
Bow	1984	3.5	–	–	–	3.5
Cahernahallia	1983	9.0	–	–	–	9.0
Cappagh	1983	9.5	–	–	–	9.5
Cappawhite	1983	–	–	5.0	–	5.0
Clareen [Nenagh]	1986	–	–	–	0.5	0.5
Coos	1984	3.0	–	–	–	3.0
Dead	1985	8.5	4.0	–	–	12.5
Derrainy	1984	4.0	1.0	–	–	5.0
Graney	1986	20.5	–	3.0	–	23.5
Grange [Tipperary]	1986	2.0	–	–	–	2.0
Groody	1985	–	10.5	1.5	–	12.0
Kilcrow	1986	15.5	6.0	1.0	–	22.5
Killeengarriff	1983	4.5	–	–	–	4.5
Kilmastulla	1985	8.5	6.0	3.5	–	18.0
Lisduff	1984	1.5	–	3.0	–	4.5
Lisduff Stream	1984	–	–	1.5	0.5	2.0
Mulkear	1983	20.0	–	–	–	20.0
Nenagh	1986	34.5	–	–	–	34.5
Newport	1984	18.0	–	–	–	18.0
Newtown	1985	5.5	–	–	–	5.5
Ollatrim	1984	8.5	9.0	–	–	17.5
Oola	1985	–	–	0.5	–	0.5
Shannon	1984	29.0	–	–	–	29.0
Small	1983	2.0	–	–	–	2.0
Woodford [Galway]	1984	12.5	–	–	–	12.5
Youghal	1985	5.5	–	–	–	5.5
Total Lengths		288.0	45.0	25.5	1.0	359.5
Percentage of Total Length		80.0	12.5	7.0	0.5	100 %

(Class B combined: 65.5 km, 19.5 %.)

Ballyclogh and the Pope's River tributary (as yet unsurveyed) to creoso pollution in its upper reaches (J. O'Connell, Limerick County Council, p comm.).

3.16 Water quality in the Shannon itself was assessed as satisfactory 1984 but there were distinct indications of eutrophication. In recent years the salmon hatchery at Parteen has occasionally experienced difficulties which are attributed to phytoplankton from Lough Derg, as has the water abstraction plant at Castleconnell (N. Roycroft and M. Me pers. comm.). Any further intensification of eutrophication can only exacerbate these problems and possibly give rise to others, e.g. animal infestations in distribution systems which utilise the river or lake as source. Such infestations are frequently associated with eutrophic su waters (WRC, 1981). Deterioration of the game fishery and its gradual replacement by coarse fish species may also be expected if eutrophicatio intensifies.

3.17 Serious chronic pollution was encountered in two small streams - t Lisduff Stream, in which the pollution was caused by mine tailings, and t Clareen, polluted by point sources at Nenagh. Chronic pollution of a le serious but nevertheless pronounced degree (termed 'moderate' pollution) recorded in twelve rivers and streams, including the Graney, the Kilmastu the Kilcrow, the Lisduff and the shallow upper reaches of the Ballyfinboy Cloughjordan. Point sources account for almost all the 'moderate' pollu observed. Chronic 'slight' pollution was encountered in eight rivers and streams which included the Groody (10.5 km), the Kilmastulla (over 6 km), Ollatrim (9 km), the Kilcrow (6 km) and the Ballyfinboy (3 km). In most this level of pollution was associated with a more serious level of pollut immediately upstream, which is to say that the reaches affected were mostl recovery zones. Point sources appear to have been the cause of this poll

3.18 The available physicochemical data, summarised in Table 3.3, indica that the mandatory limit set for D.O. in the E.E.C. Freshwater Fish Direct (9 mg/l O_2 in 50 per cent of samples) would most likely have been complied at most stations sampled. However, this may not have been true in some ca including the Cappawhite and Clareen Rivers. The D.O.E. salmonid water g line limit of not less than 4 mg/l O_2 in any sample would most likely have

TABLE 3.3

Ranges of Minimum and Median Values for D.O. and of Maximum and Median Values for B.O.D., Ammonia, Oxidised Nitrogen and Orthophosphate on Rivers and Streams in the Lower Shannon Catchment. [The bulk of the measurements were made in 1983-85 by the Regional Water Laboratories]

RIVER/[Number of Sampling Stations]	Dissolved Oxygen [% Saturation]		Biochem Oxygen Demand [mg/litre O2]		Ammonia [mg/litre N]		Oxidised Nitrogen [mg/litre N]		Orthophosphate [mg/litre P]	
	Min	Med	Med	Max	Med	Max	Med	Max	Med	Max
Annagh [3]	72-80	90-92	1.1-1.2	3.5-4.5	0.02-0.03	0.05-0.27	0.3-0.4	0.9-1.0	0.01-0.02	0.06-0.11
Ballintotty [3]	74-76	93-100	1.4-1.5	3.3-30.0	0.03-0.05	0.06-0.24	2.1-2.5	3.8-5.0	0.04-0.09	0.12-0.29
Ballyfinboy [8]	66-76	87-93	1.1-1.6	1.7-3.5	0.03-0.06	0.06-0.22	1.7-1.9	3.3-4.1	0.02-0.05	0.08-0.20
Bilboa* [3]	9.6-9.7a	10.4-10.5a	0.8-1.3	1.8-1.9	-	-	-	-	-	-
Blackwater [Clare]+ [3]	60-72	92-94	1.5-1.7	4.7-6.1	-	-	-	-	-	-
Cahernahallia [3]	76-86	92-92	1.1-1.2	1.6-2.2	0.02-0.03	0.05-0.13	0.6-0.9	1.5-1.7	0.01-0.02	0.02-0.10
Cappagh [5]	70-82	80-90	1.3-1.5	2.2-3.4	0.02-0.05	0.08-0.12	0.16-0.81	0.46-1.61	0.01	0.02-0.06
Cappawhite [2]	34-74	70-84	2.0-4.1	1.5-15.5	0.07-0.63	0.4-4.4	1.7-1.9	2.4-2.8	0.06-0.19	0.12-0.68
Clareen [1]	10	44	21.1	53.4	1.37	4.09	4.1	11.0	1.52	2.70
Dead [3]	64-65	82-86	1.5-1.8	4.1-8.1	0.08-0.14	0.36-2.7	0.9-1.1	1.5-2.2	0.09-0.13	0.18-0.32
Graney+ [4]	69-75	88-92	1.6-2.0	3.2-4.4	-	-	-	-	-	-
Grange [Tipperary] [1]	80	90	1.0	4.3	0.04	0.14	0.9	1.6	0.03	0.12
Groody* [4]	7.5-8.9a	8.9-11.3a	1.4-2.8	3.2->7.6	-	0.20	-	-	-	-
Kilcrow [7]	67-78	87-92	1.2-1.7	2.4-4.6	0.03-0.05	0.12-0.40	0.71-1.14	1.95-2.63	0.01-0.02	0.03-0.14
Killeengarriff* [3]	8.9-10.0a	10.3-11.1a	1.4-1.5	1.6-2.7		0.16	-	-	-	-
Kilmastulla [10]	76-83	88-112	0.6-1.4	1.3-4.5	0.02-0.05	0.07-0.46	0.1-1.1	0.4-2.9	0.01-0.02	0.03-0.11
Nenagh [9]	72-84	89-96	1.2-3.0	2.5-5.0	0.02-0.17	0.07-0.60	1.5-2.2	2.4-4.5	0.01-0.10	0.05-0.50
Newport [4]	81-84	92-95	1.1-1.2	2.0-5.9	0.01-0.03	0.06-0.20	0.4-0.5	0.8-1.1	0.01-0.02	0.10-0.31
Newtown [2]	78-84	90-92	1.6-1.7	3.5-4.5	0.02-0.04	0.08	1.1-1.4	1.8-2.0	0.01-0.02	0.04-0.05
Ollatrim [5]	74-76	98-104	1.2-1.3	1.8-23.5	0.02-0.04	0.05-1.5	1.5-2.1	2.8-4.3	0.02-0.03	0.05-0.20
Shannon [15]	62-87	80-103	1.5-2.3	2.5-9.8	0.02-0.30	0.08-0.10	0.6-0.8	1.6-2.4	0.01-0.02	0.02-0.08
Small [2]	82-83	90-91	1.1	2.9-3.5	0.01-0.02	0.04	0.3-0.8	0.9-1.3	0.01	0.03
Woodford [Galway] [3]	72-80	84-90	1.0-1.3	4.6-7.9	0.02-0.04	0.05-0.09	0.2-0.3	0.4-0.7	0.01-0.02	0.04-0.18
Youghal [3]	80-84	92	1.2-1.5	3.0-5.5	0.02-0.04	0.1-1.7	0.8-1.4	2.0-2.3	0.02-0.05	0.07-0.21

* : Data from Limerick County Council; + : Data from Clare County Council; a : D.O. recorded as concentration in mg/l O2.

breached in the two last-mentioned rivers. The more stringent E.E.C. s water guideline ('G') limit of not less than 7 mg/l O_2 in any sample wou probably not have been achieved in the Ballyfinboy, Cappawhite, Clareen, and Kilcrow, and in the Shannon itself. It should be stressed that no has been taken here of possible nocturnal depletion of D.O. and so the impression emerging may well be an over-optimistic one. In view of the and also in view of the relatively significant proportion (20%) of river channel biologically assessed as polluted (Classes B and C), it is recom that more consideration be given to the measurement of diurnal fluctuati D.O., particularly in the critical summer/autumn period.

3.19 Mandatory limits for B.O.D. are not specified in the E.E.C. Freshw Fish Directive. The available data indicate that very few rivers survey would have been in compliance with the guideline limit (less than 3 mg/ℓ in 95 per cent of samples) specified in this Directive and only the Bilbo Cahernahallia, Killeengarriff, Shannon and Small Rivers would have been i compliance with the D.O.E. requirement of less than 4 mg/ℓ O_2 in all samp

3.20 The E.E.C. mandatory limit for total ammonia in salmonid waters (0.8 mg/ℓ N in 95 per cent of samples) would probably have been complied with in most of the rivers for which information is available but not in t Ballintotty, Cappawhite, Clareen, Dead, Ollatrim or Youghal Rivers where concentrations well in excess of this limit have been recorded. The more stringent guideline limit (0.03 mg/ℓ N) would probably have been exceeded practically all of the rivers surveyed with the exception of the Small River and possibly the Bilboa. It might be mentioned here that National Limit Values (NLVs) for the parameters specified in the Freshwater Fish Directive, including ammonia, are presently under consideration by a D.O.E Technical Committee. The NLVs emerging are likely to be less stringent than the guideline ('G') limits in the Directive.

3.21 Limit values for Oxidised Nitrogen and Orthophosphate have not been proposed for fishery waters but levels recorded in the Lower Shannon Catchment were generally within the ranges expected of unpolluted rivers. Abnormally high levels for both parameters have been recorded in the Cappawhite, Clareen and Nenagh Rivers and in addition very high Oxidised Nitrogen concentrations have been recorded in the Ballintotty, Ballyfinboy, Kilcrow, Nenagh and Ollatrim Rivers.

3.22 Although it is unlikely that significant chronic pollution remains undetected in the main rivers and streams of the Lower Shannon Catchment, it is quite possible that short-term and 'once-off' type pollution has gone undetected. Such pollution cannot be assessed with any confidence by means of routine river monitoring surveys. The potential for this type of pollution is best assessed by regular inspections of potential sources of such pollution e.g. silage pits and animal manure holding tanks and the like (See Volume 3). Fish-kills are a dramatic and obvious indication of such 'once-off' pollution; in rural Ireland such kills are often caused by silage liquor. Much unseen damage is also caused by this effluent which affects salmonid life. It is estimated that significant numbers of fish, particularly fry of the year (which are often unrecorded), are wiped out. (J. Spillane, Shannon Regional Fisheries Board, pers. comm.).

3.23 Limited physicochemical investigations show that the Kilmastulla and Lisduff Rivers and some of their small tributary streams continue to be seriously polluted by zinc which leaches from worked out mines at Silvermines and Tynagh. High levels of lead and to a lesser extent copper have also been recorded in streams in these areas. More detailed analysis, including sediment metal analysis is required in order to fully assess the degree of contamination in the main Kilmastulla and Lisduff Rivers. The analyses should include silver, a highly toxic metal about which no information is yet available. Sediment metals analysis should also be carried out on the Shannon and Kilcrow Rivers below the Kilmastulla and Lisduff confluences.

3.24 Results of a pilot study on the levels of organic micropollutants in Irish waters which included the Graney, Nenagh, Ollatrim and Woodford Rivers showed that pesticide levels were everywhere quite low in comparison with E.E.C. limits whilst PAH levels were closer to those limits. Sediment analysis for organic micropollutants is also desirable as sediment contaminants tend to find their way into the food chain via aquatic macroinvertebrates.

3.25 The various criteria and standards for toxicants (see Tables 5.2 and 5.3) cannot and should not be regarded as absolute values for water quality. It should be borne in mind that toxicants such as metals can exert their effects in an additive or synergistic manner. The use of biossay techniques for assessing the toxicity of whole effluents is recognised as the ideal method for establishing safe concentrations of toxicants and in setting effluent standards (Technical Committee on Effluent and Water Quality Standards, 1978). Such bioassay techniques should be seriously considered for assessing existing and future potentially toxic discharges in the catchment. Some consideration should also be given to the use of biomonitoring techniques (fish monitors) for abstractions potentially at risk from contamination by metals or other toxicants. Such an abstraction is the Limerick City abstraction from the Shannon at Castleconnell downstream of the Kilmastulla River confluence. This plant had to be shut down as a precautionary measure following a spillage of liquor to the Kilmastulla at Silvermines which took place in 1980 (M. Meighan, Limerick Corporation, pers. comm.).

LOUGH DERG

Introduction

3.26 Lough Derg is, by far, the largest lake in the Lower Shannon Catchm it and the small (11.5 ha) Poulawee Lough north of Nenagh are the only tw out of the 45 named lakes in the catchment for which recent water quality data are available. The latter lake was assessed as strongly eutrophic the basis of surveys carried out in 1982-83; these surveys were undertak to assess the impact of the discharge of treated sewage to a feeder strea from a new plant at the village of Puckane. Details of these surveys a given in Volume 5.

3.27 Lough Derg is the fourth largest lake in Ireland and the largest of the Shannon lakes. It is the major feature of the Lower Shannon Catchme and is of considerable economic importance to the area. The major features of the lake are set out in Table 3.4. The lake is presently us as the source for the Portumna water supply and a major abstraction is planned in the near future to provide a regional supply in Co. Tipperary (NR). In addition the major abstractions for the Limerick City supply taken from the River Shannon below Lough Derg are essentially lake water. The lake supports both salmonid (brown trout) and coarse fish stocks and these provide good angling. Lough Derg is also a popular part of the Shannon inland navigation system and a number of hire-cruiser operators are located in the area; boating and other amenities have been construct at a number of points along the shore. There has been a number of complaints in recent years from anglers and others regarding water qualit

TABLE 3.4

Lough Derg : Summary of the morphological and topographical characteristics.

National Grid Reference (lake centre)	R 800 900
Latitude	52^{0} 49' - 53^{0} 06' N
Longitude	8^{0} 09' - 8^{0} 31' W
Altitude (m.O.D.)	33.5
Surface Area (A) (km^2)	117.5
Maximum length (km)	35
Maximum width (km)	14.5
Volume (m^3)	887×10^6
Maximum depth (m)	36
Average depth (volume ÷ Surface Area) (m) ($\bar{z}$)	7.55
Length of Shoreline (L) (Including Islands (km))	179*
Development of Shoreline $\frac{L}{(2\sqrt{\pi \times A})}$ **	4.66
Catchment Area (km^2) (incl. lake)	10,400

* Total Shoreline of Islands - 24 km

** i.e. the ratio of the shoreline length (L) to the circumference of the circle which has the same area (A) as the lake.

conditions in the lake, e.g. the presence of algal scum and peat silt accumulations along shore lines. These have prompted a number of investigations which are included in those described below.

3.28 The lake waters are relatively hard (∿200 mg/ℓ $CaCO_3$), reflecting the limestone nature of much of the catchment, and pH values are usually in excess of 8.0. However, the water has a distinct colour at times (60-100 Hazen), particularly in the upper section, this being attributable to the large peat lands upstream of Portumna. The transparency of the water is not high on this account and may be reduced to less than 1.0 m in the upper lake at time of high flow in the River Shannon.

Water Quality Investigations

3.29 The water quality data available in respect of Lough Derg arise from investigations carried out by R. Southern and A. C. Gardiner in 1922-1923 (Southern, 1935; Southern and Gardiner, 1926, 1932, 1938) and the various surveys carried out by An Foras Forbartha since 1972. The most detailed of the latter investigations are those carried out in the period 1976-1978 while the most recent are those carried out in August 1982 and summer and autumn 1984 (Toner et al, 1973; Flanagan and Toner, 1975; Toner and Clabby, 1975; Bowman, 1985).

3.30 Surveys of 1921-23 In the 1921-1923 investigations Southern and Gardiner carried out a detailed examination of the phytoplankton and zooplankton of the River Shannon and Lough Derg. The general composition and succession of the phytoplankton described in the lake at that time is characteristic of a productive system with the blue-green form *Oscillatoria* spp. a prominent component of the algal standing crops. Extensive fringing reed beds were noted in most of the bays and abundant growths of sessile algae and other attached plants were noted on the sandy bottoms of many of these bays. Furthermore, the abundance of *Asellus* spp. in the bottom fauna in 1921-23 is also an indication of the productive status of the lake at that time. Considerable turbidity and high colour were noted in the River Shannon and upper part of the lake. In these features the lake did not differ greatly from the situation observed in the more recent surveys.

3.31 A.F.F. Survey - 1972 and 1974 General chemical and biological examinations of the water quality of Lough Derg were carried out by An Foras Forbartha in July 1972 and in February and July 1974. These surveys indicated that a substantial increase in the production of planktonic algae, and a decrease in water transparency, had occurred since 1922-1923. It was concluded from the findings of both of these surveys that a significant enrichment of the lake had occurred over the preceding fifty years.

3.32 A.F.F. Survey of 1975 A detailed survey of the benthic macroinvertebrate fauna of Lough Derg was carried out in May 1975. The observations on the bottom fauna showed that this was typical of a eutrophic lake. The dominant organism in the littoral and sub-littoral areas was *Asellus* spp. with Mollusca, Oligochaeta, Chironomids, Tricladida and Hirudinea also of importance. The fauna of the deeper muddy substrata was dominated by chironomids and oligochaeta. Some restriction of faunal abundance was indicated in the case of Portumna Bay and those deep areas of the northern section of the lake with peat silt deposits. The survey showed that peat silt was present on the substratum of the deeper parts of the lake as far south as Hagans Rock. Except for the Portumna Bay area silt was lying outside the sub-littoral zone, generally at depths greater than 5 - 6 m.

3.33 A.F.F. Survey of 1976 - 78 The principal investigation of the water quality of Lough Derg was carried out between 1976 and 1978. Sampling was carried out at approximately monthly intervals at selected lake stations and on the feeder streams. The locations of these lake and feeder stream sampling stations are indicated on Fig. 3.1. Measurements made included the following parameters of water quality: dissolved oxygen, B.O.D., total phosphorus, orthophosphate, ammonia, oxidised nitrogen, chlorophyll a and transparency. Examinations of the phyto- and zooplankton were undertaken.

3.34 A summary of the values recorded in Lough Derg between 1976 and 1978 for water quality and related parameters is given in Table 3.5. The highest concentrations of phosphorus, nitrogen, silica and chlorophyll were recorded in the upper section of the lake, values gradually reducing through the middle and lower sections. In contrast, transparency was higher in the lower part of the lake compared to the upper. These differences are clearly attributable to the inflow of the River Shannon at Portumna. In each section, however, the variations between sampling dates of the concentrations of the nutrients (phosphorus, nitrogen and silica) showed the typical seasonal patterns with late winter or early spring maxima and summer minima. Chlorophyll concentrations peaked in spring and in the late summer and early autumn, the latter representing the annual maxima at most stations. Transparency was also greatest at the time of high chlorophyll concentrations, reflecting the greater influence of water colour and, perhaps, organic silt

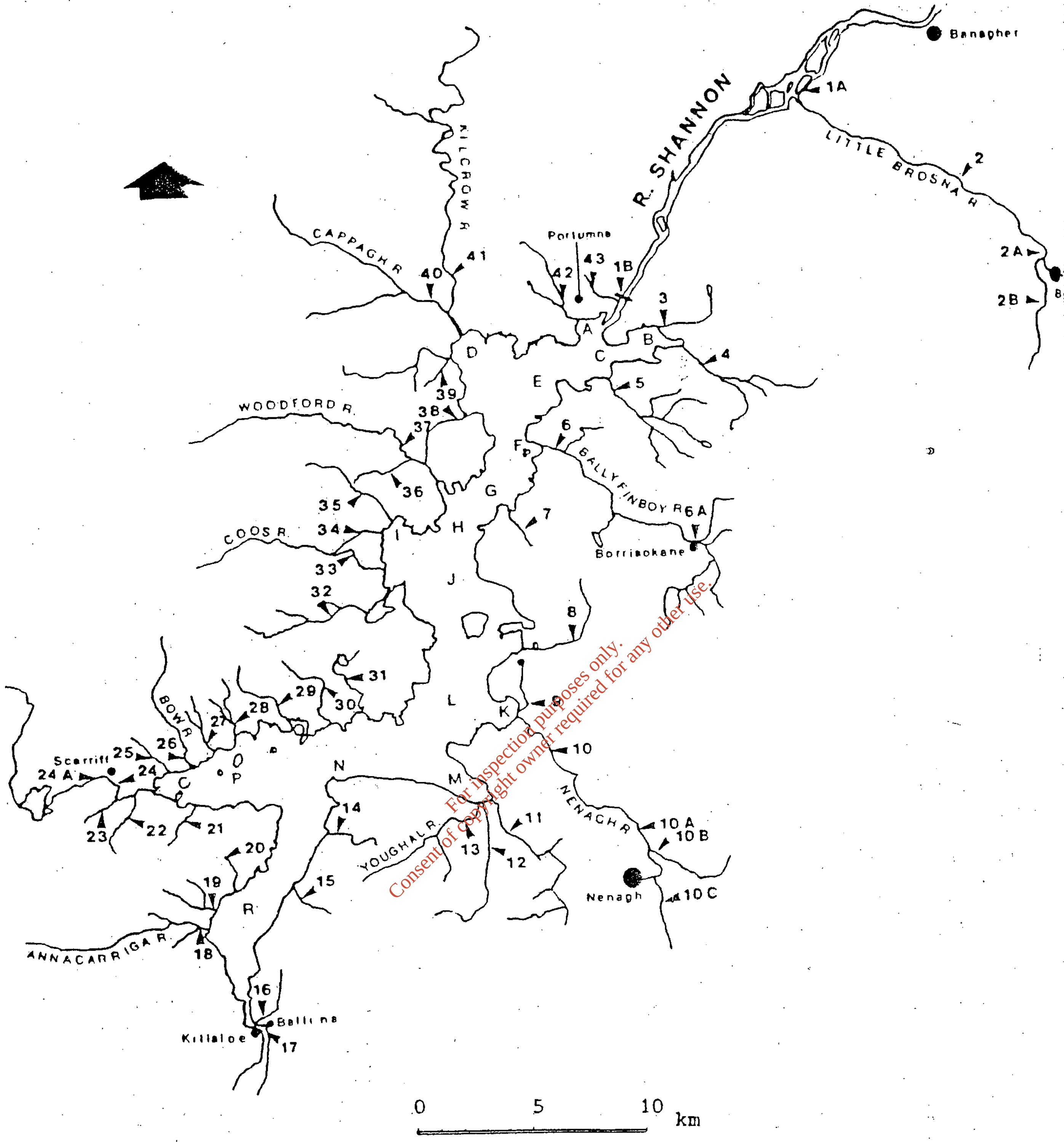


FIG. 3.1. Lough Derg. Showing locations of lake (A - R) and stream (1 - 43) sampling points, 1976 - 78.

TABLE 3.5

Lough Derg : Summary of water quality and related data recorded during the period January 1976 to December 1978 in the Upper, Middle and Lower sections of the lake. Figures are the ranges of the mean values recorded in each individual survey and the overall means (in parentheses) for the period.

ND : not detectable (<1 mg P m^{-3}; <1 mg N m^{-3})
T : Trace (<5 mg N m^{-3})

PARAMETER	Lake Section		
	Upper	Middle	Lower
Dissolved Oxygen[1], % sat.	S : 78 - 130 (96) B : 13 - 102 (86)	S : 87 - 110 (96) B : 72 - 97 (90)	S : 87 - 113 (96) B : 72 - 94 (90)
Total Phosphorus, mg P m^{-3}	8 - 85 (30)	5 - 55 (22)	5 - 55 (19)
Orthophosphate, mg P m^{-3}	ND - 28 (8)	ND - 18 (6)	ND - 25 (5)
Oxidised Nitrogen, mg N m^{-3}	60 - 3740 (960)	250 - 2100 (940)	300 - 2000 (930)
Ammonia, mg N m^{-3}	T - 135 (25)	ND - 85 (21)	ND - 80 (19)
Silica, mg Si ℓ^{-1}	0.1 - 2.5 (1.3)	0.1 - 4.5 (1.2)	0.1 - 2.4 (1.1)
Chlorophyll, mg m^{-3}	2.0 - 22 (8.3)	2.0 - 20 (7.3)	2.0 - 16 (7.3)
Transparency, m	0.9 - 2.8 (1.9)	1.1 - 3.2 (2.2)	1.8 - 4.5 (2.7)

[1] Data are for Station E (Upper Section), Station L (Middle Section and Station N (Lower Section) and relate to 1976-77 only.

S : Surface. B : Bottom. (Stat. E, 10 m; Stat. L, 35 m; Stat. N, 33 m) in suspension on this parameter than that of planktonic algae. The ph plankton populations in the lake were dominated by diatoms while the b green forms, *Oscillatoria* spp., were prominent in the summer and autumn periods.

3.35 The water column was generally well mixed on most sampling occasi with well oxygenated conditions at all depths. However, short periods thermal stratification were observed in summer months, particularly in Such conditions were accompanied by substantial deoxygenation in the lo layers in the upper lake but had a much more moderate effect in the dee middle and lower sections.

3.36 With the exception of a small stream at Portumna (No. 43) none of inflowing streams to Lough Derg was consistently polluted with organic waste during the 1976 - 1978 survey period. However, evidence of organi pollution during the summer period was noted in the Little Brosna River (at Birr) and the Nenagh River (d/s Nenagh). Consistently high phospho concentrations were recorded in a number of the principal inflowing stre However, those in the River Shannon at Portumna were relatively low and main inflow to the lake showed little sign of pollution.

3.37 <u>A.F.F. Surveys of 1982 and 1984</u> The results of less extensive examinations of the water quality of Lough Derg during the summers of 198 and 1984 are given in Table 3.6. The data indicated a significantly gre level of planktonic algal development compared to the 1976 - 1978 period, chlorophyll <u>a</u> values exceeding 50 mg m^{-3} in the upper section of the lake both 1982 and 1984. Also notable in these surveys were the values for total phosphorus concentrations and for transparency which were significa higher and lower, respectively, than those measured in the corresponding months of 1976 - 1978. In the 1984 survey accumulations of dead and deca algae were noted on several shores. These deposits seemed to have arise from the detachment of benthic algae in the littoral and sub-littoral are and not from planktonic forms.

3.38 <u>Nutrient Inputs to Lough Derg</u> Estimates are given in Table 3.7 of the annual inputs to Lough Derg in 1976 - 78 of total phosphorus, ortho-phosphate and dissolved inorganic nitrogen (oxidised nitrogen + ammonia). The estimates for the larger inflowing rivers and streams were based on fl and nutrient concentration data, using statistically significant relations established between nutrient load stream flow. Estimates for the smaller

Lough Derg : Ranges and means (in parentheses) of values recorded on sampling dates in 1982 and 1984 for water quality parameters in the Upper (U) (Stations B - G), Middle (M) (Stations H - M) and Lower (L) (Stations N - R, excluding Q) Sections.
NM : not measured. T : trace.

