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A CASE STUDY ON OPTIMAL WATER MANAGEMENT OF SMALL CATCHMENTS

AAROS RIVER IN NORWAY

WATER RESOURCES DIRECTORATE

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ABSTRACT

The Norwegian Water resources and Energy Administration (NVE) is the national authority responsible for the main elements of water resources management.

The present case study is mainly based on the "Water Master Plan, Aaros River" in Norway with a catchment area of 115 square kilometres which is in course of preparation.

In terms of range, and taking into account practical experience, rivers with catchment areas between a hundred and a few thousand square kilometres are considered as small rivers.

The study is one out of more similar studies to be prepared for the "Economic Commission for Europe, Environment and Human Settlements Division" on the same subject.

Accordingly, the content of the present study is strictly following the "outline for the preparation" which is submitted from the Divison and contains the following main items: • Natural conditions, • Socio-economic conditions, • Water management and river-basin development, • Relation between catchments and neighbouring basins and environments, • Interaction between management and socio-economic activities, • International co-operation.

In addition to the outline, one chapter dealing with the Norwegian Watercourse Archives is added.

EMNEORD

Forvaltning
Vassdrag

SUBJECT TERMS

Management
Watercourse

ANSVARLIG UNDERSKRIFT

Pål Mellquist
Vassdragsdirektør

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ANNEXES

0. INTRODUCTION

On behalf of the "Ministry of Environment" the "Norwegian Water Resources and Energy Administration, Water Resources Directorate" with this is presenting a case study on "Optimal Water Management of Small Catchments".

The Case Study is based on a "Water Master Plan" (WMP) for the watercourse Aaros River which the Directorate just now is about to complete. The main objectives with the WMP are to reduce the pollutions, control the water flow and improve the environment aspects.

In this study we have tried to follow up your intention according to the outline for the preparation, items 1-6 as later referred, added item 7 "The Norwegian Watercourse Archives".

Some of the following informations are taken directly from the WMP, some other are worked out as supplements to the Case study, others are educated guesses or estimates according to our local knowledge to the catchment area after working with the problems the last three years.

According to your outline we have tried to indicate which data are estimates only, in the study marked with *).

A river profile in a scale suitable for the study is not yet worked out but might later be forwarded if desired.

Oslo, June 1989

Erik Kielland
Director

1. NATURAL CONDITIONS

1.1 Name of the main catchment

The Aaros River is an independent watercourse with a catchment area which is separated by the natural watershed. The river is draining dirctly to the Oslo Fjord. Geographical coordinates of its centre of gravity are in the UTM-system and M711-series sheet 1814 I 3-NOR Edition Grid Zone Designation 32V:

580800 East
6629000 North

The location is shown on the maps attached at the end of the study.

1.2 Characteristics

1.2.1 Topography and land use

- Catchment area: 115 km^2
- Altitude of the highest peak: 481 m.a.s.l.
- Altitude of the lowest point: Sea level ($\pm$ 0)

SLOPE CONDITIONS		
SLOPE %	SURFACE in km^2	SURFACE in % of the total
0- 5	6	5
6-12	17	15
13-17	57	50
18-25	23	20
>25	12	10
TOTAL	115	100

The figures are calculated and partly assumed out of map in scale 1:50,000 and 20 m contours.

LAND USE		
	SURFACE	
	in km^2	in % of the total
Settlements	10	9
Ploughed field	13	11
Vineyard and orchards	10	9
Pasture	3	3
Forest	66	57
Roads and railways	1	1
Water surfaces and wetlands	5	4
Others	7	6
TOTAL	115	100

- Reserves and protected areas: Nothing, except restrictions against pollutions and new buildings near the rivers and lakes.

1.2.2 Geology, soils

- Situation, dimensions and capacity of aquifers, their water quality.

MAIN SOIL TYPES:		
SOIL TYPES	SURFACE	
	in km^2	in % of the total
Marine deposits	50*)	43
Moraine	40*)	35
Rock (granite and kambrosilur)	25*)	22
TOTAL	115	100

- Infiltrating capacities of soils are varying as an average approx 0,3-7 mm/min.

  The groundwater is of a good drinking quality, however of a very limited use. Only a few separate farms and huts are supplied by groundwater and therefore no official water analyses are available.

1.2.3 Vegetation, erosion

Dominant natural vegetation within the ara is fir and spruce forest and a mixed deciduous/conifer forest, all together 66 km^2.

The main crops are grain, potatos, carrots and salad of different kinds.

Eroded surfaces and areas are mostly along parts of the river which have limited agriculture and therefore only minor influence on the riverbank's natural vegetation.

1.2.4 Meteorology

Station: 1971 Asker
Air Temperature: ^0C, annual mean, 5.4 (multi-annual mean)
min.max, Min: -26.0, max: 33.0 (multi-annual values)
annual repartition, figure 1 (multi-annual values)
Air humidity: 82.1% (multi annual mean) repartition, figure 2 (multi annual values).
Precipitation: See under 1.3.2.

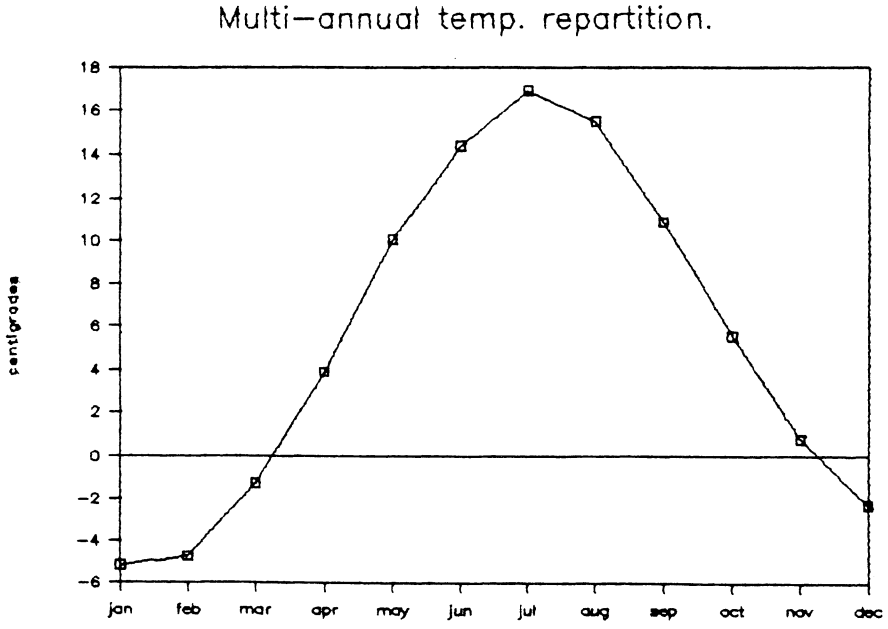


Fig. 1: Air temperature. Multi-annual repartition. Monthly mean values.

