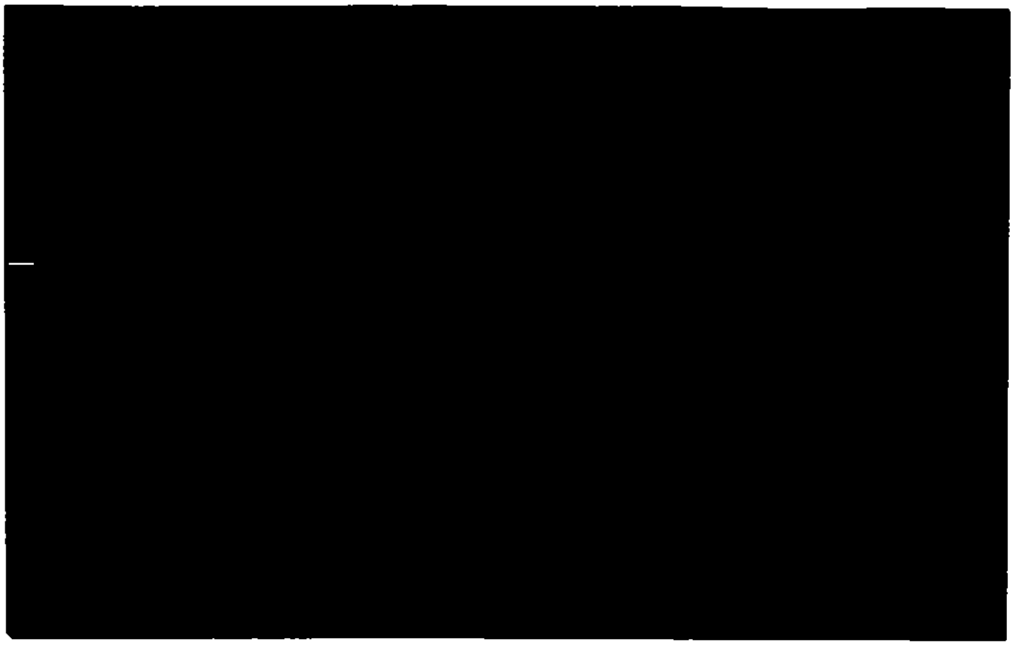
Institute of Hydrology

Centre for Ecology & Hydrology

Natural Environment Research Council



European Small Hydropower Association

HydrA Dissemination Sub-Contract
(EEC Ref: 4.1030/D/96-005)

Final Report

March 1999

This report is an official document prepared under contract between the European Small Hydropower Association (ESHA) and the Natural Environment Research Council. It should not be quoted without permission of both the Institute of Hydrology and ESHA.

Institute of Hydrology
Crowmarsh Gifford
Wallingford
Oxfordshire
OX10 8BB
UK

Tel: 01491 838800
Fax: 01491 692424
e-mail: softdev@ioh.ac.uk

Contents

		Page
1.	INTRODUCTION AND SCOPE OF WORK	3
2.	ACTIVITY PROGRAMME	5
	2.1 Start-up activities	5
	2.2 On-going activities	10
	2.3 Promotion	11
	2.4 Variations against planned activities	16
3.	FINANCIAL REPORT	18
4.	CONCLUSIONS	19
	ACKNOWLEDGEMENTS	21

ANNEXES

A Institute of Hydrology Proposal [without Appendices] dated 27/10/95

B (i) English and Spanish brochures
(ii) User Guide contents list
(iii) HydrA V1.0 Demonstration Software Guidance Notes

C Launch workshop materials

(i) Workshop flyer
(ii) List of registrants
(iii) List of presenters

D Published papers covering HydrA dissemination

E (i) Press Releases & Articles in Trade Publications
(ii) International Conferences attended

F List of customers who have purchased the HydrA software

1. Introduction and Scope of Work

This is the final report covering progress and activities carried out under the HydrA Dissemination Sub-Contract made between the European Small Hydropower Association (ESHA) and the Institute of Hydrology (IH).

The formalities covering this work are contained in a document signed by NERC (for the Institute of Hydrology) on 22/1/98 and countersigned by ESHA on 2/2/98. The initial part of that document sets out the objective and scope in these terms (before continuing with details about payments and legal matters).

> "Whereas within the framework of the Altener Programme of the European Community the European Small Hydropower Association has concluded a contract (4.1030/D/96-005) with the Commission of the European Communities ("Commission") on the 31 July 1996 for the dissemination of the software "HydrA" developed for UK and Spain under the ATLAS Phase II contract (4.1030/E/95-006) hereinafter together called the "EEC-Contract" which has been formally incorporated into this Sub-Contract as Annex A and B thereto;
>
> and
>
> whereas the European Small Hydropower Association and the Commission have agreed that the Institute of Hydrology as a Sub-Contractor shall perform part of the work contracted for under the EEC-Contract (Annex A), the following is hereby agreed between European Small Hydropower Association and the Institute of Hydrology.
>
> 1) *Objective of the Sub-Contract*
>
> The objective of this Sub-Contract is for the Institute of Hydrology to contribute to the achievement of the requirements of the EEC-Contract (Annex A) together with the European Small Hydropower Association performing the EEC-Contract (Annex A) in accordance with the terms and conditions as stated in this Sub-Contract.
>
> 2) *Terms and Conditions*
>
> Unless otherwise agreed, the Parties shall be bound *"mutatis mutandis"* by the terms and conditions of the EEC-Contract (Annex A) including Annex I, (Work Programme) and any special conditions which may be agreed as a separate Annex thereto, which form part of the Sub-Contract as Annex A, but excluding particular provisions of the EEC-Contract between the Commission and European Small Hydropower Association (such as provisions referring to ESHA as main Contractor).
>
> 3) *Scope*
>
> The Institute of Hydrology shall perform and complete its share of the work under this Sub-Contract in accordance with the respective requirements of the Budget and Work Programme at Annex 1 of the EEC-Contract (Annex A)."

The Annex 1 referred to above is included in the report as Annex A.

The aim of the contract was to ensure wide dissemination of HydrA (the European Atlas of Small-scale Hydropower Resources) via software and documentation in the UK and Spain. HydrA software was developed on behalf of ESHA under Phase II of its European Atlas project which was awarded at the end of 1993 and started formally in 1995. HydrA was designed to enable local authorities, water resource planners and potential investors to assess the feasibility of developing small hydropower schemes anywhere in the countries for which it has been developed.

This report summarises activities undertaken throughout the dissemination contract and provides details of income and expenditure for both start-up costs and running costs. This document constitutes the final report under this sub-contract and covers our contribution to the reporting requirements specified in ESHA's contract with EEC; that states, *inter alia*:

"4. Undertake to transmit to the Commission, in triplicate, within three months of completion of the project and not later than 15 July 1998 (in accordance with budget rules, the validity of the appropriations committed to this project is limited);

- a report on the use of the above mentioned financial assistance;
- an account statement certified by the person in charge of the body receiving the contribution, or a financial statement together with duly certified supporting documents indicating the nature and amount of each item of expenditure and the corresponding income (including the amount of the Commission grant);
- where applicable, the trustee's annual report."

(This report goes beyond the Interim Report (February 1998) in which we provided details of both start-up and dissemination activities from the start of the contract up to January 1998.)

2. Activity Programme

The Institute of Hydrology has undertaken a wide range of activities designed to disseminate the HydrA software. This chapter describes in successive sections:

- start-up activities
- on-going activities
- promotion

Start-up activities, largely in the first year, were followed by on-going support activities in years two and three. Additional and complementary promotion work was financed by the Institute to further widen the knowledge of HydrA among likely users. Both the sub-contract work and the supplemental activities are described below.

Section 3.4 looks at the variations between planned and actual activities and examines the reasons behind these.

2.1 START-UP ACTIVITIES UNDERTAKEN

Our proposal listed eleven project start-up items (a to k in Annex A para 11.1) that were to be carried out; these have all been completed. The paragraphs below give more detail of each of those activities, using the original order in which they were listed.

Samples of deliverables (i.e. manual, manual cover, publicity brochure in both English and Spanish) were provided to ESHA either with the Interim Report, or as a supplement to it, in February 1998. However, copies of the publicity brochure are also included in this report for convenient reference, and because of their importance in conveying the essence of HydrA's value (Annex B).

2.1.1 Design and produce a manual cover

Manual covers were designed by our staff, taking into account current trends in the software industry with this type of material when it has to be produced in relatively small print runs. The plastic cover, hiding the ring binding, permits a spine title to be inserted. This enables the HydrA manual to be readily identified on the user's shelf.

An attractive colour cover design was adopted incorporating the logos of the Altener programme, of ESHA and the Institute (together with its parent body). The photograph deliberately illustrates the HydrA software features in showing both a river and a turbine.

The English and Spanish language versions of the cover that were produced under this project were similar in layout and content. Sufficient were printed to cover those likely to be sold during and slightly beyond the contract period.

The covers used some of the same graphics and logos as the publicity brochure and other publicity material (see below), in order to establish an easily recognisable product identity.

2.1.2 Design disk label and logo

It was necessary for our staff to produce floppy disk labels for each of the versions, both English and Spanish, of HydrA that were released. This involved, over the course of the project, two Spanish versions and three English versions. The current version reference number is v1.05 for both language editions.

Such labels need to be to an industry standard and hence show:

- title
- version number
- installation instructions
- contact for telephone support.

The existing Institute of Hydrology disk label design was modified to cope with additional logos for Altener and ESHA recognition.

2.1.3 Determine pricing structure

Following advice from a meeting in October 1996 in Spain between representatives of ESHA, Centro de Estudios y Experimentación de Obras Públicas (CEDEX) and Internacional de Ingeniería y Estudios Técnicos S.A. (INTECSA) to the effect that there would be problems distinguishing between academic and non-academic organisations in Spain, it was suggested that there should be a single price and licence for all copies of the software. In the interests of consistency, and because of the relatively low price of the software, it was further suggested and agreed that the same approach would be taken in the UK.

Following our written proposal of 24 October 1996 to Dr Eric Wilson (Project Manager on behalf of ESHA) of a price of £330+VAT, this was accepted and adopted for all sales. That price then corresponded to a figure of 400 ECU (+VAT) and was approved by Altener.

2.1.4 Design and produce publicity literature

A four page publicity brochure was designed and printed in both English and Spanish. 3000 brochures were printed in English and another 500 in Spanish. These have been distributed in the cost-effective manner adopted for all the publicity material published by the Institute of Hydrology. This includes a mailing with the workshop invitation, distribution through the Institute's staff contacts, placement at key relevant conferences and exhibitions, and their additional availability through the display stand at our Wallingford headquarters. Copies also went to the ESHA secretariat. This brochure has been widely distributed at conferences and exhibitions in the UK and overseas by the Institute of Hydrology and by APPA (the Spanish Hydropower Association) in Spain. Copies of both the English and Spanish brochures have been made available via the Institute's World Wide Web (WWW) pages (section 2.3.6).

A brief description of the HydrA software is also included in the Institute's Software Sales and Support general publicity brochure; the text was included in our Interim Report. This is backed by a web page listing of Institute of Hydrology software packages, which cross-refers to the HydrA web page illustrated in section 2.3.6.

2.1.5 Produce an installation program for software distribution

In order to ensure simple and trouble-free installation of the HydrA software on users' personal computers (PCs), a tailor-made installation program was created. This was re-created for each release version of the software in order to ensure that any new or changed files would be installed correctly.

To prevent unlicensed use of the HydrA software, the Institute of Hydrology's standard copy protection mechanism was added to each issued copy of the software.

Production of the installation program for the Spanish version of HydrA also necessitated changes to the master installation routine and to the copy protection program in order to enable messages to be displayed in languages other than English.

2.1.6 Test pre-release versions

In order to ensure that installation programs for new software, or software updates, will install without incident, it is Institute of Hydrology procedure to test each installation program thoroughly.

This is done by producing a standard software issue, as would be produced in response to a customer order, and then using the installation program to set up the software, and check the basic functionality of the program, on a "clean" machine. (The "clean" machine has a choice of operating environments (Windows 3.1, Windows 95 and Windows NT); however by definition it has no software or files other than those issued with the operating system. This allows the Institute of Hydrology to ensure that the software is not dependent on files or programs which may have been installed by other software packages.)

This has proven very effective in ensuring subsequent trouble-free installation for software users.

2.1.7 Set up a database for recording clients and queries

Details of callers and the nature of contacts (requests for information, quotations, orders, requests for assistance, etc.) relating to HydrA were logged on the Supportline software acquired from Logical Software Ltd. This enabled us to identify any recurring difficulty (and so address improvements) and to trace requests that are repeated from a single organisation.

A typical enquiry log is shown as Figure 1. Four priority scales are used as follows:

PRIORITY	Rating	Logic
1	Urgent	Bug causing failure
2	High	Date critical order/secondary bug
3	Medium	Firm order/desired enhancement
4	Low	Typical non-urgent enquiry

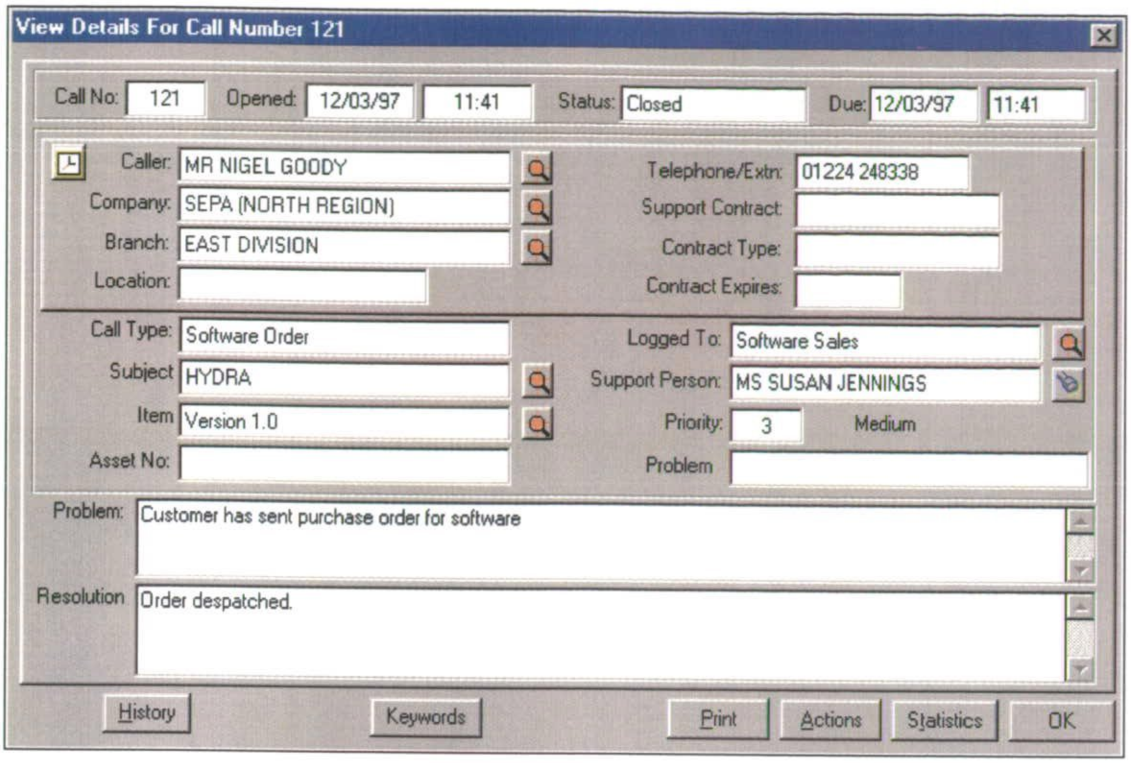


Figure 1 *Typical log enquiry*

2.1.8 Print manuals

The draft English manual produced as part of the Phase II contract was checked and corrected to bring it into line with the release version of the software. Further changes, including addition of version control, a disclaimer and a legal notice, were also made to ensure that the manual was consistent, easy-to-use and professional in appearance.

The resulting manual, 90 pages long, was then reduced to A5 format and 100 copies were printed.

Once completed, the English manual was passed to Dr Celso Penche, (ESHA's Spanish representative) who kindly translated the manual into Spanish. The translated manual was then re-reviewed to ensure consistency with the Spanish version of the software. The finished Spanish manual is 104 pages long. It was printed (25 copies) and bound in a similar fashion to the English manual, save that the Spanish language versions of the manual covers and spines were utilised.

Issued manuals, in both English and Spanish, were enclosed in a white A5, 3-ring binder; transparent wallets on front and spine took the printed title inserts referred to in section 2.1.1.

2.1.9 Product familiarity for help desk assistance

Institute of Hydrology software sales and support staff, who provide a dedicated Help Desk service for users of Institute of Hydrology software products, spent time becoming familiar with the software in order to be able to respond to enquiries and provide a first line support service for customer queries

This was achieved by:

- Institute of Hydrology sales and support staff attending the launch workshop,
- spending time experimenting with the software and its supplied sample data files,
- testing the installation program.

2.1.10. Provide support and assistance at product launch workshops

Although the proposal merely called for Institute of Hydrology staff to provide support and assistance at product launch workshops, the Institute of Hydrology organised and ran a product launch workshop in the UK in March 1997. This was well attended.

In an effort to promote further uptake of the HydrA software, a second UK workshop was organised in early 1998. Unfortunately, this had to be cancelled due to lack of response.

Significant attempts, (including a visit to Spain and approaches to a number of Spanish organisations and individuals) were made to organise an equivalent Spanish event, but these were unsuccessful. The fact that such a workshop could not be run in Spain will almost certainly have contributed significantly to the lack of uptake of the software in Spain. Chapter 4 (Conclusions) offers some speculative analysis of the reasons why attempts to run this workshop proved ultimately unsuccessful.

Further detail about the UK workshops (including the promotional literature, plus details of speakers and attendees) is provided in section 2.3.

2.1.11. Provide demonstrations at exhibitions/conferences

Institute of Hydrology scientific staff have attended a number of hydropower and alternative energy conferences and exhibitions in order to publicise and demonstrate HydrA. The venues for these events have been located in the UK, Europe (including Italy, Spain, Greece, France) and even as far afield as India. Further detail about conference attendance and provision of demonstrations is provided in section 2.3.10.

Interested visitors to the Institute have also received demonstrations of the software. A demonstration version of the software was also produced and made available.

2.2 ON-GOING ACTIVITIES

This section describes the activities undertaken in providing software to purchasers and in providing after-sales support.

The costs of supporting each copy of the software sold were detailed in Section 11.2 of the original proposal (included as Annex A). These costs cover a number of activities (e.g. staff time in preparing orders for despatch, staff time to provide helpdesk support, costs of materials (disks, binders, labels etc) and carriage costs).

The funding for these activities was intended to be provided through the income from sales of software, plus income from maintenance agreements. However, volume of sales has not been in line with initial predictions and therefore these activities have been partly funded by the Institute in order to ensure that customers receive high-quality customer service.

2.2.1 Software Sales

In the UK a total of 25 customers have bought copies of the software. Four of these have bought site licences or multiple copies of the software. Four copies of the Spanish version of the software have also been sold. Customers include environmental agencies, higher education institutes, energy authorities and hydropower consultancies. A complete list of all purchasers of the software is included as Annex F.

A copy of the software has been supplied free of charge to a number of individuals who have been instrumental in developing and/or promoting the software. These include:

- Kieron Hanson (of Hydroplan, hydropower consultants) who carried out preliminary beta testing of the UK version.
- Dr Celso Penche (hydropower consultant, Spain) who was of great assistance in translating the manual and related documentation
- Andrea Lamberti (MSc student, Barcelona) who assisted with development of an Italian version.

A copy has been provided free of charge to several post-graduate students at UK universities (e.g. Nottingham, Liverpool) for use in connection with their research projects.

For several other university students, a retrieval service has also been provided. This allowed the student to specify a catchment which Institute of Hydrology scientific staff then ran through the HydrA program, relaying details of the results to enquirer.

2.2.2 Distribution of general software update

Through operational use of the software a number of minor errors were identified and some cosmetic/layout improvements identified. These corrections were incorporated into a revised version of the software which was distributed free of charge as part of the maintenance agreement. The last general release version was v1.05

2.2.3 Software Support

The total number of help-desk calls relating to HydrA now totals approximately 90. Analysis of calls logged shows the following breakdown.

specific product enquiries (i.e. relating to HydrA rather than Institute of Hydrology software generally)	28
software orders	30
requests for demonstration disks	8
support (difficulties in installing the software or in understanding the application of the methodology)	16
copy protection	6

Approximately one quarter of specific product enquiries were converted to software sales.

Given the Institute of Hydrology's experience with other newly-released software products, the number of support calls has been noticeably low. Most of these have been directly resolvable by first line support (Help Desk) or second line support (Institute of Hydrology scientific staff), without recourse to third-line support (programmer). This testifies to the high quality of the software program and the thoroughness of the pre-release testing.

2.3 PROMOTION

The activities described under this section are, in part, funded by the set-up costs provided by this contract. The remainder have been funded by the Institute of Hydrology in the interests of promoting the HydrA software and methodology as widely as possible.

2.3.1 Launch

In January 1997 the Institute held two Open Days. The first of these was for commercial customers (including environmental protection agencies, local authorities, and major consultancy firms). The second was for academic customers (including universities, colleges and research institutes). In all, over a thousand invitations were issued, and over a hundred customers accepted the invitation. This event was used to introduce the HydrA (UK) software ahead of its formal launch at the workshop in March 1997. A 30 minute presentation about the HydrA project and software was given on both days; the software was on permanent view during both days and interested customers were able to see it demonstrated.

The first order for HydrA was placed at this event.

2.3.2 Launch Workshop

A two-day technical workshop was held in March 1997 to launch the UK version of the software.

It had been hoped that ETSU, a member of the Organisation for the Promotion of Energy Technologies (OPET) network, would provide some promotional input to this event by means of a mailshot. Unfortunately it transpired that this would have attracted a significant, unbudgeted cost and therefore did not go ahead. However, information about the workshop was sent by the Institute of Hydrology to a list of selected companies (e.g. water companies, energy authorities, environmental protection agencies, universities and consultants) specifically known to have an interest in hydropower. A copy of the workshop flyer is included as Annex C(i).

A total of 22 delegates registered for the workshop which was divided into two complementary sessions. Annex C(ii) provides a complete list of registrants and the organisations that they represented.

The first session, "Small Hydropower Assessment: Review", was attended by 19 delegates. This session provided an appreciation of the software by giving an overview of the HydrA development and a brief description of the methods which are embodied in the software. Guest speakers from ESHA, the Environment Agency and ETSU covered themes such as EU policy on renewable energy, EA policy on small scale hydropower and renewable energy tariffs in the UK. The full list of speakers is included as Annex C(iii)

The second session, "Small Hydropower Assessment: Technical Workshop", was attended by 9 of the 19 delegates from the first session. This second session was aimed at potential operational users of the software and provided an in-depth review of the methods for estimating the hydrological regime from which hydropower potential can be derived.

From the course assessment forms completed following the launch workshop, the two-day workshop was well received.

2.3.3 Press coverage

Prior to the launch of the software, and frequently thereafter, the Institute of Hydrology has submitted press releases, articles and entries to a number of hydropower-related publications in its endeavours to ensure that the HydrA product received as much media coverage as possible. These submissions are described below.

At the time of the UK launch a press release was sent to a number of industry publications, such as *International Water Power and Dam Construction* and *International Journal on Hydropower & Dams*.

The Institute of Hydrology Software Newsletter, usually produced annually by the Institute of Hydrology Software Section, has carried features about the HydrA software both before and since the launch.

In order to maintain and promote the visibility of the software, papers regarding the HydrA software and the underlying hydrological methods have been submitted to various scientific and industry journals, such as *International Water Power & Dam Construction* and *International Journal on Hydropower and Dams*.

An entry for HydrA has also appeared in *Hydro Review Worldwide's 1998-99 Worldwide Hydro Directory*.

A complete list of published papers is included as Annex D. A further list of press releases and articles in trade publications appears as Annex E(i).

2.3.4 Further UK Technical Workshop

Hoping to further promote HydrA, the Institute of Hydrology assisted Water Training International (the organisation which provided the venue and facilities for the first UK HydrA workshop) with the organisation of a further workshop scheduled for June 1998. Invitations were sent to a number of potentially interested attendees, and information about the workshop was disseminated in journals and article(s). Unfortunately, the workshop had to be cancelled due to lack of response.

2.3.5 Launch and Workshop in Spain

It was hoped dissemination in Spain could be initiated by running a launch workshop along the lines of the previous successful workshop in the UK.

A number of organisations and individuals were approached with a view to further this attempt. Unfortunately these attempts did not bear fruit.

Instituto para la Diversificación y Ahorro de la Energía (IDAE), the Spanish OPET, was approached to provide names and address of individuals or organisations which might have an interest in HydrA, for the purpose of a planned mail-shot in late 1996. However no response was received.

In October 1996 a meeting with CEDEX and INTECSA (data providers for the Spanish version of HydrA) was held in Spain in order to agree how HydrA should be disseminated in Spain. IDAE were invited to the meeting but did not attend or respond. INTECSA saw little benefit in disseminating the software and therefore declined. CEDEX were prepared to consider disseminating HydrA as part of a range of packages. The Institute of Hydrology responded with a proposal along these lines in November 1996, but ultimately this opening did not materialise.

APPA agreed to distribute a copy of the Spanish brochure to each of its members and canvass for interest in a workshop. A supply of 200 brochures and further information about how workshops might be run and financed was provided in May 1997.

Celso Penche also approached LABEIN (a technical research centre in Bilbao) about disseminating the software but nothing came of it.

2.3.6 World Wide Web page

A page about HydrA has been added to the Institute's WWW pages. This provides some basic information about the software and allows enquirers to download the brochure if they so wish, or send an e-mail directly to the Institute if they have a query which is not answered by the WWW page. The direct address of this page is:

http://www.nwl.ac.uk/ih/www/products/iproducts.html.

The page is offered in both English and Spanish.

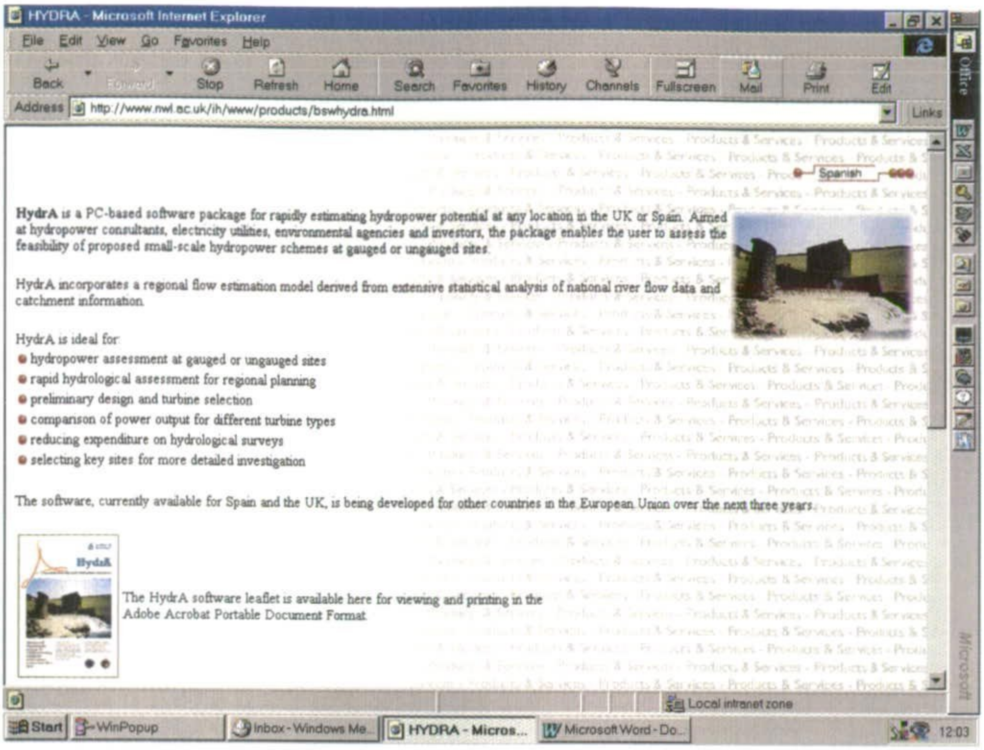


Figure 2 WWW page (English)

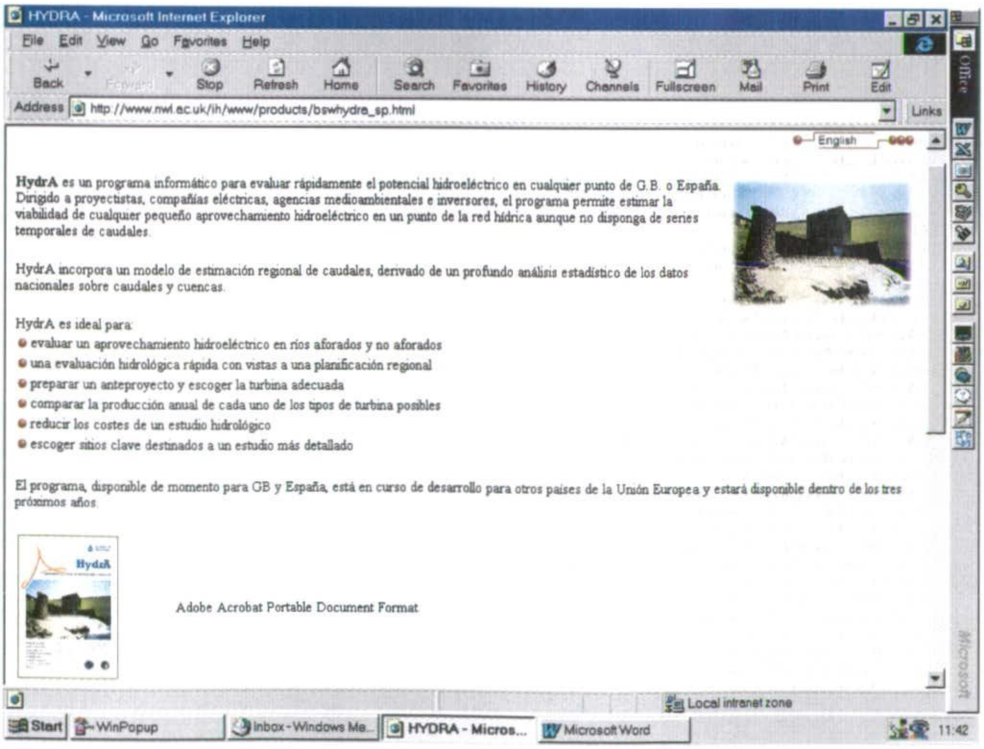


Figure 3 WWW page (Spanish)

2.3.7 Demonstration software disk

An easy-to-run user demonstration, which runs from a single 3.5"disk, was produced in early 1998. This demonstration disk allows the software to be demonstrated without risk of commercial misuse. The demonstration capability has been achieved by providing limited data grids and some specific demonstration data files. Documentation on using the demonstration has also been produced, and is included as Annex B(iii). The demonstration, which runs in English or Spanish, is available on request to interested parties.

2.3.8 Response to Enquiries

As section 2.2.3 shows the Institute has received a number of enquiries specifically about the HydrA software. These have come via fax, e-mail and phone. Each such enquiry is dealt with individually, with brochures being sent out or queries answered as appropriate.

The Institute also receives many general requests for information about its software products. The full software list and a brochure pack (including a HydrA brochure) is the required response for many such enquirers.

2.3.9 Permanent brochure display

A display stand is maintained in the reception area at the Institute of Hydrology. A supply of HydrA brochures is maintained here for visitors to peruse and/or take away. Supplies of the most recent newsletter which featured an article about HydrA are also maintained in the Institute's reception area.

2.3.10 Exhibitions & Conferences

Throughout the period of the dissemination contract Institute of Hydrology scientific staff have attended relevant hydropower and alternative energy conferences such as Hidroenergia '95 (Italy) and Low-Head Hydropower (1997) (UK). Institute of Hydrology staff have also attended conferences at a number of venues elsewhere in Europe and also in India. Where possible, exhibition space has been hired to allow the software to be demonstrated, or the software has been demonstrated on stands hired by ESHA. At several conferences, for example Hidroenergia '95, formal papers were presented. (The complete list of published papers (Annex D) includes details of such papers.)