Sampling Date	Lake Section	Dissolved Oxygen % sat.	Orthophosphate mg P m⁻³	Total Phosphorus mg P m⁻³	Oxidised Nitrogen mg N m⁻³	Ammonia mg N m⁻³	Silica mg Si m⁻³	Chlorophyll a mg Chl a m⁻³	Colour Hazen	Transparency m
1982										
August 24,25	U	97 - 104 (99)	4 - 8 (5)	45 - 70 (55)	T - 220 (95)	15 - 35 (18)	1.35 - 2.0 (1.40)	38 - 55 (49)	15 (15)	1.2 - 1.3 (1.2)
	M	97 - 104 (100)	1 - 4 (3)	28 - 40 (34)	T - 100 (25)	10 - 25 (16)	1.50 - 2.15 (1.65)	34 - 41 (39)	15 (15)	1.5 - 1.6 (1.5)
	L	94 - 106 (100)	1 - 5 (3)	28 - 35 (30)	60 - 420 (252)	10 - 30 (19)	1.30 - 1.50 (1.40)	20 - 39 (27)	15 (15)	1.7 - 2.1 (1.9)
1984										
July 3,4	U	71 - 138 (118)	T - 1 (T)	18 - 30 (24)	430 - 580 (485)	20 - 30 (25)	0.40 - 0.60 (0.45)	8.8 - 11.0 (9.7)	25	2.3 - 2.8 (2.5)
	M	98 - 137 (111)	T - 3 (1)	23 - 43 (24)	530 - 740 (670)	20 - 65 (41)	0.50 - 0.55 (0.55)	3.7 - 9.5 (5.5)	25	2.8 - 2.9 (3.2)
	L	106 - 130 (114)	T - 3 (1)	13 - 23 (15)	800 - 960 (960)	25 - 60 (45)	0.45 - 0.55 (0.50)	3.8 - 5.4 (4.5)	25	3.4 - 4.0 (3.6)
July 31 and Aug. 1	U	96 - 101 (99)	1 (1)	23 - 30 (26)	140 - 260 (210)	60 - 85 (71)	0.80 - 0.90 (0.85)	15.7 - 22.5 (19.1)	20 - 25 (21)	2.4 (2.4)
	M	99 - 121 (104)	1 - 3 (1)	15 - 38 (22)	200 - 440 (325)	10 - 40 (30)	0.90 - 0.95 (0.92)	7.6 - 14.3 (11.0)	15 - 25 (20)	2.2 - 2.8 (2.45)
	L	49 - 117 (92)	1 - 3 (2)	23 - 45 (32)	500 - 600 (560)	10 - 35 (18)	0.80 - 1.0 (0.90)	6.9 - 11.6 (9.0)	10 - 20 (15)	2.6 - 3.7 (3.1)
Sept. 5,6	U	80 - 100 (91)	1 - 4 (2)	40 - 53 (49)	T (T)	T - 10 (5)	1.55 - 1.90 (1.76)	31.1 - 48.2 (40.8)	25 - 30 (25)	1.3 - 1.7 (1.5)
	M	91 - 101 (96)	1 - 3 (1)	25 - 53 (34)	60 - 120 (140)	5 - 10 (8)	1.65 - 2.25 (1.78)	25.2 - 40.4 (33.2)	20 - 25 (22)	1.6 - 2.0 (1.8)
	L	85 - 97 (92)	1 - 3 (1)	18 - 25 (21)	280 - 480 (396)	5 - 20 (12)	1.45 - 1.75 (1.5)	10.9 - 16.7 (14.2)	20 - 30 (22)	2.4 - 3.0 (2.9)
Sept. 25	U	NM	3 - 4 (3)	23 - 35 (29)	60 - 160 (110)	5 (5)	1.9 (1.9)	31.6 - 51.0 (41.3)	55 (55)	NM
	M	NM	1 - 3 (2)	20 - 33 (27)	T - 20 (6)	5 (5)	1.90 - 2.2 (2.05)	32.7 - 44.3 (37.6)	30 - 55 (40)	NM
Oct. 23,24	U	80 - 96 (89)	T - 18 (8)	50 - 58 (52)	320 - 1040 (460)	20 - 95 (51)	1.80 - 2.25 (2.05)	8.4 - 22.7 (13.2)	20 - 30 (30)	1.4 - 2.0 (1.6)
	M	89 - 99 (93)	T - 1 (T)	38 - 58 (48)	100 - 180 (154)	10 - 50 (32)	1.95 - 2.10 (2.05)	21.0 - 25.6 (23.0)	30	1.3 - 1.6 (1.5)
	L	92 - 96 (95)	3 (3)	28 - 35 (30)	120 - 160 (127)	20 - 35 (34)	1.85 - 2.0 (1.94)	5.4 - 17.2 (16.2)	15	1.1 - 2.8 (2.2)

TABLE 3.7

Lough Derg Nutrient Input. Estimates of the annual inputs of total phosphorus, orthophosphate and dissolved inorganic nitrogen from various sources in 1976, 1977 and 1978.

Parameter / Source	Total Phosphorus Tonnes P			Orthophosphate Tonnes P			D.I.N. Tonnes N		
	1976	1977	1978	1976	1977	1978	1976	1977	1978
Streams	168.7	232.8	211.1	71.2	98.1	92.4	4553	6862	6244
Scarriff Sewage	0.64	0.64	0.64	0.64	0.64	0.64	2.1	2.1	2.1
Portumna Sewage	0.82	0.82	0.82	0.82	0.82	0.82	2.7	2.7	2.7
Pleasure Cruisers	0.25	0.25	0.25	0.25	0.25	0.25	0.9	0.9	0.9
Aeolian	2.23	2.23	2.23	2.23	2.23	2.23	100	100	100
Total	172.6	236.7	215.0	75.1	102.0	96.3	4658	6967	6349
Lake Surface loading $g\ m^{-2}\ yr^{-1}$	1.47	2.01	1.8	0.64	0.87	0.81	39.7	59.3	54.1

were derived from those made for the larger inflows by assuming constancy of nutrient export rates among adjacent sub-catchments. Inputs from waste sources were estimated on the basis of population size, industry type and level of waste treatment.

3.39 It is estimated that in the period the input of total phosphorus from the streams accounted for 98 per cent of the total input to the lake of which 77 - 80 per cent was carried by the River Shannon alone. Wastes discharged directly to the lake or a short distance from the lake were estimated to account for only 4 per cent of the total phosphorus input. In the case of orthophosphate and dissolved inorganic nitrogen, respectively, 95.7 per cent and 99.9 per cent of the total input over the three year period were estimated to be attributable to the inflowing rivers and streams.

The Trophic Status of Lough Derg

3.40 Three limnological categories, oligotrophic, mesotrophic and eutrophic, have been used since the early years of the century to classify lakes exhibiting increasing levels of nutrient availability. Oligotrophic lakes are characterised by relatively low nutrient input and consequently poor growth of algae, and the eutrophic lakes by relatively high nutrient input and large growths of algae. The mesotrophic lake is intermediate between the two former types. The description of these trophic categories has, until recent years, been made in a qualitative manner. Recognising the need to quantify the above descriptive terminology used in ascribing a trophic status to a lake system, particularly from the water quality management viewpoint, the report of the recently completed O.E.C.D. study of eutrophication in lakes (O.E.C.D., 1982) proposed a quantitative classification system for lakes based on the concentrations of total phosphorus and chlorophyll a and on water transparency (secchi disc). This classification scheme is set out in Table 3.8. In addition to the three main categories referred to above the scheme is extended to include the ultra-oligotrophic lakes of very low nutrient input and algae development and the hypereutrophic lakes with a very high level of nutrient input and algal development. The scheme is not designed specifically as a water quality classification. However, the possibility of artificial eutrophication due to pollution increases as values recorded for the parameters in Table 3.8 fall within the higher part of the eutrophic ranges. Values falling within the hypereutrophic ranges are likely to indicate serious pollution in most cases.

TABLE 3.8

Classfication of Lake Waters on the Basis of the Concentrations of Total Phosphorus and Chlorophyll a and on Transparency (O.E.C.D., 1982). (Annual Values)

Lake Category	Tot. Phos. mg/m³	Chlorophyll a mg/m³		Transparency m	
	Mean	Mean	Max	Mean	Min
Ultra-Oligotrophic	≤4	≤1.0	≤2.5	≥12	≥6
Oligotrophic	≤10	≤2.5	≤8	≥6	≥3
Mesotrophic	10 - 35	2.5 - 8	8 - 25	6 - 3	3 - 1.5
Eutrophic	35 - 100	8 - 25	25 - 75	3 - 1.5	1.5 - 0.7
Hypereutrophic	≥100	≥25	≥75	≤1.5	≤ 0.7

TABLE 3.9

Lough Derg : Mean concentrations of total phosphorus, annual mean an[d] maximum concentrations of chlorophyll a and mean and minimum water transparency values for 1976, 1977 and 197[...] The maximum chlorophyll concentration recorded in the summers of 1982 and 1984 are also given.

Year	Tot. Phos. mg P m⁻³	Chlorophyll a mg m⁻³		Transparency m	
	Mean	Mean	Max*	Mean	Min
1976	25	8.2	13.4	2.2	0.8
1977	18	6.6	14.7	2.3	1.5
1978	20	6.8	14.2	2.1	0.9
1982			38		
1984			29		

* The term maximum chlorophyll a refers to the maximum mean value measured in the lake during the year rather than the maximum indivi[...] value measured.

3.41 Classifications based on this scheme are most reliable when data are available for all five parameters, i.e. allow the calculation of annual means. The 1976 - 78 survey of Lough Derg provided sufficient data for this purpose. While the short duration of the 1982 and 1984 surveys did not allow the calculation of annual mean values of the relevant parameters for those years it has been assumed that the maximum concentrations recorded for chlorophyll during these surveys are approximations of the corresponding annual values and these have been used to assess the trophic category of the lake.

3.42 The values recorded in Lough Derg for total phosphorus and chlorophyll a concentrations and for transparency in 1976, 1977 and 1978 are set out in Table 3.9. When compared with the classification scheme in Table 3.8 these data indicate that the trophic status of the lake in those years was transitional between mesotrophic and eutrophic. However, the assumed annual maximum concentrations of chlorophyll for 1982 and 1984 indicate a clearly eutrophic condition for Lough Derg in those years. In turn, these classifications would suggest that the lake was subject to a slight to moderate degree of artificial eutrophication. The conditions observed in 1976 - 1978 would be unlikely to lead to any adverse effect on beneficial uses; however, the levels of algal growth observed in 1982 and 1984, if persistent, could have an adverse effect on game fish angling, by creating excessive turbidity, and on abstractions, by increasing the concentrations of particulate and dissolved organic matter in the water going to treatment.

3.43 An examination of the data on phytoplankton abundance in the lake in 1922, based on the work of Southern and Gardiner, mentioned above, has been undertaken. While there are some difficulties in comparing these data with those arising from the more recent surveys, there is a clear indication from the comparison that the abundance of planktonic algae has increased significantly in the lake over the 50 - 60 year period involved. In addition to the general increase in abundance, algae commonly associated with eutrophic conditions, e.g. *Oscillatoria* spp. have become more prominent since the 1920s. Some eutrophication of the lake over this period is to be expected in view of the large size of the catchment and the various developments in both the urban and rural areas which would have led to increased 'export' of nutrients to the rivers and streams. It is possible, therefore, that some or all of the change in the lake's productivity between the 1920s and the 1970s has been inevitable and, on this account, would be difficult to reverse.

3.44 The increased abundance of algae in the lake in the summers of 1982 and 1984 compared to that in the main survey of 1976 - 78 is less easily explained. If these most recent measurements are representative, and this needs further confirmation, they would indicate a significant intensification of eutrophication in the lake over the 5 - 6 year period involved. Such an increase of the lakes capacity to produce algal growth would suggest a significantly increased nutrient input. However it is difficult to see how this would have happened over such a short period and the most recent data available for the feeder streams provide no evidence for such a change. It is possible that the enhanced growths of algae in 1982 and 1984 were due to unusual climatic or hydrological conditions. Alternatively, the enhanced growth of the planktonic algae could be the result of a change in the ecology of the lake whereby the latter organisms are now capturing more of the available nutrient input compared to the benthic algae and rooted plants. Such a change has been observed in many lakes in the course of artificial eutrophication. The situation in Lough Derg clearly needs further study in order to clarify the mechanism involved in the variations of algal abundance. In addition, routine monitoring should be instituted, at least for the measurement of the key parameters, e.g. phosphorus and chlorophyll, so that any further developments may be detected at an early stage and the representativeness of the 1982/1984 data established.

CHAPTER FOUR

BENEFICIAL USES

INTRODUCTION

4.1 A detailed account of the various beneficial uses of the Lower Shannon, its lakes and main tributaries is given in Volume 4. The uses to which these waters are put at present and in the future are of great importance in deciding which water quality standards are to be adopted for waters in the catchment. These standards are, in turn, a major consideration in the setting of effluent standards and other waste input limitations at specific sites. Thus, the existing and potential beneficial uses of water in the catchment have a major bearing on the scale of expenditure on waste treatment and control which must be borne.

4.2 The more important beneficial uses of the waters of the Lower Shannon Catchment are abstractions for public and private water supply, power generation, pleasure cruising, game and coarse fish angling and commercial eel fishing. Angling is a long established traditional past-time in the catchment; up to recently this concentrated on game fish but coarse angling is gradually becoming the more important. At least 4,500 anglers fish in the Lower Shannon Catchment and their annual expenditure is conservatively estimated at £1.35 M. The pleasure cruising industry is valued at some £8.45 M for the Shannon as a whole and after suffering some decline in recent years, mainly due to high VAT rates and the recession, is set to recover and increase in the coming years. Commercial salmon fishing, which is carried out just downstream of the catchment boundary is in serious decline but commercial eel fishing has potential for expansion at present.

4.3 Other beneficial uses of the waters in the catchment include swimming, pleasure boating, rowing regattas, sailing by boat and board, water skiing, canoeing, boat rallies, wild fowling and water side camping/caravanning, and picnic areas. In addition, a number of areas of scientific interest for ecologists, botanists and ornitholigists, are located in the catchment.

WATER ABSTRACTION

4.4 Information on the public and private abstractions of water in the catchment was obtained from the National Survey of Abstractions and Discharges with updated information supplied by the local authorities.

Abstractions of less than 5 m^3/day were excluded. The total public abstraction in the catchment, which arises from 88 sources, amounts to 52.7 x 10^3 m^3/day. Of this total, 42.1 x 10^3 m^3/day (79.9 per cent) is taken from surface waters and 10.6 x 10^3 m^3/day (20.1 per cent) from groundwaters. Direct abstractions (50) by private users amount to 33.0 x 10^3 m^3/day; of this total 26.6 x 10^3 m^3/day (80.7 per cent) is taken from surface waters and 6.4 x 10^3 m^3/day (19.3 per cent) from groundwaters. Overall, therefore, 80 per cent of waters abstracted in the catchment comes from surface sources. This compares with a figure of 90.6 per cent in the Upper Shannon Catchment. However, the position in the latter case is distorted by the large river abstractions for cooling purposes in power stations. In regard to public abstractions in the Upper Catchment, the proportion of water taken from groundwaters (51.9 per cent) is more than double the corresponding figure for the Lower Shannon Catchment.

4.5 The largest single abstraction in the Lower Shannon Catchment is the Limerick City supply (31,000 m^3/day) which is taken from a side canal of the main Shannon channel near Castleconnell. This is supplemented by another abstraction of 5,500 m^3/day further downriver at Clareville. The only other public abstraction of more than 1,000 m^3/day in the catchment is that (2,500 m^3/day) taken from a reservoir on the Newtown River to supply Nenagh. There are only two private abstractions greater than 1,000 m^3/day; one of these (6,112 m^3/day) is taken from mine and spring water at Garryard for a minerals extraction plant and the other (4,000 m^3/day) from the main channel below Killaloe for an E.S.B. hatchery.

FISHERIES

Angling

4.6 While some salmon angling is carried out in the catchment, particularly on the main channel and the Mulkear River, brown trout angling is more widespread. Good brown trout fishing is available at some locations e.g. on parts of Lough Derg. Some angling representatives claim that the upper reaches of that lake are suffering from peat silt deposits which may be affecting mayfly (*Ephemera danica*). Studies by An Foras Forbartha (Toner & Clabby, 1975) did not support this claim; however, more up to date data shou[ld] be gathered to clarify the present situation.

4.7 Coarse fish angling is growing rapidly in importance, particularly in the O'Briensbridge areas and in East Clare due to extensive promotion and advertising in the U.K. However, concern has been expressed about over-fishing for pike, particularly the larger ones, as returns from pike angling competitions suggest that the average weight of pike caught is steadily declining. A serious reduction of the numbers of larger fish could affect spawning and thus stocks.

Monetary Value of Angling

4.8 Because accurate records are not kept regarding revenue generated by local and tourist anglers it is only possible to make an estimate. This estimate is based on known numbers of members of local angling clubs and estimated numbers of salmon anglers who bought licences in the Shannon Fishery District in 1982 (Department of Fisheries and Forestry, 1982). Such numbers would tend to be conservative and would omit those who fish from cruisers, casual anglers who may not be members of angling clubs or those who may not purchase a salmon licence. Spending by the estimated 5,000 anglers is £1.348 M of which £0.778 M is attributed to visitors and the rest to local anglers.

Commercial Fishing

4.9 Commercial salmonid (salmon and sea trout) fishing is carried out downstream of the catchment boundary although some of the fish stocks would have been recruited from spawning and nursery areas within the Lower Shannon Catchment. Prior to the construction of the Ardnacrusha dam in the late 1920s the River Shannon was an outstanding salmon river. The fishing declined for a time but improved after the construction of fish passes and catches built up again until the 1970s. When drift nets became widely available a decline commenced which has become marked in recent years. Since 1979 the E.S.B. have suspended netting at Thomond Weir and in the State nets in the Shannon estuary.

4.10 Commercial eel fishing on the Lower Shannon Catchment is carried out at Cloonlara on the Headrace, Castleconnell and Killaloe. The highest yield of eels recorded to date has been 92 tonnes in 1948. Moriarty (1982) has estimated that the potential annual yield for Lough Derg alone is 233 tonnes.

4.11 The combined value of the estuarine salmonid and the freshwater eel fisheries is estimated to have been £0.38 M in 1983. Combining the estimated values of angling and commercial fishing gives a total value of £1.73 M, of which the former accounts for 78 per cent.

Spawning of Game Fish

4.12 Salmon and trout spawn in the upper reaches of most of the tributary streams in the Lower Shannon Catchment. The majority of returning salmon (60-80 per cent) migrate upriver through the fish passes at Ardnacrusha and Parteen. Some of these fish are of hatchery origin having been reared at Parteen Station and subsequently released as smolts in tributary streams. Brown trout stocking is also carried out throughout the catchment by Angling Clubs and the E.S.B. (See Map 2, pocket, back cover).

PLEASURE CRUISING

4.13 The first hire cruiser for family holidays on the River Shannon navigation system became available in 1960. There are at present some 433 boats for hire compared to a maximum of 527 in 1980 (Mr. Brian Maher, Bord Fáilte, pers. comm.). It is considered that a similar number of private craft use the navigation. The value of cruising on the River Shannon (Upper and Lower) was estimated to be £8.448 M (£6.753 M excluding fares) in 1984 (Bord Fáilte). The potential growth of this industry has not been fully realised due to the recession and very high VAT levels (Mr. Derek Dann Emerald Star Line, pers. comm.). The lack of crowding on the navigation, compared to other European waterways is indicative of the immense potential of the Shannon as a premier boating holiday region. In the Lower Shannon Catchment itself, Lough Derg is a very popular part of the navigation and there are several boat-hire firms located on the lake as well as general amenities for boat users.

4.14 Complaints occur from time to time regarding the present direct waste disposal arrangements from cruisers which can give rise to unsightly floating wastes especially in small confined bays. An experiment is underway at present to solve this problem in some 20 Emerald Star Line cruisers which have been fitted with on-board sanitary treatment facilities.

RECREATION AND AMENITY

4.15 Apart from boating, angling and related water contact sports already referred to, there are also other attractions such as scenic motoring routes along the southern end of Lough Derg, forest walks (Portumna especially), camping/caravanning at Killaloe, Ballinderry and O'Briensbridge, hotels, guesthouses, self-catering 'Irish' cottages at Terryglass, Puckaun and Mountshannon, developed amenity areas at Castlelough, Dromineer, Garrykennedy, Killaloe and Portumna and historical sites at many locations including Killaloe, Portumna and O'Briensbridge.

WATER POWER GENERATION

4.16 The Shannon hydroelectric works at Ardnacrusha produces 310 million units of electricity per annum (O'Leary, 1977). There are also some 16 identified small scale hydro-electric generation sites in the Lower Shannon Catchment with a potential generation capacity of 681 KW. Two of the 16 sites are operating at present, one on the Kilcrow River and the other on the Nenagh River. Many of the remaining sites are located at former mills where conversion to power production would be relatively simple and inexpensive. However, with small scale hydro-electric power development, the need to take the necessary measures (e.g. screening fish passage) in order to protect the existing fisheries beneficial use should be borne in mind.

AREAS OF SCIENTIFIC INTEREST

4.17 There are 29 areas of scientific interest in the Lower Shannon Catchment (see Map 3, inside back cover). Six of these are of national importance, 13 of regional and ten of local importance. The areas include oakwoods, marshes, weed-fringed shorelines, ornithologically important wildfowl areas, bogs, fens, quarries with interesting geological strata and a turlough (see Chapter 3 of Volume 4 for details).

OTHER ACTIVITIES

4.18 Peat Silt Commercial harvesting of peat lands upstream of Portumna has led to the ingress of peat silt to local waters. This has been carried into the main river to form large concentrations there and in the upper reaches of Lough Derg especially in Portumna Bay. Anglers claim that such desposits are reducing mayfly (Ephemera danica) hatches and thus trout catches. Investigations by An Foras Forbartha (Toner and Clabby,1975) did not produce evidence to support this. However, large peat silt deposits were found in deep water at the northern end of the lake. A further survey is now required to update this information.

4.19 Drainage Flooding in the Lower Shannon Catchment is usually much less serious than that which occurs in the Upper Catchment where the flow of the main river exceeds the channel capacity 15 per cent of the time (Lynn, 1977). Some Lough Derg tributaries have been subjected to drainage schemes in the last 25 years and these include the Clareen, Carrigahorig, Ballyglass/Knockcroghery streams and the Nenagh and Killmor Rivers and their tributaries. In 1984 the lower reaches of the Ballyfinboy River were drained by an unofficial party resulting in the removal of bankside trees and the gravel in spawning areas. This has caused great annoyance among local anglers as a more sensitive approach could have caused far less damage while achieving the same results in terms of improved land drainage.

CHAPTER FIVE

WATER QUALITY CRITERIA AND STANDARDS

INTRODUCTION

5.1 The beneficial uses of water in the Lower Shannon Catchment have been outlined in Chapter 4. This Chapter considers the water quality standards necessary to protect such uses. Since water quality standards are the basis for determining effluent quality standards, the former play a key role in controlling water pollution as well as in water quality management. In specifying water quality standards for the catchment it is necessary to consider the needs of the most water quality-sensitive uses and of those which are most commonly exercised. The information already presented shows that sports fisheries constitute the most widespread use of water resources in the catchment; it was also shown in this connection that virtually all waters in the catchment harbour salmonid fish although coarse fish also occur in many of the waters. The most important use is the abstraction of water for public and private supply; however, this use is practised at relatively few locations in the catchment, the abstraction points for the Limerick City supply being the most notable.

5.2 An examination of published sources shows that the water quality criteria for salmonid waters would be, in general, sufficiently stringent to meet the requirement of all other uses, including water abstracted for domestic use. In the latter case there are a very few parameters, e.g. nitrate and pathogens for which the criteria for fishery waters would not be sufficiently stringent. Nitrate levels in the surface waters of the catchment are, however, well within the limit of 11 mg/ℓ N set by the E.E.C. and other authorities to protect water abstracted for drinking purposes and are unlikely to reach that level in future. Contamination of water by pathogenic organisms, as indicated by the presence of coliform bacteria, which is not important where fisheries are concerned is, however, of major importance in water abstraction and water contact sports, especially swimming. As it is impractical to insist that all surface waters in the catchment comply with microbiological standards for abstraction or bathing waters, only waters immediately upstream of sites used for such purposes should be considered for microbiological quality control.

5.3 In view, therefore, of the ubiquitous occurrence of salmonid fish in the catchment and of the generally high level of water quality required to ensure the health of such fish it is proposed that the water quality standards for the Lower Shannon Catchment should be derived from water quality criteria for salmonid fish.

SPECIFIC RECOMMENDATIONS ON WATER QUALITY STANDARDS

General Comments

5.4 Criteria and standards in respect of five water quality parameters are discussed in detail below and those for other parameters are listed in Tables 5.1 and 5.2. As the wastes discharged in the catchment are primarily of the organic biodegradable type the five most important parameters for consideration are: Dissolved Oxygen (D.O.), Biochemical Oxygen Demand (B.O.D.), Ammonia, Oxidised Nitrogen (mostly nitrate) and Orthophosphate.

5.5 It is not realistic, when setting limits for water quality parameters, to expect full compliance with these limits, due to random variations brought about by such event as floods or extreme droughts or by minor variations in effluent quality. To allow for such phenomena it is accepted that the standard adopted should be a limit which may be exceeded for short periods, usually 5 per cent of the time. This standard is known as the 95 percentile limit (for D.O., values may be less than the 95 percentile value for only 5 per cent of the time). A median value or 50 percentile may also be specified as part of the standard; if the full range of the natural variations of the parameter in question are known it may be feasible also to specify a near maximum limit (99.9 percentile).

5.6 Adherence to time-based percentile limits must be assessed usually on the basis of data arising from relatively few samples gathered over a specified period. Compliance with the 95 percentile limits should be assessed as follows:-

for sample numbers of:-

a) 4 or less, total compliance,

b) between 4 and 20 only one sample may exceed the limit, and

c) over 20, statistical techniques should be used to estimate the 95 percentile value (for normal distribution, 95 percentile value = mean + standard deviation x 1.65).

5.7 Usually the allowed for exceedances of parameter values above the 95 percentile standard (or below, for D.O.), i.e. a maximum of 18 days per annum, will coincide with the periods of relatively low flow and poor dilution. During such periods it is possible that, in small tributaries particularly, water quality at points unaffected by waste discharges may not comply with specified standard limits e.g. for D.O. and ammonia concentrations. In areas where waste discharges occur the necessity to maintain water quality standards at very low flows may put unrealistic limits on the size of such discharges if it is kept in mind that the return period of the dry weather flow may be of the order of 50 years. Therefore, it may be uneconomical to provide the necessary level of waste treatment to ensure full compliance with water quality standards at very low flows and other measures may be more appropriate e.g. waste storage or flow augmentation. Such problems are unlikely to arise in the main channel of the Lower River Shannon due to sufficient dilution being available over the full range of river flows. The statutory compensation flow in this channel, downstream of the head-race division, is 10 m^3/sec, although in emergency situations this can reduce to 6 m^3/sec. In the future, even with greatly increased water abstraction, flows of this order are unlikely to give rise to problems along the main channel. Thus, it is proposed that the water quality standards recommended for the Lower Shannon should be adhered to at all flows in the main channel between Killaloe and Limerick. However, this approach is likely to be excessively stringent in the tributaries where dry weather flows are at least an order of magnitude lower than that of the main channel. It is, therefore, recommended that, in the case of the tributaries, the 95 percentile flow should be taken as the flow at and above which the recommended standards should be met. In the case of B.O.D., designation of these critical flows for the main channel and tributaries is essential as corresponding flows have been used to calculate waste loads, as B.O.D., for the two parts of the system.

5.8 It is important to note that these proposals apply only in the case of the five parameters reflecting pollution by biodegradable, organic wastes. Where toxic and/or persistent pollutants are concerned it is proposed that, in all waters, compliance with the standards be required across the full flow spectrum. A similar approach is taken in regard to defining waste assimilation capacity for such pollutants. In addition, it is proposed that, for reasons of simplicity, the assessment of compliance of lake waters with the standards specified should be based on samples taken under all hydrological conditions.

Dissolved Oxygen (D.O.)

5.9 The maintenance of well oxygenated conditions in water is particularly important where fish, especially salmonids, are concerned and, therefore, should have a high priority in a water quality management plan. Salmonids are more sensitive to reduced D.O. levels than coarse fish. D.O. concentrations below 3 mg/ℓ O_2 are soon lethal to salmonids but sub-lethal physiological effects on growth and reproduction may occur where D.O. values remain below 5 mg/ℓ O_2 for long periods. Healthiest populations of salmonids occur in waters constantly at or near full saturation.

5.10 Available data for D.O. concentrations in the Lower River Shannon Catchment are largely based on daylight sampling. However, minimum values usually occur (in summer particularly) at night or early in the morning, due to the continued respiration of the aquatic biota after the cessation of photosynthesis during the hours of darkness. Thus, it is imperative, during critical summer months, to record at least early morning (0.500 - 07.00) D.O. levels and to determine the duration of low D.O. levels over 24 hours at those stations where D.O. minima below 5 mg/ℓ occur.

5.11 The following standards are proposed for D.O. in the waters of the Lower Shannon Catchment and take account of the limits for the parameter set out in the E.E.C. Freshwater Fish Directive (C.E.C., 1978) and in 'Water Quality Guidelines' (Technical Committee on Effluent and Water Quality Standards, 1978).

99.9 percentile limit : 4 mg/ℓ O_2 (effective minimum)
95 percentile limit : 6 mg/ℓ O_2
50 percentile limit : 9 mg/ℓ O_2 (median)

(Assessment of compliance to be based on data representative of the lowest levels likely to occur over 24 hour periods; where levels less than 6 mg/l O_2 occur it must be shown that there are no adverse implications for fish stocks).

Biochemical Oxygen Demand (B.O.D.)

