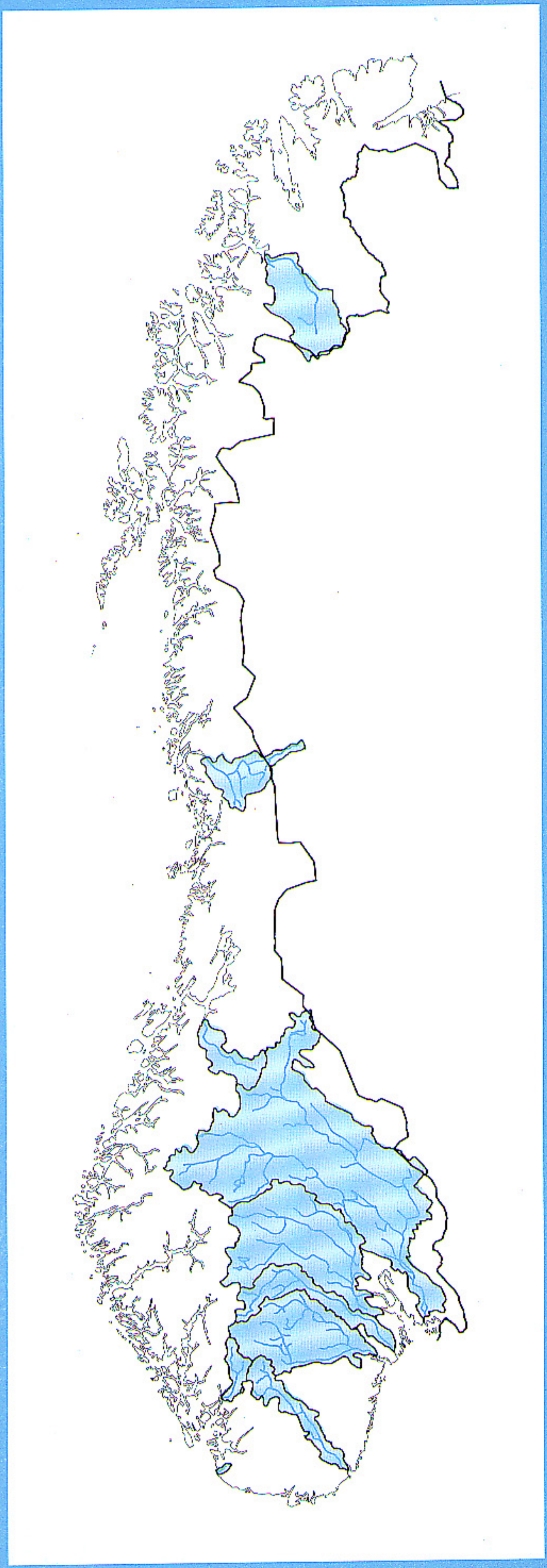

SFT The State Pollution Control Authority

Contractor	**SFT Norway**
Performing institute	**NIVA**

Report 488A/92

Paris Convention

Annual report on direct and riverine inputs to Norwegian coastal waters during the year 1991

A Principles, results and discussions

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Abstract:

Riverine inputs to Norwegian coastal waters from 10 main and 145 tributary rivers have been monitored during 1991. The loading from rivers not monitored as well as direct discharges to marine waters along the coast from Sweden to Russia have been estimated.

According to the results, total annual nutrient load to coastal waters from landbased sources, is approximately 3590 tons of phosphorus and 88600 tons of nitrogen. About 40 per cent of the phosphorus and 60 per cent of the nitrogen are inputs from the monitored rivers and tributaties. Discharges of heavy metals and micropollutants are also included in the investigation. Most inputs of these substances are low, especially the riverine inputs of Cd, Pb and Hg. Most values of these substances are below the detection limits of the specific analysis, which also is the case for the different congeners of PCBs. The herbicide lindane is detected in most analyses in small amounts. Total load of this compound is estimated to about 260 kg. The largest yields from heavy metals comprise copper and zinc, with input estimates of 356 and 1040 tons, respectively.

Retention in the fjords is not included in the above mentioned values, which in several cases would reduce the actual load to open marine waters considerably.

4 keywords, Norwegian

1. Forurensningstilførsler
2. Norske kystområder
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For the Administration

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Monitoring Programme

Paris Convention

Annual report on direct and riverine inputs
to Norwegian coastal waters during the year
1991

A Principles, results and discussion

Oslo, October 1992

Project manager:	Hans Holtan
Project coordinator:	Gjertrud Holtan
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Norwegian Institute for Water Research NIVA

PREFACE

The report presents the data from the 1991 monitoring of waterborne pollutants, both riverine and direct discharges, to the Norwegian coastal waters. The study is part of a joint monitoring programme under the "Paris Convention for the prevention of Marine Pollution from Landbased Sources". The Norwegian contribution is administered by the Norwegian State Pollution Control Authority (SFT) which has contracted the Norwegian Institute for Water Research to perform the actual investigations.

The 1991-investigation lasted from January till December. This report is the Norwegian part of the 1991 study, divided into two parts:

A: Principles - Results and Discussion
B: Data Report.

The Programme Committee has consisted of Jon Lasse Bratli and Dag Rosland (SFT), Dag Berge and Hans Holtan (NIVA). The practical investigation is coordinated, and performed by Gjertrud Holtan (NIVA). The calculations of all data has been performed by Terje Hopen (NIVA). The names of all participants are given in paragraph 5.

We would like to express our gratitude to all participants of the investigation, especially to the local fieldworkers for the collection and transport of the samples. The contact persons at the County Environmental Agencies and at the Municipalities of Oslo and Bærum are acknowledged for continous support and goodwill. The contact persons at the Norwegian Water Resources and Energy Administration (NVE) and The Norwegian Meteorological Institute (DNMI), Per Lofsberg and Stein Kristiansen, are acknowledged for their kind cooperation.

CONTENTS

SUMMARY AND CONCLUSIONS

In 1988, the Paris Commission decided to launch a comprehensive annual monitoring programme covering inputs of selected pollutants to Convention Waters. The programme was to commense in 1990, and continue the following years (PARCOM, 10/3/2-E).

The purpose is to provide the Commission, in accordance with Article 17(B) of the Paris Convention, with an assessment of the waterborne inputs to Convention waters. Another objective of the programme is to control the fulfillment of The Ministerial Declaration of the North Sea which aims at 50% reduction of nutrients and 50-70 % of selected micropollutants within 1995. Besides riverine inputs, the information sought also relates to direct discharges.

In 1987, the countries bordering the North Sea committed themselves to reducing inputs of nutrients in the order of 50 per cent into areas of the North Sea where these inputs are likely, directly or indirectly, to cause pollution. This area was in February 1990 decided to be from the Swedish border to Lindesnes. Further, discharges of selected micropollutants to the whole North Sea area are to be reduced by 50 - 70 % depending on the micropollutant in question.

In the rest of the country, the goals set by SFT, are to reduce phosphorus and nitrogen discharges to vulnerable watercources to the extent necessary to reduce local environmental impact to an acceptable level. SFT has also an additional objective to reduce discharges of erosion particles and suspended and dissolved organic material by 35 %.

In this report the results (1991) are given for riverine inputs of 10 main rivers and 145 tributaries. Thus the active monitoring programme covers drainage from 75 per cent of the main land areas. For discharges entering directly into marine recipients, i.e. sewage and industrial effluents, estimates are based on numbers from effluent control programmes. Area runoff of Total phosphorus, Total nitrogen, and in 1991 also phosphate and nitrate from these coastal zones are estimated by use of area specific runoff coefficients.

Greatest emphasis with regard to accuracy has been given to the input estimate of the Skagerrak region, as this is considered the most susceptible part of the North Sea. The Skagerrak reception of Norways total loads are 32 per cent of the phosphorus and 38 per cent of the nitrogen yield. In this region where 90 per cent of the area is river-monitored, about 56 per cent of the P- and 70 per cent of the N-load, are found in the riverine inputs.

According to the results from the 1991 investigation total annual nutrient load to coastal waters from landbased Norwegian sources is approximately 3594 tons of phosphorus and 88664 tons of nitrogen. About 40 and 56 per cent respectively of the grand total inputs of phosphorus and nitrogen are monitored in the main and tributary rivers. Riverine inputs of metals and micropollutants are low. As the detection limits of the parameters Cd and Pb at the NIVA laboratory were above those requested from PARCOM, most of these analyses were performed on an ICP-MS-instrument. Still, a great deal of the concentrations found for these substances are lower than the detection limit. Therefore, two quantities have been estimated: one assuming that the true concentration is zero and the other assuming that the true concentration is the limit of detection. This provides maximum and minimum concentrations between which lies the true estimate. When evaluating inputs these data provide a basis for upper and lower estimates.

Inputs of cadmium are in this way measured/calculated to be between 8.1 and 8.5 tons, lead between 101 and 103 tons, mercury between 415 and 748 kg. The "below detection limit problem" also applies for the inputs of PCBs which are measured to be between 2 and 74 kg. The herbicide lindane was found in most analyses, but in small amounts. Assumably lindane contamination in Norwegian rivers are mostly due to long range air pollution. Total load is estimated to about 261 kg. The largest yields of heavy metals comprise copper and zinc, with input estimates of 356 and 1039 tons, of which 86 and 93 % respectively, is river-monitored.

Retention in Norways many treshold fjords is not included in the above given values. This would in several cases reduce the actual load to open marin waters considerably.

For most Norwegian rivers the load to the sea, show large annual variations due to differences in water discharge. In order to use the data as a control of the fulfillment of the the Ministerial Declaration of the North Sea, the chemical data from 1991 are "normalized", i.e. 1991 chemical concentrations in river water have been multiplied with normal annual runoff (1930-1960).

Data from 1985 will be presented in a data-report when correlation-factors for Cd and Pb are established.

1. INTRODUCTION

At the eighth meeting of the Paris Commission (Madrid, June 1986) it was decided to carry out a pilot project to test methods for estimating transport of pollutants from rivers to marine areas. The Norwegian part of the pilot study comprised the two rivers Glomma and Skienselva (Fig. 1). The project was carried out from August 1986 till August 1987, and reported in October 1987 (Lingsten, 1987).

At the tenth meeting of the Paris Commission (Lisbon, June 1988) the principles for the comprehensive study on riverine inputs were accepted. It was then decided to commence the study with measurements carried out in 1990, and continue the work in the following years (PARCOM, 10/3/2-E).

The purpose is to provide the Commission, in accordance with Article 17(B) of the Paris Convention, with an assessment of the waterborne inputs to Convention waters. Besides riverine inputs, the information sought therefore also relates to direct discharges.

The objectives of this study are the following:

1.1 To give a quantitative assessment, as accurately as possible, of all riverborne and direct inputs of selected pollutants to Convention waters on an annual basis.

1.2 To report these data annually to the Paris Commission and review them periodically with regard to determining trends.