Attendance at exhibitions and conferences has provided the opportunity for Institute of Hydrology staff to make presentations to large audiences about the software and the underlying hydrological methods, distribute demonstration disks and publicity information about them and demonstrate the software to a large number of potential users.

Attendance at these conferences has contributed greatly to the generation of interest in the software and has been significant in contributing to levels of sales.

The complete list of conferences attended is provided as Annex E(ii).

2.3.11 Other Demonstrations

As well as demonstrating the software at conferences and exhibitions, a number of demonstrations have been provided at the Institute of Hydrology for representatives of organisations visiting the Institute of Hydrology. Those organisations directly involved with hydro topics include the UK Department of Trade and Industry, ENEL and AEM (both from the Italian electricity industry) and the Portuguese Institute of Water.

Visiting scientists from the UK and overseas, members of the press (New Civil Engineer) and other visitors to the Institute of Hydrology have received HydrA brochures and demonstration disks. Besides the IH Software Open Days in January 1997, the following groups have had presentations:

August 1996	Hilly Hydro Project (Nepalese delegation)
October 1996	Ministry of Water Resources, China (7 delegates)
November 1997	Hydrology Project India (13 participants)
December 1997	Finnish delegation (6 people)

2.4 VARIATIONS AGAINST PLANNED ACTIVITIES

There were several areas of activity where time and/or costs were not expended as originally planned. They were:

2.4.1 Product launch workshops and marketing:

The Institute of Hydrology proposal (Section 1) stated that "marketing and training for the product will be undertaken separately and are not covered in this proposal". Section 5 of the proposal went on to detail a marketing exercise which was expected to be carried out by IDAE in Spain and ETSU in the UK.

Given these provisions, it was not anticipated that the Institute of Hydrology would be involved in marketing or training, beyond supporting the initiatives of others.

Unfortunately, the expected initiatives did not come to fruition, and so the Institute of Hydrology undertook the time and expense of organising and running the UK launch workshop as well as attending as guests. Further significant, but equally unbudgeted, amounts of time were spent trying to organise a workshop in Spain but these efforts were in vain. Additional efforts were also made to organise a second UK workshop.

Details about the UK launch workshops and attempts to organise a Spanish workshop are provided in section 2.3.

During the course of the project, Institute of Hydrology staff presented papers and demonstrated the software at nine international conferences and workshops in Spain, the UK and other countries. Given the small amount of time allowed for this activity, the staff time and expenses for attendance at most of these events had to be funded from alternative sources.

Given that product launch workshops and marketing were clearly not covered under the dissemination contract, it can be seen that considerable additional expense and effort has been incurred by the Institute of Hydrology in undertaking these activities.

2.4.2 Preparation of the manual

Although a draft manual had been produced as part of the Phase II contract, a significant amount of further effort was also required to bring the manual into line with software changes (generated from beta testing and translation issues) and to convert the draft into a finished manual of a professional standard which would be suitable for issue to end-users.

Additional time and effort was required to produce the manual, plus supporting documentation and release program, in Spanish. The manual (and supporting documentation) was translated into Spanish by Celso Penche. Again, this took more time than anticipated and took time to put into the correct format for the manual.

2.4.3 Printing manuals

In order to minimise initial storage requirements and in order to apply a degree of caution regarding expected levels of software sales (initially estimated as 600), a smaller number of manuals were printed than originally scheduled. In the light of low levels of software sales, there has been no requirement to print further copies.

3. Financial Report

A summary of costs (manpower and expenditure) and income against the HydrA project is presented in Table 1. The figures below relate to both start-up activities and running costs. However the proportion of expenditure relating to start-up activities versus running costs varies over time:

1996/97 - start-up activities only
1997/98 - start-up activities and running costs
1998/99 - running costs only.

Table 1

Year	Income	£	Expenditure	£
96/97	Sales (UK)	660	Staff time	7,378
	Sales (Spain)		Expenses	120
			Printing	1,218
			Misc.	25
97/98	Sales (UK)	5,606	Staff time	14,755
	Sales (Spain)	1,320	Expenses	309
	ESHA contract	6,073	Printing	1,972
			Consultancy	547
			Other	117
			Computing charge	1,000
98/99	Sales (UK)	990	Staff time	4,363
	Sales (Spain)		Computing charge	375
	ESHA contract	6,500		
TOTAL		**£21,149**		**£32,179**

Financial information certified by:

....

Frank M. Law
Deputy Director, Institute of Hydrology

4. Conclusions

The HydrA software package provides a rapid means of estimating hydropower potential at any location in Spain or the UK. Written for PCs running Windows 3.1 or above, the software reaches the widest possible audience. Its user-friendly, icon-driven interface leads the user easily through the initial steps of hydropower design, from defining the catchment boundary, automatically deriving a flow duration curve to selecting appropriate turbines and estimating power and energy outputs. Priced very reasonably at 400 ECU, the software is affordable to even the smallest hydropower consultancy.

Prior to this dissemination contract, and prior to public release, the software was beta tested thoroughly by consultants in Spain and the UK. The testers gained familiarity with the software in a very short time and were able to provide good constructive comments. They quickly realised, with HydrA, assessments that would normally take a matter of days, weeks or even months, could be carried out in just one or two hours. Some minor changes were, of course, required but the effort of testing was worthwhile with the resulting software being extremely robust and reliable. In the three years that the software has been in operational use, there have been very few problems reported by users with most concerning the application of the software rather than bugs in the software itself. The software has also been extensively and successfully tested for Year 2000 compliance.

Although initial hopes for the number of sales of HydrA were overestimated, the software has a reasonably solid user base of 25 paying customers in the UK. A number of short-term loan copies have also been provided to individual students from British universities who have requested the software for their undergraduate or postgraduate projects. The response in Spain, where only four copies have been sold, has been most disappointing. Reasons for this are considered later. As can be seen in the Financial Report (Chapter 3), the shortfall in sales has resulted in Institute of Hydrology expenditure (in pursuance of the contract) exceeding income by a considerable margin. The financial loss has been covered by the Institute at no extra cost to the client.

The shortfall in sales occurred despite some very active promotion work by the Institute of Hydrology. During the course of the project, Institute of Hydrology staff demonstrated the software at 9 international conferences and workshops in Spain, the United Kingdom and other countries. With a limited budget available for such activity, attendance at most events was funded from alternative sources. Some 30 papers, articles or press releases were published in 15 international and national publications and a WWW page, dedicated to HydrA, was implemented on the Institute of Hydrology web-site. A total of 1200 English and Spanish language brochures have been distributed. Mail-shots to a potential user-base were made in the UK and through APPA in Spain. A two-day launch workshop held in the UK in March 1997 registered 22 delegates from 18 different companies and organisations. Plans for a similar workshop in Spain were abandoned due to lack of interest.

The actions described clearly show that the Institute of Hydrology not only fulfilled but exceeded its contractual obligations to disseminate and promote the HydrA software. A major disappointment of the project was, of course, the lack of response in Spain. The problems in Spain, cannot be attributed to one single factor but may be due to a combination of several, as follows:

- A critical factor has been the inability to identify a Spanish stakeholder who was able to actively disseminate the software. Although two local organisations, CEDEX and INTECSA, were involved during the development of the hydrological model, neither had national responsibility for software dissemination. Furthermore, the dissemination was not supported by the OPET network in Spain. IDAE, the member of the OPET network recommended by Altener, were approached by both ESHA and the Institute of Hydrology but ultimately provided no assistance toward the dissemination of HydrA. The involvement of IDAE, was a key assumption for the dissemination of HydrA in Spain and their failure to contribute may have been significant. Some assistance was, however, provided by APPA who kindly distributed 200 Spanish language brochures to its members. However, the response of APPA members to the suggestion of a Spanish launch workshop was less than encouraging, causing the initiative to be abandoned.

- A second reason may be related to the hydrological method within HydrA being new to the Spanish hydropower market. The regional flow estimation method is a statistical approach for estimating the flow regime at ungauged sites. It is used extensively in the European water industry and is regarded internationally as a reliable means for determining the river flow at sites where no observed data is available. The method, which has been described in many scientific journals, is recommended in the European Commission (DGXVII) report, "Layman's Guidebook on How to Develop a Small Hydro Site". Nevertheless, lack of familiarity with the method could explain the Spanish reaction to the software, despite the full support of both Altener and the Spanish representative in ESHA.

- With many packages now freely available over the WWW, the price of HydrA may also be a factor to explain the poor sales in Spain, even though the cost would probably have been recovered with the very first commercial application of the software.

During the three years of the HydrA dissemination contract, the development of the European Atlas of Small Scale Hydropower Potential has continued as a separate project. With that project approaching completion, HydrA will soon be available for Austria, Belgium, Italy, Luxembourg, Portugal and the Republic of Ireland as well as for Spain and the UK. Learning from the experiences of this (dissemination) contract, the proposal for the dissemination of the new version of HydrA has a fundamentally different strategy. Briefly, it is proposed that the HydrA software and associated User Guides will be freely available over the WWW, with users given the option to pay for product support. Stakeholders will be sub-contracted, and adequately resourced, to undertake local promotional activities and conduct launch workshops in each of the five new countries plus Spain. It is hoped that this approach will see a far greater uptake of the software and encourage the development of small-scale hydro in each of the countries. Ultimately this would help the European Union to attain its objective of a 12% contribution from renewable energy sources to the gross inland energy consumption by the year 2010.

Acknowledgements

The Institute of Hydrology is grateful to the following for their support and input to the dissemination contract:

Dr Eric Wilson, Wilson Energy Associates Ltd, United Kingdom
Mr Mark Allington, ETSU, United Kingdom
Mr Kieron Hanson, Hydroplan Ltd, United Kingdom
Mr Gwyn Williams, Environment Agency (Midlands), United Kingdom
Mr Michael Allchin, Scientific Software Systems, United Kingdom

Dr Celso Penche, ESHA representative, Spain
Dr Teodoro Estrella, CEDEX, Spain
Mr Manuel De Delas, APPA, Spain
Mr Ximénez de Embún, INTECSA, Spain
Andrea Lamberti, MSc student, Barcelona, Spain

Mrs Sylvie Baudini, European Small Hydropower Association, Belgium

Mme Pérez Latorre, Altener Programme, European Commission-DGXVII

Annex A

Institute of Hydrology Proposal [without Appendices] dated 27/10/95

This became Annex 1: Budget and Work Programme of the relevant EEC contract under which ESHA sub-contracted these proposed activities to the NERC Institute of Hydrology.

Institute of Hydrology

THE DISSEMINATION OF HYDRA

A proposal to the European Union DGXVII Altener Committee

by the

EUROPEAN SMALL HYDRA POWER ASSOCIATION

27 October 1995

Natural Environment Research Council

1. Introduction

This proposal by the European Small Hydropower Association (ESHA) is made with the aim of ensuring wide dissemination of the European Atlas software and documentation, for practical application, in the UK and Spain. ESHA has been responsible for Phase I and II of the Atlas and the Institute of Hydrology (IH) has been its principal sub-contractor for Phase II. It is proposed to appoint the UK Institute of Hydrology (IH) as the sub-contractor for this proposal also.

The proposal is to provide a distribution system for HYDRA, the software developed in Phase II, and subsequently release the product, at an agreed price; to advise customers and manage after-sales support and maintenance. Marketing and training for the product will be undertaken separately and are not covered in this proposal. It is assumed that the product is stable and that dissemination costs are not intended to recoup income for further development. The sale price only includes modest programming time for bug fixing to the current version.

2. Background

The European Atlas of Small-Scale Hydropower Resources will enable local authorities, water resource planners and potential investors to assess the feasibility of developing small hydropower schemes anywhere in the countries for which it has been developed. It is a menu-driven software package for an IBM-compatible PC (386 or equivalent) and incorporates methods for deriving flow duration curves at ungauged sites and provides a means of using these curves to estimate hydropower potential. The current phase (Phase II) of the development, which is due for completion in December 1995, has focused on developing the Atlas for Spain and the United Kingdom. HYDRA is the property of the EU's DGXVII (the owners). This document is drawn up in response to a request by the owners for a proposal for the dissemination and distribution of the HYDRA software in Spain and the United Kingdom.

3. Relevant Expertise

ESHA is now recognised as the main channel for dissemination of information and promotion of all matters relating to small hydropower in the EU. It has representatives of all Europe's national hydropower associations on its Governing Board and has contacts and members in all the member states. Its constituent members together constitute the widest array of expertise in small hydropower in the world.

The Institute of Hydrology (IH) is the UK's leading centre for hydrological research and one of the most prestigious hydrological research organisations in the world. In 1988 IH formed a hydrology software group, IH Software, which supplies software development, sales and support skills in support of the IH research groups. Historically, IH Software has provided software for funded research, and has also provide "off-the-shelf" software products to encourage the use of IH researched results by outside practitioners. The software provision is supported by marketing and publicity to ensure interested clients are aware of the product, and is followed up by a high standard of quality in customer support.

During the last two years the software sales and support service has expanded to cover other Centre for Ecology and Hydrology Institutes' software, and the portfolio of products is now 11 in total. The sales and support team man a help desk with an answer-phone system during non office hours. An e-mail address, fax and telephone line are available for users' queries, and information is publicised on the World Wide Web. The HYDRA package was developed under the supervision of the IH Software manager.

4. The HYDRA Product

The software will be provided as a package running under Microsoft Windows 3.1, or above, and will be supplied on 3½" DD diskettes. The computer should have the following minimum configuration:

Memory:	2 Mb (conventional); 4Mb preferred
Processor:	80386SX chip @ 20 Mhz or better
Hard disk:	20 Mb
Graphics card:	VGA, EGA or compatible
Operating System:	Microsoft Windows 3.1 or above
Floppy disk drive:	3½" DD
Output device:	Industry standard output devices should be supported

The software enables the user to:

- Calculate climate characteristics and flow characteristics for natural catchments based on digitised catchment boundaries or a file of coordinate pairs;
- View and alter existing catchment boundary, climate, flow and power definitions;
- Select processing options which allow modules to be run sequentially with automatic generation of reports;
- Run estimation procedures using the specified catchment, flow and power definitions;
- Generate reports and graphs for all results on the screen and on hardcopy;
- Delete existing data results files;
- Select the language (English or Spanish) of operation.

The United Kingdom version of HYDRA will be supplied on 2 x 3½" DD diskettes and will be accompanied with one copy of the HYDRA user manual written in English.

It is envisaged that the Spanish version of the software will be supplied on 4 x 3½" DD diskettes and will be accompanied with one copy of the HYDRA user manual written in Spanish.

The purchaser, in Spain or the United Kingdom, will automatically be eligible for one year's free support and maintenance through the IH Helpdesk.

5. The HYDRA Market

A marketing exercise will need to be carried out to identify groups of people with an interest in HYDRA and to publicise the availability of the software to them. It is assumed that this exercise will be carried out by IDAE in Spain and ETSU in the United Kingdom. For the marketing exercise, it will be necessary to identify the product strengths and weaknesses. Market competitors are unlikely but a market survey should be made if this has not already been done.

The day to day management for HYDRA sales and support will be the sole responsibility of the IH Software Manager who will appoint a HYDRA Sales and Support Manager. This manager will monitor and report about HYDRA sales and marketing to ESHA and DGXVII at regular 3 monthly intervals.

6. Licensing

Licences for the software will be issued for a period of 15 years. Use of HYDRA will be unrestricted. Educational and academic licences will be available but use of these will be restricted to non commercial applications. A licence agreement similar to the standard IH software licence will be issued as shown in Appendix A.

The software will be copy protected using the current IH software protection system (see Appendix B). The software protection is not transferable to other floppy discs and so protects those with copyright from illegal or unlicensed copies of the software being produced and operated. The software copy protection is flexible, allowing multiple installations from one set of discs, if multiple licences are required. It also allows the pre-programmed removal of copy protection after a certain date or a specified number of executions of the program. This is useful for providing demonstration versions to clients.

7. Quality Assurance

The provision of software sales and support services will be subject to established QA procedures within the IH Software section.

8. Software Support and Maintenance

It is recommended that the software is sold with one year's free support and maintenance contract. The provision of one year's support and maintenance enables all users to achieve a working package with help from scientists and programmers. Most user problems are experienced during installation and learning a package.

Software support and maintenance shall be the responsibility of the IH software section. An example maintenance contract is shown in Appendix C. A one year renewable maintenance contract will be available for any user who wishes to take out an additional maintenance contract with the Institute of Hydrology once the first year has lapsed.

The software section will receive and file all queries from the users and all bug reports and suggestions. There will be an identified scientific support within IH who will supply all scientific inputs required to identify bugs and answer user scientific queries. There will be an identified program support person who will be capable of locating and fixing bugs and provide future development as required.

All bug reports shall be gauged for severity by the HYDRA sales and support manager with inputs from the scientific support and the programming support staff. Catastrophic bugs should be fixed as soon as possible, bugs causing incorrect results should be notified immediately and fixed within 3 months, and minor bugs (titles, wording etc.) which do not affect the results should be part of the next upgrade exercise. A dedicated e-mail, FAX and telephone line are set-up for IH software sales and support including an answer-phone for out of office hours use. All bug reports and queries will be recorded with both the customer and in the product file.

9. Promotion

Promotion of the product, once it has been released, will be required to create a high degree of awareness of HYDRA amongst potential user groups. This will increase and support the effective utilisation of HYDRA. To this end IH Software will develop a plan of promotional actions including mail-drops, attendance at conferences, workshops, demonstrations, etc. with the agreement of ESHA, and to support other marketing initiatives. Promotion can include advertising through the WWW (IH already has WWW pages and may expand these to include HYDRA information and link to other suitable WWW pages as required) and bulletin boards.

10. Pricing Structure

A pricing structure will be necessary to cover multiple sales, network use, educational licences etc. The suggested price for the software is estimated assuming that initial set up costs will be covered externally by DGXVII, but that the running costs of dissemination and maintenance of the product will be covered by the sale price. The estimate also relies on the expected sales of at least 600 packages (300 in Spain, 300 in the United Kingdom). It is proposed that a pricing structure be set up with full commercial licence and educational licence (See Licences).

11. Costs

11.1 SET-UP COSTS

There are several tasks which need to be completed before the package can be made available for release. These are:-

Item		Breakdown	Cost ECU
a.	Design and produce a manual cover (with spline) to fit standard IH user manual plastic wallet.	2 man days @ ECU 400 plus ECU 1000 printing costs for 600 copies	1800.00
b.	Design disk label and logo to suit package and agree with ESHA/IH	1 man days @ ECU 400	400.00
c.	Determine pricing structure (for multiple copies, educational discount etc.) and agree with all parties	1 man days @ ECU 400	400.00
d.	Design and produce publicity literature to send to interested clients and for mail-shots. Additional translation costs may be incurred.	2 man days @ ECU 400 plus ECU 1540 printing costs for full colour A4 document (see Appendix D)	2340.00
e.	Produce a program for making up the release versions (to ensure every UK and Spanish release version is identical)	1 man day @ ECU 400	400.00
f.	Test the first release versions of UK and Spanish package, to ensure the product is being produced correctly.	1 man day @ ECU 400	400.00
g.	Setting up the database for recording clients and queries	1 man day @ ECU 400	400.00
h.	Print 600 manuals, black and white, 80 pages (300 English and 300 Spanish)	ECU 5000	5000.00
i.	Product familiarity for help desk assistance	2 man days @ ECU 400	800.00
j.	Provide support and assistance at product launch workshops	4 man days @ ECU 400 plus T&S @ ECU 1200	2800.00
k.	Provide demonstrations at exhibitions/conferences, info on WWW etc.	8 man days @ ECU 400 plus T&S @ ECU 2400	5600.00
	TOTAL SET-UP COSTS ECU		20,340.00

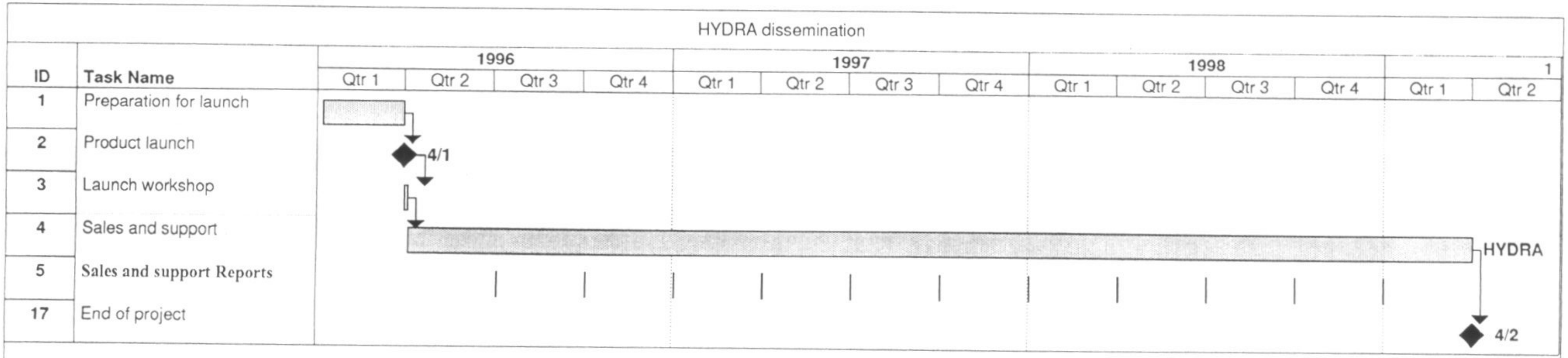
11.2 RUNNING COSTS

There are also on-going running costs incurred by supplying the product which will be recovered in the purchase price. It is assumed that a 600 copies of the software will be sold over a period of 3 years. Costs for the printing of User Manuals are not considered within Running Costs having already been included in the Set-Up.

The running costs are therefore:-

Item		Breakdown	Educational costs ECU	Commercial cost ECU
a. b. c. d.	Send out publicity material on request and answer queries regarding product capability Produce the release version Entry of information onto database Provide first line user support and one years front line maintenance including sending out bug fixes and newsletters.	0.4 man day @ 440 ECU for educational (includes only installation support) and 0.7 @ 440 ECU man day for full release to reflect extra support	176.00	308.00
e.	Cost of discs and labels	3.00 each	3.50	3.50
f.	Plastic disc wallet and manual binder	3.00 each	3.50	3.50
g.	Post and packing	4.00 each	4.50	4.50
h.	Provide expert hydrological support. This is required if the query cannot be sorted through the front line help support, and will not be available to educational users	15 man days per year @ 440 ECU. Assuming 200 pachages a year for 3 years, cost per package = 33 ECU	0.00	33.00
i.	Programming support, this will be required in the case of bug fixing as a result of users bug reports	20 man days per year @ 440 ECU. assuming 200 packages a year for 3 years = 44 ECU per package	0.00	44.00
j.	Administration and invoicing, includes overall IH project management and the issuing and follow up of invoices and payments by accounts, plus 3 monthly accounting reports to ESHA.	15 man days per year @ 440 ECU. Assuming 200 packages per year for 3 years cost per package = 31 ECU	33.00	33.00
TOTAL RUNNING COSTS ECU			220.00	430.00

In the event of more than the initial 600 being sold some provision will need to be made for another print run of the User Manuals.



Project: HYDRA dissemination
Date: 10/25/95

Task		Summary		Rolled Up Progress	
Progress		Rolled Up Task			
Milestone		Rolled Up Milestone			

Annex B (i)

English and Spanish brochures

Minimum PC configuration

PC with 386 processor, 2 Mb (preferably 4Mb) RAM, VGA or EGA monitor, 3.5" DD and Windows 3.1 or above. Any WINDOWS-supported hard copy device may be used for output. All trade marks are acknowledged.

Further developments

The software, currently available for Spain and the UK, is being developed for other countries in the European Union over the next three years.

Acknowledgements

HydrA has been produced on behalf of the European Small Hydropower Association (ESHA) with funding from the Commission of European Communities' Directorate-General for Energy (DGXVII) ALTENER Programme. The project was undertaken by a consortium of contractors: Wilson Energy Associates Ltd, UK. (project coordination), Institute of Hydrology (IH), UK; Internacional de Ingeniería y Estudios Técnicos, SA (Intecsa), Spain and Verdeacqua, Italy. River flow and spatial data were kindly provided by hydrological agencies in Spain, Italy and the UK.

More information

Software Sales & Support, Institute of Hydrology, Wallingford
Oxfordshire, OX10 8BB, United Kingdom
Tel: +44 (0)1491 838800
Fax: +44 (0)1491 692424
E-mail: softdev@ioh.ac.uk
WWW: http://www.nwl.ac.uk/ih

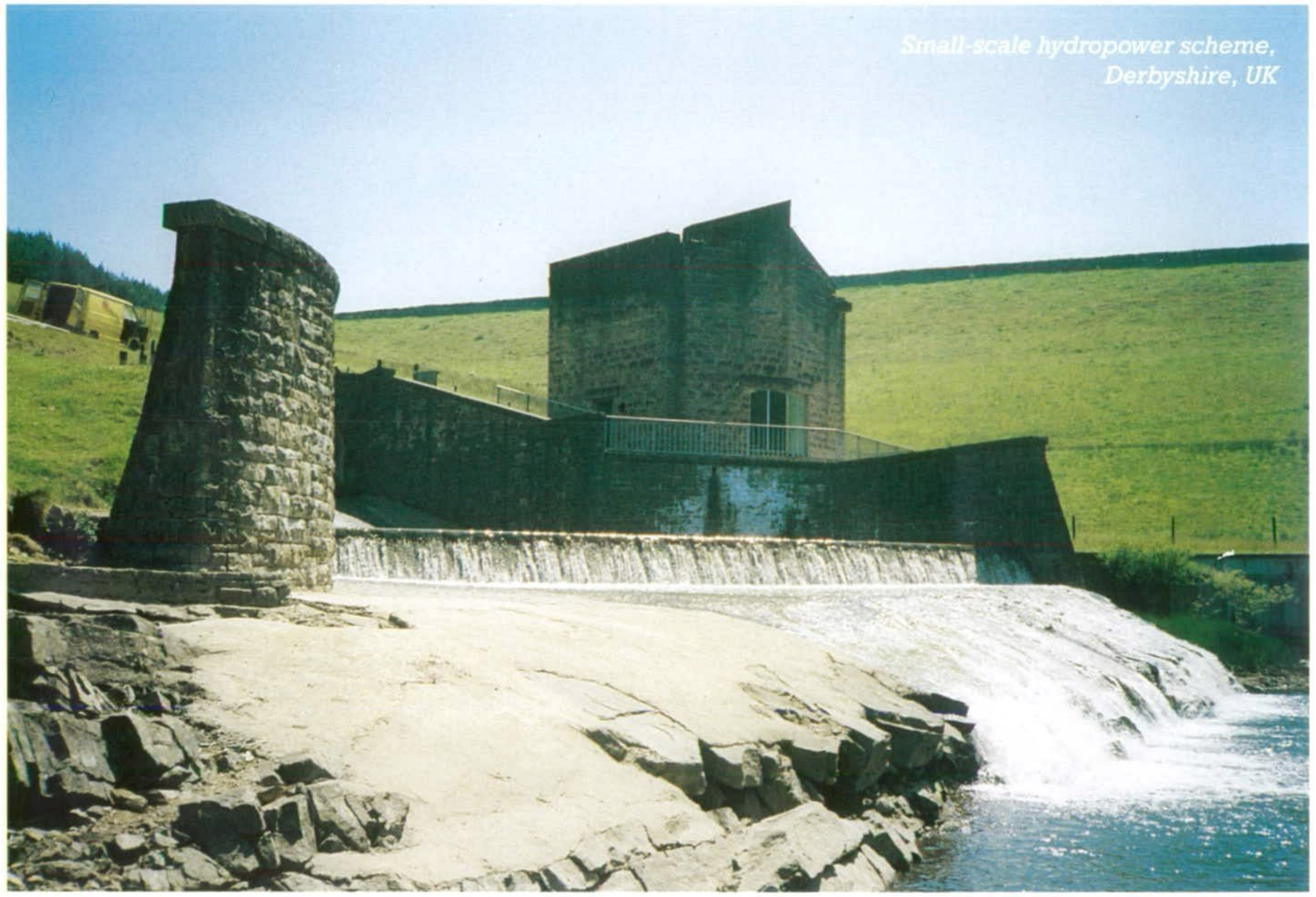
Centre for Ecology & Hydrology
Institute of Freshwater Ecology
Institute of Hydrology
Institute of Terrestrial Ecology
Institute of Virology & Environmental Microbiology
Natural Environment Research Council

11/96

Institute of Hydrology

HydrA

European atlas of small-scale hydropower resources

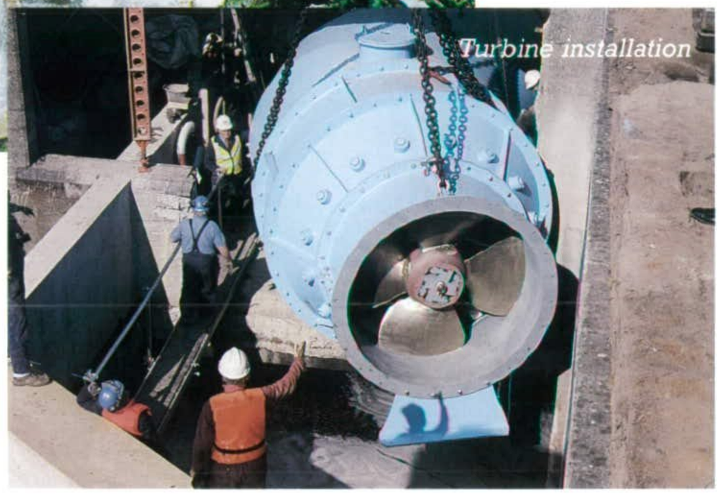


Small-scale hydropower scheme, Derbyshire, UK

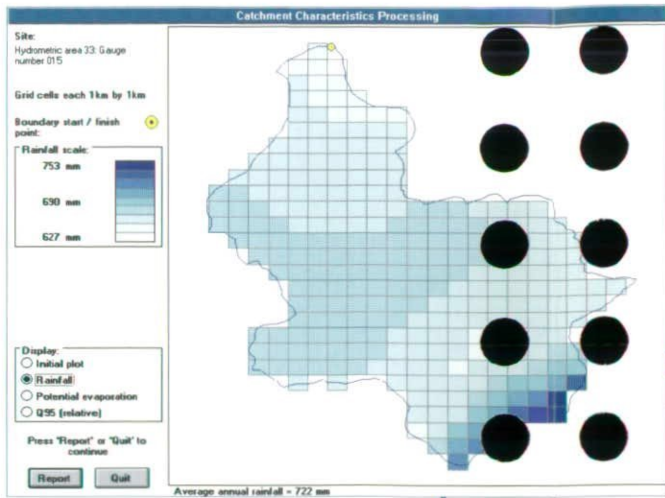
HydrA is a PC-based software package for rapidly estimating hydropower potential at any location in the UK or Spain.

Aimed at hydropower consultants, electricity utilities, environmental agencies and investors, the package enables the user to assess the feasibility of proposed small-scale hydropower schemes at gauged or ungauged sites.

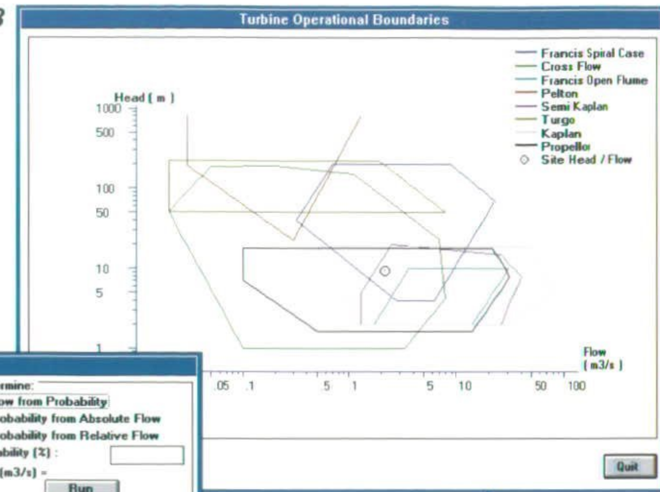
HydrA incorporates a regional flow estimation model derived from extensive statistical analysis of national river flow data and catchment information.



