United Nations Educational, Scientific and Cultural Organisation

International Hyrological Programme III

Project 6.1 The use of representative and experimental basins for monitoring natural and man made changes in the various hydrological regimes

Flow Regimes from Experimental and Network Data

F R E N D

Steering Committee Meeting

3 - 6th April 1988

Koblenz, FR Germany

FREND Steering Committe Meeting

Koblenz, F.R. Germany, April 6-8 1988

Present:

Dr N.W. Arnell	Mr H. Lumadjeng
Mr E. Berntsen	Mr G. Oberlin
Dr S. Demuth	Ms M. Polarski
Dr A. Gustard	Mr L. Roald
Dr K. Hofius	Dr M.I. Rusinov
Dr A. Kapotov	Dr P. Warmerdam
Dr H. Liebscher	

Addresses in Annex 3

1) Dr Liebscher opened the meeting by welcoming the Steering Committee to Koblenz.

2) Dr Rusinov welcomed the group on behalf of UNESCO and distributed copies of the proposed draft plan for IHP-IV. He summarised the significance of the FREND project within IHP-III.

3) Dr Gustard was elected as Chairman

4) The agenda was adopted.

5) The minutes of the last meeting in Norway in 1987 were agreed.

6) All of the matters arising from the minutes were covered in the present agenda.

7) Progress Report (appended)

Dr Gustard summarised the contents of the Progress Report, emphasising that a conscious decision had been made to keep the Report brief. The project scientists then gave short presentations:

Dr Demuth described his work on the analysis of data from small

research basins. He had been calculating measures of baseflow and recession and relating them to catchment characteristics, looking particularly at methods of standardisation, the use of different time periods and groups of catchments. There was some discussion about the incorporation of land use data in the catchment characteristic data set, and Dr Demuth explained that unfortunately consistent data were not available for all catchments. Dr Demuth's contract expires in July, so he will spend one month more on analysis before writing up the results.

Mr Roald described the progress with the flood analysis, which had involved the identification of groups of catchments with similar flood behaviour and the investigation of catchment characteristics discriminating between groups. He had also studied the timing of floods and, in some areas, the relationships between snow and rain floods. Mr Roald explained that all the small catchments in his data set were research basins. Dr Arnell then outlined some preliminary work on recent trends in flood magnitudes in the FREND area.

Dr Gustard explained that the low flow studies had involved both regional investigations into low flow behaviour and catchment characteristics, and the development of low flow analysis techniques. He outlined the results from some investigations into the relationship between low flow indices and soil characteristics, and described a new technique for estimating low flow measures at ungauged sites based on the river network rather than catchment area. Ms Polarski then briefly described her work with low flow estimation in Belgium and procedures for fitting a 3-parameter Weibull distribution to annual minimum flow data.

Mr Lumadjeng presented a summary of his work on some human influences on flow regimes. He has investigated the effects of groundwater drawdown on soil moisture levels and evaporation using the MUST model, and has extended his studies to Hupselsee Beek in the Netherlands. He confirmed that he is no longer using the SHE model, due to difficulties with both using the model at small scales and inconsistencies in the calibration. Mr Lumadjeng also mentioned studies at Wallingford into the effects of land drainage. During the discussion Dr Gustard pointed out that 'human influence' in general terms is very difficult to study and noted that previous meetings had agreed that only some human influences could be

studied. He outlined future work using a simple conceptual runoff model which would, when run with different interception storages, provide a link between studies of human influence, low flows and small research basins.

8) Final Report

Dr Gustard, Dr Demuth, Mr Roald and Mr Lumadjeng summarised the proposed contents of the final report, as given in Annex 1. Discussion of the contents focussed on two issues, namely data quality and final recommendations. It was suggested that the final report would include an evaluation of the quality of the network and research basin data used in the study, and during the discussion the project team explained that this would be difficult due to a lack of detailed information about the gauging stations and the inherent problems of data collection in some environments. However, the team will be able to list the stations used for each part of the project and will emphasise that research basin data are not necessarily much better than network data. The discussion over the final recommendations concerned those that would be made in addition to the scientific recommendations. It was agreed that these should make reference to the links between the FREND project and other international projects (such as the French network of research basins and the WMO World Climate Program), about the experiences gained in running the FREND project, and, more practically, about research basin management and the availability of research basin data.

The Project Team expect that Volume 1, containing the research results, and Volume 2, containing data, will have approximately 250 pages each. Volume 3 will be the literature survey of human influences on flow regimes (Item 9), and will be between 80 and 100 pages long.

Dr Rusinov suggested that the UNESCO Technical Document series was appropriate for the FREND Final Report (the Studies and Reports series is more expensive and takes longer to approve and produce), and the Report can be produced and bound in UNESCO covers at Wallingford. UNESCO have already allocated $4000 for preparation of the Final Report, although this also includes an allowance for the literature review (Item 9). Dr Gustard explained that the UK will probably be able to provide approximately £2000, and Mr Berntsen expected to be able to react positively to a request for

funding. Estimates for production costs range from £5000 to £20,000 (with the upper value representing a very high quality report), and costs cannot be offset by sales because UNESCO Technical Documents must be distributed freely. Dr Gustard will prepare and circulate a detailed proposal.