5.12 The B.O.D. test has been in use for almost a century as a general index of the effects of biodegradable waste on rivers. The most striking effect of such wastes is that of deoxygenation, although no direct relationship exists between B.O.D. and D.O. concentration due to complicating factors such as photosynthesis and respiration by aquatic plants, sediment respiration and, in particular, reaeration rates. The reaeration capacity of a river is mainly dependent on depth and current velocity. In a fast flowing reach of river the reaeration rate may be sufficiently high to prevent severe D.O. depletion even where high B.O.Ds occur (e.g. >10 mg/ℓ); in contrast, in deep, slow moving rivers, such as the main channel of the River Shannon, high B.O.D. values could produce anaerobic conditions, especially in eutrophic waters with abundant weed and algal growths. As a rule, concentrations of B.O.D. appreciably above background should be regarded as undesirable and indeed increased organic content in water used for abstraction purposes may lead to problems in treatment and supply.

5.13 In consideration of the above and of the limits suggested in the Freshwater Fish Directive and 'Water Quality Guidelines', the following standards are recommended for B.O.D. concentrations in the Lower Shannon Catchment:-

99.9 percentile limit	:	no proposal at present
95 percentile limit	:	5 mg/ℓ
50 percentile limit	:	3 mg/ℓ

Ammonia

5.14 Ammonia in the un-ionised form is toxic to aquatic life. The proportion of ammonia present in water in the un-ionised form increases with increase in pH and temperature. High concentrations of ammonia may react with chlorine in water treatment, reducing the effectiveness of the disinfection process. Studies have shown that a concentration of 0.025 mg/ℓ NH_3 (≡0.02 mg/ℓ N) of un-ionised ammonia is the 'no effect' limit below which adverse effects on salmonid and coarse fish will not occur. The concentrations of total ammonia (mg/ℓ N) giving rise to 0.02 mg/ℓ N of un-ionised ammonia, at different pH and temperature values, are given below. The above 'no effect' criterion is recommended by EIFAC (Alabaster and Lloyd, 1980) and is a little less stringent than that recommended by the E.P.A. (1976) and the Technical Committee on Effluent and Water Quality Standards (1978); their value is 0.02 mg/ℓ NH_3 (≡0.016 mg/ℓ N).

pH / Temp °C	6.5	7.0	7.5	8.0	8.5	9.0
5	52.1	16.5	5.2	1.6	0.54	0.19
10	34.9	11.0	3.5	1.2	0.37	0.13
15	23.8	7.6	2.4	0.77	0.26	0.10
20	16.5	5.2	1.6	0.54	0.18	0.072
25	11.4	3.6	1.2	0.38	0.13	0.057
30	8.1	2.6	0.8	0.28	0.10	0.046

5.15 In Ireland the most critical time for high ammonia concentrations would be in summer when high temperatures and significantly alkaline pH due to photosynthesis may occur. These conditions are likely to vary from 15 - 20 °C or higher and from 8.0 to 8.5; such conditions would produce a 'no effect' level of un-ionised ammonia (0.02 mg/ℓ N) in the presence of total ammonia ranging from 0.18 to 0.77 mg/ℓ N. The E.E.C. Freshwater Fish Directive (C.E.C., 1978) sets mandatory (I) limits of 0.8 mg/ℓ N for total ammonia and 0.02 mg/ℓ N for un-ionised ammonia.

5.16 In consideration of the foregoing the following standards are recommended for ammonia in the waters of the Lower Shannon Catchment:-

95 percentile limit : 0.5 mg/ℓ N (total); 0.02 mg/ℓ N (un-ionised)
50 percentile limit : 0.2 mg/ℓ N (total)

Oxidised Nitrogen (Nitrate and Nitrite)

5.17 Excessive concentrations of nitrate may arise from fertilisers leaching from land or from organic waste discharges. Nitrate levels in excess of 20 mg/ℓ N may cause methaemoglobinaemia in bottle fed babies. In addition, high nitrate levels show possible links with stomach cancer (Fraser and Chilvers, 1981; Mason, 1983). In view of the possible health risks it is accepted by leading authorities that nitrate levels in abstracted water used for public consumption should not exceed about 11 mg/ℓ N.

5.18 In terms of eutrophication in lakes high nitrate levels have been associated with excessive plant growth. However, in most freshwaters enhanced plant growth is attributed to increased phosphorus supply and in unpolluted waters nitrate is usually not the limiting factor for plant growth.

5.19 The following standards are recommended for oxidised nitrogen in the Lower Shannon Catchment. As the concentrations of nitrite are usually very low in surface waters (<0.01 mg/ℓ N), these standards may be applied also to nitrate:

99.9 percentile limit	:	11 mg/ℓ N
95 percentile limit	:	5 mg/ℓ N
50 percentile limit	:	3 mg/ℓ N

Phosphorus (Total and Orthophosphate)

5.20 The effect of increased phosphorus inputs to waters, especially freshwaters, is to promote the growth of green plants. This usually involves rooted plants and attached algae in rivers and planktonic algae in lakes.

Excessive plant growth is likely to have adverse effects on most uses of water. The worst effects are likely to be experienced with standing waters because of the presence of suspended algae.

5.21 The growth promoting effect of phosphorus (mainly the inorganic form) is due to its status as the growth 'limiting factor' in freshwaters; increased amounts enhance and reduced amounts diminish plant production. However, because of the interrelationships with other factors such as light, temperature, depth and current speed it has proved difficult to develop clear-cut criteria for phosphorus. In addition, there is no general agreement on the tolerable levels of plant biomass in standing or running waters. Recent studies co-ordinated by the O.E.C.D. (1982) have shown significant correlation between phosphorus input and in-lake phosphorus and chlorophyll concentrations; however, the confidence limits for these correlations are still quite wide.

5.22 <u>Rivers</u> Respiration and decay of excessive plant growths can result in severe pre-dawn deoxygenation in rivers and streams in late summer/early autumn. Jorga and Weise (1977) suggested that the '<u>critical biomass</u>' (viz. biomass above which respiration is likely to produce significant deoxygenation) of rooted plants in rivers is 250 g dry weight/m^2. However, studies by Horkan (unpub.) on the River Suir have shown that attached algae such as *Cladophora* may have a greater impact per unit weight than rooted plants. Pitcairn and Hawkes (1973) found that excessive growths of these algae only occurred at concentrations exceeding 1 mg/ℓ P. Median orthophosphate levels in the Lower Shannon Catchment are, in general, much less than one-tenth of this value.

5.23 In the absence of clear-cut criteria, Toner *et al* (1981) suggested that standards for orthophosphate in the River Suir should be based on maximum and median values at clean water stations, these values being designated, respectively, as the 95 percentile and 50 percentile concentrations. In the Lower River Shannon and tributaries the maximum and median concentrations of orthophosphate at such stations range, respectively, from 0.03 - 0.41 and from 0.01 - 0.04 mg/ℓ P the bulk of these, respectively, being less than 0.13 mg/ℓ P and 0.03 mg/ℓ P. At present, the cause/effect relationship of phosphate in the river is not clear, so it is considered prudent to adopt values somewhat greater than the latter values as appropriate percentile limits for orthophosphate. Thus the following tentative limits are proposed for orthophosphate in the flowing waters of the Lower Shannon Catchment.

95 percentile limit : 0.15 mg/ℓ P

50 percentile limit : 0.05 mg/ℓ P

N.B. More stringent limits may be required in the larger rivers and streams discharging into lake waters.

5.24 Lakes Increased phosphorus loading to lakes usually results in enhanced growth of planktonic algae which may become excessive leading to adverse effects on some or all beneficial uses. In shallow lakes growth of attached plants may also be stimulated by increased phosphorus loadings. The point at which 'nuisance' growth occurs depends, to a large extent, on local circumstances e.g. where water is abstracted, the degree of treatment is an important factor determining the likely effect of excessive algal growths. Game fisheries are also adversely affected by such growths; in contrast, coarse fisheries may be only moderately or not at all affected by such developments although the appearance of algal scums or discoloured water may deter anglers.

5.25 Phytoplankton biomass is usually assessed by the chlorophyll a content of the water. This is used in the O.E.C.D. (1982) classification of the lake waters (which also takes into account total phosphorus concentrations and water transparency) shown in Table 5.1. The lake categories given are

TABLE 5.1

Classification of Lake Waters on the Basis of the Concentrations of Total Phosphorus and Chlorophyll a and on Transparency (O.E.C.D., 1982). (Annual Values)

Lake Category	Tot. Phos. mg/m^3	Chlorophyll a mg/m^3		Transparency m	
	Mean	Mean	Max	Mean	Min
Ultra-Oligotrophic	≤4	≤1.0	≤2.5	≥12	≥6
Oligotrophic	≤10	≤2.5	≤8	>6	>3
Mesotrophic	10 - 35	2.5 - 8	8 - 25	6 - 3	3 - 1.5
Eutrophic	35 - 100	8 - 25	25 - 75	3 - 1.5	1.5 - 0.7
Hypereutrophic	≥100	≥25	≥75	≤1.5	≤0.7

those of classical limnology and do not refer specifically to water quality. However, the likelihood that the values observed in respect of the parameters in this table result from pollution induced eutrophication increases with the higher values in the eutrophic range and is virtually a certainty in the case of values in the hypereutrophic range.

5.26 As the effects of increased phosphorus concentrations in lakes are mainly expressed through increases in algal growth it is essential to consider the chlorophyll a ranges in Table 5.1 in respect of water quality requirements. Because of the relatively stringent requirements for water abstraction and salmonid fisheries, indicated earlier, it is suggested that suitable conditions for these uses would be present only where the chlorophyll a content of the lake did not exceed the lower part of the eutrophic range in Table 5.1. Thus, suitable guidelines for maximum acceptable algal production in such lakes might be an annual mean concentration not greater than 12 mg/m^3 and an annual maximum chlorophyll a concentration not greater than 35 mg/m^3.

5.27 An examination of the O.E.C.D. classification scheme given in Table 5.1 indicates that these guideline values for chlorophyll would equate with an annual mean total phosphorus concentration of 50 mg/m^3. However, the data available suggest that this relationship is not valid for Irish lakes and that a considerably lower phosphorus concentration limit is applicable. In lakes such as Loughs Ennell and Sheelin, it is probable that annual mean total phosphorus concentrations as low as 20 mg/m^3 could give rise to chlorophyll levels similar to the guideline limits suggested. However, higher annual mean concentrations of total phosphorus are likely to occur in markedly coloured lakes and these would need special consideration. It must be remembered also that permissible increases of phosphorus concentrations in lakes should take account of the greater bioavailability of the element in wastes compared to its composition in natural sources.

5.28 In consideration of the foregoing a tentative guideline for total phosphorus in lake waters used for abstractions and for game fisheries is as follows:-

Mean annual concentration not to exceed 25 mg/m^3 P

(N.B. This limit may not be sufficiently stringent for very low coloured lakes and may be too stringent for those of high colour).

Other Parameters

5.29 The above parameters will adequately assess water quality in respect of the bulk of waste inputs to the Lower Shannon Catchment. It is desirable, however, that water quality monitoring be expanded to take into account parameters which reflect contamination by non-biodegradable wastes such as pesticides and metals. This is particularly important because of the water abstractions presently made or those planned in the catchment and also because of recent mining activity at two sites which has resulted in water pollution problems in the past.

5.30 Detailed lists of these less common types of pollutants are given in Tables 5.2 and 5.3 at the end of this chapter. Recommended limits are given for the protection of the two main beneficial uses identified in the catchment, viz. water abstraction and salmonid fisheries. The limits recommended are based on water quality criteria produced by the U.S. E.P.A (E.P.A., 1972, 1976 and 1980) on the E.E.C. water directives (C.E.C., 1975, 1978) and on the 'Water Quality Guidelines' issued by the Technical Committee on Effluent and Water Quality Standards (1978) and these are also shown in the Tables.

AESTHETIC QUALITIES

5.31 Aesthetic quality standards are required to protect the general appearance and amenity value of the nation's waterways. In the Lower Shannon Catchment these standards should ensure that the waters are free from such substances as may cause offence or injury.

5.32 The recommended standards for aesthetic quality in the Lower Shannon Catchment are:-

All waters should be free from substances attributable to waste-water or other discharges that

- settle to form objectionable deposits,
- float as debris, scum, oil or other matter to form nuisances,
- produce objectionable colour, odour, taste or turbidity,
- injure or are toxic to or produce adverse physiological response in humans, animals or plants,
- produce undesirable or nuisance aquatic life.

MIXING ZONES

5.33 The concept of the mixing zone is based on the simple observation that when an effluent enters a receiving water, dilution is not instantaneous but takes place in an area known as the mixing zone (Technical Committee on Effluent and Water Quality Standards, 1978). General water quality standards cannot apply to these zones but it is essential to establish a level of control which will ensure that acute toxicity and other problems will not arise and that the zones will not act as barriers to prevent passage of migratory fish.

5.34 *The mixing zone is defined as an area adjacent to a discharge where initial dilution occurs and where receiving waters may not meet all quality* *criteria nor requirements otherwise applicable to the receiving water.* As damage may be inflicted on the aquatic resource by a partially-mixed discharge, the permissible size of the mixing zone depends on the strength of mixing forces (such as river flow), the exchange rate and the size of the receiving water body and whether other mixing zones are involved. Thus the permited extent of the mixing zone depends on a site-specific characteristics and requirements.

5.35 The quality guideline suggested by the E.P.A. (1976) is that, 'the quality for life within a mixing zone should be such that the 96-hour LC_{50} for biota significant to the indigenous aquatic community is not exceeded; the mixing zone should be free from effluent substances that will settle to form objectionable deposits, free from effluent-associated substances that form unsightly masses and free from effluent-associated substances that produce objectionable colour, odour or turbidity.

5.36 Because shallow waters tend to be important from an ecological point of view, providing spwaning and nursery areas for fish and supporting relatively abundant invertebrate fauna, it is desirable, where possible, to ensure that mixing zones be confined to deeper waters. Likewise, the zone should not form a barrier to migrating fish. Bearing these considerations in mind, it is logical to locate the mixing zones where maximum protection is afforded to aquatic life and least impairment occurs to other beneficial uses.

5.37 The recommended standard for mixing zones in the Lower Shannon Catchment is:-

Although water quality characteristics in mixing zones may differ from those in receiving systems, to protect uses in both regions it is recommended that mixing zones be free of substances attributable to discharges or wastes as follows:-

- materials which form objectionable deposits,
- scum, oil and floating debris,
- substances producing objectionable odour, colour, taste or turbidity,
- conditions which produce objectionable growth of nuisance plants and animals,
- concentrations of pollutants in the mixing zones should not give rise to acute toxicity, e.g. the 96-hour LC_{50} value for indigenous organisms should not be exceeded,

the mixing zone should be sited and sized to ensure the free passage of migratory fish and the maximum protection of fish and other aquatic life. The permissible size of a mixing zone will depend on the strength of mixing forces such as river flow, the exchange rate of the waterbody and the number of discharges. Where a number of mixing zones are involved each must be small enough to avoid overlap and to maintain an appropriate ratio of mixing zone to waterbody.

TABLE 5.2

Water quality criteria published for the less commonly measured pollutants of water and the corresponding water quality standards recommended for the Lower Shannon Catchment. Sources for criteria: 'Water Quality Criteria', (E.P.A., 1972); 'Quality Criteria for Water', (E.P.A., 1976); 'Ambient Water Quality Criteria', (E.P.A., 1980); EEC 'Surface Water Directive', (C.E.C., 1975); EEC 'Freshwater Fish Directive', (C.E.C., 1978); 'Water Quality Guidelines', (Technical Committee on Effluent and Water Quality Standards, (D.O.E.), 1978). I : mandatory limit; G : guideline limit (where the directive gives both I and G limits only the I limit is shown in the Table). See also notes at end of Table.

Potential Pollutants	Sources	Abstraction Waters [1]	Fisheries [2]	Recommended Standard for the Lower Shannon Catchment
Aluminium: See note at end of Table				
Arsenic mg/ℓ As	used in manufacture of glass, cloth, fungicides and wood preservatives.	0.1 (E.P.A., 1972) 0.05 (E.P.A., 1976) zero desirable (otherwise based on incremental increase in cancer risk, as follows: 10^{-5} 22 ng/ℓ 10^{-6} 2.2 ng/ℓ 10^{-7} 0.2 ng/ℓ) (E.P.A., 1980) 0.05 (EEC) (I)	0.4 (E.P.A., 1980)	0.05 (Provisional) zero desirable
Bacteria [3] I Total Coliforms nos./100 ml. II Faecal Coliforms nos./100 ml.	sewage, organic wastes, run-off from agricultural land for both I and II	20,000 (E.P.A., 1972) 5,000 (E.E.C.) (G) 2,000 (E.P.A., 1972) 2,000 (E.E.C.) (G)	No proposal No proposal	) See EEC) Guide Values)) See footnote 3))
Barium mg/ℓ Ba	paint and glass manufacture, electronic and medicinal uses	1.0 (E.P.A., 1972, 1976) 1.0 (E.E.C.) (I)	No proposal	1.0
Boron mg/ℓ B	manufacture of fire retardants, glass production, leather tanning and finishing, cosmetics, metallurgy.	1.0 (E.E.C.) (G)	No proposal	1.0
Cadmium mg/ℓ Cd (Total recoverable)	mining, smelting, electroplating, textile and chemical industries.	0.01 (E.P.A., 1972, 1976, 1980) 0.005 (E.E.C.) (I)	0.0004 (soft water (<75 mg/ℓ $CaCO_3$)) 0.0012 (hard water (>150 mg/ℓ $CaCO_3$)) (E.P.A., 1976) For hardness of 50 and 100 mg/ℓ $CaCO_3$ 0.000012 and 0.000025, respectively, (24 hr averages); concentrations not to be exceeded at any time are 0.0015 and 0.003, respectively (E.P.A., 1980)	0.0005
Chlorine: see note at end of Table.				

Table 5.2: Continued

Potential Pollutants	Sources	Abstraction Waters [1]	Fisheries [2]	Recommended Standard for the Lower Shannon Catchment
Chromium mg/ℓ Cr (Total recoverable hexavalent)	metal finishing, electroplating, cleaning agents, leather tanning, paints, fungicides and wood preservatives.	0.05 (E.P.A., 1972, 1976, 1980) 0.05 (E.E.C.) (I)	0.10 (E.P.A., 1972, 1976) 0.00029 (24 hr average); concentration not to be exceeded at any time : 0.021 (E.P.A., 1980) 0.05 (DOE, Irl.)	0.02 (0.05 total metal)
Copper mg/ℓ Cu (Total recoverable)	mining, electrical products, metal plating, alloys, control of nuisance algae.	1.0 (E.P.A., 1972, 1976, 1980) (For control of taste) 0.05 (EEC) (G)	0.006 (24 hr average) For hardness of 50, 100 mg/ℓ $CaCO_3$ concentrations not to be exceeded at any time are 0.012 and 0.022 respectively (E.P.A. 1980). 0.022 when hard = 50 mg/ℓ $CaCO_3$ 0.04 when hard = 100 mg/ℓ $CaCO_3$ (EEC) (G) 0.025 when hard >50 mg/ℓ $CaCO_3$ (DOE).	For hardness of 50 100 mg/ℓ $CaCO_3$ 0.01 and 0.02, respectively.
Cyanide mg/ℓ CN (free)	manufacturing processes including production of nitriles such as acrylonitrile.	0.005 (E.P.A., 1972). 0.2 (E.P.A., 1976, 1980) 0.05 (EEC) (I)	0.005 (E.P.A., 1972, 1976) 0.004 (24 hr average); concentration not to be exceeded at any time : 0.052 (E.P.A., 1980). 0.01 (DOE).	0.01
Fluoride mg/ℓ F	toothpastes, water treatment.	1.4 - 2.4 (E.P.A., 1976)[4] 0.7 - 1.7 (EEC) (G)[4]	1.5 (DOE Irl.)	1.5
Iron mg/ℓ Fe (soluble)	industrial wastes, mining, iron-bearing groundwaters.	0.3 (E.P.A., 1972, 1976) 2.0 (EEC) (I) 1.0 (EEC) (G)	1.0 (E.P.A., 1976)	0.3
Lead mg/ℓ Pb	electroplating, metallurgy manufacture of construction materials, plastics and electronics equipment	0.05 (E.P.A., 1972, 1976, 1980) 0.05 (EEC) (I)	0.03 (E.P.A., 1972) For hardness of 50, 100 mg/ℓ $CaCO_3$ 0.00075 and 0.0038, respectively (24 hr averages); concentrations not to be exceeded at any time : 0.074 and 0.17, respectively (E.P.A., 1980). 0.05 (DOE).	0.05

Table 5.2: Continued

Potential Pollutants	Sources	Abstraction Waters [1]	Fisheries [2]	Recommended Standard for the Lower Shannon Catchment
Manganese mg/ℓ Mn (soluble)	metal alloys, dry cell batteries, micro-nutrient fertiliser additives, organic compounds.	0.05 (E.P.A., 1972, 1976) 0.10 (EEC) (G)	No proposal	0.05
Mercury µg/ℓ Hg	electrical apparatus, electrolytic preparation of chemicals, industrial control instruments.	2.0 (E.P.A., 1972, 1976) 0.144 (E.P.A., 1980) 1.0 (EEC) (I) 0.5 (EEC) (G)	0.05 (E.P.A., 1972, 1976) 0.00057 (24 hr average); concentration not to be exceeded at any time is 0.0017 (E.P.A., 1980) 0.05 (DOE)	0.05 (Provisional)
Methylene Blue Reactive Substances (Foaming Agents) mg/ℓ laurylsulphate	detergents, chemicals.	0.5 (E.P.A., 1972) 0.2 (EEC) (G)	0.2 (E.P.A., 1972)	0.2
Nickel mg/ℓ Ni	stainless steel manufacture, alloys, electroplating.	0.013 (E.P.A., 1980)	For hardness of 50, 100 mg/ℓ $CaCO_3$: 0.056 and 0.096, respectively (24 hr averages); concentrations not to be exceeded at any time are 1.1 and 1.8, respectively. (E.P.A., 1980) 0.5 (DOE).	0.013 (Provisional)
Odour/Taste (Tainting Substances)	Creosote, phenols, some spp. of algae.	unobjectionable (E.P.A., 1972) Odour threshold dilution factor at 25 °C : 10 (EEC) (G)	no undesirable flavours detectable by organoleptic tests performed on edible aquatic organisms. (E.P.A., 1976).	substances should be absent from waters which cause objectionable tastes or odours and which taint the edible portions of aquatic organisms.

Table 5.2: Continued

Potential Pollutants	Sources	Abstraction Waters[1]	Fisheries.[2]	Recommended Standard for the Lower Shannon Catchment
Oils and Grease	Petrochemicals	should be absent (E.P.A., 1972, 1976) dissolved or emulsified hydrocarbons (after extraction with petroleum ether): 0.2 mg/ℓ (EEC) (I)	a) no visible oil on surface, b) emulsified oils should not exceed 0.01 of 96 hr LC50, c) conc. of hexane extractable substances (excl. elemental S) should not exceed 1000 mg/kg dried sediment (E.P.A., 1972). a) no visible film on surface, b) concentrations present should not impart taste to fish, c) concentrations present should not produce harmful effects in fish. (EEC) (I)	Dissolved or emulsified hydrocarbons (after extraction with petroleum ether): 0.2 mg/ℓ. a) no visible film on surface, b) concentrations present should not impart taste to fish. c) concentrations present should not produce harmful effects in fish.
Organics-Carbon Adsorbable (substances extractable with chloroform - CCE) mg/ℓ	organic compounds	0.3 (E.P.A., 1972) 0.2 (EEC) (G)	no proposal	0.2
Pesticides mg/ℓ	biocides for agricultural, horticultural, forestry and domestic use (e.g. wood perservation).	See Table 5.3 (E.P.A.) Total Pesticides (Parathion + BHC + Dieldrin) 0.0025. (EEC) (I)	See Table 5.3 (E.P.A.).	see individual pesticides. Table 5.3
pH	mining wastes, acidic or alkaline industrial wastes.	5 - 9 (E.P.A., 1972, 1976) 5.5 - 9 (EEC) (G)	6.5 - 9.0 (E.P.A. 1972, 1976) 6 - 9 (artificial change within these limits not to exceed 0.5 units). (EEC) (I).	6 - 9 (artificial change within these limits not to exceed 0.5 units)
Phenols mg/ℓ C_6H_5OH	mainly produced as an intermediate for the preparation of other chemicals including phenolic resins, plastics; phenolic wastes from gas works, coking of coal, oil refineries, livestock dips, distillation of wood.	0.001 (E.P.A., 1972, 1976) 0.3 (E.P.A., 1980) 0.001 (EEC) (G) 0.005 (EEC) (I) (All to prevent taste)	0.1 (E.P.A., 1972) (toxicity) 0.001 (E.P.A., 1972, 1976) (to prevent tainting). Should not be present in concs which adversely affect flavour of fish flesh (EEC) (I)	0.001

Table 5.2: Continued

Potential Pollutants	Sources	Abstraction Waters [1]	Fisheries [2]	Recommended Standard for the Lower Shannon Catchment
Polychlorinated μg/ℓ Biphenyls (PCB's)	electricity transformers, plasticizers, heat transfer fluids, hydraulic fluids, fluids in vacuum pumps and compressors, lubricants and wax extenders.	zero desirable (otherwise based on incremental increase of cancer risk as follows:- 10^{-5} 0.8 ng/ℓ, 10^{-6} 0.08 ng/ℓ, 10^{-7} 0.008 ng/ℓ (E.P.A., 1980)	0.001 (E.P.A., 1976)	zero desirable (otherwise based on incremental increase of cancer risk as follows: 10^{-5} 0.8 ng/ℓ, 10^{-6} 0.08 ng/ℓ, 10^{-7} 0.008 ng/ℓ
Polynuclear Aromatic Hydrocarbons (PAH's)	incomplete combustion of organic substances; reaching water from atmosphere or, e.g. road run-off.	0.0002 mg/ℓ (EEC) (I) zero desirable (otherwise based on incremental increase of cancer risk as follows: 10^{-5} 28 ng/ℓ, 10^{-6} 2.8 ng/ℓ, 10^{-7} 0.3 ng/ℓ) (E.P.A., 1980)	no proposal	0.0002 mg/ℓ zero desirable
Selenium mg/ℓ Se	glass, electronic devices, figments, dyes, insecticides, veterinary products.	0.01 (E.P.A., 1972, 1976, 1980) 0.01 (EEC) (I)	0.035 (24 hr average); concentration not to be exceeded at any time is 0.26 (E.P.A., 1980).	0.01
Silver mg/ℓ Ag (total recoverable	electroplating, photographic materials, mirror production, conductors, dental alloys, paints, some bactericidal agents.	0.05 (E.P.A., 1972, 1976 and 1980)	For hardness of 50, 100 mg/ℓ $CaCO_3$ 0.001 and 0.004, respectively, (E.P.A. 1980) 0.01 (DOE)	For hardness of 50, 100 mg/ℓ $CaCO_3$ 0.001 and 0.004, respectively.
Sulphides mg/ℓ H_2S (undissociated)	industrial wastes from tanneries, paper mills, chemical plants and gas works; anaerobic decomposition of sewage, sludge beds, algae and other naturally deposited organic material.	no proposal	0.002 (E.P.A., 1976) 0.002 (DOE).	0.002
Sulphate mg/ℓ SO_4	acid production, alum treatment.	250 (E.P.A., 1972) 250 (EEC) (I) 150 (EEC) (G)	250 (DOE, Irl.)	250

Table 5.2: Continued

Potential Pollutants	Sources	Abstraction Waters [1]	Fisheries [2]	Recommended Standard for the Lower Shannon Catchment
Suspended Solids mg/ℓ	wastes from industry and domestic sources; run-off from land.	no proposal	25 (E.P.A., 1972) settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10 per cent from the seasonally established norm for aquatic life. (E.P.A., 1976) 25 (EEC) (G)	25 (provisional)
Temperature °C	cooling water from industries, power stations.	no temperature change that detracts from the potability of public water supplies and no temperature change that adversely affects the standard treatment process. (E.P.A. 1972) 25 (EEC) (I) 22 (EEC) (G)	(1) In spring, summer and autumn, max. weekly average should not exceed 1/3 range between opt. temp. and upper incipient lethal temp. of species, nor should temps. above weekly average exceed criterion for short term exposure. Max. weekly average temps during winter should not exceed the acclimation temp. (minus a 2° safety factor) that raises the lower lethal threshold temp. above the normal ambient water temps. In addition the criterion for short term exposure should not be exceeded. (E.P.A., 1972). (2) Increase in water temperature should not be more than 1.5; thermal discharges should not result in temps. greater than 21.5; during the breeding season in those reaches inhabited by species which reproduce in cold water, temp. should not exceed 10 (EEC) (I).	21.5 (10 in breeding season). Artificial increase on ambient value should not exceed 1.5 (subject to foregoing limits).
Zinc mg/ℓ Zn (total recoverable)	industrial wastes, in corroded material from galvanised products, brass and bronze alloy production, photoengraving and printing industry.	5.0 (E.P.A., 1972, 1976, 1980) 5.0 (EEC) (I) 1.0 (EEC) (G)	0.047 (24 hr average) For hardness of 50, 110 mg/ℓ $CaCO_3$ concentrations not to be exceeded at any time are 0.18 and 0.32 (E.P.A. 0.2 when hardness = 50 mg/ℓ $CaCO_3$ 0.3 when hardness = 100 mg/ℓ $CaCO_3$ (EEC) (I) 0.1 when hardness 50 mg/ℓ $CaCO_3$ (DOE)	0.1

1 In the case of the E.E.C. standards the limits given are those for A2 abstraction waters, i.e. waters receiving normal physical treatment, chemical treatment and disinfection.