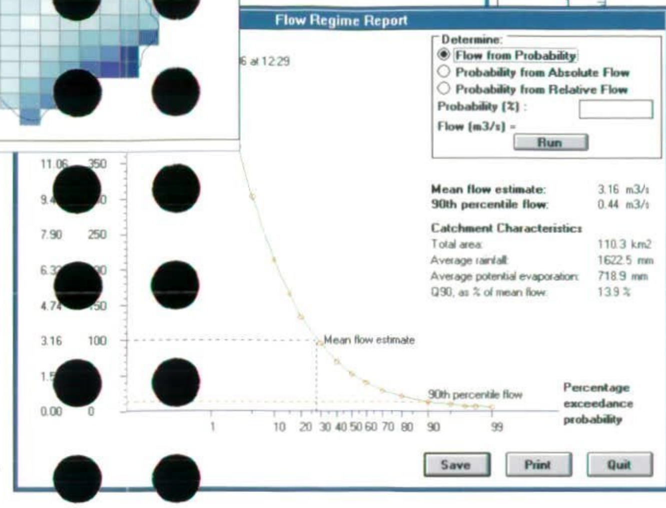
1



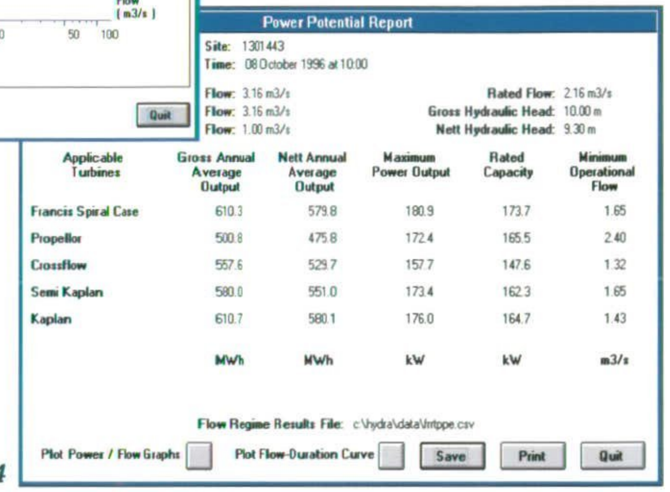
3



2



4



Applicable Turbines	Gross Annual Average Output	Nett Annual Average Output	Maximum Power Output	Rated Capacity	Minimum Operational Flow
Francis Spiral Case	610.3	579.8	180.9	173.7	1.65
Propellor	500.8	475.8	172.4	165.5	2.40
Crossflow	557.6	529.7	157.7	147.6	1.32
Semi Kaplan	580.0	551.0	173.4	162.3	1.65
Kaplan	610.7	580.1	176.0	164.7	1.43
	MWh	MWh	kW	kW	m3/s

HydrA is ideal for:

- hydropower assessment at gauged or ungauged sites
- rapid hydrological assessment for regional planning
- preliminary design and turbine selection
- comparison of power output for different turbine types
- reducing expenditure on hydrological surveys
- selecting key sites for more detailed investigation

HydrA allows the user to:

- define a catchment boundary for the site
- estimate key catchment characteristics including area, mean flow, hydrological response, average annual rainfall and evaporation
- derive a synthetic flow duration curve describing the hydrological regime
- enter design flow and head conditions for the site
- calculate power potential for up to eight different turbine types

HydrA comprises four key modules

Catchment characteristics module

This requires the user to enter the catchment boundary of the proposed site, defined by a series of coordinate pairs. The software overlays the boundary onto 1 km x 1km grids of average annual rainfall, potential evaporation and a standardised low flow statistic. It automatically calculates the mean flow and low flow hydrological response for the catchment. *1*

Flow regime estimation module

This takes the output from the catchment characteristics module to determine a synthetic flow duration curve for the site. An interactive facility enables the interrogation of the flow duration curve providing value of flow from probability or vice versa. For gauged sites, ordinates of the flow duration curve may be entered manually. *2*

Turbine selection module

This requires the user to specify the design flow and head conditions for the site. The software automatically compares these with the operational envelopes of eight key turbine types to select which are operable under the stated conditions. *3*

The turbine types supported are:

- Cross Flow
- Francis Open Flume
- Francis Spiral Case
- Kaplan
- Pelton
- Propeller
- Semi-Kaplan
- Turgo

Power potential module

This calculates the power output for each selected turbine by relating the amount of available water to the manufacturers' approved flow-efficiency relation-ships; the available water being defined by the flow duration curve, the design flow and the residual flow requirements of the river. *4*

Configuración mínima para el PC

PC con procesador 386, 2 Mb (preferiblemente 4 Mb) de RAM, monitor VGA o EGA, unidad de disquete de 3,5" DD, y sistema operativo Windows 3.1 o superior. Se reconocen todas las marcas registradas.

Ulteriores desarrollos

El programa, disponible de momento para GB y España, está en curso de desarrollo para otros países de la Unión Europea y estará disponible dentro de los tres próximos años.

Reconocimientos

HydrA ha sido desarrollado para la European Small Hydropower Association (ESHA) con fondos de la Dirección General de Energía (DG XVII) de la Comisión de las Comunidades Europeas, en el marco del programa ALTENER. El proyecto ha sido llevado a cabo por un consorcio de contratistas: Wilson Energy Associates Ltd, GB (coordinador del proyecto), el Instituto de Hidrología (IH) de GB, Internacional de Ingeniería y Estudios Técnicos, SA (INTECSA) España, y Verdeacqua de Italia. Las estadísticas de caudales y los datos espaciales han sido proporcionados por las agencias hidrológicas de España y GB.

Mas información

Software Sales & Support, Institute of Hydrology, Wallingford
Oxfordshire, OX10 8BB, United Kingdom
Tel: +44 (0)1491 838800
Fax: +44 (0)1491 692424
E-mail: softdev@ioh.ac.uk
WWW: http://www.nwl.ac.uk/ih

Centre for Ecology & Hydrology
Institute of Freshwater Ecology
Institute of Hydrology
Institute of Terrestrial Ecology
Institute of Virology & Environmental Microbiology
Natural Environment Research Council

3/97

Institute of Hydrology

HydrA

Atlas europeo de recursos mini-hidráulicos


Cordiñanes, Picos de Europa, León, España

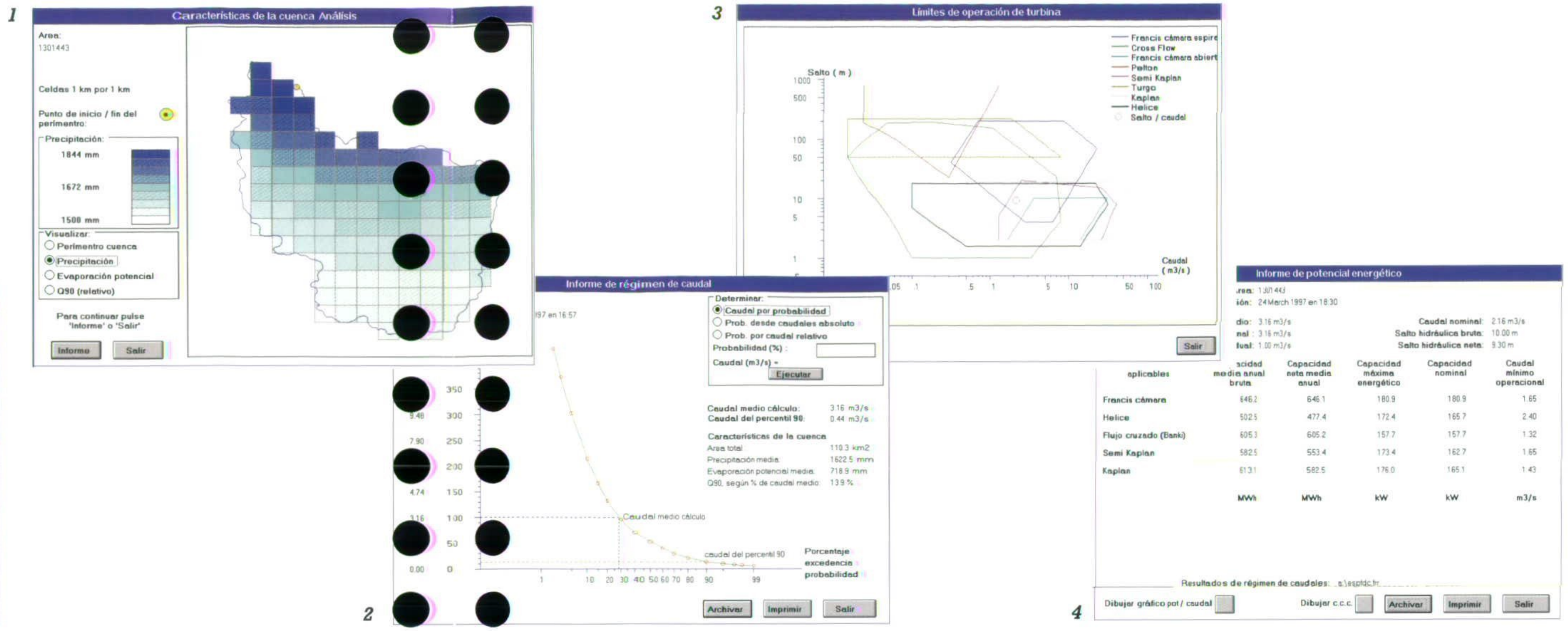
HydrA es un programa informático para evaluar rápidamente el potencial hidroeléctrico en cualquier punto de G.B. o España

Dirigido a proyectistas, compañías eléctricas, agencias medioambientales e inversores, el programa permite estimar la viabilidad de cualquier pequeño aprovechamiento hidroeléctrico en un punto de la red hídrica aunque no disponga de series temporales de caudales.

HydrA incorpora un modelo de estimación regional de caudales, derivado de un profundo análisis estadístico de los datos nacionales sobre caudales y cuencas.

Pequeño aprovechamiento hidráulico, Guipuzcoa, España

Instalación de la turbina



HydrA está constituido por cuatro módulos fundamentales:

HydrA es ideal para:

- evaluar un aprovechamiento hidroeléctrico en ríos aforados y no aforados.
- una evaluación hidrológica rápida con vistas a una planificación regional
- preparar un anteproyecto y escoger la turbina adecuada
- comparar la producción anual de cada uno de los tipos de turbina posibles
- reducir los costes de un estudio hidrológico
- escoger sitios clave destinados a un estudio más detallado

HydrA permite al usuario:

- definir el perímetro de una cuenca
- evaluar las características de la cuenca, incluido el área, el caudal medio, la respuesta hidrológica, la precipitación anual media y la evaporación.
- construir una curva de caudales clasificados sintética que caracterice el régimen hidrológico.
- introducir el caudal de diseño y la altura de salto
- calcular el potencial energético para hasta ocho tipos diferentes de turbina

Módulo de características de cuenca

El usuario debe introducir el perímetro de la cuenca mediante una serie de pares de coordenadas. El programa superpone el perímetro sobre bases de datos celulares, con celdas de 1km ∞ 1km, de precipitación anual media, evaporación potencial, y una estadística normalizada de caudales, para calcular automáticamente el caudal medio y la respuesta hidrológica de la cuenca. ***1***

Módulo de estimación del régimen de caudales

El programa, basándose en los datos obtenidos por el módulo anterior, selecciona una curva sintética de caudales clasificados. Mediante una utilidad interactiva se puede conocer el valor del caudal que es igualado o excedido durante un cierto porcentaje de tiempo y viceversa. En tramos de río aforados, el usuario puede introducir manualmente los valores que definen la curva de caudales clasificados. ***2***

Módulo de selección de turbinas

El usuario debe introducir el valor del caudal de diseño y la altura del salto. El programa automáticamente compara estos valores con los de la envolvente de cada una de los ocho tipos de turbina soportados, para seleccionar las que son operativas en esas condiciones. ***3***

Los tipos de turbina soportados son:

- Crossflow
- Francis de cámara abierta
- Francis de cámara espiral
- Kaplan
- Pelton
- Hélice
- Semi-Kaplan
- Turgo

Módulo de potencial energético

Este módulo calcula la producción de energía para cada tipo de turbina aplicable, basándose en la cantidad de agua turbinada dada por la zona útil de la CCC definida por los caudales, de diseño, mínimo técnico y ecológico exigido por el río, y la relación entre caudal y rendimiento de la turbina dado por los fabricantes. ***4***

Annex B (ii)

HydrA Technical Reference & User Guide

Contents List

		Page
Preface		i
Acknowledgements		iii
Disclaimer		v
Version Control		vii
Contents		ix
1.	INTRODUCTION	1
2.	TECHNICAL SPECIFICATIONS	3
	2.1 Software requirements	3
	2.2 Hardware requirements	3
	2.3 Program Structure	4
3.	ESTIMATION PROCEDURES	7
	3.1 Introduction	7
	3.2 Estimation of catchment characteristics	7
	3.3 Estimation of the flow duration curve	13
	3.4 Estimation of hydropower potential	14
4.	USING HYDRA	19
	4.1 Introduction	19
	4.2 Installation	19
	4.3 Starting the application	21
	4.4 Deleting files	25
	4.5 Operating language/National Version	25
	4.6 Quit	26
	4.7 Template Files	26

		Page
5.	CATCHMENT ANALYSIS	29
5.1	Catchment boundary definition	29
5.2	Catchment characteristic definition	34
5.3	Catchment analysis options	38
5.4	Catchment characteristic processing	39
5.5	Catchment characteristics report	41
6.	FLOW REGIME ANALYSIS	43
6.1	Defining the flow regime	43
6.2	Flow regime calculation options	46
6.3	Flow regime analysis	46
6.4	Flow regime report	48
7.	POWER POTENTIAL ANALYSIS	51
7.1	View/alter generating gear details	51
7.2	Power potential calculation options	52
7.3	Power potential analysis	52
7.4	Power potential report	55
8.	FILE FORMAT SPECIFICATIONS	59
8.1	HydrA file formats	59
8.2	Template files	60
8.3	Format specification	61
9.	HYDRA DIRECTORY STRUCTURE	71
9.1	HydrA installation directory	71
9.2	HydrA data directory	71
9.3	HydrA system files directory	71
10.	USE OF LOCAL DATA	73
10.1	Estimating the mean flow	73
10.2	Estimating the flow duration flow	73
APPENDIX A		77
REFERENCES		83
GLOSSARY		83

Annex B (iii)

HydrA V1.0 Demonstration Software Guidance Notes

Institute of Hydrology

HydrA V1.0

European Atlas of Small-Scale Hydropower Resources

Demonstration Software Guidance Notes

March 1998

This document is an official document prepared by the Institute of Hydrology. It should not be quoted without permission of the Institute of Hydrology.

Centre for Ecology & Hydrology

1. INTRODUCTION

THIS DOCUMENT

The demonstration version of HydrA enables the user to investigate the functionality of the software through a structured tutorial using an example catchment. This note provides detailed instructions for running the demonstration software and obtaining results. Any queries or problems should be directed to the address on the final page of this document.

DESCRIPTION OF THE SOFTWARE

The European Atlas of Small Scale Hydropower Resources has been developed as a tool which will enable local authorities, water resource planners and potential investors to assess the feasibility of developing small hydropower schemes within the European Union (EU). The software is currently operational for the UK and Spain, and will be operational in Italy during 1998.

HydrA is a user-friendly software package which can be run on a PC running Windows™, and requires very little hydrological knowledge and limited experience of hydropower design in order to use it. The modular design of the software enables the user to obtain estimates of catchment, flow and turbine characteristics very quickly from several different points of entry, simply by selecting the appropriate icons and completing a series of dialogue boxes.

HydrA incorporates facilities which allow data to be entered and edited interactively or to be retrieved from existing data files and edited if required. The results of the analysis are quickly displayed on the screen, and may be written to a file for use by other applications.

HARDWARE REQUIREMENTS

The software has been designed to run on a personal computer from within the Microsoft Windows™ environment. The computer should have a minimum of:

Memory:	Minimum of 2 Mb (conventional); 4 Mb recommended
Processor:	80386SX chip @ 20 MHz
Hard disk:	20 Mb
Graphics card:	VGA, EGA or compatible
Operating system:	Windows Version 3.1 or above
Floppy disc drive:	3½" DD
Output device:	Flexible; most industry standard output devices are supported

ACKNOWLEDGEMENTS

The Atlas is available as a menu-driven software package which has been developed on behalf of the European Small Hydropower Association (ESHA) by the Institute of Hydrology in the UK, acting as technical co-ordinators. Data and technical information has been supplied by consultants within the contributing countries of the European Union. Overall project management has been undertaken by Wilson Energy Associates Ltd., UK with funding from the EU (DGXVII) ALTENER Programme.

PROGRAM STRUCTURE

There are three key elements in the estimation of hydropower potential at a site: the estimation of catchment characteristics; the derivation of the overall flow regime and the estimation of the power and energy output for the specified flow conditions. The program has been structured so that each of these elements may be considered by a separate module. The components of these modules are illustrated in Figure 1.

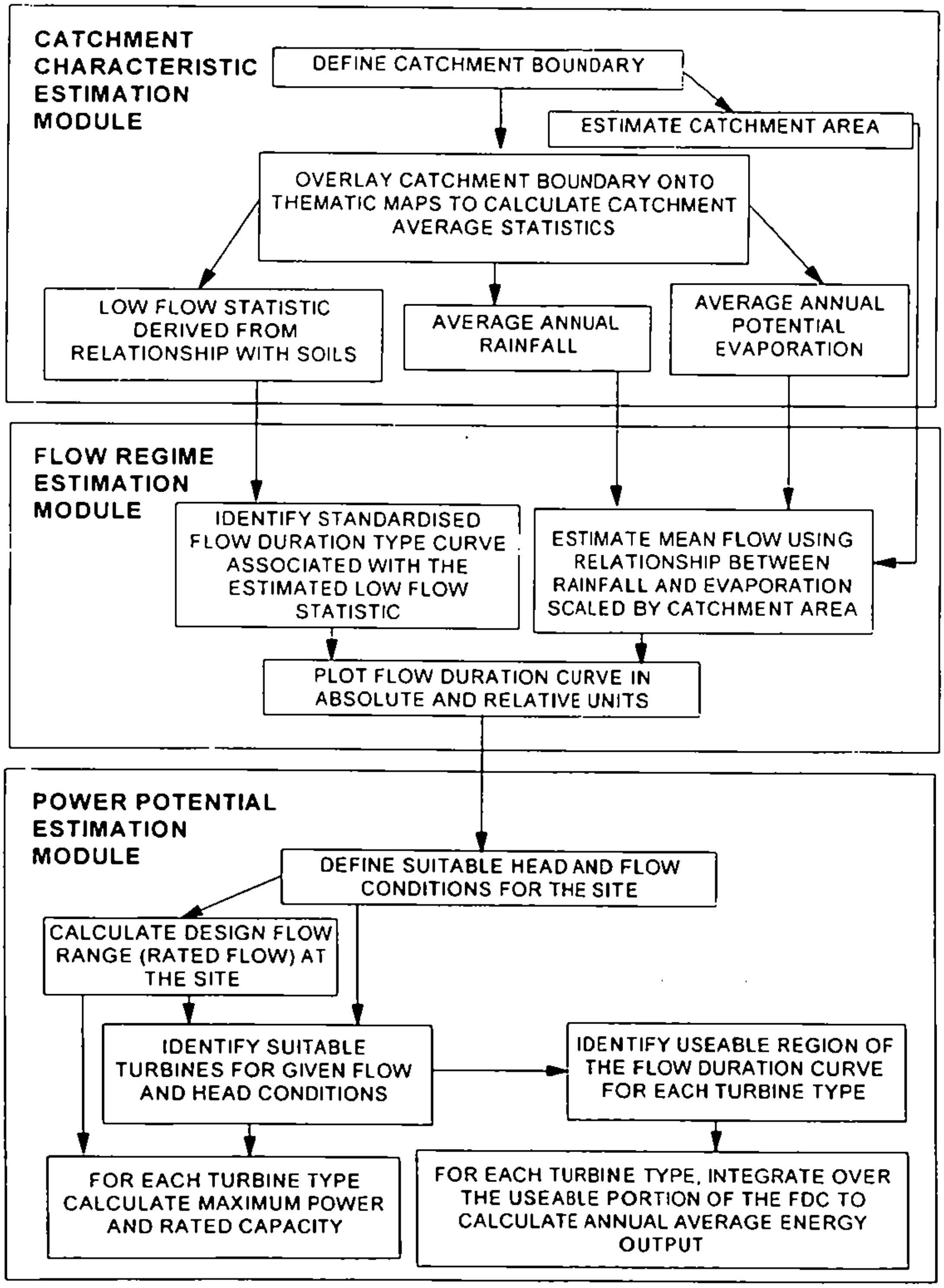


Figure 1 *Structure of the HydrA program*

2. RUNNING THE HYDRA DEMONSTRATION SOFTWARE

The demonstration software is designed to be run under the Microsoft Windows™ environment. It will run only from a floppy disk drive (A: or B). There is no limitation on the number of times that the demonstration software may be run.

The demonstration software can be used with the demonstration data files (or user-defined files based on a subset of the demonstration catchment) as described in the following section. Attempts to perform a hydropower assessment of a user-defined catchment outside the specified area will be unsuccessful.

PREPARATION

The demonstration software requires the presence of a file called VBRUN300.DLL in the \WINDOWS\SYSTEM directory on your computer. If your computer does not have this file, please copy the VBRUN300.DLL file provided on the demonstration disk to your \WINDOWS\SYSTEM directory.

RUNNING THE HYDRA DEMONSTRATION SOFTWARE

The software is supplied on a 3.5" floppy disk, from which it must be run as described below. (Please substitute drive letter as appropriate for your computer.)

1. Insert **Disk** into drive **A:** ;
2. From **Program Manager** or **File Manager**, select **File** then select **Run**. (For Windows 95, select **Run** from the Taskbar);
3. At the **command line** prompt, type **A:\HYDRA** followed by **ENTER** or the **OK** button;
4. Click on the button marked ">>" to start the software and to display the HydrA Application Shell from which all the HydrA functions can be run.

BASIC USAGE OF THE HYDRA SOFTWARE

From the Application Shell the user is able to:

1. Define boundaries, climate characteristics and flow characteristics for new catchments;
2. View/alter existing catchment boundary, climate, flow and power definitions;
3. Select processing options which allow modules to be run sequentially with automatic generation of reports;
4. Run the estimation procedures using the saved catchment, flow and power definitions;

5. Generate reports and graphs for all results, on the screen and as hard copy.

6. Delete existing data and results files;

7. Choose the language in which subsequent text will be written. (At present, British and Spanish language versions are available.)

1The user may choose these options from the pull-down menu bar, or from the tool bar.

Menu bar

To use the menu bar, use the mouse to move the cursor-arrow to a menu option, then press the left mouse-button. Alternatively, press the **ALT** button, followed by the underlined letter in the chosen key word. To initiate processing for any option, highlight the option using the mouse or arrow buttons, then press the left mouse-button or press **ENTER**.

Tool bar

The tool bar comprises a series of icons which correspond to the menu options. To select an option move the mouse-pointer over the chosen icon, then press the left mouse-button. As the mouse-pointer moves over the tool bar icons, the function of each icon is shown in the information box on the tool bar. The icons are displayed in Table 1.

Table 1 *The HydrA tool bar icons*

Function	Catchment Definition	Catchment Characteristics	Flow and Regime	Power
Input new data				
Retrieve existing data				
Delete files				
Processing options				
Run calculations				
Generate summary results				
Language option				
Quit				

3. TUTORIAL

The following step-by-step procedures guide the user through each of the modules for obtaining estimates of catchment characteristics (area, rainfall, evaporation and low flow statistics), flow characteristics (mean flow and flow duration curve) and power potential at a site. The demonstration software incorporates climate and low flow grids covering a small part of Hydrometric Area 33 - East Anglia, UK.

The HydrA software is provided with a set of template files (included on the disk) that contain sample data and can be retrieved and manipulated by the user to investigate the functionality of the software. The files are found in A:\HYDRA\DATA and are listed in Table 2.

Table 2 Data templates

Template	File Name	Description
Catchment boundary file	demo.cbf	Provides the co-ordinates of the catchment boundary for input to the catchment analysis module . The file may be viewed and altered through the catchment definition dialogue.
Catchment characteristics file	demo.ccf	Provides estimated catchment characteristics for input to the flow-regime module . The file may be viewed and altered through the catchment characteristics dialogue.
Flow-regime results file	demo.frr	Provides co-ordinates of the flow duration curve for input to the power-potential module. The file may be viewed and altered through the flow-regime dialogue.
Power-potential results file	demo.ppr	Provides results displayed in the power-potential report, but principally for export of power-potential results into word-processors or spreadsheets, when saved as .csv or .txt.

STEP 1 DEFINING THE CATCHMENT

In general, the first stage in the estimation procedure is to identify the site(s) of interest from maps. It is recommended that 1:50 000 scale maps or better would provide the most appropriate base maps from which to determine the catchment boundary. Once the site has been chosen, the topographic catchment boundary needs to be defined, using contours and spot heights to guide the process. Having identified the boundary, the co-ordinates of the boundary can then be entered into the software.

In order to save the user having to do this, HydrA is provided with a template catchment boundary file (demo.cbf) that can be loaded and edited. This file contains a definition of the Ouzel catchment at Willen within Hydrometric Area 33. To load the file:

1. Select **Data** from the menu, then select **Catchment Definitions**, or

2. Select the **View/Alter Catchment Definitions** icon from the toolbar.

3. Enter A:\hydra\data\demo.cbf in the dialogue box to load and view the catchment

boundary;

4. Edit the file, if wished, as described below. Alternatively quit the edit to leave the file unchanged.

If the user wishes to create their own catchment boundary file, they can do so as described in the following steps. However, the defined catchment defined by the user must be within the area covered by the Ouzel at Willen catchment for the demonstration software to work.

1. Select **Data** from the menu bar, then select **New Catchment Definition**, or

2. Select the **Input New Catchment** definition icon from the toolbar.

3. A dialogue box will be displayed into which you should enter the following:

   - A name or description for the site;
   - The grid reference system to be used, either GB, NI or UTM Zone;
   - A National identifier to indicate the country, either GB or E;
   - The x-y co-ordinates of the catchment boundary in metres. The first co-ordinate pair needs to be repeated to close the loop.

   To move around the boxes use the cursor or the **TAB** key. Points can be inserted or deleted by pressing the **Insert Pt** or **Delete** Pt buttons (respectively).

4. To save the file, press **Save**. Then select drive A:, plus the appropriate directory and file name. By default, the file will be saved as a binary file with a .cbf extension. To read the data in applications other than HydrA, then the file can be saved as text or commas-separated variable format by selecting the appropriate file type from the list.

In the full system, it is also possible to load a .txt or .csv file that has been created externally to HydrA provided that the file is in a specified format However this is beyond the scope of the demonstration software.

STEP 2 SETTING PROCESSING OPTIONS

The user can control the way that the modules can be run by checking the appropriate options in the dialogue boxes. These options include being prompted to run the next module and displaying the report automatically. To change the options:

1. Select the appropriate modules from the **Options** menu, or

2. Select the relevant processing options icon(s) from the toolbar.

STEP 3 CONFIRMING TURBINE CHARACTERISTICS

The HydrA software incorporates the efficiency characteristics of the individual components (generator, gearbox and transformer) required for eight common turbine types. This information is required when determining the power output from the turbines at each site. The data can be displayed by:

1. Selecting **Data** from the menu bar, then **Generating Gear Details**, or;

2. Selecting the **View/Alter Generating Gear Details** icon from the toolbar.

The numbers in the boxes can be edited, for example to represent a reduction in efficiency with age of the equipment. Use the **TAB** keys or mouse to move between boxes and then press the **Save** button to retain the changes.

STEP 4 CALCULATING CATCHMENT CHARACTERISTICS

The physical characteristics of a catchment control the amount of water available and the response of the catchment through the year. HydrA can determine the characteristics by overlaying the catchment boundary onto maps of rainfall, evaporation and low flow response (held within the system) and calculating the average of all the cell values that fall within the catchment boundary. To calculate the catchment characteristics:

1. Select **Run!** from the menu bar, followed by **Catchment Analysis**, or

2. Select the **Run catchment analysis** icon from the toolbar

3. Enter the appropriate drive, directory, file type and filename of the catchment boundary file in the dialogue box;

The catchment will be drawn on the screen and the cells within the catchment will be identified (displayed in green). Once the display has been completed, the distribution of the rainfall, potential evaporation and low flow response across the catchment can be displayed by selecting the appropriate button. Moving the cursor over the catchment will display the value in each cell.

To display the catchment average values, press the **Report** button. To continue, press the **Save** button and enter details of the drive, directory, file type and filename for the catchment characteristics file. By default, this will be saved as a binary file with the .ccf extension. To use this data in other packages, specify that the data should be saved as text or comma-separated variable format.

Assuming the appropriate options have been selected, you will now be asked whether you want to run the **Flow Analysis** module. Press **Yes** to continue.

If you do not wish to accept the estimated values derived within the software, for example if local data is available, press **No**, overwrite the values, and then re-save the file. To do this:

1. Select **Data** from the menu bar, followed by **Catchment Characteristics**, or;

2. Select the **View/Alter Catchment Characteristics** icon from the toolbar;

3. Enter the appropriate drive, directory, file type and filename of the catchment characteristic file to be edited;

4. Alter the values in the boxes, using the **TAB** or mouse keys to move around the dialogue box;

Press **Save** to continue, and either overwrite the existing file (you will be prompted to confirm this) or **Save As** with new filename.

STEP 5 CALCULATING FLOW CHARACTERISTICS

Using the catchment characteristics already determined, it is possible to determine the flow profile at a site. To run the Flow Analysis module:

1. Run the **Catchment Analysis** module as described above;

2. Select **Run**! from the menu bar, followed by **Flow Regime Calculation**;

3. Select the **Run Flow Regime Calculation** from the toolbar.

In the case of 2 & 3, the user will be prompted to enter the filename of the catchment characteristics file.

The flow duration curve will be displayed, showing the flow against the percentage of time that the discharge is equalled or exceeded. The curve can be interrogated to identify particular flows from specified percentage exceedence, or vice-versa. To do this, select the appropriate button in the top right hand corner of the screen and enter either a flow (in cubic metres per second or as a percentage of the mean flow) or the percentage exceedence, then press **Run**.

To continue, press **Save** to retain the co-ordinates of the flow duration curve in a file. Enter the appropriate disk, directory, file type and filename and press **Save**.

Assuming the appropriate options have been selected, you will now be asked whether you want to run the **Power Potential Analysis** module. Press **Yes** to continue. Choosing **No** will return you the Application Shell.

In common with the **Catchment Characteristics** module, it is possible to overwrite the co-ordinates of the flow duration curve, if gauged data is available.

STEP 6 CALCULATING POWER POTENTIAL

The final step is to determine how much of the total flow is available to generate electricity (the useable part of the flow duration curve), the capacity of the turbine(s) and the power output from the turbine(s). To do this:

1. Run the **Catchment Analysis** and the **Flow Regime** modules as described above;

2. Select **Run**! from the menu bar, then select **Power Potential Calculation**;

3. Select the **Run Power Potential Calculation** icon from the toolbar;

If 2 or 3 are selected, then you will be prompted to enter the filename as described above.

A dialogue box will be displayed, into which the user is prompted to enter values for the provisional rated flow (by default this will be set initially at the mean flow), the minimum residual flow to remain in the river and the gross hydraulic head. The flows can be entered as either a flow in cumecs or in terms of the percentage exceedence, such as Q95. The nett head is determined as a percentage of the gross head. The default value is set at 93%, but this can be altered depending on losses through the system.