9) Literature Survey

Dr Demuth outlined the proposed structure of the literature survey of human influences on hydrological processes (Progress Report item 5). UNESCO have allocated funds for a consultant to prepare the survey (Item 8 above), who will be found and appointed by the Project Team. The review will be strongly based on - but not limited to - reviews received by the Project Team. Dr Warmerdam presented the Dutch review at the meeting, and Mr Oberlin presented some relevant papers from France. Mr Roald will prepare some papers from Norway, and the review from F.R. Germany is expected soon. Dr Kapotov informed the meeting that the review from the Soviet Union will be ready soon.

10) FRIENDS conference

The first circular for the FRIENDS conference in Norway in April 1989 has been circulated. A second circular will be drafted and sent during the summer. Abstracts will be submitted to the local organising committee who, together with Dr Gustard, will select the papers to be presented. Copies of the abstracts will be circulated to Steering Committee members for their comments. The decisions of the local committee concerning the selection will be discussed with the Steering Committee at an informal meeting to be held on June 21 in Paris during the Intergovernmental Council meeting of the IHP.

The Norwegian IHP Committee will cover the conference costs not met by the registration fee, and will publish the proceedings. IAHS have been asked informally to fund one person's attendance at the conference, and the UK has submitted a proposal for the funding of four participants (assistance will be given to participants from the developing world). It is too late for funds for the running of the conference to be provided by UNESCO, but Dr Rusinov informed Mr Berntsen that the Norwegian IHP Committee could apply for funds to support participants from developing countries. He also suggested partial funding as a means of supporting more

people.

Two possible structures for the conference emerged during discussions. One involves all the FREND participants speaking on the first day, whilst the other has one FREND member presenting the first paper - approximately 40 minutes long - each day, with the rest of the day devoted to that theme (floods, low flows, management of international projects, etc). Steering Committee members agreed to provide names for the convenors of each session.

11) FREND data base

Not all of the countries included in the FREND project area have responded to the request for guidance on the release of data collected during the FREND project. The Committee felt that the FREND data archive was an important result of the FREND project, and agreed that people requesting data should first obtain written permission from the National IHP committees of the relevant countries (who would then ask the agencies supplying data). It was recognised that the FREND data archive will soon be several years out of date. The data base will be transferred to Norway, F.R. Germany and the Netherlands, and these, together with Wallingford, will deal with data requests.

Dr Liebscher described the data base held by BfG in Koblenz for the WMO World Climate Program. It may be possible to incorporate the FREND data into this archive.

12 b) European Network of Research Basins

Mr Oberlin briefly described the new European network of research basins, which has developed from a French initiative following a Council of Europe discussion on scientific collaboration between laboratories. The basic idea is of a club of research basin managers, providing a forum for the exchange of information and experience. At the heart of this club is a proposed inventory of research basins, describing, for example, their equipment and objectives. The inventory is currently being developed in France on a PC using the ORACLE data base, and Mr Oberlin hopes to use the French inventory as a model for other countries. Mr Oberlin envisages a 'distributed' archive, with each country (in Europe and the Mediterranean

basin) holding an ORACLE-based archive of it's own research basins. A meeting is planned for the autumn in Perugia, Italy, to discuss more fully the development of the inventory. Dr Gustard noted that if the network had existed three years ago the job of the FREND team would have been much simplified (the first version of the French inventory was in fact used to help select research basins in France)! Mr Oberlin's network will be supported in the FREND final report.

a) FREND 2

Three proposals for a 'FREND 2' project are given in Annex 4. There was unanimous support for such a continuation, and the consensus amongst the Committee was that the first proposal - involving further analysis of FREND data and an extension of the project area to the east and south - was the one which built most closely on FREND expertise. Further analysis of the FREND data base was necessary, and would provide a sound platform for further developments. Dr Kapotov informed the Committee that data from the Soviet Union and eastern Europe should soon be available in a form allowing easy transfer. There was also strong support for the third proposal - studying water quality of rivers entering the North Sea - but the Committee felt that at present the FREND project did not have the appropriate experience. Nevertheless, the project was seen to be important, and could run in parallel with a more straightforward extension of FREND, using the regional expertise gained so far. The second proposal - to study water resources and climatic change in southern Africa - was less well supported by the Committee, who felt it to be too different from FREND 1, but it again could benefit from the experience of the project team.

Dr Rusinov drew the Committee's attention to the draft program for IHP-IV, and there was some discussion about the proper place for a FREND 2 within this draft. It was felt by the Committee that both FREND 1 and FREND 2 would fit into Theme H-5 (Hydrological problems of specific regions), and it was agreed that Mr Berntsen and Dr Gustard would submit to UNESCO new wordings for Project H-5-4 to cover the proposed new projects. The description of 'previous activities' under Theme H-5 could also be changed to make reference to FREND 1.

13) IHP Intergovernmental Council Meeting, June 1988

13) IHP Intergovernmental Council Meeting, June 1988

The FREND project must be described at the IHP Intergovernmental Council meeting in Paris in June 1988. Mr Roald will attend the meeting as a FREND representative, and Dr Gustard may be able to attend also. The formal presentation of the FREND project will be made by Dr Liebscher and a short two page summary of the project will be prepared. The Steering Committee will hold an informal meeting in Paris on June 21 (see also Item 10) to discuss the presentation and the draft plan for IHP-IV, as well as the FRIENDS conference.

14) Steering Group Meeting, November 1988

The Steering Group will next meet in Paris, on a date at the end of November to be determined. The meeting will last two days. A draft of the Final Report will be circulated to Steering Group members one week before the meeting.

15) Any Other Business

It was suggested that the Steering Committee would meet during (or perhaps just before or after) the FRIENDS conference in April 1989. This will be confirmed at either the June or November meetings in Paris.

