1996/044

Institute of Hydrology

Centre for Ecology & Hydrology

Natural Environment Research Council

Natural
Environment
Research
Council

THE JIZERA MOUNTAINS
TRAINING FOR DATA ACQUISITION & EVALUATION

Progress Report 1995 - 96
incorporating inception and visit reports

J.R. Blackie and M. Robinson

This report is an official document prepared under contract for the PHARE Programme Management Unit of the Czech Republic by the Natural Environment Research Council. It should not be quoted without permission of the Institute of Hydrology and the PHARE PMU

Institute of Hydrology
Maclean Building
Crowmarsh Gifford
Wallingford
Oxon
OX10 8BB

Tel: 01491 838800
Fax: 01491 692424
Telex: 444293 ENVRE G

December 1996

STATEMENT

This report is submitted to the PHARE Programme Management Unit of the Ministry of Environment of the Czech Republic in partial fulfilment of the Contract:

Water Quality Monitoring Programme - CS 9002/22.6 - Wat/28, Number 28/Ser/5

awarded to the United Kingdom NERC Institute of Hydrology in April 1995.

Under the terms of reference of this contract the Institute of Hydrology undertook to provide the services of the specialists listed below to provide training in the use of new water monitoring equipment in order to improve the effectiveness of monitoring in the catchment areas of the Jizera Mountains of the Czech Republic which form part of the Black Triangle.

Specifically, the terms of reference required

a) An initial site visit by the Programme Manager and the Hydrological Monitoring Specialist to advise on the selection of monitoring sites and to initiate a pilot water balance study to be undertaken by the recipient organisations under the guidance of the Specialist.
b) The mounting of a study tour in UK for 1 hydrologist from TGM VUV and 4 hydrologists from CHMU to cover current methods of monitoring hydrology and water quality in small catchment studies of the effects of afforestation/deforestation. The tour programme was also to include instruction on the use of the plastic sheet net rainfall gauge and on methods of water balance evaluation.
c) The training of Czech staff by an Instrument Specialist in the installation and operation of new instrumentation and in the construction of plastic sheet net rainfall gauges in the Jizera mountains.
d) The mounting of a study tour for 3 hydrologists from CHMU to cover current techniques of snow monitoring in Alpine catchments.
e) The training in UK of 1 chemist from TGM VUV in the evaluation of trends in soil and surface water acidification using the MAGIC model.
f) The mounting of a study tour in UK lead by a Biological Monitoring Specialist for 3 biologists from TGM VUV to cover current techniques in monitoring and evaluating the relationships between stream chemistry and biology.
g) The provision of follow-up training by the Specialist in biological monitoring and evaluation in the Jizera mountains.
h) A site visit by the Hydrological Monitoring Specialist to evaluate the performance of the monitoring equipment and to guide in the analysis of the data obtained in the pilot water balance study.

Specialists provided:

James R. Blackie	Institute of Hydrology	Programme Manager
Mark Robinson	Institute of Hydrology	Hydrological Monitoring Specialist
Dr Alan Jenkins	Institute of Hydrology	Chemical Monitoring Specialist
Dr Stephen Ormerod	University of Wales	Biological Monitoring Specialist
Paul T. W. Rosier	Institute of Hydrology	Instrument Specialist

CONTENTS

1. INTRODUCTION

The Black Triangle covering North-West Bohemia in the Czech Republic and parts of Poland and the former East Germany has suffered considerable environmental damage from the heavy concentration of industry in the area. Under the former regimes this industry was powered by brown coal from the local deposits and the emissions from this caused some of the worst atmospheric pollution in Europe. A regional PHARE project now has the aim of implementing practical steps to improve the environment in the area. The Czech national PHARE programme is contributing to the regional project by supporting a Water Quality Monitoring Programme. Part of this Programme is aimed at the improvement of the equipment used to monitor water quality in the Jizera Mountains, the training of staff in the use of this equipment and the application of current techniques to analyze and interpret the data collected.

The Jizera Mountains are situated in the eastern part of the Black Triangle immediately downwind of the main industrial concentrations. The area contains the headwaters of a number of important water supply reservoirs. The higher altitudes were originally under mixed forest but during the 19th century much of this was replaced with conifers, predominantly Norway spruce. This change caused some increase in the natural tendency towards acidification. The massive build up of coal consuming industry during the mid 20th century accelerated this process and signs of damage to the conifer forests were already apparent in the 1970s. During the 1980s the weakened trees were further devastated by insect attacks and gales and by the end of the decade large scale clearing programmes had left the upper areas almost entirely deforested and subject to considerable erosion. The acidification of the soils and surface waters had resulted in considerable concern about the concentrations of Al, Cd and Mn in the water supplies and there had been a dramatic reduction in the aquatic biota.

To monitor the effects of this pollution on water supplies, seven small catchment in the upper area of the Jizera Mountains were instrumented in the early 1980s. These studies produced valuable information and will continue to do so as a means of monitoring changes in trends as anti-pollution measures are introduced and the forests are re-established. The equipment in use is out-dated however and new techniques are now available which can increase the efficiency and effectiveness of the monitoring. The Water Quality Monitoring Programme is designed to introduce modern equipment and techniques to ensure that this monitoring continues to produce valuable information.

This report covers the progress to date in the contract placed with the NERC Institute of Hydrology to undertake the staff training component of the Water Quality Monitoring Programme.

2. PLANNING

Formal notice that the contract to undertake this project had been awarded to the Institute of Hydrology (IH) was received in April 1995.

Discussion started immediately with TGM VUV and CHMU on the scheduling of the various training sessions. Following receipt of the formal contract in May 1995 the provisional arrangements were confirmed as follows:

6-14/7/95 Programme Manager, JRB, and Hydrological Monitoring Specialist, MR, to visit the Czech Institutes and the Jizera Mountains catchments.

13-22/7/95 Study tour in UK for 3 Czech biologists to be organised and led by Dr Steve Ormerod of the University of Wales College of Cardiff.

16-22/9/95 Follow up visit by SO to Jizera Mountains and continuation of training there.

16-26/9/95 Study tour in UK for 5 Czech hydrologists, to include lectures and demonstrations at IH laboratories and visits to IH experimental catchment studies in Wales, Cumbria and Scotland.

5-16/2/96 Training in the use of the MAGIC hydrochemical model for evaluating acidification trends for one Czech chemist at IH.

13-19/3/96 Study tour for 3 Czech hydrologists to include snow monitoring and snowmelt forecasting techniques in the Alps.

No firm dates were identified at that stage for the visit to the Jizera mountains by the IH Instrument Specialist or for the second visit by the Hydrological Monitoring Specialist. It was agreed that the first would be most effective if it took place after the new monitoring equipment was on site and the second should take place after a reasonable amount of data has been collected.
Subsequently an appropriate time for the visit by the IH Instrument Specialist was identified as **13-26/7/96**.
As of December 1996 the date for the second visit by the Hydrological Monitoring Specialist has been provisionally identified as **summer 1997** by which time sufficient data will have been collected, using the new equipment, to allow some meaningful water balance analysis.

3. IMPLEMENTATION

The visits and training sessions listed above were undertaken as per schedule. Detailed reports on the work covered in them are given in Appendices A to E. The main points arising from each are summarised in the following paragraphs.

3.1 Initial visit to Jizera catchments
6-14/7/95

This visit was carried out by Programme Manager, J.R. Blackie, and Hydrological Monitoring Specialist, Mark Robinson,both from IH, accompanied by Sarka Blazkova from TGM VUV and Josef Hladny and Libuse Bubenickova from CHMU headquarters and Rudolf Hancvencl and Alena Kulasova from the CHMU office in Jablonec nad Nisou.

The seven catchments originally instrumented in the early 1980s were visited. These comprise the adjoining Uhlirska (Cerna Nisa), Blatny Potok and Kristianov (Kamenice) in the west above the Bedrichov and Josefu Dul reservoirs and a group of four adjoining catchments to the east of the area, namely the Bila Smeda and Cerna Smeda headwaters of the Smeda, the Jezdecka (Cerna Desna) above Sous reservoir and the larger Jizerka catchment. This provided the opportunity to familiarise the IH contingent with the existing instrumentation, the variations in soil type and depth over the catchments and the extent and age of forest cover. The on-site and post visit discussions covered the siting of the new instrumentation to be acquired through the Supply Contract, the merits of the catchments viewed in terms of their use for the proposed model water balance study and possible sites for the proposed plastic sheet interception studies. The present and possible future methods of data processing, storage and analysis were also discussed. It was proposed that two catchments should be used for the water balance exercise, namely the Uhlirska and the Jezdecka. Both have a generally southerly aspect but apparently contrasting water balances, a situation which the detailed study would help to resolve or explain.

In the course of discussion it emerged that the soil moisture monitoring equipment to be ordered under the Supply Contract was of the capacitance probe type, because of its lower cost, rather than the neutron probe type. This caused JRB and MR some concern, particularly after having viewed the range of soil types in the catchments. Whilst the recently introduced capacitance probe has been found to perform reasonably well on stable, stone-free soils it is not recommended for stony soils or for soils where swelling and shrinking may cause air gaps to develop around the access tubes. On return to the UK, JRB followed up this point with PMU and recommended that the order be changed to a neutron probe because of the soil conditions in the Jizera.

The opportunity was taken to identify aspects of catchment monitoring and data analysis that it would be appropriate to cover during the UK visit by the Czech hydrologists and to identify provisional dates for this visit.

3.2 UK study tour for Czech biologists
13-22/7/95

This visit overlapped with the Czech visit by JRB and MR, a point which caused no real problems since the logistics had been organised beforehand by JRB and the detailed technical work was undertaken by the Biological Monitoring Specialist, Dr

Steve Ormerod.
Biologists Ondrej Slavik, Jiri Kokes and Pavel Rosendorf were met on arrival at Heathrow on 13/7/95 by P. Rosier of IH and placed on a train to Wareham where their tour started on 14/7/95 with a visit to the Rivers Laboratory of the Natural Environment Research Council's Institute of Freshwater Ecology at Wareham in Dorset where Dr John Wright introduced them to the RIVPACS system of detecting and modelling effects of acidification. Thereafter the programme was based at the University of Wales College of Cardiff. Dr Ormerod lead them in a series of lectures and demonstration field trips to mountain areas in Wales where acidification effects are being monitored.
J. Blackie met the group at Reading on their way back to Prague and discussed the progress made during the visit.

3.3 Follow up biological training in Czech Republic 16-22/9/95

This was undertaken by Dr Steve Ormerod and Dr Ingrid Juttner who had assisted with the initial training in Wales. The seven catchments in the Jizera described above were visited to assess the status of the streams and discuss the chemical and biological monitoring to be carried out there. It was suggested that it may be necessary to monitor additional sites to enable the development of models relating invertebrate communities and fish population status to stream acid-base status. With this in mind a number of sites in the mountain areas east of the Jizera were surveyed to see whether an expanded network covering a greater range of acid conditions and forest cover could be established.
The proposed programmes of the Czech biologists were reviewed and discussed and a number of suggestions made. These included the expansion of the monitoring network, the inclusion of survival studies on caged fish, the assessment of the effects of bankside planting of deciduous trees on benthic productivity and the use of a small lake in one catchment to carry out tests of the effects of liming on stream biology.
A general recommendation was made that regular meetings of the biologists, chemists and hydrologists involved in the monitoring studies should be instituted to ensure efficient and effective co-ordination of activities.

3.4 UK study tour for Czech hydrologists 16-26/9/95

Hydrologists Sarka Blazkova from TGM VUV, Josef Hladny and Libuse Bubenickova from CHMU headquarters and Rudolf Hancvencl and Alena Kulasova from the CHMU office in Jablonec nad Nisou arrived in UK on 16 September 1995. The tour was organised by J. R. Blackie and sections were conducted by Paul Rosier, Instrument Specialist, (Wales), Mark Robinson (Coalburn) and JRB (Scotland) with inputs from many other IH field and HQ staff. The tour started with an introductory meeting at the Institute of Hydrology HQ at Wallingford on 17 September, followed by a drive to the main IH Field Station at Plynlimon in the Welsh mountains.
In this area long term studies of the effects of various stages of plantation forestry and of upland sheep grazing on hydrology, sediment yield and water chemistry are conducted in a series of experimental catchments. Over the following two days IH staff demonstrated the monitoring techniques and instrumentation networks used and

discussed the data processing methods and the results emerging from these studies. The party then moved on to Carlisle in NW England. A morning session in the local office of the National Rivers Authority was followed by a visit to the Coalburn catchment. This small upland catchment has been monitored continuously since 1967, recording and analysing the changes in hydrological response, sediment yield and water chemistry that have taken place as the land use has gone from moorland grazing through plough drainage and conifer planting to the present 23 year old forest cover just reaching canopy closure. The monitoring networks were viewed and some time was spent examining the instrumentation on two "plastic sheet " interception study plots.

The IH Field Station in Stirling, Scotland, was the next venue. After introductory lectures the party spent a day viewing the monitoring networks in the Balquhidder catchments and discussing the results emerging. These two catchments were instrumented in the early 1980s to extend the Plynlimon type studies into the more extreme climatic and topographic conditions encountered in the Scottish Highlands where plantation forestry is replacing heather moorland rather than the short grassland encountered in Wales.

Thereafter the party returned to Wallingford, via Edinburgh, and spent a final day at IH HQ before returning to Prague. The programme on the final day included a lecture on UK Forestry Practices by Dr Tom Nisbet from the Forestry Commission Research Station and demonstrations of both capacitance probe and neutron probe soil moisture monitoring equipment as well as a review of the tour and discussion of the future programme.

3.5 Training of Czech chemist in the use of hydrochemical models including MAGIC
5-16/2/96

Jan Willmec from TGM VUV arrived at IH on 5 February having previously received a number of briefing papers and a list of data requirements for use in calibrating the model for Czech conditions. Over the next 10 days he was given an intensive course in the principles of the MAGIC model, the calibration methods, its application in both forecast and hindcast mode to forested and moorland catchments and the calculation of critical loads for both soils and surface waters. This course was conducted by Michael Renshaw under the supervision of Alan Jenkins, the Chemical Monitoring Specialist.

3.6 Alpine study tour for Czech hydrologists
13-19/3/96

This tour was organised by Mark Robinson in cooperation with Dr Patrick Tourasse of Electricite de France General Technical Division's Water Resources Department based at Grenoble. This organisation was chosen for the tour because they have unrivalled experience and technical expertise in snow monitoring and snowmelt forecasting in high mountain areas. Dr Robert Moore of IH, who has active research interests in snowmelt modelling, acted as technical leader of the group. The Czech participants were Libuse Bubenickova, Rudolf Hancvencl and Alena Kulasova from CHMU.

Day 1 of the tour included an introduction to the range of work carried out by EDF-

DTG Water Resources Department, seminars on automatic hydrometeorological measurement and snow cover monitoring and on hydrometeorological forecasting for reservoir operation and a visit to the Operational Forecasting Centre.
The following day was devoted to field visits to measuring sites in the Bourne River Basin where, as well as more conventional monitoring equipment, a vertical beam telenivometer was seen in operation and a horizontal beam version operating in a remote high altitude location was viewed from a helicopter.
The morning of Monday, 18 March was devoted to a seminar on snowmelt forecasting and reservoir yield forecasting in an area where snowmelt is a major component of the input. This was followed by a visit to the Centre d'Etudes de la Neige, MeteoFrance, where Dr Eric Brun gave a comprehensive overview of the Centre's research and operational avalanche forecasting activities.
Before the start of the return journey on 19 March the morning was spent at the Laboratoire d'Etude des Transferts en Hydrologie et Environment of the Institute de Mechanique de Grenoble where Professor Charles Obled outlined the activities undertaken and a lively discussion of the merits of various types of snowmelt models ensued.

3.7 Training visit to the Jizera by the Instrument Specialist 13-26 July 1996

After the long delays suffered in the acquisition of some items of instrumentation under the Supply Contract, this visit by Paul Rosier of IH finally took place in July 1996. After ongoing discussion with CHMU and the PMU it was agreed that Mr Rosier should concentrate first on assisting in the final choice of sites for the plastic sheet interception studies and of sites for the soil moisture monitoring access tubes. Thereafter he would provide "hands on" training in the installation and operation of the equipment used in interception studies and in the installation of access tubes and the safe use of the neutron probe soil moisture meter.
After initial discussions with Libuse Bubenickova on arrival in Prague, Mr Rosier proceeded to Jablonec nad Nisou where the monitoring project field team are based. Suitable sites for soil moisture monitoring were identified in the Cerna Nisa catchment and a total of eight access tubes were installed with his assistance and supervision. The team were then made competent in the storage, transport and field practices to be followed in using the neutron probe. The Soil Water Information Processing System, SWIPS, used to convert the neutron probe readings to profile soil moisture data and store the results, was installed on a computer at the office in Jablonec nad Nisou and Alena Kulasova was trained in its use.
A number of possible sites for the plastic sheet net rainfall installations to be used in the interception study were inspected and, after discussion with Sarka Blazkova, three sites covering a range of tree ages and conditions were selected within the Cerna Nisa catchment. Working with the project team, one installation was completed during the visit and the staff trained in the methods of maintenance, data collection and data processing. He also trained the staff in the use of the Rainlog rainfall recording system and its associated software.
In Prague Mr Rosier briefed Josef Hladny and CHMU director Dr Obrusnik on the work done during the visit before travelling back to UK.