When all the boxes have been filled, it is possible to display the turbines that are appropriate under the specified flow conditions for the site. To do this, press the **Plot on Head/Flow Graph** button. The specified head and flow conditions will be plotted on the manufactures operation envelopes for the common turbine types. Press **Quit** to continue. Then press **Process** to calculate the energy output.

If the appropriate run-time options have been selected, then a list of the generating gear details for the selected turbines will be displayed. Press **Process** to continue to display a summary of the energy output for each turbine. A full report is obtained by pressing **Report**.

The full report gives details of the flow conditions on which the energy statistics are based and the energy statistics, including the gross/nett annual average output, the maximum power, the rated capacity and the minimum operation flow for all turbines that are appropriate for the site.
The power information can also be displayed with the turbine efficiency curves, which are selected by pressing the **Plot Power/Flow Graph** button. The efficiency curves and power/energy statistics for each of the different turbine types can be selected by choosing the appropriate buttons from the list. The operational flow limits for each of the turbines can be superimposed on the flow duration curve, by pressing the **Plot Flow-Duration Curve** button. Both the power/flow curves and the useable flow duration curves can be printed by pressing the **Print** button. To return to the main **Power Potential Report**, press the **Quit** button.

The data can be saved by pressing the **Save** button. In common with the other modules, the data can be saved as the default, which has the .ppr extension, or as text or comma-separated variable format for input into other applications. Once the data has been saved, you can then print the results using a standard printer, by pressing the **Print** button.

STEP 7 QUITTING THE APPLICATION

Press **Quit** to return to the Application Shell.

To close the application, and return to the Windows program manager or other application, select **Quit** from the menu bar or select the **Quit** icon from the tool bar.2

FURTHER INFORMATION

For further information about HydrA or for any queries relating to the demonstration software, please contact:

Software Sales and Support,
Institute of Hydrology,
Wallingford,
OXON OX10 8BB

Tel: 01491 838800
Fax: 01491 692424
E-Mail: softdev@ioh.ac.uk
Telex: 444293 ENVRE G

Annex C (i)

Launch workshop materials

Workshop flyer

Institute of Hydrology

Training for Success

Small Hydropower Assessment Review and Technical Workshop

A workshop is being held on 20-21 March, 1997 at Water Training International, Tadley Court, Nr. Basingstoke, Hampshire to publicly launch the UK version of HydrA, a new PC package for low flow and hydropower estimation, developed by the Institute of Hydrology on behalf of the European Small Hydropower Association (ESHA) and the ALTENER Committee of the European Union. The workshop will be divided into two complementary sessions:

SP745 - Small Hydropower Assessment: Review will be of interest to power utility managers, hydropower consultants, environmental regulators, academics and others who have an interest in the design of small scale hydropower schemes and is aimed at promoting an awareness of small scale hydropower and providing an introduction to the HydrA software and the principles of estimating hydropower potential;

SP746 - Small Hydropower Assessment: Technical Workshop aimed at potential operational users of the software, including hydropower consultants, engineers and technicians, incorporates SP745 and provides a more detailed review of the methods for estimating the hydrological regime and hydropower potential, with practical experience using the software.

Full details of the timetable and content of each day are attached.
The cost of the workshop will be:

SP745	*20 Mar '97*	***£40***	*to include lunch and refreshments*
SP746	*20-21 Mar '97*	***£179***	*to include attendance on SP745, overnight accommodation and all meals*

To attend, please complete and return the attached Booking Form to:

Water Training International,
Tadley Court,
Tadley.
RG26 3TB.
UK

Tel: 0118 981 3011
Fax: 0118 982 0755

Course Booking Form

Please return to:
Customer Services
WTi
Tadley Court
Tadley
Basingstoke
Hampshire RG26 3TB

Tel 0118 981 3011
Fax 0118 982 0755

Do you require accommodation for one-day or early-start courses? Please ask Customer Services - rooms usually available at £40 per night.

WTi *Training for Success*

COURSE CODE	TRAINING CENTRE	START DATE	DELEGATE'S NAME (if known)	JOB TITLE	*FOR WTi USE*

Please send joining instructions to:

FIRST NAME ____________________

FAMILY NAME ____________________

TITLE ____________________

ORGANISATION ____________________

ADDRESS ____________________

____

POSTCODE __________ TEL NO. __________

SIGNATURE __________ DATE __________

Invoicing address (if different)

____

____

____

____

____

Customer Order No.

Customer Account No. (if known)

NOTES

COURSE FEE
We assume bookings are made based on the full residential fee basis (if appropriate), unless specified otherwise on this form (See our latest Training Course Programme for details).

PROVISIONAL BOOKINGS
We are happy to accept provisional bookings, which will be held for five working days.

PAYMENT
Payment will be due upon receipt of invoice which will be issued 4 weeks prior to the course commencement date. Should the course commencement date be within 4 weeks of the booking date payment should be with order.

CANCELLATIONS & SUBSTITUTES
For cancellations notified by letter or fax more than 3 weeks before the start of the course, a full refund will be made. Cancellations between 1 and 3 weeks before the start date will be subject to a £50 administration charge. For cancellations made within one week of the start date, the full fee will be charged.
Substitute delegates are welcome at no extra charge.

CB

Small Hydropower Assessment: Review

Overview

A two day workshop is being held to describe HydrA, a new low flow and hydropower estimation tool developed by the Institute of Hydrology on behalf of the European Small Hydropower Association (ESHA) and the ALTENER Committee of the European Union. The workshop will be divided into two complementary sessions - ***Small Hydropower Assessment: Review*** and ***Small Hydropower Assessment: Technical Workshop***. ***Small Hydropower Assessment: Review***, aims to provide an appreciation of the software by giving an overview of the HydrA development and a brief description of the methods which are embodied within the software. The second part, entitled ***Small Hydropower Assessment: Technical Workshop***, is aimed at potential operational users of the software and provides an in-depth review of the methods for estimating the hydrological regime from which hydropower potential can be derived.

Small Hydropower Assessment: Review will benefit

Power utility managers, hydropower consultants, civil engineers, electrical engineers, environmental regulators, academics and others who have an interest in the design of small scale hydropower schemes.

(Maximum number of delegates: 50)

Small Hydropower Assessment: Review will cover

- Introduction to EU policy on renewable energy;
- Definition of the problem from ESHA's perspective;
- Background to the project;
- Demonstration of the HydrA software;
- The principles of estimating the hydrological regime;
- Calculating the hydropower potential;
- Environment Agency policy on small scale hydropower;
- Renewable energy tariffs in the UK.

Training Methods

Small Hydropower Assessment: Review will be led by staff from the Institute of Hydrology and will consist of lectures and demonstrations only with invited guest speakers.

Date and Location

Small Hydropower Assessment: Review will be held on Thursday, 20 March 1997, at Water Training International, Tadley Court, Tadley, Basingstoke, Hampshire.

Timetable

10:00-10:30	Registration
10:30-13:00	Morning session
13:00-14:00	Lunch
14:00-15:30	Afternoon session
15:30-16:00	Open discussion and informal demonstrations

Small Hydropower Assessment: Review will cost:

£40 per person including morning coffee, lunch and afternoon tea.

Small Hydropower Assessment: Technical Workshop (incorporating Small Hydropower Assessment: Review)

Overview

A two day workshop is being held to describe HydrA, a new low flow and hydropower estimation tool developed by the Institute of Hydrology on behalf of the European Small Hydropower Association (ESHA) and the ALTENER Committee of the European Union. The workshop will be divided into two complementary sessions - ***Small Hydropower Assessment: Review*** and ***Small Hydropower Assessment: Technical Workshop***. ***Small Hydropower Assessment: Technical Workshop***, is aimed at potential operational users of the software and provides an in-depth review of the methods for estimating the hydrological regime from which hydropower potential can be derived. Delegates attending ***Small Hydropower Assessment: Technical Workshop*** will be required to attend the first part of the workshop, ***Small Hydropower Assessment: Review***.

Small Hydropower Assessment: Technical Workshop will benefit

Potential users of the system including hydropower consultants, engineers and technicians.

(Maximum number of delegates: 20)

Small Hydropower Assessment: Technical Workshop will cover

- Manual derivation of the hydrological regime, as defined by the flow duration curve, from flow data;
- Manual derivation of catchment characteristics;
- Manual derivation of the flow duration curve from catchment characteristics;
- Alternative methods for estimating the flow duration curve;
- Hydropower estimation from the flow duration curve;
- Hands-on introduction to the HydrA software;
- HydrA in practice.

Training methods

The workshop will be led by staff from the Institute of Hydrology. ***Small Hydropower Assessment: Technical Workshop*** will feature practical sessions on the derivation of the hydrological regime at a proposed site and the subsequent calculation of the hydropower potential. Hands-on experience of using the software will be provided in the afternoon session. All course materials will be provided. Delegates are each asked to bring a scientific calculator.

Date and Location

Small Hydropower Assessment: Technical Workshop will be held on Thursday and Friday, 20-21 March 1997, at Water Training International, Tadley Court, Tadley, Basingstoke, Hampshire.

Timetable

DAY 1

10:00-10:30 Registration

Small Hydropower Assessment: Review

10:30-13:00	Morning session
13:00-14:00	Lunch
14:00-15:30	Afternoon session
15:30-16:00	Open discussion and informal demonstrations

Small Hydropower Assessment: Technical Workshop

16:30-18:00 Evening session

DAY 2

09:00-13:00	Morning Session
13:00-14:00	Lunch
14:00-17:00	Afternoon session
17:00-17:30	Informal discussion

Small Hydropower Assessment: Technical Workshop will cost:

£179 per person including the cost of attending ***Small Hydropower Assessment: Review***, overnight accommodation and all meals.

Annex C (ii)

Launch workshop materials

List of Registrants

Name	Organisation	Address
P. Wyllie		12 Copperwood, Harford, SG13 7HZ
M. McCourt		NEL Nasmyth Building, Scottish Enterprise Technology Park, East Kilbride, Glasgow, G75 0QU
T. Clare		60 Bellingham Road, Kendal, Cumbria, LA9 5JP
J. Hemsworth	Binnie, Black & Veatch	Grosvenor House, 69 London Road, Redhill, Surrey, RH1 1LQ
R. Arrowsmith	British Waterways	Water Development Section, Willow Grange, Church Road, Watford, WD1 3QA
D. Williams	Energy Power Resources Ltd	White Cottage, Croedkernew, Newport, Gwent, NP1 9UF
A. Plommer R. Spence	Environment Agency	Sapphire East, 550 Streetsbrook Road, Solihull, West Midlands, B91 1QT
R. Murchie	Environment Agency	Guildbourne House, Chatsworth Road, Worthing, West Sussex, BN11 1LD
A. Thompsett, H. West	Hyder Plc	PO Box 295, Alexandra Gate, Rover Way, Cardiff, CF2 2UE
P. Cowley	IT Power Ltd	The Warren, Bramshill Road, Eversley, Hants, RG27 0PR
R. Simms	Massey University N.Z.	ETSU 154, Harwell, Didcot, Oxon, OX11 0RA
I. Carter, I. Davison	Montgomery Watson Ltd.	Terriers House, 201 Amersham Road, High Wycombe, Bucks, HP13 5AJ
R.V. Weeks	Rofe, Kennard & Lapworth	2/4 Sutton Court Road, Sutton, Surrey, SM1 4SS
B. Graham, A. Hunter	Scottish Agricultural College	West Mains Road, Edinburgh, Scotland, EH9 3JG
R.C. Brown	SEPA	Grasser House, Fodderty Way, Dingwall Business Park, Dingwall, IV15 9XB
T.L. Shaw	Shawater Limited	The Old Vicarage, Ston Easton, Nr Bath, BA3 4DN
S. Dunthorne	Sir Alexander Gibb & Partners	Earley House, London Road, Reading, Berkshire, RG 1BL
S. Cryer	South West Water Services Ltd.	Peninsula House, Rydon Lane, Exeter, EX2 7HR

Annex C (iii)

Launch workshop materials

Small Hydropower Assessment: Technical Workshop
Tadley, 20 - 21 March 1997

Presentations being made by:

Eric Wilson	Member of ESHA Wilson Energy Associates Ltd
Mark Allington	Project Manager, Hydro ETSU
Alan Gustard	Project Manager Institute of Hydrology
Gwyn Williams	Water Resources Manager Environment Agency, Midland Region
Gwyn Rees	Project Leader Institute of Hydrology
Karen Croker	Hydrological Modeller Institute of Hydrology

Annex D

Published papers covering HydrA Dissemination

ALLCHIN, M., IRVING, K.M., YOUNG, A. 1995. European Atlas of Small-Scale Hydropower Resources. Technical Reference and User Guide. pp90. (also translated into Spanish).

GUSTARD, A., IRVING, K.M., REES, H.G., YOUNG, A 1995. Hydrological models for small-scale hydropower assessment. In: *Proc. Hidroenergia '95*. Sep 1995. Milan. **(Following)**

Institute of Hydrology 1996. Publicity brochure - HydrA: European atlas of small-scale hydropower resources. **(Annex B (i))**

Institute of Hydrology 1997. Publicity brochure - HydrA: Atlas europeo de recursos mini-hidráulicos. **(Annex B(i))**

REES, H.G. 1997. HYDRA - Rapid assessment of small scale hydropower potential. In *World Directory of Renewable Energy Suppliers and Services 1997*, James and James Science Publishers, London, UK. 78 - 80 pp.

ALLCHIN, M., IRVING, K.M., YOUNG, A. 1998. HydrA V1.0: Atlas Europeo del Potential Hidroeléctrico con Pequenas Centrales: Referencia Técnica y Guiá del Usuario, 104pp.

CROKER, K.M. and REES, H.G. 1998. Software package puts small hydro on the map. *International Water Power & Dam Construction* (March 1998), p.40-41.

CROKER, K.M., REES, H.G. and GUSTARD, A. 1998. Developing hydrological models in Spain for small-scale hydropower assessment: *Small Hydro '98*, Athens, Greece, 16-18 November 1998. 12pp. **(Following)**

GUSTARD, A., CROKER, K.M., REES, H.G. 1998. Developing regional design techniques for estimating hydropower potential. In: *Proc. of International Symposium on Hydrology of Ungauged Streams in Hilly Regions for Small Hydropower Development.* New Delhi, India, 9-10 March, 1998. 1-9pp. **(Following)**

REES, H.G. 1998. "HydrA - The European Atlas of Small Hydropower Potential" - Presentation at the European Commission Conference on *"Renewable Energies Technologies and Strategies in Central and Eastern European Countries"*, Sophia-Antipolis, France, 19-21 October 1998.

REES, H.G., CROKER, K.M. 1998. Software for small-scale hydropower estimation. In: *Proc. of International Symposium on Hydrology of Ungauged Streams in Hilly Regions for Small Hydropower Development.* New Delhi, India, 9-10 March, 1998. 11-20pp. **(Following)**

REES, H.G. and CROKER, K.M. 1998. HydrA - rapid assessment of small-scale hydropower potential. *Int. J. of Hydropower and Dams*, 5 (1).

SEPTEMBER 18-20, 1995
MILAN, ITALY

HIDROENERGIA 95

4th International Conference and Exhibition

Organised by

European Small Hydropower Association

Federation of Scientific and Technical Associations
Established in 1898

Supported by

European Commission
Directorate General for Energy (DG XVII)

CONFERENCE PROCEEDINGS

ACTES DE CONFERENCE

ATTI DELLA CONFERENZA

(Paper to be added in 2^nd *SESSION*)

Hydrological models for small scale hydropower assessment

Authors: Dr A Gustard, Ms K Irving, Mr G Rees, Mr A Young

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

ABSTRACT

The assessment of hydropower generation potential of a site requires a knowledge of the distribution of flows in the river and the relationship between the flows and the generating capacity of turbines.

This paper describes the development of regional hydrological models which can be used to estimate flows at sites where recorded data is not available and summarises techniques for hydropower estimation. The approach will be illustrated using a case study based on analysis of data from the UK for incorporation into hydropower design software called HydrA.

ACKNOWLEDGEMENTS

The European Atlas of Small-Scale Hydropower Resources has been developed on behalf of the European Small Hydropower Association (ESHA) by the Institute of Hydrology with funding from the European Union (DGXVII) ALTENER Programme. The overall management of the project has been undertaken by Professor Eric Wilson (Wilson Energy Associates Ltd, UK). Historical time-series data of gauged flows, catchment characteristic information and climate maps were provided by Dr J. Xieménez de Embún (INTECSA, Spain), Dr Teodoro Estrela (CEDEX, Spain) and Professor Virgilio Anselmo (Verdeacqua, Italy).

INTRODUCTION

In assessing the hydrological potential of a proposed site for a small hydropower scheme, the objective of the water resource planner is to determine whether there is a sufficient discharge in the river to drive the generating turbines. An effective technique available to characterise the distribution of flows over the whole range is a flow duration curve. This identifies the percentage of time that a given discharge, sufficient to operate the turbines, is exceeded. Suitable ranges of discharges can then be used to define the size of the turbines that would be required at the site. Where long records of measured river flows are available at the design site then these provide data from which the flow duration curve can be derived.

However, there are a large number ungauged sites and sites where records are too short to provide estimates of the long term distribution of river flows.

Hydrological analyses have been undertaken as part of the European Atlas of Small-Scale Hydropower Resources project. These analyses were directed at revising the estimation of flow statistics in the UK, using existing methods developed by the Institute of Hydrology, and developing similar estimation procedures for Spain.

The overall objectives of the project have been to:

1. Establish databases of river flow data, gauging station information, catchment characteristic data for countries in the EU. Initial funding from the ALTENER Committee has been available to develop databases for the UK, Spain and Italy;

2. Develop methods for estimating the flow regime for ungauged catchments within the UK and Spain;

3. Identify current engineering methods for estimating hydropower generation potential;

4. Develop software to implement these methods for ungauged locations.

This paper presents an overview of objectives 1 and 2 concentrating on database and estimation procedures developed for the UK only. Objectives 3 and 4 will be considered in a supplementary paper. The opinions expressed are those of the Authors and are not necessarily those of ESHA or the ALTENER Committee.

HISTORICAL BACKGROUND

The development of hydrological design methods by the Institute of Hydrology (Low Flow Study Report, 1980) identified that once low flows are expressed as a percentage of the long-term mean flow (MF), the dependence on the climatic variability across the country and the size of the catchment is removed, and therefore the successful estimation at an ungauged site within the UK is largely dependent on the nature of the geology of the catchment.

The design methods were updated to incorporate advances in the hydrological classification of soils, represented by a provisional Hydrology Of Soil Types (HOST) classification (Boorman *et al.*, 1991) and described in more detail in following sections, and the availability of data to the end of 1989. Methods were developed which relate HOST to the measured low flow response of gauged catchments at the national scale. The results were published in Report 108, Low Flow Estimation in the United Kingdom within the IH report series (Gustard *et al.*, 1992).

These methods have been developed into a PC software package, Micro LOW FLOWS (Young, 1992, Sekulin *et al.*, 1992), which has been widely adopted as a water resources evaluation and planning tool by the UK water industry. The methods have also been applied within the Baden-Württemburg area (Wesselink *et al.*, 1994) of Germany in the development of a regional version of the Micro LOW FLOWS software package.

The estimation procedures updated within the framework of the ESHA project incorporate recent hydrological data to the end of 1992 and have incorporated the final Hydrology Of Soil Types (HOST) hydrological response classification of the UK (Young *et al.*, 1995).

THE UK DATABASES

The river flow database

Gauged flow data up to the end of 1992 from the UK National River Flow Archive (held by the Institute of Hydrology) were used from which a dataset of gauging station records were identified as having good quality data and relatively natural river flows from which reliable natural flow statistics were calculated. The principal artificial influences which affect the flow regime include surface water and groundwater abstractions, surface water discharges and impounding reservoir structures. A set of quality indices were established for the classification of the gauging stations (Gustard *et al.*, 1992) used in Report 108 to identify UK gauged catchments which satisfy these constraints. Additional constraints were placed on the data to ensure the analysis would not be influenced by catchment size and length of record. The total number of gauged flow records available for this study was 727.

During the period 1988-92, the UK suffered an extreme drought period (Institute of Hydrology, 1992). Through the use of flow data up to the end of 1992 the current study has incorporated the impact of this recent drought period on historical flow statistics.

The UK HOST hydrological response classification

The physical properties of soils are very important in influencing the hydrological characteristics of a catchment by controlling the storage and transmission of water and affecting the chemical properties of the water. (Boorman *et al.*, 1994). The soil associations of England and Wales have been mapped at a scale of 1:250 000 by the Soil Survey and Land Research Centre (SSLRC) and those in Scotland by the Macaulay Land Use Research Institute (MLURI). A collaborative project between the Institute of Hydrology, SSLRC, MLURI and the Department of Agriculture in Northern Ireland categorised the soils into 29 discrete groups to represent different physical properties and the hydrological response of soils. The classification system is referred to as the Hydrology Of Soil Types (HOST) classification (Boorman & Hollis, 1990 and Boorman *et al.*, 1991). In Northern Ireland the soil mapping has not been completed, however a provisional HOST map has been prepared for the province.

The HOST project has finalised a national database containing of the proportions of each HOST class in every 1 km^2 grid cell within the UK. The proportion of each HOST class within gauged catchments in the UK has also been derived from which the proportions of the 29 HOST classes within each of the 727 catchments selected in this study were obtained.

The final HOST classification offers a significant improvement as a result of coverage having been extended to include Northern Ireland; the fractional extent of all HOST classes within each 1 km^2 cell is mapped and stored, and the mapping of soil associations beneath urban areas and assignment of these to HOST classes has been undertaken.

Climatic data

As a consequence of the temperate maritime climate of the UK, it has been found that long term average annual climate data are sufficient to characterise climatic variations across the UK (Institute of Hydrology, 1980 & Gustard *et al.*, 1992).

Maps of standard period (1941-1970) average annual rainfall (SAAR) at 1:625 000 scale covering the UK are available from the Meteorological Office and were published in the Flood Studies Report (NERC, 1975). The maps were digitised at the Institute of Hydrology and a 1 km^2 grid was derived from the digitised isohyetal data. The grid stores precipitation data to a resolution of 1 mm.

Potential evaporation is estimated from the Meteorological Office 1:2 000 000 map (provisional version) of average annual potential evaporation which is based on the Penman equation with a surface albedo of 0.25. The map has been digitised at the Institute of Hydrology and a 1 km^2 grid derived using a polynomial fitting method. Although the data are held to a resolution of 1 mm the error in estimating PE from the map is of the order of 25 mm.

THE HYDROLOGICAL ESTIMATION METHODOLOGY

Standardised low flow statistic

In the UK, (IH 1980 & Gustard *et al.*, 1992) identified that Q95 (the flow exceeded 95% of the time) (expressed as a percentage of the long term mean flow) could be used as the key low flow statistic used to identify the flow duration curve at an ungauged. In order to estimate the standardised Q95 flow statistic, multivariate regression models have been derived by relating Q95 to the distribution of HOST classes within these catchments. In developing the models, HOST classes with similar low flow response were amalgamated to give 10 Low Flow HOST Groups and two additional groups representing the areal extent of urbanisation and lakes.

Flow duration curves

Within the UK the gradient of a flow duration curve is controlled by the catchment low flow response, as represented by the magnitude of the standardised Q95 flow. Having estimated the value of Q95, the appropriate flow duration curve can be selected from the set of type curves, illustrated in Figure 1. These curves represent typical geological conditions and were derived by calculating the flow duration curves (expressed as a percentage of mean flow) for the low flow graded stations using gauged flow data and pooling them into 16 classes based on the value of standardised Q95. The family of type curves were derived by smoothing the pooled flow duration cures and interpolating between them such that 20 curves were generated which were equally spaced at the Q95 value using gauged flow data.

Mean flow

The final step in the estimation method is to determine a value of mean flow to scale the flow duration curve. The mean flow is calculated using a catchment water balance methodology where the long term average annual runoff is the difference between average annual rainfall (SAAR) and actual evaporation (AE).

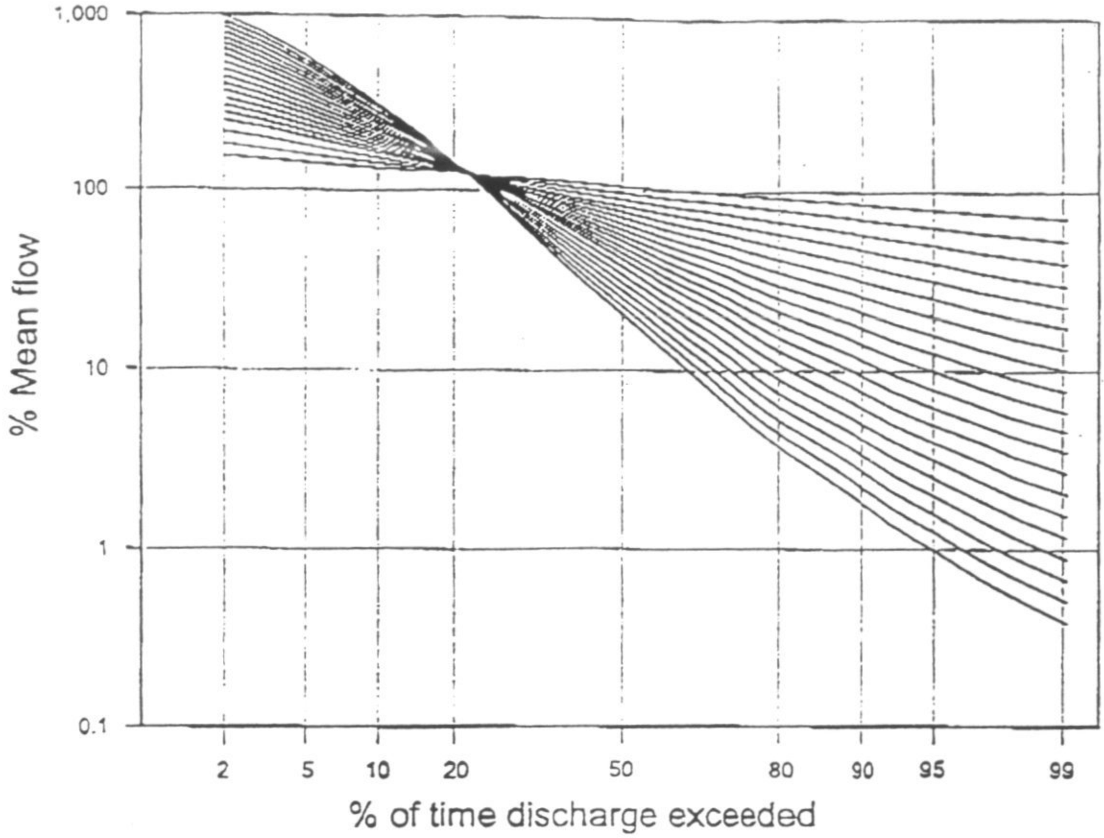


Figure 1 Flow duration type curves

Catchment values of SAAR and potential evaporation are estimated from the UK Meterological Office maps (discussed previously). Actual evaporation is estimated from potential evaporation using a scaling factor (r) where r is a function of catchment rainfall. The value of r increases with SAAR and hence increasing water availability. For catchments with annual average rainfall in excess of 850 mm yr^{-1}, it is assumed that actual evaporation is equal to the potential evaporation as a result of relatively short periods when evaporation is limited by soil moisture deficit. This relationship between r and SAAR, calibrated on the flow records from high quality gauging stations, is given by:

$$r = (0.00061 \times SAAR) + 0.475 \qquad \text{for SAAR} < 850 \text{ mm} \tag{1}$$
$$r = 1.0 \qquad \text{for SAAR} \geq 850 \text{ mm}$$

and actual evaporation is calculated using:

$$AE = r \times PE \tag{2}$$

The average annual runoff depth (AARD in millimetres) over the catchment is converted to mean flow in m^3s^{-1} by:

$$MF = \frac{AARD \times AREA}{31536} \tag{3}$$

RELATIONSHIP BETWEEN THE Q95 LOW FLOW STATISTIC AND HOST

Linear least square multiple regression analysis has been undertaken to relate the Q95 statistic with the Hydrology of Soil Type (HOST) classification using the flow records from 727 gauging stations in the UK. The relationship between Q95 and HOST within a catchment can be described by a linear relationship of the form:

$$Q95 = a + b \,.\, HOST1 + \ldots\ldots + x \,.\, HOST29 + y \,.\, HOST97 + z \,.\, HOST98 \quad (4)$$

Where: HOST1-29 represent the proportional extent of the 29 HOST classes
HOST97 represents the proportional extent of urban areas
HOST98 represents the proportional extent of lakes within the catchment

The results of this analysis indicated that the model explained 54% of the variance with a factorial standard error of 7.422. Negative parameter estimates and high standard errors reflected HOST classes which are not well represented within the UK. These HOST classes account for a mean coverage of less than 1% of the soils within the UK and generally less than 30% coverage at their maximum occurrence within gauged catchments. The HOST classes were therefore grouped into 12 low flow response units based on similar physical characteristics, in order to improve both the sample size and proportional representation within the catchments of the HOST classes.

When Q95 is regressed against the Low Flow HOST Groups the new model explains 51% of the variance with an overall model factorial standard error of 7.571. The parameter estimates of the model are presented in Table 1. Grouping the HOST classes does not significantly improve the explanation of variance of the overall model but the factorial standard errors associated with the individual parameter estimates are reduced compared with the full HOST data set and no negative parameter estimates have been calculated. The revised Q95 regression model has been used to estimate the Q95 flow for 1 km^2 grid squares throughout the UK, illustrated in Figure 2.

Table 1 Q95 estimates for Low Flow HOST Groups

Low Flow HOST Group	Q95 Parameter	s.e of parameter
LFHG1	38.10	1.7
LFHG2	29.18	2.5
LFHG3	58.06	2.8
LFHG4	27.63	3.1
LFHG5	41.13	5.2
LFHG6	12.07	5.0
LFHG7	9.69	0.8
LFHG8	1.95	1.9
LFHG9	15.73	2.3
LFHG10	6.08	1.5
LFHG11	15.25	2.4
LFHG12	62.31	27.5

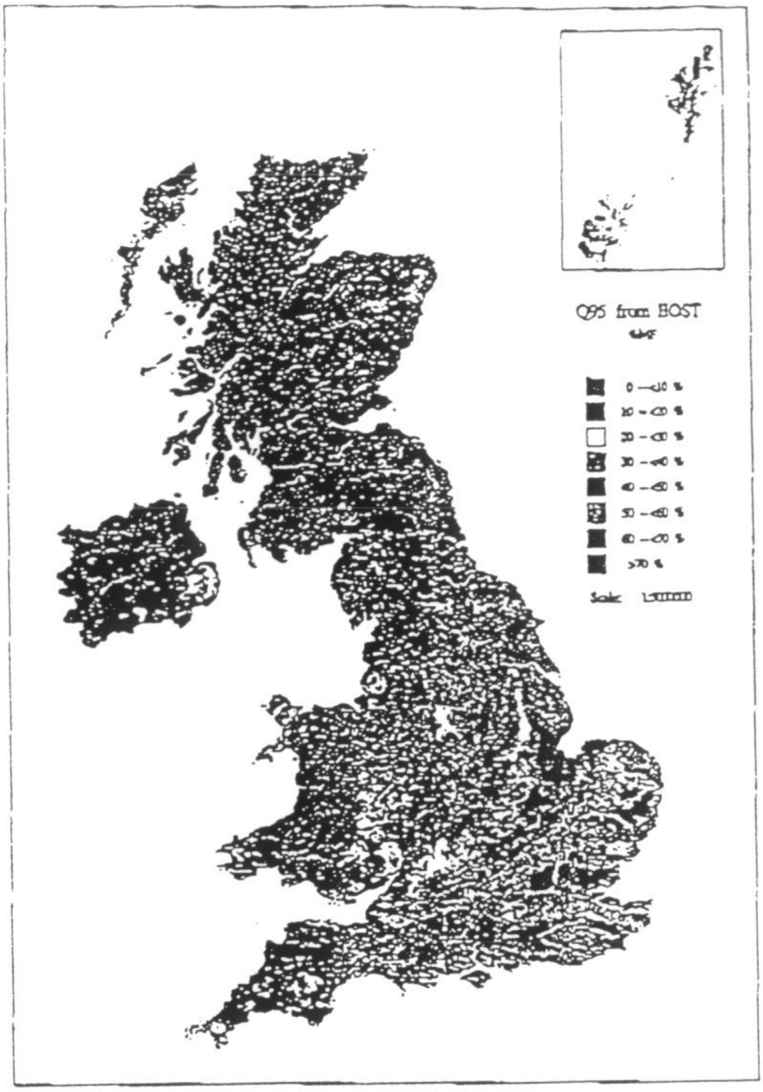


Figure 2 Distribution of Q95 in the UK

The impact of incorporating the final HOST classification, flow data from the 1989-92 drought and increased record lengths are considered in Table 2.