Dr Gustard then closed the meeting by thanking Dr Liebscher for his hospitality.

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International Hydrological Programme III

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Flow Regimes from Experimental and Network Data

F R E N D

PROGRESS REPORT I

MARCH 1988

CONTENTS

FREND PROGRESS REPORT MARCH 1988

1. Introduction

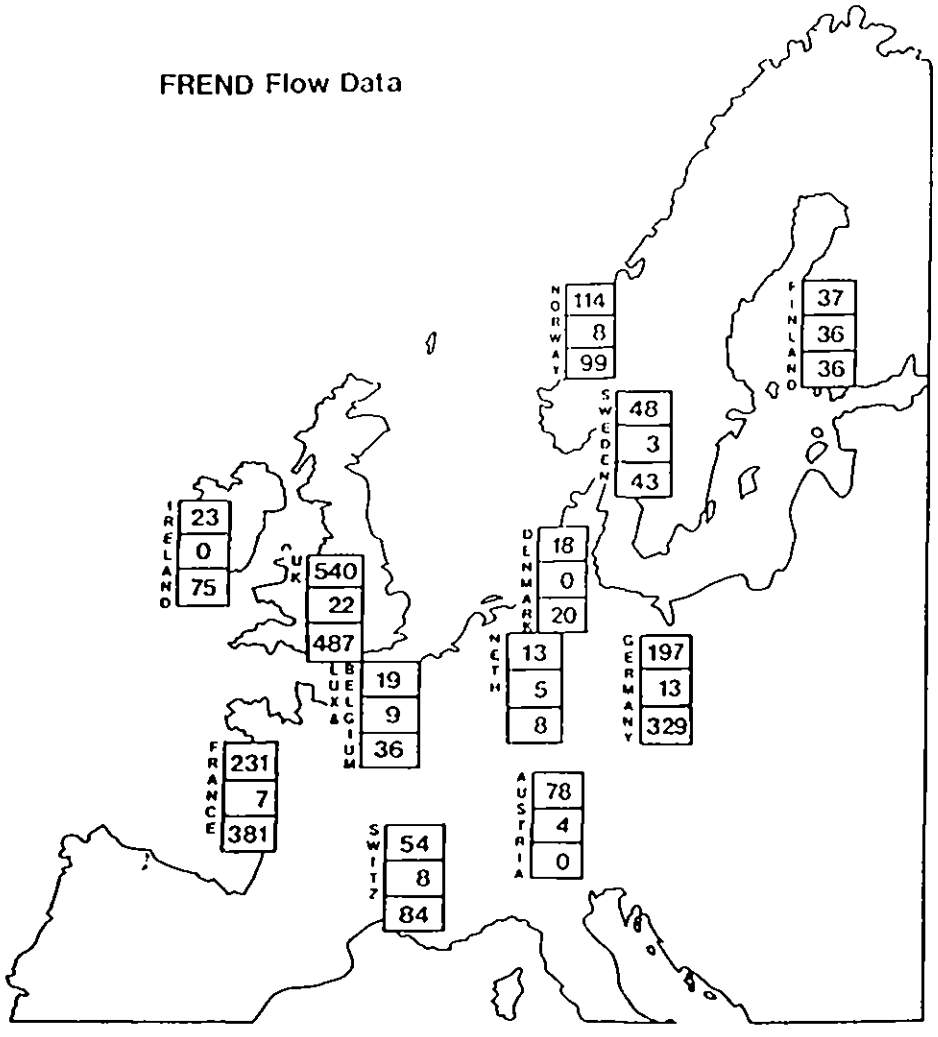
The last meeting of the Steering Committee was held in Ustaoset, Norway, in September 1987. Since then the FREND catchment characteristic database and the suite of analysis programs have been completed. Work in the area of low flows continues with studies of the annual minimum flow series, the relationships of catchment soil type to flow regime, and a new initiative in using stream networks as the basis for calculating catchment characteristics. These regional low flow studies have been supported by Marianne Polarski who joined the project team for seven months on secondment from the University of Gembloux, Belgium. More detailed investigations in relating catchment properties to low flow measures is nearly complete for the network of small research basins. In flood studies, more work has been done to obtain homogeneous groups of stations and to relate the mean annual flood to catchment characteristics. Further modelling work has explained differences in calculated results using the MUST model, and work will continue on a new method to simplify river-aquifer interaction in groundwater models.

2. FREND Database

The complete FREND flow database, subsequent to quality control checks, is summarised in Figure 1. From these records a number of flow statistics have been calculated, including base flow index, mean annual minimum, 95 percentile flow and recession constant.

The gridded database, covering a large part of the study area, is now also complete, containing data on rainfall, two-day 10-year return period rainfall and stream frequency on a 2.5 km grid, and 1.25 km grid data on forest, urban, lake and hydrological soil type. This data has been used to

calculate catchment characteristics for the entire data set, and for the small research basins a number of additional characteristics have been calculated.



TOTAL	STATIONS
LOW FLOW CATCHMENTS	1372
RESEARCH CATCHMENTS	115
FLOOD CATCHMENTS	1598

Figure 1

3. Analysis

3.1 Small Research Basins

Studies of small research basins have concentrated mainly on completing the FREND database by adding rainfall from 58 stations and establishing relationships between low flow measures and catchment characteristics. From about 115 research basins daily flow data and basin properties such as area, shape, median altitude, drainage density, river length, river slope and bifurcation ratio are available. The range in catchment size, between 0.06 and 300 km^2, is quite considerable.