2 These criteria are for salmonid waters.

3 The 1981 Report of the Water Quality Criteria Working Party set up by the New Zealand Water Resources Council recommended for water which is a source of public supply and will be treated at least by flocculation, filtration and disinfection before being put into supply, that the standard for microbiological quality should be "The median faecal coliform bacteria concentration shall not exceed 2,000 per 100 mℓ based on a minimum of one water sample taken on each of ten separate days over not more than a 30 day period; nor shall more than 10% of samples taken on separate days during any 30 day period exceed 4,000 faecal coliforms per 100 mℓ".

It was noted in an appendix to the report that "WHO no longer proposes any standard for raw water suitable for treatment as a potable supply, on the assumption that the most polluted water if treated sufficiently can be brought to the WHO standard for drinking water". WHO have issued in 1984 ' Guidelines for Drinking-water Quality" which supersedes their previous standards. This document suggests that in the selection of a source for a drinking-water supply the raw water quality should be such that, with appropriate treatment, available water under locally prevailing conditions water can be supplied that meets or exceeds the quality specified in the drinking-water standards in force under the legislation of any particular country.

4 Limit values decreases with rise in air temperature (10°C - 32°C for E.P.A. values).

Note on Aluminium

There are as yet no generally accepted criteria for aluminium levels in surface and ground waters (although the EEC Drinking Water Directive sets a limit of 0.2 mg/ℓ Aℓ for water in supply). The toxicity of aluminium is very much dependent on pH; adverse effects on aquatic fauna are most likely in markedly acidic (<5.5) and alkaline (8.0-9.0) conditions under which the toxic chemical species of the element are present. Levels of total aluminium which may give rise to damaging concentrations of the toxic species are likely to vary from situation to situation. However, limits for total aluminium, in the range 0.1 to 0.5 mg/ℓ Aℓ, have been suggested by various workers.

Note on Chlorine

A limit for chlorine (total residual) has not been listed above as there are difficulties in analysing on a routine basis for this parameter in the range (<0.02 mg/l) of interest. The EC Freshwater Fish Directive sets a mandatory limit of 0.005 mg/l, this being applicable to waters of pH6. Thus, in the waters of the Upper Shannon Catchment, a less stringent limit (0.01-0.02 mg/l) would probably apply.

TABLE 5.3

Water quality criteria for selected pesticides published by the U.S. Environmental Protection Agency (E.P.A., 1972, 1976, 1980) and corresponding water quality standards recommended for the Lower Shannon Catchment.

Potential Pollutant	Sources	Abstraction Waters	Fisheries	Recommended Standard for The Lower Shannon Catchment
Acrolein µg/ℓ	biocide for aquatic weeds, algae and molluscs; slime control in the paper industry, leather tanning processes. Related compounds arise from many other sources including plastics and polyurethane production	320 (E.P.A., 1980)	Chronic toxicity to aquatic organisms has been measured at concs. as low as 21 (E.P.A., 1980)	2 (Provisional)
Aldrin µg/ℓ	pesticide spills on farms, industrial sources include wool and carpet industries.	1.0 (E.P.A., 1972) zero desirable (E.P.A., 1976) zero desirable (or else based on incremental increase of cancer risk as follows: 10^{-5} 0.74 ng/ℓ 10^{-6} 0.074 ng/ℓ 10^{-7} 0.0074 ng/ℓ) (E.P.A., 1980)	0.003 (E.P.A., 1972, 1976)	zero
Dieldrin µg/ℓ	same sources as for aldrin	1.0 (E.P.A., 1972) zero desirable (E.P.A., 1976) zero desirable (or else based on incremental cancer risk as follows: 10^{-5} 0.71 ng/ℓ 10^{-6} 0.071 ng/ℓ 10^{-7} 0.0071 ng/ℓ) (E.P.A., 1980)	0.003 (E.P.A., 1972, 1976) 0.0019 (24 hr average); concentration not to be exceeded at any time is 2.5 (E.P.A., 1980)	zero

Cont'd./...

TABLE 5.3 (cont'd.)

Potential Pollutant	Sources	Abstraction Waters	Fisheries	Recommended Standard for the Lower Shannon Catchment
DDT and Metabolites µg/ℓ	Agricultural and horticultural insectides and other pesticides mostly.	50 (E.P.A., 1972) zero desirable (E.P.A., 1976) zero desirable (or else based on incremental increase of cancer risk as follows: 10^{-5} 0.24 ng/ℓ 10^{-6} 0.024 ng/ℓ 10^{-7} 0.0024 ng/ℓ) (E.P.A., 1980)	0.001 (E.P.A., 1972, 1976) 0.001 (24 hr average); concentration not to exceed at any time is 1.1 (E.P.A., 1980)	zero
Endosulfan µg/ℓ	agricultural, horticultural, insecticides.	74 (E.P.A., 1980)	0.003 (E.P.A., 1972, 1976) 0.056 (24 hr average); concentration not to be exceeded at any time is 0.22 (E.P.A., 1980)	0.06
Hexachlorocyclohexane (Lindane, i.e. γ isomer) µg/ℓ .	cereal seed sprays, insecticides.	4.0 (E.P.A., 1972, 1976) zero desirable (or else based on incremental increase of cancer risk, as follows: 10^{-5} 186 ng/ℓ 10^{-6} 18.6 ng/ℓ 10^{-7} 1.9 ng/ℓ) (E.P.A. 1980)	0.01 (E.P.A., 1972, 1976) 0.08 (24 hr average); concentration not to be exceeded at any time is 2.0 (E.P.A., 1980) 0.1 (EC Directive 84/491) (Total HCH, in waters affected by discharges of HCH) 0.05 (Do.) (Total HCH in other waters).	zero
Malathion µg/ℓ	crop sprays for protection from insects and mites	no proposal	0.1 (E.P.A., 1972, 1976)	0.1
Parathion µg/ℓ	insecticides	no proposal	0.04 (E.P.A., 1972, 1976)	0.04
Pentachlorophenol µg/ℓ	wood preservatives, (bactericides, fungicides and slimeicides).	30 to prevent taste and odour problems (E.P.A., 1980).	chronic toxicity can occur at concentrations as low as 3.2 (E.P.A., 1980)	0.3

Cont'd./...

TABLE 5.3 (cont'd.)

Potential Pollutant	Sources	Abstraction Waters	Fisheries	Recommended Standard for the Lower Shannon Catchment
Toxaphene μg/ℓ	agricultural pesticides	5 (EPA, 1972, 1976) zero desirable (or else based on incremental increase of cancer risk, as follows: 10^{-5} 7.1 ng/ℓ 10^{-6} 0.7 ng/ℓ 10^{-7} 0.07 ng/ℓ) (E.P.A., 1980)	0.005 (E.P.A., 1972, 1976) 0.013 (24 hr average); concentration not to be exceeded at any time is 1.6 (E.P.A., 1980).	zero
T.B.T.	See note below.			

Note: Fishery Bye-Law No. 657 of 1987 prohibits the application of organotin antifouling compounds, the most commonly known of which is tributyltin (T.B.T.) based antifouling paint.

CHAPTER SIX

WASTE ASSIMILATION CAPACITY IN THE LOWER SHANNON CATCHMENT

RIVERS

6.1 General Comments The discharge of waste to a river channel must of necessity alter the quality of the water in that river to some extent. The limits within which such a change in quality must be controlled are governed by the river water quality standards specified for the protection of the beneficial uses of those waters. The waste assimilation capacity of a river at any particular location may be defined as the maximum quantity of waste which may be discharged under set conditions of river flow that does not lead to any significant exceedance of the specified water quality standards outside the mixing zone of the discharge location. This capacity for waste assimilation provides the link between water quality standards and effluent emission standards and thereby determines the degree of treatment which must be provided to wastes before they are discharged to a river system. The management of water quality in a river system must therefore be exercised within the limits set for the waste assimilation capacity as defined above.

6.2 The concept of waste assimilation capacity as defined above is sometimes referred to as the 'Environmental Quality Objectives' (EQO) approach and represents the most logical and economical strategy for water quality management. Other approaches to water quality management have been proposed both in the U.S. and in Europe which include a system of uniform or fixed emission standards. In this system, dischargers would be required to bring their effluents to a uniform level of quality regardless of the assimilation capacity of the receiving water, provided the receiving water quality objectives are met. While such a system has merit where persistent or toxic substances are concerned, in the case of the Lower Shannon River, where the vast majority of the wastes discharged are of an organic biodegradable nature, this system would lead to an undesirable degree of inflexibility and in some cases unnecessary expense in relation to the treatment of conventional waste.

6.3 The practical advantage of adopting the EQO approach is that it provides for the efficient use of water resources while at the same time providing maximum benefit from the capital investment in effluent treatment facilities. In its application however, the use of the assimilation capacity of the river as being the maximum amount of a particular waste which can be accommodated by a receiving water may not be the most desirable approach and it may be considered more prudent to discharge a lesser waste load thereby providing a reserve capacity in the receiving water to accommodate future development.

THE DETERMINATION OF WASTE ASSIMILATION CAPACITY

6.4 The capacity of a river or any water body to assimilate waste is largely a function of the amount of dilution afforded to the waste by the receiving water. In addition, the natural characteristics of the receiving water, physical, chemical and biological, may have a modifying effect on the fate of pollutants after discharge; for instance, heavy metals such as zinc and copper will be precipitated in hard waters while the deoxygenation caused by the presence of biodegradable pollutants may be lessened or completely compensated for by rapid reaeration in shallow, fast flowing streams. In contrast, in acidic waters of low hardness, metals may remain in soluble form and exercise a toxic effect at relatively low concentrations; again, in slow flowing, deep rivers even moderate increases in concentrations of biodegradable waste (B.O.D.) may lead to excessive deoxygenation.

6.5 Most of the wastes discharged to Irish rivers are organic, biodegradable substances and, as the information given in Volume 3 demonstrates, this generality holds for the Lower Shannon Catchment. The main effects of such wastes are deoxygenation and eutrophication; in some cases a toxic effect may be exercised, particularly in the case of septic wastes, through the presence of ammonia or other reduced compounds in high concentrations. While it is rarely possible to demonstrate a straightforward relationship between B.O.D. and the above effects, this parameter is the most useful and commonly employed measure of pollution by organic biodegradable wastes. This applies particularly to rivers and estuaries; in the case of lakes, where the main effect of importance is eutrophication, the phosphorus content of organic wastes is a more appropriate basis for assessment of the situation likely to arise from the discharges of such wastes than is the B.O.D. content. A further advantage of the use of B.O.D. concentration to characterise the degree of pollution by organic wastes is that the waste loads may be quantified in a readily appreciated form e.g. as the amount of B.O.D. (as kg) discharged per unit time.

6.6 The accurate prediction of the effects of organic wastes on receiving waters, on the basis of their B.O.D. content, is not easily achieved. This is due to the complex of factors, chemical, physical and biological, which are involved in the process of self-purification. A variety of mathematical modelling procedures have been developed over the years to deal with this situation particularly in respect of effects on the dissolved oxygen regime. The earliest efforts in this direction were those of Streeter and Phelps who developed a mathematical model for dissolved oxygen prediction in the Ohio River in the US; this model is the basis for most of the more recently developed procedures. The mathematical modelling approach is particularly useful where there is a number of large waste discharges and water abstractions concentrated along relatively short stretches of a river and where, therefore, the full extent of the assimilative capacity may be required to effect the necessary controls. However, in the case of rivers receiving relatively small waste discharges at locations well separated, as is the case on most Irish rivers, the advantage of the modelling approach is probably marginal. In these cases a simple mass balance approach to the calculation of assimilative capacity seems sufficient, i.e. to treat B.O.D. as a conservative parameter so that only dilution need be taken into account. There is the further consideration that it is desirable to maintain B.O.D. concentrations at relatively low levels in receiving waters in order to protect both the natural ecosystem and the quality for uses such as a source of public water supply. Therefore, it may not be advisable to take advantage of the capacity of well aerated streams and rivers to maintain satisfactory dissolved oxygen levels in the presence of relatively high B.O.D. concentrations.

6.7 Two factors only are considered, therefore, in the calculation of the assimilative capacity in the present context; these are the maximum permissible concentration of B.O.D. and the river flow, the product of these being a waste load. In the case of the Shannon river and its tributaries the considerations discussed in the foregoing chapter and in Volume 4 suggest that the upper limit for B.O.D. should be 5 mg/ℓ (95 percentile limit). However, it is considered desirable, for the purpose of calculating waste assimilation capacity, that this should be reduced to 4 mg/ℓ in order to lessen the possibility of carry over of wastes between locations and a consequent increase in background B.O.D. concentration at the downstream location. Ideally this maximum limit on B.O.D. concentrations should be adhered to under all flow conditions. To act on this basis however, particularly in the case of small rivers feeding Lough Derg, would severely limit the amount of waste which could be discharged at different locations; in these cases such a restriction would be completely impractical. The general practice, which is followed here, is to adopt the 95 percentile flow as the lowest in which the B.O.D. limit should be met. This is a relatively low flow and represents a reasonable compromise for management purposes.

6.8 In the case of the main Shannon River where the flow is controlled for hydro-electric power generation the flow criteria which might be adopted for pollution abatement purposes requires a different approach to that which is used for uncontrolled natural channels. The Shannon river as it enters Lough Derg is a large river even at very low flows and provides many dilutions to the relatively small volumes of wastes discharged to it. Because of this and also because of its importance as a salmonid river it is considered acceptable to adopt a flow in the order of the estimated dry weather flow as the appropriate flow criterion which might be adopted for pollution abatement purposes. Downstream of Lough Derg at Parteen Weir, the ESB is obliged to discharge a minimum flow of 10 m^3/s compensation flow down the old river channel and it is only in emergency situations that flows in the old river channel were less than this. In these circumstances, therefore, it is considered reasonable to adopt this compensation flow as the flow criterion which should be adopted in the lower Shannon for pollution abatement purposes downstream of Parteen Weir. The flow in this channel is augmented by the three tributaries - Kilmastulla, Mulkear and the Groody all of which enter the left bank of the channel upstream of Limerick. The amount of which the compensation flow is augmented should be taken as the 95 percentile flow in these tributary streams which is the flow criterion adopted for pollution abatement purposes in all tributaries streams of the lower Shannon river.

6.9 The restriction of waste assimilation capacity to the dilution available at 95 percentile flow in the tributary streams implies that there is a wide spectrum of river conditions providing greater dilutions of which advantage cannot be taken. This drawback can be overcome where it is feasible to store wastes during periods of low flow and to discharge them when adequate dilution conditions are available. This is a practical proposition in the case of some industrial wastes but for many others and for domestic wastes, in general, longterm storage would be impractical or else unacceptable on aesthetic or public health grounds. A further strategy to overcome the drawback of limited waste assimilation capacity is augmentation of low flow from in-river or reservoir storage or from groundwaters. This may not be a practical proposition in some cases, e.g. for waste discharges located on the periphery of the river catchment; in addition there are considerations of extra costs, the quality of the stored water and the changes in reaeration and deoxygenation constants with change in flow of the river.

6.10 It is probably less acceptable that the criterion for dilution should be the 95 percentile flow where toxic substances are concerned than it is for organic biodegradable wastes. While the available data suggest that pollution with toxicants is not a significant problem in the lower Shannon Catchment at present, it is opportune to consider the appropriate controls which should be adopted for wastes containing these substances. The maximum permissible concentrations of the commoner toxicants likely to occur in water borne wastes have been given in Tables 5.2 and 5.3. These are based on the most up to date information and offer a reliable basis on which to determine assimilative capacity. In view of the direct effects of toxicants on organisms and the tendency of some, such as pesticides, to accumulate in the environment, it seems desirable that the total amounts discharged should be kept to a minimum. Therefore it is proposed that the permissible concentration limits for toxicants should be adhered to across the whole flow spectrum; in practical terms this implies that the assimilation capacity for toxicants should be calculated as the product of the maximum permissible concentration and the Dry Weather Flow. In the case of mixtures of toxicants (e.g. a waste containing three toxic heavy metals) recent work suggests that where the resultant concentrations of the individual substances in the receiving water are less than the limits suggested as criteria (E.I.F.A.C., 1980) the possibility of an additive effect may be ignored.

ASSIMILATION CAPACITY AT IMPORTANT LOCATIONS ON RIVERS IN THE LOWER SHANNON CATCHMENT

6.11 The waste assimilation capacity (WAC) as outlined above for organic biodegradable wastes expressed as kilograms of B.O.D. per day at a number of key locations in the lower Shannon has been calculated as follows:

$$WAC = \{C_{max} - C_{back}\} \times F_{95} \times 86.4 \text{ kg B.O.D./day}$$

where C_{max} = maximum permissible B.O.D. concentration (4 mg/ℓ for salmonid waters)

C_{back} = background B.O.D. concentration (mg/ℓ) upstream of the discharge location

F_{95} = 95 percentile flow (m^3/s)

86.4 = factor to convert WAC to a daily load (kg B.O.D./day) when C_{max} and C_{back} are expressed in mg/ℓ and F_{95} is expressed as m^3/s

The details and results of these calculations are set out in Table 6.1 for towns and large villages (population greater than 400) in the catchment. The calculations are based on an estimate of the 95 percentile flow which is derived from processed records where available. In a number of cases, the 95 percentile flow is estimated from other locations in the catchment which have similar catchment characteristics. While these estimates are sufficiently accurate for planning purposes they would need to be refined in time as additional gauges are installed and more records become available. The background B.O.D. concentrations used are the medians of the values recorded at the nearest sampling station upstream of the discharge at the location in question. In cases where no chemical data are available and biological surveys show the river water quality to be good, a background concentration of 2 mg/ℓ B.O.D. is assumed for the river upstream of the discharge point.

LAKES

6.12 In the case of organic biodegradable wastes, which are the main concern in the present case, the potential effect of greatest importance, in respect of discharges to lakes and other standing waters, is eutrophication and the associated increase in the growth of green plants, in

TABLE 6.1

Theoretical Waste Assimilation Capacity At Locations Of Discharges To Rivers In The Lower Shannon

Location	River	Estimated 95 Percentile Flow (m^3/s)	Median Upstream B.O.D. (mg/ℓ)	Waste Assimilation Capacity		Waste load represented by an increase of 1 mg/ℓ in B.O.D. at 95 percentile flow	
				kg/B.O.D/ day	Pop. Equiv.**	kg B.O.D./ day	Pop. Equiv.**
Nenagh	Nenagh	0.35	2.0	60	1,100	30	550
Castle-connell	Shannon	10.15*	2.0	1750	32,400	877	16,240
Killaloe	Shannon	11.00*	2.0	1900	35,200	950	17,600
Scarriff	Graney	0.64	1.6	133	2,460	55	1,020
Borrisokane	Ballyfinboy	0.06	1.5	13	240	5	90
Newport	Newport	0.22	1.3	51	940	19	350
Cappamore	Bilboa	0.60	1.2	145	2,700	52	960
Cahercon-lish	Groody	0.03	1.4	7	130	3	60
Castletroy/ Monaleen	Groody	0.06	1.8	11	200	5	90
Cloghjordan	Ballyfinboy Trib.	0.03	1.5	6	110	3	60
Toomevara	Ballintotty	0.02	2.0	3	60	2	40
Doon	Banniv Trib of Mulkear	0.01	2.0	2	40	1	20
Cappawhite	Dead	0.01	2.0	2	40	1	20
	Mulkear	2.20	1.8	418	7,740	190	3,520
Oola	Dead Trib.	0.02	2.0	3	60	2	40

* Estimated Dry Weather Flow

** Assuming a per capita B.O.D. of 0.054 kg/day figures rounded off to nearest ten.

particular the planktonic algae. The primary (B.O.D.) effect of organic wastes is usually not very marked in such waters due to a sufficiency of dilution and to rapid reaeration rates although significant pollution can arise in localised areas, e.g. small, narrow-necked bays, due to poor dispersal of waste. In contrast, the input of excess nutrients is likely to have appreciable effects on water quality in most lakes. The stimulatory effect of these nutrients on algal growth depends not only on the concentrations of such substances in the lake water but also on the length of time over which the nutrients and algae remain in the lake water. In very rapidly flushed lakes there may not be any significant growth of planktonic algae because the water residence time is too short to allow the algae to complete their life cycle.

6.13 Accurate prediction of the response of algae in lakes to nutrient input is difficult because of the many variables involved. Over the last 20 years mathematical modelling has been used and many of the models devised have successfully predicted algal growth variation in particular lakes. However, the general application of such models is difficult because of the necessity to make fresh measurements of the various model parameters in each case and of the need for computing facilities to allow quick solutions. A more simplified approach, which has received wide acceptance in recent years, is that developed by Vollenweider (1971, 1975, 1976). From existing data Vollenweider was able to show that concentrations of phosphorus in lake waters could be predicted from annual phosphorus inputs (i.e. the sum of the loads carried by feeder streams and the direct inputs from waste discharges). This was achieved using a simple input-output model the main modifying parameters of which are mean depth and water retention time (Vollenweider, 1975). In addition, relationships were also established between phosphorus inputs and lake concentrations, on the one hand, and algal growth, expressed as chlorophyll _a_ concentrations, on the other (Vollenweider, 1976). The latter relationships have been established also by other, independent investigations. The main assumptions in Vollenweider's approach are the 'limiting nutrient' status of phosphorus (and, therefore, in cases of artificial eutrophication the stimulation of algal growth is mainly attributable to phosphorus) and that lakes operate as completely mixed reactors. The first of these assumptions is more justified than the second.

6.14 Vollenweider's simplified modelling approach was used in assessing the results of an international project on lake eutrophication which was undertaken between 1973 and 1978 under the auspices of the O.E.C.D. (O.E.C.D., 1982). The model was largely vindicated by the data generated, e.g. concentrations of phosphorus measured in the lakes were in reasonable agreement with those predicted by the model from the annual phosphorus inputs. The data were subjected to statistical analysis in order to determine quantitative relationships between phosphorus loading, phosphorus concentrations and algal growth (directly measured as chlorophyll a concentrations or indirectly by water transparency). The most useful of the relationships established are those between phosphorus inputs and annual average and annual maximum chlorophyll a concentrations. The regression equations for these relationships are as follows:

(a) for annual average chlorophyll a concentration, $[\overline{Chl}]$

$$[\overline{Chl}] = 0.37 \{[\bar{P}]_j / (1+\sqrt{\zeta_\omega})\}^{0.79}$$

(b) for annual maximum chlorophyll a concentration, $\begin{bmatrix} max \\ Chl \end{bmatrix}$

$$\begin{bmatrix} max \\ Chl \end{bmatrix} = 0.74 \{[\bar{P}]_j / (1+\sqrt{\zeta_\omega})\}^{0.89}$$

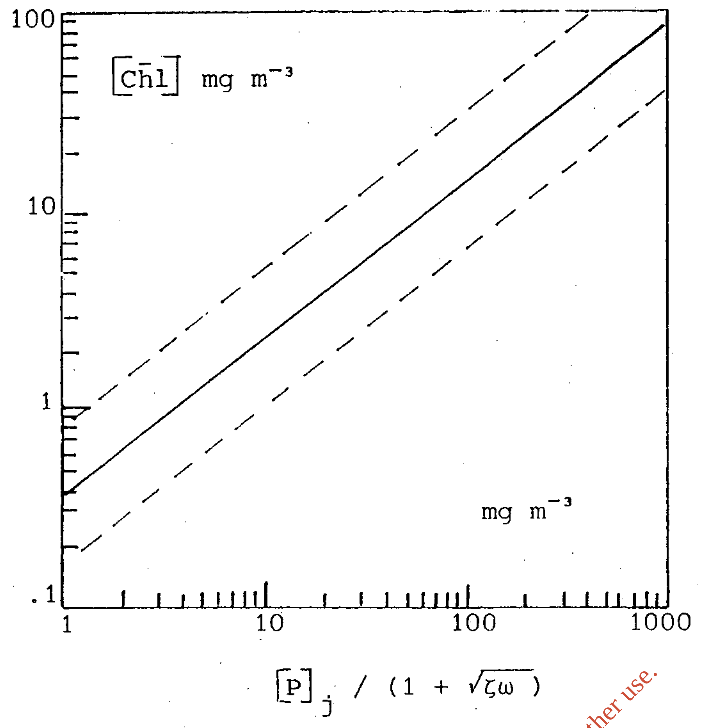
wherein $[\overline{Chl}]$ is the annual average chlorophyll concentration (mg m^{-3}) $\begin{bmatrix} max \\ chl \end{bmatrix}$ the annual maximum chlorophyll concentration (mg m^{-3}), $[P]_j$ the annual average concentration of phosphorus in the inflow (i.e. the yearly input of phosphorus divided by the total water flow) (mg m^{-3}) and $\zeta\omega$ the water retention time (i.e. lake volume divided by the inflow) (yr). The term on the right hand side of these equations is referred to as the 'flushing corrected' annual average inflow concentration of phosphorus.

6.15 The regression lines for the latter two equations are shown in Fig. 6.1; the log scales are necessary to give a straight-line relationship in each case. The 80 and 95 percent confidence limits are also shown in the figures and, as may be seen, these are relatively wide. This is a reflection of the heterogeneous nature of the group of lakes and reservoirs included in the O.E.C.D study and on the characteristics of which the relationships are based. In the use of the figures it is suggested (O.E.C.D., 1982) that the 80 percent confidence limits provide a working reference; thus if new data points lie outside these limits they probably or certainly reflect non-conforming special cases or else indicate that the data are unreliable. A further drawback in the scheme is the use of total phosphorus (i.e. all forms of the element, organic and inorganic) as a measure of the nutrient supply for algae. Many naturally occurring forms of phosphorus (e.g apatites) are only sparingly or not at all available to growing algae because they are not readily hydrolysed to the orthophosphate form. Thus the algal growth response to unit areal loadings of phosphorus from different lake catchments may vary widely; where the phosphorus load is derived mainly from natural sources the response may be relatively moderate; where, however, the load is dominated by artificial sources, e.g. sewage and similar wastes, in which phosphorus is present mainly as orthophosphate, the response is likely to be marked and to result in abundant growths. This, undoubtedly, is a major factor inducing the relatively wide confidence limits for these statistically significant relationships.

6.16 Bearing these reservations in mind it is possible to make use of the O.E.C.D predictive equations to assess the waste assimilation capacity for a lake; this assumes that the waste fraction of greatest interest is phosphorus because of its key role in promoting the growth of algae and other plants. Before such predictions can be made it is necessary to consider what levels of algal growth are compatible with the uses of a particular lake. This topic has been discussed above in Chapter 5. It was concluded that the waters of the Lower Shannon could be classified primarily as salmonid waters and that maintenance of water quality conditions appropriate to this designation would be a general assurance of fitness for all other uses. In regard specifically to algal growth in lakes in the catchment it was therefore concluded that this should be kept to a relatively low level viz the annual mean and maximum concentrations of chlorophyll a should not exceed, respectively, 12 mg m^{-3} and 35 mg m^{-3}, these values falling in the lower part of the eutrophic range as defined in the O.E.C.D classification scheme shown in Table 5.1. In order to keep algal growth to these levels it was proposed that the annual mean concentration of total phosphorus in the lake should not exceed 50 mg m^{-3}.

6.17 Using the diagrams in Fig 6.1 or the regression equations, the annual inputs of phosphorus corresponding to the above chlorophyll values may be obtained. The inputs obtained are, in theory at least, those which should not be exceeded if chlorophyll levels are to be maintained at or below the limits decided on in each case. Where actual measurements of chlorophyll a concentrations and phosphorus input are not available the predictions must be made using the main regression line in Fig.6.1 In such cases a 'pessimistic' prediction must also be considered this corresponding to the intercept with the upper 80 per cent confidence limit. However, in cases where data are available and plot within the 80 per cent confidence limits, Jones and Lee (1982) have suggested that predictions should be based on intercepts with a line drawn through this regression point parallel to the main regression line. This approach is justified by observations made on the changes in lakes subject to phosphorus input reduction which showed that the regression points for chlorophyll a against phosphorus input at different stages in the recovery process tended to lie parallel to the main regression line in the diagram. Jones and Lee further argued that in using the diagram in this fashion the confidence limits did not apply.