1.3 For each country, to aim at monitoring on a regular basis 90% of the inputs of each selected pollutant.

2. To control that the objectives of the Ministerial Declaration for reducing the loads of heavy metals, organic micropollutants and nutrients to the North Sea in an order of 50 per cent, between 1985 and 1995, are fulfilled.*

*In 1987, the countries bordering the North Sea committed themselves to reducing inputs of nutrients in the order of 50 per cent into areas of the North Sea when these inputs are likely, directly or indirectly, to cause pollution. This area was in February 1990 decided to be from the Swedish border to Lindesnes (Fig. 1 and Fig. I.I. Appendix I, Report B). Further, discharges of prioritied micropollutants to the whole North Sea area, are to be reduced by 50 - 70 %, depending on the micropollutant in question.

In the rest of the country, the goals set by SFT, are to reduce phosphorus and nitrogen discharges to vulnerable watercources to the extent necessary to reduce local environmental impact to an acceptable level. SFT has also an additional objective to reduce discharges of erosion particles and suspended and dissolved organic material by 35 %.

The study is to be completed for each calender year and submitted to PARCOM by June following the year to which the data relate.

2. RIVERSYSTEMS INCLUDED IN THE STUDY

2.1 General aspects

The length of the Norwegian mainland coast line including fjords and bays is 21347 km, and the length of the islands' coast line is 35662 km. (Table 1). Because of the length of the coast line, the great numbers of rivers, and the fjords acting as sedimentary basins, in- and out-washing areas, monitoring of riverborne pollutants in Norway faces quite a few problems with respect to assessing their impact on coastal waters. Further, to measure 90 % of the load from the Norwegian rivers, a great number of rivers would have to be included, which would be extremely expensive. It was therefore decided that 8 of the major load bearing rivers should be monitored in accordance with the objectives of the comprehensive study. Further it was decided that 2 "unpolluted" rivers should be monitored at a reduced, but appropriate frequency. In these 10 rivers a number of investigations have been carried out during many years, and they have all been included in the National Monitoring Programme of Watercourses (SFT, 1980 - 1991).

These investigations mainly concentrate on nutrients. Therefore there are relatively good data on the load of the nutrients, while the data on heavy metals and organic micropollutants are rather insufficient. In addition to the ten rivers it was decided to estimate the load of 145 other rivers (tributaries) based on other 1991-monitoring programmes, and existing knowledge of the river systems concerned, supplemented with random samples taken in 1991.

The total drainage area of these monitored rivers is 229152 km^2, while the total area of mainland Norway is 323878 km^2 (Table 1). Totally 306747 km^2 of the drainage area is included in the investigation, of which 75 per cent is river monitored (Tables 4 and I.IV (Appendix I)). It was of special importance to estimate the major loads to Skagerrak. In this region the monitored rivers and tributaries cover 94, and the main rivers alone 80 per cent of the total area.

The coastline is divided into subareas/-regions, first between the drainage basins of the ten main rivers with tributaries, as shown in Fig. 1, and then after which surrounding seas the actual coastline belongs to (Fig. 1 and I.I-I.IV (Appendix I, Report B)). For this purpose, the surrounding seas with discharge areas are divided as follows (see also Table 5):

Barents Sea : From the Russian border (about $70^0 30$''N, $70^0 30$''E), to about $70^0 30$''N, 21^0E

Norwegian Sea: Southwards of $70^0 30$''N, to about 62^0 N

North Sea : Southwards of 62^0 N, to the Swedish border

Skagerrak : From Lindesnes (the southernmost point of Norway), about $57^0 44$''N to Sweden about $58^0 58$''N, 11^0E.

Some key information about Norway and the adjacent oceans is given in Table 1.

Table 1. Norway: Population, areas and length of coastline

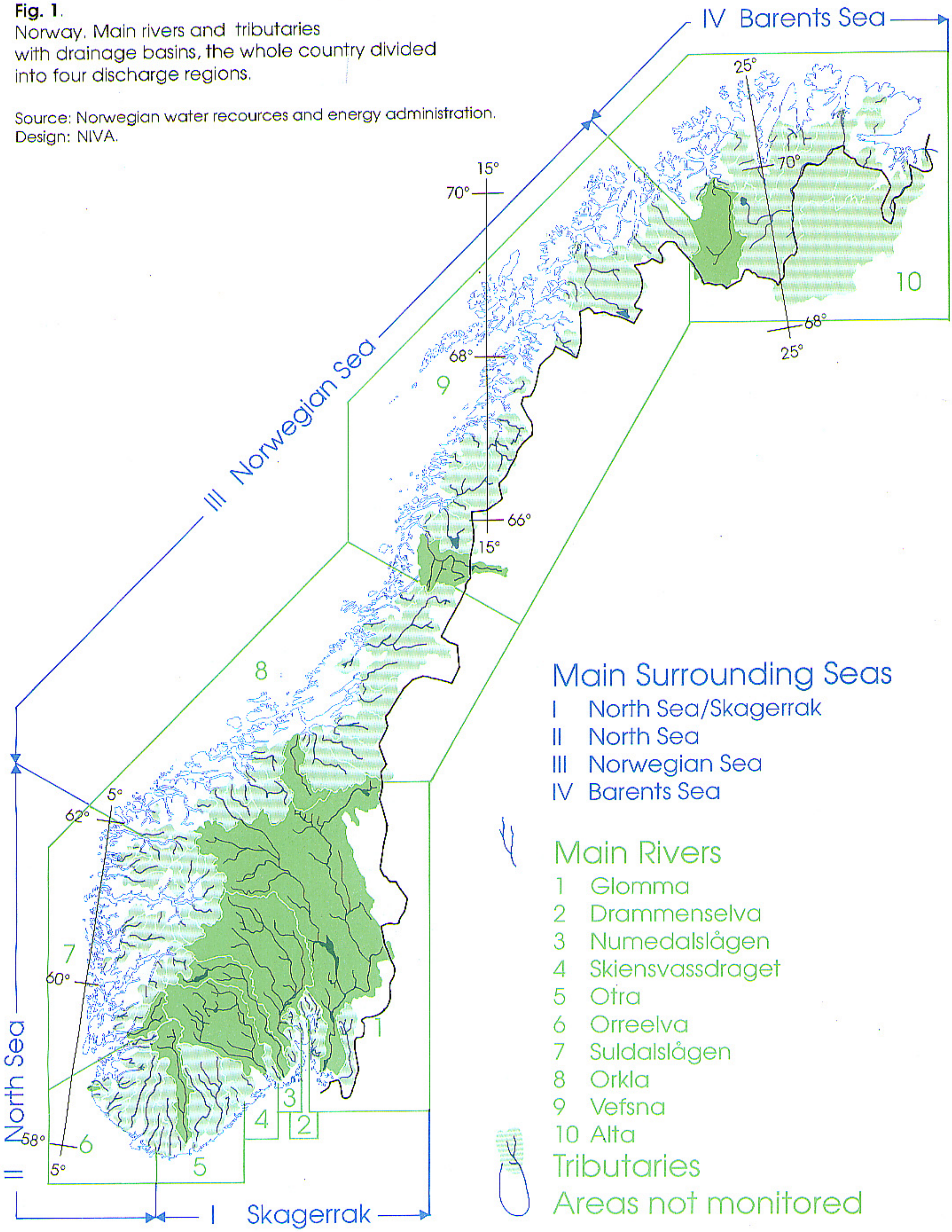
Population	4.2 million
Area:	
- Mainland Norway	323878 km^2
_ The whole country incl. Svalbard and Jan Mayen	386958 km^2
Coastline:	
- Length of the continental coastline	21347 km
- Not including fjords and bays	2650 km
- Length of the islands' coastline	35662 km

2.2 Monitored riversystems

The rivers chosen for the comprehensive study are the same as in 1990 and presented in Table 2 and Fig. 1. The rivers marked 1 to 5, represent the major load bearing rivers in Norway. As mentioned in chapter 2.1 it was of special importance to estimate the major loads to Skagerrak (Fig. I.I, Appendix I, Report B) which is an important part of the North Sea, and considered to be most susceptible to pollutions. The five rivers (No 1 to 5) drain into the Skagerrak area. River Suldalslågen (No 7) and river Alta (No 10) are "unpolluted" river systems where actual measurements have been carried out at a reduced frequency.

Fig. 1.
Norway. Main rivers and tributaries with drainage basins, the whole country divided into four discharge regions.

Source: Norwegian water recources and energy administration.
Design: NIVA.



Orreelva (No 6) is draining the most intensive farming area in Norway especially concerning domestic animals (milk and meat production). Discharges from manure stores and silos together with areal runoff from heavily manured field are causing great problems (eutrophication, including toxic algal blooms) both in Orreelva and in the other water bodies in this area.

Orkla (No 8) is also draining farmland, but the farming in this part of the country is rather extensive compared to the Orre area. More important here is the abandoned mines even if situated in the upper part of the watercourse. Several other rivers in this area are also receiving waste water from abandoned mines (heavy metals).

Vefsna (No 9) is a watercourse where the runoff in periods is carrying quite a lot of suspended solids and as such is comparable with other rivers in this part of the country.

Table 2. The main rivers with catchment areas and mean annual flow (1930-60)

No	River	Catchment area, km^2	Annual flow, mill.m^3
1	Glomma	41.918	21.600
2	Drammenselva	17.034	10.100
3	Numedalslågen	5.577	3.720
4	Skienselva	10.772	9.100
5	Otra	3.738	4.900
6	Orreelva	105	155
8	Orkla	3.053	2.040
9	Vefsna	4.122	6.000
7	Suldalslågen	1.457	3.260
10	Alta	7.373	2.570
Total		86.319	63.445

The ten water courses are all representing typical river systems in different parts of the country. As such they are very useful when estimating loads of comparable rivers, i.e corrections and adjustments in the tributary estimates which are based on fewer data.

All these watercourses except Orreelva are regulated for hydroelectric power production.

2.3 Other riversystems included (tributaries)

In additon to the ten main rivers, it was determined to assess inputs from the same 145 river systems as in 1990 (Fig. 1) using "best estimates" of concentrations and flows. In total all Norwegian rivers with catchment areas larger than 500 km^2, and several of the minor rivers (streams) also are included in the 1991 study. Some information about these rivers are shown in Tables 8.1-8.10 (Appendix VIII, Report B).

3. METHODOLOGY

3.1 Methodology for assessing riverine inputs

In carrying out the Survey, the methodology described in the Commissions Document "Principles of the Comprehensive Study on Riverine Inputs" and in the 1990-Report from Norway (Holtan et al, 1991*), was followed.

*In this document hereafter refered to as "The 1990-Report".

As for "Site selection" we refer to the abovementioned documents but have chosen to repeat most of the text concerning "Sampling strategy and frequency", only with necessary adjustments.

Most monitoring effort has also in 1991 been directed towards the river with the highest input load (Glomma), and the rivers where the load to the sea show large seasonal and annual variations due to differences in water discharge (Orreelva and Vefsna).