For the research basin dataset the baseflow according to Kille[1] and the recession constant based on a newly developed modified recession analysis has been evaluated and the two parameters are available now for both a given period and a selected period of 1970 - 1980. The database was then split into three main groups. The criteria used were based on the rainfall pattern in the catchments (the altitude - rainfall relationship). A multiple regression model of the form

$$Y = f(X, Z, K)$$

with

Y: flow parameter
X: basin properties
Z: soil index
K: climatic parameter

has been applied to all groups using both baseflow and recession constant as predictor. Two different ways of standardising the baseflow and the effects on the multiple regression model have been investigated. Further work will concentrate on looking into the role of time in the regression model. For all groups, empirical equations were found.

[1] Deutsches IHP/OHP-Nationalkomitee, 1985. Empfehlung fur die Auswertung der Messergebnisse von kleinen hydrologischen Untersuchungsgebieten. Heft 5.

3.2 Flood Analysis

The FREND archive contains series of annual instantaneous flood maxima from 1598 stations. The series are, with a few exceptions, fairly short, the average length being about 18 years. A regional approach to the analysis is therefore necessary.

The main objective of the analysis is to identify groups of stations for which the underlying standardised flood frequency distributions may be assumed to be identical. If such groups can be found, classification criteria will be derived based on catchment characteristics.

Following the approach by Wiltshire[1](1986) the data space defined by the mean specific annual flood QBARSP, and the coefficient of variation CV, of the flood series is partitioned into a number of groups by non-hierarchical cluster analysis. For each group, regional flood frequency distributions are fitted by the index method. The EV1, GEV and Wakeby distributions are fitted using the probability weighted moments method. For each group the Wiltshire R-test is applied to test the homogeneity. Using discriminant analysis, criteria are established from various catchment characteristics. Relationships between the mean annual flood QBAR and catchment characteristics are established by multivariate regression analysis.

At the last Steering Committee meeting the results of a partitioning of the data into five groups was presented. These groups were later found to be highly heterogeneous. The discriminant analysis resulted in good criteria for classifying four of the five groups from catchment characteristics. One problem with cluster analysis was the occurrence of outliers in the data space, which led to groups of very different sizes. By removing these outliers prior to the analysis, more equal sized groups were found. The analyses have been repeated for 10, 15 and 20 groups. By increasing the number of groups, homogeneous groups appeared. The outliers were grouped in smaller groups without a marked influence on the partitioning of the majority of the stations. Regardless of the number of groups, some groups are still heterogeneous according to the Wiltshire R-test. Relationships between catchment characteristics and QBAR have been established for the

entire data set as well as each of the five and ten groups. More analysis will be done to consider the influence of lakes and urban runoff which affects a minority of the catchments. A study using the longer flow series is investigating the dependency of the flood moments on the record length using 'slice analysis'. The analysis is performed for 10, 20, and 30 year 'slices' of data.

[1] Wiltshire, S.E., 1986. Regional Flood Frequency Analysis II: Multivariate classification of drainage basins in Britain. Hydrological Sciences Journal 31, 3, 9. pp335-346

3.3 Low Flow Studies

The relationship of flow regime to soil type is being investigated now that the percentage of each of the five hydrological soil types has been calculated for all the digitised catchments in the study area. These values have been used in stepwise regression analyses to find relationships with flow statistics. Initial investigation showed that of the four low flow measures considered (10 day 95 percentile flow, 10 day mean annual minimum, recession constant and base flow index, BFI) BFI showed the highest correlation with soil type, and resulted in the most significant regression equations. Studies were subsequently confined to the relationship between BFI and catchment characteristics.

A summary of the analyses, including parameters of the best regression equation and the percentage variance thus accounted for, is given in Table 1.

Analysis of catchments grouped by country showed very poor results for the Netherlands, France and West Germany. In the case of France and West Germany, significant improvements could be made by further grouping catchments on the basis of annual rainfall and analysing these sub-groups.

Table 1

Summary of soil regression analysis results

REGION	NO. STATIONS	PARAMETER COEFFICIENTS Const.	S1	S2	S3	S4	S5	% VARIANCE ACC FOR
Denmark	18		.89	.61	.61			81.5%
U.K.	501	.89		-.30	-.42	-.49	-.54	59.7%
France	224	.67		-.17	-.19	-.09		13.5%
West Germany	248	No significant result						
Belgium	19	.58	.18					31.4%
Netherlands	13	No significant result						

Daily flow data for about 30 extra Belgian stations has recently been obtained for a study of the relationships between low flows and catchment characteristics in Belgium. In addition, a hundred stations located around Belgium have been selected in order to extend the data set for analysis.

65 stations with more than 50 years daily flow data and less than 500 km^2 in area have been selected from the FREND archive in order to fit a three parameter Weibull distribution to the flow frequency curves derived from these data. Results will be compared to those obtained from a two parameter Weibull distribution, and the relationships of the parameters of the distribution with flow duration and with catchment characteristics will be investigated.