4. OTHER WORK UNDERTAKEN

Whilst the contractors on this project were not directly involved in the choice or acquisition of the monitoring equipment to be used in the Jizera catchments, a considerable amount of time was devoted to responding to requests for information and advice on instrumentation from both Czech Institutes and from the PMU.

This involvement went further in respect of two components of the equipment, namely the neutron soil moisture monitoring equipment and the plastic sheet interception equipment. The company contracted to provide the neutron probe stopped trading abruptly just as this equipment was about to be shipped. IH managed to rescue the instrument and organised its shipment together with all the relevant paper work for customs and health and safety regulations..

When no contractor could be found to tender for the supply of the plastic sheet net rainfall equipment and the associated instrumentation, IH workshops agreed to submit a tender and subsequently fabricated and supplied the equipment, meeting the tight deadline.

5. FUTURE WORK

Since the completion of Mr Rosier's assignment in July 1996 the IH involvement has been in response mode, dealing with queries from the CHMU and TGM VUV staff as required. Under the terms of the contract the work remaining consists of the final visit of the Hydrological Monitoring Specialist, Mark Robinson, to assist in the evaluation of the data collected from the Uhlirska and the Jezdecka catchments. Ideally one year's data should be collected from the catchments using the new equipment before this takes place. After consultation with CHMU and TGM VUV, it has been agreed that this visit will take place in late summer 1997.

6. COMMENT

As a result of the personal contacts established during these sessions there has been a growing level of informal communication between all the parties involved which has helped to clarify detail and consolidate the understanding of the topics covered in the project.

The TGM WRU and CHMU staff involved have gained a confident grasp of the instrumentation and the monitoring and evaluation techniques currently in use in UK and elsewhere in western Europe.

The IH staff and those involved from other organisations in UK and France have also gained considerably from the experience in terms of broadening their knowledge and understanding of the interactions between atmospheric pollution and catchment hydrology, chemistry and biology.

7. APPENDICES

APPENDIX A

Report on initial visit to Jizera mountain catchments

Water Quality Monitoring Project: The Jizera Mountains

Inception Report on a visit to the Jizera Mountain catchments

M. Robinson & J. R. Blackie
Institute of Hydrology

1. Background

The Terms of Reference of the Contract called for an initial visit to the Czech Republic by the Programme Manager and the Hydrological Monitoring Specialist in order to discuss details of the programme with their Czech counterparts and to familiarise themselves with the Jizera Mountains catchments. This visit took place during the period 6 - 14 July 1995. **J. R. Blackie** and **M. Robinson** arrived in Prague on the evening of 6 July. On 7 July they were met by **Sarka Blazkova** of the T. G. Masarysk Hydrological Research Institute (TGM VUV) and discussed the details of the programme arranged. They then travelled to the Jizera Mountains on 8 July. There they met **R. Hancvencl** and **A. Kulasova** of the Czech Hydrometeorological Institute (CHMU) at the Regional Office in Jabonlec nad Nisou and were joined there on 10 July by **J. Hladny** and **L. Bubenickova** from CHMU headquarters in Prague.

2. The Jizera Mountains

The background to the monitoring work in the mountains was explained.
The Jizera Mountains are situated in the eastern part of the Black Triangle immediately downwind of the main industrial concentrations. The area contains the headwaters of a number of important water reservoirs which supply some 20% of the drinking water of Bohemia. The higher altitudes were originally under mixed forest but during the 19th century much of this was replaced with conifers, predominantly Norway spruce. This change caused some increase in the natural tendency towards acidification. The massive build up of coal consuming industry during the mid 20th century accelerated this process and signs of damage to the conifer forests were already apparent in the 1970s. During the 1980s the weakened trees were further devastated by insect attacks and gales and by the end of the decade large scale clearing programmes had left the upper areas almost entirely deforested and subject to considerable erosion. The acidification of the soils and surface waters had resulted in considerable concern about the concentrations of Al, Cd and Mn in the water supplies and there had been a dramatic reduction in the aquatic biota.

3. The Catchments

To monitor the effects of this pollution on water supplies, seven small catchment in the upper area of the Jizera Mountains were instrumented in the early 1980s. These studies produced valuable information and will continue to do so as a means of monitoring changes in trends as anti-pollution measures are introduced and the forests are re-established. The equipment in use needs to be replaced by however and new techniques introduced so that the efficiency and effectiveness of the monitoring can be improved.

RIVER	NAME	AREA (km^2)	COMMENTS
Cerna Nisa	Uhlirska	1.87	Thin plate weir. Curved approach. Soil map.
Blatny Potok		4.56	Thin plate weir. Long, straight artificial approach channel. Wetlands upstream.
Kamenice	Kristianov	6.62	Rated section upstream of a bridge. Proposed permanent AWS site.
Bila Smeda		3.72	Thin plate weir.
Cerna Smeda		4.74	Thin plate weir.
Cerna Desna	Jezdecka	4.75	Thin plate weir. Proposed transport-able AWS site.
Jizerka		10.6	Rated section (weir planned d/s of section). Proposed permanent AWS site in valley and transportable AWS on ridge.

The seven catchments (see Figure 1) which have been monitored since the early 1980s are the adjoining Uhlirska (Cerna Nisa), Blatny Potok and Kristianov (Kamenice) catchments above the Bedrichov and Josefu Dul reservoirs in the West of the area and a group of four adjoining catchments to the East of the area, namely the Bila Smeda and Cerna Smeda headwaters of the Smeda, the Jezdecka (Cerna Desna) above Sous reservoir and the larger Jizerka catchment.

The existing equipment consists of elderly chart recorders for river level monitoring and chart recording raingauges of the "Hellman" type. Snow input is measured at selected sites by manual depth/density measurements. 50 m long transects are depth measured at 10 m intervals and density cores taken at three profiles.

Over the period 9 -12/7/96 all seven of the instrumented catchments were visited and the gauging structures, raingauges, snow lines, vegetation cover, topography and soil types assessed. Suggestions were made concerning the choice of locations for the new instrumentation and a number of possible sites for the plastic sheet net rainfall gauges, under spruce plantations of different ages, were inspected.

Only a very few small stands of mature trees remain within the catchments. Within these the damage is very patchy, with healthy looking trees close to - or on the opposite side of a valley - to areas of dead trees. Dead trees have been removed from all but the steepest land and most of the area has been or is being replanted. The young trees appear to be healthy so far.

There is still much evidence of serious erosion after the large scale removal of the dead trees. The worst erosion was on concave slopes with deeper soils and fast water flow. Some rills had eroded to more than 2 m deep. On all but the steepest slopes, however, these erosion scars are being colonised and stabilised by grasses and herbs.

4. Discussions

Visits to the catchments were interspersed with sessions in the office in Jablonec where the present systems of data processing and analysis were demonstrated. The changes that would be necessary when the new automatic logging equipment was installed were debated and notes were made of the points to be demonstrated during the study tour to UK. The timing of this visit was discussed in terms of the probable installation times of the new equipment and the commitments of the TGM VUV and CHMU headquarters staff. The timing of the visit by the Instrument Specialist was also agreed to be dependent on progress in the supply and installation of the new equipment.

In this context concern was expressed over the difficulty in locating a supplier for the equipment necessary to mount the proposed rainfall interception studies. The IH staff indicated that if a commercial supplier could not be found it might be possible for the IH Instrument Section to fabricate the equipment.

When discussing the location of sites for soil moisture monitoring it emerged that the equipment ordered by the PMU under the Supply Programme was of the capacitance probe type. Blackie and Robinson expressed concern at this. Having had the opportunity to view the range of soil types present they were of the opinion that the neutron probe type of equipment would be much more suitable for the Jizera catchments. This equipment has more rigorous requirements in terms of storage, transport and handling but gives consistent and reliable results over a much wider range of soil types than the capacitance probe.

The objectives of the proposed model water balance study and the catchment to be used were the subject of ongoing discussion. After much debate it was agreed that the model water balance study should concentrate on two catchments, namely the Uhlirska and the Jezdecka. Both of these had reliable, well calibrated stream gauging structures. More background information and longer records were available for them than for the others. Preliminary analysis of these data seemed to suggest that there significant differences in the water balances, despite broad similarities in their vegetation covers. More detailed analyses using data from the new equipment would help to resolve this problem.

5. Conclusions

The main points emerging from this busy week on the catchments in the Jizera were:

a) The catchments were well defined and understood in terms of their soils, vegetation and topographic characteristics but there was indeed a requirement to update the equipment in the monitoring networks and to expand these to include within-catchment meteorological monitoring, soil moisture monitoring and measurements of rainfall interception by the forest canopy at different stages of growth.

b) The model water balance study could best be deployed to investigate the apparent differences in water use by the Uhlirska and the Jezdecka catchments indicated by the historic data.

c) The monitoring of soil moisture in the particular range of soil types present in the Jizera catchments would best be undertaken using equipment of the neutron probe type rather than the capacitance probe type. [(1)]

d) September 1995 seemed to be the best time to have the hydrology study tour to UK in terms of the commitments of the Czech personnel involved.

e) The timing of the visit by the Instrument Specialist to the Jizera catchments would be determined by the speed of delivery and installation of the new equipment. Present projections suggested that this was most likely to be late spring or early summer 1996.

f) If no commercial supplier can be found for the plastic sheet net raingauge equipment it may be possible for the Instrument Section of the Institute of Hydrology to manufacture and supply the three sets required.

[(1)] This point was raised in an initial brief report on the visit, dated 19 July 1995, addressed to Mr Vaclav Krejci of the PMU and in a telephone conversation with Mr Stephen Pritchard. Action was subsequently taken which resulted in a neutron probe being supplied in 1996.

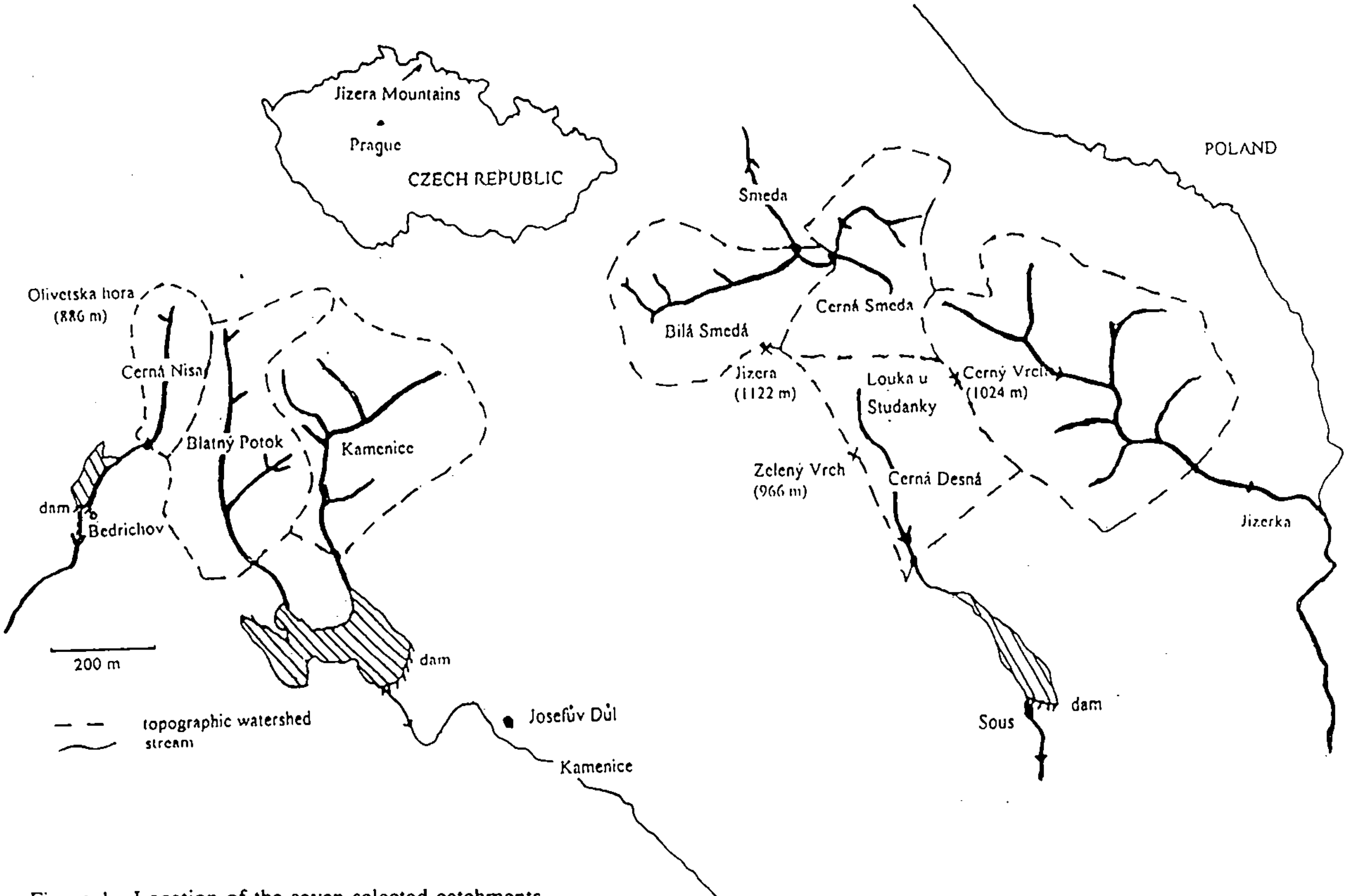


Figure 1. Location of the seven selected catchments.

Appendix 1

Visit itinerary

6/1/95	Travel to Prague in p.m.
7/1/95	Prague; discussions of project with S Blazkova.
8/1/95	Travel from Prague to Jablonec nad Nisou in morning. p.m. meet local staff (RH and AK) and visit catchment.
9/1/95	Whole day visiting catchments, looking at current instrumentation. Evening meeting with Mr Navratil to learn about background to pollution impacts on forest health.
10/1/95	Morning in the Office at Jablonec nad Nisou to see the data processing system, and to discuss office procedures and discuss the rating of the flow gauges. p.m. catchments.
11/1/95	Meet staff from Prague (LB and JH). p.m. Visit catchments to see the proposed instrumentation locations and reach agreement on the sites for new equipment.
12/1/95	Office - agree programme of work, and then tour the catchments to finalise the sites to be used for the forest interception studies.
13/1/95	Office in morning. Return to Prague in p.m.
14/1/95	Depart from Prague.

APPENDIX B

Report on biological training in UK and in Czech Republic

Water Quality Monitoring Project: The Jizera Mountains

Report on Aquatic Biology

Dr Steve Ormerod & Dr Ingrid Juttner

Catchment Research Group, School of Pure and Applied Biology
University of Wales College of Cardiff, UK.

1. Background

As part of the Jizera Programme, the outline brief of the Catchment Research Group has been:

1.1 To provide for a study tour of 3 Czech biologists to the UK, allowing theoretical and applied training in the use of biological systems for detecting impacts by acidification.

1.2 To undertake on-site field training in the Jizera mountains, including an evaluation of how indicator and modelling systems could be adjusted to local conditions.

These two areas are discussed here as 'Phase 1' and 'Phase 2', for which the itineraries are listed at Appendix 1 and 2..

2. Phase 1: Study tour in Wales

Day 1

Ondrej Slavik, Jiri Kokes and Pavel Rosendorf arrived in Britain on July 13, 1995, spending their first working day with Dr John Wright of the Institute of Freshwater Ecology in discussions on RIVPACS (River Invertebrate Prediction and Classification System). This system has direct relevance to detecting and modelling effects by acidification, forming the basis for subsequent studies in Wales by Ormerod.

Days 3-5

In Wales, in formal and informal sessions, information was presented on :

2.1: the causes, consequences and management of acidification from a Welsh perspective;

2.2: The development, role and value of biological indicators for detecting acidity;

2.3: The benefits and problems of biological indicators;

2.4: The contrasting groups of indicators available (diatoms, invertebrates, fish, river birds);

2.5: The role of palaeolimnology in reconstructing acidification;

2.6: The rationale, strengths and weaknesses of biological models for predicting effects by acidification and de-acidification on biological systems;

2.7: The data requirements for biological models;

An important recommendation was that at least 15 sites, of contrasting chemistry, would be required to build biological models in the Jizera mountains

2.8: Scientific Publications by the Catchment Research Group were provided (Appendix 3).