In the main rivers (No 2 to 5 and No 8), it has been taken 12 samples at regularly monthly intervals during the sampling period from January till December 1991 as prescribed in PARCOM 10/3/2/E. In river Glomma (No 1), the largest watercourse of Norway, there has also been taken monthly samples, but in addition every second week during expected flood periods (18 data sets).

In the rivers Orreelva (No 6) and Vefsna (No 9) the samples have been taken at a frequency which appropriately reflects expected flow patterns, i.e. more intensive sampling during periods of high flow (weekly) and less intensive during the rest of the year (19 data sets from Orre, 20 from Vefsna).

For the "unpolluted" rivers Suldalslågen (No 7) and Alta (No 10), where, on the basis of existing knowledge, the concentration levels are very low, the requirement of 12 data sets per annum was found too stringent. These rivers were therefore sampled 4-5 times per annum. This sampling strategy should be sufficient enough to obtain a reliable estimate of the pollution load for these two rivers.

For the other rivers (tributaries), the concentrations are partly based on samples taken at the "standard" frequency (12, i.e. monthly, or more data sets per annum), which is the case in the Glomma, Oslo and Drammenselva areas. This is also the case for some of the rivers up North in the Alta area. As for the rest of the rivers the concentrations are based on measurements of samples taken at random (at least twice) and compared with measurements from the last decade.

For all main rivers except Suldalslågen and Alta the parameters lindane and PCBs have been monitored four times in 1991, in Suldalslågen and Alta, twice. For the other rivers these parameters have been analyzed once in samples from the tributaries draining to the Skagerrak and to the North Sea region. This is also the case for the rivers Rana-, Sulitjelma-, Målselv-Bardu- and Reisawatercourses draining to the Norwegian Sea, and for Tana- and Pasvikwatercourses draining to the Barents Sea. For the rest of the rivers the concentrations of lindane and PCBs are estimated on the basis of knowledge about the activity in the different drainage areas and the findings from the main rivers.

The sample frequency for the main rivers is shown in Table 3.

Table 3. Sampling sites and frequency of the main rivers

River/Location	J	F	M	A	M	J	J	A	S	O	N	D
Glomma at Sarpsfoss	x x	x x	x x	x x	x	x x	x x	x	x	x	x	x
Drammense. upstr.outl.	x	x	x	x	x	x	x	x	x	x	x	x
Numedalsl.at Bommestad	x	x	x	x	x	x	x	x	x	x	x	x
Skiense.at Klosterfoss	x	x	x	x	x	x	x	x	x	x	x	x
Otra upstream outlet	x	x	x	x	x	x	x	x	x	x	x	x
Orre upstream outlet	x		x x	x x x	x	x	x	x	x	x x x	x x x x	x
Orkla at Vormstad	x	x x	x	x	x	x	x	x	x	x	x	x
Vefsna upstr. Mosjøen	x		x	x x x	x x x	x x x	x	x	x	x x x	x x x	
Suldalsl. upstr. outl.		x				x	x	x		x		
Alta upstr. Alta			x			x		x		x		

In 1991 the water samples were taken by local persons as in 1990. The persons were carefully instructed in advance. The samples were sent to the laboratory at NIVA immediately after sampling, usually arriving at NIVA within 24 to 36 hours later.

3.2 Monitoring parameters and analytical methods

3.2.1 Chemical parameters - detection limits and analytical methods

In 1991 the following parameters were monitored in accordance with the mandate: 4 nutrients (total phosphorus, orthophosphates, total nitrogen, and nitrates), 5 metals (copper, zinc, cadmium, lead and mercury), 1 pesticide (lindane) and a general parameter (suspended particulate matter). PCBs were to be monitored on a voluntary basis for the 7 congeners (IUPAC numbers 28, 52, 101, 118, 138, 153 and 180).

As detailed information on methodology and obtainable limits of detection for all measured parameters were given in the 1990-Report, only new or improved methods will be described in this report.

As informed in the 1990-Report, the detection limits of the parameters Cd and Pb at the NIVA laboratory were above those requested from PARCOM. Most of the Cd- and Pb-samples from 1991 therefore have been re-analyzed at the Norwegian Institute for Air Research (NILU) where metal determinations are performed on an ICP-MS-instrument (NILU, 1990). On this instrument the recommended detection limits from Parcom (Cd: 10 ng/l, Pb: 0.1 µg/l) are obtainable.

According to PARCOM (10/3/2-E) it was necessary to choose an analytical method which would give at least 70 % of positive findings (i.e. above the detection limit).

When Cd was determined on ICP-MS, more than 70 % of the findings in samples from 4 of the main rivers were positive and correspondingly in 8 of the main rivers for Pb. As for the tributaries more than 70 % were above the detection limits both in the Cd- and Pb-samples. The results may suffer from increased uncertainty as all samples had been opened for analysis at NIVA, then reopened at NILU. Especially the Pb-results might be contaminated. However, most of the results lies between the detection limits at NIVA and NILU, and at about the same level as the findings in 1992.

The 1990- and the 1991 results are not directly comparable at this stage due to differences in the methods of analysis the two years. Therefore to establish a correlation factor between the 1990- and the 1991-data a series of samples will be analyzed in parallell using both methods.

In 1991 we had problems to obtain representative values for mercury, which during most of the investigation period were below the detection limit. This was also the case with PCBs. For these parameters most of the measured concentrations were extremely low, and certainly below "PARCOM-detection limits" (Table II (Appendix I) and Appendix VII - VIII, Report B). From 1990 to 1991 the detection limit of the PCBs and lindane is improved from <0.5 ng/l to <0.05 ng /l. It is therefore difficult to compare the 1990- and the 1991-results, unless parallell determinations for some samples are performed with the old and the new method.

However, we assume that these difficulties do not affect the main results and conclusions of the 1991-study. In those cases were the results recorded were less than the limits of detection, two load quantities have been estimated, one assuming that the true concentration is zero and the other assuming that the true concentration is the limit of detection. This provides maximum and minimum concentrations within which the true estimate will fall. When used to evaluate inputs these data provide upper and lower boundaries for the estimate.

At 3 occasions in 1991 samples from 5 of the main rivers were taken on a voluntary basis for the determination of the metals arsenic, total chromium and chlorinated and organotin compounds. The results are given in table 7B (Report B), and for the metals and the chlor organic som-parameter AOX also in tables 4.1-4.2 and 4.4-4.6 (Report B). As for the other chlorinated organic (pentachlorophenol and 4 haloforms) and the organotin compounds, all results showed values lower than the respective detection limits (table 7B, Report B) and therefore are not reported as pollution loads.

Except for AOX, the concentration of chlorinated organic compounds were determined at the Center for Industrial Recearch (SI) according to the following methods (Oddvar Ringstad, SI, personal message):

The samples (5 l) taken for haloform analysis were purged with nitrogen, and the compound concentrated on an absorbent. The absorbed compounds were analyzed by GC/MS.

The samples (5 l) taken for pentachlorophenol and organotin analysis were isolated from the water phase by an extraction of organic solvent. Pentachlorophenol was analyzed by GC/ECD, organotin by GC/MSD.

As for AOX these determinations were performed at The Norwegian Pulp and Paper Industry Research Institute (PFI). The methodology is described in SCAN-W 9:89.

3.2.2 Method used to estimate flow rate

For the period 1930-60 the annual specific runoff from the total area of Norway is estimated at 42.9 l/s km^2. Expressed in volumetric units this amounts to 438 km^3 water, which distributed over the whole country equals a mean runoff of 1350 mm. Mean annual runoff in Norway and from the sub-regions to the main surrounding seas for the period 1930-60 are shown in Table 4. For the main rivers mean annual runoff (1930-1960) together with annual runoff for the years 1985, 1990 and 1991 are shown in Fig. 2, mean annual and annual precipitation for the same stations and periods in Fig. 3.

Table 4. Mean annual runoff (1930-1960) from the subregions to the main surrounding seas (Fig. 1 and Appendix I, Report B).

Subregions	Main Seas	Drainage area km^2	Runoff mill.m^3
The Swedish border - Lindesnes	Skagerrak	98699	57934.47
The Swedish border - Stad	North Sea	138902	164875.88
Stad - the border of Finnmark	Norwegian Sea	94704	231928.67
Finnmark-the border of Sovjet	Barents Sea	73141	41462.90
Total		306747*	438267.45

* The difference between the total area and the area given in Table 1 is due to rivers which drain into the neighbouring countries.