Traditional procedures of estimating a variety of low flow measures at numerous ungauged sites often burden water resource planners with the time-consuming exercise of first calculating catchment characteristics from thematic maps and then applying values to appropriate equations. A pilot study has sought to minimise the required effort in low flow estimation by integrating gridded data bases of relevant catchment characterisics with a digitised network of the natural drainage channels. By inputting the co-ordinates of the site of interest estimates of catchment characteristics are derived from the correlation of the stream network above the identified point with the gridded data bases. An algorithm has been developed which first

identifies those 1 km^2 grid squares upon which the stream network is imposed, and second, interpolates between sampled grid squares to approximate the natural basin planform. The numerical values associated with the total set of sampled grid squares are then utilised in the calculation of catchment characteristics. This method has been applied to the calculation of catchment area, average annual rainfall and proportional soil indices.

Figure 2 demonstrates the planform of the grid squares sampled by the described method, and compares estimates of catchment characteristics calculated from the digitised stream network with those in which the natural catchment boundary was known.

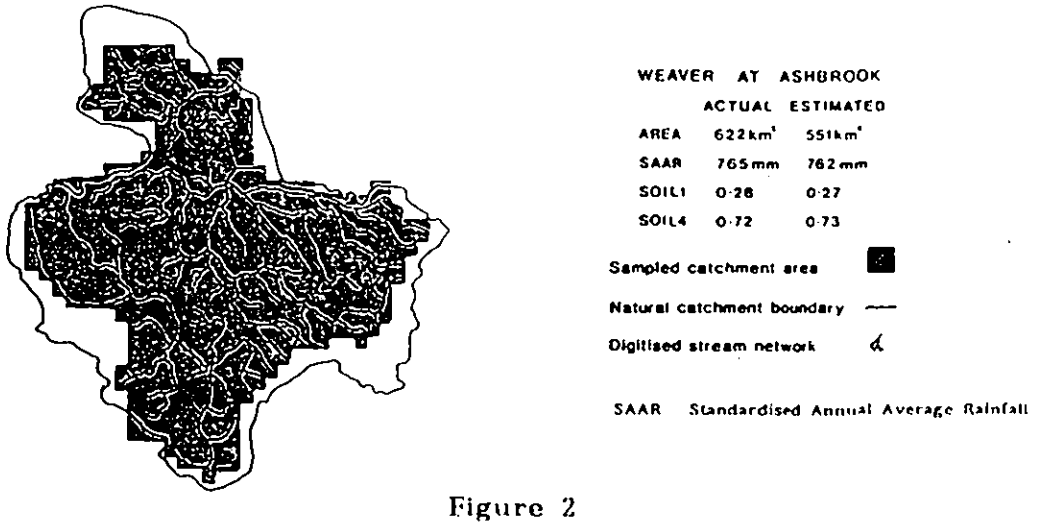


Figure 2

Natural and estimated catchments superimposed on the digitised river network (see text).

3.4 Modelling Human Impact

The application of the MUST model using data from the Yarnton site (Oxford) to study the effect of groundwater table drawdown on the soil moisture condition and evaporation has shown a relatively large difference in evapotranspiration calculated using the model and that provided by the Penman-based calculation (Nass[1] 1987). The MUST Ep for the summer half year of 1985 is 373 mm while the Penman evapotranspiration for the same period is 507 mm. The values for 1986 are respectively 443 and 555 mm. A further study of these differences revealed that the data for the fraction of sunshine duration were faulty (suspected), and the use of different methods has explained more than 11 % of the discrepancies. This range of differences

is widely acceptable in practice, as the formulae are empirically derived (J.B. Stewart and H.A.R. de Bruijn, personal communication).

Calculations are still in progress in an attempt to estimate the impact of the 1976 situation where the soil moisture is expected to be most sensitive to a drawdown in groundwater table.

A well known problem in the application of a physically-based model in a regional and/or water resources study is that there are a large number of parameters to be calibrated and they are usually unknown.

Another problem is the conflict between the 'micro' and 'macro' scale. An example of this problem is the interaction between channel flow and two-dimensional groundwater flow. In the micro scale it is incorrect to apply the Dupuit assumption of horizontal flow close to the channel since the vertical flow component is no longer negligible, but for regional groundwater flow studies this approach is widely accepted. If the channel flow is modelled using the St. Venant equation (as in the SHE model) the exchange between groundwater and channel flow is a micro scale problem with respect to the groundwater flow model. It is illustrated in van der Kloet and Lumadjeng[2] (1986) that this conflict can be avoided using a simple model for the channel. In essence, this simplification will mean that the momentum equation in the channel can be neglected as far as the regional groundwater resources model is concerned. This approach, which is complementary to the SHE model, will be studied in more detail, together with the MUST model, in the remainder of the project.

1. Nass, A., 1987. Application of the MUST model to the sites Yarnton Mead and Hupselse Beek. IH internal report.

2. Kloet, van der P., and Lumadjeng, H.S., 1986. The development of an economic objective function for decision making in a water resources control problem. Proc. UNESCO IHP Symposium, May 5-7 1986, Oslo. pp 221-237.

4. Final Report

Drafting of the final report is progressing, with most advances having been made in Chapters 1, 2, 3 and 5. Revisions are being made to the

proposed chapter contents as work develops. An updated list of provisional chapters and sub-sections is given in Annex 1. The finished report is anticipated to be approximately 250 pages in length and printing costs for about 1000 copies will be in the region of £4000. An additional volume comprising data tables is also envisaged.

In response to the decision at the last Steering Committee meeting it was agreed that Steering Committee members would approach their IHP committees with a request for finance to cover publishing costs. Funds to contribute to these costs have provisionally been made available by the U.K.