Day 6

Field visits were made to sites in the Brecon Beacon sector of Welsh regional survey of acid waters. There were demonstrations of electro-fishing, invertebrate survey methods, HABSCORE and River Habitat Survey.

Days 7, 8

Visits were made to Llyn Brianne, the site of a major catchment-based research project on ecological effects by acidification. The group then drove north to visit both stream and lake sites in Snowdonia, a mountain region subject to acidification that is also included in the Welsh regional survey of acid waters.

3. Phase 2: Visit to Jizera

Work in the Czech Republic followed the itinerary outlined in Appendix 2. The report of the trip below presents a listing of the major observations and recommendations reached on each day of the field visit:

Day 1

3.1 Ormerod, Juttner and the Czech contingent established the need for clear objectives for the biological part of the Jizera programme. There are several possibilities, but these should be prioritised since they have an important bearing the data requirements. The objectives, which are not mutually exclusive, might include:

i) to establish a baseline for monitoring trends in biology and chemistry at hydro-chemical sites only (i.e. n = 7);

ii) To place studies at the hydrochemical sites into a wider regional context, by studying biology and chemistry at 7 + n sites;

iii) To develop models relating biology to chemistry; this would also require more than 7 sites;

iv) To develop biological indicators of acidity;

v) To assess effects by acidity on biota;

vi) To carry out process studies relating acid-base factors on biota;

A sound and prioritised set of objectives will guide decisions over:

What should be the frequency of chemical sampling ?
What chemical parameters should be measured ?
What should be the frequency of biological study ?
What parameters should be measured ?
How many sites should be included ?
Will the same intensity of effort be required at all sites ?
Will the same intensity of effort be required in all seasons?

The options among these are several:

ii) - vi) would require additional sites than just the 7 hydrochemical sites in Jizera, and at least 15+ across a gradient in acidity. It was recommended that good geological/soil maps, or an outline sampling programme, would aid in the selection of appropriate additional sites.

3.2 Outline investigations at the sites showed that:

i) <u>Baetis</u> mayflies were present at 1 site visited on Day 1, usually indicative of non-acid conditions. However, this may be seasonally variable due to the species present and due to seasonally variable chemistry. The seasonal aspects of biological sampling should be considered. It was recommended that all sites be sampled for invertebrates at least in Spring (following snowmelt), with some of these sampled once subsequently in the year. Fish surveys will be best carried out in summer, thus avoiding the sensitive spawning and early fry periods.

ii) Waters were everywhere brown and rich in humics. A firm recommendation is that metal determinations should involve speciation where possible.

iii) In addition, studies of groups other than fish and invertebrates might indicate effects of anthropogenic acidity in addition to natural humic acidity. Work on diatom communities were discussed, and Juttner undertook to provide a methodology.

Day 2

3.3 The group established the possibility for more geographically extensive studies in mountain areas east of Jizera, where deforestation has been less. This area might provide for reference locations, or for a more pronounced gradient in acidity to which biological features could be related. This will be particularly important in model development.

Individual discussions were held with Slavik and Kokes about their research plans. It was established that the minimum aims of the two workers were :

i) a model relating invertebrate communities to acid-base status (i.e. requiring > 15 sites)
ii) studies relating fish density, condition, age structure, fecundity, age-specific survival to acid-base status. Again this would require > 7 sites across an acidity gradient.

It was recommended that survival studies on caged fish are also considered.

Day 4

3.4 Further investigations around the Jizera catchments demonstrated that:

i) most sites have benthic invertebrate communities typical of acidic rivers (dominated by leuctrid/nemourid Plecoptera; polycentropodid and rhyacophilid Trichoptera; simuliide Diptera). Only one site visited on Day 4 had Baetis mayflies, and also dippers Cinclus cinclus, indicating lower acidity. There was clear evidence that only one site had salmonid fish, providing at least some opportunity for fish population studies in an acidified location.

At the same time, the scarcity of circumneutral conditions in the Jizera region will limit opportunity for models relating biological character to stream chemistry without broader geographical coverage.

ii) there is a large degree of dynamism in the Jizera study area which will need careful consideration in study design: narural regeneration, re-afforestation with broadleaf and conifer species, deposition reduction, recreation, past (and unmapped) use of limestone, uncontrolled fish stocking programmes

iii) some site attributes, in addition to acidity, may influence biological productivity either now, or in the future as recovery occurs. For example, the streams have predominantly gravel substrata which often has a lower density of organisms than cobbles and pebbles. High altitude may limit benthic production, fish prey and fish growth due to low average temperature and reduced nutrient supply. Riparian zones predominantly of conifers and grasslands may limit inputs of allochthonous energy which are often important in stream systems. These features represent both potential limits on recovery, but also provide opportunities for management. For example, bankside planting of deciduous trees as part of current re-afforestation programmes can increase benthic productivity even in the absence of recovery from acidification.

iv) One site had a dam and small lake within the drainage system. This can provide an opportunity for direct liming to test models which predict biology from chemistry. It can also provide for a symptomatic treatment against acidification. However, the lake is small, and likely to have a short residence time, so that lime applications would have to be frequent.

3.5 A further important recommendation was that a co-ordinated approach between project workers might be facilitated by meetings between members and disciplines.

Appendix 1:

Itinerary, Phase 1.

Day 1 (13/07/95) : With IFE, Wareham

Day 2 (14/07/95) : Travel to Cardiff

Day 3 (15/07/95): Meet with Ormerod & Juttner. Informal discussions and visit to Magor Marsh SSSI

Day 4 (16/07/95): Formal sessions with Ormerod

Day 5 (17/07/95): Formal sessions with Ormerod

Day 6 (18/07/95): Field visit to sites in Welsh regional survey and demonstration of biological methodology

Day 7 (19/07/95): Field visit to Llyn Brianne

Day 8 (20/07/95): Field visit to Snowdonia National Park, and further sites in Welsh regional survey.

Return to Cardiff

Day 9 (21/07/95): Travel to Prague

Appendix 2:

Itinerary, Phase 2

Day 1 (16/09/95): Ormerod & Juttner fly to Prague; driven to Jizcra Region

Day 2 (17/09/95): Field visit to Catchments around Jizerka river
Discussion of chemical data
Bankside assessment of benthic samples

Day 3 (18/09/95) Field visit to catchments east of Jizera
Individual discussion with Slavik and Kokes

Day 4 (19/09/95) Field visit to further catchments in Jiezera
Bankside assessments of benthic samples.

Day 5 (20/09/95) Further field visits by Kokes.
Report writing by Ormerod.

Day 6 (21/09/95) Return to Prague

Day 7 (22/09/95) Informal discussion with Pavel Rosendorf and Jan Fot (Charles University, Prague)

Appendix 3:

Publications passed to the Czech Biology Team

1. **S. J. Ormerod**, R. W. Edwards (1985) Stream acidity in some areas of Wales in relation to historical trends in afforestation and the usage of agricultural limestone. J. Environmental Management, 20, 189-197.

2. **S. J. Ormerod**, P. Boole, P. McCahon, N. S. Weatherley, D. Pascoe, R.W. Edwards (1987) Short-term experimental acidification of a Welsh stream: comparing the biological effects of hydrogen ions and aluminium. Freshwater Biology, 17, 341-356.

3. **S. J. Ormerod**, R. W. Edwards (1987) The ordination and classification of macroinvertebrate assemblages in the catchment of the River Wye in relation to environmental factors. Freshwater Biology, 17, 533-546.

4. **S. J. Ormerod**, G. W. Mawle, R. W. Edwards (1987) The influence of forest on aquatic fauna. In: Environmental aspects of plantation forestry in Wales (Ed. J. E. Good). I.T.E. symposium no. 22, Institute of Terrestrial Ecology, Grange-over-Sands,

5. **S. J. Ormerod**, K. R. Wade, A. S. Gee (1987) Macro-floral assemblages in upland Welsh streams in relation to acidity, and their importance to invertebrates. Freshwater Biology 18, 545 - 557.

6. **S. J. Ormerod**, N. S. Weatherley, P. French, S. Blake, W. M. Jones (1987) The physiological response of brown trout Salmo trutta to induced episodes of low pH and elevated aluminium in a Welsh hill-stream. Annls. Soc. r. zool. Belg. 117 Suppl. 1, 435-447.

7. N. S. Weatherley, **S. J. Ormerod** (1987) The impact of acidification on macroinvertebrate assemblages in Welsh streams: towards an empirical model. Environmental Pollution. 46, 223-240.

8. **S. J. Ormerod**, N. S. Weatherley, P. V. Varallo, P. Whitehead (1988). Preliminary empirical models of the historical and future impact of acidification on the ecology of Welsh streams. Freshwater Biology, 20, 127-140.

9. N. S. Weatherley, **S. J. Ormerod**, S. P. Thomas, R. W. Edwards (1988). The response of macroinvertebrates to experimental episodes of low pH with different forms of aluminium, during a natural spate. Hydrobiologia, 169, 225-232.

10. **S. J. Ormerod**, A. P. Donald, **S. J.** Brown (1989). The influence of plantation forestry on the pH and aluminium concentration of upland Welsh streams: a re-examination. Environmental Pollution, 62, 47-62.

11. G. P. Rutt, N. S. Weatherley, **S. J. Ormerod** (1989). Microhabitat availability in Welsh moorland and forest streams as a determinant of macroinvertebrate

distribution. Freshwater Biology, 22, 247-262.

12. K. R. Wade, **S. J. Ormerod**, A. S. Gee (1989). Classification and ordination of macroinvertebrate assemblages to predict stream acidity in upland Wales. Hydrobiologia, 171: 59-78.

13. N. S. Weatherley, S. P. Thomas, **S. J. Ormerod** (1989). Chemical and biological effects of acid, aluminium and lime additions to a Welsh hill-stream. Environmental Pollution, 56, 283-298.

14. N. S. Weatherley, **S. J. Ormerod** (1989). Modelling ecological impacts of the acidification of Welsh streams: temporal changes in the occurrence of macroflora and macroinvertebrates. Hydrobiologia, 185, 163-174.

15. N. S. Weatherley, G. P. Rutt, **S. J. Ormerod** (1989). Densities of benthic macroinvertebrates in upland Welsh streams of different acidity and land use. Archiv fur Hdrobiologie, 115, 417-431.

16. **S. J. Ormerod**, N. S. Weatherley, A. S. Gee (1990). Modelling the ecological impact of changing acidity in Welsh streams. In: Acid Waters in Wales (Ed. by J. H. Stoner, A. S. Gee, & R. W. Edwards), pp 279-298. Kluwer, The Hague.

17. **S. J. Ormerod**, K. R. Wade (1990). The role of acidity in the ecology of Welsh lakes and streams. In: Acid Waters in Wales (Ed. by J. H. Stoner, A. S. Gee, & R. W. Edwards), pp 93-119. Kluwer, The Hague.

18. **S. J. Ormerod**, A. S. Gee (1990). Chemical and ecological evidence for the recent acidification of Welsh lakes and streams. In: Acid Waters in Wales (Ed. by J. H. Stoner, A. S. Gee, & R. W. Edwards), 11-25. Kluwer, The Hague.

19. **S. J. Ormerod**, N. S. Weatherley, W. J. Merrett, A. S. Gee, P. G. Whitehead (1990). Restoring acidified streams in upland Wales: a modelling comparison of the chemical and biological effects of liming and reduction in sulphate deposition. Environmental Pollution, 64, 67-85.

20. **S. J. Ormerod**, N. S. Weatherley, W. J. Merrett (1990). The influence of conifer plantations on the distribution of the Golden Ringed Dragonfly Cordulegaster boltonii in the upper catchment of the River Tywi. Biological Conservation, 53, 241-251.

21. **S. J. Ormerod**, N. S. Weatherley, & P. G. Whitehead (1990). Temporal patterns of ecological change during the acidification and recovery of streams in the Welsh region according to a hydrochemical model. In: Regional Acidification Models: Geographic Extent and Time Development, pp 167-184. Ed by J. Kumari, D. F. Brakke, A. Jenkins, S. A. Norton & R. F. Wright. Springer Verlag, Heidleberg..

22. G. P. Rutt, N. S. Weatherley, **S. J. Ormerod** (1990). Relationships between the physicochemistry and macroinvertebrates of British upland streams: the development of modelling and indicator systems for predicting fauna and stream acidity. Freshwater Biology, 24, 463-380.

23. N. S. Weatherley, **S. J. Ormerod** (1990). The constancy of invertebrate assemblages in soft-water streams: implications for the prediction and detection of environmental change. Journal of Applied Ecology, 27, 952-964.

24. N. S. Weatherley, A. P. Rogers, X. Goenaga, **S. J. Ormerod** (1990). The survival and early life stages of brown trout (Salmo trutta L.) in relation to aluminium speciation in upland Welsh streams. Aquatic Toxicology, 17, 213-230.

25. P. G. Whitehead, **S. J. Ormerod** (1990). Modelling the chemical and biological response of Welsh streams to changes in atmospheric deposition and land use. EEC Cost 612 Workshop, April 1988, Cardiff, pp. 152-169. Ed by H. Barth.

26. R. W. Edwards, **Ormerod, S. J.** & Turner, C. (1991) Field experiments to assess biological effects of pollution episodes in streams. Verhandlungen der Internationalen Vereinigung fur Theoretische und Angewandte Limnologie, 24, 1734-1737.

27. W. J. Merrett, G. P. Rutt, N. S. Weatherley, S. P. Thomas, S. **J. Ormerod** (1991). The response of macroinvertebrates to low pH and increased aluminium concentrations in Welsh streams: multiple episodes and chronic exposure. Archiv fur Hydrobiologie, 121, 115-125.

28 **S. J. Ormerod**, R. W. Edwards (1991). Modelling the ecological impact of surface water acidification: problems and possibilities. Verhandlungen der Internationalen Vereinigung fur Theoretische und Angewandte Limnologie, 24, 1738-1741.

29 **S. J. Ormerod**, J. O' Halloran, S. D. Gribbin, **S. J.** Tyler (1991) The ecology of Dippers Cinclus cinclus in relation to stream acidity in upland Wales: breeding performance, calcium physiology and nestling growth. Journal of Applied Ecology, 28, 419-433

30. S. D. Rundle, **S. J. Ormerod** (1991). Micro-invertebrate communities in upland Welsh streams in relation to physico-chemical factors. Freshwater Biology, 26, 439-451.

31. N. S. Weatherley, **S. J. Ormerod** (1991). The importance of acid episodes in determining faunal distributions in Welsh streams. Freshwater Biology, 25, 71-84.

32. N. S. Weatherley, E. W. Campbell-Lendrum, **S. J. Ormerod** (1991). The growth of brown trout (Salmo trutta L.) in mild winters and summer droughts in upland Wales: model validation and preliminary predictions. Freshwater Biology, 26, 121-131.

33. N. S. Weatherley, G. P. Rutt, S. P. Thomas & **S. J. Ormerod** (1991). Liming acid streams: aluminium toxicity to fish in mixing zones. Water, Air and Soil Pollution, 55, 345-353.

34. **S. J.** Tyler, **S. J. Ormerod** (1992). A review of the likely causal pathways

relating the reduced density of breeding Dippers Cinclus cinclus to the acidification of upland streams. Environmental Pollution, 78, 49-56.

35. N. S. Weatherley, **S. J. Ormerod** (1992). The biological response of acidic streams to catchment liming compared to the changes predicted from stream chemistry. J. Environmental Management 34, 105-115

36. **S. J. Ormerod**, S. D. Rundle, E. C. Lloyd, A. A. Douglas (1993). The influence of riparian management on the habitat structure and macroinvertebrate communities of upland streams draining plantation forests. Journal of Applied Ecology, 30, 13-24

37. N. S. Weatherley & **S. J. Ormerod** (1993). The utility of biological indicators of stream acidity in Wales. In: Ecological Indicators, Volume 2. Ed by D. H . Mackenzie, D. E. Hyatt, V. J. McDonald. Elsevier Applied Science, Chichester, pp 1341-1354

38. **S. J. Ormerod**, A. Jenkins (1994). The biological effects of acid episodes. In : R. Wright & C. Steinberg (Eds). Acidification of freshwater ecosystems: implicatons for the future. Dahlem Workshop Report 14, pp 259-274. John Wiley & Sons, Chichester.

39. B. Reynolds, **S. J. Ormerod** & A. S. Gee (1994). Spatial patterns in stream nitrate concentrations in upland Wales in relation to catchment forest cover and forest age. Environmental Pollution, 84, 27-33

40. A. G. Hildrew, **S. J. Ormerod** (1995). Managing the effects of acidification in upland rivers. In: D. M. Harper, A. Ferguson, (Eds). The Ecological Basis for River Management. John Wiley, Chichester, pp 147-160

41. S. D. Rundle, N. S. Weatherley, **S. J. Ormerod** (1995). The effects of catchment liming on the chemistry and biology of upland streams: testing model predictions. Freshwater Biology, 34, 165-176.