Table 3 Summary results of Q95 model

Data set	HOST classification	N	R_2	rmse
$Q95_{1989}$	Provisional HOST	659	57.34	7.427
$Q95_{1989}$	final HOST	659	58.35	7.282
$Q95_{1989}$ including NI	final HOST	693	58.23	7.321
$Q95_{1992}$	final HOST	727	51.31	7.571

The impact of incorporating the final HOST classification is to marginally increase the fit of the model. More significantly the model increases the confidence with which the parameter estimates have been estimated and reduces the residual errors, especially in the permeable chalk and limestone catchments.

However, the impact of the 1989-92 drought and the sensitivity of shorter flow records to the drought are dominant factors in accounting for the high variance and marginal fit of the model. The drought showed a clear NW/SE divide, therefore long term Q95 flows, in particular in the Chalk areas of southern and eastern England, have been more severely affected than catchments in the north. Experience has shown that Q95 calculated from flow records of less than 10-15 years duration are likely to undergo significant change as additional data from an extreme event like the 1989-92 drought are added.

The additional gauging stations included in the 1992 data set have Q95 values which are close to the mean of the distribution, where the sample size is already sufficient to describe these flow regimes, and thus they do not contribute significantly to increasing the representativeness of the sample set.

SOFTWARE IMPLEMENTATION OF DESIGN PROCEDURES

The above design procedures, plus standard equations for calculating the generating power of turbines, have been incorporated into a public domain software application called HydrA which has been developed as a tool to assist in the assessment of hydropower potential at ungauged sites in Europe.

The software has been designed such that users with little or no hydrological knowledge and limited experience of hydropower design are able to make estimates of catchment characteristics, flow profiles and turbine information. In order to achieve this, the software stores the grids of standard period rainfall and potential evaporation, the derived Q95 grid for the UK, the standard flow duration curves and a set of efficiency and operating specifications for standard turbines.

The software operates within a Microsoft Windows™ environment and allows the user to:

1. Define a catchment boundary for the site of interest, either read from a file or entered interactively through an editor;

2. Estimate the key catchment characteristics, including area, mean flow, Q95, average rainfall and potential evaporation using the geographical databases (Figure 3);

3. Use the estimated Q95 and mean flow values to identify and plot the appropriate flow duration curve for the site;

4. Use the flow duration curve to identify a suitable flow range within which common turbine types will operate then calculate the power output for these conditions. This is done using standard design procedures and default turbine operational data.

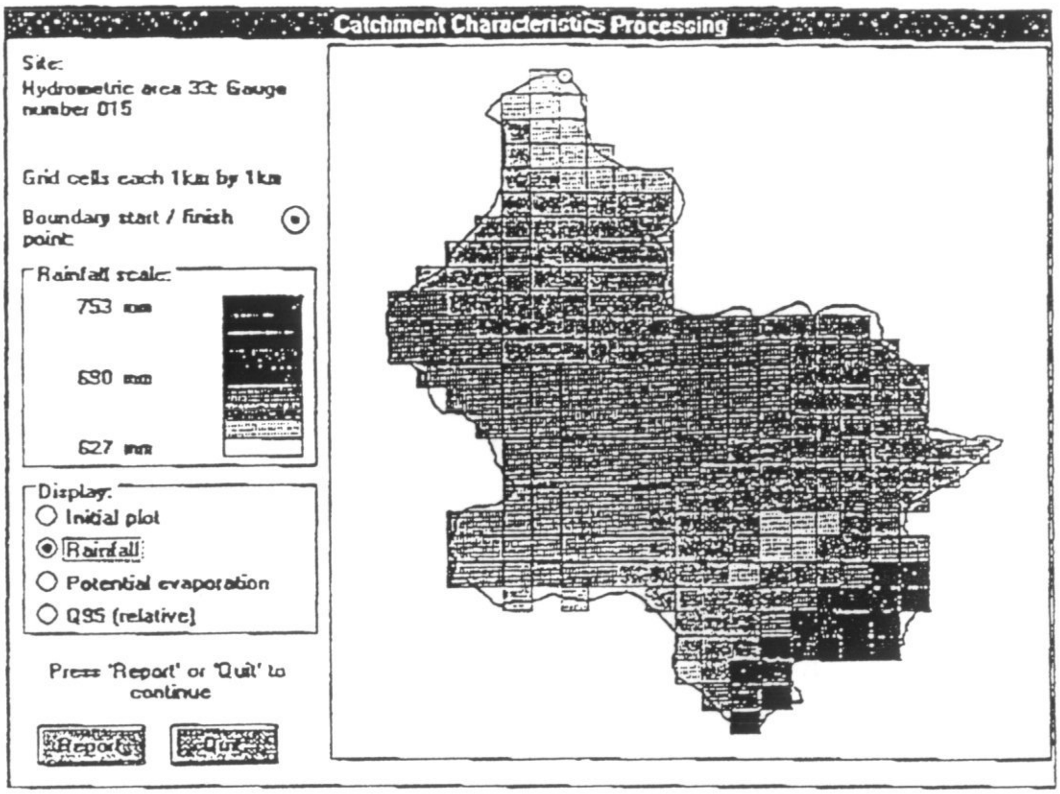


Figure 3 Catchment characteristic estimation

CONCLUSIONS

Methods have been developed for the estimation of low flow statistics in the UK based on the relationship between the Q95 statistic and the HOST classification. Recent developments in availability of a final HOST classification to include Northern Ireland and the proportional extent of soil types within urban areas has resulted in a model for Q95 in which the parameter estimates for HOST are estimated with increased confidence. However, the impact of the drought in the UK during 1989-92 has decreased the explained variance of the model.

The estimation procedures for Spain will be developed based on similar principles to relate CEC soil classes to a low flow statistic calculated using data from Spanish gauging stations. Type curves will also be used as the basis of flow duration curve estimation in Spain derived from pooled flow duration curves.

The software is currently being tested in the UK and will soon be available for Spain.

REFERENCES

Boorman, D.B. & Hollis, J.M. 1990. Hydrology of Soil Types. A hydrologically-based classification of the soils of England and Wales. MAFF Conference of river and coastal engineers, Loughborough University.

Boorman, D.B., Hollis, J.M. & Lilley, A. 1991. The production of the Hydrology of Soil Types (HOST) data set. BHS Third Symposium. Southampton 6.17-6.13.

Boorman, D.B., Gannon, B., Gustard, A., Hollis, J.M. & Lilley, A. 1994. Hydrological aspects of the HOST classification of soils. Report to MAFF.

Gustard, A., Bullock, A. & Dixon, J.M. 1992. Low flow estimation in the United Kingdom. Institute of Hydrology Report No. 108.

Institute of Hydrology 1980. Low Flow Study Report.

Institute of Hydrology 1994. The 1988-92 Drought. Hydrological data series.

Natural Environment Research Council 1975. Flood Studies Report.

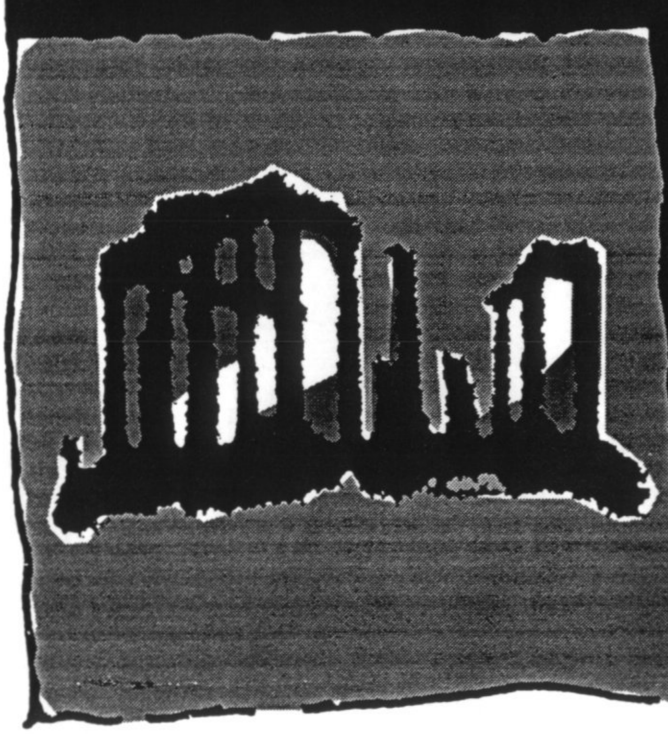
Sekulin, A.E., Bullock, A. & Gustard, A. 1992. Rapid calculation of catchment characteristics using an automated river network overlay technique. Water Resources Research Vol. 28, No. 8, pp. 2102-2109.

Wesselink, A., Hagemann, I., Demuth, S. & Gustard, A. 1994. Computer application of regional low flow study in Baden-Würtemburg, Germany. In: FRIEND Flow Regimes from International Experimental and Network Data. Proceedings of International Conference, Braunschweig Oct. 1993.

Young, A.R. 1992. Micro LOW FLOWS System V1.31., User and Technical Guides: Software Documentation.

Young, A.R., Irving, K.M., Rees, H.G. & Gustard, A. 1995. European Atlas of Small-Scale Hydropower Resources Phase II. UK Hydrological analyses and software. Final Report to ESHA.

SMALL hydro



ATHENS
16-18 NOVEMBER
1998

conference proceedings

SMALL HYDRO '98

Astir Palace Hotel
Athens, Greece

16-18 November 1998

Published by: International Water Power and Dam Construction
and Wilmington Publishing
Wilmington House
Church Hill
Wilmington
Dartford
Kent
DA2 7EF
United Kingdom
Tel: +44 (0)1322 277788
Fax: +44 (0)1322 276474
E-mail: conferences@wilmington.co.uk

Developing hydrological models in Spain for small-scale hydropower assessment

Authors: Mrs K.M Croker, Mr H.G Rees, Dr A Gustard

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

ABSTRACT

The European Small Hydropower Association (ESHA) is keen to promote investment in small-scale hydropower development across Europe. With funding from the ALTENER Committee of the European Union, ESHA commissioned the Institute of Hydrology (IH) to develop the European Atlas of Small-Scale Hydropower Resources. Referred to as HydrA, the Atlas is a menu-driven PC-based package that provides an automated procedure for assessing the feasibility of developing hydropower schemes in Europe. In particular, the software provides the capabilities to determine whether there is an adequate supply of water available for driving turbines, whether the resource can be sustained over a significant period of time and the generating capabilities of the turbines within the specified hydrological conditions.

The software is currently operational in the UK and Spain and a version of the software covering Italy will be available in 1998. This paper describes the development of the regional hydrological models in Spain for estimating flows at ungauged sites (i.e. where recorded flow data are not available) and the subsequent implementation of the models within the HydrA software.

1 INTRODUCTION

The feasibility of a small run-of-river hydropower scheme will depend on whether there is an adequate supply of water available to drive the turbines. A reliable method for determining the hydrological conditions at the proposed site is of critical importance. A generally accepted method for characterising the hydrological regime is to determine the cumulative frequency distribution of flows, expressed as a percentage of time that the specified flows are equalled or exceeded. The relationship is more commonly referred to as the flow duration curve and provides a graphical representation of the complete flow regime between low and high flows. The flow duration curve can be derived directly from time series of measured daily river flows. However, many sites that may be suitable for hydropower schemes are located in remote areas where flow measurements are limited or unavailable. Through an Altener funded (EU-DGXVII) project on behalf of the European Small Hydropower Association (ESHA), the Institute of Hydrology has developed a PC-based software package (named HydrA) which overcomes this problem. Through the development of regional low flow models, the software is able to provide an automated procedure for assessing the hydrological regime, thus allowing users to estimate both the hydrological and hydropower potential at any ungauged site. The overall estimation procedure for deriving the flow duration curve for an ungauged location considers the physical characteristics of the catchment to determine a synthetic flow duration curve. The method is summarised in Figure 1.1.

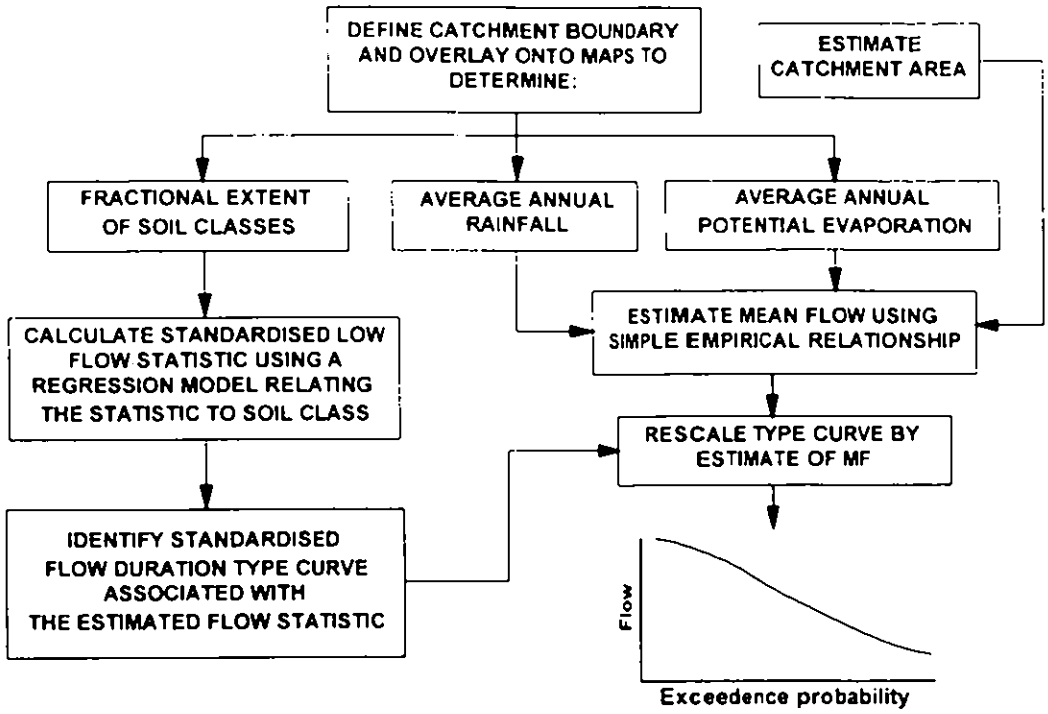


Figure 1.1 *Estimation of the flow duration curve at an ungauged location*

The regional low flow models make use of rainfall and evaporative losses, which are important in determining the mean available water resource. The fractional extent of soils within catchments are also considered, since they tend to reflect the hydrogeological characteristics which influence the distribution of flows through the year and the shape of the flow duration curve (Gustard *et al*, 1992, Boorman & Hollis, 1990). The rainfall and potential evaporation information is incorporated within the software in the form of grids with a cell resolution of 1km by 1km. The soil information is represented within the software by a grid of the standardised low flow statistic, derived through the regional modelling.

The principles of the estimation procedure can be applied to any country, although the source data and hydrological models will be different. In order to develop the software for a particular region, it is necessary to establish databases of the river flow data, gauging station information, catchment boundaries, catchment characteristic data (rainfall, temperature, potential evaporation etc) and undertake statistical analyses of the assembled data. This paper describes the development of the regional hydrological models from catchment data for Spain and the subsequent implementation of the models within the HydrA software.

2 ESTABLISHING THE SPANISH DATABASES

2.1 River flow database

A data set of gauged daily flow records for 198 catchments, provided by Spanish civil engineering consultants (INTECSA) in co-operation with the Centros de Estudios y Experimentaticíon de Obras Públicas (CEDEX), was available for use in the analysis. The catchments were initially selected on the following basis:

1. Catchment size of less than 2000 km^2, but greater than 5 km^2, in order to limit the impact of large variations in climate and artificial influence, while avoiding the possibility of introducing errors due to small catchments;

2. Daily flow records of 10 years or more to ensure that the flow statistics are representative of the long-term flow regime;

3. Minimal artificial influences to ensure that the flow regime is not affected by major abstractions, discharges, reservoirs and transfers between catchments;

The data were assessed further by IH in order to ensure that hydrological models were reliable and sufficiently representative of the environmental conditions. The selection of the 'usable' catchments was based on the following:

1. the hydrometric quality of the flow records: gauging stations should not be affected by weed growth, sluice gate operation etc and should have reliable stage-discharge relationships so that the flow regime is not distorted. Anomalies were identified through inspection of daily hydrographs, flow duration curves and double mass plots of flow. Grades A to C (A being good and C being poor quality data) were assigned to the gauging station data. Only stations which demonstrated serious anomalies, i.e. graded C overall were excluded;

2. comparison of quoted catchment rainfall with gauged flow data: catchments were excluded from the data set if the mean flow for the catchment (expressed in millimetres of annual runoff) exceeded the catchment rainfall. Catchments were also excluded from the data set where the losses (rainfall - runoff) were excessive.

Following these further quality control checks, a total of 144 stations remained available for use in the analysis.

2.2 Catchment boundaries

Catchment boundaries were drawn and digitised for each of the 198 selected catchments. The boundaries were used to derive climate and soil statistics for the catchments to be used within the analysis.

2.3 Climatic data

The Atlas Climatico de España (1983) contains maps of mean annual and monthly rainfall, average annual evaporation and other climate data at a scale of 1:3 million or 1:6 million scale. These maps were derived from data for the period 1931-1960 from 5000 measuring stations. The Institute of Hydrology digitised the annual average rainfall and annual average evaporation maps and generated 1km grids from the isoline maps.

Additional maps of standard period (1961-1990) average annual rainfall (SAAR) and monthly rainfall at 1:625,000 scale covering Spain were also provided by CEDEX in the form of 1 km^2 grids. These grids provided more up-to-date rainfall data than were provided in the Atlas and were therefore used for deriving catchment average rainfall totals for use in the analysis. The catchment average values of evaporation were derived using the 1km grids from the Atlas.

2.4 Soils data

Previous studies (for example, Boorman *et al*. 1994) have shown that the physical properties of soils are important in influencing the hydrological characteristics of a catchment by controlling the storage and transport of water. The Soil Map of the European Communities (CEC, 1985), based on the FAO/Unesco Soil Classification of the World (FAO, 1975), was used in the present study. Available as an ARC/INFO coverage, the maps were used to extract the fractional extent of different soil types in each catchment for use in the analysis.

3 DEVELOPMENT OF REGIONAL HYDROLOGICAL MODELS

The hydrological suitability of a proposed site for a small hydropower scheme is dependent upon whether there is an adequate supply of water available to drive the turbines and whether the resource can be sustained over a significant period of time. Where no gauged flow data are available, the flow duration curve needs to be derived from hydrological models. This Section describes the development of the regional hydrological models for Spain.

3.1 Estimation of the flow duration curve

The flow duration curve represents the cumulative frequency distribution of flows over the whole flow range. The shape of the standardised flow duration curve (i.e. where flows are expressed as a percentage of the mean flow) is principally controlled by the hydrogeology of the catchment. The response can be characterised by a low flow statistic, which in Spain is the standardised Q90, the flow equalled or exceeded for 90 percent of the time. The analysis focuses on defining a relationship between the Q90 and soils.

Spain can be separated into two hydrologically homogeneous regions: the northern, mountain region (the Green Iberia) and the central and southern region (the Grey Iberia). As a result, two models were developed, one for each of these regions. A total of 29 soils are represented in Spain, however only 19 soils are represented within the gauged catchments used in the study. The proportional extent of soils in Spain is given in Table 3.1.

Stepwise regression analysis was undertaken in order to identify the individual soil types which were the most significant in each region. This identified that only five soil units (common to both regions) were significant. These five units account for 60% of the total area in Spain. The relationship between the Q90 and these soil units is given in Equation 1 and the corresponding parameter estimates for the significant soils are given in Table 3.2.

$$Q90 = a \,.\, U + b \,.\, Bh + c \,.\, Id + d \,.\, (Bq + Bm) \qquad \text{(Equation 1)}$$

Where

a-d are the parameter estimates for the soil types
U, Bh etc represent the fractional extent of the soil types within the catchments

Table 3.1 *Proportional extent of soils in Spain*

	Percentage area					Percentage area			
Soil	Nationally	Within gauged catchments			Soil	Nationally	Within gauged catchments		
		Whole	Green	Grey			Whole	Green	Grey
-4	0.56	0.10	0.12	0.90					
Bd	4.39	1.68	0.12	3 40	Od	0.07	0.12	0.22	0.00
Be	12.36	1.84	0.00	3.86	Phf	0.22	0.57	1.10	0.00
Bg	5.16	3.84	0.75	7.24	Qc	0.46	0.01	0.00	0.02
Bh	10.32	32.69	39.40	25.32	Ql	0.40	0.00	0.00	0.00
Bk	39.11	34.13	31.01	37.57	To	0.03	0.28	0.00	0.58
Ic	0.30	0.39	0.70	0.05	U	4.59	11.16	18.83	2.72
Id	1.39	4.82	4.52	5.16	Vc	1.35	0.89	0.19	1.67
Ie	0.65	0.00	0.00	0.00	Vp	0.68	0.00	0.00	0.00
Je	5.70	3.60	1.35	6.08	Wd	1.52	0.32	0.00	0.68
Jeg	0.06	0.00	0.00	0.00	We	0.26	0.00	0.00	0.00
Lcr	1.89	0.90	1.71	0.00	Xk	2.72	0.00	0.00	0.00
Lga	0.01	0.00	0.00	0.00	Xy	1.26	0.00	0.00	0.00
Lkc	2.32	0.28	0.00	0.60	Zg	0.32	0.00	0.00	0.00
Lo	0.03	0.00	0.00	0.00					
Lv	1.89	2.37	0.00	4 98					

Table 3.2 *Parameter estimates for the significant soils*

	Green Iberia			Grey Iberia	
Soil	Parameter	Error	Soil	Parameter	Error
U	19.14	2.98	U	10.59	11.43
Bh	17.86	2.30	Bh	8.84	3.17
Id	47.26	5.946	Id	2.99	6.37
Bg + Bk	13.73	2.14	Bg + Bk	21.62	2.07
R^2	35.50		R^2	29.56	
rmse	7.66		rmse	10.71	

Once the low flow statistic has been determined, the flow duration curve can be defined. By grouping together flow duration curves derived for catchments with similar geological characteristics, a family of flow duration curves can be derived. Flow duration curves derived from gauged data for the Spanish catchments were grouped together based on Q90 and a mean (pooled) flow duration curve for each group was calculated. From the pooled curves a set of smooth type curves were derived by interpolating between the pooled curves such that the logarithm of Q90 was equally spaced, illustrated in Figure 3.1.

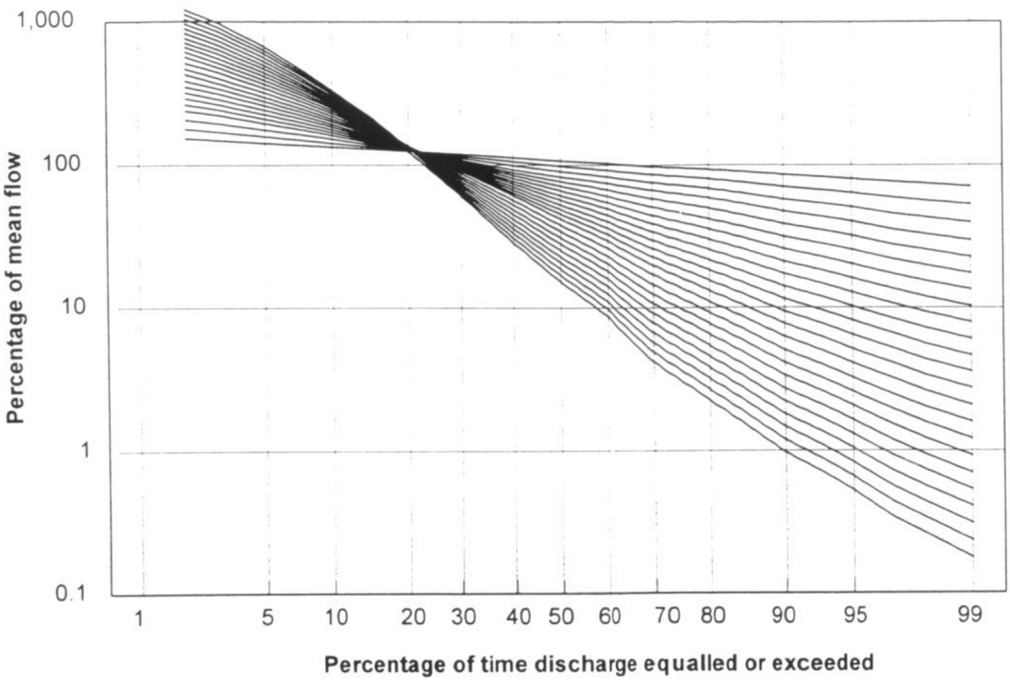


Figure 3.1 *Flow duration type curves for Spain*

3.2 Estimation of the mean flow in Spain

The runoff from a catchment is a function of the rainfall (input) and evaporation (output) across the catchment. A number of different approaches for estimating the runoff for a catchment using rainfall and potential evaporation have been considered in order to identify which is the most appropriate for estimating the runoff (and hence mean flow) in Spain. These include the Budyko equation, the Turc-Pike equation, direct regression models and the water balance approach.

Conceptually, the water balance model is the simplest model in which the runoff is the difference between the standard annual average rainfall (SAAR) and the losses (or actual evaporation - AE) to the catchment i.e.

Runoff = SAAR – Losses (Equation 2a)

where

Losses = r . PE (Equation 2b)

Gustard *et al.* (1980 and 1992) suggested that the value of r was dependent upon the rainfall i.e. that as the water availability increased, the amount of water available for evaporation was increased as soil moisture deficits were replenished. When the rainfall reaches a certain point, the soil moisture deficits are satisfied and the losses (or actual evaporation) will be equal to the potential evaporation i.e. r equals one. It possible to derive values of r for each gauging station by substituting Equation 2a into Equation 2b and re-arranging the equation. Regression analysis was then undertaken to determine a linear relationship between r and rainfall for Spain, given by:

r = 0.00003. Rainfall + 0.55 (Equation 2c)

A second approach defined a regression model to estimate the mean flow directly from the rainfall and potential evaporation data and catchment area:

$$MF = 7.98 \times 10^{-4} \times SAAR^{2.074} \times PE^{-1.607} \times Area^{0.869} \qquad \text{(Equation 3)}$$

Budyko (referenced in Estrela *et al* 1995) developed an equation for estimating runoff within regions in the USSR, given by:

$$\text{Runoff} = SAAR \cdot e^{(-PE/SAAR)} \qquad \text{(Equation 4a)}$$

Since this equation was developed using catchments in the USSR, it cannot be assumed to represent the flow regime in Spain. Therefore, the fit of the model was optimised against the observed runoff for the Spanish gauging stations. The optimised Budyko model for Spain is now given by

$$\text{Runoff} = SAAR \cdot e^{(-0.79\,PE/SAAR)} \qquad \text{(Equation 4b)}$$

The Turc-Pike (1954, referenced in Dooge, 1989) equation is used for estimating actual evaporation that can then be incorporated into a water balance model to derive runoff:

$$\text{Runoff} = SAAR - \frac{SAAR}{\sqrt{\left[1 + \left(\frac{SAAR}{PE}\right)^2\right]}} \qquad \text{(Equation 5)}$$

A comparison of the performance of the different models was undertaken by looking at the relationship between the observed and predicted flows. The errors associated with the models can be expressed in terms of a bias between the predicted and observed runoff where the bias is calculated for each station using Equation 6. The results of the analysis are summarised in Table 3.3.

$$\text{Bias} = \frac{\text{Predicted Runoff}}{\text{Observed Runoff}} \times 100\% \qquad \text{(Equation 6)}$$

Table 3.3 *Estimated bias for each of the runoff models*

	N	Mean Bias	S.D of Bias	Predicted against Observed Runoff R^2	Predicted against Observed Runoff f.s.e
Regression	144	104.89	33.55	79.46	1.36
Water Balance	144	107.98	37.42	80.62	1.39
Calibrated Budyko	144	103.57	38.88	80.85	1.38
Calibrated Turc-Pike	144	118.68	44.78	85.46	1.38

From Table 3.3, all the models show a tendency to over-predict the runoff (mean bias > 100%). With the exception of the Turc-Pike model, the mean of the predicted runoff values is within 10% of the observed runoff values. The explained variance and factorial standard errors are also very close for each of these models. Therefore, the behaviour of the models was investigated to identify how well these reflected the observed data. Based on the response of the models and the results from Table 3.3, it was identified that the Budyko equation (Equation 4b) was the most appropriate model for calculating the runoff in Spain. The relationship between observed and predicted flows is illustrated in Figure 3.2 and the distribution of runoff across Spain is illustrated in Figure 3.3.