5. Literature Survey

Proposals for the structure of the literature survey have been forwarded to UNESCO with a view to a consultant being appointed to produce a camera-ready copy of the final version of the survey as Volume 2 of the final report. It is proposed that the material from all the contributions be collated and then presented by topic under the following headings:

I Introduction
II Methodology
III Water Management Needs
IV Surface and Groundwater Regimes
V Patterns of Streamflow
VI Sediment
VII Water Quality

Each topic would be further sub-divided by region, for example Europe, America, Asia.

A summary of the literature survey contributions so far received is given in Table 2.

LITERATURE SURVEY ; HUMAN INFLUENCE ON FLOW REGIMES

	U.S.A.	SWEDEN	POLAND	KOREA	JAPAN	HUNGARY	FINLAND	U.K.	CHINA	VIETNAM	CANADA	ROMANIA	SWITZERLAND	IRELAND	F.R.G	G.D.R	KENYA	NETHERLANDS	NORWAY	USSR	ZIMBABWE
METHODOLOGY	X				X			X													
LAND USE CHANGE	X	X	X	X	X	X	X														
- irrigation			X			X					X										
- clear cutting		X	X		X		X														
- drainage		X					X							X							
- forestry	X		X		X	X	X				X										
- urbanisation	X	X	X	X	X																
- reservoirs/ hydropower		X	X	X										X							
- surface water	X	X	X		X	X	X	X						X							
- ground water	X	X	X		X	X	X	X						X							
WATER QUALITY				X	X		X	X			X										
- sediment	X	X	X	X	X			X													
- acidification		X						X						X							
STREAM TEMPERATURE			X	X	X			X													
RIVER REGULATION			X	X										X							
Pages of Contribution	21	9	18	18	22	16	3	16	11	6	6	20	2	13	1 contribution promised but not yet rece						

Table 2

6. Reports and Publications

Technical notes continue to be written to record the progress of project work, including the development of software, the analysis of data and any visits made by the project team. An up to date list of the Technical Note series is given in Annex 2.

Publications

Kloet, van der P., and Lumadjeng, H.S., 1986. The development of an economic objective function for decision making in a water resources control problem. Proc. UNESCO IHP Symposium, May 5-7 1986, Oslo. pp 221-237.

7. Final Conference

As agreed at the Steering Committee meeting, the FREND final conference will be held in Norway in April 1989. The conference, titled 'FRIENDS (Flow Regimes from International Experimental and Network Data Sets) in Hydrology' will take place in Bolkesjø, Norway, from April 1st to 6th 1989. The first circulars publicising the conference have been printed and are being distributed internationally through UNESCO, IAHS, WMO and other organisations.

The following deadlines have been set:

1st May 1988 Provisional registration
1st June 1988 Receipt of abstracts of papers
1st Nov. 1988 Final registration for the conference
1st Dec. 1988 Receipt of final papers for the Proceedings

Convenors of the sessions and reviewers of the papers have not yet been determined, so proposals for these need to be put forward.

8. FREND Data Release

In order to encourage a wide use of the valuable FREND database after the end of the project it is intended to hold copies of the data in West Germany, Norway and the Netherlands. In preparation for this, sample tapes containing a subset of each of the various types of data have been prepared and documented, and sent to the appropriate organisations in order that data transfer problems may be forseen and solved. Final versions of the tapes, containing the whole database, will be made available in May 1988.

All the national IHP committees of those countries contributing data to the project have been asked to clarify the conditions under which data from their country may be made available for use after the end of the FREND project. Replies have so far been received from Belgium, Finland, Norway, Switzerland and the United Kingdom.

9. FREND 2

It was agreed at the last Steering Committee meeting that firm proposals for follow-up work to the FREND project would be put to the next meeting. Discussion would be greatly enhanced if these proposals were circulated to the Steering Committee before the meeting.

ANNEX 1

FREND - Final Report Contents

Preface

Forward

Chapter 1. Executive Summary *Editor: AG*

1.1 Objectives
1.2 Project implementation
1.3 Study area
1.4 Outline of report
1.5 Summary of conclusions

Chapter 2. Hydrological Database *Editor: LR*

2.1 Introduction
2.2 Selection of catchments
2.3 Data transfer and liaison with hydrological organisations
2.4 Database management and quality control
2.5 Summary of FREND hydrological database

Chapter 3. Thematic Database *Editor: SD*

3.1 Introduction
3.2 Topographic maps
3.3 Morphometric characteristics
3.4 Soil and geological indices
3.4 Land use data
3.5 Climate characteristics
3.6 Summary of FREND thematic database

Chapter 4. Regional Flood Studies *Editor: LR*

4.1 Introduction
4.2 Summary of flood regimes
4.3 Homogeneous flood regions
4.4 Regional flood frequency analysis
4.5 Classification criteria
4.6 Relations between mean annual flood and catchment characteristics
4.7 Frequency analysis of floods of mixed origin

Chapter 5. Regional Low Flow Studies *Editor: AG*

5.1 Introduction
5.2 Summary of low flow statistics
5.3 Hydrological response maps
5.4 Relationship between flow indices and catchment characteristics
5.5 Design methods based on river networks
5.4 Modelling land use change

Chapter 6. Small Research Basin Studies *Editor: SD*

6.1 Introduction
6.2 Review of small research basins
6.3 Towards an international standard of data analysis
6.4 Base flow analysis
6.5 Recession analysis
6.6 Relationship between hydrological parameters and catchment characteristics