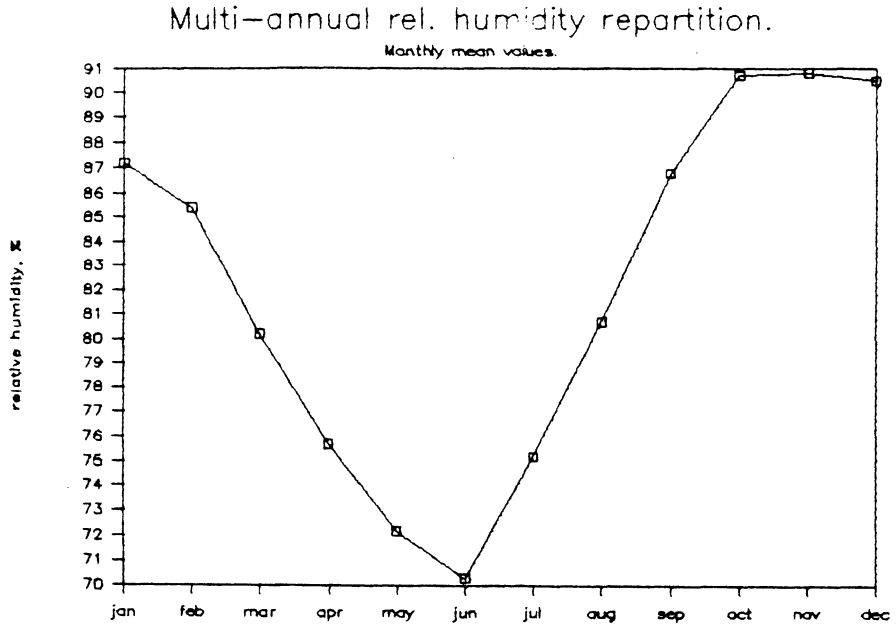


Fig. 2: Relative humidity. Multi-annual repartition. Monthly mean values.

1.3 Hydrography, water balance

1.3.1 Hydrography

Length of the main Aaros river is 20 km. The main tributaries are Grobruelva, Sagelva, Kjoselva and Skithegga, totalling 15 km.

The density of the water courses is accordingly approx. 0,3 km/km^2.

1.3.2 Water balance

Station:	1971 Asker
Multi-annual mean precipitation, mm:	926
Multi-annual max and min. precipitation (extreme values), mm:	max 1305, min 390
Characteristic precipitations of short duration, and high intensity (i.e. mm/15 min), occurance and frequency	5.7 mm/15 min (max observed value) (Information about occurance and frequency not available).

Characteristic precipitations of long duration (i.e. mm/3 days)	113.5 mm/3 days (max observed value)
Occurance and frequency	Occurance : Sep-Dec. 10-year return period: 105 mm/3 days 100-year return period: 141 mm/3 days.
Multi-annual mean of real evapotranspiration, mm	375 (penmanestimate)
Multi-annual max/min of evapotranspiration, mm	Inform. not available.
Multi-annual mean runoff, mm	495
and $10^6 m^3$/year:	54
Annual runoff repartition,	figure 3

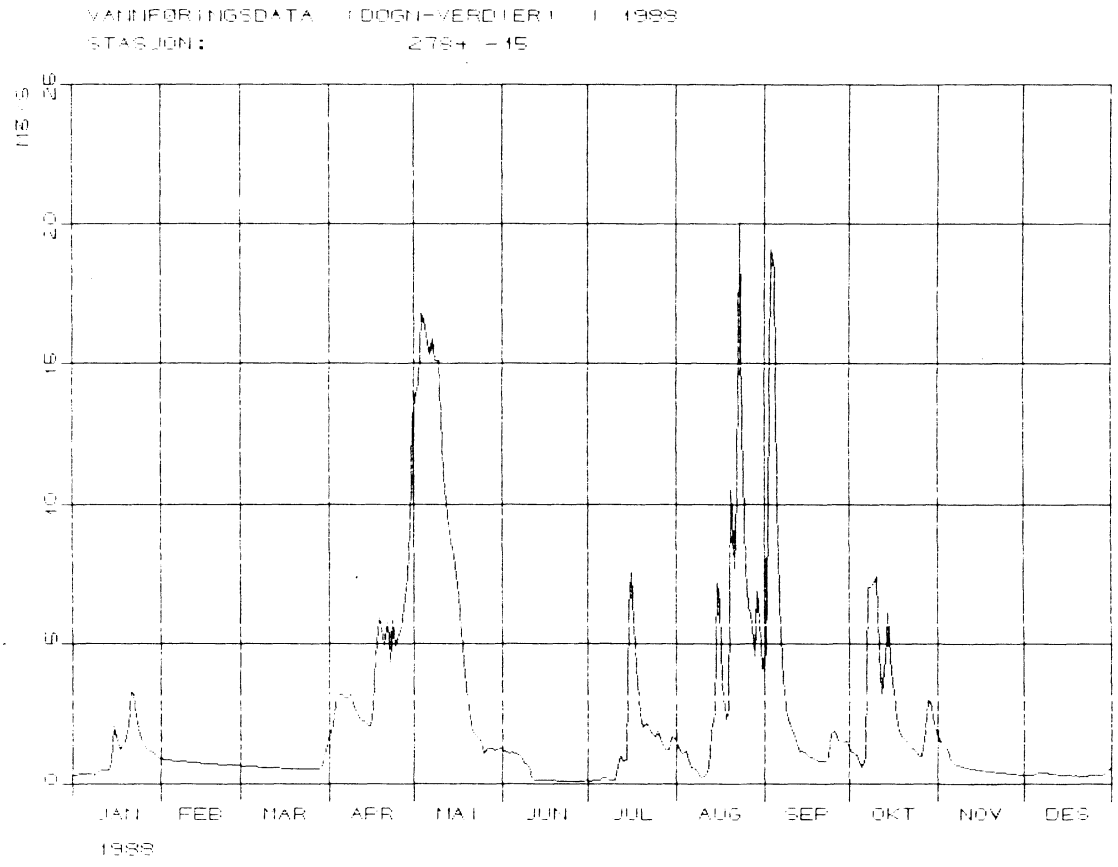


Fig. 3: Runoff repartition 1988 measured at the station VM 2784 Aaros. The station is located appr. one km upstream the mouth of the river.