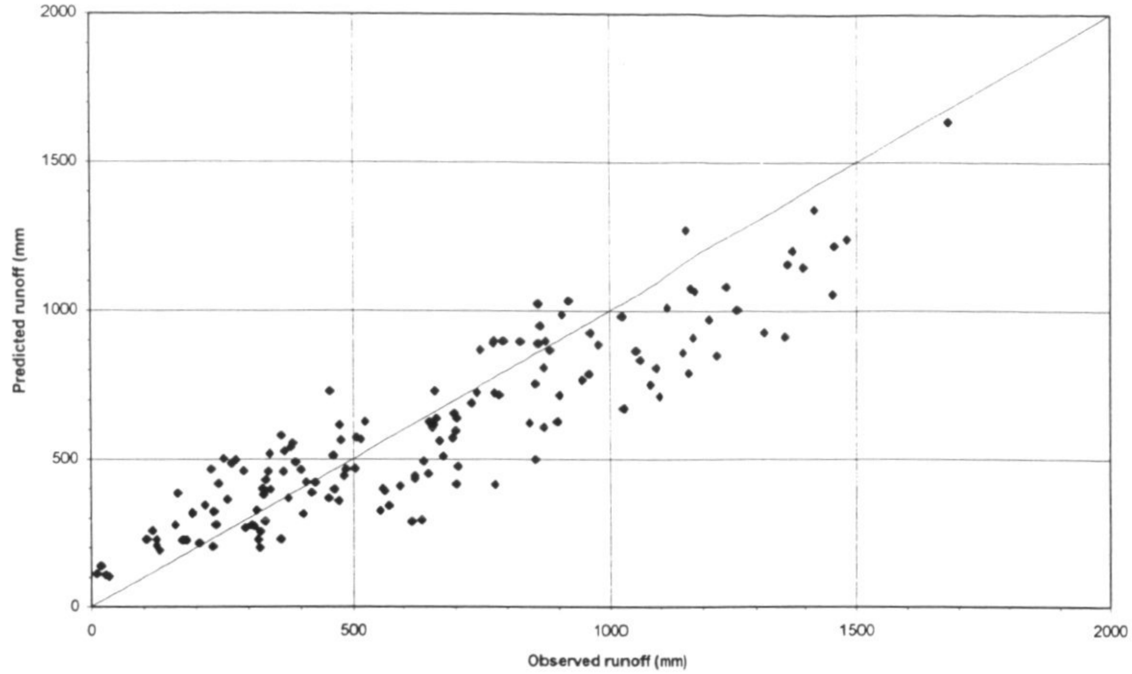


Figure 3.2 *Predicted against observed runoff using the optimised Budyko equation*

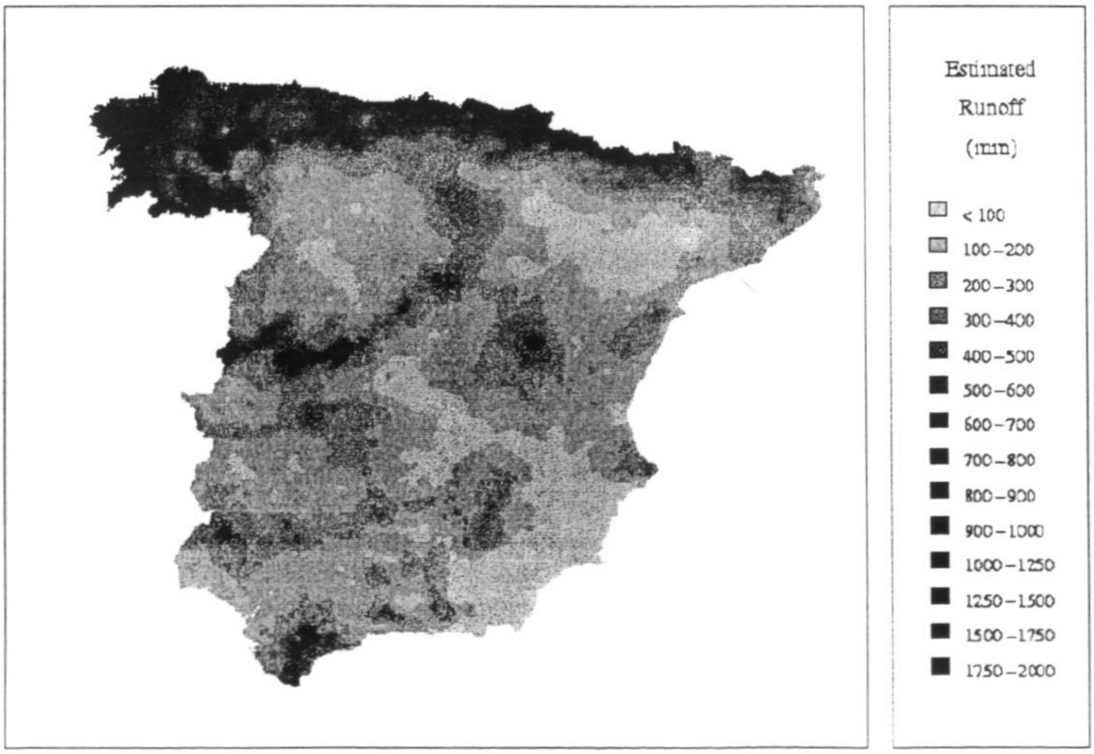


Figure 3.3 *Spatial distribution of runoff in Spain*

The spatial distribution of the errors identified that the model over-predicts the runoff in areas where rainfall is less than 1000 mm but performs better in the mountain regions of Northern Spain where the predicted runoff is within 10% of the observed runoff for many catchments. In order to calculate the mean flow in cubic metres per second (m^3s^{-1}), the runoff, expressed in millimetres per year over the catchment, needs to be converted using the equation:

$$MF = Runoff \, . \, Area \, . \frac{1000}{60.60.24.365} \qquad \text{(Equation 7)}$$

4 SOFTWARE IMPLEMENTATION OF DESIGN METHODS

The previous Sections have shown how the regional low flow models make use of the hydrological properties of soils to calculate the low flow statistic from which to determine the flow duration curve and the rainfall and evaporative losses to determine the mean flow at an ungauged location. In order to apply these models automatically, the input data and calculation algorithms have been incorporated into the HydrA software.

The rainfall and potential evaporation maps are incorporated within the software as grids at a cell resolution of 1km by 1km, referenced in Universal Transverse Mercator (UTM) co-ordinate system. With the UTM system, the globe is divided into 60 zones, each spanning six degrees of longitude. Spain spans three UTM zones (29, 30 and 31), therefore, the rainfall and potential evaporation grids have been projected in the three zones and are stored separately within the software. The grids overlap each other, which enables catchments with boundaries that cross from one UTM zone to another to be defined relative to a single UTM zone only.

The soil coverage was converted to a grid with a cell resolution of 1km x 1km. By applying Equation 1 and the parameter estimates given in Table 3.2 to each cell of the soil grid, a grid of Q90 was derived for the Green and Grey Iberia. These grids were combined to provide coverage for the whole of the country. In common with the rainfall and evaporation grids, the grid was projected to each of the three UTM zones and archived separately within the software.

To access this information, the user simply needs to enter the UTM co-ordinates defining the catchment boundary upstream of the site on the river being considered. HydrA overlays the boundary onto the grids to determine catchment average estimates of rainfall, potential evaporation and Q90. An example of the calculation of average rainfall for a catchment in Spain is illustrated in Figure 4.1.

Within the software the flow duration type curves are stored as an array of seventeen co-ordinate pairs. Using the estimated catchment average Q90 the appropriate type curve(s) can be identified from the array. If the Q90 does not correspond exactly to a single type curve, then the two adjacent curves are selected. The synthetic flow duration curve for the site is then generated by interpolating between these two curves, so that it passes through the correct Q90 value. The flow values from this curve are expressed as a percentage of the mean flow. By inserting the derived values of catchment rainfall, potential evaporation into Equation 4b and then inserting the derived runoff and area into Equation 7, the mean flow for the catchment can be calculated. This is used to re-scale the selected flow duration curve to cubic metres per second.

The purpose of deriving the flow duration curve is to be able to assess whether the selected location is suitable for hydropower generation. Therefore, the selected flow duration curve is analysed using conventional techniques to determine the volume of water available for hydropower generation as illustrated in Figure 4.2. Standard equations and turbine information are incorporated within the software for deriving the hydropower potential of the site.

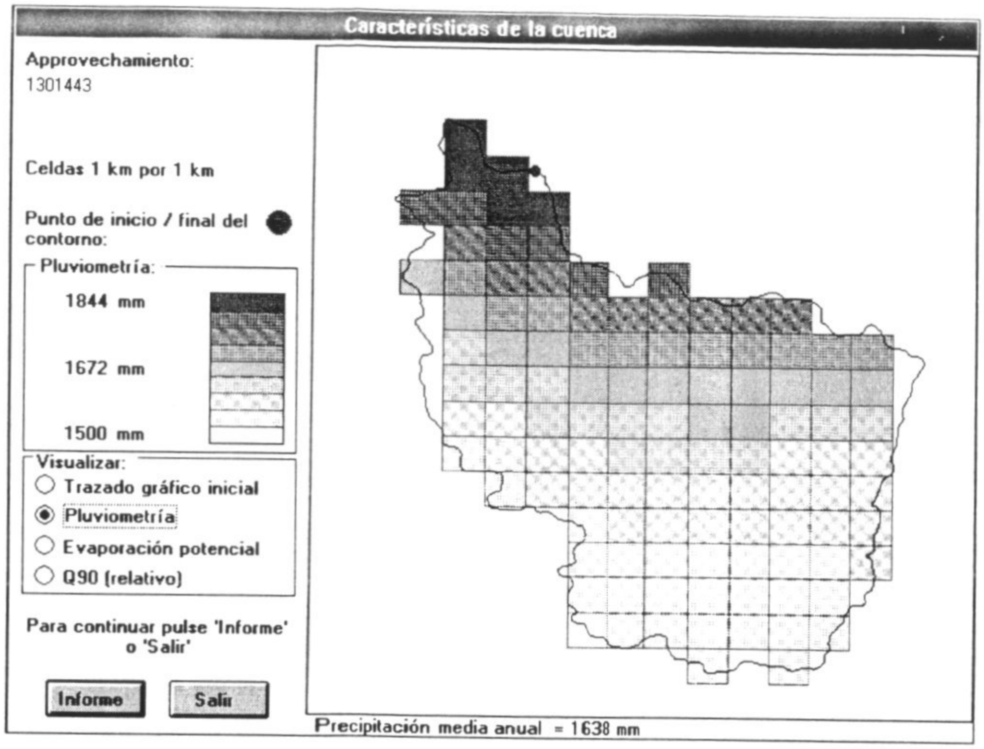


Figure 4.1 *Estimation of catchment average rainfall*

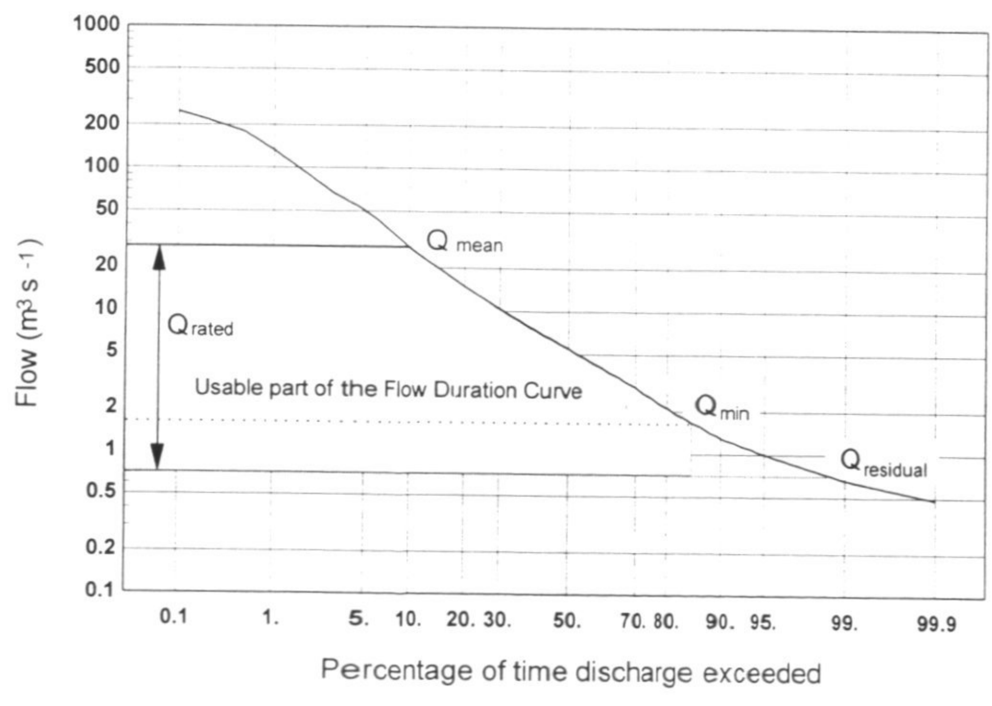


Figure 4.2 *Defining the usable part of the flow duration curve*

5 CONCLUSIONS

HydrA has been developed by the Institute of Hydrology as a tool for automatically assessing the feasibility of hydropower schemes in Europe. The software has already been completed for the UK, Spain and Italy through the development of regional hydrological models for determining the flow regime at ungauged locations in each country. In Spain, databases of river flow data, gauging station information, catchment boundaries, climate (rainfall and potential evaporation) and soils were collated and used as the basis for the statistical analysis to determine relationships between flow statistics and catchment characteristics.

The method for deriving the flow duration curve in Spain is based on the selection of the relevant curve from a family of typical flow duration curves, which is dependent upon the magnitude of the Q90. The relationship between Q90 and soils was determined. Although there are 28 different soil units in Spain, only five of them were found to provide a significant contribution to the low flow regime. The distribution of soils indicated two distinct regions, therefore separate models were derived for each region, thus providing better estimates of Q90 in each region compared to a single model for the whole of the country.

Four methods of estimating runoff were considered in Spain, but the calibrated Budyko equation was identified as being the most appropriate. The model performs well over the whole of Spain, with a mean bias (i.e. the ratio of predicted to observed runoff) of 104%, and in particular, in the mountain regions of the north east where hydropower schemes are more likely to be located.

As with any model, the results of the analysis in Spain are limited by the quality of the input data. Improvements could potentially be made with longer time series data from a greater number of gauging stations. In addition, the analysis would have benefited from more detailed data relating to the climate and hydrogeology of Spain. However, such 'ideal' data were not available and the models were developed based on the best available data that could be collated at the time. In spite of these limitations, the regional flow estimation methods described in this paper represent a significant advance by providing rapid method of deriving tangible estimates of the flow conditions at ungauged sites anywhere in Spain. Therefore, as a feasibility tool, HydrA would be invaluable.

ACKNOWLEDGEMENTS

The European Atlas of Small-Scale Hydropower Resources has been developed on behalf of the European Small Hydropower Association (ESHA) by the Institute of Hydrology with funding from the European Union (DGXVII) ALTENER Programme.

The authors acknowledge the contribution made by Dr Eric Wilson (Wilson Energy Associates Ltd, UK) in the overall management of the project and Dr Celso Penche who undertook the testing of the software and provided the translation of the HydrA User Manual, software dialogue boxes and publicity brochures in Spanish. The databases and hydrological analysis were based on historical time-series data of gauged flows, catchment characteristic information and climate maps provided by Dr J. Xieménez de Embún (INTECSA, Spain) and also additional precipitation maps made available by Dr Teodoro Estrela (CEDEX, Spain). The development of software modules was undertaken by Mr Michael Allchin.

REFERENCES

Atlas Climatico de España 1983. Madrid Ministerio de Transportes. Turismo y Communicaciones.

Boorman, D. B. and Hollis, J.M. 1990. Hydrology of soil types. A hydrologically-based classification of the soils of England and Wales. MAFF conference of river and coastal engineering. Loughborough University, UK.

Boorman D.B., Gannon, B., Gustard, A., Hollis, J.M. and Lilley, A. 1994. Hydrological aspects of the HOST classification of soils. Report to MAFF.

CEC.1985. Soil map of the European Communities. 1:1 million. CEC-DGVI. Luxembourg

Estrela, T., Ferrer, M. & Ardiles, L. 1995. Estimation of preciptation-runoff regional laws and runoff maps in Spain using a geographical information system. Proceedings of FRIEND AMHY Conference. Thessalonika.

Dooge. J.C.I. 1989. The role of the hydrological cycle in climate. In Berger *et al* (Eds). Climate and Geo-Sciences, 335-366. Kluwer Academic Press.

ESHA, 1994. Layman's Guidebook on how to develop a small hydro site. Commission of the European Communities, Directorate General for Energy (DG-XVII).

FAO-UNESCO. 1975. Soil map of the world at 1:500 000. Volume I. Legend. Unesco. Paris.

Gustard, A., Bullock, A. and Dixon, J.M. 1992. Low estimation in the United Kingdom. Institute of Hydrology Report Number 108.

Institute of Hydrology 1980. Low Flow Studies.

PROCEEDINGS

INTERNATIONAL SYMPOSIUM

HYDROLOGY OF UNGAUGED STREAMS IN HILLY REGIONS FOR SMALL HYDRO POWER DEVELOPMENT

March 9-10, 1998

New Delhi

Organised By

Alternate Hydro Energy Centre
University of Roorkee, Roorkee - 247667
INDIA

Sponsored By

INDIA REPSO

Renewable Energy Project Support Office
(REPSO)
WINROCK INTERNATIONAL
New Delhi

International Symposium of 'Hydrology of Ungauged Streams in Hilly Regions for Small Hydro Power Development' March 9-10' 1998. New Delhi. INDIA

Developing regional design techniques for estimating hydropower potential

Dr A Gustard, Ms K Croker, Mr G Rees
Institute of Hydrology, Maclean Building, Crowmarsh Gifford, Wallingford, Oxon OX10 8BB, UK

ABSTRACT

The assessment of hydropower generation potential of a site requires a knowledge of the distribution of flows in the river and the relationship between the flows and the generating capacity of turbines. This paper describes the development of regional hydrological models which can be used to estimate flows at sites where recorded data is not available and summarises techniques for hydropower estimation. The approach is illustrated using a case study based on analysis of data from the UK for incorporation into hydropower design software called HydrA. The technique has been developed in other European countries and the feasibility of developing the method in India and Nepal is being evaluated.

INTRODUCTION

A key aspect of assessing the hydropower potential of a proposed small hydropower scheme is to determine whether there is a sufficient discharge in the river to drive the generating turbines. The most appropriate analysis for this task is to derive the flow duration curve - a graph which plots the discharge against the percentage of time that the discharge is exceeded. Where long records of measured river flows are available at the design site then these provide data from which the flow duration curve can be derived. However, there are a large number of ungauged sites where there is a need to estimate the flow duration curve from the characteristics of the upstream catchment area. This paper describes the result of a hydrological study which has developed a technique for estimating the flow duration curve for use in hydropower design. Rees *et al.* (1998) describes the software components which enable the design engineer to use this technique to estimate the power potential of an ungauged site.

The overall objectives of the project have been to:

1. Establish databases of river flow data, gauging station information, catchment characteristic data for countries in Europe.

2. Develop methods for estimating the flow duration curve for ungauged catchments within the UK, Spain and Italy.

3. Identify current engineering methods for estimating hydropower generation potential;

4. Develop software to implement these methods for ungauged locations.

This paper presents an overview of objectives 1 and 2 illustrated by reference to database development and estimation procedures developed in the UK.

HISTORICAL BACKGROUND

The development of hydrological design methods (Gustard *et al.*, 1992) in the UK, identified that the spatial variability of low flows (expressed as a percentage of the long-term mean flow) are controlled primarily by the physical properties of the soils and the geology of the catchment. These characteristics have been grouped into 29 HOST (Hydrology of Soil Types) classes following a major study of UK soils and their hydrological response (Boorman *et al.*, 1991). Relationships were developed between low flow response and HOST classes at gauged sites which can be applied at ungauged sites using the HOST data base.

These methods have been developed into a PC software package, Micro LOW FLOWS (Young, 1992, Sekulin *et al.*, 1992), which has been widely adopted as a water resources evaluation and planning tool by the UK water industry. The methods have also been applied within the Baden-Württemburg area (Wesselink *et al.*, 1994) of Germany in the development of a regional version of the Micro LOW FLOWS software package.

THE UK DATABASES

The river flow database

Gauged flow data up to the end of 1992 from the UK National River Flow Archive (held by the Institute of Hydrology) with good quality data and relatively natural river flows were used in the study. The principal artificial influences which affect the flow regime include surface water and groundwater abstractions, surface water discharges and impounding reservoir structures. Flow records which were significantly influenced by these factors were removed from the database leaving a data set of 727 daily flow records.

The UK HOST hydrological response classification

The physical properties of soils are very important in influencing the hydrological characteristics of a catchment by controlling the storage and transmission of water (Boorman *et al.*, 1994). The soil associations of England and Wales have been mapped at a scale of 1:250 000 by the Soil Survey and Land Research Centre (SSLRC) and those in Scotland by the Macaulay Land Use Research Institute (MLURI). A collaborative project between the Institute of Hydrology, SSLRC, MLURI and the Department of Agriculture in Northern Ireland categorised the soils into 29 discrete groups. Each group had different physical properties and a distinct hydrological response. The classification system is referred to as the Hydrology Of Soil Types (HOST) classification (Boorman & Hollis, 1990 and Boorman *et al.*, 1991).

The HOST project has finalised a national database containing the proportions of each HOST class in every 1 km^2 grid cell within the UK. The proportion of each of the 29 HOST classes within 727 gauged catchments in the UK was derived by overlaying digital topographic catchment boundaries over the HOST grid using ARC INFO.

Climatic data

As a consequence of the temperate maritime climate of the UK, it has been found that long term average annual climate data are sufficient to characterise climatic variations across the UK (Institute of Hydrology, 1980 & Gustard *et al.*, 1992). Maps of standard period (1941-1970) average annual rainfall (SAAR) at 1:625 000 scale covering the UK are available from the Meteorological Office and were published in the Flood Studies Report (NERC, 1975). The maps were digitised at the Institute of Hydrology and a 1 km^2 grid was derived from the digitised isohyetal data. The grid stores precipitation data to a resolution of 1 mm.

Potential evaporation is estimated from the Meteorological Office 1:2 000 000 map (provisional version) of average annual potential evaporation which is based on the Penman equation with a surface albedo of 0.25. The map has been digitised at the Institute of Hydrology and a 1 km^2 grid derived using a polynomial fitting method. Although the data are held to a resolution of 1 mm the error in estimating PE from the map is of the order of 25 mm.

THE HYDROLOGICAL ESTIMATION METHODOLOGY

The 95 percentile low flow

In the UK Q95 (the flow exceeded 95% of the time, expressed as a percentage of the long term mean flow) has been used as a key low flow statistic in regional hydrology (IH 1980 & Gustard *et al.*, 1992). Linear least square multiple regression analysis has been used to relate the Q95 (estimated from flow records from 727 gauging stations in the UK) to the Hydrology of Soil Type (HOST) classification. The relationship between Q95 and HOST within a catchment can be described by a linear relationship of the form:

$$Q95 = a + b \, . \, HOST1 + ... + x \, . \, HOST29 + y \, . \, HOST97 + z \, . \, HOST98 \qquad (4)$$

Where: HOST1-29 represent the proportional extent of the 29 HOST classes
HOST97 represents the proportional extent of urban areas
HOST98 represents the proportional extent of lakes within the catchment

The results of this analysis indicated that the model explained 54% of the variance of the standardised Q95 with a factorial standard error of 7.6% of the mean flow. Negative parameter estimates and high standard errors reflected HOST classes which are not well represented. These HOST classes account for a mean coverage of less than 1% of the soils and generally less than 30% coverage at their maximum occurrence within gauged catchments. The HOST classes were grouped into 12 low flow response units based on similar physical characteristics, in order to improve both the sample size and proportional representation within the catchments of the HOST classes. The parameter estimates of the model are presented in Table 1. Grouping the HOST classes does not significantly improve the explanation of variance of the overall model but the factorial standard errors associated with the individual parameter estimates are reduced compared with the full HOST data set and no negative parameter estimates have been calculated. The revised Q95 regression model has been applied to the UK HOST grid to estimate the Q95 flow for 1 km^2 grid squares throughout the UK, illustrated in Figure 1.

Table 1 Q95 estimates for Low Flow HOST Groups

Low Flow HOST Group	Q95 Parameter	s.e of parameter
LFHG1	38.10	1.7
LFHG2	29.18	2.5
LFHG3	58.06	2.8
LFHG4	27.63	3.1
LFHG5	41.13	5.2
LFHG6	12.07	5.0
LFHG7	9.69	0.8
LFHG8	1.95	1.9
LFHG9	15.73	2.3
LFHG10	6.08	1.5
LFHG11	15.25	2.4
LFHG12	62.31	27.5

Flow duration curves

The gradient of the flow duration curve represents the variance of daily flows and in the UK can be estimated from the value of the standardised Q95 flow. (Steep flow duration curves have low values of Q95). Flow duration type curves (Figure 2) were derived by calculating all 727 flow duration curves (expressed as a percentage of mean flow) from the gauged flow data and pooling them into 16 classes based on the value of standardised Q95. The family of type curves were derived by smoothing the pooled flow duration curves and interpolating between them such that 20 curves were generated which were equally spaced at the Q95 value using gauged flow data. The appropriate flow duration type curve can be estimated at the ungauged site from the value of the estimated Q95 (Figure 1).

Mean flow

The final step in the estimation method is to determine the mean flow in $m^3 s^{-1}$ to scale the flow duration curve. The mean flow is calculated using a catchment water balance where the long term average annual runoff is the difference between average annual rainfall (SAAR) and actual evaporation (AE).

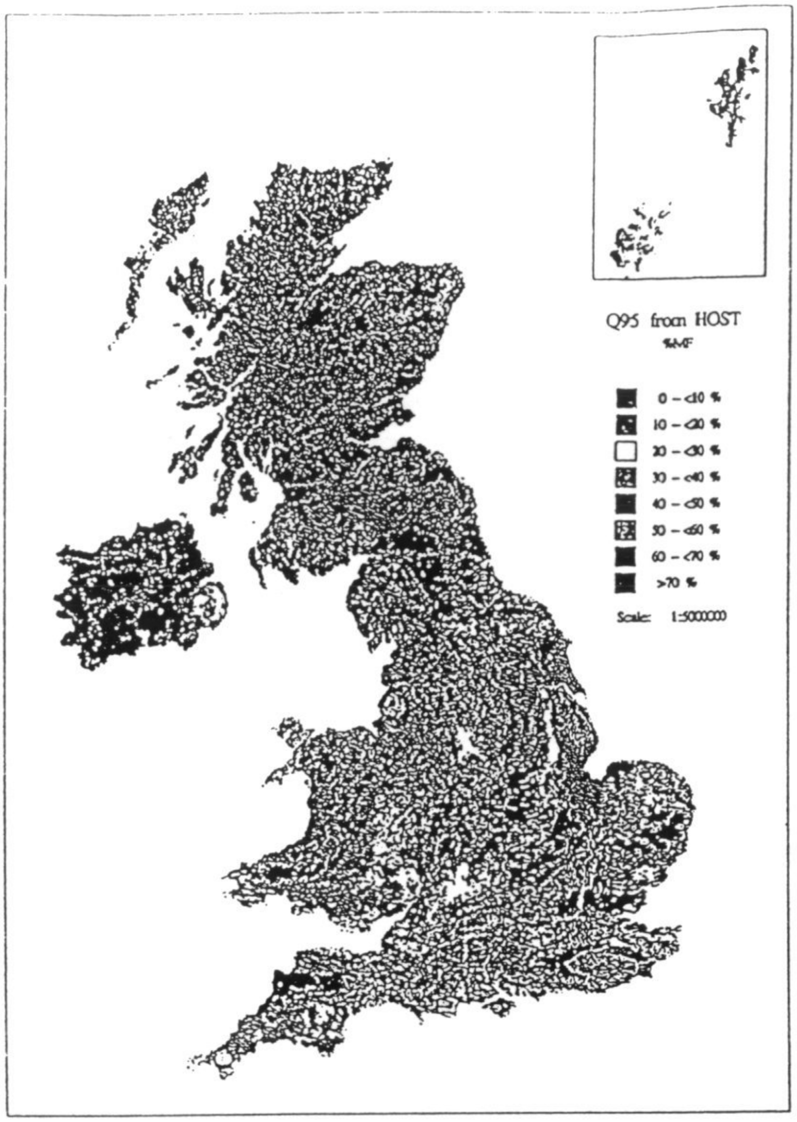


Figure 1 Distribution of Q95 in the UK

Catchment values of SAAR and potential evaporation are estimated from the UK Meterological Office maps (discussed previously). Actual evaporation is estimated from potential evaporation using a scaling factor (r) where r is a function of catchment rainfall. The value of r increases with SAAR and hence increasing water availability. For catchments with annual average rainfall in excess of 850 mm yr^{-1}, it is assumed that actual evaporation is equal to the potential evaporation as a result of relatively short periods when evaporation is limited by soil moisture deficit. This relationship between r and SAAR, calibrated on the flow records from high quality gauging stations, is given by:

$$r = (0.00061 \times SAAR) + 0.475 \qquad \text{for } SAAR < 850 \text{ mm} \tag{1}$$
$$r = 1.0 \qquad \text{for } SAAR \geq 850 \text{ mm}$$

and actual evaporation is calculated using:

$$AE = r \times PE \tag{2}$$

The average annual runoff depth (AARD in millimetres) over the catchment is calculated from the difference between SAAR and AE and is converted to mean flow in m^3s^{-1} using the topographic catchment area.

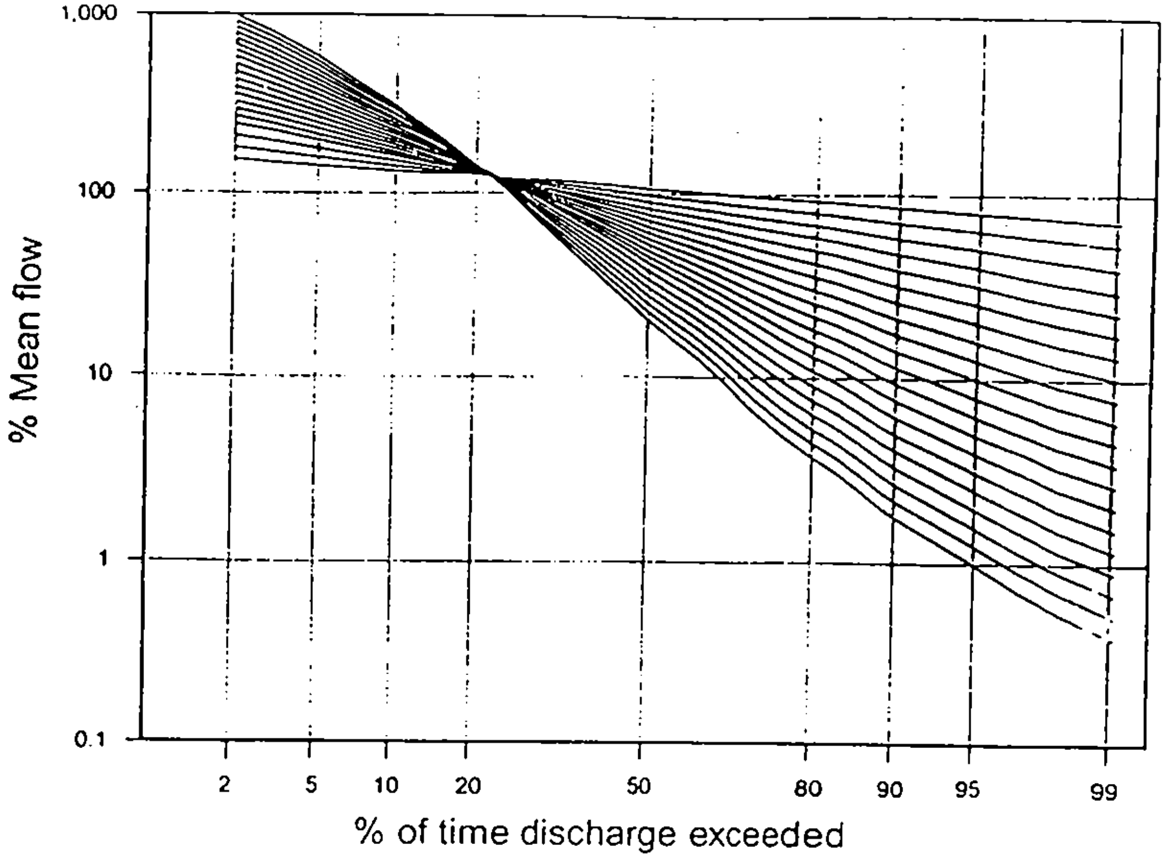


Figure 2 Flow duration type curves

SOFTWARE IMPLEMENTATION OF DESIGN PROCEDURES

The above design procedures, plus standard equations for calculating the generating power of turbines, have been incorporated into a public domain software application called HydrA which has been developed as a tool to assist in the assessment of hydropower potential at ungauged sites in Europe (Rees *et al.*, 1998). The software has been designed such that users with little or no hydrological knowledge and limited experience of hydropower design are able to make estimates of catchment characteristics, flow profiles and turbine information. In order to achieve this, the software stores the grids of standard period rainfall and potential evaporation, the derived Q95 grid for the UK, the standard flow duration curves and a set of efficiency and operating specifications for standard turbines.

The software operates within a Microsoft Windows™ environment and allows the user to:

1. Define a catchment boundary for the site of interest, either read from a file or entered interactively through an editor;

2. Estimate the key catchment characteristics, including area, mean flow, Q95, average rainfall and potential evaporation using the geographical databases (Figure 3);

3. Use the estimated Q95 and mean flow values to identify and plot the appropriate flow duration curve for the site;

4. Use the flow duration curve to identify a suitable flow range within which common turbine types will operate then calculate the power output for these conditions. This is done using standard design procedures and default turbine operational data.