6.18 In the lower Shannon catchment the data required to make an assessment of waste (phosphorus) assimilation capacity, using the O.E.C.D. predictive equations in the manner described above, are available for only one lake, Lough Derg. This lake represents, however, a major fraction of the water resources of the catchment. Information on phosphorus inputs to and chlorophyll a concentrations in Lough Derg are available from the investigations carried out by A.F.F. in the period 1976 - 78 (Bowman, 1985). The appropriate data from this study (using averages of the three years) have been plotted in the diagram, Fig.6.2.,



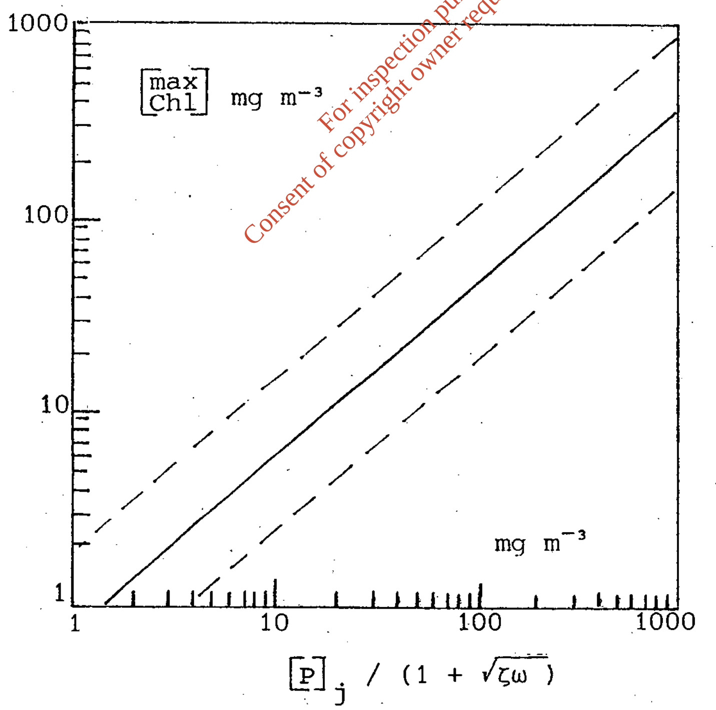


Fig. 6.1 Regressions (solid lines) of annual average, [$\overline{Chl}$], and annual maximum, [max Chl], chlorophyll a concentration on the 'flushing corrected' average annual inflow concentration of total phosphorus (O.E.C.D., 1982). Broken lines indicate the 80 per cent confidence limits. See text for regression equations.

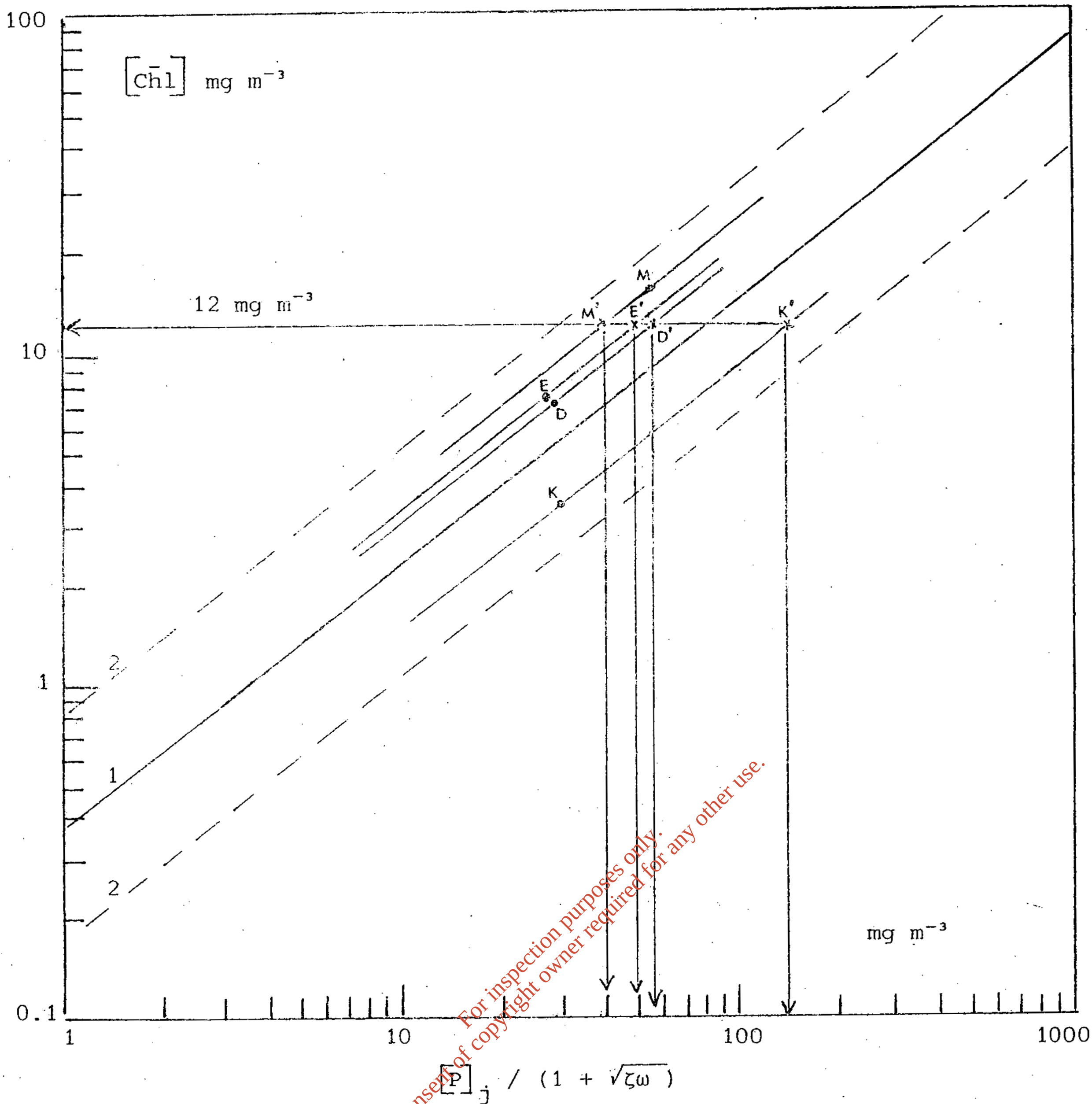


Fig. 6.2 Regression line (1), with 80 per cent confidence limits (2), of the annual average chlorophyll a concentration, [Chl], on the flushing corrected annual average inflow concentration of total phosphorus based on the O.E.C.D. equation given in the text. Regression points are shown for the data sets for Lough Derg (1976 - 1978) (D), Lough Ennell 1984 (E), Lough Key 1976 (K) and Lough Muckno 1978 (M). The intercepts of lines drawn through these points, parallel to the main regression line, with the line representing a value of 12 mg m^{-3} for annual average chlorophyll a concentration are also shown (D', E', K', M'). The corresponding values for the flushing corrected annual average inflow concentrations of total phosphorus (indicated by arrows) are given in Table 6.2 together with the total inputs represented by these concentrations. See text for further explanation.

which shows the O.E.C.D relationship between the annual average chlorophyll a concentration and the 'flushing corrected' annual average inflow concentration of total phosphorus. Also shown are regression points for three other lakes, Loughs Ennell, Key and Muckno studied by A.F.F. in recent years. In all four cases the regression points plot within the 80 per cent confidence limits and may be regarded, therefore, as providing a reasonable working reference. In line with the above suggestion of Jones and Lee, lines have been drawn through these points parallel to the main regression line to intercept with the line representing an annual average chlorophyll a concentration of 12 mg m^{-3}, one of the two guideline limits recommended in Chapter 5 for this parameter in salmonid waters. Vertical lines have been dropped from these intercepts to give the corresponding values for the flushing corrected inflow concentration of phosphorus.

6.19 The values obtained are set out in Table 6.2 together with the equivalent annual inputs. Predicted values are also shown for Lough Owel in the Table. Since an estimate of total phosphorus input is not available, a specific regression point for this lake cannot be plotted on Fig. 6.2 and the prediction is obtained from the intercept with the main regression line. In this case, therefore, a 'pessimistic' prediction must be considered (intercept with the upper 80 per cent confidence limit). This intercept indicates a value of 30 mg m^{-3} for the flushing corrected inflow concentration of phosphorus or 1.5 tonnes P for the annual input. This contrasts with values of 81 mg m^{-3} and 4.1 tonnes indicated by the intercept with the main regression line.

6.20 Of the five lakes dealt with in Table 6.2 only one, Lough Muckno had an annual chlorophyll a concentration greater than 12 mg m^{-3}. The predictions indicate that the input of 7.1 tonnes estimated for this lake in 1978 would have to be reduced to 5.4 tonnes to bring the average chlorophyll a concentration down to 12 mg m^{-3}. In the other four cases the predictions indicate that substantial increases of phosphorus loadings would be required to increase the annual average chlorophyll a concentration to 12 mg m^{-3}. However, these predictions must be treated with

TABLE 6.2

Values predicted for the flushing corrected average annual inflow concentrations of total phosphorus ($[P]_j / (1 + \sqrt{\zeta\omega})$) corresponding to an annual average chlorophyll *a* concentration $[\bar{Chl}]$ of 12 mg m^{-3} in 5 Irish lakes using the O.E.C.D. relationship shown in Fig. 6.1. The derivation of the predicted values is depicted in Fig. 6.2 and explained further in the text. Other details are given including the actual values for phosphorus input and average chlorophyll *a* concentration in the periods concerned.

Lake	Period	Ann. Inflow $m^3 \times 10^6$	Retent.Time ($\zeta\omega$) yr.	Values predicted for $[\bar{Chl}]$ = 12 mg m^{-3}		Actual Values in Period	
				$[P]_j / (1 + \sqrt{\zeta\omega})$, mg m^{-3}	Input, Tonnes P	$[\bar{Chl}]$, mg m^{-3}	Input, Tonnes P
Derg[1]	1976-78	5,032	0.19	55	397	7.2	204
Ennell	1984	80	1.09	49	8.0	7.5	4.4
Key	1976	286	0.16	114	46	3.4	12
Muckno	1978	93	0.20	40	5.4	14.0	7.1
Owel[2]	1981	16	4.4	81	4.1	4.0	-

[1] Based on the average values for the three year period of record.

[2] Predictions are based on the intercept of the line representing 12 mg m^{-3} for $[\bar{Chl}]$ with the main regression line for the O.E.C.D. relationship as there is no reliable estimate of phosphorus input to Lough Owel available. In this case, therefore, a pessimistic estimate must be considered being the intercept of the line for $[\bar{Chl}]$ = 12 mg m^{-3} with the upper 80 per cent confidence limit. This gives $[P]_j / (1 + \sqrt{\zeta\omega})$ = 12 mg m^{-3} corresponding to an input of 1.5 tonnes P for Lough Owel for 1981 conditions.

caution as the tolerable increases of phosphorus input indicated are likely to be valid only if such increases arise from the same type or types of sources as give rise to the present loadings. In all five lakes, particularly in Loughs Derg and Key, the bulk of the phosphorus arises from natural sources; because of the relatively low bioavailability of such phosphorus the present inputs to these lakes would have a much smaller effect on algal growth than would arise if they were attributable to artificial sources such as sewage treatment plants. Thus, the assimilation capacities for phosphorus indicated in Table 6.2 for the five lakes in question are likely to be very much overestimated if only artificial inputs are being considered. A further point to be noted is that if the hydrological conditions change substantially, thereby leading to an increase or decrease of retention time and inflow, the nature of the relationship between phosphorus input and algal growth may not remain the same as that operating under the previous hydrological regime.

6.21 Thus the usefulness for management purposes of the value of 397 tonnes of phosphorus per annum as a guideline limit to controlling algal growth in Lough Derg is limited. However, some improvement of the position is possible if the relative bioavailabilities of phosphorus from natural and artificial sources are considered. Recent research (e.g. Stevens and Stewart, 1982; Lee et al, 1980; Peters, 1981; Cowen et al, 1978) has shown that the bulk of phosphorus from natural sources is not available for plant growth due mainly to its being held in refractory complexes of an organic or inorganic nature. Bioavailable fractions for this type of phosphorus have been shown to vary from less than 20 per cent to about 40 per cent. In contrast, the phosphorus in wastes such as sewage treatment plant effluent and the run-off from agricultural wastes such as manure slurries is likely to be fully available to growing plants. This is due to the nutrient being present in such wastes as the mineralised phosphate or as compounds readily hydrolysed to the free phosphate; this is the form in which the nutrient is taken up by the growing plants. Thus, taking a conservative value of 10 per cent as the bioavailable fraction of phosphorus from natural sources, it would seem advisable that artificial inputs of phosphorus should be weighted by a factor of 10 before adding them to the natural sources to obtain the total input.

6.22 It was pointed out above that the bulk of the phosphorus input to Lough Derg is likely to be of natural origin and that the increased load predicted by the O.E.C.D equation necessary to increase the annual average chlorophyll concentration to 12 mg m^{-3} must be interpreted as coming from similar sources. Thus, a consideration of the relative bioavailabilities of natural and artificial phosphorus inputs discussed in the preceding paragraph suggests that the predicted increase of phosphorus input to Lough Derg corresponding to an increase of average chlorophyll concentrations to 12 mg m^{-3} (397 - 204 = 193 tonnes P, see Table 6.2) would have to be reduced by a factor of 10 if the increase were to be brought about by artificial sources.

6.23 This approach suggests, therefore, that the assimilation capacity for waste-derived phosphorus in Lough Derg should be taken to be of the order of 20 tonnes. Assuming a per capita value of 2.5 g P per day in domestic sewage and no removal of phosphorus in conventional treatment this input is equivalent to the waste from a population of some 21,000 persons. However, it must be remembered that this extra load is likely to increase the annual average chlorophyll concentration to 12 mg m^{-3}; this compares with a value of around 7 mg m^{-3} recorded in 1976 - 78 so that the increase of algal growth would be appreciable. If it was felt desirable to maintain algal growth at the more moderate level represented by e.g., an annual average chlorophyll concentration of 9 mg m^{-3}, use of Fig. 6.2 shows that the corresponding phosphorus input would be of the order of 280 tonnes. This would imply an increase of about 80 tonnes over the average load for 1976 - 78 and, on the basis discussed above, would be equivalent to an addition of 8 tonnes of waste-derived phosphorus.

6.24 Two qualifications must be added at this point. Firstly, as pointed out in Chapter 3, concentrations of chlorophyll a measured in Lough Derg in the summer-autumn period of 1982 and 1984 were appreciably higher than those measured in the main survey of 1976-78. These later concentrations, if taken as the annual maxima, would indicate a clearly eutrophic status for the lake according to the values given for annual maximum chlorophyll a concentrations in the O.E.C.D classification scheme set out in Table 5.1. The representativeness of the relatively high chlorophyll levels measured in 1982 and 1984 remain to be established as there is a possibility that they were due to unusual climatic or hydrological conditions. However, they suggest that the phosphorus input/algal growth relationship established on the basis of the 1976 -78 investigation data should be treated as tentative. Secondly, the proposal that the assimilation capacity for waste-derived phosphorus in Lough Derg should be taken as 20 tonnes has implications for the recommended guideline limit of 50 mg m^{-3} for the annual average concentration of total phosphorus in the lake (see paragraph 5.28). This limit was based on a direct correlation with the recommended chlorophyll a concentration limits using the O.E.C.D established relationships between these parameters. However this does not take account of the fact that any added phosphorus which raises the present concentration levels is likely to be more bioavailable than that accounting for the bulk of the latter concentrations. It is necessary therefore that the recommended limit of 50 mg m^{-3} for total phosphorus be kept under close review and that further investigations be carried out to enable the designation of a more realistic limit.

6.25 While the O.E.C.D. equations are the only readily used means presently available for assessing the impact of phosphorus inputs on freshwater lakes they can be regarded only as giving a general guideline. It is desirable that each lake should be considered in its own context, viz. with respect to its uses, susceptibility to eutrophication and the nature of the waste sources likely to affect its water quality. Information of this nature, including hydrological aspects, needs to be obtained for all of the lakes in the Lower Shannon catchment so that a tentative assessment of their susceptibility to waste inputs, particularly phosphorus, can be made. However, as an interim measure and following on from the arguments made above, it might be suggested that waste-derived phosphorus inputs to these other lakes be restricted to 10 - 20 per cent of the natural input. The latter may be derived from the catchment area assuming that the natural 'export' of phosphorus is of the order of 25 mg m^{-2} per annum. This value is fairly typical of unpolluted lake catchments investigated in detail in recent years (e.g see Bowman, 1985, p.71). In calculating acceptable phosphorus inputs in this manner both point and non-point sources of waste must be considered.

CHAPTER SEVEN

WASTE LOADS AND WATER ABSTRACTIONS

INTRODUCTION

7.1 The vast majority of the waste loads discharged to the Lower Shannon river, its tributaries and the feeder streams to Lough Derg are organic in nature. These waste loads arise from two main sources; firstly, domestic wastes which are discharged to the river system from local authority sewerage schemes, and secondly, waste loads which arise from established industry in the area which in this case is taken to include non-manufacturing activities such as milk collecting stations, and cattle marts. Some of the industrial wastewaters are treated in company owned treatment plants from which they discharge directly to surface waters; others discharge their wastewater, untreated, directly to surface water courses, or spread them on land, while others discharge their wastewater treated or untreated to local authority or industrial estate sewers.

7.2 Some additional wastes enter the river system from non-point or diffuse sources such as the run-off from agricultural land and the run-off from built up urban and industrial areas, but no attempt is made in this chapter to quantify the magnitude of the wastes entering the river in this way. In the context of the water quality management plan, conservative wastes, as distinct from the organic wastes referred to above, will be dealt with on an individual basis where they arise, having regard to the water quality criteria relating to the constituents of the waste and the low flow in the river at the particular discharge point.

ESTIMATED EXISTING WASTE LOADS

7.3 Specific details of existing domestic and industrial wastewater discharges in the Lower Shannon are given in Volume 3 -'Abstractions and Discharges'. Estimates of domestic waste loads generated and discharged were made using data submitted by the local authorities. The estimates of the generated domestic waste load were made using a load factor of 0.054 kg BOD/head/day to the population contributing to the scheme, and the discharged waste load was estimated in most cases based on information supplied by the local authorities on effluent B.O.D. concentrations. In the absence of this information the discharged waste loads were estimated on the basis of the level of treatment provided, Where primary treatment is provided a reduction of 40% in the generated waste load was assumed and where secondary treatment is provided a reduction of 85% of the generated waste load was assumed.

7.4 Industrial waste loads were estimated also on the basis of information supplied by the local authorities having regard to effluent discharge conditions laid down in licences issued under the Local Government (Water Pollution) Act 1977. In cases where licences were not issued, industrial waste loads were estimated from literature data available for the industry type and the intensity of production in each case. Data was also available at An Foras Forbartha from effluent surveys carried out by the Institute of Industrial Research and Standards in the operation of the joint A.F.F/I.I.R.S industrial effluent advisory service provided to the Industrial Development Authority.

7.5 For ease of reference the estimated generated and discharged waste loads at the various population centres in the Lower Shannon have been summarised and set out in Table 7.1. It is clear from the table that at all but one location - Ballina - some reduction in the total generated waste load is achieved before the wastewater is discharged. The total waste load generated at population centres in the catchment is 4117 kg B.O.D/day and the total load discharged is estimated to be 830 kg B.O.D./day; this represents an overall reduction of 80% in the total waste load generated. Overall in the area, the ratio of the domestic to the industrial generated waste loads is 1 : 1.3.; however, taking the locations in the area having a population equivalent of 1000 persons or more (Total load generated > 54 kg B.O.D./day) this ratio is increased to 1 : 1.5

ESTIMATED FUTURE WASTE LOADS

7.6 In the fifteen year period between 1966 and 1981 the population of the Lower Shannon increased by 19% and this trend is expected to continue. With continued population growth and future industrial development the magnitude of the waste loads generated will also continue to increase. The population of the catchment is projected to increase to about 100,000 persons by 2006 A.D. and this will result in an increase in the magnitude of the domestic waste load generated. In relation to the future generated domestic waste load, it must be borne in mind that

TABLE 7.1

Estimated Waste Loads Generated and Discharged at Population Centres in the Lower Shannon

Population Centre	Waste Load Generated (kg BOD/day)			Waste Load Discharged (kg BOD/day)		
	Domestic	Industrial	Total	Domestic	Industrial	Total
Borrisokane	62	66	128	1	1	2
Cloghjordan	26	–	26	1	–	1
Moneygall	17	–	17	2	–	2
Toomevara	24	8	32	1	8	9
Nenagh	600	2000	2600	32	43	75
Portroe	22	–	22	1	–	1
Puckaun	19	–	19	1	–	1
Ballina	28	2	30	28	2	30
Silvermines	12	8	20	2	8	10
Newport	38	40	78	1	40	41
Cappawhite	22	–	22	9	–	9
Doon	36	–	36	4	–	4
Cappamore	60	27	87	8	27	35
Caherconlish	48	–	48	7	–	7
Pallas Green	9	–	9	2	–	2
Oola	30	–	30	2	–	2
Moroe	23	–	23	0.4	–	0.4
Castleconnell	84	–	84	40	–	40
Castletroy	350	–	350	100	–	100
Portumna	49	6	55	19	2	21
Woodford	14	–	14	5	–	5
Killimor	11	12	23	4	12	16
Killaloe	65	–	65	40	–	40
Whitegate	11	2	13	1	2	3
Shannon Banks	56	–	56	43	–	43
Parteen	20	29	49	12	29	41
Scarriff	74	39	113	70	39	109

TABLE 7.2

Estimated Future (2006) Generated Waste Loads at the Main Population Centres in the Lower Shannon

Population Centre	Projected Population Increase to 2006	Projected Population 2006	Projected Domestic Load (kg BOD/day)	Projected Increase in Industrial Load (kg BOD/day)	Industrial Load 1986 (kg BOD/day)	Total Projected Waste Load 2006 (kg BOD/day)
Nenagh	2630	8500	595	276	2000	2871
Castletroy	9000 ø	18000 ø	-	-	-	1260
Castleconnell	890	1940	136	93	-	229
Portumna	380	1500	105	40	6	151
Scarriff	520	1390	97	55	39	191
Killaloe	340	1360	95	36	-	131
Newport	390	1190	83	41	40	164
Borrisokane	270	1120	78	28	66	172
Cappamore	340	1090	76	36	27	139
Portroe	510	830	58	54	-	112
Annacotty*	370	770	54	39	>51 *	>144
Caherconlish	240	740	52	25	23	100
Toomevara	300	730	51	32	8	91
Ballina	220	670	47	23	2	72
Cappawhite	150	560	39	16	-	55
Cloghjordan	30	500	35	3	-	38
Oola	70	470	33	7	45	85

* Existing discharge under investigation. The existing domestic discharge will be intercepted in the Castletroy S.S. in the future.

ø Expressed as population equivalent

living standards and personal hygiene practices are improving and this trend will continue to develop. The increasing and more frequent use of sink disposal units, washing machines, dishwashers and similar domestic appliances will mean that the unit domestic organic waste load will increase. For planning purposes, in estimating the future generated domestic load, it is assumed that the unit B.O.D. load will increase from 0.054 to 0.07 kg B.O.D/person/day by the beginning of the next century.

7.7 Continued industrial development and expansion will be necessary to sustain the projected increase in population in the catchment. It is difficult to anticipate what type of industry might be established in the catchment in the future or at what locations in the catchment such new industry might be established. For planning purposes in the context of the Plan it is assumed that new industries would be attracted to the larger population centres in the catchment or to locations where an existing industrial tradition exists. On the basis of this, Table 7.2 sets out the estimated future (2006) waste loads at the main population centres in the catchment. The future generated waste loads are estimated on the basis of a unit domestic waste load factor of 0.07 kg B.O.D./person/day, and the projected increase in the industrial load is calculated on the basis of the domestic to industrial waste load ratio of 1 : 1.5 as already established for the larger population centres, applied to the projected increase in population.

EXISTING WATER ABSTRACTIONS

7.8 A total of 86,000 m^3/day of water is abstracted from surface and groundwaters in the catchment and 80% of this water is abstracted from surface waters. The main water abstractors are "Public Bodies" who abstract about 53,000 m^3/day, and of this, 37,000 m^3/day is exported across the catchment boundary to serve Limerick city. Industry and others abstract 33,000 m^3/day in the catchment. Included in this figure is an abstraction of 26,000 m^3/day which is taken by the E.S.B. for the fish hatchery at Birdhill, the remaining 7,000 m^3/day is used for normal industrial purposes in the catchment.

CHAPTER EIGHT

EFFLUENT TREATMENT CONSIDERATIONS

INTRODUCTION

8.1 In the foregoing chapters estimates have been made of the waste assimilation capacity of receiving waters in the Lower Shannon together with estimates of the existing waste loads discharged to these waters, and the projected future waste loads likely to be discharged as a result of future developments in the catchment. This chapter deals with the final step in the implementation of water quality management, that is the setting of standards for effluents and the degree of treatment required to achieve such standards. Of prime importance in this context are the effluent controls necessary in the first place to eliminate or abate any existing pollution and secondly the controls required to maintain the desired level of water quality in the future taking into account the projected increase in the wastes generated by the projected increase in population and the expansion in industrial and agricultural activities.

8.2 The water quality information discussed in Chapter 3 and given in more detail in Volume 5 indicates a number of locations where water quality conditions are unsatisfactory and require improvement. It is necessary therefore, to examine these situations in detail in order to establish the nature of the improvements required and how these might be effected. It is also opportune at this stage to carry out a similar examination at locations where significant wastes are discharged and water quality conditions are at present satisfactory in order to gain a better perspective of the residual waste capacity which may be available at these locations and the extent to which additional wastes could be accommodated.

RIVERS

General Considerations

8.3 In the examination of waste treatment requirements, use has been made of the calculations and estimates of waste assimilation capacity already undertaken in Chapter 6 and of the estimated existing and projected future waste loads as set out in Chapter 7. In addition, a number of other assumptions have been made and these are listed below:

(a) As the bulk of the wastes discharged to waters in the catchment are of an organic biodegradable nature, the main water quality parameter to be considered is B.O.D.

(b) The control of effluents is based on the Environmental Quality Objectives approach i.e. the total amount of waste (as B.O.D.) in the case of rivers which may be discharged at any location in relation to the waste assimilation capacity as determined for the discharge point.

In the case of lakes, it is the total amount of nutrient (as P) estimated to give rise to acceptable levels of chlorophyll "a" in the water body concerned.

(c) For the purpose of determining the waste treatment strategy to be followed in the present and future context, three discrete levels of treatment are considered each removing a specific percentage of B.O.D. from the influent load to the treatment works. These are, for primary (including preliminary) treatment - 40% removal, for secondary treatment - 85% removal, and for tertiary treatment - 95% removal. Where detailed information was available from effluent samples taken at existing treatment works, this was also used.

(d) All wastes are discharged at a uniform rate and with a constant composition.

(e) The water quality standards for B.O.D. in the Shannon tributaries and the feeder streams to Lough Derg must be met at the 95 percentile flow rate. In the main Shannon channel these standards must be met at a lower flow rate which is in the order of the dry weather flow.

(f) Primary treatment will be provided to all waste discharges as a minimum measure in order to prevent public nuisance and to enhance the use of the river system for amenity and recreational purposes.

8.4 The analysis carried out for rivers in the catchment involves the calculation of the waste discharges which would result from the level of treatment now provided for domestic and industrial waste loads, and also for the projected increase in these loads. Where detailed information was available in relation to the quality of the effluent discharged, estimates were made of the discharged load based on the average B.O.D. concentration in the effluent as derived from samples taken and the volume of waste discharged. Using this information together with the detailed information on background B.O.D. levels in the river upstream of the discharge point as established from the water quality surveys carried out, resultant B.O.D. concentrations arising downstream of each location were calculated using a simple mass balance equation. The estimate of the projected future waste load discharges was made on the basis of the projected increase in population assuming the existing rates of water consumption are maintained and the current level of treatment provided. Resultant B.O.D. concentrations downstream of the discharge point arising from the existing and projected future waste discharges were used to assess what change, if any, would be required in the existing treatment provided. For salmonid waters when the resultant B.O.D. concentrations arising downstream of the discharge point is 4 mg/ℓ or less an acceptable situation is indicated. Where the waste assimilation capacity is exceeded some degree of improvement is desirable, particularly if the resultant B.O.D. concentration exceeds the recommended 95 percentile limit of 5 mg/ℓ. In deciding on the degree of treatment which is desirable or necessary it must be borne in mind that the calculations carried out are largely theoretical and should be regarded as a general index of the nature of the situation at each point considered rather than a precise measure of the effects of the separate discharges considered on the river stretches in question. While the B.O.D. levels in the river are a very good indication of the level of organic pollution present, from a fisheries point of view, it is the extent to which these levels affect the dissolved oxygen (D.O.) level in the river which is of prime importance.

8.5 The analysis at each location involves the calculation of the B.O.D. concentration which would result from the discharge of the waste loads produced by the discrete levels of treatment considered and the flow criteria adopted for pollution abatement purposes. The calculations have been made by simple mass balance using the equation:

$$T = \frac{FC + fc}{F + f}$$

where T is the concentration in the river downstream of the discharge point (after complete mixing) F and f are the discharge rates respectively of the river and the effluent, and C and c are the B.O.D. concentrations respectively in the river upstream of the discharge point and in the effluent. In the case of the Shannon tributaries and feeder streams to Lough Derg the flow criteria adopted will be the 95 percentile flow. In the Shannon river a lower flow criteria has been adopted which is in the order of the dry weather flow. In considering effluent discharges to the Shannon river the discharge rate for effluent (f) can be disregarded as in all cases this discharge rate is insignificant in relation to the river flow. In the following section each discharge is separately considered for the main population centres in the catchment.