Multi-annual mean discharge at the mouth of the river, m^3/s:	1.7
Multi-annual max/min discharges at the mouth, m^3/s:	max: 18.5, min: 0.18
Suspended load at the mouth	
Density, g/m^3 multi-annual mean values	34.3 g/m^3 inorganic 12.0 g/m^3 organic 46.3 g/m^3 total
Volume t/year " " "	1850 t/year inorganic 650 t/year organic 2500 t/year total
Characteristic values of suspended load:	Period, density, volume, figure 4.

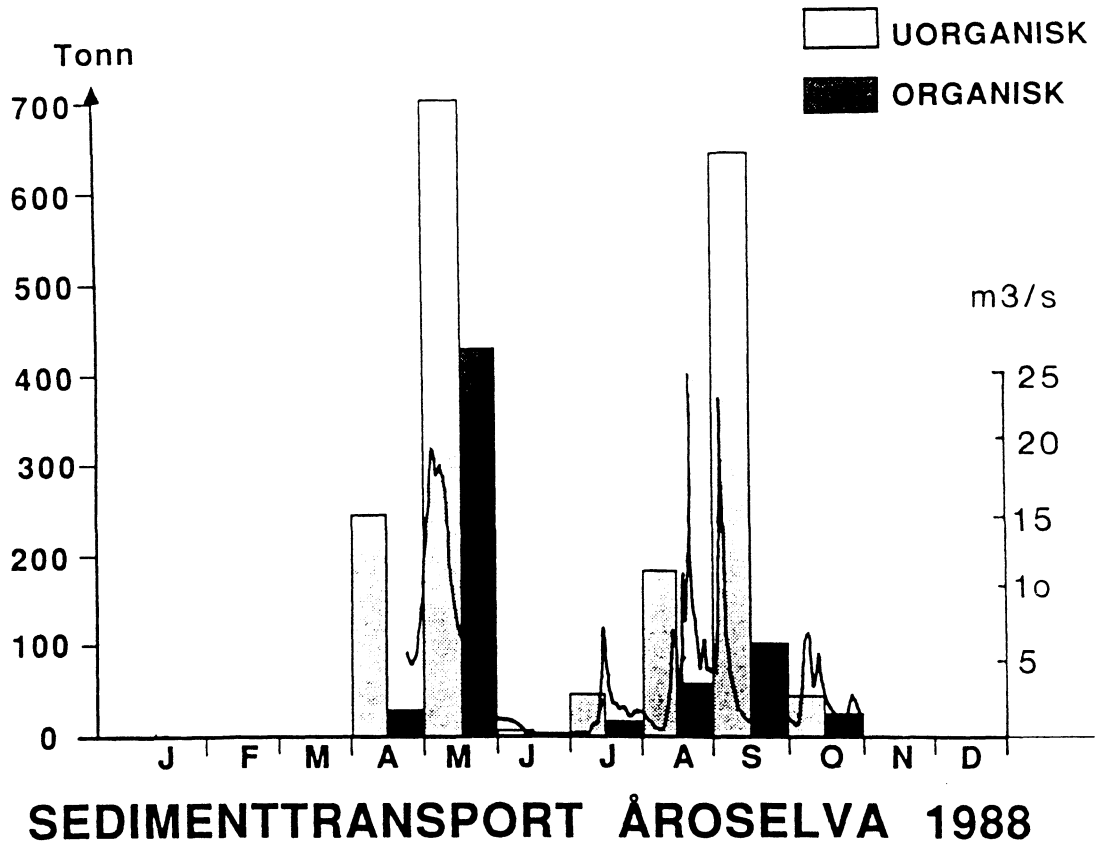


Fig. 4: Sedimenttransport in the Aaros river, 1988. Annual repartition, volume and density is shown together with discharge, measured at the station VM 2784 Aaros, 1988.

Ph of precipitation water and its annual repartition. Ph at the nearest measurement station, Lillestrøm, mean of 1987: 4.35
Repartition, figure 5.

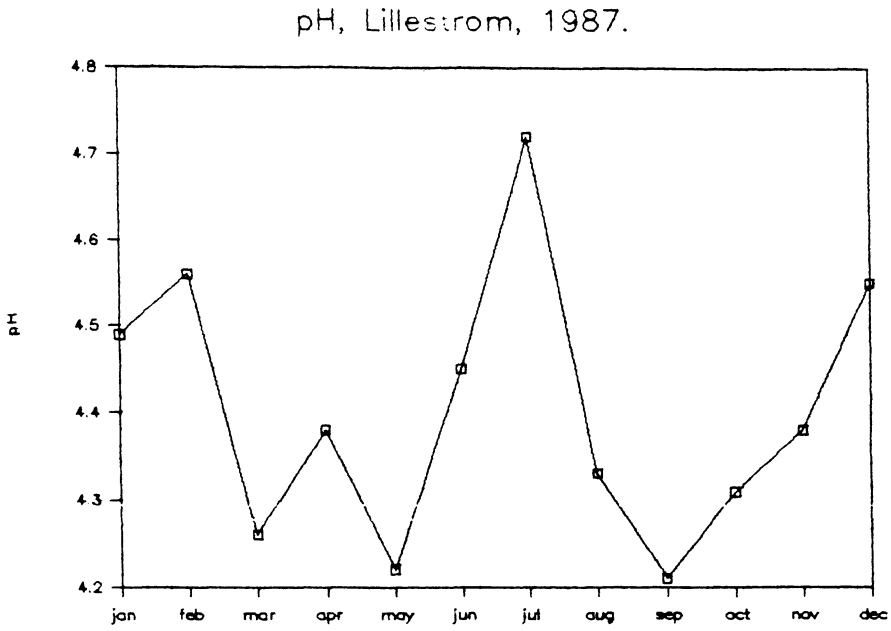


Fig. 5: Repartition of pH in precipitation wer measured at the nearest station, Lillestrom, 40 km northeast of the catchment. Monthly mean values, 1987.