APPENDIX C

Report on UK hydrological tour

Water Quality Monitoring Project: The Jizera Mountains

Report on the UK Study Tour for Czech Hydrologists

J. R. Blackie, M. Robinson and P. T. W. Rosier

NERC Institute of Hydrology

1. Background

An important component of the contract was to organise a tour of UK small catchment monitoring sites for the Czech hydrologists involved in the Jizera Mountains programme. The tour would give them the opportunity to familiarise themselves with the instrumentation, monitoring techniques and methods of data analysis in use in UK.

The tour took place in September 1995 under the guidance of **J. R. Blackie, M. Robinson** and **P. T. W. Rosier** of the Institute of Hydrology and included inputs from other Institute staff based at the main laboratories at Wallingford and the field stations in Wales and Scotland. Meetings were also arranged with **Dr T. Nisbet** of the UK Forestry Commission Research Station and **Mr R. Moore** of the National Rivers Authority North West Division based at Carlisle.

The Czech hydrologists participating in the tour were **Sarka Blazkova** from TGM VUV, **Josef Hladny** and **Libuse Bubenickova** from CHMU headquarters and **Rudolf Hancvencl** and **Alena Kulasova** from the CHMU office in Jablonec nad Nisou.

2. Programme

Wallingford (1).
After the arrival of the Czech party on 16 September and an overnight stay in Oxford the programme started with an introductory session at the Institute headquarters at Wallingford on the morning of 17 September. This covered a brief overview of the range of research undertaken by the Institute, confirmation of the tour itinerary and travel and domestic arrangements. The party then drove to the Institute's main field station at Plynlimon in mid Wales under the leadership of Paul Rosier with an overnight stay in Llanidloes.

Plynlimon
In this area long term studies of the effects of various stages of plantation forestry and of upland sheep grazing on hydrology, sediment yield and water chemistry are conducted in a series of experimental catchments.

At the Plynlimon Office on 18 September Jim Hudson, the station manager, outlined the programme for the group's visit. This would include an introduction to Plynlimon, a visit to the Severn catchment and a demonstration of data retrieval, quality control and archiving. During the introduction information was given on the scientific reasoning for the setting up of the Plynlimon studies, on the monitoring networks and the process orientated experiments, on some of the more important results emerging from the studies and on the new science programmes for the future.

The Institute has been involved with Plynlimon since the late 1960s when the adjacent headwaters catchments of the Wye and the Severn rivers on the eastern side of the mountain were chosen for a paired catchment study comparing the hydrological effects of plantation forestry (Severn) and mountain grassland (Wye). Within both catchments, three sub-catchments are also fully instrumented with streamflow structures and raingauge networks. Over time the studies have developed from straight "compare and contrast" catchment experiments into a programme covering many different aspects of the effects of forestry and grazing on hydrology, sediment yields and water chemistry. The station has also developed new science programmes with other research institutes and university departments and undertakes commissioned work for a number of agencies.

During the visit to the Severn (forested) catchment main stops were made at the trapezoidal flume at the catchment outfall, at the meteorological site at Moel Cynnedd and at the raingauge comparison study at Carreg Wen. The rationale for the choice of the trapezoidal flume design, the methods of construction and calibration and the evolution of data collection methods were described and discussed at the outfall site. At Moel Cynnedd the original manual meteorological site was demonstrated together with one of the automatic weather stations (AWS) in the present network and the relative merits of the two systems were discussed. Short walks from here took the group to the specially designed steep stream gauging structures on the Hafren and Tanllwyth sub-catchments and to the sediment monitoring site on the latter where the methods of monitoring bedload, suspended sediment, turbidity, pH and conductivity were explained and demonstrated. At Carreg Wen another of the AWS in the network was viewed, together with a cloud deposition gauge and a long term comparison study of raingauge mounting systems. The gauges are mounted at the standard British exposure height of 30.5 cm, at the same height but surrounded by a turf wall and at ground level in the centre of a pit covered by an anti-splash grid. Results from the study were described and the merits of each approach discussed.

The morning of 19 September was spent in the Office where aspects of data collection, quality control, storage and analysis were demonstrated and discussed. In addition the "Wallingford" neutron probe was demonstrated, together with its storage facility and the radiological protection measures necessary during transport, field use and storage were also described.

Carlisle/Coalburn

In the afternoon of 19 September the party travelled to Carlisle in NW England. Sarka Blazkova left the group at the University of Lancaster. The 20 September started with a morning session in the local office of the National Rivers Authority where Ray

Moore described the wide range of hydrometric and water quality monitoring activities undertaken by his group, including the use of current meters to produce rating curves for flow gauging stations and the calibration of tipping bucket recording raingauges.

The Coalburn catchment study was visited in the afternoon. The study was initiated by the Institute of Hydrology and is now run by the NRA in conjunction with the Forestry Commission, North West Water plc and the Institute. This small upland catchment has been monitored continuously since 1967, recording and analysing the changes in hydrological response, sediment yield and water chemistry that have taken place as the land use has gone from moorland grazing through plough drainage and conifer planting to the present 23 year old forest cover just reaching canopy closure.

The monitoring networks in the catchment, including the streamflow structure and gauging equipment, the automatic weather station, the cloud water collectors and the water quality instrumentation as well as the standard and ground level raingauges, were viewed and Mark Robinson outlined the results emerging from the study. Some time was spent examining the "plastic sheet" net rainfall gauges installed by Paul Rosier and other associated instrumentation on two plots being used by the Institute in an interception study. Mark Robinson explained that most of the information on interception by conifers in UK had been obtained from mature plantations. This study was designed to obtain information on plantations just reaching canopy closure.

Stirling/Balquhidder

After a second night in Carlisle the group moved North into Scotland under the leadership of Jim Blackie. The IH Field Station in Stirling, Scotland, was the next venue. After introductory lectures there by David Price on the work of this station and, in particular, the background and current work in the Balquhidder catchments the party spent all of the following day in these catchments. The two catchments, with one nested sub-catchment, were instrumented in the early 1980s to extend the Plynlimon type studies into the more extreme climatic and topographic conditions encountered in the Scottish Highlands where plantation forestry is replacing heather moorland rather than the short grassland encountered in Wales. The group viewed the rainfall and snowfall networks, the streamgauging structures, the AWS network and the sediment and water chemistry sampling techniques and discussed the results emerging. Thereafter the party returned to Wallingford, with an overnight stay in Edinburgh en route.

Wallingford (2).

The final day was spent at the Institute headquarters at Wallingford. The programme on the final day began with a lecture by Mr Tom Nisbet from the Forestry Commission Research Station at Alice Holt on UK forestry practices, including an introduction to the Forestry and Water Guidelines publication. this was followed lectures on and demonstrations of the Institute developed HYDATA hydrological database system and the SWIPS software for processing and storing soil moisture data. Demonstrations of both capacitance probe and neutron probe soil moisture monitoring equipment were given and the day concluded with a review of the tour and discussion of the future programme.

3. Comment

The programme for the study tour was designed to cover the requirements laid out in the terms of reference and also to provide as much background information as possible on the hydrological and environmental problems relating to forestry practices in Britain and the approaches being adopted in trying to combat them. The discussions and exchanges of experience and information that took place during the tour were stimulating and of value to both Czech and British participants.

Appendix 1

Visit itinerary

16/9/95	Arrive London. Transport to Oxford. Rest of day and overnight in Oxford.
17/9/95	To IH, Wallingford. Introduction, lectures. Drive to Plynlimon in afternoon.
18/9/95	Field visits to Plynlimon and Llanbrynmair catchments to see instrumentation, structures, etc.
19/9/95	Plynlimon catchment office. Data processing techniques and analysis. Drive to Carlisle in pm. Drop SB at Lancaster en route.
20/9/95	National Rivers Authority in Carlisle in am. Coalburn catchment, including "plastic sheet" interception study in pm.
21/9/95	Drive to Stirling. IH Office, then to Balquhidder catchments.
22/9/95	Balquhidder catchments, instrumentation, structures, snow studies.
23/9/95	Drive to Edinburgh
24/9/95	Drive back to Wallingford.
25/9/95	At IH. Lectures,discussions, visit to Software Section, instrument demonstrations.
26/9/95	London, Heathrow----- Prague

Appendix 2

SELECTED REFERENCES GIVEN TO THE CZECH PARTY

Blackie, J.R. 1993: The water balance of the Balquhidder catchments. J. Hydrology, 145, 239-258.

Calder, I.R. 1976: The measurement of water losses from a forested area using a 'natural' lysimeter. J. Hydrology 30, 311-325.

Forestry Commission, 1993: Forests and Water Guidelines. HMSO London.

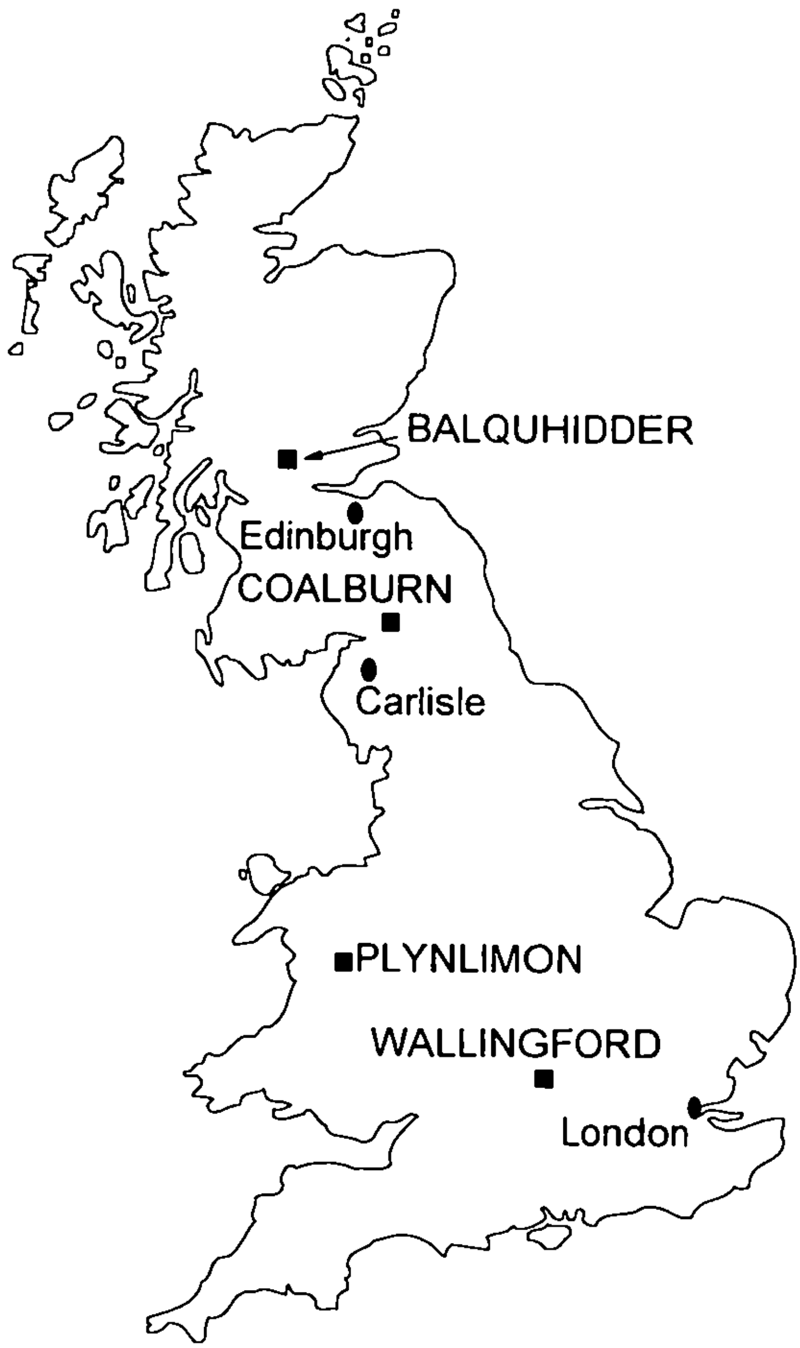
Johnson, R.C. 1990: The interception, throughfall and stemflow in a forest in highland Scotland and the comparison with other upland forests in the U.K .J. Hydrology 118, 281-287.

Kirby, C., Newson, M.D. and Gilman, K. (eds.) 1991: Plynlimon research: The first two decades. Institute of Hydrology Report No. 109, 188 pp.

Robinson, M., Jones T.K. and Blackie, J.R. 1994: The Coalburn catchment experiment - a 25 year review. National Rivers Authority, Research and Development Note 270. Bristol. 54 pp.

Appendix 3

Location map of the catchments visited



APPENDIX D

Report on MAGIC training

Work Programme: MAGIC training related to PHARE Project

Institute Visitor: Mr Jan Willmec

Date of Visit 5 February 1996 to 16 February 1996.

Mr Willmec was trained in the use of the catchment hydrochemical model MAGIC during his visit to the Institute of Hydrology.

His training involved the following aspects:

1. Preparatory work. Prior to his visit Mr Willmec was sent a number of related papers and data requirements for calibrating the model.

2. On his arrival a general model description and interactive demonstration and problem solving session was given. Chemical principles of the model and concepts of 'hindcasting' and 'forecasting' were also explained.

3. Method of model calibration to site data, initially to data from the UK Acid Waters Monitoring Network (AWMN) and later to data from the Czech Republic.

4. Forecast simulations using calibrated files, generation and interpretation of results, plotting results in a spreadsheet.

5. Methods of calibration to a forested catchment, forest hindcast and forecast sequences and comparison of moorland/forest sites and the effects of land use on acidification.

6. Calculation of critical loads for soils and surface waters.

7. Running the model from external files.

Mr Willmec should now be fully conversant with the principles of the MAGIC model, the method of calibration and generation and interpretation of results.

Michael Renshaw.

APPENDIX E

Report on Alpine tour

ALPINE STUDY TOUR

ON SNOW COVER MONITORING

This report is prepared under the EU Phare Programme:
The Jizera Mountains - training for data acquisition and evaluation
Water Quality Monitoring Programme - CS9002/22.06 - Wat/28
Contract Number: 28/Ser/5.

Institute of Hydrology
Crowmarsh Gifford
Wallingford
Oxfordshire
OX10 8BB
UK

Tel: 01491 838800
Fax: 01491 692424
Telex: 849365 Hydrol G

March 1996

Contents

1. Introduction

A study tour concerned with snow cover monitoring was organised by the Institute of Hydrology in Grenoble, France from 14 to 19 March 1996, under the general management of Dr Mark Robinson. The local itinerary (Table 1) for the tour was organised by the Electricité de France (EDF) with Dr Patrick Tourasse as coordinator. Three hydrologists of the Czech Hydrometeorological Institute (CHMU) participated in the tour: Libuše Bubeníčková, Rudolf Hancvencl and Alena Kulasová. Robert Moore of the Institute of Hydrology served as technical leader of the group whilst in Grenoble. This report summarises the main information exchange that took place during the tour.

2. EDF's interests in snow

Snowmelt forecasting is the concern of the Water Resources Department within the General Technical Division (DTG) which provides centralised specialist support to the regional operating centres of EDF. The main use of forecasts is for managing the operation of dams used for hydropower production, which accounts for 25% of the French electricity supply with nuclear power providing the remainder. In the 1960's EDF operated some 600 rainfall stations, but responsibility for some sites has since transferred to MeteoFrance as their interest in tourism and avalanche forecasting developed, leaving EDF operating some 400 stations. EDF now operate 1160 measuring stations (of which 500 are automatic) comprising 430 automatic tipping bucket precipitation gauges (heated), 355 flow stations, 280 snow measuring points (40 automatic telemetry stations), and with 45 air temperature and 50 water temperature stations. There are 24 automatic water quality stations measuring temperature, pH, dissolved oxygen and conductivity. EDF is the only service in France which operationally monitors snow water equivalent, MeteoFrance only measuring snow depth. There is an ongoing rationalisation of services operated by EDF and MeteoFrance involving joint operation, information exchange, standardisation of equipment and data transfer protocols, etc.

The DTG employs 87 persons concerned with the hydroclimatic network, forecasting model, estimation of the risk of extreme events, water quality and optimal water management. Since a fall in air temperature to -1°C can increase the power demand by 1200 MW, air temperature forecasting is very important to electricity supply despatching. Snowfall can affect the reliability of supply through wet, sticky snow building up on power lines and causing the lines or poles to break. The DTG provide a service to warn of this problem.