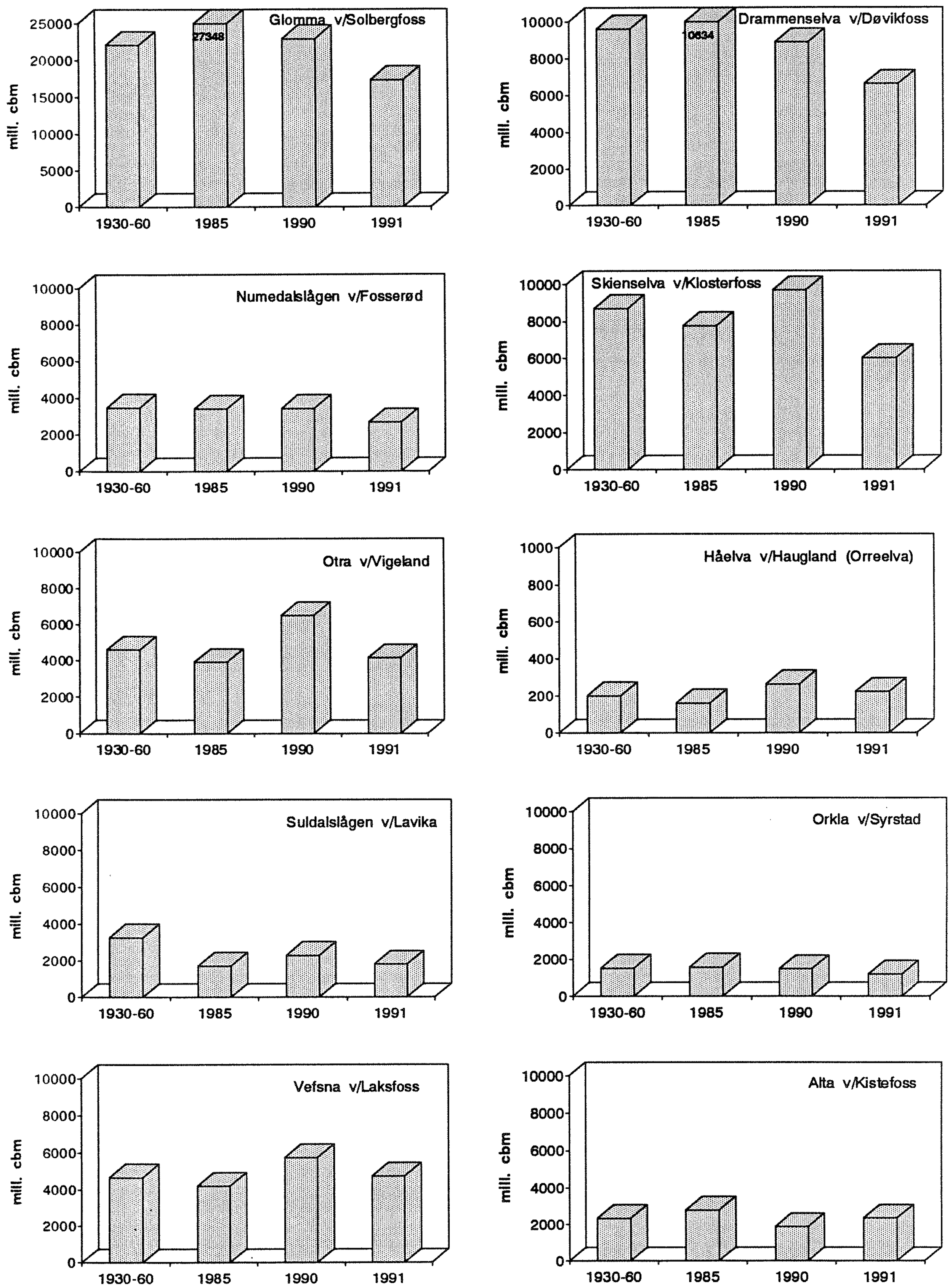


Fig. 2 Main Rivers. Mean Annual Runoff (1930-60) and Annual Runoff for the Years 1985, 1990 and 1991 (mill.cbm.).
Source: Norwegian Water Resources and Energy Administration

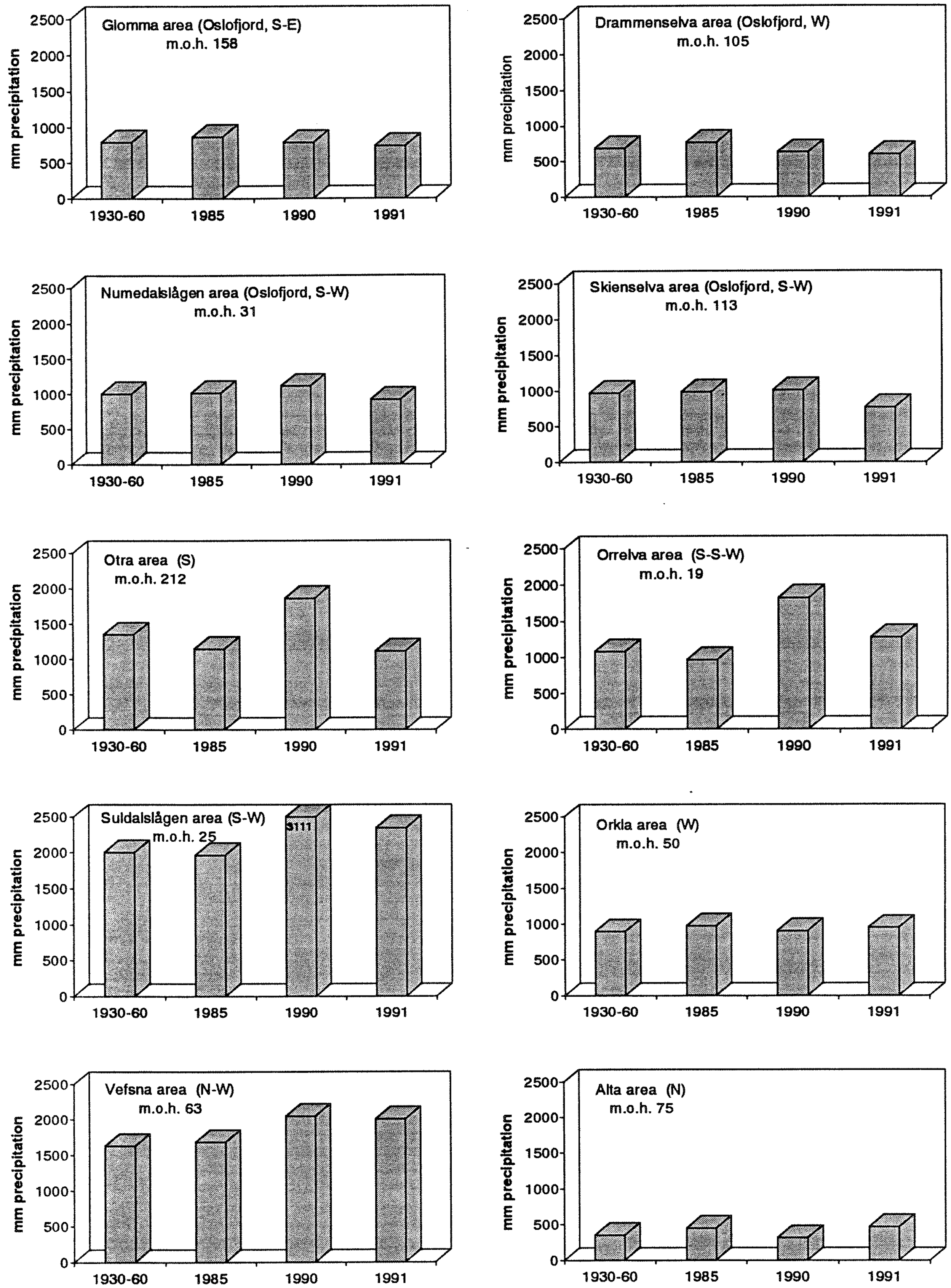


Fig. 3 Main Rivers. Mean Annual Precipitation (1930-60) at Stations near Outlet and Annual Precipitation in the Years 1985, 1990 and 1991 (mm/year).

Source: The Norwegian Meteorological Institute

At a given location the runoff will change from one year to another and throughout the year. In natural river basins the seasonal variations will depend mostly on the distance from the coast, the altitude and the latitude, and on variations in precipitation. The mean discharge is determined both by the precipitation and the catchment area. Along the coast of Southern and Western Norway the summer low flows are usually dominant together with high runoff in autumn and winter. Thus although Western Norway has much more precipitation than Eastern Norway, its smaller catchment areas lead to much less absolute discharge in western rivers. In the central part of Southern Norway and in the Northern part of the country low water flows are typical both in summer and winter, whereas periods of higher runoff will appear during the snow melting period (spring and early summer). In late summer and in autumn the flow depends on the precipitation and may therefore vary considerably.

In all main rivers continous observations of the rate of flow are collected. For most rivers these stations are located upstream the sampling stations (NVE, 1991). The additional water supplied is estimated using measured rainfall data from the local catchment areas (DNMI, 1991).

For all main rivers, seasonal changes in runoff in the period 1930-60, together with mean runoff in 1991, are shown in Fig. 4. In Fig. 5 monthly precipitation for the same period together with mean precipitation in 1991, are shown.

For the other rivers (tributaries) the runoff data partly are from continous observations as the case is for most rivers in the Skagerrak area, and also for many of the rivers draining to the remaining North Sea. For the rest of the rivers mean runoff data (1930-60) and measured rainfall data (1991) are used for flow estimates.

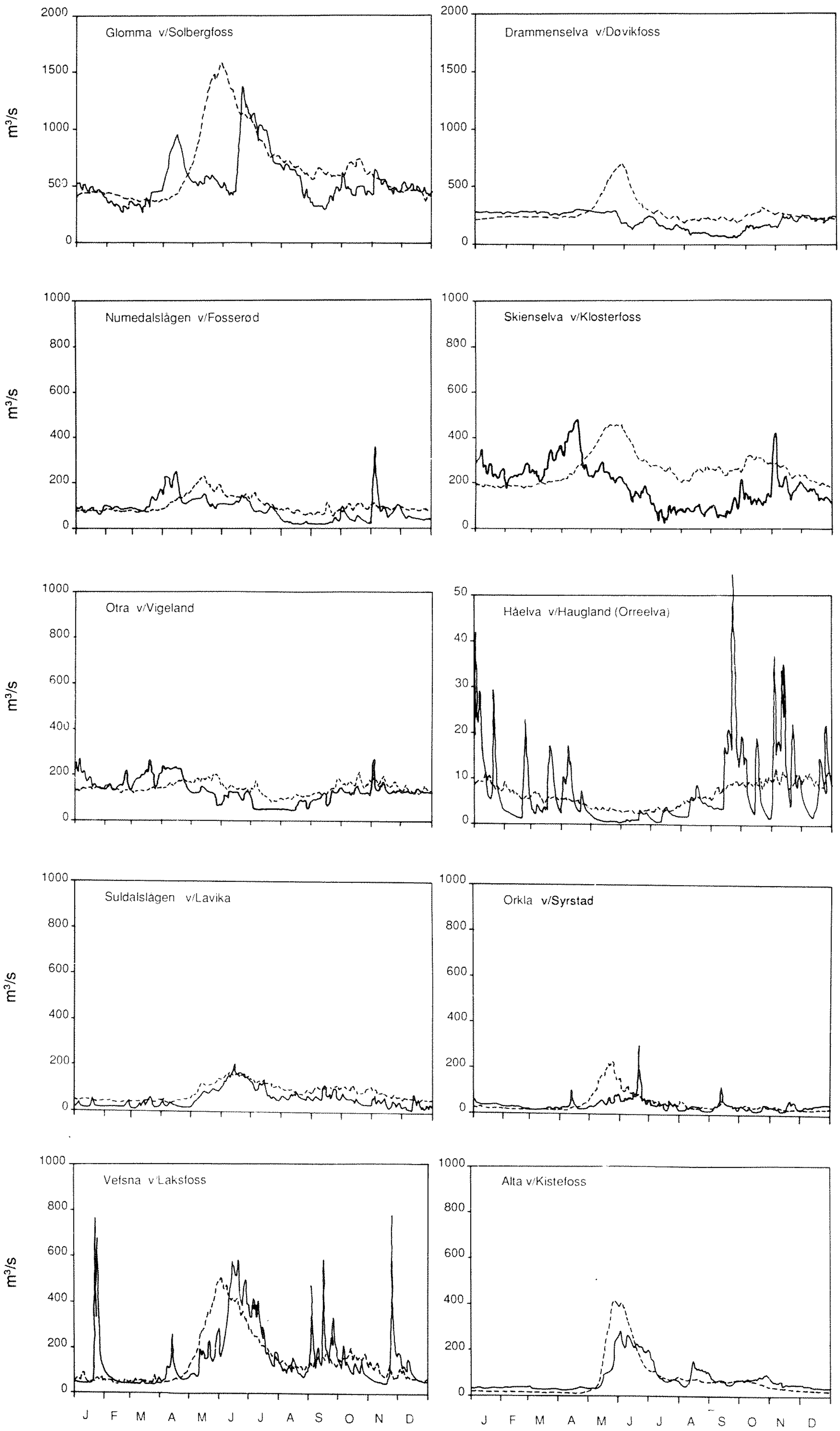


Fig. 4 Seasonal Changes in Daily Runoff (m^3/s) ----- 1930-1960 —— 1991
Source: Norwegian Water Resources and Energy Administration