- Water quality
  Classification the water quality of the river (main) following the national standards.

According to Norwegian Standard (NS) the quality of the water in the Aaros River does not satisfy the standard of a drinking water.

The agriculture, industry and built-up areas within the catchment area do not allow drinking water quality without a heavy investment and rehabilitation of the existing installations.

As the existing water supply is based on water sources outside the catchment area, a realistic future objective will be to obtain and maintain a good bathing water quality which also will satisfy the fishing interests and the environment all together.

2. SOCIO-ECONOMIC CONDITIONS

2.1 Demography

A considerable part of the active earners have their employment outside the catchment area, especially in nearby Asker village and Oslo town.

Nos. of active earners given in the table below are employments within the area.

	POPULATION number	
	1988	2000
Total population within the catchment	12,500	17,200
Population of towns/settlements	10,300	14,700
Rural population	2,200	2,500
Population living in zones exposed to inundation	1,000*)	50
EMPLOYMENT	ACTIVE	EARNERS
Industry	200	500
Agriculture	500	400
Other sectors	2,300	2,000
TOTAL	3,000	2,900

2.2 Economy

2.2.1 Industry

Within the catchment area there are only a limited number of local small industries which have no relevance to the GDP or GNP.

2.2.2 Agriculture, fishing and forestry

CHARACTERISTIC PRODUCTS	1988	2000
In natural units:		
Agriculture	9,000 t	7,000 t (open land crop production)
Fishing	230 kg	2,000 kg (Salmon and throut)
Forestry	21,000 m^3/year	21,000 m^3/year

2.2.3 Infrastructure

TRANSPORT FACILITIES	1988	2000
Length of railways, km	16	16
Length of roads, km (main roads)	62	70

2.2.4 Energy

ENERGY	1988	2000
Power generation Capacity, MW:		
Thermal	-	
Nuclear	-	
Hydro	0,11	0,11
Other	-	
TOTAL	0,11	0,11
Energy production within the catchment GWh/year:		
Thermal	-	
Nuclear	-	
Hydro	0,2*)	0,2
Other	-	
TOTAL	0,2	0,2
Imported energy from other territorries, GWh/year (hydro-electric energy)	175	175

The only local power station is mainly supplying part of a nearby hospital's concumption.

2.2.5 Public Water Supply

	1988	2000
Total length of the network, km (mains)	65	70
Population with public water supply, number	11,250	16,340
Share of the population with public water supply, %	90	95
Number of settlements with public water supply	7	7

2.2.6 Public Sewerage

	1988	2000
Total length of the sewage network, km (main)	57	62
Population served by public sewerage, number	9,800	15,480
Share of the population served by public sewerage, %	78	90
Number of settlements with public sewerage	7	7

3. WATER MANAGEMENT AND RIVER BASIN DEVELOPMENT

3.1 Meteorological and hydrological network in 1988

a.	Number of meteorological stations	0
b.	Number of precipitation gauges not included in a.	0
c.	Number of rain-water quality measurement stations	0
d.	Number of evapotranspiration measuring stations	0
e.	Water stage gauges	1
f.	Streamflow measurement stations	2
g.	Surface water quality sampling stations	1 permanent 7 temporary for water master plan

h. Water table observation wells 0

i. Aquifer observation wells 0

3.2 Regulation of water courses and water shed control

a. Length of regulated rivers and water courses, km 20

b. Ratio of regulated rivers, % 57

c. Protected areas against floods, km^2 0 Existing 0,22 Planned in water master plan

d. Protected area against floods in settlements, km^2 0 Existing 0,05 *) Planned in water master plan

e. Length of protection levels, km 0 Existing 13,8 Planned in water master plan

f. Length of drainage canal network, km 4*)

g. Drained area, km^2 8*)

h. Area of erosion control, km^2 0 Existing 0,22 Planned in the WMP

3.3 Fresh water use

DOMESTIC AND COMMUNAL FRESH WATER USE	$10^6 m^3$/ year	m^3/day mean	max	min
From surface waters (outside sources)	1.2	3,100	3,700	2,000
From ground water (cold)	0,004*)	10	15	5
From thermal water	-			
TOTAL	1,204	3,110	3,715	2,005

INDUSTRIAL FRESH WATER USE	$10^6 m^3$/ year	m^3/day mean	max	min
From surface waters (Aaros River)	2.0	5,440	8,640	0
From ground water (cold)	-			
From thermal water	-			
TOTAL	2.0	5,440	8,640	0
FRESH WATER USE F AGRICULTURE AND FISHERIES				
From surface water (Aaros River)	0.13	6,500	13,000	0
From ground water (cold)	-			
From thermal water	-			
TOTAL	0.13	6,500	13,000	0
FOR OTHER PURPOSES				
From surface waters	-			
From ground water (cold)	-			
From thermal water	-			
TOTAL	-			

IRRIGATED LAND	
Traditional irrigation, ha	2,000
Sprinkling irrigation, ha	-
Drip irrigation, ha	-
TOTAL, ha	2,000

Total water surface of fishing ponds, 0

HYDRO-POWER PLANTS			
NAME AND SITE	CAPACITY, MW	MAX. HEAD, m	TYPE AND NUMBER OF TURBINES
Dikemark hydro-power plant, Asker	0.11	15	Low pressure Francis No 1

DAMS AND STORAGE FACILITIES					
Name, site and pupose(s)	Dam			Reservoir	
	Height m	Length m	Type	Capacity $10^6 m^3$	Surface km^2
Verkensdam multipurpose	4	40	Concrete stones	1	1
Kistefossdam industry	10	20	Concrete stones	0.4	0.5

3.4 Waste water disposal

REJECTED WATER	MEAN ANNUAL VOLUME $10^6 m^3$	MAXIMAL DISCHARGE m^3/s
To surface waters (Aaros River)		
• Only "heat polluted"	-	
• Domestic waste water	0.6	0.046
o untreated	0.3	0.023
o only mechanically treated	0.3	0.023
o biologically treated	-	
o having tertiary treatment	-	
• Industrial waste water (Aaros River)	0.004	-
o untreated	0.002	-
o only mechanically treated	0.002	-
o biologically treated	-	
o having tertiary treatment	-	
To ground water		
• only "heat polluted"	-	
• domestic waste water	0.2	0.014
o untreated	0.1	0.007
o only mechanically treated	0.1	0.007
o biologically treated	-	
o having tertiary treatment	-	
• Industrial waste water	-	
o untreated		
o only mechanically treated		
o biologically treated		
o having tertiary treatment		

Approx. one half of the waste water is transported out of the area to the two nearby treatment plants.