Table 1 Itinerary for the Alpine Study Tour, 13-19 March 1996

Wednesday 13	Arrive at Grenoble	
Thursday 14	EDF-DTG Water Resources Dept	
	0830 - 1000	Welcome to EDF-DTG Water Resources Dept., Patrick Tourasse, Deputy Head of WR Dept.
	1015 - 1215	Automatic hydroclimatological measurement and snow cover monitoring in mountainous areas, instruments demonstration, Pierre Dupouy, Engineer, Head of Methods & Quality (MQ) Section in WR Dept.
	1400 - 1530	Operational hydrometeorological forecasting at EDF for reservoir operation. Christian Lallement, Engineer, Head of Alps Hydrometeorological Centre in WR Dept.
	1600 - 1700	Visit to the EDF-DTG Operational Forecasting Centre.
Friday 15	Visit to measuring sites	
	0800 - 1300	Study tour of Bourne River Basin visiting automatic hydrological remote stations and Geve vertical beam telenivometer.
	1400 - 1700	Flying over Agnelin automatic snowgauge and discussion at EDF-DTG.
Monday 18	Operational snowmelt forecasting at EDF-DTG	
	0830 - 1200	Long-term reservoir yield forecasting and operational models for daily snowmelt forecasting, R. Garcon, Engineer, Head of Hydrology & Water Management Section in WR Dept.
	1400 - 1600	Visit to the "Centre d'Etudes de la Neige", MeteoFrance, Eric Brun, Head of Centre.
	1730 - 1830	Closing session with Patrick Tourasse and Pierre Dupouy.
Tuesday 19	Modelling research at LTHE, IMG	
	0930 - 1100	Snowmelt modelling, Prof. C. Obled.
	1100 - 1200	Topsimple modelling, Dr Georges-Marie Saulnier.

3. Snow monitoring in EDF

Pierre Dupouy provided information on snow monitoring in EDF. Measurement of snowfall by EDF began some 40 years ago using an MPT precipitation gauge which integrated the snowfall over the winter season. From the time of creation of EDF in 1946 to 1965 a very dense network of manual measurements was operated. A period of automation followed to 1965, including the introduction of telemetry but with operation being somewhat "delicate". Most recently, database activities and application development have figured prominently, including software for long-term flow forecasting and short-term flood forecasting.

Manual snow measurements are made every 10 days from 10 January to 20 June; a typical station is Serre Chevalier at a height of 2200 m located at a ski resort with records from 1952. The average annual water equivalent of snow over the French Alps is ~950 mm. Measurement points for snow course surveys are marked by *snow poles* with black/yellow divisions at 0.5 m intervals. The *snow corers* used are of aluminium construction, incorporating attachments for weighing using a spring balance, and comprise four 1 m lengths 7 cm in diameter which slot together to provide the length of corer required. The four sections are attached to a rucksack frame for carrying. (Larger diameter corers are used in the Czech Republic with 50 cm^2 and 30 cm^2 cross-sectional areas.) Samples are made at three locations in the vicinity of each site. (In the Czech Republic a fibre-glass construction has been found to be better at temperatures below freezing because there is less inclination for the snow to block the tube; also 1 or 2 m lengths suffice usually).

The *MPT integrating snowfall gauge* employs a solution of glycol and water in a reservoir to melt the snow, and an orifice 200 cm^2 in area is used. It is now not used. (In the Czech Republic a plastic barrel containing salt, as an antifreeze, is used and is weighed with a balance but poor results led to the method being abandoned).

A *vertical-type telenivometer* measures the depth and water equivalent of a snowpack using a gamma source (Caesium 137 with a half-life of 30 years) and detector (Geiger-Muller sensor). The instrument is used for lower mountain locations between 1100 and 1500 metres. The source power is 100 milliCurie but with improvements to the detector this is likely to be reduced to 10. A solar panel provides power at remote locations and can operate for one month with no sun. For safety reasons the instrument is operated within a wire compound. A brochure describing the instrument is included in the Appendix.

A *horizontal-type telenivometer* can provide measurements of snow density and water equivalent in 10 cm layers over the full depth of the snowpack. Emitter and receiver are moved within cylinders 0.6 m apart, located vertically in the snowpack. Provision is made for air temperature measurement, a solar panel and an Argos transmitter on the top of one cylinder above the snow surface. The overall height is 6 m with an active measuring range of 5.5 m. A source power of 10 milliCurie is used although this will be reduced to 2 milliCurie. In this case a power supply is essential to operate the vertical movement of the receiver and emitter. One problem is that a cone of melted snow forms around the cylinders causing measurements near the snow surface to be biassed. The electronics are now located on top of one of the cylinders to provide ease of access. A brochure describing the instrument is included in the Appendix.

An *Association raingauge* positioned at an orifice height of 2 m is used for manual measurement at 8 am each day. Overfilling of the funnel by snow is a problem, and the quality of measurement depends on the observer. The gauge is warmed in a house to melt the snowfall and allow the water equivalent to be measured. A pair of gauges is used so whilst one is indoors the other is collecting snowfall.

Trials have been made with different orifice surface areas and sizes of *tipping-bucket precipitation gauges* (e.g. 2000 cm^2 and 20 g, 400 cm^2 and 4 g, 200 cm^2 and 20 g) giving different sensitivities e.g. 1/10 mm.

Development of a heated raingauge by EDF began in 1950 and by 1965 a reliable device became available for operational use called the *P2000 raingauge*. A 2000 cm^2 collecting cone is used below which is an insulated aluminium case housing a 20 g tipping-bucket gauge, and is heated by air driven by a fan over a 200W/24V heating element. The gauge is used at 185 sites, over 75% of which have operated for nearly 30 years. Good results from the gauge are reported by Lallement (1996) but at 30 000 F the instrument is expensive. Development of new generation heated raingauges began in the mid-1980s, especially experimenting with methods of heating the cone funnel but the results were less good than the P2000. Finally, the period of experimentation with heating systems led in 1992 to the selection of an off-the-shelf weighing raingauge, Hyetocap, and its further development as a joint venture between EDF and the manufacturers to incorporate a heating system. Testing over the winter of 1992/93 provided good results and a set of 10 *heated Hyetocap gauges* were commissioned as a result. Ongoing work concerns testing autonomous power sources, which is not seen as a major problem given its low power demand of 40W. Further details are provided in the paper by Lallement (1996).

An "English House", or Stevenson Screen, is used for climate measurements.

Check flow measurements are made using *current meters* and using *dilution gauging*. Rhodamine WT is used as a tracer with a concentration in the river of 10 μg/l. Typically 300 measurements are made each year. The USGS safety limit is 50 μg/l of liquid solution of Rhodamine WT, corresponding to 200 μg/l of pure Rhodamine WT. The safety limit for ingestion by humans is 1.75 mg/day in the USA.

4. Operational Forecasting Centre

Christian Lallement outlined the activities of the Operational Forecasting Centres within EDF. EDF operate two regional Hydrometeorological Forecasting Centres, one at Grenoble serving the Alps, Massif Central and the Jura, and the other at Toulouse, serving the rest including the Garonne, Loire and Rhone basins. Forecasts are made of flow, water and air temperature and water yields.

Flash flooding in Mediterranean areas is an important problem. Particularly notable was the flood of 22 September 1992 in the Haute-Loire when 260 mm fell in 6 hours giving rise to flows of 8 $m^3/s/km^2$ in the Loire at Rictourd (62 km^2 drainage area). Rainfall was spatially organised over a length of 300 km lasting for 5 to 6 hours. One operational problem was lightning which stopped several stations: as a result the standard of protection has been improved. *Meteorage* is used for lightning forecasts. The system detects cloud to ground strikes from 15 sensors in France plus some in Italy. *Safir* also detects lightning but employs more sensors and is only available in the vicinity of Paris. Three stages of the forecast are the rainfall forecast, the time of concentration and the propagation time.

Information involves observations, models and people. Observations come from satellite and radar. *Meteosat* provides infrared cloud-top temperature. France is supported by 12 *weather radars*. A 13th north of Nimes will be installed in August to compensate for the heavy sheltering effect in this area; a total of 20 are planned overall. The forecast centre displays both Meteosat and radar data through a PC radar/satellite display system.

A Hydrometric Data PC Display system provides displays of hourly data from main stations with a memory of the last four days. Tabular and graphical displays are available via a DEC Display system linked to a VAX 4000-205 for all stations, with a daily telemetry scan occurring at 2 am. All data can be accessed for up to 20 days in the past, with even 1 minute data being recovered if specified. It provides access to the last 2 years of hourly data; data before this time are maintained on a definitive historical data archive.

Models provide forecasts of humidity, temperature and pressure at different heights for different lead times. Forecasts are made using the weather prediction model of MeteoFrance and using the ECWMF model in Reading, UK. The MeteoFrance model excludes the effects of topography and provides forecasts at 6 hour time steps. These forecasts are complemented by an "Analogue Model" based on the experience of the past 30 years, identifying the closest 10 events using a correlation distance measure.

At present a flow forecasting system is under development which will give a scenario of forecasts from no-rain, max-rain to other possible futures. The FDTF (First Differenced Transfer Function) Rainfall-Runoff model is being used, together with a neural network model for channel flow routing.

An important element in the operation of the Forecast Centre is the integration of hydrometric network and forecast staff, with all staff experiencing both so as to ensure they are in touch with reality.

5. Visit to measuring sites

On the Friday a field visit was made to typical automatic stations for measuring weather variables, river level and snow water equivalent. These were located in the Bourne river basin. The river gauging station provided an opportunity to see an old-style bubble gauge for measuring river level; the principle of the gauge is outlined below. A vertical beam telenivometer using a gamma source to measure the profile of snow water equivalent was seen at Geve. In the afternoon a helicopter flight over Agnelin allowed a horizontal beam telenivometer to be seen at a distance, but turbulent air conditions prevented a landing to observe the instrument more closely.

The principle of operation of the *bubble gauge* for river level measurement was discussed. Evolution of the design of the gauge means that two types of sensor are in use by EDF. The old generation design employs a constant flow of air from a compressor in order to maintain a permanent pressure balance by automatic regulation. A higher river level reduces the rate of bubble release and the regulator adjusts the air flow from the compressor accordingly. The actual signal measured is based on a mercury manometer floating device with measurement of the mercury level. Now, the new generation sensor avoids the use of mercury, as a potential health hazard. It also employs a small automatic compressor which releases the exact air flow only when required and pressure is measured electronically. The new sensor is named LPN8 made by HYDROLOGIC, a Grenoble firm which was previously part of Neyrtec. An important advantage of the bubble gauge is that the capillary tube transmitting the air between the measurement station and the sensor in the river can be long, stretching over lengths as long as 300 m. In contrast a pressure transducer operating over this length would be very prone to failure by lightning strikes due to the electric connection employed in the cable. Measurement of temperature is also required to correct the transducer measurement of pressure. The new bubble gauge sensor is designed as a "clever sensor" which is both integrated and simple: both the sensor measurement and transmission system are contained within the same unit, removing the need for an interface device between the two components. The integrated bubble gauge unit costs 30,000 F whilst a pressure transducer together with transmission system costs 25,000 F. The book "Streamflow Measurement" by R.W. Herschey provides a general introduction to the bubble gauge, and the range of methods different designs use to sense the reaction pressure. Use of a bubble gauge is appropriate for locations not well suited to stilling wells and where the recorder hut must be some distance from the river level measuring point, a common combination of circumstances in Alpine streams.

6. Operational snowmelt forecasting models

The problem of long-, medium-, and short-term forecasting was discussed in the context of the 3000 km^2 catchment of the Durance gauged at Serre-Poncon, within which there is reservoir storage of 1200 M m^3 available for hydropower production. Highest flows occur in Spring, especially July, when floods are associated with snowmelt and/or rain. A further peak in flows occurs in autumn, especially November, associated with Mediterranean rainfall. Historical records are used to derive the 10, 50 and 90% annual flow hydrograph and a hydrograph for a particular year is compared with this.

Long-term forecasting involves making an operational forecast every 15 days, starting in February, of the total volume of water during the melt period. This may be for a period of 2, 3 or 4 months; for example April to July. Depending on the expected volume compared to the normal this forecast can be used to guide reservoir operation. The forecasting method employs multi-linear statistical analysis. The dependant variable is the observed volume of melt water - for example for the months May, June and July - and the period of record used to derive the regression coefficients is 1949-1993. Confidence limits on forecasts are derived from the multiple regression procedure, and these allow risk-based management of the reservoirs for a given level of security of supply. Different models exist for different forecast time. For example, the April to July flow is predicted using the following explanatory variables: November to March precipitation, November precipitation and November to January precipitation. Flows for May to July are predicted from precipitation in November and precipitation in December to May, plus an intercept term; over a period of 40 years used for calibration this model gives an R^2 of 0.83. The models also tend to give greater weight to spring precipitation for locations further south. Other explanatory variables used are the May air temperature and the wetness of the snowpack in April. If May is warm then a smaller yield in the following months can be expected.

For *medium-term forecasting* a daily conceptual model has been used since 1990 to make forecasts two to three days ahead. The model is called MORDUR: Model for Objective Determination of Runoff for Reservoir Operation. It is a classic lumped conceptual model, in the spirit of Bergstrom's HBV model used in Scandinavia. The model has been applied to the 3584 km^2 Durance catchment spanning an elevation range of 700 to 4000 m. A 30 year record has been used for model calibration. Heteorogeneity is a problem for this lumped model but parameterisations have been developed to represent the variability in snow cover area. Simulation from the model are used to derive the 10, 50 and 90% catchment water storage and the current year water storage superimposed on these to determine the water surplus/deficit. Thirty sites provide measurements of snow and temperature and precipitation are measured at 8 sites, but only 3 provide real-time data transmission. A Meteorological Forecast provides the catchment model with five day forecasts (from yesterday) of temperature and precipitation, associated with R^2 performance measures of .73 and .33

respectively; flow forecasts have an R^2 of .88. The MORDUR model has been used operationally for medium-term forecasting since 1994 and the main forecast variable of interest is the water stock deficit across the catchment. It is a nine parameter model. Being a lumped model, an important component is how the snowpack is distributed over the catchment through model parameterisation. This is done by distributing the snow according to altitude, broadly reflecting a temperature lapse rate control on snow accumulation.

7. Snow Research Centre

Dr Eric Brun, head of the Centre d'Etudes de la Neige, MeteoFrance, outlined the work of the centre. The centre forms part of the National Centre for Meteorological Research (CNRM) and is sited on the university campus in Grenoble. It had primarily been set up to support avalanche forecasting, which in other countries can be the responsibility of the forest service or disaster prevention service. There are 10 departmental centres for weather and avalanche forecasting in France. The first floor of the centre houses the Operational Service which produces a daily forecast from mid December to the start of May. According to elevation, aspect and location a forecast of the state of snow cover is given, including the trend for the next 3 to 4 days. Audiotext reports are disseminated widely.

The Research Centre was concerned with developing "helping tools" to support the operational forecast centres, such as software for data collection and modelling. It employs 26 staff, half being engineers/researchers and the remainder technicians and computer support staff. There are three research groups concerned with avalanche forecasting and snow cover, snow cover depending on weather conditions and mountain meteorology. Their activities are summarised below.

(i) *Avalanche forecasting and snow cover:* This group is concerned with the mechanical and stress properties of snow. A seismic sensor network, located in the Alps and Pyrenees, together with signal processing algorithms, are used to provide a measure of avalanche activity. An expert system has been developed to identify weak layers based on mechanical calculations of slope stability from the snow profile.

(ii) *Snow cover depending on weather conditions:* The temperature, density and stratigraphy of a snowpack depends on the energy/mass exchange which is determined by the weather. A snow model has been developed and tested using field measurements from a special research station at Col de Porte at a height of 1320 m, 20 km north of Grenoble in the Chartreuse Massif. Hourly measurements are made of wind, air temperature, humidity and rainfall (EDF heated raingauge, and unheated). Snow depth is measured using an ultrasonic sensor and pit profiles are taken weekly along with vertical ice cores. Two lysimeters, of area 5 and 1 m^2, are used to obtain an hourly balance from flow measurements of the meltwater. Tipping bucket precipitation gauges, with a 5 cm^2 bucket and 4,500 cm^2 surface area, provide a measure of the input; about 2000 mm precipitation per year falls. Incoming longwave radiation and net radiation measurements are made. Outgoing longwave radiation measurements are found to be biased. These meteorological sensors are kept "clean" using an automatic cleaning device operating to heat the sensors over a 10 minute period followed by cooling to ambient temperature over 5 minutes followed by a 45 minute measurement period. The station is located in a forest glade providing shelter: wind velocities are normally below 5 ms^{-1}, with little drifting and a reasonably homogeneous environment.

A special sensor is used to measure the temperature and settling of different layers within the snowpack. Circular plates 15 cm in diameter are slid down a wire after every 20-30 cm of fresh snow has fallen, with a set of plates gliding along the wire as the snow settles providing a profile of measurements after several snowfalls. Each plate measures temperature at its location within the pack. There are 28 plates and there is an array of three glider wires.

The radiative properties of snow are important with the spectral reflectances of snow depending on the snow type and quality (eg. effects of carbon burning). Research is also done on wet snow behaviour, including how much free liquid water can be stored in a snowpack depending on grain size and the development of saturated layers and the formation of ice lenses.