Chapter 7. Human Impact Studies *Editor: HL*

7.1 Introduction
7.2 Impact of groundwater abstraction on soil moisture
7.3 Modelling land use change
7.4 Land drainage
7.5 Summary of literature review

Chapter 8. Conclusions and Recommendations *Editor: AG*

8.1 Regional studies
8.2 Small basins
8.3 Human impact
8.4 International projects
8.5 Further research

ANNEX 2

FREND Technical Notes

1. **Minutes of meetings**
   FREND Team meetings 1-17

2. **Administrative and project proposals**
   - 2.1 Proposal for the use of the SHE model
   - 2.2 Floods project proposal
   - 2.3 Proposal for IHP III project 6.1
   - 2.4 Ministry of Agriculture, Fisheries and Food projects
   - 2.5 Hydrological response classification of the soils of the U.K.
   - 2.6 Low flow studies
   - 2.7 The impact of afforestation on the hydrological regime
   - 2.8 FREND summary - International Activities
   - 2.9 Note on the use of the SHE model in the FREND project

3. **Reports of visits**
   - 3.1 France, March 1986
   - 3.2 Sweden and Finland, January 1986
   - 3.3 Austria and Switzerland, May 1986
   - 3.4 West Germany, December 1985
   - 3.5 Koblenz, Germany, March 1986
   - 3.6 France, July 1986
   - 3.7 Northern Ireland, July 1986
   - 3.8 Netherlands, April 1986
   - 3.9 France, October 1986
   - 3.10 Belgium, November 1986
   - 3.11 Denmark, December 1986
   - 3.12 Norway, December 1986
   - 3.13 Netherlands, January 1987
   - 3.14 Ireland, March 1987
   - 3.15 Program of work for visit of Arjan Nass to IH 6.5-28.7.87
   - 3.16 Visit of Dr. Nippes to IH 21,22.7.87
   - 3.17 Visit of AG and SD to Valdai, USSR

4. **Station selection, location and numbering**
   - 4.1 Norway
   - 4.2 Overview of Nordic data
   - 4.3 Gauging station numbering system
   - 4.4 Austria gauging stations
   - 4.5 Country numbering system
   - 4.6 Numbering of raingauges
   - 4.7 Classification of gauging stations

5. **Flow data**
   - 5.1 Collection and archiving of flow data
   - 5.2 GDFLOWS quality control procedure
   - 5.3 Quality control of flow data

6. Climate characteristics
   - 6.1 Basin properties definitions (with 7.1, 8.1)
   - 6.2 Lake indices, precipitation and base flow

7. Geomorphological characteristics
   - 7.1 Basin properties definitions (with 6.1, 8.1)

8. Soils
   - 8.1 Basin properties definitions (with 6.1, 7.1)
   - 8.2 Use of Regional Soil Survey information
   - 8.3 Video data capture - European WRAP map

9. Database development

10. Reports and publications
    - 10.1 Land Use - Water interactions
    - 10.2 Changes in catchment runoff
    - 10.3 Evaluation of the Base Flow Index
    - 10.4 Papers from Switzerland and Austria
    - 10.5 Final Report - Draft Index

11. Water quality
    - 11.1 Predicting long term trends in soil and water acidification
    - 11.2 Water quality modelling

12. Software
    - 12.1 Plotting routines

ANNEX 3

ADDRESSES

Steering Committee members

Dr H Liebscher
Federal Institute of Hydrology
Kaiserin-Augusta-Anlagen 15-17
Postfach 309
Koblenz
D-5400
F R GERMANY

Mr E Berntsen
Norwegian Committee for
Hydrology
PO Box 5091
Majorstua
Oslo 3
NORWAY

Dr P Warmerdam
Department of Hydraulics
and Catchment Hydrology
Agricultural University
"Die Nieuwlanden"
Niejwe Kanaal 11
Wageningen
NETHERLANDS

Dr M I Rusinov
Division of Water Sciences
UNESCO
7 Place de Fontenoy
75700 Paris
FRANCE

Project Staff

Dr A Gustard
Dr N W Arnell
Institute of Hydrology
Crowmarsh Gifford
Wallingford
Oxon OX10 8BB
UK

Mr L Roald
Institute of Hydrology
seconded from:
Norwegian Water Resources
and Electricity Board
Box 5091 Majorstua
0301 Oslo 3
NORWAY

Ms M Polarski
Institute of Hydrology
seconded from:
Faculte des Sciences
Agronomique de l'Etat
Gembloux
BELGIUM

Dr S Demuth
Institute of Hydrology
seconded from:
Institute of Physical
Geography
Freiburg University
Werderring 4
D-7800
F R GERMANY

Mr H Lumadjeng
Institute of Hydrology
seconded from:

Department of Hydraulics
and Catchment Hydrology
Agricultural University
"Die Nieuwlanden"
Niejwe Kanaal 11
Wageningen
NETHERLANDS

Steering Committee Participants

Dr K Hofius
Federal Institute of Hydrology
Kaiserin-Ausgusta-Anlagen 15-17
Postfach 309
Koblenz
D-5400
F R GERMANY