Discharges to Rivers

8.6 Nenagh At the present time 75 kg B.O.D./day are discharged to the Nenagh river, 32 kg of which are discharged from the town sewage works. A further 27 kg B.O.D./day are discharged to a tributary immediately upstream of its confluence with the Nenagh river. The total load discharged to the river is therefore equivalent to 102 kg B.O.D./day in an estimated volume of 5174 m^3/day. Having regard to the median B.O.D. concentration measured in the river (2 mg/ℓ) upstream of Nenagh the effect of these combined discharges would be to raise the B.O.D. in the river downstream of the town to 4.6 mg/ℓ. Reduction in the overall load is desirable to allow for future expansion in the town.

8.7 There are two licensed discharges in the town, both of which are limited to a B.O.D. concentration of 20 mg/ℓ in their licence conditions. If the effluent discharged from the town sewage works was also to be reduced to a B.O.D. concentration of 20 mg/ℓ the effect of the combined discharges would be to raise the B.O.D. in the river to 4.6 mg/ℓ downstream of the town. While this provides only a slight improvement on the existing situation it would nevertheless provide satisfactory protection for the river in the short term at least.

8.8. A new sewage works comprising an Oxidation Ditch, Final Clarifier, Picket Fence Thickener and Sludge Drying Beds has been recently commissioned and is producing a final effluent with a B.O.D. concentration between 7 and 8 mg/ℓ. This will provide a satisfactory situation in the short term at least. In the long term additional and a more refined level of treatment may be required as the town continues to expand and develop. In the meantime it is considered that the performance of the new treatment plant should be monitored in order to assess the effect of the new discharge on water quality in the river.

8.9 Castleconnell The total waste load discharged to the Shannon river at Castleconnell is 40 kg B.O.D./day in a volume which is insignificant when compared to the flow in the river. The effect of this discharge would be to raise B.O.D. in the river by 0.05 mg/ℓ which is of no significance as far as water quality in the river is concerned. Neither the existing nor projected future waste load will have any significant effect on water quality in the Shannon and the only aspect to be watched is to ensure the existing plant is properly maintained in order to prevent problems of a localised aesthetic nature arising in the future.

8.10 Killaloe There are two separate sewerage schemes in Killaloe at the present time both of which discharge to the Shannon river downstream of Lough Derg. Scheme A consists of sedimentation tank and percolating filter and Scheme B consists of a septic tank; both schemes have sludge drying beds and both are considered to be overloaded. While the overall load discharged to the Shannon (40 kg B.O.D./day) would have no appreciable effect on water quality in the river, aestetic affects could be noticeable as both schemes are overloaded. There is a current proposal to replace both schemes with an activated sludge treatment plant which would ensure satisfactory water quality conditions in the Shannon and obviate any problems arising in the future.

8.11 Scarriff The total waste load discharged to the Graney river at Scarriff is estimated to be 109 kg B.O.D./day and the waste assimilation of the river is estimated to be 133 kg B.O.D./day (Table 6.1). While the water quality surveys show that the quality of the water in the river is satisfactory, there is only a small reserve capacity to accommodate future development in the town. The total projected future waste load at Scariff is estimated to be 191 kg B.O.D/day.

8.12 The bulk of the waste discharged to the Graney (64%) arises from the Scarriff Sewerage Scheme which is at present treated in septic tanks. The remainder of the wastes consists of three separate industrial discharges each having individual outfalls to the river. The existing treatment works at Scarriff should be upgraded in order to provide for future development in the town. The feasibility of intercepting the three separate industrial discharges to incorporate these in the Scarriff Sewerage Scheme should also be examined with the view to reducing the number of outfalls to the river at Scarriff thereby providing better overall control over the quality of effluents discharged.

8.13 <u>Borrisokane</u> The treatment works at Borrisokane was recently constructed (1981) and produces a high quality effluent having a B.O.D. load of 1 kg B.O.D./day discharged to the Ballyfinboy river. The waste assimilation capacity of the river at Borrisokane (Table 6.1) is estimated to be 12 kg B.O.D./day and accordingly the discharge from the sewage treatment works on its own would be satisfactory and allow adequate reserve capacity in the river for future developments. In the past, a second discharge to the river at Borrisokane did exist which could have been as high as 66 kg B.O.D./day at peak production. Because of the nature of the operation, peak production was likely to occur in the summer period when river flows are likely to be low. The waste load discharged from this operation has now been reduced under a licence issued by the local authority and the reduced waste load is now discharged to the local authority sewer.

8.14 <u>Newport</u> The situation in Newport is similar to that in Borrisokane, in this case, however, the waste assimilation capacity of the river (51 kg B.O.D./day) is four times greater than that in the Ballyfinboy river at

Borrisokane. Newport has a new sewage treatment works (1983) which is reported to achieve a very high quality effluent and the waste load discharged to the Newport River is estimated to be 1 kg B.O.D./day. There was a second discharge to the river in the town (40 kg B.O.D./day approx) which was of an intermittent nature, about once a fortnight, and this was discharged to the river over a short period of about 1 to 2 hours. While the waste assimilation capacity of the river when considered on a daily basis could accommodate this load, the discharge of this shock load to the river should be avoided and the discharge period extended to 12 hours at least. In the recent past, an effluent holding tank and pump have been provided and the effluent is now discharged to the local authority sewer. Having regard to the spare assimilation capacity available in the river and the spare treatment capacity available in the new treatment works the existing treatment facilities available in Newport should provide adequate protection to water quality in the river for the foreseeable future.

8.15 Cappamore The total waste load discharged to the Bilboa river at Cappamore is 35 kg B.O.D./day from domestic sources and established industry in the town. The assimilation capacity of the river is estimated to be 145 kg B.O.D./day and the results of the water quality surveys show that the river is unpolluted (Quality Class A) downstream of the town. The population of Cappamore is projected to increase by about 340 people to the year 2006 A.D., and the total generated (untreated) waste load is projected to increase to 139 kg B.O.D./day (Table 7.2) by the year 2006 A.D. It is clear, therefore, that the spare assimilation capacity now available in the Bilboa river is sufficient to accommodate the projected increase in waste loads at Cappamore for the foreseeable future. The existing independent industrial discharge at Cappamore will be reducing with rationalisation in the industry, nevertheless, the feasibility of intercepting this discharge at Cappamore into the town treatment works should be examined in order to have better overall control over the waste loads discharged.

8.16 Caherconlish Caherconlish is situated near the headwaters of the Groody river and because of this the volume of water available to dilute waste discharges and the capacity of the river to assimilate waste loads is very low. The sewage treatment works at Caherconlish was built about twelve years ago and at present it is producing effluent having a B.O.D. concentration of around 40 mg/ℓ. The waste load discharged to the river is estimated to be 7 kg B.O.D./day. There was another discharge of untreated industrial effluent to a tributary of the Groody river close by which is estimated to have been about 23 kg B.O.D./day. This activity has now ceased operations and the discharge of industrial effluent no longer applies.

8.17 Cloghjordan A waste load of 1 kg B.O.D./day is discharged to a tributary of the Ballyfinboy river from the sewage treatment works at Cloghjordan. The waste assimilation capacity of the river at Cloghjordan is estimated to be 6 kg B.O.D./day. The projected increase in population in Cloghjordan is not significant and accordingly the existing treatment works are adequate.

8.18 The water quality surveys (biological) in the Ballfinboy river in 1984 show that the river was moderately polluted both upstream and downstream of Cloghjordan. The cause of this pollution, which was attributed to agricultural activities in the upper reaches of the river would need to be further investigated before appropriate remedial measures could be recommended.

8.19 Toomevara The water quality surveys show that the Ballintotty river is seriously polluted downstream of Toomevara. The cause of this pollution has been attributed to an industrial discharge and farm wastes.

8.20 The Ballintotty river is only a small stream at Toomevara having an estimated waste assimilation capacity of 3 kg B.O.D./day. The sewage treatment works produces a high quality effluent which corresponds to a waste load of 1 kg B.O.D./day discharged to the river. There is a separate discharge to the river which is estimated to be 8 kg B.O.D./day. The discharger in this case has a licence issued under the Local Government (Water Pollution) Act 1977 which requires that the discharge be eventually connected to the town sewer. The implementation of this condition would effect a considerable reduction in the total waste load discharged at Toomevara. Agricultural waste disposal practices in the area would need to be examined and remedial measures as appropriate should be taken to control pollution arising from such practices.

8.21 Doon The effluent from the Doon Sewerage Scheme, having a B.O.D. concentration of about 40 mg/ℓ , is discharged to a small tributary of the Dead river. The total load discharged is estimated to be about 4 kg B.O.D/day. The catchment area of the river to the treatment works outfall is very small (2 km^2) and because of this and in the absence of any long term hydrometric data it is not possible to give a reliable estimate of what the flow in the river might be for any stated percentage of time. It could be possible that in prolonged dry periods the river at Doon would for all practical purposes be dry. The waste assimilation capacity of the river at Doon has been provisionally estimated to be 2 kg B.O.D./day. An improvement in the quality of the B.O.D. concentration of the effluent discharged to 20 mg/ℓ would reduce the waste load discharged to an acceptable level in the short term at least. In these circumstances the quality of the effluent discharged from the Doon Sewage Treatment Works would need to be improved to the highest standard which is practicable.

8.22 The water quality surveys show that the Doon stream is slightly to moderately polluted downstream of the village and an improvement in the quality of the effluent discharged from the Doon Treatment Works should be reflected by an improvement in the quality of the water in the Doon stream. The Dead river downstream of the confluence of the Doon stream is shown to be unpolluted, so there is no evidence at the present time of the carry over of waste from the Doon stream having any adverse affect on water quality in the Dead river.

8.23 Annacotty The discharge from the Annacotty Sewerage Scheme is to the Shannon river downstream of the outfall of the Mulkear. It is proposed in the future to intercept this discharge to the Castletroy sewerage scheme.

8.24 There are two separate industrial discharges at Annacotty. The first discharge of about 10 kg B.O.D./day is to the Mulkear river from creamery operation. The assimilation capacity of the Mulkear at Annacotty is estimated to be about 418 kg B.O.D./day. In this case the situation here is satisfactory. The second discharge is from the Annacotty Industrial Estate to the main Shannon river and the total load discharged from the effluent treatment plant on the estate amounts to about 11 kg B.O.D./day. The assimilation capacity of river is many times greater than the waste load discharged. A third discharge at Annacotty which was to the Mulkear river did exist in the past but this activity has now ceased operating.

8.25. Oola The results of the water quality surveys showed that the small stream at Oola was moderately polluted at a time when there were two separate discharges to the stream. The upstream discharge from an industrial concern was about 45 kg B.O.D./day and the downstream discharge from the Oola sewerage treatment works was about 2 kg B.O.D./day. The industrial concern has now been closed down and the discharge of this relatively large load has ceased.

8.26 The quality of the effluent discharged from the Oola Sewerage Scheme is of a high standard having an average B.O.D. concentration of 15 mg/ℓ and this corresponds to a waste load of 2 kg B.O.D./day. The waste assimilation capacity of the small stream at Oola has been estimated to be about 3 kg B.O.D./day and this provides a small reserve capacity in the stream to accommodate some future development in Oola in the short term at least.

8.27 Castletroy The discharge from the Castletroy Sewerage Scheme is to the lower reaches of the Groody river and amounts to about 100 kg B.O.D./day. This includes the discharge from the NIHE, Thomond College plus two industrial discharges. The waste assimilation capacity of the Groody river near its outfall to the Shannon is estimated to be 11 kg B.O.D./day which is considerably less than the waste load presently discharged. The existing treatment plant at Castletroy is overloaded and a new treatment plant is proposed with a design capacity of 18,000 population equivalent and provision to allow for staged extensions up to a total of 72,000 population equivalents in future years, as part of the Limerick Suburban Development Programme. The effluent from the proposed new sewage treatment plant will be discharged to the Shannon river.

8.28 Between the outfall of the Groody and the upper limit of the tidal reach at Limerick, there is an area of the river which is used for swimming by some local residents. While the strategies outlined above will provide adequate protection for water quality in the river from the point of view of pollution by organic biodegradable matter the possibility of pollution of a bacteriological nature has not been considered.

8.29 The Department of the Environment in a circular letter issued to local authorities (ENV 3/80) recommended National Limit Values in relation to bacteriological parameters of quality for Bathing Water. While these limit values have no strict legal standing at the present time, they are listed below for consideration in relation to locations on Lough Derg or areas on the river where bathing/swimming or other water contact sports might be practiced by a large number of persons.

Recommended National Limit Values for Bathing Waters

Total coliforms/100 mℓ	5,000 (80% compliance)
Faecal coliforms/100 mℓ	1,000 (80% compliance)
Faecal streptococci/100 mℓ	300 (90% compliance)

For the purpose of the plan, it is recommended that the policy of the local authorities shall be to authorise bathing/swimming only in identified areas of the rivers or the lake where compliance with the recommended National Limite Values can be confirmed. To this end, water quality monitoring programmes for the bacteriological parameters outlined above should be initiated at areas which have been identified as being regularly frequented by significant numbers of bathers and this monitoring should be continued on a regular basis during the bathing season.

8.30 Cappawhite The Cappawhite stream has been shown to be slightly to moderately polluted and the cause of this has been attributed to the discharge of sewage effluent at Cappawhite. The treatment works at Cappawhite consists of an Imhoff tank and drying beds and the B.O.D. concentration of the effluent is estimated to be about 105 mg/ℓ and the total waste discharged is estimated to be 9 kg B.O.D./day. Cappawhite is situated in the upper reaches of the Mulkear/Dead River Catchment and the catchment area to the outfall from the sewerage works is estimated to be 6 km^2. In a dry period, the flow in the river at Cappawhite is likely to be very small. In the absence of any long term hydrometric records a provisional estimate of the waste assimilation capacity of the river at Cappawhite (2 kg B.O.D./day) has been made in Table 6.1. In the light of this, it is recommended that the treatment works at Cappawhite should be upgraded to a secondary level and producing 20/30 (B.O.D./ s.s.) effluent. This would effect a very considerable improvement in water quality in the river. At this level of treatment the waste assimilation capacity of the river is likely to be fully utilised and water quality in the river should continue to be monitored in the light of future developments in Cappawhite.

8.31 Killimor Killimor has a new sewage treatment plant which was commissioned in 1983 and produces a high quality effluent estimated to be 4 kg B.O.D./day. There is a second discharge in the town from an industrial concern which discharges 12 kg B.O.D./day to the river. The total discharge to the river is, therefore, 16 kg B.O.D./day. The assimilation capacity of the river at Killimor based on a 95 percentile flow of 0.04 m^3/s in the river and a median background B.O.D. concentration of 2.0 mg/ℓ is estimated to be 7 kg B.O.D./day. This allows no reserve capacity in the river at the present time for future development in Killimor. The flow in the Kilcrow river 0.5 km approximately downstream of Killimor is augmented by a tributary which increases the assimilation capacity to the river to 16 kg B.O.D./day. A licence has been granted in relation to the industrial discharged referred to above which provides for the interception of this discharge into the public sewer. While this mode of disposal is not yet operational, the interception of this discharge to the public sewer and treatment in the sewerage treatment plant would considerably reduce the waste load discharged to the river at Killimor.

8.32 While the river downstream of Killimor has been shown to be moderately polluted, part of this impairment in quality could be attributed to the carry over of waste from the Lisduff river which drains from the area of the old Tynagh mining operations. The full recovery of the Kilcrow river to satisfactory water quality conditions may be dependant on improved water quality in the Lisduff river and this should be monitored as part of the Plan.

8.33 Portroe The Portroe Sewage Treatment Works which was built in 1974 for a design population of 500 is now serving a population of some 400 persons. The quality of the treated effluent is good, giving a total load of 1 kg B.O.D./day discharged to the Youghal river. The quality of the water in the Youghal river is good having a median background B.O.D. concentration of 1.5 mg/ℓ. On the basis of this and an estimated 95 percentile flow of 0.036 m^3/s the assimilation capacity of the river is estimated to be about 8 kg B.O.D./day. It is clear from this that there is sufficient reserve capacity both in the treatment works and in the Youghal river to provide for future development in Portroe in the short term at least.

8.34 Silvermines There are two discharges to a tributary stream of the Kilmastulla river at Silvermines, the first from the sewerage scheme and the second from an industrial concern in the town. The total load discharged is 10 kg B.O.D./day, which is made up of 2 kg B.O.D. from the sewerage scheme and 8 kg B.O.D. from the industrial concern. The river at Silvermines is very small having a catchment area of approximately 3 km^2. In these circumstances the 95 percentile flow and the assimilation capacity of the river at Silvermines is also very small and would certainly be less than 10 kg B.O.D./day. It is clear therefore that a reduction in the organic waste load is desirable.

8.35 The Kilmastulla river is shown to be moderately polluted for most of its length except for the lower reach of the river at its outfall to the Shannon. The cause of this deterioration in water quality has been attributed to mining operations in the Silvermines area in the upper reaches of the catchment. The main contaminants discharged from these operations are metals (Zn and Cu) and the organic load discharged is generally insignificant. While the river is reported to be moderately polluted at present, the results of the most recent water quality surveys show an improvement in water quality in the river over and above that which was recorded in earlier surveys. At the present time a licence is being prepared for the discharge of effluent from the mining operations and compliance with the conditions set in this licence should gradually effect a further improvement in water quality in the Kilmastulla river. As mentioned, while reduction of the organic waste load discharged to the tributary will not appreciably alter the quality classification of the river nevertheless such a reduction is desirable.

8.36 Shannon Banks The total waste load discharged at the upper limit of the tidal reach of the Shannon river from the Shannon Banks Sewerage Scheme is 43 kg B.O.D./day. The effect of this load on water quality in the river is insignificant. The treatment works which consists of three primary settling tanks now serves a population of 1350 and was designed for a population equivalent of 4000. The scheme however is hydraulically overloaded at times due to storm water inflows and it is proposed to intercept these flows to a separate discharge. In the long term however, the level of treatment should be upgraded to provide secondary treatment in accordance with the policy commitment in the plan which states that secondary treatment should be provided for all large centres of population. As an alternative the feasibility of intercepting this discharge into the Limerick Main Drainage Scheme should be investigated.

8.37 Ballina The effluent from the Ballina Sewerage Scheme is discharged untreated to the Shannon river at its outfall from Lough Derg. The waste load generated and the waste load discharged from the scheme are insignificant in relation to the waste assimilation capacity of the river at this location. This is a combined scheme and the quality of the discharge effluent is reported to be considerably better than that which is normally taken for raw sewage. Because of this, water quality problems such as increased B.O.D. or reduced D.O. concentration in the river downstream of the discharge point are unlikely to arise. Nevertheless, problems of an aesthetic nature could arise. The overall policy of the plan to prevent public nuisance and interference with recreational and amenity use of the river as far as possible should be applied.

8.38 Lisduff and Barnacullia Streams These two streams drain the area of operation of the old Tynagh mining activities. Both these streams have been seriously polluted due to the ingress of heavy metals from the mining activities in the area. The mining operations have now ceased and while the most recent surveys have shown a slight improvement in water quality in the rivers the situation here still remains unsatisfactory. While it is not possible to predict how long it will take to restore satisfactory water quality conditions to these streams, it is considered that water quality should continue to improve as less and less metals (Zinc, Lead and Copper) are leached out of the area of the old mining operations.

8.39 Ollatrim River While there are no known direct discharges to the Ollatrim river, the results of the water quality surveys show that the river is moderately polluted. The deterioration in water quality occurred in the recent past as surveys carried out pre 1984 showed the river to be in a generally satisfactory condition. This reduction in water quality has been attributed to excessive nutrient enrichment in the upper reaches of the river. A possible cause of this deterioration in water quality is attributed to agricultural practices in the upper catchment and this possibility should be further investigated.

8.40 Mining Operations Remedial measures will be carried out on a site specific basis and in the light of local conditions at both the Silvermines and Tynagh mining areas in order to reduce the ingress of polluting material to surface water streams in the areas.

8.41 Derrainy River The river discharges to a small lake, Lough Alewnaghta on the western shore of Lough Derg before it enters Lough Derg. Water quality in the lower reaches of the Derrainy river has deteriorated since 1982. The cause of this deterioration in water quality which now classifies the lower reaches of the river as being moderately polluted based on the biological survey would need to be further investigated before any remedial measures could be recommended at this stage.

Discharge To Lough Derg

8.42 Portumna The outfall from the Portumna Sewerage Scheme is to Lough Derg at a location which is close to the entry of the Upper Shannon River to the lake. The sewerage scheme has a primary treatment works and the waste load discharged is estimated to be 21 kg B.O.D./day at an average concentration of about 100 mg/ℓ. The effect of this discharge on water quality in the lake is insignificant. Similarly the nutrient load discharge to the lake from the sewage works in terms of orthophosphate is insignificant when compared to the orthophosphate load discharged to the lake from contributing rivers and streams. In the light of this it is felt that any further reduction in the waste loads discharged to Lough Derg from Portumna Sewerage Scheme would not have any appreciable effect on improving water quality in the lake. The population of Portumna had grown to about 1120 in 1981 and if past trends are continued the population could increase to about 1500 in the year 2006 A.D. In line with the overall policy of the plan therefore, which states that all public discharges from large centres of population should be subject to secondary treatment it is recommended that secondary treatment should be provided to the waste loads discharged from Portumna in the long term.

8.42 (a) Mountshannon The Mountshannon Sewerage Scheme consists of a septic tank which serves approximately 80 persons in the village and discharges to a small stream close to its outfall to Lough Derg. Other establishments in the village such as hotel, school, public convenience, etc., are served by individual septic tanks. Clare County Council proposes to intercept these separate discharges in the village and treat to a 20/30 (B.O.D./S.S) standard prior to discharge to Lough Derg.

Summary Conclusions and Recommendations on Discharges to Rivers and Streams in the Lower Shannon Catchment.

8.43 The strategies recommended above for the control of wastes generated at the eighteen centres of population considered are summarised in Table 8.1. The recommendations in relation to the long term situation can only be regarded as broad guidelines as the estimates of the magnitude and volume of the waste loads generated and discharged by the year 2006 A.D. have been made in a largely arbitary manner. The precise manner in which the required waste reductions can be achieved in particular where non-point sources of

TABLE 8.1

Summary of Recommended Strategies for Waste Treatment at Population Centres in the Lower Shannon River Catchment

Location	Recommended Waste Treatment Strategy
Nenagh	Tertiary treatment may be required in the future.
Castleconnell	Present position satisfactory; no change anticipated.
Killaloe	Implement current proposal to provide activated sludge treatment plant for combined existing discharges.
Scarriff	Intercept existing separate discharges and provide secondary treatment.
Borrisokane	Intercept industrial discharges. No change anticipated.
Newport	Intercept existing industrial discharge over extended period.
Cappamore	Present position satisfactory.
Caherconlish	Present position satisfactory.
Cloghjordan	Investigate possible agricultural sources of waste and take appropriate remedial measures.
Toomevara	Intercept existing industrial discharge, investigate possible agricultural sources of waste and take appropriate remedial measures.
Doon	Improve effluent quality to 20/30 (B.O.D./S.S.) standard.
Annacotty	Intercept Annacotty sewage discharge to Castletroy/Monaleen Scheme. Investigate existing discharges to the Industrial Estate Sewerage Scheme.
Oola	Present situation satisfactory in the short term.
Castletroy/Monaleen	Provide full secondary treatment and discharge to the River Shannon. Monitor river for compliance with National Limit Values for bathing waters.
Cappawhite	Provide full secondary treatment.
Killimor	Intercept existing industrial discharge.
Portroe	Present arrangement satisfactory.
Silvermines	Intercept existing industrial discharge.
Ballina	Provide Primary Treatment in the short term at least.
Shannon Banks	Separate Storm Flows, secondary treatment should be provided in the long term.
Portumna	Secondary treatment should be provided in the long term.
Kilmastulla River	Monitor compliance with licences (industrial) discharge conditions.
Ollatrim River	Investigate possible agricultural sources of waste.
Derrainy River	Further investigation needed of possible waste sources.
Mountshannon	Provide secondary treatment.

wastes are concerned needs further investigation in the light of detailed examination on the ground to ascertain the pathways in which these wastes reach a particular water course and the local controls which can be implemented in each case.

LAKES

General Remarks

8.44 The main concern in regard to lake water quality in the catchment is the presence of or possibility of eutrophication and the associated increased growth of green plants, in particular planktonic algae. It is now well established that the main factor in eutrophication is phosphorus because of the 'growth limiting' status of this element for green plants, at least in freshwaters. Thus the control and prevention of eutrophication is primarily concerned with minimising artificially induced inputs of phosphorus to water; such inputs may arise directly through the discharge of wastes such as sewage or indirectly, e.g. through the leaching of land on which animal manures or artificial fertilisers have been spread.

8. 45 Considerable quantities of phosphorus reach freshwaters through the leaching of rock, soil and vegetable material containing phosphorus compounds. Under natural conditions such leaching is likely to give rise to the 'export' of 20 to 50 mg P m^{-2} per annum in a lake catchment (Vollenweider, 1971); values in this range have been reported for a number of unpolluted lake stream catchments in Ireland (Bowman, 1982, 1985; F.B.I.U., 1975; Horkan and Toner, 1984; Toner, 1977, 1979). A further natural source of phosphorus is direct precipitation on the lake surface; measurements made at Ballinamore in Co. Leitrim (Burke et al, 1974) have shown that this may account for 10 mg P m^{-2} per annum in that area. The potential impact of these natural inputs of phosphorus on algal growth appears, however, to be relatively modest; this arises from the fact, as pointed out in Chapter 6, that much of the phosphorus carried into lakes by natural agencies is 'unavailable' to growing algae, i.e. it does not enter as dissolved, inorganic phosphate (orthophosphate) the form in which it is taken up by the plants.

8.46 Compared to the natural sources of phosphorus, the artificial sources, particularly biodegradable wastes such as sewage and animal manures, are of much greater significance as plant growth promoters. This is due to the fact that phosphorus in these wastes exists mainly as orthophosphate or as compounds which are readily hydrolysed to orthophosphate in water. Of these wastes, sewage has been most commonly associated with artificial eutrophication and excessive algal growth. The importance of sewage in this respect has increased considerably since the 1949s due to the introduction of artificial detergents containing polyphosphates. It is estimated that in most developed countries (excepting those where low-phosphate detergents have been introduced) detergent phosphorus accounts for about 50 per cent of the total amount of the element in raw sewage (Golterman, 1975).

8.47 Animal manures are a potentially large source of bioavailable phosphorus in surface waters. These wastes are of particular importance when generated in intensive rearing units which necessitates their disposal as dilute slurries by spreading on land. The following figures contrast the per cap. phosphorus content in sewage with that in livestock manures:

	g P/day
Domestic Sewage	2 - 4 (incl. detergent P)
Cattle Manures	28
Pig Manures	9
Sheep Manures	0.5

It has been estimated (Water Pollution Advisory Council, 1983) that the total amount of phosphorus generated in agricultural wastes (animal manures and silage effluent) in the country is of the order of 75,000 tonnes per annum. Assuming 3.0 per cap. in domestic sewage this amount of phosphorus has a human waste population equivalent of some 68 x 10^6 or 19 times the present population. However, the impact of this load is relatively much less than that of domestic sewage and industrial wastes because the latter are, in general, discharged directly to water while the former are mostly applied to land. Phosphorus in artificial fertilisers is not likely, under normal circumstances, to present a problem as the phosphate ion, which dominates in these preparations, is readily held in the soil matrix (Morgan, 1983); however, there may be significant losses on peaty or sandy soils or where heavy rainfall immediately follows application of the fertilizer. The same situation is likely to apply for phosphorus in wastes from septic tanks which are allowed to overflow to the ground; where soils are suitable and where the septic tanks are not located close to the lake shore then such wastes are unlikely to contribute significant quantities of phosphorus to adjacent surface waters (Jones and Lee, 1979).

Strategies for Phosphorus Control

8.48 The reduction of or prevention of excessive growths of algae and weeds in freshwaters, particularly in lakes, is most likely to be achieved by minimising the ingress of phosphorus from artificial sources. However, it is also necessary to have some idea of the natural productivity of the system being considered so that unrealistic targets for plant growth reduction or limitation are not adopted. This question could be resolved by examining the situation in adjacent waters which are free of artificial inputs of phosphorus. Before a phosphorus input control programme can be implemented it is also necessary to have as full an account as possible of the magnitudes of the different sources of phosphorus, natural and artificial, affecting the lake involved. This would show, firstly, the relative importance of the artificial sources compared to the natural sources and thus the degree of overall control of phosphorus input which is possible. In this respect it must be remembered, as pointed out already in Chapter 6, that the growth promoting potential of naturally derived phosphorus (when measured as total phosphorus) is likely to be considerably less than that of the artificially derived phosphorus. Thus some weighting of the latter is required when assessing the situation. On the basis of previous remarks this could be done by assuming that only 10 - 20 per cent of the naturally derived phosphorus is 'bioavailable' but that all of the artificially supplied phosphorus is of this status.