(iii) *Mountain meteorology:* This concerns the snow model used with relevant weather data. Weather conditions are analysed daily in real-time and adjustments made for altitude and aspect. The second stage involves predicting the evolution of snow using a snowpack model. The third stage involves an expert system for assessing avalanche risk. Programs used for each stage are called SAFRON, CROCUS and MEPRA.

Studies of the glacier mass balance over 50 years has been made in the Sarennes catchment, extending over an elevation from 800 to 3000 m. Three discharge measurements are made at different altitudes, reflecting seasonal snow cover, intermediate snow cover and cover with two months of the 6 month snow season bare. Type and age of snow affects the shortwave albedo. Snow is almost a black body in terms of longwave radiation. The pack is affected by condensation, freezing, percolation and metamorphism processes.

The operational system for avalanche forecasting comprising the SAFRON, CROCUS and MEPRA programs, employs the following network of stations: twice a day synoptic observations, 15 automatic weather stations including snow depth, 30 weather stations giving temperature, wind and humidity. AVHRR is used to obtain cloudiness information employed in calculating incoming longwave radiation from clouds. A full radiation model is employed of the type used in meteorological models, with representation of different layers in the atmosphere. SAFRON employs nine weather types to identify appropriate lapse rates, derived from past data, to adjust for elevation effects using a 300 m elevation interval. Snow types recognised are fresh snow, rounded grains, facetted crystals (formed in high temperature gradients) and fine-grain snow (formed under low temperature gradients). The software operates in an X-windows environment on IBM RS6000 workstations. For a 24 hour forecast for 10 elevation/slope/aspect locations, it takes 15 minutes for the analysis step and 5 to 35 minutes for the forecast. For the precipitation forecast, a combination forecast is made from the numerical weather prediction model and the analogue model, using a nearest neighbour analysis. The snow model maintains up to 50 levels of snow depth, depending on the complexity of the snow profile structure to be represented. Representation of slab snow, formed from wind driven fresh snow, is important for avalanche forecasting. The system has also been applied in Bulgaria (Sophia) employing ECWMF weather forecasts from Reading, UK.

8. LTHE, IMG

Professor Charles Obled, outlined the structure of the Laboratoire d'Etude des Transferts en Hydrologic et Environment of the Institute de Mécanique de Grenoble. He was responsible for the surface water group, whilst three other groups were concerned with hydrometeorology (including radar, climatology and extremes), unsaturated zone groundwater (including nitrate/pesticide transport) and porous media (including artificial media such as concrete). His groups concern over the last 10 years had focused at the basin scale with small mediterranean basins experiencing no snow. Prof Obled's research on snow over 10 years ago had included energy budget formulations, which at the time had not been well validated. Progress since then at the Snow Studies Centre, had advanced knowledge of the propagation of water through the snow for avalanche forecasting purposes, where hard layers build up to form a sliding plane; metamorphism of snow had also seen advances. The data assimilation system, Saffron, had been developed to adjust for elevation/aspect effects. Of most interest to hydrologists was the melting layer at the bottom of the snow pack and the rate at which this released water to the catchment.

An information exchange on common interests took place during the meeting. Ing. Bubénicková outlined the work of the Water Research Institute in the Jizera Mountains located in the Black Triangle, one of the most polluted areas of Europe. Measurements over 16 years from a 1.87 km^2 catchment were available. Severe air pollution affecting the catchment had led to spruces in the catchment dying; felling of the trees was completed in 1987, leaving only 10% of the forest. The replacement vegetation was a special grass with a dense root system penetrating to depths of 20 cm; a few trees were also planted. Research was focusing on how the peak flow had changed and of the effect on sediment transport. Nutrient transport through the soil profile was being investigated using a Swedish model.

Mr Moore outlined the three year snowmelt forecasting study undertaken in the UK and provided a brief article outlining this work. The consensus was whilst energy budget melt models might provide better results, use of simple temperature models might prove more reliable due to the sensitivities of the sensors required to implement the more complex approaches.

A demonstration of Topsimple was given by Dr Georges-Marie Saulinier. A simple to use Windows package allowed the topographic based catchment model to be initialised and the effect of changing parameters visualised.

9. Conclusion

The study tour had provided an invaluable experience of how snow was monitored and modelled in an Alpine region where its importance was great, both in economical terms from a hydropower generation viewpoint and from a hazard warning viewpoint in terms of avalanche forecasting. Both industrial and academic perspectives to the problem were gleaned from visits to EDF, the Snow Research Centre and Grenoble University. There is clearly no cheap, reliable means of measuring the water equivalent of snow cover. Whilst gamma devices provide an automatic measurement, they are both expensive and carry health risks associated with the radioactive source employed. Snow cores and snow pits, although labour intensive, are still seen as the primary means of measurement suitable for Czech conditions. Complemented by automatic weather stations these can provide a snow measurement network that can be sustained in Czech conditions. Snow pillows are not used in the French Alps due to the depth of packs experienced and the high likelihood of bridging, as hard layers develop in the pack. Snow pillows are seen as more viable in Czech conditions, but need to be maintained in an operative condition by severing any hard layers as they develop to ensure that the full depth of snow is weighed.

The detailed design of the heating elements associated with the French tipping-bucket precipitation gauge might also have something to offer to improve snowfall measurement in the Jizera mountains. The siting of such gauges in sheltered locations, such as forest glades, would mitigate against the adverse effects of wind on gauge catch. It is significant that the French experience has led to a design which does not incorporate any form of wind shield.

Considerable scope exists in the Czech Republic to develop from monitoring of snow to use of snow measurements for flood forecasting and water management, especially with respect to the water supply reservoirs in the Jizera mountains. The experience gained in France and in the UK in snowmelt modelling and forecasting, should provide a valuable guide for future developments in the Czech Republic.

Papers, Reports and Brochures received

Brun, E., David, P., Sudul, M. & Brunot, G. (1992) A numerical model to simulate snow-cover stratigraphy for operational avalanche forecasting. J. of Glaciology, 38 (128), 13-22.

Brun, E., Martin, E., Simon, V., Gendre, V. & Coleon, C. (1989) An energy and mass model of snow cover suitable for operational avalanche forecasting. J. of Glaciology, 35 (121), 333-342.

EDF (undated) DTG. Specialist Consultant Engineering Services: Development, Measurement and Industrial Controls. Electricité de France, 20pp (brochure).

EDF (undated) 1995 Activity Report: Division Technique Grenoble. Studies, measurement and industrial controls. Electricité de France, 24pp (brochure).

EDF (undated) Hydrology and Meteorology at EDF. Electricité de France, 11pp.

EDF (undated) Horizontal beam telenivometer: Automatic snow mantle measuring device on mountain sites, 2pp.

EDF (undated) Vertical beam remote level measuring instrument: Automatic device for measurement of the snow layer in medium mountains, 2pp.

Garçon, R. (1996) Precision Operationnelle des Apportes de la Durance a Serre-Poncon a l'aide du modele MORDOR - bilan de l'année 1994-1995. Society Hydrotechnique de France, Section de Glaciologie, 14-15 March 1996, Grenoble, Theme 2, Hydrologie de Haute Montagne, 18pp.

Hydrologic (undated) Niveau. Brochure for LPN8 bubble gauge, 15pp.

Lallement, C. (1996) Heated raingauge systems designed by EDF: Application to the HYETOCAP raingauge, 6pp.

Obled, C & Tourasse, P. (1994) Uncertainty in flood forecasting: A French case study. In: G. Rossie *et al.*, (eds),. Coping with Floods, 475-501.

Rodriguez, J.Y. (1994) An operational forecasting snowmelt model with objective calibration. Nordic Hydrology, 25, 79-100.

Appendix

Gamma-ray snow measuring instrument brochures

Direction
Électricité Production Transport

HORIZONTAL BEAM TELENIVOMETER

AUTOMATIC SNOW MANTLE MEASURING DEVICE ON MOUNTAIN SITES

FUNCTION

. Automatic measurements

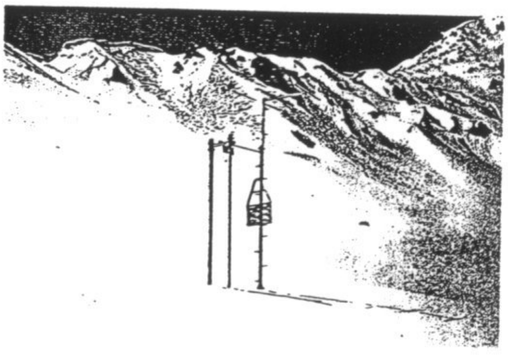
This device measures **the thickness and density of the snow mantle in 10 centimeter slices**. It also provides the water value and thickness of the mantle as well as the density of the different 10 cm layers.

. Automatic transmission

The measurements are carried out automatically at programmable intervals and are stored for 24 hours or more.

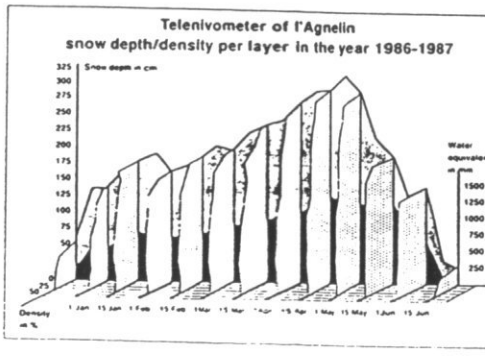
The transmission of the measurements is carried out by means of:
- satellite, e.g. ARGOS (256 coded bits). The measurements can be recovered approx. 6 hours after being emitted by the beacon;
- or by any other means adapted to a RS 232 C link.

PERFORMANCES



. Snow height measurement
- Measurement scale: 0 to 580 cm.
- Accuracy 0 to 10 cm (approximation on the last layer).

. Water value measurement
- Measurement scale: 0 to 2,142 mm (34 layers of 63 mm transmitted by ARGOS).
- Accuracy ±5%.



. Air temperature measurement
- Measurement scale: -40°C to +87.5°C.
- Accuracy ±0.5°C.
- ARGOS restitution with resolution of 1 degree.

. Measurement duration
- On average 30 min for 6 metres.
- This may vary.

PRINCIPLE

The measurement principle is based on the **absorption of Gamma rays by the snow layer**.

The radioactive source Geiger-Müller-counter assembly is moved vertically through the snow mantle.

As the movement occurs, the radiation passes through the horizontal snow layers and is absorbed to a greater or lesser extent depending on the snow quality.

A signal is sent for each 10 cm covered. Therefore, the number of signals received indicates the number of 10 cm slices, and the total height of the layer can be obtained by addition. The interval between two signals depends on the snow density.

TECHNICAL CHARACTERISTICS

. Long autonomy

- Approx. 5 months without solar panel with Cadmium/Nickel 20 A/H battery.
- Can operate for several years without the need for intervention with a 12 V-10 W solar panel.

. Low electrical consumption

- ± 30 mA to 60 mA in the standby state.
- ± 800 mA for beacon emission.
- ± 800 mA during a nivometre measurement.
- ± 30 mA during a temperature measurement.

. Weatherproofing

- On average from -40° to +50°C;
- Immunity of electrical and mechanical parts: (4K3) -50°C to +40°C, 15 to 100% humidity (French standard NFC 20 000);
- Operating immunity of electronic parts: (3K6) -25°C to +55°C, 10 to 100% humidity (French standard NFC 20 000);
- Corrosion (chemical agents, UV radiation).

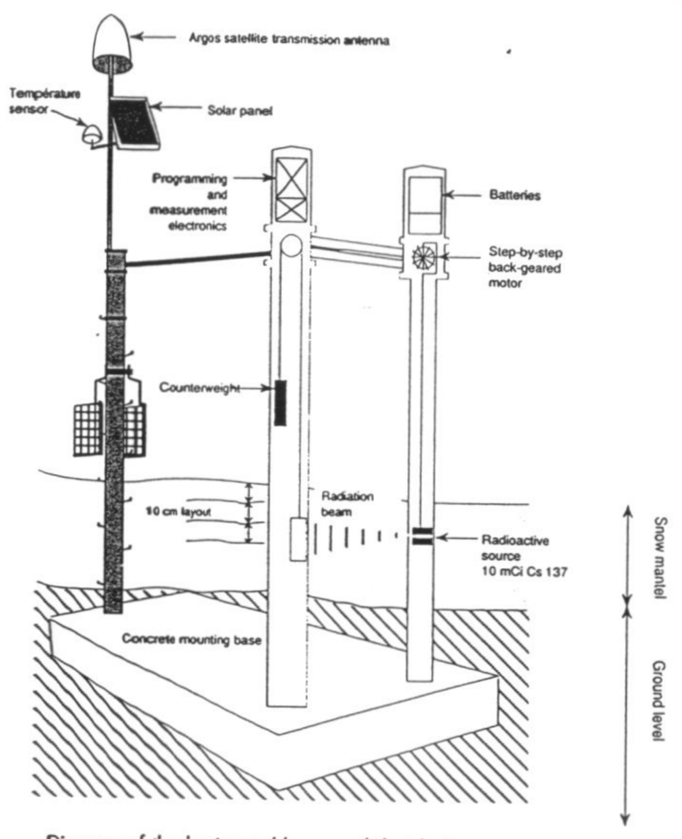


Diagram of the horizontal beam mobile telenivometer

REFERENCES

- Approved by the Commission Interministérielle des Radioéléments (CIREA) (French Interministerial Radio-isotope Commission), the organization responsible for regulation of this matter in France
- 31 installations in the French mountain ranges (Alps, Pyrenees, Massif Central) with a 10-year feedback experience.

APPLICATIONS

Monitoring of the snow mantle for:

- evaluation of avalanche risks
- optimum management of water reserves
- measurement of snow depth in mountainous regions above 1000 M(eters).

This device is suitable for use by:

- hydrologists
- foresters
- the winter sports industry
- snow removal and avalanche technicians.

EDF
Electricité de France

Direction
Électricité Production Transport
Transport and Production Electricity Management

General ingeneering Division (DTG)
37 rue Diderot
BP 41
38040 GRENOBLE CEDEX
Tel. (33) 76 20 80 00

EDF
Electricité
de France

Direction
Électricité Production Transport

VERTICAL-BEAM REMOTE LEVEL-MEASURING INSTRUMENT

AUTOMATIC DEVICE FOR MEASUREMENT OF THE SNOW LAYER IN MEDIUM MOUNTAINS

FUNCTION

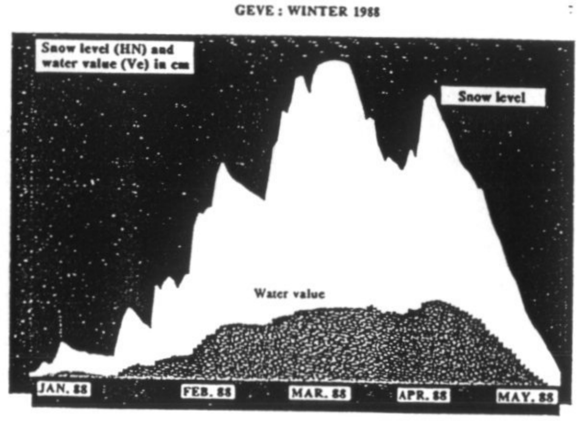
• **Automatic measurement** of the thickness and the water value of the snow layer at an altitude between 1100 and 1500 metres. The measurements are made daily during a cycle which comprises for example :

- 3 water values and snow heights at 5, 13 and 21 hours.
- 4 four-hourly air temperatures.

• **Automatic transmission** of the data by telephone, satellite (ARGOS) or any other medium suitable for use with an RS 232 C output.

PERFORMANCES

GEVE : WINTER 1988



• **The snow height h measurement**

- Measuring scale : 0 to 170 cm.
- Accuracy : ± 1 cm.

• **The water value measurement**

- Measuring scale : 0 à 600 mm.
- Accuracy ± 5%.

• **The air temperature measurement**

- Measuring scale : - 40°C to + 87,5°C.
- Accuracy : ± 0,5°C.
- Résolution of 1°C if ARGOS restitution .

• **Measuring time for water value**

- from 16 seconds (0mm) to 28 mn (600 mm) depending on the quantity of water.

PRINCIPLE

The measurement principle is based on the attenuation of a vertical beam of radioactive radiation. A radioactive source fixed on a gantry above the ground allows a narrow pencil of GAMMA radiation to escape downwards.

The detector placed in a sealed casing under ground level vertically below the source is a GEIGER-MÜLLER counter.

The dosage received is a decreasing exponential function of the water thickness passed through, irrespective of the physical state of the latter (water or ice, dry or wet snow).

An ultrasonic pickup (40 kHz) positioned 2,5 m from the ground measures the snow height by emission of a 1 ms burst, followed by reception of the echo reflected from the snow or the ground.

A 100 ohm platinum probe takes a measurement of the air temperature under "PATAC" type miniature shelter. It should be noted that the activity of the source requires an enclosure around the equipment which, experience shows, does not disturb the measuring field significantly and does not affect the snow layer.