3.5 Waste water treatment

Both of the treatments plants are located outside the catchment area.

WASTE WATER TREATMENT PLANT	NUMBER	CAPACITY 1000 m^3/day
• For domestic waste water only	-	
• For domestic and industrial waste water	2	33.2
• Only for industrial waste water	-	
TOTAL		33.2

WASTE WATER TREATMENT CAPACITIES	x 1000 m^3/day
Biological treatment	-
Tertiary treatment	33.2

3.6 Water resources protection

Description of special measures and laws on water quality protection concerning the catchment area.

WATER TARIFFS	
ANNUAL MEAN PAYMENTS FOR WATER USE IN NATIONAL CURRENCY BY	
Population	4.2 mill NOK (Norwegian kroner)
Industry	0.2 "
Agriculture	-
Others	-
TOTAL	4.4 mill NOK*)

FINES (POLLUTION)					
FINES PAID IN NATIONAL CURRENCY BY	IN 1984	1985	1986	1987	1988
Population or sewage works	----------				
Industry	----------				
Agriculture	----------				

There has up to now been no organization of preparedness for accidental water pollution. The Governmental Pollution Control (SFT) has the running control with water quality and pollution.

4. RELATION BETWEEN THE CATCHMENT AND ITS NEIGHBOURING ENVIRONMENT (NATIONAL)

- Description of administrative units. The catchment area is divided in three rural districts which have the responsibility for their part of the area.

  The next superior to the rural districts is the county in connection with the water management.

- Economy: Main factors of export-import of the catchment.

  The area is of a small extend with a very limited industry production and agriculture.

- Description of trends in demographical movements.

  The main trend compared to the past is the consentration of built-up areas instead of scattered houses. Another trend is people from outside moving into the area maintaining their employments in the nearby Oslo town.

- Water management, inter-basin transfer: Due to the scarce resources and poor quality of the water within the catchment, most of the drinking water is transferred from neighbouring areas.

  From Holsfjorden
  To Aaros Catchment Area
  → $1.2 \times 10^6 m^3$/year

5. THE INTERACTION BETWEEN WATER MANAGEMENT AND SOCIO-ECONOMIC ACTIVITIES

Reliability of meeting water demands

WATER DEMANDS	$10^6 m^3$/year 1988	2000
• Domestic	0	0
• Industrial	0.27	1.0
• Agricultural (unknown, multi-annual mean is used)	0.13*)	0.33
• Other	0	0
Balance of demands and resources:		
• Demands	0.4	1.33
• Resources	75.4	54 (multi annual mean)

- Description of actual or foreseen conflicts due to scarce resources or water quality problems:

  The actual conflicts have so far been the use of water for irrigation and industrial purposes compared to a necessary low flow in the river which is promoting the fish breeding, fishing activities and general outdoor life in the area.

  Reduced low flow is also a problem due to poor dillution of the pollution which is drained into the river.

  In the future a reduced use of water supplying the industry is expected. However, the increasing irrigation is still a foreseen conflict due to the scarce resources and will automatically lead to a poorer water quality.

- Problems and solutions of flood protection:

  Some parts of the riverbed and flat nearby areas are flooded more than once a year. The poor natural possibilities to reduce flows and the hilly area is resulting in fast and heavy floods.

  Plans for flood protection are prepared in more alternatives all in-cluding dam construction, straightening and lowering of the river bed and protection leeves.

- Public involvement in decision making concerning management (e.g. dam construction):

  The different alternatives for flood protection are all involving a lot of money so the choise of solution and to make the necessary money available, has to be a political decision.

- Evaluation of the implication of existing master- or other water management planes (if any), since 1960. Description of new ones.

  So far no complete plans are prepared.

  A Water Master Plan for the Aaros River is just about to be completed (summer 1989). The content of the WMP is as follows:

  1. Introduction
  2. Summary
  3. Organization and account
  4. Summary of scientific reports
  5. Plan assumptions and juridical aspects
  6. Description of the watercourse
  7. Conflicts within the watercourse
  8. Objectives
  9. Alternative solutions for improvement (water-flow, water-quality and environment)
  10. Recommended alternative and construction costs
  11. Follow up of the WMP
  12. Other plans in the area

  The WMP is based on eight scientific reports and three descriptive reports, one from each of the three municipalities/rural districts.

Scientific reports:

- Hydrology
- Agriculture
- Erosion and sediment-transport
- Geochemical investigations
- Biological activities (bottom)
- Fish biological investigations
- Pollution
- Flood protection

6. INTERNATIONAL CO-OPERATION AND THE CATCHMENT AREA

The whole catchment area is located in Norway far away from the borders to neighbouring countries. There is no international co-operation within the catchment.

7. THE NORWEGIAN WATERCOURSE ARCHIVES

In the following pages there is a short introduction of the Norwegian Watercourse Archives.

Using the archives

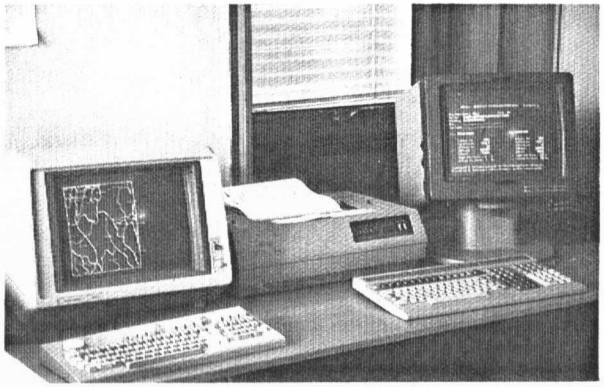
The Watercourse Archives will be an important tool for water management and hydrological research, constituting in effect a reference library which will greatly simplify information retrieval.

The archives is intended to serve watercourse information consumers, such as scientists and managers. Subscribers receive a user definition and the contents of the archives are available on diskette/magnetic tape. (It is possible that the entire system may eventually be accessible on-line.) One condition for rational use of the archives is that the users are equipped with the necessary software.