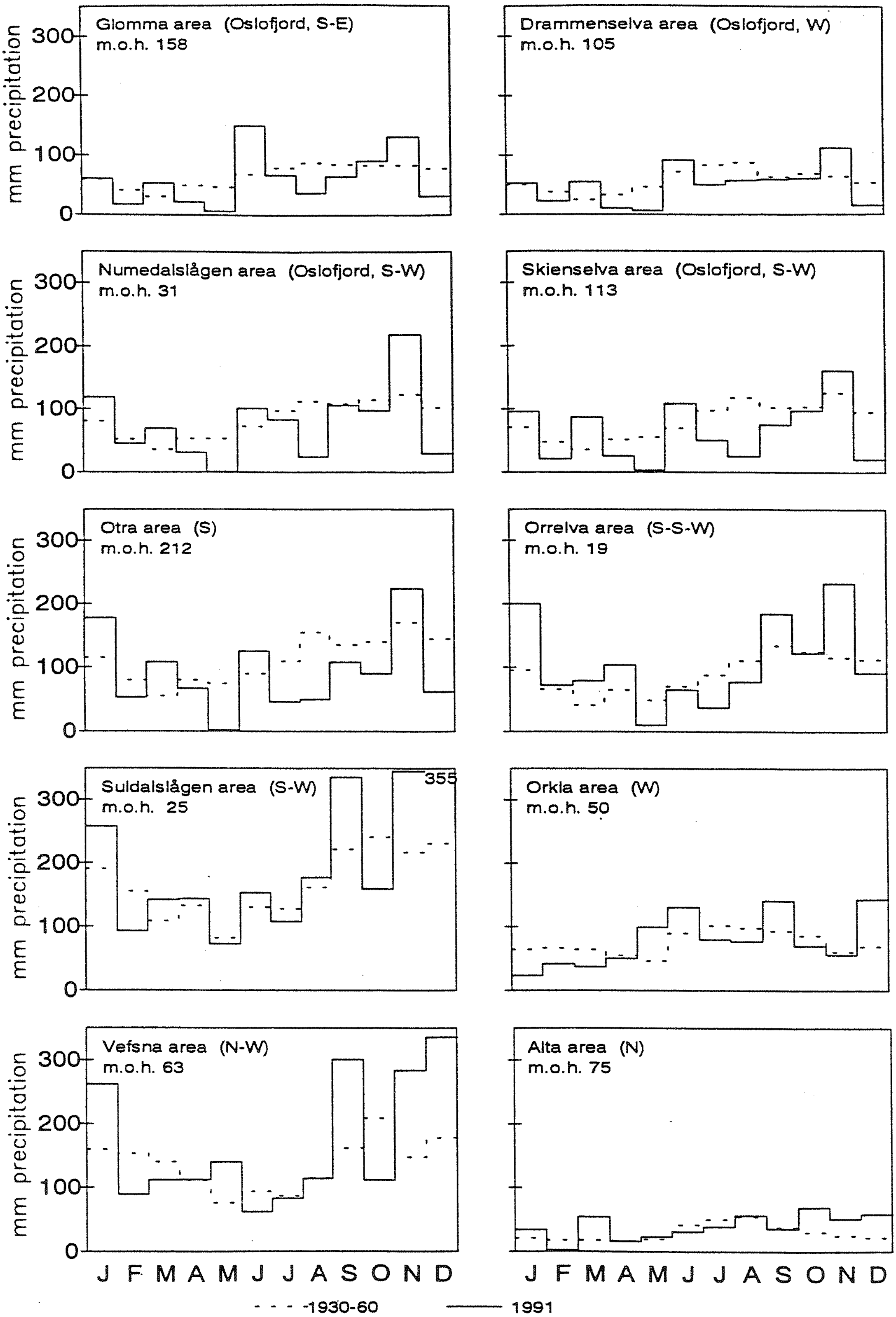


Fig. 5 Monthly Changes in Precipitation (mm/month)
(m.o.h. = meters above sea level)

Source: The Norwegian Meteorological Institute

3.2.3 Calculation of annual load

The first of the 2 formulas given in the Paris Commission document and the 1990-Report was used for calculating loads for all main rivers and most of the larger rivers. The second formula was used where continous records were not available.

For the other rivers, which have been monitored only twice, the best available estimates of flow (catchment area multiplied by specific runoff adjusted for deviations from normal precipitation) and flow-weighted concentrations have been used to estimate contaminant loads.

Drainage basins to the different areas and regions (km^2 and per cent) is shown in Table III (Appendix I).

3.3 Methododology for assessing direct discharges to marine waters

As the methodology for assessing direct discharges to marine waters is outlined in the 1990-Report, and the same procedure is adopted for 1991, we refer to the abovementioned document for further information about this matter.

3.3.1 Waste water treatment plants/sewage effluents

As a basis for monitoring sewage effluents, the Central Bureau of Statistics (CBS) and SFT, in 1991, established a data base on all the waste water treatment plants in Norway. A total of 1387 such plants were registered in 1990 with a combined capacity of 3.9 million population units (p.u.*) and a load of 2.9 million p.u. This is about 100 more plants than registered in 1988, and the capacity has increased by about 0.5 million p.u. A marked increase in capacity, 0.3 million p.u., was registered for chemical plants. The highest capacities were recorded in Eastern Norway, where most of the waste water is treated in so-called "high-grade" plants (i.e. plants with biological and/or chemical treatment steps). Mechanical plants dominate in Western Norway and northwards. Fjords are the recipients of the discharges from about 65 per cent of the total capacity of the plants. It should be noted that the registration only included plants with a reported capacity of more than 50 p.u. (CBS, 1992).

* P.U. (population units) is the number of permanent residents plus the number of population equivalents (next page) in an area.

Preferably, the annual loads from sewage effluents have been estimated as the product of annual flow and flow-weighted concentrations, which in particular has been the case for the sewage plants situated in the Skagerrak area (i.e. the area involved in the North Sea Agreement).

For the rest of the municipal wastewater, the loads were estimated by multiplying the number of people with the coefficients listed.

For crude (untreated) sewage discharges, PARCOM (10/3/2-E) has recommended the following derived per capita loads to be used for nutrients:

	PARCOM:	NORWAY:*
BOD	0.063 kg O/person/day	0.046 kg O/person/day
COD		0.094 kg O/person/day
TOC		0.023 kg /person/day
SPM	0.063 kg /person/day	0.042 kg /person/day
Total N	0.009 kg N/person/day	0.012 kg N/person/day
Total P	0.0027 kg P/person/day	0.0017 kg P/person/day

* Based on recent studies of Norwegian sewerage districts. These data are also used to calculate pollutional loads from the different treatment plants, reduced by the removal efficiency of the treatment plants. Municipal sewage also includes a portion of industrial effluents. The fraction of the total person equivalents (p.e.) is proportioned between sewage and industrial wastewater according to the number of persons and the size of industrial effluents connected to each treatment plant.

For metals in sewage discharges the calculated loads are based on measured concentrations and flows in larger treatment plants in the Oslo part of the Glomma area. Metal inputs from the rest of the country are estimated from local knowledge (**) as follows:

Substance	Cu	Zn	Cd	Pb	Cr-T	Hg
mg/person-equivalent/day (p.e.)	35	50	0.3	4.0	20	0.25

** Sources: Knutzen and Øren (1983), Myhrstad (1985), VEAS (1992), OVA (1992).

The coefficients used in 1991 are lower than those used for calculations in 1990. Especially based on monitoring at the treatment plants in the Oslo part of the Glomma area, we have found that the coefficients used in the 1990-Report were more correct for the period 1980-1985, but assumably too high both for the 1990- and the 1991-waste water. This year, however, SFT has launched a new investigation on this topic, which hopefully will result in an improved basis for these calculations. Measured/estimated loads from sewage are shown in Appendix II, Report B.

3.3.2 Industrial effluents

Sampling frequency for industrial wastewater varies from weekly mixed samples to samples taken at random, but at least twice a year. Measured and estimated loads from industrial activities in the different areas are shown in Appendix III, Report B. According to SFT about 90 per cent of the industrial discharges (i.e. of the substances in question) are included in the total, and probably more for Total-P and Total N.

3.3.3 Other inputs (nutrients in areal runoff from "Down Stream areas" of main and tributary rivers and rivers not monitored)

The pollution load model calculates the load from each pollution source by using area and activity specific load coefficients multiplied by areas (in square kilometres) of different categories and activity numbers, eg. population (Holtan and Åstebøl, 1990). The coefficients used are prepared according to precipitation, climate, vegetation and soil in the different areas.

To estimate load from agricultural land area runoff, coefficients in the range of 50-200 kg Total-P and 2000-6500 kg Total-N km^2/year are used depending on point sources, location of the agricultural land in relation to major tributaries, and agricultural production intensity. Load from upland (remote unpolluted) areas were estimated by using export coefficients in the range of 4-6 kg Total-P and 200-600 kg Total-N km^2/year. The highest values were used in areas most affected by long range pollution (acid rain) along the Southern and Western coast. The coefficients are based on mean annual runoff for the period 1930-60.

Total direct nutrient discharges (Down stream areas) are shown in Table I (Appendix I), in the different subareas (1-10) in Appendix VI, Report B. Direct discharge areas (km^2) are shown in Table III (Appendix I).

4. RESULTS AND DISCUSSION

4.1 Pollutants

Norwegian watercourses, coastal fjords and sea areas are recipients of various substances discharged from many different sources. The discharges may have widely different impacts of varying severity. SFT (1990) considers that the most serious problems are connected to eutrophication (nutrient effluents and runoff), discharges of metals and organic micropollutants and acidification of water and soil.

In this investigation riverine and direct inputs of nutrients (P- and N-compounds), heavy metals, lindane and PCBs are measured or estimated. In addition to these contaminants the water is polluted by dissolved organic matter, especially from the pulp and paper industry and from municipal sewage, which also has been taken into account in this investigation.

SFT (1990) has given first priority to eliminating the effluents of 13 of the substances classified as micropollutants, which are in use in Norway, as quickly as possible. Most of this pollution comes from industry, but other sources are the municipal sewerage network, landfill leachate, and pesticide residues from agriculture. Long-range transboundary air pollution is another source of pollution by heavy metals and organic micropollutants.

Pollution by heavy metals is either due to discharges from industry, discharges from existing and abandoned mines, leaching from landfills, polluted ground or atmospheric fallout. The municipal sewerage network is the source of several heavy metals.

Polychlorinated biphenyls (PCBs) are present in different industrial effluents and also released from discarded electrical equipment containing PCBs (e.g. transformer oil), when such equipment is unsatisfactorily stored or destroyed by incineration. There is no enterprise in Norway discharging PCBs regularly.