TECHNICAL CHARACTERISTICS

- **Long operating time**
- Approximately 3 months without solar panel, with 12 V 36 Ah battery,
- Can operate for several years without intervention with 12 V-10 W solar panel.
- **Low electrical power consumption**
- ≈ 27 μa in stand-by condition.
- ≈ 1A during emission (for one second, every 180 s for 6 hours).
- ≈ 70 mA during a measurement of water value.
- ≈ 150 mA during a measurement of air temperature or snow height.
- **Weather resistance**
- On average from - 40° to +50°C.
- Immunity of the electrical and mechanical parts : (4K3) -50°C to +40°C, 15 to 100% humidity (standard NFC 20 000);
- Immunity of the electronic parts : (3K6) -25°C to +55°C, 10 to 100% humidity (standard NFC 20 000);
- Corrosion (chemical agents, UV radiation).

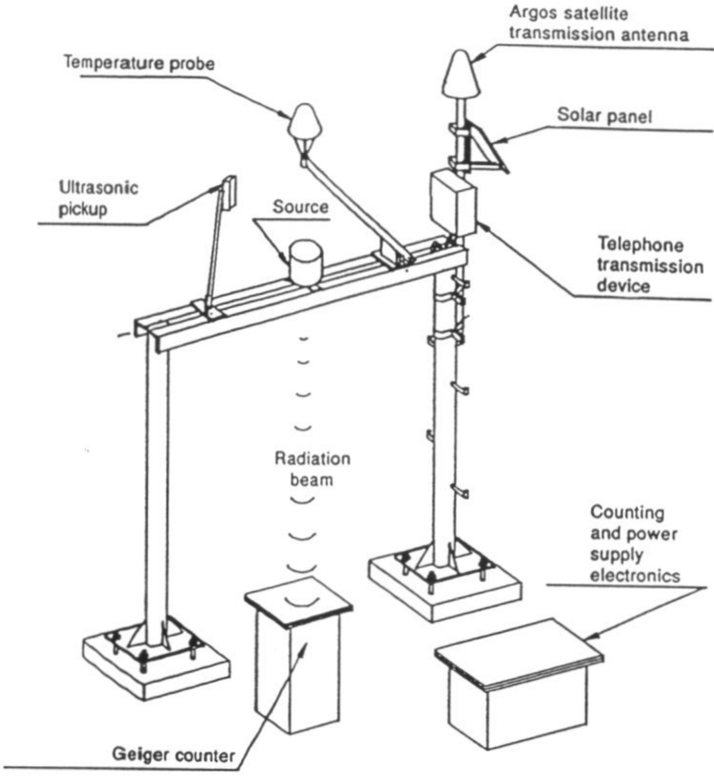


DIAGRAM OF VERTICAL-BEAM REMOTE LEVEL-MEASURING INSTRUMENT

APPLICATIONS

Monitoring of the blanket of snow in medium mountains (<1500 m)

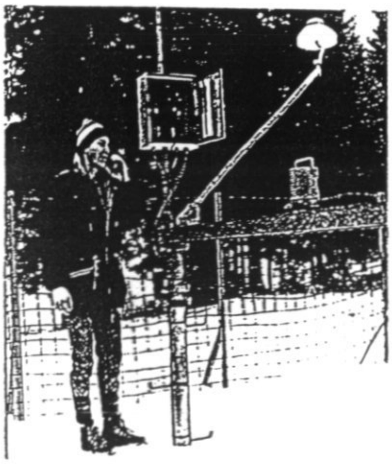
- to evaluate the risks of avalanches,
- for optimum management of water reserves,
- to survey the formation of crude rainwater resources,
- to measure the thickness of snow.

This apparatus is intended for :

- hydrologists,
- foresters,
- the winter-sports industry,
- snow-clearing and avalanche experts.

REFERENCES

- Approved by the Interministerial Commission of Radio-Elements (CI-REA), national body responsible for the regulations in this matter.
- 10 installations in French moutain ranges (Jura, Pre-Alps, Massif Central) with a 10 years feedback experience .



EDF
Electricité de France

Direction
Électricité Production Transport

Division Technique Générale
37, rue Diderot - BP 41 - 38040 Grenoble Cedex
Tél. : (33) 76 20 80 00

APPENDIX F

Report on instrument training

Water Quality Monitoring Project: The Jizera Mountains

Report on an instrument training visit to the Jizera catchments, Czech Republic

Paul Rosier
Institute of Hydrology

Contents

1. Summary

A visit to the Czech Republic was made by Mr P T W Rosier from 13 July to 26 July 1996.

A network of eight soil moisture access tubes, covering a range of vegetation, soil types and topography, were installed in the Cerna Nisa catchment operated by the Czech Hydrometeorological Institute (CHMU). Staff of the CHMU were trained how to install the soil moisture access tubes, how to read them with a soil moisture neutron probe and to process and quality control the data using a Windows based processing system (SWIPS). Details were also given on the safe storage and transportation of the neutron probe. A set of course notes relating to radiological protection for neutron probe users was discussed and handed over for translation.

Three sites, representing a range of tree age and condition within the Cerna Nisa catchment, were identified for the installation of large plastic-sheet net-rainfall gauges. One site was fully instrumented and staff were trained in the construction of the gauge, the methods of data collection, data processing and maintenance of the plastic sheet and the tipping bucket.

The RAINLOG software package was installed and staff were trained in the use of this software and the field use of the Rainlog.

2. Terms of Reference

The terms of reference for this visit were:

i. To train staff from the Czech Hydrometeorological Institute how to install soil moisture access tubes, to make observations using the soil moisture neutron probe and to enter, process and quality control the data collected. To advise on radiological protection.

ii. To identify sites for the installation of large plastic-sheet net-rainfall gauges within the Cerna Nisa catchment. To design and construct 1 large plastic sheet net rainfall gauge. To train staff from the Czech Hydrometeorological Institute how to undertake routine data collection and maintenance of the equipment.

3. Soil moisture

One of the main aims of this visit was to instruct Mr Hancvencl and Mrs Kulasova in:

site selection;
the installation of soil moisture access tubes;

the use of a soil moisture neutron probe;
the processing of soil moisture data, and
safe working practices

in relation to the setting up and running of a network of access tubes to collect soil moisture data.

Within the Cerna Nisa catchment a total of eight access tubes were installed. Five in a transect towards the top end of the catchment and three others at selected key positions, see Figure 1. The tubes within the transect cover a range of vegetation types, altitude, soil type and different depths. The other tubes were located at positions which are frequently visited by Mr Hancvencl and Mrs Kulasova in the course of their normal duties. Details of the eight access tubes are given in Table 1.

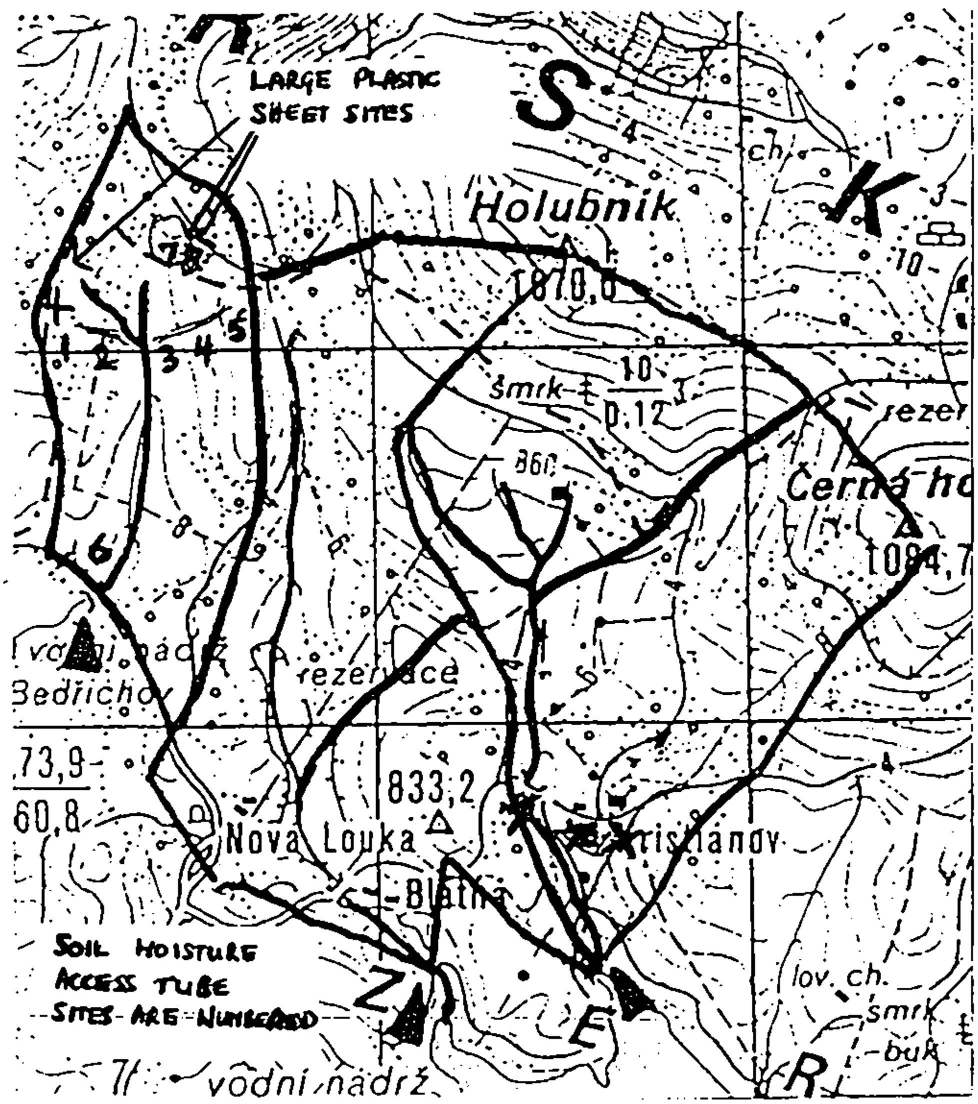


Figure 1. Location of the three large plastic sheet sites and the eight soil moisture access tubes within the Cerna Nisa catchment.

Access tube no.	Depth (cm)	Soil type
1	170	Peat from 0 to 10 cm and then brown earth to bottom of tube
2	50	Peat from 0 to 10 cm and then brown earth to bottom of tube
3	200	Peat from 0 to 40 cm and then clay to bottom of tube
4	110	Peat from 0 to 10 cm and then brown earth to bottom of tube
5	80	Brown earth throughout the profile
6	100	Peat from 0 to 10 cm and then brown earth to bottom of tube
7	200	Peat from 0 to 160 cm and then brown earth to bottom of tube
8	80	Brown earth throughout the profile

Table 1. Description of the eight access tubes in the Cerna Nisa catchment.

Access tube installation

All tubes were installed using the 'auger ahead' method. This method relies upon the use of a steel guide tube and a hand auger, inserted through the guide tube, to prepare the hole in which the aluminium access tube will be inserted. The correct technique is as follows:

use the hand auger to remove approximately 10 cm of soil
insert the steel guide tube to the same depth, ensure that the guide tube is vertical
insert auger into steel guide tube and remove another 10 cm of soil

continue in this way until it is no longer possible to drive the guide tube into the ground or the auger is unable to remove any more soil. Guide tubes of 1, 2 3 and 4 m lengths were provided along with appropriate lengths of aluminium access tube. Notes should be made of the soil type and the depth of all significant changes. This information will be necessary when setting up the boundary conditions when processing the data using SWIPS.

When installing access tubes care should be taken over site selection which should be representative of the area under consideration and to minimise damage to the surrounding vegetation. Trampling of the vegetation should be kept to a minimum and if at all possible wooden boards laid on the ground surface should be used during access tube installation. These will help to prevent damage to the vegetation and also prevent compaction of the soil surface.

Once the augering has been completed the guide tube will have to be removed. Care should be taken to minimise damage to the access tube hole and to the soil surface by any vigorous extraction of the guide tube. Once the guide tube has been extracted the access tube can be inserted. This should be placed in the hole and with a gentle twisting motion pushed in as far as possible by hand. The final placement of the access tube will have to be done with the hammer ('the bonker'). Once the tube is into its final position a rubber bung should be firmly placed into the top of the tube to prevent any water entering.

Soil moisture measurements

The neutron probe is used to make the soil moisture measurements in each of the access tubes and consists of the:

neutron probe (within its transport housing)
ratescaler
battery charger
transport case

The neutron probe and ratescaler should be transported to the catchment in the aluminium (transport) case provided. Before going to the field the batteries (within the ratescaler) should be charged. This is done by connecting the ratescaler to the battery charger with the cable provided. The timer on the battery charger should be set to 6 hours and the current to 250 mA. In the field the ratescaler should be connected to the transport housing, of the neutron probe, by the bolt provided.

Measurements from the access tube are made every 10 cm below ground level in the following way:

Remove the rubber bung from the access tube.
Measure the height of the access tube rim from the ground level, note this reading.
Place the neutron probe on top of the access tube.
Unlock the neutron probe in the transport housing with the key provided.
Unclip the ratescaler from the transport housing.
Connect the cable to the ratescaler.
Switch on the ratescaler by pushing the On/Off switch to the On position.
Ensure that the two switches are in the 16 and Sec positions.
Ensure that the cable depth reading is set to 00000 adjust if necessary.

Lower the neutron probe to the first reading below ground level, which is 10 cm plus the height of the access tube above ground level, ie if the tube height is 17 then the first reading will be at 27 cm. Ensure that the cable is held vertical at all times.
Start the ratescaler counting by pushing the On/Off switch (which is already in the On position) further towards the On position.
Once the ratescaler has finished counting the bleeper will sound and the reading will be displayed. Note the reading.
The neutron probe should then be lowered to the next reading depth and the reading obtained.This is continued until all the readings in the tube have been obtained. It is not necessary to switch off the ratescaler between readings.

Once the tube has been read the neutron probe is raised by the cable ensuring that it is held vertically and the depth counter adjusted if necessary. The probe is locked back into the transport housing and the ratescaler switched off and the cable removed and rewound around the clips on the transport housing. The cable should never be left connected to the ratescaler and the ratescaler clipped back onto the transport housing as this will put undue pressure upon the cable, just above the plug, and will, with time, cause it to break.

This procedure is repeated for all of the tubes to be read. A data sheet to record the readings in the field is shown in Appendix 1.

Data processing

Soil moisture data are processed using SWIPS - Soil Water Information Processing System. This is a Windows based processing system which requires at least 10MBytes of space for it to run efficiently. The system is organised around Projects, with the extension .PRJ within the database. A project name can be literally anything but for convenience within this training programme has been called **JIZERA**. Within each project there can be any number of sites and within each site there can be any number of tubes. The site must be numbered as well as the individual tubes. The eight soil moisture access tubes that were installed during this visit were within the site **UHLIRSKA** and are numbered **1** to **8**. Each tube has its own calibration for each reading depth which is based on the soil present and which was noted during installation. Once the basic parameters have been set up for each individual tube they do not need to be changed, unless, for example, there is a change of reading depths because the tube was deepened. Readings should be processed as promptly as possible as this aids in interpretation and helps to identify if there are any problems.

Water counts

All of the soil moisture readings made within the access tubes are referenced to a standard value which is made within a drum full of water. This value is called the water count. The drum should be large enough to include all of the sphere of influence (of the radioactive source) and ideally should have minimum dimensions of 60 cm height by 40 cm diameter. An oil drum is ideal. An access tube should be fitted into the drum and held in place by a happen before the readings are made. It is important to identify the exact position within the water drum that the neutron probe should be lowered to take a water count. To do this it is best to take 16 second readings every 5 cm, starting at the top of the access tube, and to continue 'through' the water drum until the neutron probe reaches the bottom of the water drum. Figure 2 shows a diagram of a water drum and the profile of readings that have been obtained. It can be clearly seen that a well defined plateau has been obtained. The depth at which all subsequent water count readings should be taken will be the mid point of the plateau. Before each visit to the catchment a standard water count reading should be taken. However before taking a reading remember to check the water level in the drum and top up if necessary. The water level should not be less than 2 cm from the top of the drum. As a minimum **one 16 minute** count should be taken. This value will have to be input into SWIPS when the data is processed. As an additional check on the neutron probe **one 64 minute count** should be taken every month. A graph of all water count values should be plotted. The graph will indicate, with time, if there is any long term drift of the neutron probe.