8.49 The inventory of sources would also indicate the composition of the artificial input of phosphorus, in particular the relative contribution from point and non-point sources. This is of considerable importance in the assessment of effective remedial or preventive measures. In general the most cost-effective strategy is to give priority to relatively large inputs of phosphorus and the most amenable situation in this respect is that in which the bulk of the phosphorus containing waste is derived from one or a small number of point sources, e.g. sewage treatment plants. In such cases it is a relatively straight forward matter, from a technical point of view at least, to effect considerable limitations on or reductions of the phosphorus inputs to the lake concerned by appropriate measures at the treatment plants. This approach has been found appropriate in many eutrophication control programmes in Europe and the U.S. over the last two decades; in recent years such measures have been adopted in Ireland in the case of Loughs Ennell and Neagh.

8.50 In contrast, the remedial strategy may not be so clearly definable nor as technically feasible where a relatively large number of point sources are involved or, in particular, where non-point sources are likely to contribute a substantial fraction of the artificially derived phosphorus. In such cases the priorities for phosphorus input, limitations or reductions may require detailed studies of the magnitudes of the different sources and an assessment of their relative impact. The latter will be a function not only of the magnitude of the source involved but also of its position in the catchment and the associated possibility of attenuation of the phosphorus content before the waste stream reaches the lake proper.

8.51 The most intractable situation for phosphorus control arises where the bulk of the artificial input is attributed to non-point sources. Such sources may be represented by the surface run-off from urban areas or from forested land which has received fertiliser applications. However, the most important of such sources in terms of the likely impact on surface waters is agricultural land, particularly that on which animal manures and other farm wastes have been spread. Minimising losses of phosphorus to drainage waters in these cases requires a carefully controlled management scheme for the application of the waste on the land, taking account of such factors as rainfall, soil moisture deficit, the slope of the land and the composition of the waste. Since the responsibility for safe disposal of waste rests with individual farmers the commitment to and the understanding of the measures required may be lacking; thus waste may be spread at the wrong period or at too high a rate leading to excessive losses of phosphorus and other constituents in run-off. Occurrences of this nature are particularly likely in the case of intensive livestock rearing operations where the area and/or nature of the land available for the spreading of the resulting wastes may be inadequate. The problems for pollution control presented by these circumstances have been clearly demonstrated in recent years by the case of Lough Sheelin. It is probable that such situations can be properly managed only where the body charged with the statutory responsibility for water pollution control is directly involved in the design and monitoring of the waste disposal operation (Dodd and Champ, 1983).

8.52 In some cases the relatively great difficulty of adequately controlling non-point source pollution will require that the social and economic desirability of the activities giving rise to such pollution be weighed carefully against the possible damage to water resources. This is particularly the case where the latter are to be used as water supply sources. In such situations it may be necessary to restrict or even prevent activities giving rise to non-point source pollution in the catchment concerned if it is considered that the degree of control which can be exercised over such pollution will not be adequate. Such a policy is, however, likely to present problems of a political nature and the best that might be achievable is the creation of 'buffer strips' in the immediate vicinity of the lake where waste producing activities would not be allowed. Alternatively, as in the case of Lough Sheelin, mentioned above, some or all of the wastes may be 'exported' from the catchment for disposal in areas where the risk of water pollution is much lower.

Control of Eutrophication in the lakes of the Lower Shannon Catchment

8.53 The information required for an assessment of the need for and nature of counter-eutrophication measures is available for only two lakes in the Lower Shannon Catchment, viz. Lough Derg and Poulawee Lough. These two lakes are treated separately in the following sections. General information obtained on the other lakes in the catchment, of which there are over forty, suggests that artificial eutrophication is not a problem in these water bodies. Thus future management decisions in these cases should mainly concern preventive rather than remedial measures.

8.54 While it is not possible to make specific recommendations for these unsurveyed lakes, there are a number of generally applicable measures which should be taken into account. In general, significant discharges of biodegradable wastes should not be made directly to lakes or to their feeder streams within a short distance (< 5 km) of the lake. In line with the proposals put forward in Chapter 6, a significant discharge in this respect might be taken as one which is likely to give rise to an annual phosphorus input equal to or greater than 10 - 20 per cent of the 'natural' input; this approach is recommended to weight the artificial inputs of phosphorus because of their greater bioavailability compared to natural inputs. The 'natural' input may be estimated by assuming that the 'export' rate of phosphorus from the catchment is of the order of 25 mg P m^{-2} per annum. As pointed out in Chapter 6, this is fairly typical of values which have been reported for unpolluted lake stream catchments in Ireland in recent years.

8.55 Where direct discharges of wastes to lakes or to their feeder streams near the lake cannot be avoided the provision of a phosphorus removal step in waste treatment should be considered. This consideration should include an assessment of the relative magnitude of the point and non-point waste sources affecting the lake; if the point source is not contributing a substantial fraction (say greater than 30 per cent) of the estimated total input of bioavailable phosphorus extra treatment may not be justified in terms of the likely benefit for water quality. Furthermore, as most lakes in the catchment area are likely to have rapid water renewal rates in winter and spring months it may be sufficient to reduce phosphorus inputs only in the summer and autumn months. The water renewal rates are likely to be appreciably slower and the probability of the growth of nuisance algae (e.g. the scum forming blue-green types) higher in the latter months. This strategy could be assessed on a trial and error basis.

8.56 In regard to the control of non-point sources of waste the problems of instituting adequate controls are, as pointed out above, much greater. In the first instance some reduction of phosphorus input is likely to be achieved by the adherence to good management practices in disposing of waste by land spreading. This requires that the local authority has a full knowledge of all locations where waste is stored and of the constraints operating on the safe disposal of such wastes; it is also desirable that the spreading operations are supervised and their adequacy checked by the monitoring of the quality of drainage waters. Where more stringent controls are necessary, e.g. in order to protect drinking water sources, the desirability of restricting in the catchment the type of activities giving rise to the wastes or, at least, the disposal of such wastes by land spreading, or to zoning them outside 'buffer' strips around the lake would have to be addressed. Alternatively, the 'export' of wastes from the catchment area may be considered. The extent to which such measures, which clearly entail problems other than those of a technical nature, could be justified or find acceptance would depend on the perceived importance of the water body under consideration.

8.57 The foregoing general guidelines do not obviate the need to obtain detailed information on the lakes in the catchment. Because of the relatively variable response of lake systems to nutrient input it is preferable to be in a position to make specific assessments for particular lakes. The more important information required for this purpose relates to hydrological and physical aspects (e.g. water retention time and lake volume), nutrient, particularly phosphorus input levels (and the breakdown of these between natural and artificial sources) and the present response of the lake to the latter in terms of algal growth (chlorophyll a concentrations). It is recognised that a considerable effort is needed to obtain information of this type. Thus any resources which can be deployed to make the necessary investigations should be allocated on a priority basis, viz. lakes used for water supply or which harbour high quality game fish stocks should be given precedence over those classified as coarse fisheries.

The Position in Lough Derg

8.58 Lough Derg is by far the largest lake in the Lower Shannon Catchment and represents the bulk of the surface water resources in the area. Several abstractions for water supply purposes are made from the lake and its outlet (including those for Limerick City) and a further large abstraction is being planned to serve a regional water supply scheme in Tipperary (NR). In addition the lake is an important angling water, harbouring good stocks of brown trout and several coarse fish species. In recent years the value of the lake as a recreational and amenity area has been increasing not least because of the development of boat hire facilities on the Shannon navigation system, of which Lough Derg forms a substantial and popular part. Thus the quality of the lake waters is an important consideration. In view of the presence of game fish and the use of the lake as a source of water supply, it is necessary, as argued above in Chapter Five, that the growth of algae and, consequently, the input of phosphorus be kept to moderate levels.

8.59 The available data on water quality in Lough Derg and on nutrient inputs through the feeder streams and from other sources have been set out in Chapter Three. The most comprehensive data base is that generated by the An Foras Forbartha survey of 1976-1978 (See Table 3.5). These data place the lake on the border between the mesotrophic and eutrophic categories according to the O.E.C.D. classification system (Table 5.1) and thus of a type which should be compatible with the main beneficial uses identified in the preceding paragraph. The values recorded for total phosphorus and chlorophyll a concentrations in the 1976-1978 period were well within the limits proposed for these parameters in Chapter Five (See Paragraph 5.24 et seq.). In addition, the estimated input of total phosphorus to the lake in these years was considerably less than that predicted by the O.E.C.D. relationship as likely to give rise to the afore mentioned limiting values for chlorophyll a concentrations. These observations suggest a satisfactory position in the lake in regard to water quality in the period concerned; they also suggest that the lake has a substantial capacity to assimilate further phosphorus inputs (equivalent to 20 tonnes/annum of bioavailable phosphorus) if it is considered acceptable that algal growths be permitted to increase to the levels represented by the proposed limits on chlorophyll a concentrations.

8.60 This assessment of the situation in Lough Derg is put in considerable doubt by further measurements made by An Foras Forbartha in the lake in the summer and autumn months of 1982 and 1984. Concentrations of chlorophyll a and total phosphorus at these times were considerably greater than the maxima recorded in the 1976-1978 investigation; if these values for 1982 and 1984 are taken as the annual maxima they would place the lake well into the O.E.C.D. eutrophic category. Furthermore, if this higher level of algal growth represents a permanent change in the productivity of the lake it is possible that it could have adverse effects on the beneficial uses, particularly water abstractions and game fisheries. As pointed out in Chapter 3, the representativeness of these recent data needs to be investigated[1] but they do suggest the need for caution in interpreting the relationship between phosphorus input and algal growth apparent in the data from the main survey of 1976-1978.

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1 As part of its national programme of investigation into lake water quality, An Foras Forbartha is carrying out further surveys of the lake and its feeder streams through 1986.

8.61 It has also been pointed out in Chapter 3 that the productivity of the lake, as assessed by the numbers of planktonic algae in the water column, showed a substantial increase between the early 1920's and the 1970's. It is arguable that this change is largely irreversible as it would reflect a response to many developments in the catchment over the fifty year period, each facilitating an increased input of nutrient substances to drainage waters. The more important of such developments would have been the installation and extension of sewerage schemes and an intensified use of land, particularly for agricultural purposes. However, the data for 1976-1978 indicate that this increase in productivity had not led at that stage to conditions incompatible with the main uses of the lake waters. It is difficult to accept that the apparent further increase of productivity between the 1976-1978 and 1982-1984 periods was caused by an increased input of nutrients and available data on the quality of inflowing rivers and streams would not support such a conclusion. A further updating of the phosphorus input estimates is desirable. More likely explanations for the apparent increase of algal growth may be advanced. It is possible that a phosphorus input of the order measured in 1976-1978 can produce a greater growth of algae than that observed during the period (and the wide confidence limits of the O.E.C.D. relationships illustrate this possibility). Alternatively, as suggested in Chapter 3, the increased growth of planktonic algae may indicate a change in the ecology of the lake whereby the latter organisms are out-competing the plants on the substratum for the available nutrients.

8.62 It is clear that further investigations would be needed to obtain a full understanding of the relationship between phosphorus input and algal growth in Lough Derg. In this situation it is advisable to adopt a conservative attitude to the management of water quality in the lake. Firstly, there is a strong case to be made against any further point discharges of waste derived phosphorus of significant size directly to the lake or to feeder rivers and streams within a short distance (< 5 km) of the lake. A similar restriction or close control should be placed on activities likely to increase the input of bioavailable phosphorus from non-point sources, in particular the land spreading of farm wastes such as animal manures. While the calculations made above suggest that the lake has an assimilation capacity for some

20 tonnes of bioavailable phosphorus, to take advantage of this capacity would mean accepting a substantial increase of algal growth. Furthermore, as the 1982 and 1984 data suggest that the present phosphorus input can, under certain conditions, lead to a greater growth of algae than that observed in 1976-1978, a further input may well lead, on occasion, to growths represented by chlorophyll concentrations well in excess of the limits proposed in Chapter 5.

8.63 The second point to be considered in a water quality management strategy for the lake is whether it is desirable and feasible to reduce algal growths. If further surveys of the lake show that growths of the order measured in 1982 and 1984 have become typical, there would be a strong case for attempting such reduction. However, if these prove exceptional and the conditions observed in 1976-1978 are more typical, the need for growth reduction measures would be much less and probably not justified in terms of the improvements likely to be achieved. This leads on to the feasibility of bringing about a decrease of algal growth in the lake which may be assumed to require mainly a reduction of phosphorus input. Assuming that the estimated input in 1976-1978 of approximately 200 tonnes per annum is still valid (although as pointed out above this requires updating), it is clear from the details given in Chapter 3 that only a very small reduction of total phosphorus input could be achieved by removing phosphorus from the main waste discharges on or near the lake (Nenagh, Portumna and Scarriff) as these account for only 4 per cent of the total. The bulk of phosphorus input is accounted for by the load in the River Shannon (approximately 80 per cent in 1978-1978). Thus substantial reduction of phosphorus input to the lake would require reduction of the River Shannon load. This would be feasible only if the waste inputs at the major population centres upstream, in particular Athlone, Ballinasloe and Birr, were responsible for a substantial fraction of the phosphorus load in the river at Portumna. Assessment of this fraction would be difficult; in view of the long distances involved the 'carry-over' of phosphorus from these waste sources is likely to be small.

8.64 The foregoing remarks consider total phosphorus and, as mentioned already, this parameter is not a reliable measure of the likely impact on plant growth because of the different bioavailabilities of the nutrient in natural and artificial sources. It has been assumed above that the bioavailable fraction of natural inputs is as low as 10 per cent in contrast to the virtual total availability of artificial inputs. That this may be an underestimate of the importance of natural sources is indicated by estimated inputs of 'orthophosphate' to the lake in 1976-1978 which were about 40 per cent of the total phosphorus inputs. However, taking the most conservative estimate of 10 per cent bioavailability for the natural sources and also assuming, as was done above, that the bulk of the input of 200 tonnes/annum in 1976-1978 was from such sources, then it may be calculated that the waste derived phosphorus from the near-lake towns (Nenagh, Portumna and Scarriff) could account for as much as 38 per cent of the bioavailable phosphorus input to the lake. While this figure is likely to exaggerate the importance of these sources, it emphasises that they could not be ignored in a catchment wide programme of phosphorus input reduction. Apart from assessing their impact on the general body of the lake, it would be desirable to investigate whether these sources have any localised effects, e.g. shore-line growths of sessile algae, which should and could be controlled.

8.65 The overall importance of these near-lake waste sources depends on the characteristics of the phosphorus load carried into the lake at Portumna by the River Shannon. While it has been assumed in making the calculations with the O.E.C.D. relationships that the bulk of this load reflects natural inputs this requires further investigation. As pointed out above the 'orthophosphate' load entering the lake is considerably greater than 10 per cent of the total phosphorus load (∿ 40 per cent) and this also holds for the River Shannon input[1]. The investigations necessary to determine the bioavailability of the phosphorus loads in the River Shannon would probably require bioassay experiments as well as chemical analysis. While this aspect would be relatively easily accomplished the allied task of determining how much of the bioavailable phosphorus in the River Shannon at Portumna is attributable to controllable waste sources upstream would be much more difficult. However, until such investigations have been undertaken, it is not possible to state with any

1 The 'orthophosphate' fraction referred to herein is not strictly the soluble phosphate ion as samples are not filtered before analysis. The more correct term for this fraction is 'total molybdate reactive' phosphorus and would include, in addition to phosphate <u>sensu strictu</u>, complexed forms of phosphate which are hydrolysed relatively easily.

certainty whether a phosphorus reduction programme for the three main near-lake waste sources (Nenagh, Portumna and Scarriff) would be justified as a means of restricting algal growth in the lake.

8.66 The third element of a management strategy for Lough Derg is a set of measures to deal with excessive algal growths in the lake. There is a strong possibility that significant reduction of the present levels of growth in the lake will not prove feasible on technical grounds and that periodic loss of water quality, in terms of high algal densities in the water column, will have to be expected. In this situation, it would seem prudent to have extra facilities available in treatment plants, e.g. activated carbon filters, which can help to mitigate the effects of high algal cell content in the abstracted water. It would be desirable also to have contingency plans to remove deposits of algae and other plants when these occur on shores in areas which are used for bathing, boat berthing or as general amenities. In regard to fish stocks and angling there is little of a contingency nature which can be planned to deal with possible effects of excessive algal growths. However, the largest growths observed to-date in the lake are unlikely to have a serious impact on fish unless they persist for long periods.

8.67 In summary, a water quality management strategy for Lough Derg should consist of the following principal elements :

a) A restriction on further significant inputs of waste derived phosphorus (from point or non-point sources) either directly to the lake or to feeder rivers and streams within, say, 5 km from their outfall to the lake.

b) A programme of investigation to determine the desirability and feasibility of reducing the present level of algal growth in the lake. This programme would have two main elements, viz. continued surveillance of water quality conditions, particularly algal growth, in the lake and an assessment of the relative importance of the various sources of bioavailable phosphorus entering the lake and whether and in what manner these could be controlled so as to significantly reduce the input of nutrients.

c) A set of contingency measures to deal with the adverse effects of episodes of above normal algal growth.

8.68 Finally, it should be noted that the above discussion concerns water quality, per se and a separate assessment is required for the impact of peat silt on the lake. There has been much public concern in recent years that the commercial harvesting of the peatlands upstream of Portumna is leading to the ingress of large amounts of silt to Lough Derg with adverse impact on fish, invertebrate fauna and shore-line amenities. The situation in the mid 1970's was investigated by An Foras Forbartha (Toner and Clabby, 1975) and the findings are summarised in Chapter 3 (paragraph 3.32). While that investigation concluded that the peat silt entering the lake was not likely to have any significant adverse effect on fish or bottom fauna, there is a need to up-date the position by further investigation. These further studies should also assess the possibility of a connection between increase of peat silt input to the lake and eutrophication. There is evidence from recent research (see Bowman, 1985, page 79) that phosphorus associated with organic matter in humic acids may be released as phosphate ion under the influence of U.V. radiation in strong sunlight. This conceivably could intensify algal growth, particularly in summer months.

The Position in Poulawee Lough

8.69 This is the only other lake in the catchment for which recent data on water quality are available. Poulawee Lough is one of a group of small lakes located in the vicinity of Puckane, north of Nenagh, which drain into the Luska area on the eastern shore of Lough Derg. The water quality position in this lake, shortly before and following the commencement (May 1982) of the discharge of treated sewage from the village of Puckane, was investigated by An Foras Forbartha on behalf of Tipperary (NR) (Bowman, 1983, Toner and Bowman, 1985). These investigations indicated that a substantial increase of algal growth occurred in the lake in 1983 and 1985 compared to that in 1982. In addition, it was estimated that the discharge of treated sewage would give rise to a three to four fold increase of the input of phosphorus to the lake. Thus a substantial increase of algal growth is to be expected.

8.70 The situation in Poulawee Lough is, in general, a reverse of that described above in Lough Derg. In this case the cause of the increased algal growth can be readily identified as the discharge of treated sewage from the new works at Puckane and a restoration of original conditions should be achievable by appropriate measures in treatment. However, in contrast to Lough Derg, the need to reduce algal growth is not immediately obvious as no beneficial uses have yet been identified which might be adversely affected by the change in the condition of the lake. In this situation it has been recommended by An Foras Forbartha that further surveillance of the position be undertaken to determine the scale of algal growth which might ultimately occur and whether this could be sufficiently high to cause nuisance conditions, e.g. due to the decay of shore-line scums. In this connection, it was pointed out by Toner and Bowman (1985) that there is a possibility that algal growth in the lake may have become limited by nitrogen rather than phosphorus availability following the discharge; this could result in smaller increases of such growth than would be indicated by a consideration only of the extra input of phosphorus.

CHAPTER NINE

THE DRAFT PLAN AND ITS IMPLEMENTATION

INTRODUCTION

9.1 This chapter sets out the principles and action plans to be adopted and implemented by the responsible agencies in order to exercise adequate control of water quality in the Lower Shannon River and in Lough Derg in the short term and for the foreseeable future. These principles and action plans arise from the considerations set out in the preceding chapters and in the relevant back-up volumes, and constitute the Draft Water Quality Management Plan for the Lower Shannon River. They are dealt with as a series of rational steps; the general principles to be followed are indicated first and then the specific actions required are set out in order of priority.

THE PLAN

Scope of the Plan

9.2 The Plan applies to the main Shannon River from the upper limit of the tidal reach at Limerick to the point of entry of the Upper Shannon River to Lough Derg at Portumna and includes Lough Derg. The Plan also applies to all significant tributary streams to the Shannon and feeder streams to Lough Derg for which specific beneficial uses have been identified. The principal tributaries and feeder streams contained in the plan include the following: the Groody, the Mulkear and its tributaries including the Newport, Annagh, Bilboa, Dead, Cahernahillia rivers and the Doon and Cappawhite streams, the Kilmastulla, the Grange, the Youghal, the Nenagh and its tributaries, the Ollatrim and Ballintotty rivers, the Ballyfinboy, the Kilcrow and its tributaries, the Killuran, Cappagh, Lisduff and the Lisduff stream, the Woodford, Coos, Derrainy, Bow, Graney, Ballyteige and Blackwater (Clare) rivers. It is proposed to exclude from the Plan a number of small streams and drains for which beneficial uses have not been identified and in which such uses are unlikely before the end of the first review period of the Plan. In these cases the main concern will be the prevention of public nuisance and the carry over of pollution to larger streams.

9.3 The Plan applies to all lakes in the Catchment which are presently used or are likely to be used in future for water abstraction, as fisheries or for their recreational and amenity value. The larger of such lakes included in the Plan are Lough Derg, Lough Graney and Lough O'Grady. The map enclosed at the back of this report outlines approximately the rivers, streams and lakes included in the Plan. The official Plan Map and schedule is lodged with each local authority included in the Plan.

9.4 All existing and future waste discharges to waters in the area of the Lower Shannon River, that is, between the upper limit of the tidal reach at Limerick and the point of entry of the Upper Shannon river to Lough Derg at Portumna, are deemed to come within the scope of the Plan.

Beneficial Uses Protected by the Plan

9.5 The main beneficial uses of the Lower Shannon River and its tributaries and lakes to be protected by the Plan comprise the abstraction of water for public supply, industrial and agricultural use, fisheries, including game and coarse fisheries, amenity use and water based recreational activities.

Water Quality Criteria

9.6 In order to provide a general measure of protection for all beneficial uses, the Plan specifies the water quality criteria applicable to salmonid fish as the basis for the establishment of water quality standards for all the waters in the Lower Shannon. These criteria are adequate to protect all other planned uses with some important exceptions, e.g. the microbiological quality of water abstracted for public supply or use for swimming, bathing and other water contact sports. In these cases the Plan envisages site specific rather than general water quality controls.

Water Quality Standards

9.7 Standards are specified in respect of five water quality parameters, viz. dissolved oxygen (D.O), biochemical oxygen demand (B.O.D.), ammonia, oxidised nitrogen and orthophosphate/total phosphorus. These parameters have been selected for special attention as they give a measure of the effects of organic biodegradable wastes, such wastes being, by far, the most important type generated in the area of the Lower Shannon

River. The standards are specified in the form or percentile limits, as set out below:

Dissolved Oxygen

Equal to or greater than 4 mg/ℓ O_2, for 99.9 per cent of the time.

Equal to or greater than 6 mg/ℓ O_2, for 95 per cent of the time.

Equal to or greater than 9 mg/ℓ O_2, for 50 per cent of the time.

(Assessment of compliance to be based on data representative of the lowest levels likely to occur over 24 hour periods; where levels less than 6 mg/ℓ O_2 occur it must be shown that there are no adverse implications for the fish stocks).

Biochemical Oxygen Demand (B.O.D.)

Equal to or less than 5 mg/ℓ for 95 per cent of the time.

Equal to or less than 3 mg/ℓ for 50 per cent of the time.

Ammonia

Equal to or less than 0.5 mg/ℓ N (total) for 95 per cent of the time.

Equal to or less than 0.02 mg/ℓ N (un-ionised) for 95 per cent of the time.

Equal to or less than 0.2 mg/ℓ N (total) for 50 per cent of the time.

Oxidised Nitrogen

Equal to or less than 11 mg/ℓ N for 99.9 per cent of the time.

Equal to or less than 5 mg/ℓ N for 95 per cent of the time.

Equal to or less than 3 mg/ℓ N for 50 per cent of the time.

Orthophosphate/Total Phosphorus

Rivers and Stream Waters (Orthophosphate)

Equal to or less than 0.10 mg/ℓ P for 95 per cent of the time.

Equal to or less than 0.05 mg/ℓ P for 50 per cent of the time.

(N.B. More stringent limits may be required in the larger rivers and streams discharging into lake waters).

Lakes (Total Phosphorus)

Lakes used primarily for abstraction and/or game fisheries:

mean annual concentration not to exceed 0.025 mg/ℓ P (N.B. This limit may not be sufficiently stringent for very low coloured lakes and may be too stringent for those with high colour).

The standards adopted here for Orthophosphate and Total Phosphorus are of a tentative nature and will be reviewed as more data become available.

9.8 The standards specified above will apply only outside the mixing zone; in the mixing zone, the main objective where organic wastes are concerned will be the prevention of nuisance and to ensure the passage of fish.

Flow Criterion for the Application of Standards

9.9 In general, the water quality standards specified will be taken to apply at flows equal to or greater than 95 percentile flow. In the case of the main Shannon river downstream of Lough Derg, however, the standards specified above will be taken to apply over the full spectrum of flows including the Dry Weather Flow. In the case of the 99.9 percentile limit of 4 mg/ℓ for dissolved oxygen (D.O.) and of the standards set for toxic substances such as heavy metals, these standards will apply in all cases over the full spectrum of flow including the Dry Weather Flow.

9.10 In the case of lakes it is not considered appropriate to incorporate a water retention time "cut-off" value analogous to the 95 percentile flow in rivers in assessing compliance with water quality standards. Thus in lake waters the designated standards must be adhered to under all hydrological conditions.

Waste Assimilation Capacity

9.11 In rivers and streams this is defined in the present circumstances as the maximum input of wastes as B.O.D. consistent with the maintenance of a post discharge or downstream concentration of B.O.D. of 4 mg/ℓ or less at 95 percentile flows in rivers generally, and at the dry weather flow in the main Shannon river downstream of Lough Derg. In cases where it may be necessary to control the discharge of potentially toxic substances, the waste assimilation capacity will be calculated in all cases using the dry weather flow.

9.12 In the case of lakes the main concern is the development of eutrophication due to the excessive input of phosphorus. The statistical relationships between phosphorus input and algal growth in lakes (expressed as chlorophyll a concentrations), derived from a recent O.E.C.D. sponsored study, provide the only practicable method presently available for assessing the capacity of a lake to assimilate additional phosphorus loads. Where this approach is used in the case of lakes in the Lower Shannon Catchment it will be assumed that only 10 percent of the calculated, additionally assimilable phosphorus can be taken up, in order to take account of the greater bioavailability of artificial compared to natural sources. Where hydrological and other data are not available, it will be assumed, as a general guideline, that artificial inputs of phosphorus should not be greater than 20 percent of the expected natural inputs, where the latter is expected to arise from catchment 'exports' of the order of 25 mg P m^{-2} yr^{-1}.

Control of Effluents

9.13 General Approach. The Plan is based on the Environmental Quality Objectives approach in relation to the control of waste effluent discharges. Thus, the degree of control required for effluents will be determined by the waste assimilation at the particular location in question, this capacity being defined in the manner set out in paragraphs 9.11 and 9.12 above.

9.14 Minimum Control of Effluents Notwithstanding the foregoing remarks, the Plan proposes as a minimum measure, the provision of preliminary and primary treatment for all significant waste discharges in order to prevent public nuisance and interference with recreational and amenity uses. As an additional measure of control, all waste discharges from local authority sewerage schemes serving large centres of population shall be subject to full secondary treatment. The only exceptions which may be considered from the minimum controls as outlined above are for minor discharges to small streams in isolated areas.

9.15 Effluent Treatment In dealing with the degree to which the B.O.D. of the generated waste loads must be reduced in order to protect water quality, a number of discrete levels of waste treatment are recognised each removing a specified percentage of the BOD load and/or producing an effluent of a specified strength. These levels are:

Primary Treatment (including preliminary treatment) removing 40 per cent of the influent B.O.D.; Secondary Treatment removing 85 per cent of the influent B.O.D. and/or producing an effluent having a specified strength in terms of its B.O.D./ss concentrations of 20/30 mg/ℓ; and

Tertiary Treatment removing 95 per cent of the influent B.O.D. It is recognised that the percentage removals may vary to some extent where industrial wastes are concerned depending on the nature of the waste and the options available for treatment.

9.16 The degree of control required for an individual waste discharge shall be defined in terms of B.O.D. load which may be discharged having regard to the waste assimilation capacity of the receiving water at the discharge location. In order to facilitate effluent monitoring this waste load can be converted to an appropriate B.O.D. concentration in the effluent, making due allowance for the volume of effluent discharged.

9.17 In cases where removal of phosphorus from wastes is required to counter eutrophication it is assumed that the standard method of treatment to achieve this end (chemical precipitation) will reduce the phosphorus content of the waste by 80-90 per cent.