Major sources of phosphorus and nitrogen pollution are considered to be municipal sewage, agriculture and to a certain degree, industry.

4.2 1991-results and discussion

The results given for riverine inputs (main rivers and tributaries) and discharges entering directly into marine recipients, are mainly based on monitoring data (paragraph 3.3).

Measured concentrations of the chemical parameters of the ten main rivers (1991), mean values, standard deviation and range are listed in Appendix VII, Report B. In the case of Cd, Pb, Hg and the different congeners of PCBs, where most of the rivers had concentrations below the respective detection limits, the concentrations are statistically treated as "limit-values". Mean annual concentrations (1991) of the chemical parameters and the rate of flow for the main rivers are also listed in Table II (Appendix I). Total annual loads of the main rivers 1991 are shown in Appendix IV, Report B. Annual loads of nutrients and S.P.M. are also presented in Fig. 6. Total annual loads of the tributaries are shown in Appendix V, Report B. For the whole country, total annual loads (Direct discharges and Riverine inputs are shown in Table I (Appendix I) and for the four subregions in Appendix I, Report B, nutrients and S.P.M. also in Fig. 7.

As in 1990 the greatest emphasis with regard to accuracy has been given to the input estimate of the Skagerrak region, as this is considered the most susceptible part of the North Sea. The Skagerrak reception of total loads in 1991 were 32 per cent of the phosphorus and 38 per cent of the nitrogen yield. In this region where 94 per cent of the area is river-monitored, about 56 per cent of the P-load and 70 per cent of the N-load were found in the riverine inputs.

According to the results from the 1991 investigation, total annual nutrient load to coastal waters from landbased Norwegian sources, is approximately 3594 tons of phosphorus and 88664 tons of nitrogen (Fig. 7). About 40 per cent of the phosphorus and 56 per cent of the nitrogen yield were inputs from the monitored rivers and tributaries. The largest inputs of heavy metals were of copper and zinc, which in 1991 amounted to about 356 and 1039 tons, of which 86 and 93 per cent respectively, were river monitored (Fig. 8).

In most areas except in northernmost Norway (Alta with subarea), the riverine inputs both of nutrients and the heavy metals copper and zinc, were lower in 1991 than the year before, mainly due to lower precipitation/runoff (paragraph 4.3).

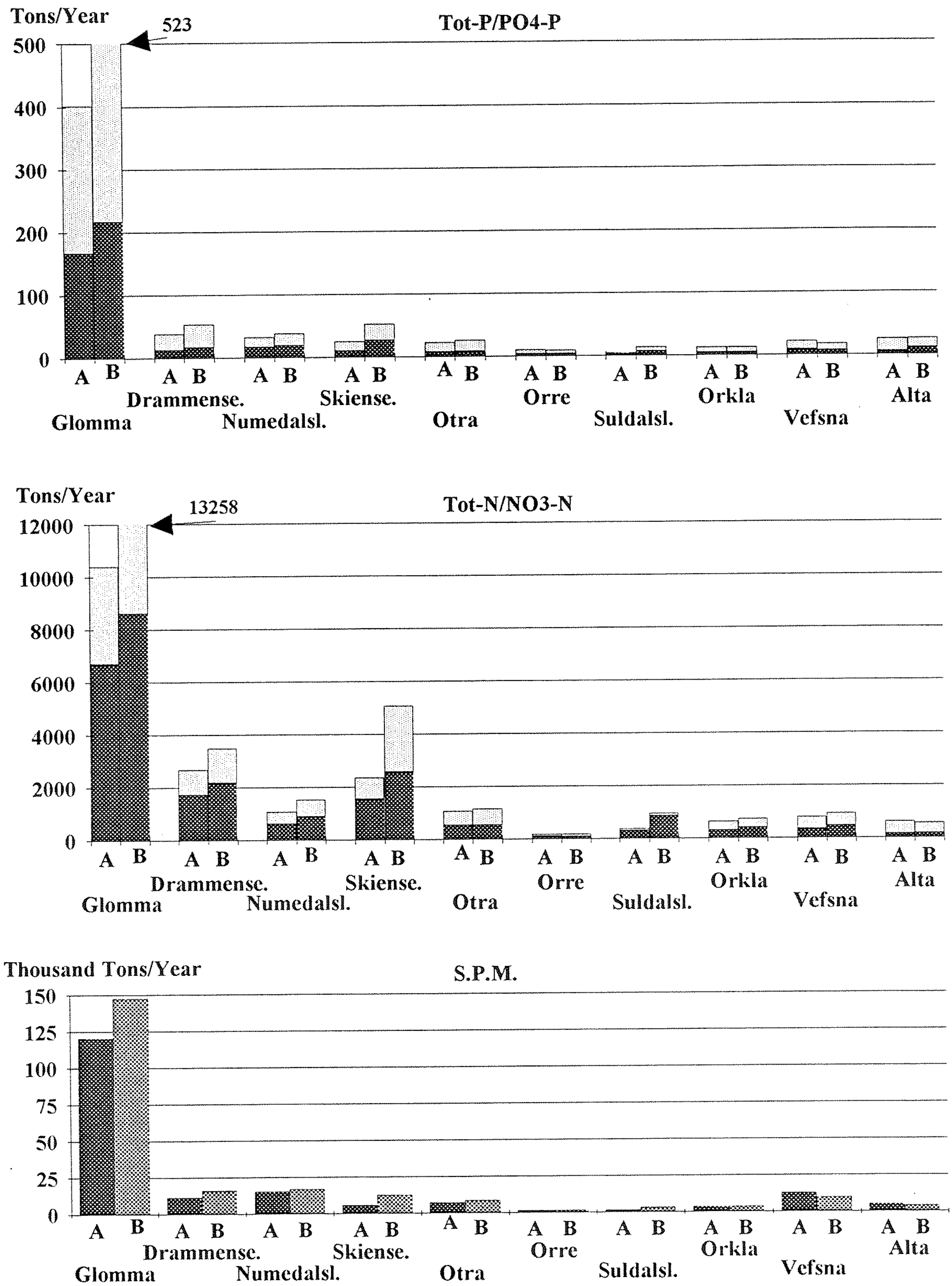


Fig. 6 Main rivers. Nutrients and S.P.M. Total loads 1991(A) and Total normalized loads (B) in the different rivers

Whole columns = Total P / N / S.P.M.
Dark hatching = Phosphates / Nitrates

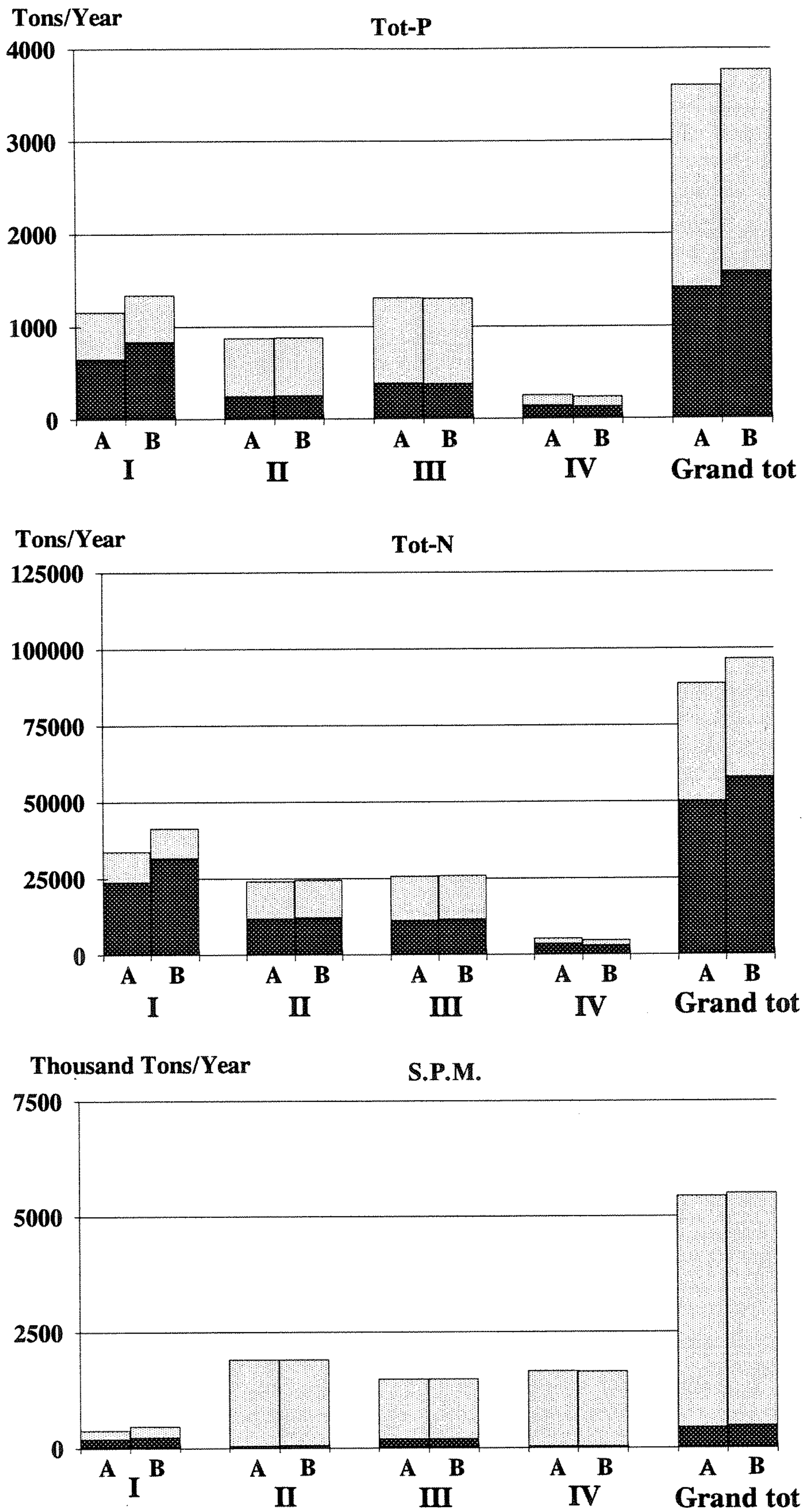


Fig. 7 Nutrients and S.P.M. Total and river discharges 1991 (A) and Total normalized loads (B) from mainland Norway to convention waters and the four subregions: I: Skagerrak, II: The remaining North Sea, III: The Norwegian Sea, IV: The Barents Sea

Whole columns = Grand total
Light hatching = Direct discharges
Dark hatching = Main and tributary rivers