Dr A Kapotov
Pobeda 2
175400 Valday
Novgorod Region
USSR

Mr G Oberlin
CEMAGREF
Groupement de Lyon
3 quai Chaveau
69009 Lyon
FRANCE

Annex 4

Proposals from the United Kingdom for a continuation of the FREND programme

Title	Flow Regimes from Experimental and Network Data - Phase 2
Description	A three year programme to extend the geographical scope and hydrological analysis of the current FREND project in Europe.
Objectives	1. To extend the geographical area of the project to Eastern Europe and Mediterranean areas. 2. Develop existing techniques of regional analysis. 3. Develop techniques for applying estimation techniques to digital data bases of river networks and catchment characteristics. 4. To extend the application of analysis techniques for small research basins.
Proposed Work	The current FREND data base would be extended to other countries who wish to cooperate in the second phase of the FREND project. This phase would also develop techniques for estimating extreme events using the large data base of flood and daily flow data. Opportunity would be taken to apply further analysis techniques proposed by the W. German IHP. Recent developments in digital cartography have made available a wider range of data bases on river networks, rainfall, land use, soil, etc. and one aim of the project would be to incorporate digital mapping techniques for the rapid assessment of floods and low flows. This would have three major advantages. First it will enable the full advantages of digital map data to be incorporated in design techniques. Second it will enable estimates to be compared with and adjusted by observed flow statistics based on long records. Third it will improve the accuracy and speed with which flows can be estimated at ungauged sites.
Implementation	Funds are being sought from United Kingdom funding bodies to maintain the existing input to the FREND project. Office, Computing, Secretarial and support facilities could be made available at the Institute of Hydrology. The project should be incorporated where possible into the appropriate IHP programmes.

Title

An assessment of the implications of human influences and climatic change upon the natural hydrological regimes of southern Africa.

Description

This project will aim to use data from network, representative and experimental drainage basins in southern Africa to study natural hydrological regimes and changes in runoff patterns arising from anthropogenic influences and climate change scenarios.

Objectives

1. To summarise regional patterns and variations in hydrological regime in terms of
   - water balance
   - low flow frequency
   - storage-yield relationships.
2. To assess the nature and significance of man-induced land use change (deforestation, land management practices) upon the local and regional hydrological regimes.
3. To investigate the implications of CO2-induced climate change scenarios upon surface and groundwater resources.
4. To identify regions or catchment types in which runoff patterns may be most susceptible to land use or climatic changes.
5. To develop a methodology for the transfer of results from network, representative or experimental basins to ungauged sites.

Proposed Work

The main tasks of the project will be:

1. Selection of basins.
2. The collection and archiving of annual, monthly and preferably daily discharge and rainfall data.
3. The development and derivation of appropriate basin characteristics from published maps and where necessary the derivation of new maps, benefitting where possible from remotely sensed data sources.
4. The analysis of these data to establish relationships between catchment characteristics and indices of the natural hydrological regime, and to examine the variations in response attributable to anthropogenic influences.
5. The derivation of climatic change scenarios and investigation of the implications for the hydrological regimes.

Implementation

It is proposed that the study should be based in Africa with close links with the Institute of Hydrology, Wallingford (UK) to attain maximum benefit in terms of staff experience and computational and administrative facilities. It is envisaged that the Institute would provide one or two full-time scientists for a period of three years, supported by suitably qualified staff, where appropriate. It is stressed that the project would greatly benefit, if not be dependent upon, the contribution of staff from organisations within the study area.

Funding is sought within the UK principally from the Overseas Development Administration but also from other organisations such as UNESCO, UNEP, WMO, UNDP and FAO. The aims and timetable of the project should be incorporated, where possible, within established IHP, WMO and/or FAO projects.

Title: Estimates of Pollutant Loads Entering the North Sea from major European Rivers

Description: An international programme of work to determine pollutant load from European Rivers for input into a comprehensive water quality model of the North Sea. The Institute of Hydrology has been the focus of a three year study of flow regimes from European Rivers and the project could be implemented most effectively within a similar structure for international co-operation. The first phase of the work will review both the techniques for estimating pollutant loads and the feasibility of integrating existing Surface Water (IH) and Harmonised monitoring (DoE) archives. This phase will also identify additional relevant water quality data available in the UK from Regional Water Authorities and River Purification Boards and from mainland Europe by making full use of the international co-operation developed during the current FREND project. The second phase of the project will produce an international water quality and quantity archive of major pollutants entering the north sea and apply techniques developed in phase 1 to estimate pollutant loads.

Objectives:

1. Identify availability of relevant water quality data for European Rivers.
2. Review and develop techniques for estimating pollutant loads.
3. Extend international FREND data base to include water quality data
4. Estimate pollutant loads entering the North Sea,

Proposed Work Phase 1 of the project will be used to co-ordinate activities from European Countries in order to develop an international project group to develop analysis techniques and organise the exchange of data. A methodology will be developed for estimating pollutant loads including the seasonal variability in loadings. (Results from the current FREND project on the variation of monthly flow regimes will assist in this work). Of particular importance for the UK data input to the project will be to combine time series of flow and quality data from the Surface Water Archive and Harmonised Monitoring System and make recommendations for the most efficient long term development and integration of these archives. During the first phase of the project the most important pollutants to be considered in the North Sea model should be identified in order to limit the data collection exercise to the most relevant water quality variables.

The second phase of the project will develop the existing European FREND archive of river flows by the transfer and archiving of water quality time series. This combined quantity and quality data base will be analysed to estimate pollutant loads into the North Sea. Opportunities will be take to analyse more detailed time series of water quality

data in order to assess sensitivity of load estimates to sampling interval and to excessive seasonal variation in load.

Implementation

Funds are being sought from United Kingdom funding bodies. Office, Computing, Secretarial and support facilities could be made available at the Institute of Hydrology. The project should be incorporated where possible into the appropriate IHP programme.