9.18 Discharge Regime It shall be the policy of the Plan to ensure that the discharge of wastes is made in a uniform manner, in respect of volume and strength in so far as this is practicable. In order to achieve this, it will be the policy of the Plan to require the provision of balancing facilities in treatment plants to ensure uniformity of discharge over the 24-hour period. In addition, it shall be the general policy of the Plan to minimise the extent of the mixing zone below outfalls, e.g. by the use of properly designed outfall diffuser systems, and to ensure also that the mixing zones do not act as barriers to fish movement or that acutely toxic conditions to fish or other aquatic life are not created in these zones.

9.19 Combined Treatment In general, the Plan favours the combined treatment and discharge of domestic and industrial wastes in each population centre where this is practicable. The purpose of this strategy is to reduce the number of industrial outfalls and treatment plants thereby allowing a greater degree of control by the local authorities over the total amount of waste discharge at any location. The quality of effluents accepted to the local authority sewers is subject to licence. Where separate industrial outfalls already exist, the necessary investigations will be carried out to determine the extent to which these waste discharges can be intercepted by the public sewerage systems and to determine the degree of pretreatment required, if any, in each case.

9.20 Agricultural Wastes. Wastes generated by agricultural activities in the area, in particular animal manures and silage liquor, represent a potentially serious threat to water quality in lakes, rivers and in groundwater. In recognition of this, it will be the policy of the Plan to carry out a detailed examination, in consultation with the relevant agricultural authorities and advisers, of locations where these wastes are produced in significant quantities and of the present arrangements made for their disposal. Arising out of this, measures to be undertaken in order to protect water quality will be specified where necessary.

9.21 Lake Eutrophication In order to counter the artificial eutrophication of lakes and other standing waters in the Catchment it will be the policy of the Plan to avoid, where possible, the discharge of significant amounts of waste directly to such waters or to feeder streams within a short distance (<5 km) of their outflow point to the lake. Where this is unavoidable, the removal of phosphorus from the waste will be undertaken if it can be shown that this will lead to a significant reduction of algal growth in the lake or to the prevention of increased growths. In regard to non-point waste sources, it will be the policy of the Plan to have these identified and inspected regularly so that the measures required to minimise the carry over of waste to waters can be specified and enforced. In the case of those lakes used as water supply sources, for which extra protection is deemed desirable, it will be the policy of the Plan to restrict the type of activities likely to lead to non-point source pollution.

Groundwaters

9.22 Groundwaters constitute a potentially important source of water supply to satisfy domestic, agricultural and industrial needs and are being exploited already at a number of locations in the Lower Shannon Catchment for these purposes. It is the policy of the Plan, therefore, to exercise control over the quality of such waters and, to this end, it is intended to make a complete inventory of groundwater resources in the catchment including the establishment of their present quality. It is also intended, in this area, to assess the likelihood of contamination of groundwaters by direct or indirect inputs of waste and to specify any control measures deemed necessary; the measures specified will take account of the provisions of the E.E.C. Directive on the protection of groundwater against pollution caused by certain dangerous substances (C.E.C. 1980).

Improvements Required in Existing Conditions

9.23 The foregoing sections and provisions in the Plan are designed to maintain the satisfactory level of water quality presently in evidence in the greater part of the Lower Shannon system. It is recognised, however, that improvement in water quality conditions are required at a number of locations, and it is the policy of the Plan to implement these improvements at the earliest opportunity. In addition, the requirement that, as a minimum, primary treatment be given to all wastes, and secondary treatment to sewage from large centres of population, will be implemented.

9.24 The locations where waters are classified as being seriously or moderately polluted as a result of point waste discharges have been identified in foregoing chapters and provisions for dealing with them are set out below. Three separate riverine reaches have been classified as being seriously polluted; these include the Nenagh river downstream of Nenagh, the Ballintotty downstream of Toomevara and the Barnacullia Stream downstream of the old mine workings at Tynagh. In the case of the Baranacullia Stream and the carry over effect from this on the Lisduff river which is fed by this stream, the pollution which has been identified here has not been associated with point waste discharges. In this case the pollution arises from the leaching of metals from the area of the old mining operations at Tynagh. In its natural state, the restoration of satisfactory water quality conditions in the Barnacullia and the Lisduff river will take some years to accomplish. The Plan provides for additional on-site investigation to ascertain the feasibility and cost effectiveness of controlling the diffuse sources of waste entering the river at this location.

9.25 At Nenagh a new secondary treatment plant has been recently commissioned which should restore satisfactory water quality conditions in the river downstream of the town. Effluent and water quality in the river will be monitored to ascertain if more advanced treatment is necessary as Nenagh continues to expand and develop.

9.26 The existing industrial discharge at Toomevara will be intercepted and treated in the local authority treatment plant. The Plan also provides for the investigation of potential agricultural waste sources and setting down appropriate discharge conditions in each case as required.

9.27 Provision is made in the Plan for the improvement in water quality at the following locations where rivers are shown to be slightly to moderately polluted. At Cappawhite the Plan allows for full secondary treatment and at Doon provision is made to improve the quality of the effluent discharged to 20/30 (B.O.D./S.S.) standard at least. At Silvermines, provision is made for the interception of an industrial discharge to the local authority sewage treatment works or otherwise this waste load to be reduced; provision is also made for the strict application of effluent discharge conditions as set out in a discharge licence currently being prepared for a second industry at this location. Detailed on-site investigations will be carried out on the Ballyfinboy river in the vicinity of cultural waste sources and appropriate control strategies will be applied. At Killimor the existing industrial discharge will be intercepted to the local authority sewerage scheme in order to improve water quality in the Kilcrow river. Further investigations will be carried out on the lower reaches of the Derrainy river to establish the possible cause of water quality deterioration before remedial measures can be implemented.

9.28 In accordance with the overall policy of the Plan provision will be made for secondary treatment facilities at Castletroy, Scarriff, Killaloe and Portumna. In the case of the Shannon Banks sewerage scheme two options will be investigated, the first being to provide secondary treatment to the effluent prior to discharge to the Shannon river, and the second, to investigate the feasibility of intercepting the existing discharge to the proposed Limerick Main Drainage Scheme. The least cost option will be adopted in this case. The Plan provides for preliminary and primary treatment to be provided at Ballina in the short term at least in order to prevent public nuisance and preserve the recreational and amenity value of the waters in the area.

9.29 At other locations in the Lower Shannon the Plan provides for improvements to the sewerage treatment works at Mountshannon to the level of full secondary treatment and the interception where feasible of the industrial waste loads discharged at Borrisokane, Newport, Cappamore and Caherconlish. These measures are necessary in order to preserve satisfactory water quality conditions in the rivers at these locations and provide for future development in each case. Provision is made in the Plan for the diversion of the Annacotty Sewerage Scheme to the Castletroy/ Monaleen Scheme in the future, and the investigation of waste loads currently discharged to the industrial estate sewerage scheme.

9.30 The extent of artificial eutrophication in the lakes and other standing waters of the Catchment is presently unknown as water quality data are available for only two such waters, i.e. Lough Derg and Poulawee Lough. It is the policy of the Plan to make up this shortfall in the data base as soon as resources allow so that a comprehensive picture of the position may be obtained and the need, if any, for remedial measures assessed.

9.31 In the case of Lough Derg, it is the policy of the Plan to implement the following management strategies :

a) A restriction on further significant inputs of waste-derived phosphorus (from point or non-point sources) either directly to the lake or to feeder rivers and streams within 5 km of their outfall to the lake.

b) The institution of a programme of investigation to determine the desirability and feasibility of reducing the present level of algal growth in the lake. This programme would have two main elements, i.e. continued surveillance of water quality conditions, particularly algal growth, in the lake and an assessment of the relative importance of the various sources of bioavailable phosphorus entering the lake and whether and in what manner these could be controlled so as to significantly reduce the input of nutrients.

c) Adoption of a set of contingency measures to deal with the adverse effects of episodes of above normal algal growth, e.g. the availability of an activated carbon facility in water treatment plants.

9.32 In the case of Poulawee Lough it is the policy of the Plan to continue surveillance of water quality conditions in order to determine if the scale of algal growth, which appears to have increased since the initiation of a discharge of treated sewage to a feeder stream in 1982, is likely to reach nuisance proportions and to warrant remedial measures, having consideration to the limited size of the lake and the lack of established beneficial uses.

Treatment Costs

9.33 It has not been possible to make a detailed cost estimate of of the work as outlined above. However, a preliminary estimate has been made of the scale of the investment necessary to achieve the required reduction in the waste loads discharged. The estimate is based on the assumption that in general domestic and industrial waste loads would be combined, and treated in a plant which would be under the control of the local authority. As a general guide for the purpose of estimating treatment costs only, it has been taken that the cost of providing conventional secondary treatment (B.O.D./ss of 20/30 mg/ℓ) for a design population of 1000 persons is about £265 per person at the present time and for a population of 8000 persons the estimated unit cost is about £105 per person. On this basis, the cost of the treatment plants as outlined in the Plan was estimated to be about £6.0 M at current prices. This estimate does not include the cost of any improvements necessary in the existing drainage networks, the provision of interceptor sewers, pumping stations or outfalls.

Qualifications and Modifications

9.34 The Plan is based on the available data and some of its provisions may be subject to modifications in the light of additional information becoming available and of future developments. The more important aspects on which further data are desirable are in relation to waste inputs, the refinement of the calculation of waste assimilation capacity, and the specification of the 95 percentile flows. While the proposals made in the Plan are regarded as valid and will meet overall objectives, it is acknowledged that a more accurate forecast of their impact and a more appropriate timing of their implementation would be possible by the availability of an extended data base. The policy of the Plan, therefore, will be to ensure a continuation of collection of data on all aspects of interest in order to refine the waste control strategies if and as required. In order to ensure that modifications are introduced in a timely manner, the Plan provides for a review of the general situation at intervals not exceeding five years. This review would take into account the most up-to-date information on waste loads and their projections and take into account any development plans which would be current at the time of the review. Where necessary the review would make modifications in the flow criteria as well as in the Plan strategy for water quality management.

CHAPTER TEN

A PROGRAMME OF FURTHER ACTION

INTRODUCTION

10.1 The data base from which the policies laid down in the Plan are developed is subject to certain limitations. It is essential that these limitations be made good by a continuing programme of research and data collection and documentation so that the Plan can be subjected to continuing updating and refinement. Aspects of particular importance in such a process would be an assessment of the validity of the general principles adopted in the Plan and a review of the efficacy of the specific measures implemented to control the effects of the present discharges of wastes and of those proposed for the control of the effects of future discharges. Such a review will ensure equity among the various competing interests who wish to avail of the water resources and at the same time ensure that the criteria necessary to support the various beneficial uses of these waters are fully met. The needs for further data relate to several different aspects and these are dealt with, in turn, below.

RIVER GAUGING

10.2 Many of the existing gauging stations (in the catchment) were erected by the Office of Public Works primarily for the purpose of recording flood flows. Records from these gauging stations are such that it is not always possible to be in any way precise when giving the flow rate, especially during periods of low flow. It is important that accurate records covering the full range of river flows be maintained at certain key locations in the catchment for the purpose of water resources management. The main need in relation to establishing the detailed and accurate data base required on river flows is the early completion of the hydrometric schemes already prepared for the local authorities in the catchment. These include the establishment of five continuous water level recorders, three of which will be on the river Graney system including one on Lough Graney and one each on the Newport and Groody rivers. In addition to this, controls will have to be constructed at a number of key locations to overcome the effects of unstable channel bed and excessive weed growth. Additional gauges will be required where partial records would be sufficient for operational purposes in the implementation of the Plan. These gauges will be at selected sites on the Kilmastulla, Killimor, Small, Doonane and Newport rivers and also on smaller rivers at Cappawhite, Whitegate and Rear Cross. It is also desirable that the hydrological and morphological parameters required for the assessment of the sensitivity of lake systems to eutrophication be measured in the near future. The more important of such parameters are annual inflow, water retention time and mean depth.

10.3 In order to improve the data base on all the various essential elements of the hydrological cycle, the feasibility of improving the collection of rainfall data particularly at higher altitudes should be investigated in conjunction with the Meteorological Service and the groundwater resources of the area should be fully assessed in co-operation with the Geological Survey Office.

WASTE LOADS

10.4 The estimates of the organic waste loads made for the purpose of the Plan were based in general on information supplied by the local authorities. In the absence of these, the estimates were based on the best information available in relation to water use in a particular activity having regard to the degree of treatment, if any, provided. Therefore, in some instances, these estimates can be regarded only as approximate. Nevertheless, they are the best estimates that can be made at this stage allowing for the limitation of data available and they are considered sufficiently adequate for the decision making required in the context of the Plan. However, it is essential that detailed industrial effluent surveys be carried out at each factory to determine accurately the waste loads generated and discharged. In particular, the volumes and composition of the discharges are required, including the maximum and minimum discharge rates and details of seasonal variations in these parameters. To facilitate monitoring of industrial effluents, suitable arrangements should be developed at each factory site to permit the measurement of discharges and the taking of representative samples.

NON-POINT SOURCES OF WASTE

10.5 It is very important that a detailed assessment be undertaken of the potential threat to water quality in the catchment from wastes arising from non-point sources, in particular those arising from agricultural activities such as the land spreading of animal manures, and the waste liquor from silage pits and intensive animal rearing units. Such an assessment should identify the locations of intensive animal rearing units in the catchment and quantify the number of animals in each case. Water quality monitoring in streams draining areas where land spreading of manures is carried out should be undertaken particularly in periods of heavy rainfall as a means of estimating the waste (nutrient) loads entering lakes and rivers. A public awareness programme should be carried out through the local agricultural advisory services indicating the potential threat to river and lake water quality arising from the uncontrolled spreading of animal manures and control measures, where necessary, should be drawn up in consultation with the relevant agricultural agencies.

WATER QUALITY DATA

10.6 There should be an increase in the intensity of water quality monitoring in the catchment. This is necessary if compliance with the water quality standards adopted is to be assessed in an adequate manner. Since these standards have a statistical basis, the minimum frequency of sampling, at key stations, at least, should be fortnightly or approximately 25 times per year. To allow for day to day variations in effluent discharges and to improve the confidence level of the results, it is desirable that sampling be carried out at 15-day intervals instead of 14-day intervals. Furthermore, such routine sampling should be supplemented by the carrying out of synoptic 24-hour surveys in important reaches at periods of low flow during summer months in order to assess, in particular, the diurnal variations in dissolved oxygen concentrations. In addition, the data base on the levels of potentially toxic substances such as heavy metals, pesticides, PCBs and other organic compounds, which is presently limited, should be expanded in the near future.

10.7 The need for extra water quality data also applies to groundwaters in the catchment. In view of the fact that the main use of such waters is increasing as a source for domestic or industrial supply, it will be particularly important in these cases to monitor the parameters of interest in connection with public health, e.g. bacteriological quality, nitrate concentrations and presence of potentially toxic substances.

10.8 It is desirable that a programme of investigation be instituted to assess the water quality position in the lakes in the Catchment area, in particular the extent of artificial eutrophication. Priority in this regard should be given to those waters used as supply sources. The investigations should cover the feeder streams and estimates of annual phosphorus inputs should be made. In view of its overall importance in the catchment Lough Derg should be the subject of a continuous water quality surveillance programme.

FISH POPULATIONS

10.9 It is desirable that detailed information should be available on the distribution of fish stocks in the system. Of particular importance is the establishment of the extent to which the smaller streams in the catchment provide spawning areas for salmon and brown trout.

RESEARCH TOPICS

10.10 In addition to the increased acquisition of basic data, as indicated above, it is also desirable to undertake further studies of a research nature in order to reduce the element of uncertainty in decision making and to improve the predictive ability of the management strategy. Such studies concern chiefly two aspects. Firstly, the development of mathematical models of the dynamic processes in rivers downstream of the major discharges. Of prime importance, in this respect, is the prediction of dissolved oxygen variations, particularly under low flow conditions. This is usually based on the Streeter-Phelps type of equation and requires information on factors such as reaeration rate, B.O.D. decay rates and oxygen production and uptake by plants. The ability to predict dissolved oxygen variations will become more important in future as waste loads increase and a greater percentage of the assimilative capacity is taken up. Such studies would also encompass an assessment of the importance of the eutrophication caused by excess nutrients, particularly phosphates, introduced in direct and indirect waste discharges, and evaluate the need for and the likely efficacy of various control measures.

10.11 Secondly, the economic aspects of water quality management in the catchment require greater evaluation. This relates particularly to the optimisation of choice in regard to the various waste treatment strategies available. The solution to such problems requires the use of systems analysis and related techniques. Other matters to be considered in this area are improvements in the rationale for defining and apportioning the waste assimilation capacity of the receiving waters and a study of the options for the methods of charging for effluents discharged directly to waters and to public sewers.

10. 12 Investigation of the natural variations of algal growth and nutrient concentrations in the lakes in the catchment are also desirable in order to assess the applicability of the O.E.C.D. established relationships between these factors for such waters. This should indicate if the relationships in question are a reliable guide in analysing the effects of waste inputs on lakes in the area.

10.13 Groundwater forms a significant part of the overall water resources in the Catchment. The location of aquifers in the area was identified for this study; nevertheless very little is known in relation to the quantity and quality of water in these aquifers. In order to overcome this, it is considered that the most practical approach is to undertake investigations of groundwater resources in areas where groundwater is considered necessary and/or would have advantages as a source of water supply. A programme of investigation should be drawn up which would have the objective of quantifying the magnitude and quality of the groundwater resources of the area. This investigation would identify aquifers where water quality monitoring would be most beneficial.

WATER QUALITY MANAGEMENT PLAN FOR THE LOWER SHANNON CATCHMENT

SCHEDULE OF GRID REFERENCES TO THE TERMINAL POINTS OF THE RIVERS AND STREAMS DELINEATED ON THE PLAN MAP

1	Shannon	R 590 590
2	Groody	R 683 501
2.1	Groody Trib	R 668 502
3	Blackwater	R 584 657
4	Mulkear	R 906 435
4.1	Newport	R 857 673
4.1.1	Annagh	R 813 602
4.1.2	Small	R 753 622
4.2	Bilboa	R 897 607
4.3	Doon Stream	R 828 503
4.4	Cahernahallia	R 853 493
4.5	Cappaghwhite	R 888 462
5	Ardclooney	R 652 723
5a	Black River	R 648 688
5a.1	Black River Tr	R 639 677
6	Kilmastulla	R 819 755
7	Ballyteige	R 679 733
8	Grange	R 716 738
9	Killaloe Stream	R 697 725
10	Annacarriga	R 665 780
11	Youghal	R 764 800
12	Newtown	R 798 778
13	Graney	R 625 967
13.1	Cloghaun	R 928 824
13.1.1	Feakle	R 568 872
13.1.2	Ayle	R 825 881

13.1.3	Glenarea	R 505 868
13.2	Caher	R 500 890
14	Bow	R 665 869
15	Nenagh	R 949 689
15.1	Ollatrim	R 978 812
15.1.1	Ballintotty	R 978 778
15.2	Clareen	R 867 774
15.3	Dolla	R 885 690
15.3.1	Dolla Tr.	R 907 708
15a	Poulawee Str	R 833 874
15b	Black Lough Str	R 843 928
16	Derrainy	R 700 913
17	Coos	R 708 947
18	Woodford	R 665 982
19	Ballyfinboy	R 978 882
19.1	Ballyfinboy Tr	R 879 879
20	Kilcrow	M 822 214
20.1	Cappagh	M 692 113
20.1.1	Cappagh Trib	M 683 128
20.1.2	Duniry	M 699 088
20.2	Lisduff	M 724 154
20.2.1	Barnacullia	M 742 126
20.2.1.1	Barnacullia Tr	M 737 138
20.2.2	Lisduff Trib	M 730 162
20.3	Killoran	M 737 219
21	Carrigahorig	R 915 986
22	Terryglass	R 901 980
1	Shannon	M 868 042

REFERENCES

Alabaster, J.S., 1982. Report of the EIFAC Workshop on fish-farm effluents. Silkeborg, Denmark, 26 - 28 May, 1981. EIFAC Tech. Pap., (41) : 166p.

Alabaster, J.S. and Lloyd, R., 1980. Water Quality Criteria for Freshwater Fish (Based on Technical Reports of the European Inland Fisheries Advisory Commission (E.I.F.A.C.)) London, London, Butterworths (by arrangement with F.A.O.).

Bowman, J.J., 1982. The Trophic Status of Irish Lakes : Lough Ramor. An Foras Forbartha, WR/L9.

Bowman, J.J., 1983. The Investigation of Poulawee Lough, March 1982 to May 1983. A Report to Tipperary (NR) County Council. An Foras Forbartha.

Bowman, J.J., 1985. The Trophic Status of Irish Lakes : Lough Derg. An Foras Forbartha, WR/L12.

Burke, W., Mulqueen, J. and Butler, P., 1974. Fertiliser Losses in Drainage Water From Surface Water Gley. Ir. J. Agric. Res. 13, 203-214.

C.E.C. (Council of the European Communities), 1975. Council directive of 16 June 1975 concerning the quality required of surface water intended for the abstraction of drinking water in the Member States (75/440/EEC). Official Journal of the European Communities No. L 194/26.

Do., 1978. Council directive of 18 July 1978 on the quality of fresh waters needing protection or improvement in order to support fish life (78/659/EEC). Official Journal of the European Communities No. L 222/1.

Do., 1980. Council directive of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances (80/68/EEC). Official Journal of the European Communities, No. L 20/43.

Cowen, W.F., Sirishina, K. and Lee, G.F., 1978. Nitrogen and Phosphorus in Lake Ontario Tributary Waters. Water, Air and Soil Pollution 10, 343-350.

Department of Fisheries and Forestry, 1982. Sea and Inland Fisheries Report, 1982. Dublin, Stationery Office.

Dodd, V.A. and Champ, W.S.T., 1983. Environmental Problems Associated with Intensive Animal Production Units with Reference to the Catchment Area of Lough Sheelin. In : Promise and Performance, Irish Environmental Policies Analysed (J. Blackwell and F.J. Convery, eds.) Dublin, The Resource and Environmental Policy Centre, U.C.D.

E.P.A. (Environmental Protection Agency, U.S.), 1972. Water Quality Criteria, 1972. A report of the Committee on Water Quality Criteria, Environmental Studies Board, National Academy of Sciences, National Academy of Engineering. E.P.A. R3.73.033. Washington D.C., E.P.A.

Do., 1976. Quality Criteria for Water. E.P.A. - 440/9-76-023. Washington D.C., E.P.A.

Do., 1980. Ambient Water Quality Criteria. E.P.A.-440/5-80-015 to E.P.A.-440/5-80-79. Washington D.C., E.P.A.

E.I.F.A.C. (European Inland Fisheries Advisory Commission), 1980. Water Quality Criteria for European Freshwater Fish. Report on Combined Effects on Freshwater Fish and other Aquatic Life of Mixtures of Toxicants in Water. EIFAC Technical Paper, No. 37. Rome, F.A.O.

F.B.I.U. (Freshwater Biological Investigation Unit, N.I.) 1975. A Preliminary Report into the Water Quality of Lough Erne, Northern Ireland.

Flanagan, P.J. and Toner, P.F., 1975. A Preliminary Survey of Irish Lakes. Dublin, An Foras Forbartha, WR/L1.

Fraser, P. and Chilvers, C., 1981. Health aspects of nitrate in drinking water. The Science of the Total Environment. 18, 103-116.

Golterman, H.L., 1975. Developments in Water Science 2. Physiological Limnology, P.88. Elsevier.

Horkan, J.P.K. and Toner, P.F., 1984. The Trophic Status of Irish Lakes : Lough Muckno. An Foras Forbartha, WR/L11.

Jones, R.A. and Lee, G.F., 1979. Septic tank wastewater disposal systems as phosphorus sources for surface waters. J. Wat. Pollut. Control Fed. 51, 2764-2775.

Jones, R.A. and Lee, G.F., 1982. Recent advances in assessing impact of phosphorus loads on eutrophication - related water quality. Water Research 16, 503-515.

Jorga, W. and Weise, G., 1977. Biomasseentwicklung Submerser Macrophyten Langsam Fliessender Gewassern in Beziehung sum Sauerstoffhaushalt. Int. Revue ges. Hydrobiol. 62, 209-234.

Lee, G.F., Jones, R.A. and Rast, W., 1980. Availability of phosphorus to phytoplankton and its implications for phosphorus management strategies. In : Phosphorus Management Strategies for Lakes. Ann Arbor Science, pp. 259-308.

Lynn, M.A. 1977. The Shannon drainage problem. Journal of the Institute of Public Administration 25, No. 2, 238-248.

Mason, D., 1983. Excess nitrates a health danger. Surveyor, June 23, p.9.

Morgan, M.A., 1983. Fertilisers and Environmental Quality. In : Promise and Performance, Irish Environmental Policies Analysed. (J. Blackwell and F.J. Convery, eds.) Dublin, The Resource and Environmental Policy Centre, U.C.D.

Moriarty, C., 1982. Stock enhancement in the Irish eel, Anguilla anguilla, fishery. In : EIFAC Symposium, Stock Enhancement in the Management of Freshwater Fisheries, Budapest, May 31 - June 2, 1982.

O'Donnell, C., 1980. Organic Micropollutants in Irish Waters. An Foras Forbartha, WR/G7.

O.E.C.D. (Organisation for Economic Co-operation and Development), 1982. Eutrophication of Waters. Monitoring Assessment and Control. Paris, O.E.C.D.

O'Leary, D.P., 1977. The management of the R. Shannon in the 1980's. Journal of the Institute of Public Administration, 25, No. 2, 160-180.

Peters, R.H., 1981. Phosphorus Availability in Lake Memphremagog and its Tributaries. Limnology and Oceanography 26, 1150-1161.

Pitcairn, C.E.R. and Hawkes, H.A., 1973. The Role of Phosphorus in the Growth of Cladophora. Water Research 7, 159-171.

Stevens, R.J. and Stewart, B.M., 1982. Some components of particulate phosphorus in river water entering Lough Neagh. Water Research 16, 1591-1596.

Southern, R., 1935. Reports from the Limnological Laboratory, III. The food and growth of brown trout from Lough Derg and the River Shannon, Proc. Roy. Ir. Acad. 42B, No. 6, 87-172.

Southern, R. and Gardiner, A.C., 1926. Do., I. The seasonal distribution of the Crustacea of the plankton in Lough Derg and the River Shannon. Fisheries, Inland, Sci. Invest., 1926, I, 170pp.

Southern, R. and Gardiner, A.C., 1932. Do., II. The diurnal migrations of the Crustacea of the plankton in Lough Derg. Proc. Roy. Ir. Acad. 40B, No. 11, 121-159.

Southern, R. and Gardiner, A.C., 1938. Do., IV. The phytoplankton of the River Shannon and Lough Derg. Proc. Roy. Ir. Acad. 45B, 89-124.

Technical Committee on Effluent and Water Quality Standards, 1978. Memorandum No. 1. Water Quality Guidelines. Dublin, Stationery Office.

Toner, P.F., 1977. Investigations of Eutrophication in Irish Lakes. In : Lake Pollution - Eutrophication Control. Proceedings of a N.S.C. Seminar, Killarney, 10-11 May, 1977. (W.K. Downey and G. Ni Uid, eds.).

Toner, P.F., 1979. The Trophic Status of Irish Lakes : Lough Key. Dublin, An Foras Forbartha, WR/L8.

Toner, P.F. and Bowman, J.J., 1985. Poulawee Lough. Water Quality Surveys 1985. A Report to Tipperary (NR) County Council. An Foras Forbartha.

Toner, P.F. and Clabby, K.J., 1975. An Investigation of Benthic Fauna in Lough Derg with particular reference to the presence of peat silt. A Report to Bord na Mona. An Foras Forbartha, WR/C22.

Toner, P.F. Clabby, K.J. and Bowman, J.J., 1973. Report on the Results of a Biological and Chemical Survey of the Main River Channel and Lakes of the Shannon System between Battle Bridge and Killaloe, undertaken in July, 1972. An Foras Forbartha, WR/R2.

Toner, P.F., Mansfield, M.J. and McCumiskey, L.M., 1981. The Draft Water Quality Management Plan for the River Suir Catchment. (5 Vols.). Dublin, An Foras Forbartha, WR/C41.

Vollenweider, R.A., 1971. Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters with particular reference to Nitrogen and Phosphorus as Factors in Eutrophication. Paris, O.E.C.D.

Vollenweider, R.A., 1975. Input-output models with special reference to the phosphorus loading concept in limnology. Schweiz, Z. Hydrol. 37, 53-84.

Wollenweider, R.A., 1976. Advances in defining critical loading levels for phosphorus in lake eutrophication. Mem. Ist. Ital. Idrobiol. 33, 53-83.

W.P.A.C. (Water Pollution Advisory Council), 1983. A Review of Water Pollution in Ireland : A Report to the Council by An Foras Forbartha, Dublin, W.P.A.C.

W.R.C. (Water Research Centre), 1981. A Guide to Solving Water Quality Problems in Distribution Systems. WRC Technical Report, TR.167.