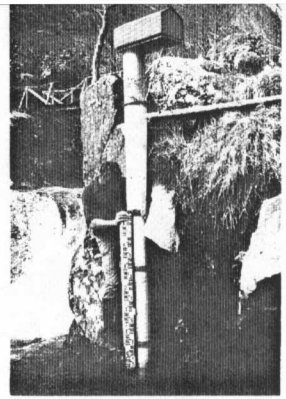
The system allows users to:

- *retrieve information from the data base*
- *use the classification system for geographical identification of hydrological data*
- *build up their own registers using REGINE as a core*
- *update the files of the central watercourse registers*
- *make suggestions regarding further subdivision of REGINE in areas where such needs may arise. However, the authorization to actually implement such suggestions must be decided centrally.*

Short courses in how to use the Watercourse Archives will be offered. Map folios will be produced for the various areas, using a variety of cross-sections and scales.

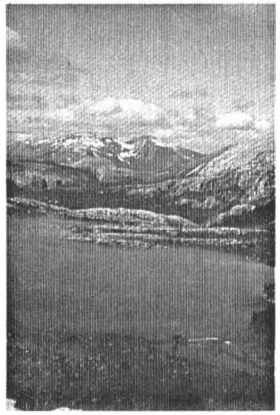


Report



Station

Encroachments



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Water Resources Directorate

The Norwegian Watercourse Archives

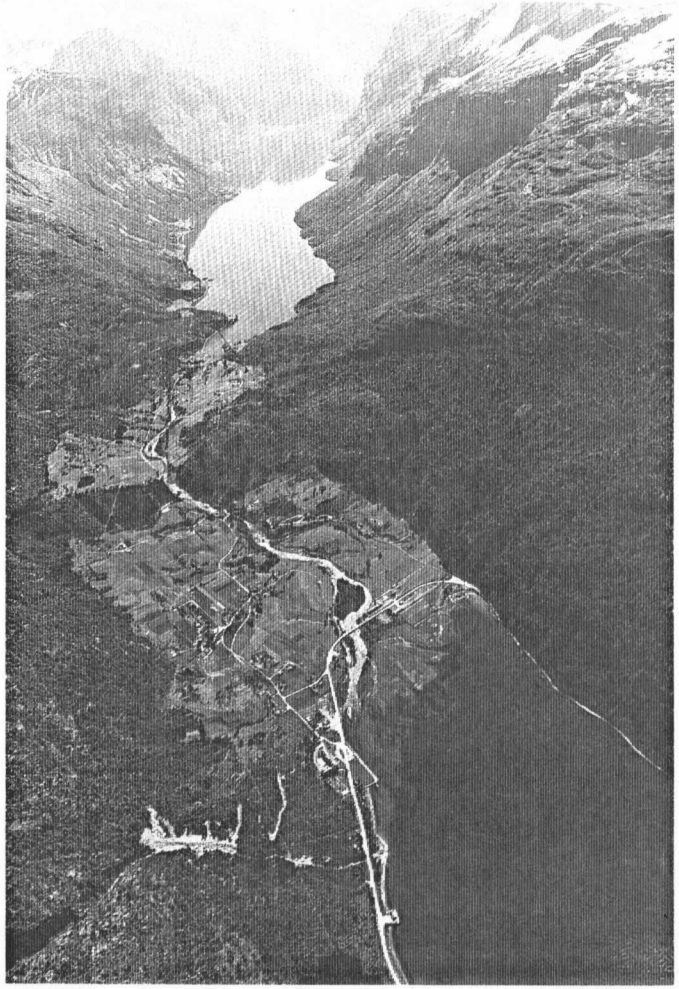


Photo: Fjellanger Widerøe

The Norwegian Watercourse Archives is a national information system which will eventually contain a **complete survey** of the information available about Norwegian watercourses and drainage basins.

References to information concerning watercourses and drainage basins are now being collected and systematized: The archives specify where information is found, who has it, how old it is, the form in which it is available, etc. **Special key information** about drainage basins is also being gathered, as is information concerning various watercourse-related objects.

The archives comprises a number of files, organized in a data base. Thus far the following files have been or are being developed.

REGINE "Register of drainage basins". Norway is divided into a number of catchment reference areas (units). Geografical information is recorded about each unit.

The units are identified by catchment reference numbers.

Report Reports in connection with watercourses.

Station Data series in connection with watercourses (hydrologi, meteorology, water quality, etc.)

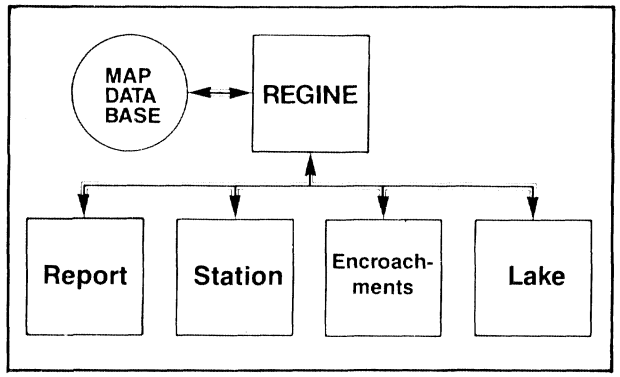
} Reference files based on geographical data, date/period and/or subject indexes.

Encroachments

Technical disturbances in watercourses (hydropower development projects, construction of river protection systems, water supply, sewage treatment, agricultural irrigation, etc.)