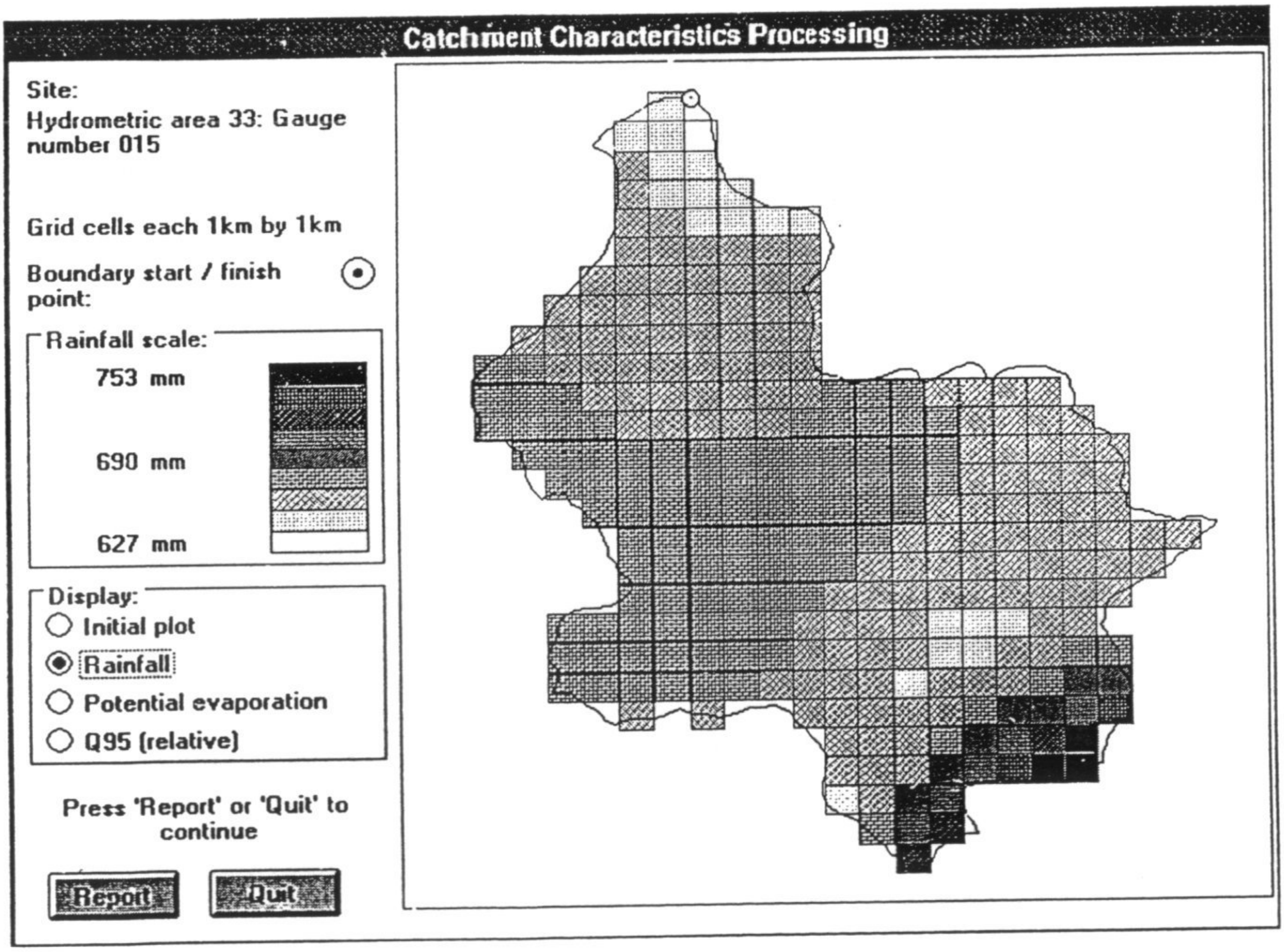


Figure 3 Catchment characteristic estimation

CONCLUSIONS

Methods have been described for the estimation of low flow statistics in the UK based on the relationship between the Q95 statistic and the HOST classification. An estimation procedure for Spain and Italy has been developed based on similar principles to relate soil classes (from a CEC map of the soils of the European Union) to a low flow statistic calculated using data from Spanish and Italian gauging stations. The methodology is generic but requires adaption to the hydrological regimes of particular regions and the main physical controls on the hydrological response. For example, in Spain where Q95 is frequently zero, the 90 percentile from the flow duration curve was used as the key variable and the greater climatic influence on low flows was accommodated by dividing Spain into two climatic regions. The design procedure is now being extended to Austria, Belgium, Ireland and Portugal in Europe and its feasibility is being evaluated in Himachel Pradesh in India and in Nepal.

ACKNOWLEDGEMENTS

The European Atlas of Small-Scale Hydropower Resources has been developed on behalf of the European Small Hydropower Association (ESHA) by the Institute of Hydrology with funding from the European Union (DGXVII) ALTENER Programme. The overall management of the project has been undertaken by Professor Eric Wilson (Wilson Energy Associates Ltd, UK). Historical time-series data of gauged flows, catchment characteristic information and climate maps were provided by Dr J. Xieménez de Embún (INTECSA, Spain), Dr Teodoro Estrela (CEDEX, Spain) and Professor Virgilio Anselmo (Verdeacqua, Italy). The feasibility study is being funded by the UK Department for International Development to evaluate the potential for developing the method in Hindu Kush region of the Himalayas. This work is being carried out by the Institute of Hydrology, Alternate Hydropower Energy Centre and Roorkee, The International Centre for Integrated Mountain Development, ICIMOD and the Department of Hydrology and Meteorology in Nepal.

REFERENCES

Boorman, D.B. & Hollis, J.M. 1990. Hydrology of Soil Types. A hydrologically-based classification of the soils of England and Wales. MAFF Conference of river and coastal engineers, Loughborough University.

Boorman, D.B., Hollis, J.M. & Lilley, A. 1991. The production of the Hydrology of Soil Types (HOST) data set. BHS Third Symposium. Southampton 6.17-6.13.

Boorman, D.B., Gannon, B., Gustard, A., Hollis, J.M. & Lilley, A. 1994. Hydrological aspects of the HOST classification of soils. Report to MAFF.

Gustard, A., Bullock, A. & Dixon, J.M. 1992. Low flow estimation in the United Kingdom. Institute of Hydrology Report No. 108.

Institute of Hydrology 1980. Low Flow Study Report.

Natural Environment Research Council 1975. Flood Studies Report.

Rees R.G. & Croker, K.M. (1998) Software for small scale hydropower estimation.

Sekulin, A.E., Bullock, A. & Gustard, A. 1992. Rapid calculation of catchment characteristics using an automated river network overlay technique. Water Resources Research Vol. 28, No. 8, pp. 2102-2109.

Wesselink, A., Hagemann, I., Demuth, S. & Gustard, A. 1994. Computer application of regional low flow study in Baden-Würtemburg, Germany. In: FRIEND Flow Regimes from International Experimental and Network Data. Proceedings of International Conference, Braunschweig Oct. 1993.

Young, A.R. 1992. Micro LOW FLOWS System V1.31., User and Technical Guides: Software Documentation.

International Symposium of 'Hydrology of Ungauged Streams in Hilly Regions for Small Hydro Power Development' March 9-10' 1998, New Delhi, INDIA

Software for small-scale hydropower estimation

Gwyn Rees and Karen Croker

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

Abstract

Determining whether there is a sufficient supply of water is essential when evaluating a proposed hydropower site. A common approach for assessing water availability is by deriving a flow duration curve for the site. Where long-term river flow data are available, the flow duration curve can be obtained directly from observed records. However, most potential sites have no flow data and methods for deriving a synthetic flow duration curve must be used. This paper describes a software package which allows the user to rapidly derive the flow duration curve and, hence, the hydropower potential at any location in Spain or the United Kingdom. While the software is country-specific, it is designed in such a way that it could be applied in any country.

1. Introduction

With the aim of reducing carbon and sulphur emissions from fossil fuels, the European Union (EU) is actively encouraging the uptake of renewable energy sources such as small-scale hydro, solar, wind and wave power. Europe has considerable hydropower resources that remain unexploited. While many EU countries have already utilised their least-cost resources, about 376 TWh is still technically exploitable (CEC, 1994). Small-scale hydro accounts for approximately 21% of this potential.

In an effort to harness this small hydro potential, the European Small Hydropower Association (ESHA), with financial support from the EU's Altener Programme, commissioned the Institute of Hydrology to develop the European Atlas of Small-scale Hydropower Resources. It was decided that that the Atlas should be developed as an easy-to-use software package which would enable the user to rapidly assess the feasiblity of proposed small-scale hydropower schemes at any gauged or ungauged site in Europe. The Atlas is being developed in phases, with Spain and the United Kingdom the focus of the first three-year development phase. Following the successful completion of Phase 1, the European Atlas of Small-scale Hydropower Resources was launched in March 1997.

The software, named HydrA, was developed to run on IBM compatible PCs within a Microsoft Windows environment. Aimed at hydropower consultants, electricity utilities, environmental agencies and investors, the design principle for the software was that it should easy to use by those with minimal hydrological knowledge. This is helped by the provision of a user-friendly man-machine interface (MMI) which allows the user to navigate the software simply by using a mouse to point and click onto a series of pull-down menus or screen-icons.

HydrA broadly follows procedures laid out in the *"Layman's Guidebook on how to develop a small hydro site"* (ESHA, 1994). It incorporates regional flow estimation models, which allow a synthetic flow duration curve (fdc) to be derived at any site in Spain or the United Kingdom, and methods for determining hydropower potential from the fdc. The regional models are derived from a multi-variate regression analysis of long-term river flow data and key catchment characteristics, as described in Gustard *et al.* (1998). The software is also able to calculate the hydropower potential of sites where gauged river flow data is available.

HydrA comprises four main modules. These are described in detail in the remainder of this paper.

2. Catchment Characteristics module

This module enables the user to estimate the physical characteristic of the ungauged catchment. A pre-requisite is for the user to enter the upstream catchment boundary for the proposed site as a set of (x,y) coordinate pairs. Embedded within the software are 1 km x 1 km grids of average annual rainfall, potential evaporation and a standardised low flow statistic. HydrA overlays the user-defined boundary onto the grids to determine a catchment estimate of average annual rainfall, potential evaporation (PE) and the low flow statistic (see Figure 1). The catchment estimates of rainfall and potential evaporation are used in an empirical relationship to calculate the mean flow for the catchment (Gustard *et al.*, 1998).

For the United Kingdom version of the software, the 95-percentile flow (i.e. Q95, the flow which is equalled or exceeded 95% of the time), expressed as a proportion of the mean flow, is used as the standardised low flow statistic. As described in the paper by Gustard *et al.* (1998), a 1 km x 1km grid of Q95, derived from a multi-variate regression relationship between observed Q95 and the proportion of soil types within catchment, is an integral part of the HydrA software. For Spain, where due to drier conditions Q95 is often zero, a grid of the 90-percentile flow (Q90) is used.

3. Flow Regime Estimation module

This module takes mean flow and the Q95 (or Q90 for Spain), calculated in the Catchment Characteristics module, to derive a synthetic flow duration curve for the site.

The Q95, when standardised by the mean flow, provides a good indication of the hydrological response of a catchment. A high value of Q95 relative to the mean flow generally represents a permeable catchment which is characterised by a flat flow duration curve. Conversely, a low value of Q95 (relative to the mean flow) would represent an impermeable catchment with a steep flow duration curve (see Figure 2). The observation, that the shape of the flow duration curve is a function of the catchment hydrogeology (Institute of Hydrology, 1980; Gustard *et al.*, 1992), is the essence of the regional estimation method that is incorporated in the HydrA software.

By pooling the flow duration curves from gauged data, 20 typical standardised type curves were generated for the UK (Gustard *et al.*, 1992). The type curves represent the flow regimes for the whole range of catchment permeabilities, from the most permeable catchment to the most impermeable. In Spain, 2 sets of type curves were defined: one set for the wetter, northern regions of the country; the other for the drier, southern parts. The standardised type curves are hard-coded into the HydrA software.

So, for any given estimate of Q95 (or Q90), as calculated in the Catchment Characterisitics module, HydrA will automatically refer to the set of standardised type curves and identify an appropriate flow duration curve for the site. The mean flow estimate for the catchment, also calculated in the Catchment Characteristics module, is then used to re-scale the standardised type curve and assign real values to the chosen flow duration curve. This "synthetic" curve characterises the flow regime at the proposed site and is used as the basis for all subsequent hydropower calculations.

Should flow data exist for the site concerned an alternative facility is available within HydrA which allows the user to enter the gauged flow duration curve directly. Throught an input form the user may enter 17 values of flow against corresponding exceedence probabilities. The flow duration curve, thus defined, may then be used, in the same way as any synthetically derived curve, for subsequent hydropower calculations.

4. Turbine Selection module

Having established a characteristic flow duration curve for the site, the software then determines how much of the water can be used for power generation.

First, the residual flow must be entered by the user. This is the minimum flow that must be maintained in the river to sustain the ecology and the requirements of downstream consumers. Any flow above this value could be used for generation. However, no turbine is able to operate efficiently in all conditions. Many can only operate upwards from about 60% of their maximum design (rated) flow (ESHA, 1994). The larger the rated flow, the larger the cut-off at low flow. Within the software, the rated discharge is provisionally set at the level of the mean flow, although this may be altered by the user. As shown in Figure 3, the usable part of the flow duration curve is defined by the residual flow, the rated flow and the minimum turbine flow.

The user is also required to enter the gross (hydraulic) head that is available at the site. Head losses may also be considered by entering an estimate of the nett head as a proportion of the gross head. By default, the nett head is assumed to be 93% of the gross.

The software contains typical operational envelopes and flow-efficiency curves for eight common types of turbine (Figure 4). A display option is available for the user to visually compare the stated head and flow conditions with the turbines' operational envelopes. The turbine types supported are:

- Cross flow;
- Francis Open Flume;
- Francis Spiral Case;
- Kaplan;
- Pelton;
- Propellor;
- Semi-Kaplan; and
- Turgo.

The selection of the appropriate turbines is done automatically by the software.

5. Power Potential module

This module calculates the hydropower potential of the site. For each selected turbine, average annual energy potential and peak power generation are calculated by combining information from the useable part of the flow duration curve with the flow-efficiency relationship, hydraulic head and acceleration due to gravity.

The gross average annual energy (E in kWh) is given by:

$$E = fn(Q, H, \eta_{turbine}, \eta_{gearbox}, \eta_{generator}, \eta_{transformer}, h)$$

where:

Q	= flow (in m^3s^{-1}) for incremental steps on the flow duration curve
H	= specified head (in m)
$\eta_{turbine}$	= turbine efficiency, a function of Q
$\eta_{gearbox}$	= gearbox efficiency, constant for specified turbine type
$\eta_{generator}$	= generator efficiency, constant for specified turbine type
$\eta_{transformer}$	= transformer efficiency, constant for specified turbine type
h	= number of hours in the year

Within HydrA this calculation is achieved by dividing the area under the usable flow duration curve into vertical 5% incremental strips starting from the origin. The final strip will intersect the flow duration curve at Q_{min} or $Q_{residual}$, which ever is larger. For each strip the flow (Q) is calculated, the corresponding turbine value is defined from the relevant efficiency curve and the energy contribution (ΔE) is calculated using the equation.

$$\Delta E = W_i \cdot Q_i \; H \cdot \eta_{turbine}, \cdot \eta_{gearbox} \cdot \eta_{generator}, \cdot \eta_{transformer} \cdot \gamma \cdot h$$

where:

W_i = width of strip I
= 0.05 for all strips except the last one
= 0.05 to 0.005 for the last strip
Q_i = width of strip i
h = number of hours in a year
γ = specific weight of water (9.81 kNm^{-3})

The software contains details of the efficiencies of the generating equipment (gearbox, generator, transformer) associated with each turbine type. Allowance can also be made for downtime due to maintenance or repair. The default settings, based on figures provided by manufacturers, may be edited if necessary.

The final output from the HydrA software is a single sheet report giving estimates of gross and nett annual average energy output (MWh), maximum power output (kW) and rated capacity (kW) for each of the selected turbines. By comparing the performance of each turbine the user is able to make an informed decision on which turbine is appropriate for the site. The output can be written to a file and, if necessary, used in other external packages for economic assessment.

A flow chart outlining the steps of the HydrA estimation procedure, as described is sections 2, 3, 4 and 5, is given in Figure 5.

6. Conclusion

As well as providing a rapid hydrological assessment of potential hydropower sites, HydrA enables users to:

- compare the power output for different turbine types at different locations;
- suggest preliminary designs for the sites, including the most suitable turbine to use;
- select key sites for more detailed investigation;
- reduce expenditure on unnecessary hydrological surveys.

The generic nature of the flow estimation methods within HydrA and the modular design of the software means that, data permitting, similar applications could be developed almost anywhere. In the latest phase of the Altener funded project, HydrA is being developed in Austria, Belgium, Ireland, Italy and Portugal. Another project, to develop a HydrA style tool in the Indian state of Himachal Pradesh and the Narayani basin of Nepal, is presently being considered. Other countries which have also shown interest in developing their own version of the software include Albania, Lithuania, Slovakia, Fiji and the Philippines.

Acknowledgements

The European Atlas of Small-scale Hydropower Resources has been developed on behalf of the European Small Hydropower Association (ESHA) with funding from the European Union (DGXVII) Altener programme. The authors of this paper are very grateful for the support and guidance provided to the project by Dr. Eric Wilson of Wilson Energy Associates Ltd., UK. Thanks also to Mr. Mike Allchin for his outstanding efforts in the design and coding of the HydrA software.

The authors' gratefully acknowledge the United Kingdom's Department for International Development whose support enables their participation in the present international symposium on Hydrology of Ungauged Streams in Hilly Regions for Small Hydropower Development .

References

Commission of the European Communities (CEC), 1994. The European Renewable Energy Study - Prospects for renewable energy in the European Community and eastern Europe up to 2010. CEC Directorate General for Energy (DG-XVII)

European Small Hydropower Association (ESHA), 1994. Layman's Guidebook on how to develop a small hydro site. CEC Directorate General for Energy (DG-XVII).

Gustard, A., Bullock, A. & Dixon, J.M., 1992. Low Flow estimation in the United Kingdom. Institute of Hydrology Report No. 108.

Gustard, A., Croker, K. & Rees, G., 1998. Developing regional design techniques for estimating hydropower potential. International Symposium on Hydrology of Ungauged Streams in Hilly Regions for Small Hydropower Development, March 9-10 1998, New Delhi. In-press.
Institute of Hydrology, 1980. Low Flow Study Report.

List of figures

Figure 1. *Estimation of catchment characteristics*
Figure 2. *Flow duration curves for permeable and impermeable catchments*
Figure 3. *Defining the usable part of the flow duration curve*
Figure 4. *Turbine operational envelopes*
Figure 5. *HydrA flow chart*

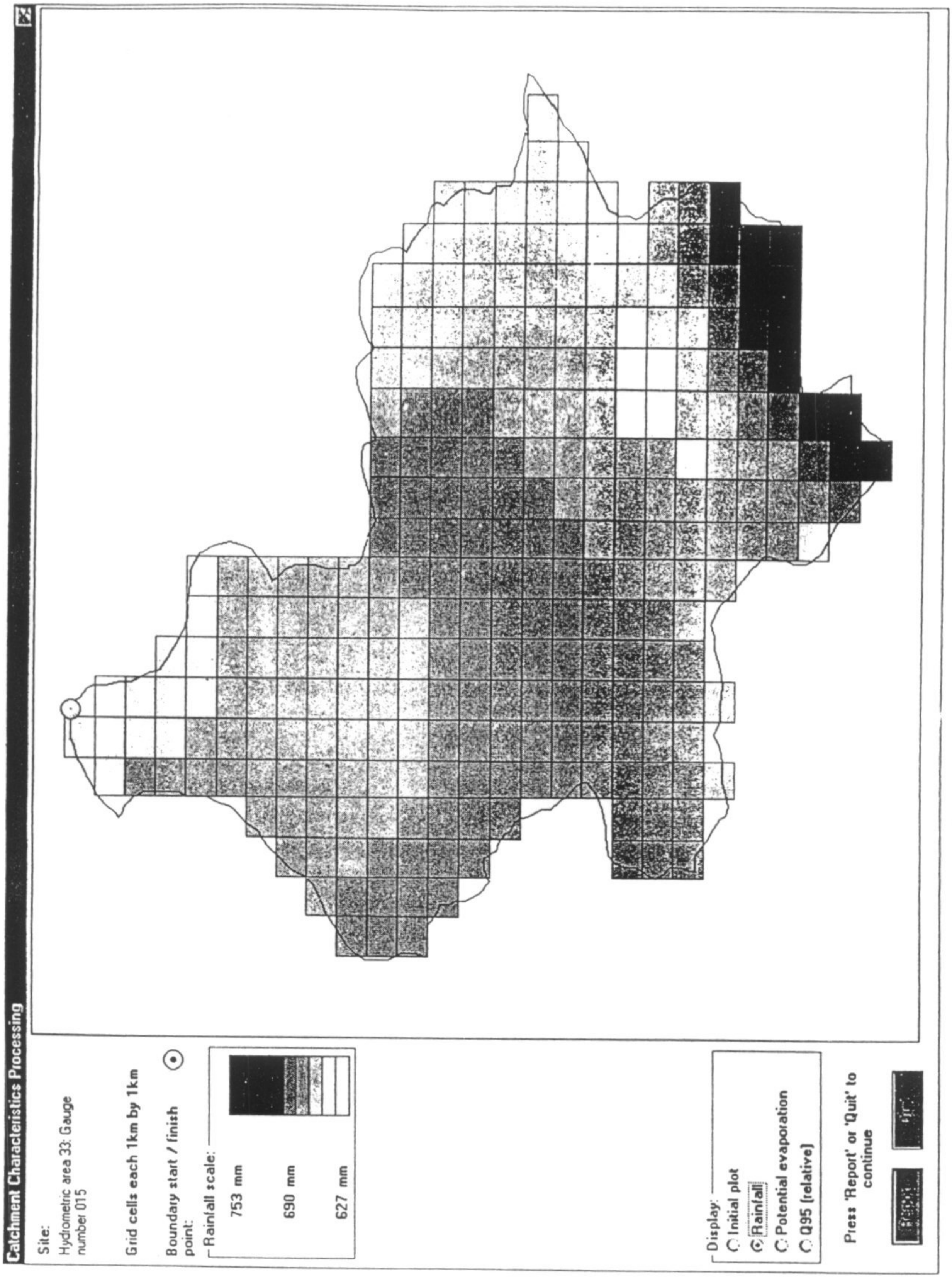


Figure 1. *Estimation of catchment characteristics*

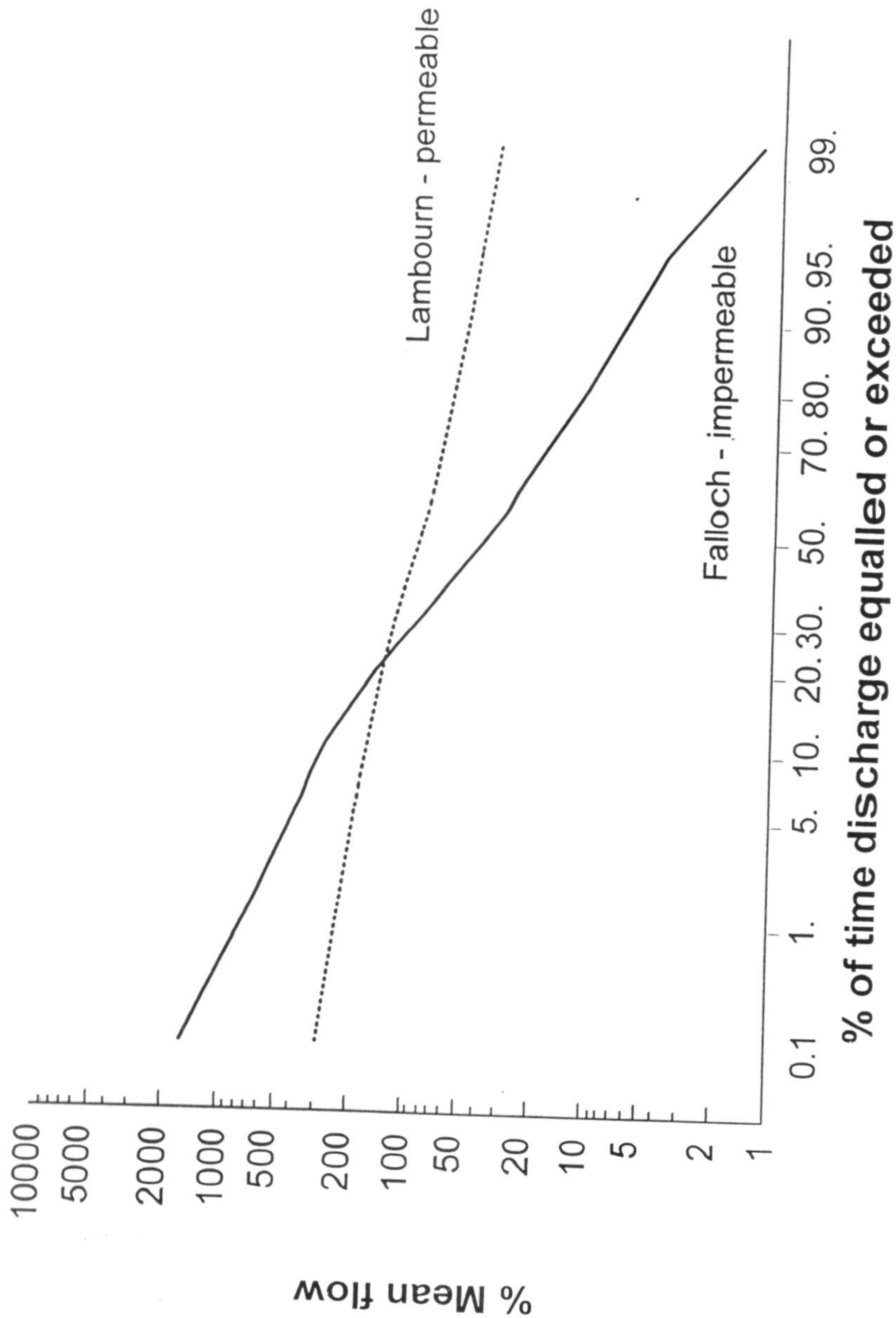


Figure 2. Flow duration curves for permeable and impermeable catchments

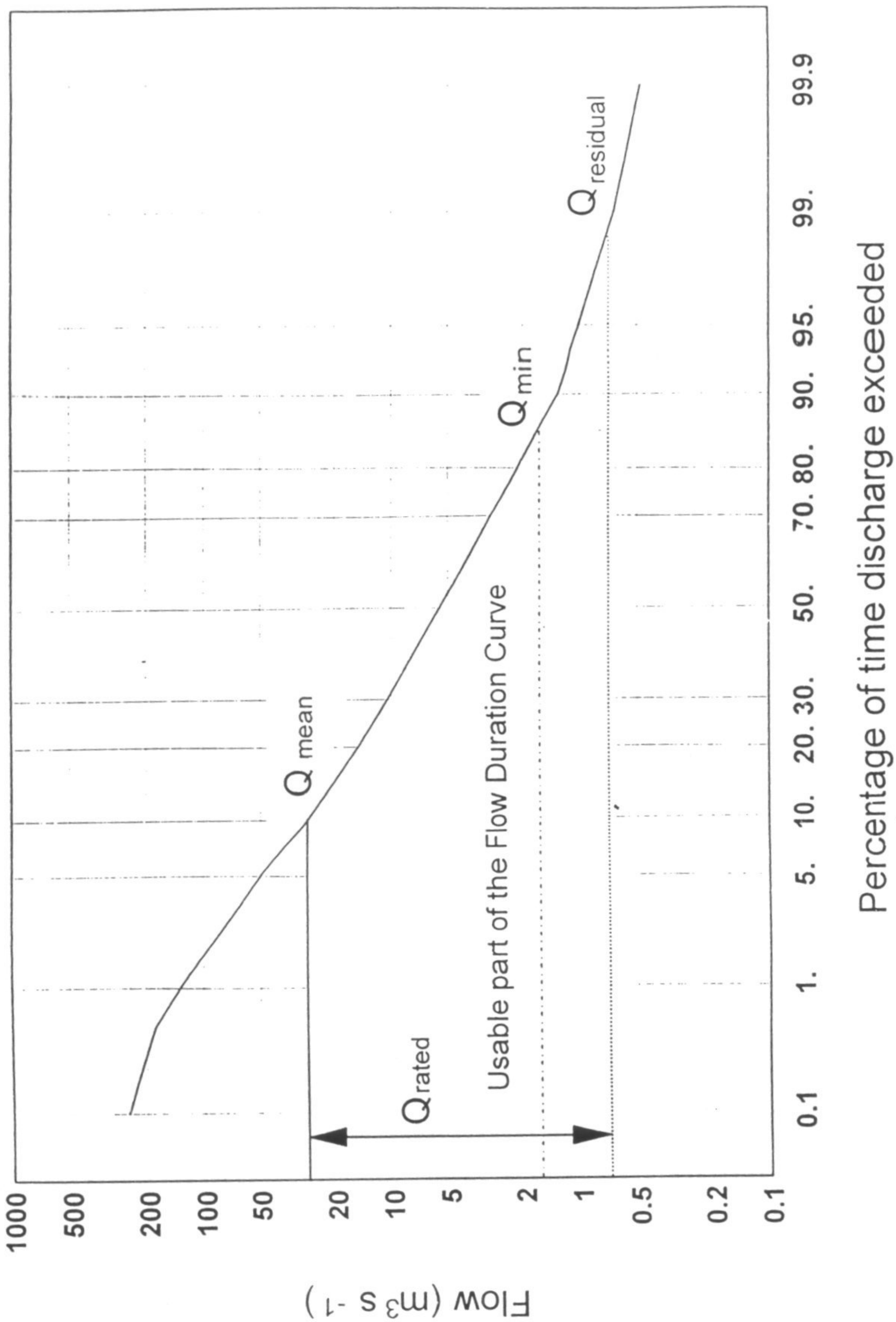


Figure 3. *Defining the usable part of the flow duration curve*

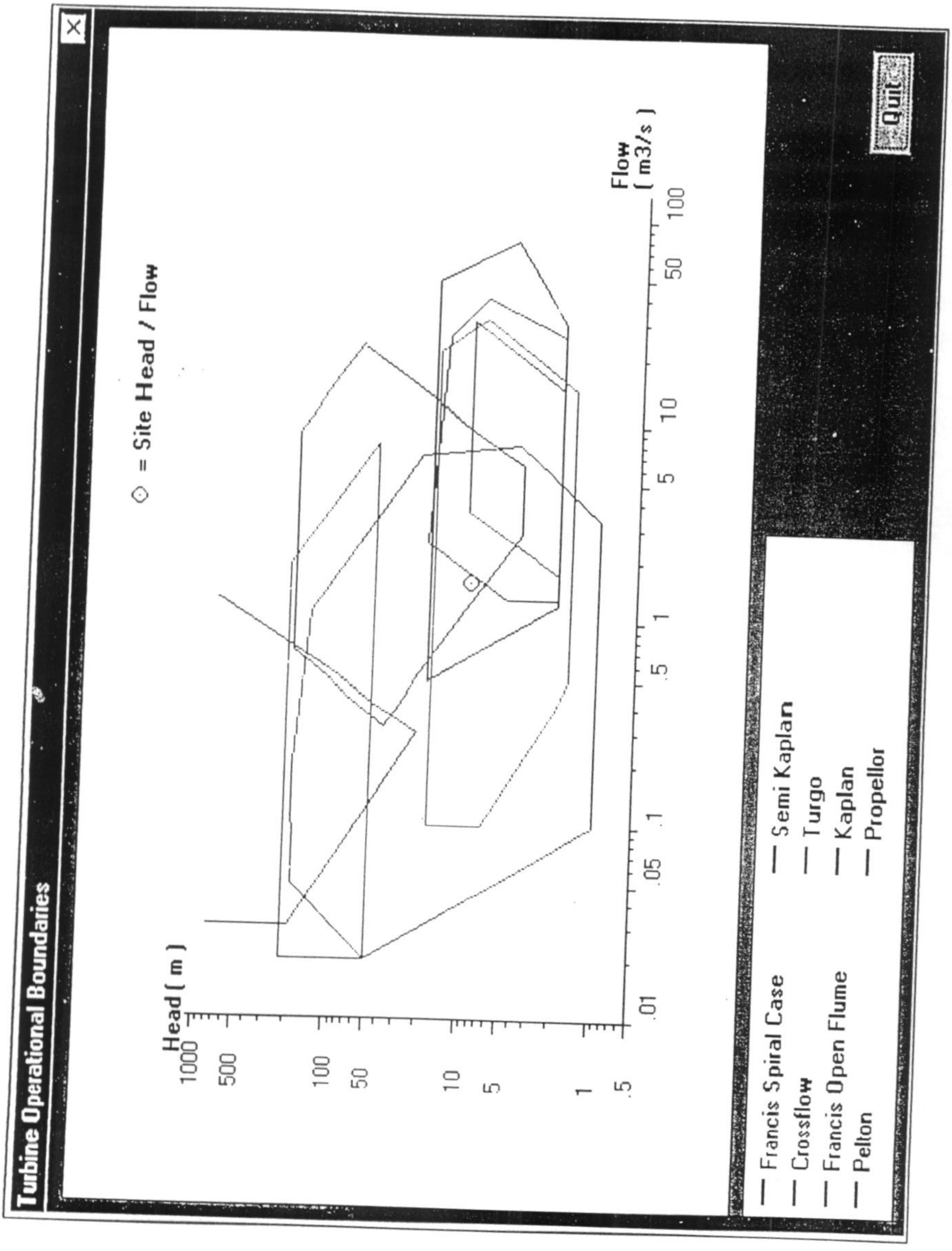


Figure 4. Turbine operational envelopes

Annex E (i)