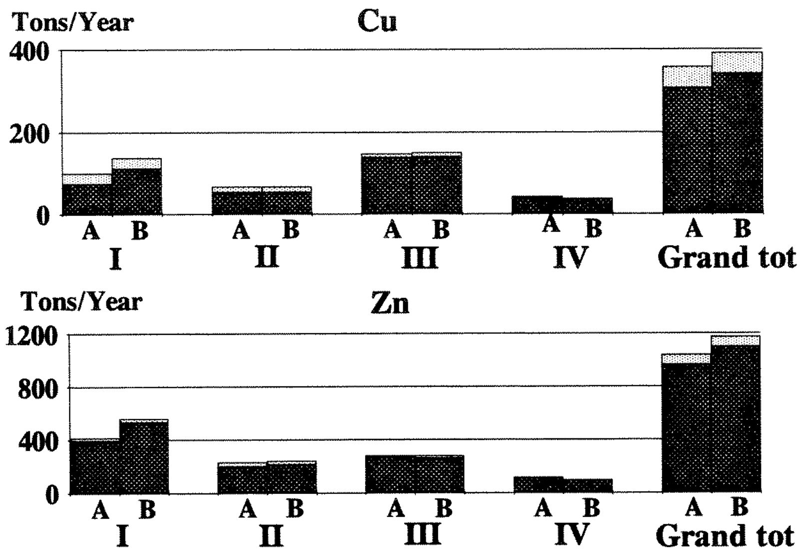


Fig. 8 Cu and Zn. Total and river discharges 1991 (A) and Total normalized loads (B) from mainland Norway to convention waters and the four subregions: I: Skagerrak, II: The remaining North Sea, III: The Norwegian Sea, IV The Barents Sea

Whole columns = Grand total
Light hatching = Direct discharges
Dark hatching = Main and tributary rivers

Inputs of other metals and micropollutants were also low. As the detection limits of the parameters Cd and Pb at the NIVA laboratory were above those requested from PARCOM, most of the 1991 analyses of these substances were re-analyzed on an ICP-MS-instrument (paragraph 3.2). Still, a great deal of the concentrations found for these parameters were below the detection limits. Therefore two quantities have been estimated, one assuming that the true concentration was zero and the other assuming that the true concentration was the limit of detection. This provides maximum and minimum concentrations within which the true estimate will fall. When evaluating inputs these data provide upper and lower boundaries of the estimate.

Inputs of cadmium were measured/calculated to be between 8.1 and 8.5 tons, lead between 101 and 103 tons, mercury between 415 and 748 kg. The same "below detection limit problem" also applies for the inputs of PCBs which were measured to be between 2 and 74 kg. In Fig. 9 the lower and upper loads of these substances in the ten main rivers are presented. The herbicide lindane was found in most analyses, but in small amounts. The findings of this substance in Norwegian rivers are likely due to long range air pollution, as we often find lindane in runoff from areas where the compound has never been used (Olav Lodhe, State Plant Protection Agency, pers. comm.). Total load is estimated to about 260 kg.

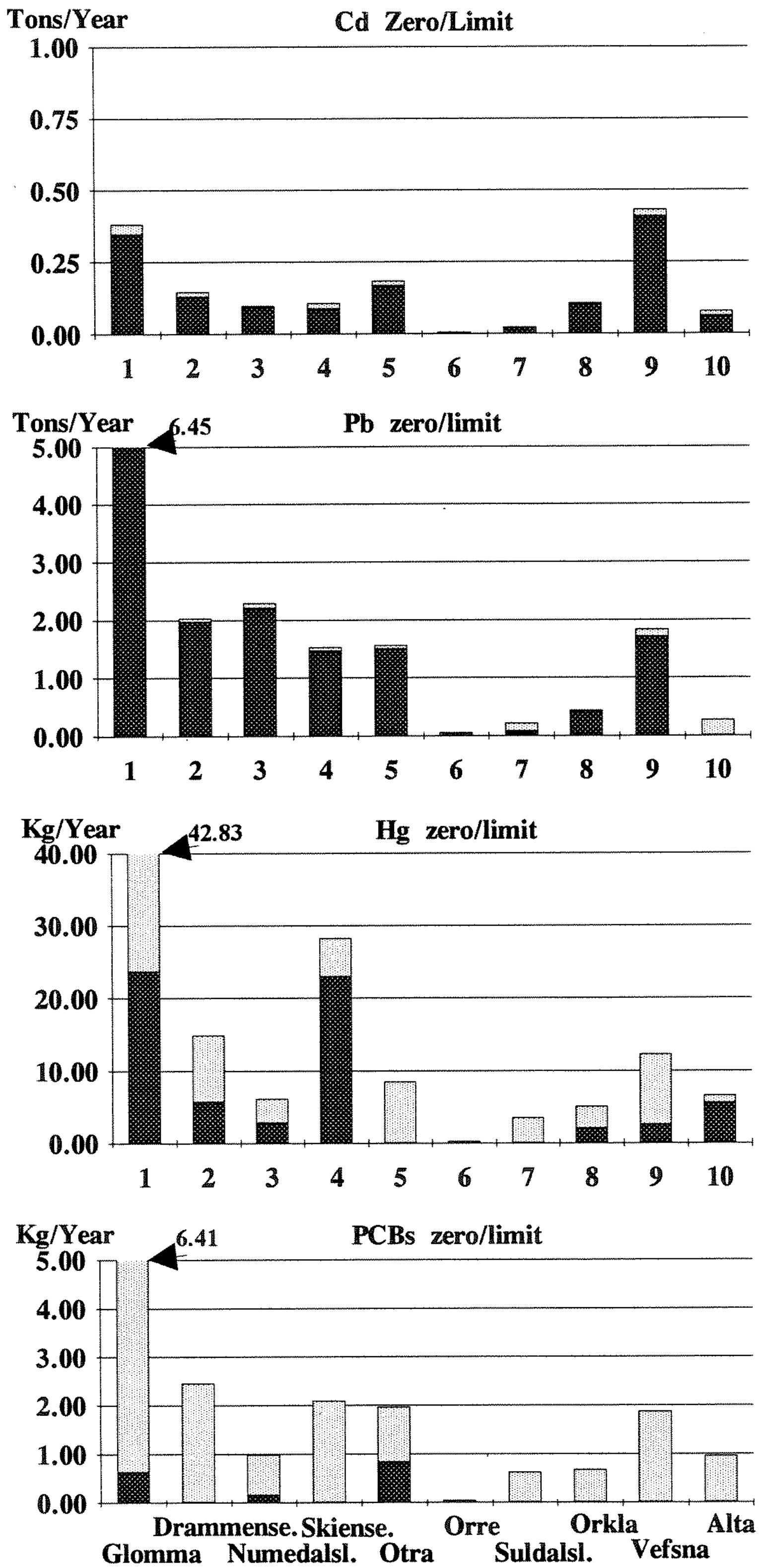


Fig. 9 Main rivers. Cd, Pb, Hg and PCBs. Total loads of the different rivers 1990 (lower and upper boundaries for the estimates)

Whole columns = upper boundary for the estimate
Dark hatching = lower boundary for the estimate

4.3 Mean annual runoff (1930-60) and "mean load"

Compared to Riverine Inputs to Marine Waters in 1990, most calculated mean concentrations were in about the same level in 1991. Total flow, and accordingly the calculated loads for all main rivers were lower in 1991 than the year before, except for river Alta, where the transport values were higher, and also the total flow.

Annual variations in precipitation/runoff, erosion and seasonal activities of man in the drainage basins, strongly influence the mass transport in the watercourses. The transport values might vary considerably from one year to another. These variations are complicating the estimation of "normal transport values" i.e. mass transport in a "normal" year. Fig. 10 illustrates variations in annual runoff for the ten main rivers in 1985, 1990 and 1991, and annual variations in total discharge, of the nutrients total N and P for the same years.

In order to adjust the 1991 transport values to a "normal year", approximation have been made by multiplying weighted mean concentrations by mean runoff (1930-60) - to normalize the concentrations is not possible. "Mean-values" (normals) for the ten main rivers and tributaries are given in Appendix X, Report B. In Table IB (Appendix I) "normalized" total discharges from mainland Norway to the convention waters are given, and in Appendix X, Report B, total discharges to the sub regions are shown. In Fig. 6 - 7 the "normalized" nutrient transport values are compared with 1991-values.

During a normal winter the upland area of Norway together with the eastern part of the country shows very little runoff. The frozen earth and snowcover protect vegetation and surface soil from erosion. But with the mild winters (1990 and 1991), soil especially in plowed field is exposed to more frequent and larger flood erosion also during the winter (eg. Glomma).

From experience we have learned that the product of weighted concentrations and mean runoff (1930-60) gives a good estimate of the mass-transport in rivers, especially for the large rivers, and those not considerably exposed to erosion-material. Special weather conditions also in winter 1991, resulted in lower discharge than the year before and also lower than normal in watercourses both in Eastern and Western Norway. As for rivers in Northern Norway, annual runoff in 1991 was higher than normal, and accordingly also the mass-transport. The river Suldalslågen is recently regulated and has now considerably less annual water discharge than in the normal period (1930-60).

4.4 Nutrient retention in fjords

Both phosphorus and nitrogen retention in watercourses is taken into account in the calculation of the Norwegian contribution to marine pollution, but in a conservative way. However, no corrections are so far made for retention in fjords.

Considering the nutrient input to the open marine waters, one should also take into account retention in fjords, at least in well defined treshold fjords. As a result of high salinity compared to freshwater, marine waters have better conditions for sedimentation than lakes. For example clay settles very poorly in lakes, but very efficient in fjords. In addition to temperature stratification, fjords also show salinity stratification, with light brackish water on top of heavier, saline waters. Thus the over all stratification in fjords is in most cases stronger than in lakes. This implies that particulate pollutants lost to deep waters by sedimentation have less chance to be brought back to the plankton producing layer than in lakes.

In addition, stronger stratification implies greater chance for oxygen depletion in deep waters, which in fact is seen in many sheltered Norwegian fjords. Theoretically this will improve the conditions for denitrification. However, this greater stability is often reduced by rougher physical conditions in fjords compared to lakes.

Retention in Norwegian fjords is very poorly studied by direct budget measurements. In the Drammensfjord Magnusson and Næss (1986) found that about 60% of the incoming phosphorus was retained in the fjord, while for nitrogen the retention was only about 15%. In the silled Inner Oslofjord preliminary calculations indicate that nitrogen retention is in the order of 30-50% (Baalsrud, K., and B. Bjerkeng, 1991).

Thus, nutrient retention in treshold fjords seems to be of the similar magnitude as we find in lakes, and it is likely to believe that retention can be estimated from the same type of models that applies for lakes. The general lack of calibration data on retention models in fjords implies that we find it to early, at this stage of knowlege, to include these correction in the Norwegian discharge budget. It should be kept in mind, however, that a significant part of the particulate pollutants, and pollutants with particle affinity, end up in fjord sediments and thus are prevented from reaching the coastal waters.