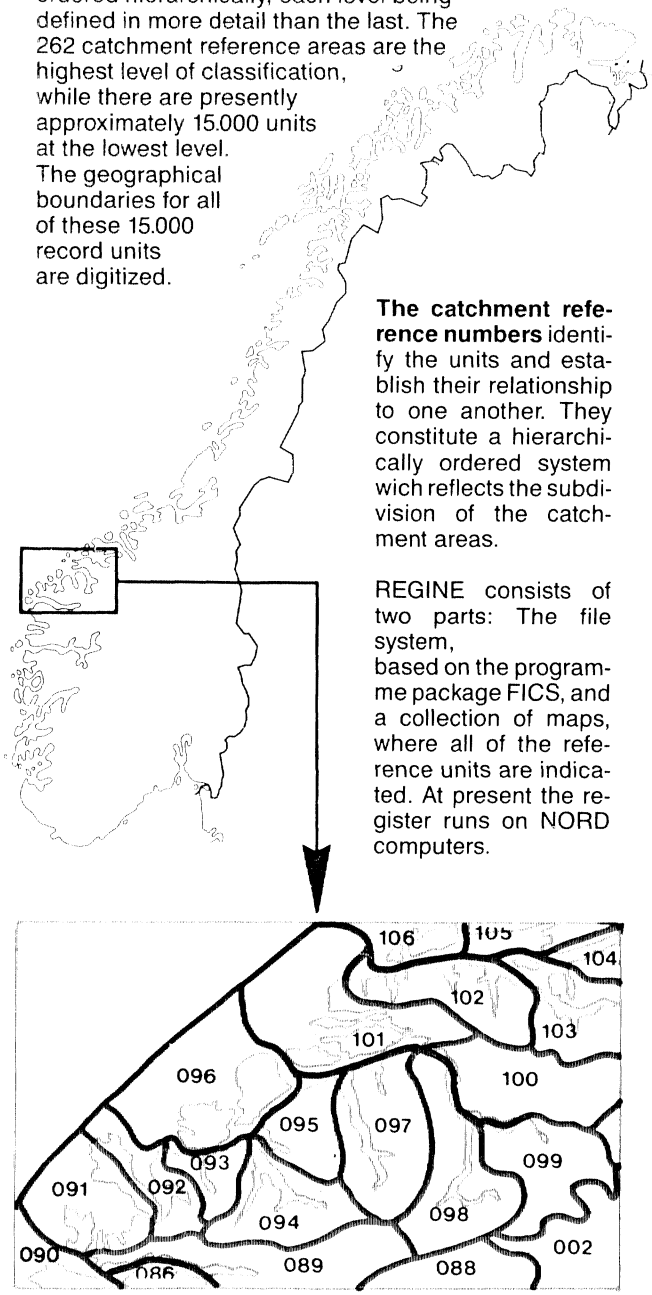
Lake Area, depth, altitude over sea level.

} Object file using area and object data as criteria.



REGINE - The classification system

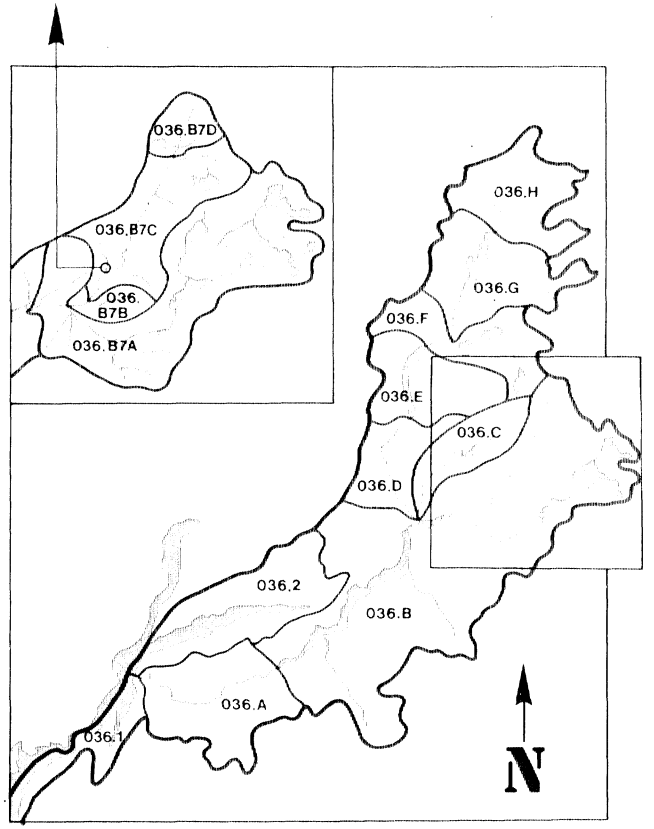
The classification system reflects the structure of the hydrological system - the referencing unit is the **catchment area**. The subdivision of catchment areas is ordered hierarchically, each level being defined in more detail than the last. The 262 catchment reference areas are the highest level of classification, while there are presently approximately 15.000 units at the lowest level. The geographical boundaries for all of these 15.000 record units are digitized.



The catchment reference numbers identify the units and establish their relationship to one another. They constitute a hierarchically ordered system wich reflects the subdivision of the catchment areas.