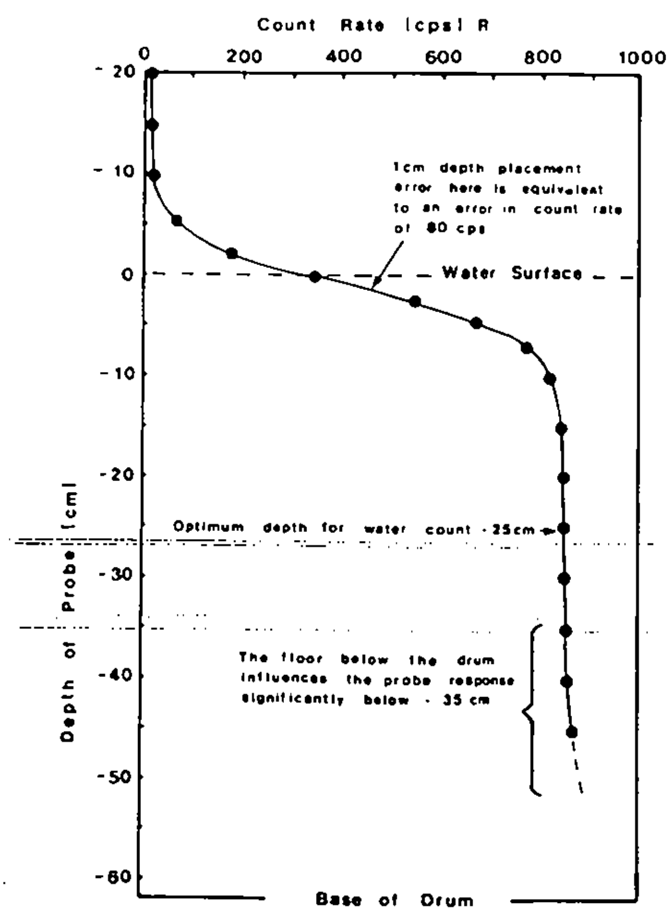


Figure 2. Diagram of water drum and profile of water counts taken with a neutron probe.

4. Large plastic-sheet net-rainfall gauges

Three sites for the large plastic-sheet net-rainfall gauges were found within the Cerna Nisa catchment and these are identified on Figure 1. The first site, which is reasonably close to the main meteorological site, is within trees of approximately 30 - 40 years of age. The canopy is completely closed and although there is some damage to a number of stems the trees look to be in a good condition. There is a gentle slope of $< 5°$, the tree spacing is about 2 m and no understorey is present. The second site is approximately 200 m away from the first and is within trees of about 70 - 80 years of age. The canopy is open and the trees are widely spaced, on average between about 4 and 6 m, and there is a well developed understorey of grasses. Again there is a gentle slope of $< 5°$. The third site is close to the highest point of the catchment at Olivetski hora and is within trees of about 30 - 40 years of age. In many respects this site is very similar to the first, a closed canopy, no understorey and similar tree spacing. Although here the slope is probably in excess of 5°. All sites are within reach of either a forest road or track.

Installation

It was decided to install the first large plastic-sheet net-rainfall gauge at the site closest to the main meteorological site. The site was prepared by the removal of a number of fallen trunks and rotten tree stumps. Where necessary any dead branches on the tree stems to be enclosed by the gauge were also removed. It is expected that during the winter snow to a depth of 1.5 m will be present therefore the 'normal' design of ridges and valleys for this type of gauge was changed to take this into account. A reinforced floor capable of withstanding approximately 500 kg of snow per square metre was constructed out of timber. Once the main timbers had been laid a floor was constructed out of 2.5 cm thick planking. The planking was then overlain with roofing felt which was sealed around all of the tree stems enclosed by the gauge. A wall of 30 cm height was constructed of planking for the two sides and the top of the gauge. The plastic was then laid over the roofing felt, gathered around the tree stems and taken over the walls. Where the plastic was gathered around the trees a seal of black bitumen was painted. At the bottom of the gauge a 15 cm wide plastic gutter was fixed and this was led into a large tipping bucket flow gauge. The dimensions of the 4 sides and 2 diagonals of the gauge are given in Figure 3. The area of the gauge was then calculated using the 'S' rule.

Equipment maintenance

To an extent the large plastic-sheet net-rainfall gauge is self cleansing simply because of its slope. However the gauge should be kept clear of all pine needles and small branches and this is best done by cleaning the gauge with a brush on a weekly basis. During cleaning the plastic should be checked for any small cuts and tears which would allow water to enter. At the same time the seals around the trees should be checked for water tightness. Any cuts found in the plastic sheet should be repaired using a small piece of plastic which is then painted over with black bitumen. If necessary the seals around the trees can be repainted with the black bitumen. If the tear in the plastic sheet is found to require a more drastic solution then it is best to use a complete new length of plastic sheet. The plastic gutter should also be kept free of pine needles. The large tipping bucket contains a mechanical counter inside a perspex housing. The mechanical counter can be affected by water in two ways; the first is that the 'striker' pin can seize and the second is that the window can become misty. Water should be prevented from entering the housing by ensuring that the 'O' ring seal between the housing and the aluminium upright is kept greased. This is easily done by removing the perspex housing and applying a liberal quantity of silicone grease. The housing should then be replaced and all four bolts evenly tightened. If the striker pin does become seized then the mechanical counter will need to be replaced. This is done in the following way:

remove the perspex housing
undo the small allen screw in the base of the housing, this will loosen the plastic pillar upon which the mechanical counter is sitting
remove mechanical counter, note position of the striker pin
replace with new mechanical counter with striker pin in same position (as above)
ensure that mechanical counter is sitting on pillar correctly, tighten up allen screw
replace the perspex housing, ensuring that silicone grease is applied to 'O' ring seal

Regular maintenance of the tipping bucket will reduce the need to change the mechanical counter. However in general a mechanical counter should remain in service for about 2 yeras.

Calculation of area and calibration factor

The area of the gauge was calculated from the dimensions given in Figure 3 using the following formula:

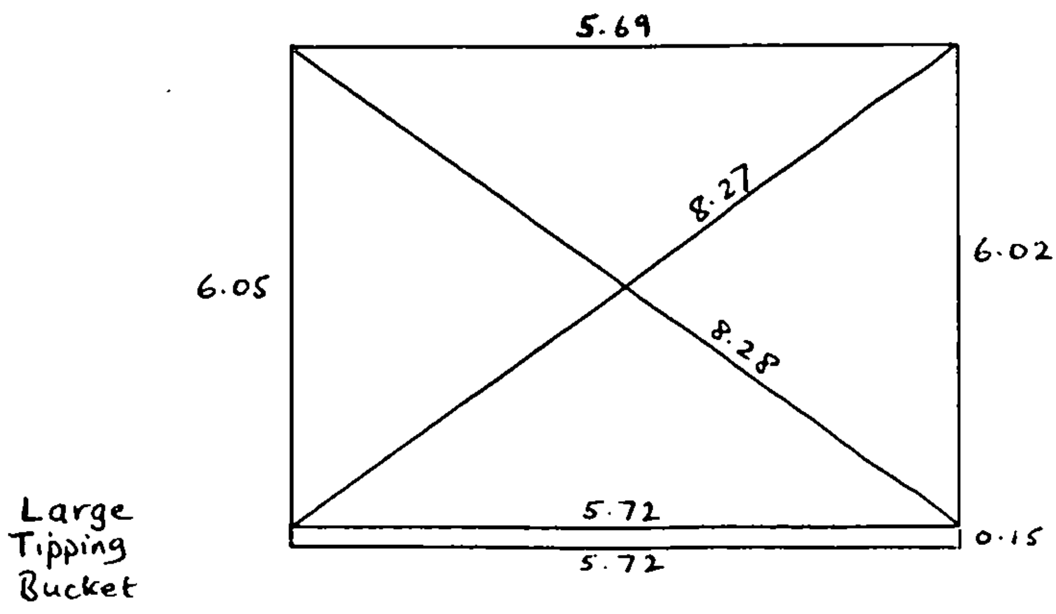


Figure 3. Dimensions of the large plastic-sheet net-rainfall gauge.

Area = $\sqrt{S(S-A)(S-B)(S-C)}$

where A, B and C are the lengths of the three sides of a triangle

and $S = 1/2\,(A+B+C)$

For triangle 1

A = 5.69
B = 6.05
C = 8.27
S = 10.005

$$\text{Area} = \sqrt{10.005\,(10.005 - 5.69)\,(10.005 - 6.05)\,(10.005 - 8.27)}$$
$$\sqrt{10.005\,(4.315)\,(3.955)\,(1.735)}$$
$$\sqrt{296.2401}$$
$$= 17.2116\ m^2$$

Triangle 2

A = 6.02
B = 5.72
C = 8.27
S = 10.005

Area = 17.2166 m^2

Triangle 3

A = 5.69
B = 6.02
C = 8.28
S = 9.995

Area = 17.1269 m^2

Triangle 4

A = 5.72
B = 6.05
C = 8.28
S = 10.025

Area = 17.3019 m^2

Area of gutter = 5.72 * 0.15 = 0.858 m^2

Therefore area of gauge

using triangles 1 and 2 = 17.2116 + 17.2166 + 0.858 = 35.2862 m^2
using triangles 3 and 4 = 17.1269 + 17.3019 + 0.858 = 35.2868 m^2

Mean area of gauge = **35.2865 m^2**.

The calibration factor for the gauge is equal to the tipping bucket volume divided by the area of the gauge.

Mean volume of bucket = 1.2219 l
Area of gauge = 35.2865 m^2
Calibration factor = **0.03463 mm per tip**

The calibration factor will need to be known for data collected using the mechanical counters and for data that is stored on the Rainlogger.

Data collection

Any water or snow melt from the large plastic-sheet net-rainfall gauge will be channelled via the plastic gutter into the large tipping bucket. Tips from the tipping bucket are recorded in two ways; the first is by alternate tips incrementing a mechanical counter and the second is by pulses from the magnetically operated reed switch being fed onto the Rainlog. In both cases the calibration factor needs to be known.

A data sheet for use in the field to record the mechanical counter tips is shown as Appendix 2.

5. Diary/Itinerary

July 1996

13 Travel to Prague on BA856. Met by Mrs Liba Bubenicova. Visit to Prague City late (pm) with Mrs Bubenicova.

14 Discussion with Mrs Bubenicova re: objectives of visit (am). Travel to Jablonec nad Nisou with Mr Ruda Hancvencl and Mrs Alena Kulasova (pm).

15 Office (am) to discuss programme with Mr Ruda Hancvencl and Mrs Alena Kulasova. Mr Kits from Eurostandard arrived with Neutron Probe. Mr Kits requested that the original Certificate issued by Amersham International regarding the activity of the source be sent to him. Discussed with Mr Kits and his colleague requirements for storage, transport and personal dosimetry, these points will have to be followed up by Mr Hancvencl with Mrs Liba Bubenicova. Sent fax to J Blackie (at Institute of Hydrology, UK) requesting copy of Certificate late (am). Received faxed copy of Certificate early (pm). This was forwarded to Mr Kits with the request that if he wanted the original Certificate for him to let me know where to send it.

The neutron probe access tube installation equipment sent with Eurogate arrived early (pm). Mr Hancvencl and I took this to his house for storage.

Installed SWIPS onto the computer of Mrs Kulasov. Machine has plenty of space, but informed her that if she wished to transfer SWIPS from her PC to laptop she will have to de-install the copyright protection. Gave basic instructions on how to set up Projects (.PRJ) by using information contained on SWIPS database on my laptop. Spent time going through the basic equation to convert raw numbers in the field to processed numbers using different slopes and intercepts for different soil types.

Visit to catchment late (pm) to see sites that Mr Hancvencl had identified for large plastic sheets. Three sites had been identified covering the age range of the trees in the catchment; circa 15/20 yrs, 30/40 yrs and 50/60 yrs. Many of these sites were not really acceptable. However in discussion with Mr Hancvencl these sites were agreed as being representative of the catchment as a whole. Took the opportunity to 'walk' the upper part of the catchment. Found at least one site that can be used. Trees have been thinned and many of them have lost their tops from the weight of the snow during the winter. Mr Hancvencl agreed to get Danny and Pavel (men doing their Civil Service with CHMU) to clear the site.

16 Discussed with Mr Hancvencl the volume of wood required to construct the plastic sheet sites. This wood was ordered and would be ready for collection on Friday. Asked for 'water drum' to be made so that daily water counts can be made for the neutron probe. This should arrive within next day or two. Went through SWIPS again with Mrs Kulasova, who had gone through manual overnight and had some questions. Discussed with Pavel and Danny whether they would be able to translate my 'Radiological Protection' notes for neutron probe users. Went to catchments late (pm) to look for two more sites. Found two within the Kristianos Catchment. Both sites will need clearing. Mr Hancvencl also having to download data and change charts from SEBA hydrometric equipment, however he was having difficulty in down loading data with memory card supplied. It was apparent that with a logger capable of storing 512KB and memory card only storing 256Kb this was going to be a problem. Worked out from manuals that the logger stores data in a ring and that maximum amount of storage (with their 16 channel logger) would be 25 days. He will have to bring laptop to field to download data. It would seem that they will have to draw up a weekly timetable for routine data collection. In evening discussed with Mr Hancvencl the use and installation of Tensiometers. They have some to be installed by the Czech Technological University in Prague and needed guidance on how to install them and possibly process data.

17 Pavel and Danny cleared all three plastic sheet sites in preparation for the wood being delivered on Friday. Mrs Kulasova, Mr Hancvencl and I installed a row of five access tubes across the top end of the Cerna Nisa catchment, tubes range in depth from 80 to 200 cm. These tubes were all read. Showed both Mr Hancvencl and Mrs Kulasova how to take readings and possible pitfalls that can occur. On the way to Office arranged for a local lorry driver to collect wood from Jablonec nad Nisou and deliver it to the three large plastic sheet sites. In evening set up ratescaler battery charger in Mr Hancvencl's house. Showed Mr Hancvencl how to use it and what to watch out for if things go wrong..

18 Following a telephone conversation with Ms Sarka Blazkova in morning Mr Hancvencl and I had to go and look for additional plastic sheet sites. Ms Blazkova not happy with sites being located outside of Cerna Nisa catchment, although she did accept that this might not be possible for technical reasons. I said that where ever possible we would find sites within the Cerna Nisa catchment. Installed three more tubes in catchment. All eight tubes were read today.

19 Went to Jablonec nad Nisou to arrange collection and payment of wood. All wood delivered to three plastic sheet sites today. All wood at three sites was taken from forestry road and moved closer to the actual sites. Sites are about 50 m from road and in areas not usually visited by tourists.

20 To Office in morning. Discuss with Mr Hancvencl and Mrs Kulasova plan for Saturday and Sunday. Visited Jablonec nad Nisou in morning. In afternoon training Mrs Kulasova on the use of SWIPS. She has set up new Project, initialised all the sites and has started to input the data. Had problem in sorting out a rainfall file for Mrs Kulasova. Said that I would sort out on Sunday morning.

21 Sorted out problem with rainfall file. To Mala Skala late (am). Lunch in pub and then walk around the forest and the sandstone rocks.

22 To Office (am). Copied over rainfall file and Virus Guard software for Mrs Kulasova. Needed to set the date within the Options menu to 1996 to get rainfall plotted out. This was successful. To first plastic sheet site, close to the main meteorological site, Mr Hancvencl, Mrs Kulasova, Danny and Pavel. The basic construction, using the large timbers and logs cut from forest, was sorted out by lunchtime and some boards laid. A hole and small drainage channel for the tipping bucket was started. The final boards were laid after lunch. The platform is about 6.5 m by 5.5 m. Tomorrow plan to make wooden walls about 30 cm tall from boards.

23 To Office by Bus (am). Telephone call from Mr Hladny. He would like to meet me on Friday late (am) to discuss progress and to meet with Director, Dr Obrusnik. Took plastic sheet and tipping bucket to site. Pavel and Dan went first to start to construct the walls. Purchased 5 rolls of roofing felt and adhesive. Put Rainlog programs onto Mrs Kulasova's laptop and PC, initialised Rainlog with Mrs Kulasova. Went through all of the procedures. Constructed walls, fixed gutter and laid roofing felt

24 To site to complete installation of large plastic sheet.

25 Pick up Mrs Kulasova from her house (am). To Jiserka catchments. Download data from 2 Aws's and 2 water level stations. To Office (pm) message from Mrs Bubenickova who needs Shipping details of neutron probe and ancillary items. Called Miss Helen Davies at Institute of Hydrology and asked her to fax it over. This was received late (pm).

26 Travel to Prague (am). Met by Mr Hladny. Discussed progress during trip. Meet Dr Obrusnik, Director of Institute, outlined progress made. To lunch with Mr Hladny. Travel to London on BA857 (pm).

Appendix 1.

Date: Site: R_w:

Tube no.	01	02	03	04	05	06	07	08
Time								
10								
20								
30								
40								
50								
60								
70								
80								
90								
100								
110								
120								
130								
140								
150								
160								
170								
180								
190								
200								
210								
220								
230								
240								
250								
260								
270								
280								
290								
300								
Total								

Appendix 2

TIPPING BUCKET MECHANICAL COUNTER VALUES

MONTH:__________ YEAR:_______

DATE	BUCKET 1	BUCKET 2	BUCKET 3
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			