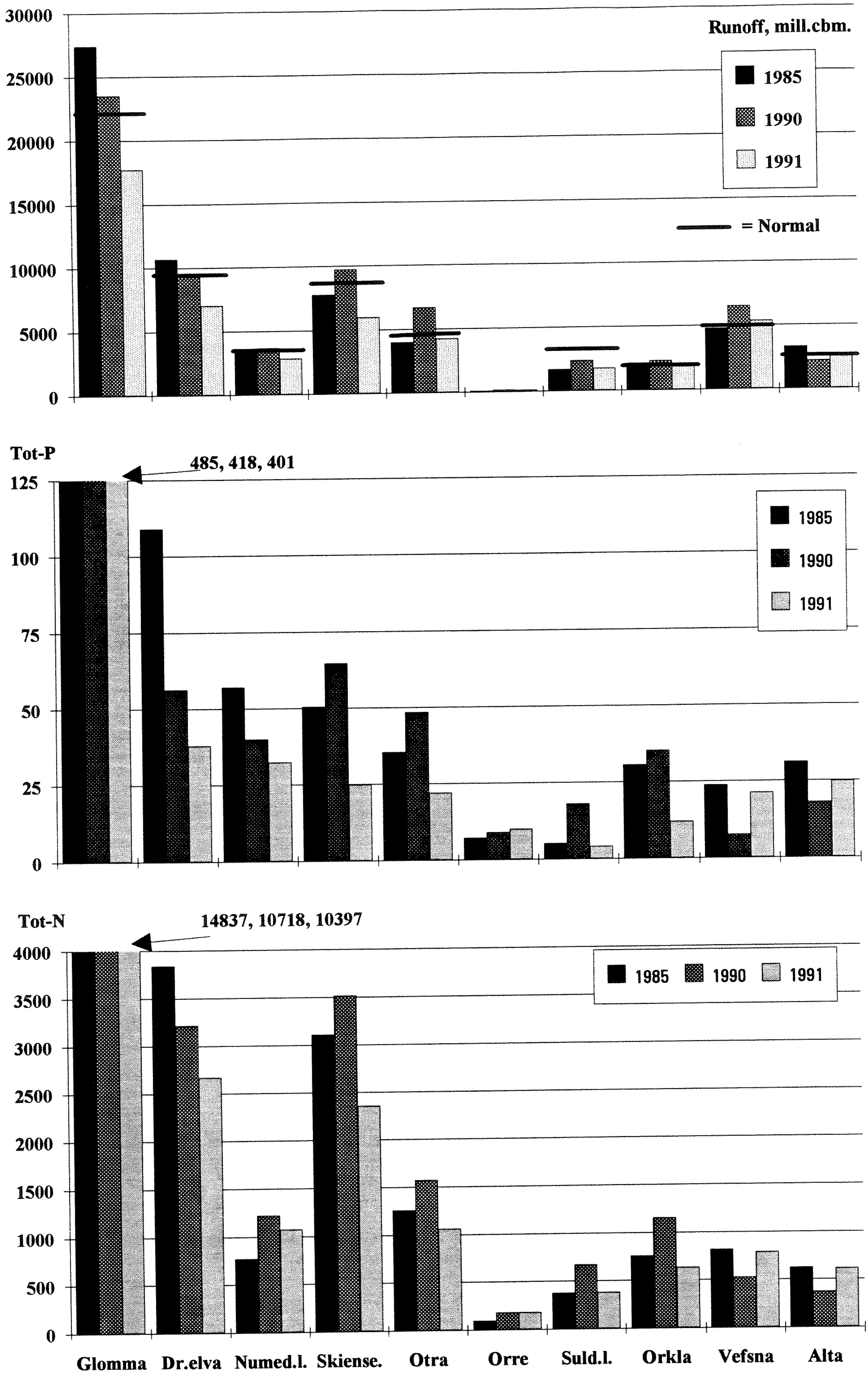


Fig. 10 Main rivers. Annual runoff and nutrient load in 1985-90-91.

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6 APPENDIX I: TABLES AND FIGURES

Table IA Total discharges from Mainland Norway to convention waters 1991

Substance:	Area runoff	Direct Discharges	Tributary Inputs		Main Riverine Inputs		Grand Total	
Cadmium		0.4	6.3	*	1.4	*	8.1	tonnes
Cadmium			6.5	**	1.6	**	8.5	tonnes
Mercury		314	36	*	65	*	415	kg
Mercury			307	**	127	**	748	kg
Copper		51	210		95		356	tonnes
Zinc		78	629		332		1039	tonnes
Lead		13.2	72.3	*	15.7	*	101.3	tonnes
Lead			73.1	**	16.7	**	103.0	tonnes
PCBs ***			0.3	*	1.6	*	1.9	kg
PCBs			56.3	**	18.1	**	74.4	kg
gamma-HCH			229		32		261	kg
NO3-N	15150	11.2	16457		12258		28726	tonnes
PO4-P	208	694.8	208		234		1136	tonnes
Total N	24259	14447	29811		20146		88664	tonnes
Total P	791	1387	825		590		3594	tonnes
S.P.M.		4556472	249835		183280		4989587	tonnes
COD		265939					265939	tonnes
BOD		39440					39440	tonnes

Table IB "Mean" total discharges from mainland Norway to convention waters (Mean runoff 1930-60)

Substance:	Area runoff	Direct Discharges	Tributary Inputs		Main Riverine Inputs		Grand Total	
Cadmium		0.4	6.4	*	1.6	*	8.5	tonnes
Cadmium			6.6	**	1.6	**	8.7	tonnes
Mercury		314	41	*	26	*	381	kg
Mercury			301	**	132	**	747	kg
Copper		51	204		135		391	tonnes
Zinc		78	630		467		1174	tonnes
Lead		13.2	69.4	*	18.8	*	101.5	tonnes
Lead			70.3	**	19.4	**	102.9	tonnes
PCBs ***			0.2	*	0.1	*	0.4	kg
PCBs			56.3	**	21.7	**	78.0	kg
gamma-HCH			231		49		280	kg
NO3-N	15150	11.2	16703		16712		33426	tonnes
PO4-P	208	694.8	205		316		1215	tonnes
Total N	24259	14447	30064		27804		96575	tonnes
Total P	791	1387	815		770		3764	tonnes
S.P.M.		4556472	248399		221358		5026229	tonnes
TOC		21339					21339	tonnes
DOC								tonnes
COD		265939					265939	tonnes
BOD		39440					39440	tonnes

Measurements below detection limits are treated in two ways :
 *) Detection limit = Zero
**) Detection limit = Linit

*** The following congeners: IUPAC Nos. 28, 52, 101, 118, 138, 153, 180

Table II. Main rivers. Mean concentration of monitored parameters 1991.

Main surrounding seas		<------North Sea						------>	Norwegian Sea		Barent Sea
		<------Skagerak				------>					
NO		1	2	3	4	5	6	7	8	9	10
Rivers		Glom ma	Drammens -elva	Numeda ls-lågen	Skiens -elva	Otra	Orre- elva	Suldals -lågen	Orkla	Vefsna	Alta
Parameters											
Runoff,	m3/s	562	223	89,3	190	134	3.5	56,1	61.5	169	86,9
Kond.,	mS/m	4,93	3,51	3,41	2,20	2,49	18,30	1,78	6,31	5,83	11,27
Tot-P,	mg P/l	23,7	5,6	10,4	3,9	5,5	75,4	2,6	6,1	3,3	9,8
PO4-P,	mg P/l	9,8	1,7	5,1	1,5	1,7	22,9	1,0	2,0	1,2	4,1
Tot-N,	mg N/l	600	368	415	380	248	1495	229	354	176	207
NO3-N,	mg N/l	391	230	243	244	116	692	184	192	84	62
Cu,	mg/l	1,8	1,1	2,0	1,1	1,0	1,5	0,6	12,5	2,0	1,4
Zn,	mg/l	6,2	4,6	9,9	6,7	7,8	3,5	3,1	26,4	5,3	2.1
Cd*,	mg/l	0,02	0,02	0,04	0,01	0,04	0,04	0,01	0,05	0,06	0,04
Cd**,	mg/l	0,02	0,02	0,04	0,02	0,04	0,04	0,02	0,05	0,06	0,04
Pb*,	mg/l	0,35	0,23	0,70	0,24	0,30	0,35	0,08	0,19	0,45	0
Pb**,	mg/l	0,38	0,25	0,73	0,25	0,34	0,36	0,14	0,20	0,47	0,1
Hg*,	ng/l	1,0	0,6	0,9	3,0	0	0,8	0	1,1	1,4	1,3
Hg**,	ng/l	2,4	2,1	2,3	4,2	2,0	2,2	2,0	2,6	3,0	2,3
As,	µg/l	0,28	0,27		0,17	0,25		0,16			
Cr-T*,	µg/l	0	0		0	0,23		0			
Cr-T**,	µg/l	0,5	0,5		0,5	0,57		0,5			
Lindane,	ng/l	0,97	0,97	0,59	0,93	0,52	0,73	1,11	0,19	0,25	0,13
PCBs*,	ng/l	0.01	0	0,01	0	0,02	0	0	0	0	0
PCBs**,	ng/l	0,05	0,05	0,05	0,05	0,06	0,05	0,05	0,05	0,05	0,05
SPM,	mg/l	6,67	1,68	4,52	0,92	1,84	10,18	0,66	1,62	1,79	1,39
TOC,	mg/l	3,67	2,29	3,15	1,66	4,19	5,95		3,22	1,70	4,03
DOC,	mg/l	3,60					4,81			1,65	3,91
AOX,	mg/l	4,0	5,3		5,0	87,3		2,7			

* Detection limit = zero. ** = Detection limit = limit.

Table III. Drainage areas of monitored main and tributary rivers and Down Stream areas (km2 and per cent monitored in each subarea and subregion). (Fig. 1, Figs. I.I - I.V).

Sub-regions	Sub-areas	Drainage area of monitored rivers km^2 km^2 Main	Tributary	Down Stream areas km^2	Total km^2	Monitored %
Skagerrak	No 1: Glomma	41218	2389	2416	46023	94,8
	" 1: Inner Oslofiord		959	342	1301	73.7
	No 2: Drammenselva	17028	226	320	17614	98.2
	No 3: Numedalslågen	5513	1043	631	7187	91.2
	No 4: Skienselva	10348	1200	1283	12831	90.0
	No 5: Otra	3730	9109	904	13743	93.4
Total		77837	14966	5896	98699	94.0
The remaining North Sea	No 6: Orre	105	7233	2513	9851	74.5
	No 7: Suldalslågen	1466	16205	12681	30352	58.2
Total		1571	23438	15194	40203	62.2
The Norwegian Sea	No 8: Orkla	2680	28118	17036	47834	64.4
	No 9: Vefsna	4113	23907	18850	46870	59.8
Total		6793	52025	35886	94704	62.1
The Barents Sea	No 10:Alta	7367	45155	20619	73141	71.8
Total		93568	135584	77595	306747	74.7

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