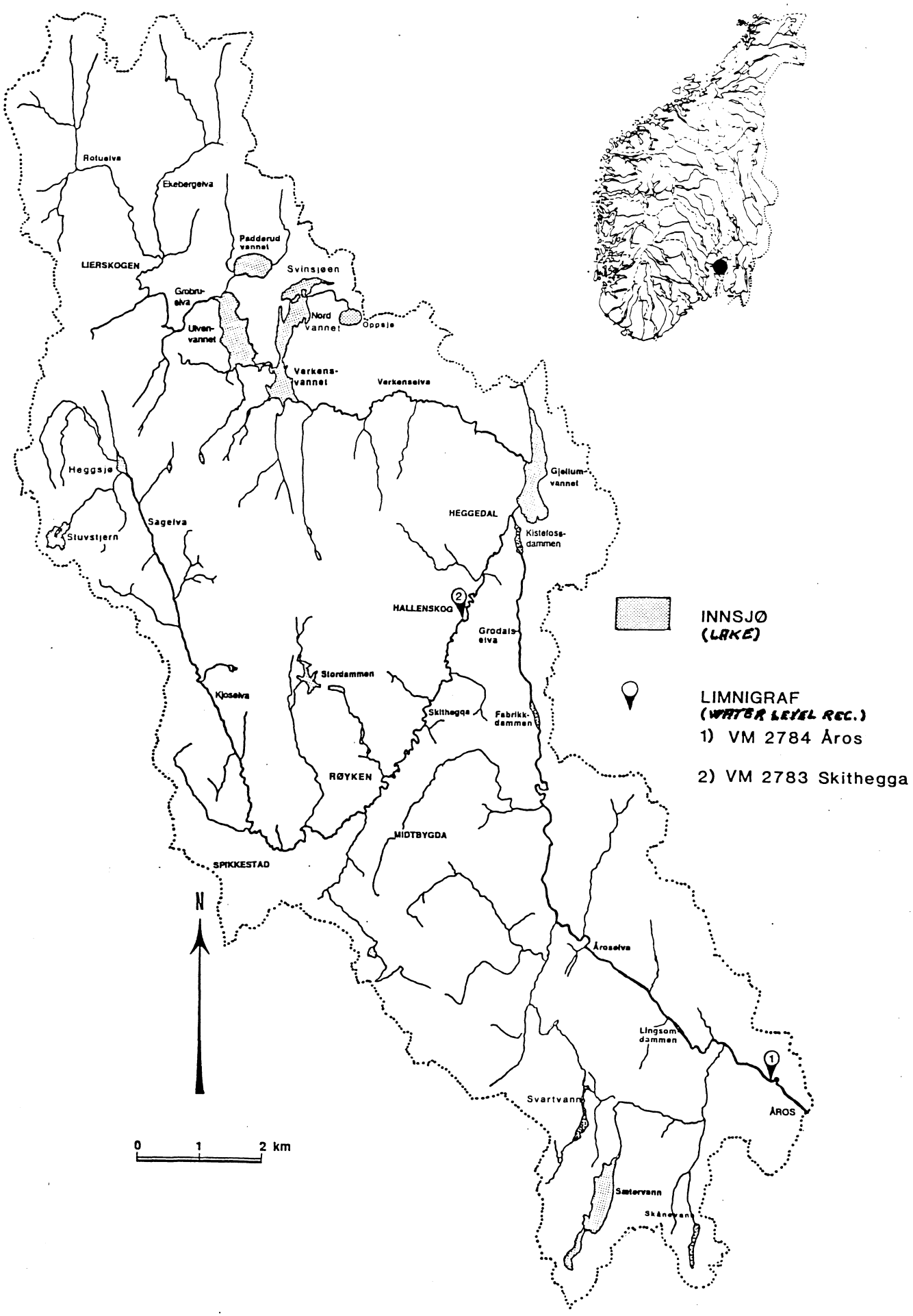
REGINE consists of two parts: The file system, based on the programme package FICS, and a collection of maps, where all of the reference units are indicated. At present the register runs on NORD computers.

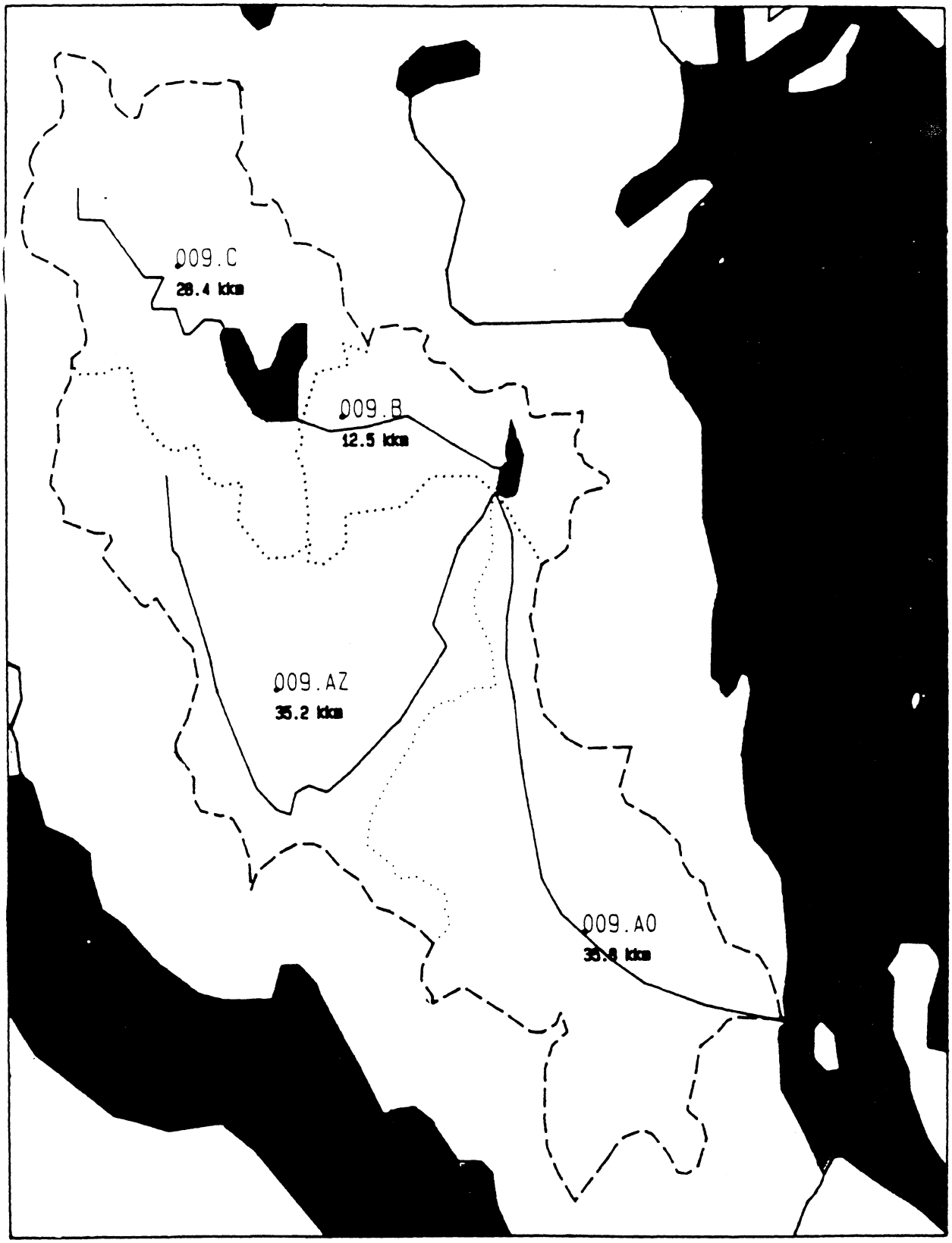
An area of the Flesåna, near its confluence with the Kvanndalsåna, a subsidiary catch ment area of the River Suldalslågen in North Rogaland County. Several sections of REGINE's classification of the area are shown on the maps below.



ANNEXES

General lay-out of the catchment area





The Aaros River Catchment with reference numbers and area all digitized. (The Norwegian Watercourse Archives).

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