Press Releases & Articles in Trade Publications

Journal	Publisher	Edition/Date	Page Nos
HRW Hydro Review Worldwide "Software package can help assess hydropower potential"	HRW 410 Archibald Street Kansas City MO 64111-3046 USA	October 1996	54
HRW Hydro Review Worldwide "New information Resources for hydro professionals" (Ed. Edward Fulton)	HRW 410 Archibald Street Kansas City MO 64111-3046 USA	1997-98 Directory	26-36
ESHA Info "HydrA offers rapid assessment of hydropower potential"	European Small Hydropower Association Rue Try Ansquet 5 B 5030 Gembloux-Lonzee Belgium	No 18 1996	6-7
ESHA Info "Atlas europeo de recursos minihidráulicos"	European Small Hydropower Association Rue Try Ansquet 5 B 5030 Gembloux-Lonzee Belgium	No 18 1996	7-8
The World Directory Of Renewable Energy Suppliers and Services 1997 "HydrA – rapid assessment of small scale hydropower potential"	James & James (Science Publishers) Ltd 35-37 William Road London NW1 3ER UK	Feb 1997	78-80
International Water Power and Dam Construction "Software package puts small hydro on the map"	Wilmington Business Publishing Wilmington House Church Hill Dartford DA2 7EF UK	March 1998	40-41
International Journal on Hydropower & Dams Calendar entry for technical workshop	Aqua-Media International Ltd Westmead House Westmead Road Sutton SM1 4JH	Vol 4, Issue 1 1997	107
International Journal on Hydropower & Dams "Rapid assessment of small hydro potential"	Aqua-Media International Ltd Westmead House Westmead Road Sutton SM1 4JH	Vol 5, Issue 1 1998	108

Journal	Publisher	Edition/Date	Page Nos
Institute of Hydrology "European atlas of small-scale hydropower"	Institute of Hydrology Maclean Building Crowmarsh Gifford Wallingford OX10 8BB	Scientific Report 1995-96	10
Institute of Hydrology Software Newsletter	Institute of Hydrology Maclean Building Crowmarsh Gifford Wallingford OX10 8BB	Autumn 1996	1
Institute of Hydrology Software Newsletter	Institute of Hydrology Maclean Building Crowmarsh Gifford Wallingford OX10 8BB	Winter 1997	3
Institute of Hydrology "Estimating water availability for small-scale hydropower production"	Institute of Hydrology Maclean Building Crowmarsh Gifford Wallingford OX10 8BB	Scientific Report 1997-98	15-16
ESHA Info "The role of the European Small Hydropower Association (ESHA) " by ESHA -	European Small Hydropower Association Rue Try Ansquet 5 B 5030 Gembloux-Lonzee Belgium	No 10 1993	15
ESHA Info "La vie de l'ESHA" by George Babalis	European Small Hydropower Association Rue Try Ansquet 5 B 5030 Gembloux-Lonzee Belgium	No 10 1993	30
HRW Hydro Review Worldwide "Hidroenergia looks at world of opportunity" by Eric Wilson	HRW 410 Archibald Street Kansas City MO 64111-3046 USA	Winter 1995	47
REPSO VISION "Hydrology of ungauged streams" by Dr Naidu	India REPSO Winrock International New Delhi India	Vol 3, April 1998	15
International Water Power and Dam Construction "A tough time for small hydro" by Janet Wood	Wilmington Business Publishing Wilmington House Church Hill Dartford DA2 7EF UK	December 1998	37

Annex E (ii)

International Conferences attended

Hidroenergia '95. 4th International Conference and Exhibition. Sept 18-20, 1995. Milan, Italy. *(Presentation of paper & software exhibited on ESHA stand)*

The Altener Programme: Renewable Energy Entering the 21st Century. Nov 25-27, 1996. Barcelona, Spain. *(Software exhibited on ESHA stand)*

Low-Head Hydropower: New Approaches and Innovative Technologies and Programmes. Apr 17-18, 1997. London, UK. *(Exhibition stand where software demonstrated to interested parties)*

Hidroenergia '97. 5th International Conference and Exhibition. Sept 29-Oct 20, 1997. Dublin, Ireland *(Software exhibited on ESHA/BHA stand)*

Small Hydro '98. International Conference and Exhibition. Nov 16-18, 1998. Athens, Greece. *(Presentation of paper & Software demonstrated to interested parties)*

International Energy Agency workshop on Implementing Agreement for Hydropower Technologies and Programmes: Small Scale Hydro Resources and Technologies. Oct 13-14, 1998. Nice, France. *(Software demonstration)*

European Commission conference on Renewable Energies Technologies and Strategies in Eastern and Central European Countries. Oct 19-21, 1998. Sophia-Antipolis, France. *(Software demonstration)*

International Symposium on Hydrology of ungauged Streams in Hilly Regions for Small Hydropower Development. Mar 9-10 1998. New Delhi, India. *(Two paper presentation & software demonstrations)*

Software package can help assess hydropower potential

The European Atlas of Small Hydropower Resources is being expanded to include Austria, Belgium, Greece, Italy, and Portugal. The Atlas, a computer software program, is designed to enable local authorities, water resource planners, and potential investors to assess the feasibility of developing small hydro schemes at a given site within the European Union.

The Atlas incorporates methods for estimating range of river flows at the ungaged site (represented by the flow duration curve) and standard engineering design procedure for estimating the generating potential for a range of common turbine types.

A non-technical developer using the software, in one hour, can obtain a good first estimate of installed capacity and annual energy production for any site on a river in Spain or in the United Kingdom — the first countries included in the system.

A consortium of contractors under the project management of Wilson Energy Associates Ltd. of the United Kingdom developed the Atlas for the two countries, and a preliminary database for Italy. The software is now being prepared for release.

Preliminary collection of data for Austria, Belgium, Greece, Portugal, and the rest of Italy began in early 1996. The Atlas including those countries is to be completed in early 1998.

The consortium, working on behalf of the European Small Hydropower Association (ESHA), includes Internacional de Ingeniera y Estudios Tecnicos, SA (INTECSA), Spain and Verde-acqua, Italy. The Institute of Hydrology, in the United Kingdom, was responsible for hydrological analysis and software development. Wilson Energy Associates collated turbine data and defined procedures for estimating generation potential.

ESHA is managing a contract with the European Commission, Altener Programme of DGXVII for the development of the European Atlas.

Japanese government approves new hydro project

A Japanese government panel has approved construction plans for a small hydroelectric project that will be located in Japan's Wakayama Prefecture. Japan's Economic Planning Agency approved construction plans for the 13.8-MW plant in August.

Kansai Electric Power Co. will develop the Shintakatsuo Power Station. Construction on the run-of-river project is expected to begin in March 1997. The project is scheduled to enter service in May 1999.

Guntur Branch Canal Project advances

Plans call for five small hydropower plants totaling 8.25 MW to be built on an irrigation canal in southern India. The first powerhouse in the Guntur Branch Canal Project scheduled for commissioning likely is to enter service by December 1996. The fifth powerhouse is expected to enter service by June 1997.

K.C.P. Ltd., Madras, India, owns the Guntur Branch Canal. The company also will own and operate the power plants, which will be constructed with private financing.

Sulzer Hydro (Sulzer Flovel Hydro Ltd.) will supply complete turbine, generator, switchgear, controls, and grid interfacing equipment under the terms of a US$7.1 million equipment electro-mechanical contract. The company also will erect and commission the project's 11 750-KW compact bulb turbine-generator sets, which will operate under net heads of from 3.5 to 5.2 meters. Although the project's total rated capacity is 8.25 MW, a 10 percent overload will boost generation to nearly 9.1 MW.

A US$2.7 million civil works contract covers construction of all five powerhouses, inlet and outlet gates for each of the powerhouses, and bypasses. The powerhouses are designed to permit flow to be passed in the event of station shutdown.

▶ BUSINESS ACTIVITY REPORT

• The state government of **Himachal Pradesh, India**, has signed memorandums with 14 private investors for more than 50 small hydro projects in Kangra (16.44 MW), Kinnaur (17 MW), Kullu (10.8 MW), Mandi (0.55 MW), Shimla (18.1 MW), and Sirmour (6.96 MW) for a total installed capacity of more than 69 MW.

The **Himachal Pradesh Energy Development Agency**, an agency of the State Science and Technology Department that reviewed proposals, has approved the allotment of 139 small hydro sites to 29 private investors. The total estimated generating potential of the 139 approved sites is 155 MW.

• The owner of seven small hydropower plants on the island of Java in **Indonesia** has completed modernizing the plants. **Sulzer Hydro** replaced 11 run-

New Information Resources For the Hydro Professional

By Edward Fulton

In this regular directory feature, HRW summarizes recently released books and computer software on a variety of subjects relating to hydropower and water resources.

Information can serve to instruct, solve problems, lend understanding, or offer new perspectives. With this article, *HRW* helps you access hydro-related information that has become available recently. We have identified a selection of books and publications and computer software that can prove valuable to you.

Where possible, prices, in local currency and U.S. dollars, are included for each featured resource. The box on page 32 provides contact information for the organizations from which the resources are available.

This article does not attempt to be all-inclusive, but is representative of the information resources currently available. We welcome your suggestions of additional resources for future coverage. Maintaining a flow of information about hydro improves all levels of the industry.

Books and Publications

The books and publications featured in this article have been divided into three categories: references, project assessment and finance, and operations and maintenance.

Ed Fulton is an associate editor for HRW.

References

The World Directory of Renewable Energy Suppliers and Services 1997 lists more than 6,000 companies worldwide that supply systems or components, or who offer design, installation, and consultancy services in renewable energy technologies.

The listings are divided by technology: hydro and wave, biomass, geothermal, instrumentation and metering, energy storage, photovoltaics, solar, thermal, and wind. An "A to Z" listing then provides full contact information for each company.

The book, published in 1997, also contains a list of nonprofit organizations supporting the renewables industries. An extensive editorial section offers articles examining each technology, and discussing its role in world energy generation.

The book is available from James & James Science Publishers Ltd. The cost is 75 pounds (US$120).

The Council of Power Utilities of India in January 1997 published *Profile of Power Utilities and Non-Utilities in India 1997*, a 300-page examination of power generation in India now and in the future.

The first section of the book provides an analysis of current electricity consumption, moves to forecasts for capacity needs in the future, and ends with a discussion of scenarios for meeting those needs. Hydroelectric, thermal, nuclear generation, renewables, and transmission and distribution systems are discussed in detail.

A second section, though not extensive, reports on the status of non-utility generators, which are defined as companies that generate power for their own use and do not supply power to the public. One portion of this section profiles the Bhoruka Power Corporation Ltd. in Bangalore, which supplies industries with power from several small hydro stations. A point the book makes is that small hydro offers a solution to increasing capacity needs in primarily rural areas.

The bulk of the book is the third section, where the country is broken into five regions and examined in detail. The book lists electric utilities serving each region, and the specific power needs of the states, major cities, and rural areas in each region.

A final section might be the most helpful for hydro professionals desiring to work in India. The section provides a list of the names, addresses, telephone numbers and facsimile numbers, and the name of the top executive of power supply organizations and state electricity boards in the country.

Appendices at the back of the book contain graphs and tables that support the editorial material presented earlier.

The book is distributed by the Council of Power Utilities (of India) and the Central Board of Irrigation & Power (of India). The cost is 8,620 rupees (US$250).

Power Development in India: 1995-96 chronicles advances and regressions in the electric energy industry in the country during the first half of the 1990s. Probably the most far-reaching development discussed in the book is the rise of private sector financing brought on by funding deficiencies within the government of India.

The book was published by the Council of Power Utilities (CPU) and the Central Board of Irrigation & Power (CBI&P). Similar books have been published periodically by CBI&P since India's independence, with the last appearing in 1989.

In the forward to the current book, C.V.J. Varma, secretary general of CPU and member secretary of CBI&P, states the background of the energy sector entering the 1990s. In its eighth five-year plan, the government in the late 1980s allocated 79,589 rupees (US$24.9 billion) to develop new capacity of 30,537 MW and associated transmission and distribution works. When that target had to be scaled back because of capital, management, and organizational inadequacies, the government mounted incentive packages to encourage private investment.

The book traces the rapid growth of the power supply in India from independence (1948) through 1995. Thermal generation remains the most significant source, but hydropower generation is growing at a much faster rate than thermal.

Authors of the book conclude that the need for massive capital investment in power capacity will have to include the mobilization of funds from private national and international financing agencies. An "annexure" lists 83 hydropower schemes — including rehabilitations, extensions, or greenfield projects — that have received various levels of approval from government agencies, but which are not yet funded.

The book is distributed by the Council of Power Utilities. The cost is 6,897 rupees (US$200).

The *Hydraulic Handbook - 9th Edition* carries this traditional, highly technical reference work into its fifth decade. Completely reworked and updated in 1996, the handbook incorporates new techniques, components, and methods introduced in recent years in the hydraulics industry.

Through figures, tables, graphs, and text, the handbook presents full details on hydraulic principles, power components, valves and fittings, hydraulic fluids and filtration, system design and control, monitoring and maintenance, special standards and training, and typical applications. A final section includes a buyers' guide of equipment manufacturers, with contact information.

The book is distributed by Elsevier Science Ltd. The cost is 125 pounds (US$200).

Another valuable reference work for hydro professionals is the *Pump Users Handbook - 4th Edition,* a 428-page, hardcover book published in 1995 that emphasizes correct interpretations of pumping requirements by both user and supplier.

The highly technical handbook incorporates new pumping techniques and technology in this fourth edition, yet continues to offer the basic information and data about the subject that made the first three editions popular. Designed for use by experienced engineers, the handbook discusses the principles of pumping, hydraulics, and fluids, and defines the various criteria necessary for pump and ancillary equipment selection.

Distributed by Elsevier Science Ltd., the handbook costs 95 pounds (US$152).

Project assessment and finance

The U.S. Department of Energy has published *International Energy Outlook 1997*, an assessment of international energy markets through 2015 and an analysis of energy-use data from 1970 to 1995.

The book provides projections of energy use, carbon emissions, and oil production through 2015. Following those, the book forecasts the prospects for hydroelectric and other renewable resources, oil, natural gas, coal, and nuclear power.

In the section on hydro and other renewables, the book says, generally, that low world prices for fossil fuels will continue to constrain development of renewable energy sources. Specifically, however, the book says environmental factors encourage development of hydro and other renewables, particularly in western Europe. Similarly, in rural areas of developing countries located far from institutional grids, hydro and wind generation will play significant roles.

The book is distributed by the National Energy Information Center of the U.S. Department of Energy. The cost is US$16.25, which includes shipping and handling.

R.J.A. Goodland, a member of the Environment Department of The World Bank, presented *Environmental Sustainability in the Hydro Industry: Disaggregating the Debates*, during a joint workshop of IUCN — The World Conservation Union and The World Bank Group, April 10-11, 1997, in Gland, Switzerland. The goal of the paper is to separate the various debates that embroil hydro and specify ways to make hydro environmentally sustainable. The 42-page paper includes five parts.

Part 1 discusses means of approaching sustainability, which is to select better dam sites in the first place. Such selection involves integrating environmental and social criteria into traditional economic least-cost sequencing.

Part 2 suggests that normal project level environmental assessments, which often seek to lower a dam or move it upstream, succumb to the proven good site.

In Part 3, Goodland says the hydro industry needs to foster "transparency and participation," which means showing that conservation is well in hand and that electricity pricing is adequate before new capacity is contemplated.

Part 4 discusses the largest negative effect of hydroelectric dams: resettlement of a population. This area, he says, requires the most attention. The bottom line, he argues, is that people that are resettled must be shown to be better off promptly after their move.

In Part 5, Goodland argues that all power sector technologies must play by the same economic rules. All power projects, he says, must absorb external environmental damage costs, including those of greenhouse gas emissions. To do less means the promotion of coal power plants, an environmentally retrogressive course.

To receive a free copy of the paper, write R.J.A. Goodland at S-5043, Environment Department, The World Bank, Washington, DC 20433 USA; (1) 202-4733203; Fax: (1) 202-4770565. Enclose a stamped, self-addressed, 9-inch by 12-inch envelope.

The U.S. Trade and Development Agency has produced a document detailing opportunities for supplying equipment and services in central and eastern Europe and the new independent states. The document was presented in May 1996 at a two-day conference in St. Louis, Missouri, in the United States.

Power Project Opportunities in Central and Eastern Europe and the New Independent States begins with a general overview of the power generation situation in the 18 countries. Though thermal generation dominates, hydroelectric generation represents more than 20 percent of output in most areas and represents huge, untapped potential.

The report states that capacity must be increased throughout the region either through construction of new projects or refurbishing and upgrading existing projects. Hydro is considered a viable option because it is clean, renewable, and sustainable. Funding for work in the region is available, on a project by project basis, from the World Bank and the European Bank for Reconstruction and Development (EBRD).

Following the general overview, the remainder of the document contains individual profiles of the energy sector in each country, including relevant political, social, and economic information. Details about specific rehabilitation or greenfield projects under consideration by the World Bank or EBRD are included in each country profile.

For a copy of the document, contact the National Technical Information Service. The cost is US$44.

The U.S. Trade and Development Agency (TDA) also has produced what it calls a briefing book titled "Infrastructure Opportunities in Southeast Asia." The document, presented during a TDA conference on the subject in San Francisco in June 1996, presents profiles of infrastructure projects in the energy and transportation sectors in Brunei, Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam.

Hydropower plants are among the specific projects being considered for development in each country. The largest section of the book contains in-depth profiles of each country, including its political and economic background, trade and industry organizational setup, factors affecting trade and investment, taxation and customs, its financial structure, and local sources of financing.

The book is distributed by the National Technical Information Service. The cost is US$49.

The International Finance Corporation (IFC), a member of the World Bank Group, in 1996 published *Financing Private Infrastructure*, a history of the IFC's experience with private infrastructure transactions in developing countries from 1966 to 1996.

The report summarizes the primary issues in structuring project finance and management of project risks based on 148 financing approvals by the IFC in 40 developing countries. IFC in recent years has become one of the major financiers of private infrastructure projects in the developing world.

The book states that private participation and financing of infrastructure has accelerated in recent years because of the generally poor performance of state-owned monopolies, combined with the rapid globalization of world economies. In addition to greenfield projects, governments also have begun to focus on privatizing existing assets, which has generated demand for technical and advisory assistance.

Experiences in financing hydropower projects are included in the general experiences discussed in book, but no single hydro project is singled out for individual examination. The importance of the book lies in its analysis of how financing is arranged despite remote locations, low-income and risky environments, unstable political situations, and negative environmental pressures.

The book, available in English, French, Spanish, Japanese, Chinese, and Arabic, is distributed by the Office of the Publisher, The World Bank. It costs US$7.95, plus US$8 for shipping and handling.

A *Directory of Financing Sources for Foreign Energy Projects* has been produced by the U.S. Department of Energy. The directory focuses on projects in the Russian Federation, Ukraine, India, China, and Pakistan. The softcover document reviews programs that offer

▶ How to Access the Information

Order your resource material direct from the publishers and software vendors mentioned in this article by using the following contact information:

Council of Power Utilities (of India), CBIP Building, Malcha Marg, Chanakyapuri, New Delhi 110 021, India; (91) 11-3015984; Fax: (91) 11-3016347.

Elsevier Science Ltd., The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, United Kingdom; (44) 1865-843842; Fax: (44) 1865-843971.

HCI Publications, 410 Archibald Street, Kansas City, MO 64111 USA; (1) 816-9311311; Fax: (1) 816-9312015.

Institute for Waterpower and Pumps, University of Technology Vienna, Karlsplatz 13, A-1040 Vienna, Austria; (43) 1-5048801; Fax: (43) 1-5041148.

Institute of Hydrology, Wallingford, Oxfordshire, OX10 8BB, United Kingdom; (44) 1491-838800; Fax: (44) 1491-692424.

James & James Science Publishers Ltd., 3537 William Road, London NW1 3ER, United Kingdom; (44) 171-3878558; Fax: (44) 171-3878998.

National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 USA; (1) 703-4874650; Fax: (1) 703-3218547.

Norconsult, Berdal Stromme Division Mechanical, Vestfjordgaten 4, 1300 Sandvika, Norway; (47) 67-571100; Fax: (47) 67-544576.

SINTEF Industrial Management, Applied Economics, N-7034 Trondheim, Norway; Fax: (47) 73-593603.

U.S. Agency for International Development, Development Information Services Clearinghouse, 1500 Wilson Boulevard, Suite 1010, Arlington, VA 22209-2404 USA; (1) 703-3514006; Fax: (1) 703-3514039.

U.S. Department of Energy, Energy Information Administration, National Energy Information Center, Forrestal Building, Room 1F-048, Washington, DC 20585 USA; (1) 202-5868800; Fax: (1) 202-5860727.

U.S. Department of Energy, Office of National Security Policy, PO-91, Room 8F-089, Forrestal Building, Washington, DC 20585 USA; (1) 202-5869399; Fax: (1) 202-5861737.

Water Resources Publications, P.O. Box 260026, Highlands Ranch, CO 80163-0026 USA; (1) 303-7419071; Fax: (1) 303-7419073.

The World Bank, Office of the Publisher, 1818 H Street NW, Washington, DC 20433 USA; (1) 202-4737711; Fax: (1) 202-4776391.

financing in the five locales from multilateral organizations; public, private, and quasi-private investment funds; U.S. government agencies; and local commercial and state development banks. Though published in September 1995, Fred H. Abel, project manager for the directory, said the listings and information — particularly addresses and telephone numbers — should remain viable for some years.

The directory's market-specific information is organized by country. Each country section follows a project cycle: pre-feasibility, feasibility, project finance, co-financing, trade finance, technical assistance, and training.

A free copy is available from the Office of National Security Policy, U.S. Department of Energy.

A publication that applies directly to India's need for private investment in its development of additional energy capacity was released in late 1995 by the U.S. Agency for International Development's Office of Energy, Environment, and Technology. The publication, *The Financing Capability of Indian Institutions to Provide Alternatives to Sovereign Guarantees*, addresses a primary issue: the reluctance of the government of India to pledge national credit for private power project financing.

The publication states that the primary problem is the generally poor credit of the State Electricity Boards, which are the primary buyers of power from independent power producers. India's Ministry of Power suggests alternatives to government guarantees. They include combinations of security arrangements based on letters of credit, escrow accounts, guarantees of performance and payment, access to annual funds transferred to the states from the central government, and balance sheet financing.

The study describes how these alternative security packages can be implemented and the ability of some of the institutions to provide credit support. A conclusion is that despite their poor financial condition, State Electricity Boards are expected to provide the largest amount of credit support for independents. Through 2003, the boards should be able to provide credit support for between 10,738 MW and 14,049 MW of new power. In addition, an estimated 21,750 MW of power could be financed from export credit agencies and 33,768 MW by Indian financing institutions through 2002.

The report says those levels of support still leave India substantially short of its forecasted capacity needs into the next century. To reach the proper level, the report says, India must undertake economic reform in general and power sector reform in particular. In this reform process, the credit quality of State Electricity Boards will rise to acceptable levels.

The report is distributed at no charge by the U.S. Agency for International Development, Development Information Services Clearinghouse.

Operations and maintenance

A survey of hydropower producers throughout the world resulted in the publication, *Report on Hydro Operations Best Practices*. The report was delivered during the HydroVision '96 conference in June 1996 in Orlando, Florida, USA.

Combined, respondents to the survey own and/or operate nearly 700 conventional hydro and pumped-storage plants with 2,141 units with a total generating capacity of over 73,000 MW. The average age of conventional units was 45 years and of pumped-storage plants was 27 years. Respondents represent hydropower producers in Brazil, Chile, Australia, New Zealand, the U.S., and Canada.

For the survey, information was gathered on operations and maintenance budgets, staffing levels, and practices. The 50-page report showed that respondents spent an average of nearly US$3.4 million per plant on operations and maintenance, and an average of US$17,409 per megawatt of capacity. O&M costs averaged nearly one-half cent (U.S.) per kilowatt-hour.

Text in the report, with supporting tables, outline both average and specific practices in the operation of plants of widely varying capacity and ownership structure.

The O&M Benchmarking Survey can be purchased for US$55 from HCI Publications.

The *Handbook of Condition Monitoring* is a 603-page hardcover book published in 1996 that details the methods and devices used to monitor the condition of machinery and products. The book consists of lengthy, in-depth essays about all aspects of the technology, written by experienced professionals.

Of direct interest to the hydro professional are separate chapters on monitoring of vibration, gear systems, hydraulic systems, electrical machinery, turbomachinery, corrosion, and the environment. Other chapters discuss the management benefits from condition monitoring equipment, including fault diagnosis, reliability-centered maintenance, and maintenance management techniques.

The book is distributed by Elsevier Science Ltd. The cost is 110 pounds (US$176).

The 1997 updated version of *Hydro Wheels: A Guide to Maintaining & Improving Hydro Units - Second Edition* was released in May 1997. The book, by hydro industry consultant Thomas Spicher, presents specific solutions to general problems in hydro wheel (turbine runner) maintenance.

Maintaining the informal, practical tone of the book, Spicher writes in a cautionary introduction that the solutions presented in the book do work, but that the analysis of any problem depends on an observant individual at the job site. Some jobs may require more than one application for a complete cure.

The focus of the book is on preventing cavitation damage to runner blades, and how to repair the damage when it does occur. Other sections examine proper inspection procedures, coatings, lubrication systems, and maintenance program enhancement.

The book is distributed by HCI Publications. The cost is US$65.

Computer Software

Computer Models of Watershed Hydrology, released in 1995, is a 1,144-page hardcover book that provides a comprehensive account of some of the more popular computers models of watershed hydrology. The author and editor is Vijay P. Singh, PhD, professor and coordinator of the water resources program at Louisiana State University.

Singh's book is an overview of watershed hydrology, but the bulk of the book closely examines 13 software programs written by their developers. The book was intended as a research tool for practicing professionals and a textbook for graduate students.

A companion, *Computer Models of Watershed Hydrology CD*, is also available. Both the book and CD are available from Water Resources Publications. The book costs US$95 and the CD costs US$95, with a discount available as a package. Postage and handling costs are US$4 in the USA, US$4.75 in Canada, and US$6 in other countries.

The Norwegian company, Norconsult, markets a software program that optimizes the efficient operation of hydropower plants. *RunAid 3.0* is designed for hydroelectric facility operators, but its simulation feature can be used by consulting and design engineers doing production and economic analyses when planning new plants or upgrading existing plants.

Its applications include determining optimum unit load allocation within one plant or in a cascade, optimizing the sequence of starting and stopping units, determining optimal reservoir regulation based on a power price prognosis and upstream inflows, and determining generation value by simulation with input in the form of flow or power output. *RunAid* has an MS Windows-based user interface.

The program is distributed by Norconsult. The cost is 120,000 kroner (Norway) (US$18,462) for the general software license or 25,000 kroner (Norway) (US$3,846) for each plant model in the system.

Two computer programs developed in Austria and Norway are designed to assist hydro plant owners considering refurbishment (see "Software aims to help in planning for refurbishment," *HRW*, October 1996, pages 40-42).

Engineers at the Institute for Waterpower and Pumps at the University of Technology Vienna are marketing *REVEX*, which helps evaluate the physical condition of older hydro plants. The program assesses "indicators" of problems, such as maintenance requirements and breakdowns, at the plant's significant components. Each component is given a number reflecting its physical state, and those numbers are compiled to reach the assessment of the plant as a whole.

The program is distributed by the Institute for Waterpower and Pumps, University of Technology Vienna.

The second program, PTGRef, evaluates optimum refurbishment intervals for high-head Francis turbines, generators, penstocks, and transformers. The software can determine the proper time interval between refurbishment based on the amount of lost efficiency caused by wear, the price of energy, and the prevailing interest rate.

A commercial version of the program is being developed, but a price has not been established. Direct inquiries on the program's availability to SINTEF Industrial Management.

The European Atlas of Small-scale Hydropower Resources, a computer software program called HydrA, in March 1997 became commercially available for use in Spain and the United Kingdom.

The Atlas enables local authorities, water resource planners, and potential investors to assess the feasibility of developing small hydro schemes at a given site (see "Software package can help assess hydropower potential," *HRW*, October 1996, page 54).

The Atlas incorporates methods for estimating the range of river flows at an ungaged site and standard engineering design procedures for estimating generation potential for a range of common turbine types. The program is established on Microsoft Windows 3.1.

A second production phase for the Atlas, which will develop it for use in Austria, Belgium, Iceland, and Portugal, is now underway, and scheduled for completion by March 31, 1999. The development is being funded by the European Commission.

The program is administered by the Institute of Hydrology for the European Small Hydropower Association. The cost of the program is ECU400 (330 pounds) (US$535). ▲

HYDRA OFFERS RAPID ASSESSMENT OF HYDROPOWER POTENTIAL

G. REES

Institute of Hydrology

Centre for
Ecology & Hydrology

Maclean Building
Crowmarsh Gifford
Wallingford
Oxfordshire OX10 8BB
United Kingdom

Tel. +44 (0) 1491 838800
Facs. +44 (0) 1491 69

A team at the Institute of Hydrology, Wallingford, UK, have recently completed the development of a software package which can estimate the hydropower potential at any location in Spain and the United Kingdom. The package, which has been given the name "HydrA" (Hydropower Atlas), was developed on behalf of the European Small Hydropower Association (ESHA) with funding from the Commission of the European Communities' Altener Programme (DGXVII). Aimed at hydropower consultants, electricity utilities, environmental agencies and potential investors, the package will enable the user to rapidly assess the feasibility of proposed small-scale hydropower schemes at gauged or ungauged sites. Incorporating grids of hydrological response derived from the extensive regional analysis of river flow and spatial data, the software provides reliable estimates of the hydrological regime, thus obviating the need for prolonged and expensive hydrological surveys at unsuitable sites.

HydrA is a PC-based package which runs under Microsoft Windows version 3.1, or above, on a PC with a minimum configuration as follows:

Processor: 386/20 MHz
RAM: 2 Mb (preferably 4 Mb)
VGA or EGA monitor
Floppy disk drive: 3.5 " DD

To initiate the assessment procedure for a scheme at an ungauged site, the user is simply required to enter the coordinate pairs defining the upstream catchment boundary. The software then uses 1 km square grids of average annual rainfall, potential evaporation and hydrological response to calculate the mean flow and the synthetic flow duration curve for the site. For sites where river flow data is available, the software allows the ordinates of the observed flow duration curve to be entered manually. Once the hydrological regime, described by the flow duration curve, is established, the user is required to enter the design flow and head conditions for the site. Standard operational envelopes for 8 turbine types are then used to determine which turbines are operable under the stated conditions. The flow duration curve is used to estimate the amount of water available while accounting for the design flow (provisional rated flow), the minimum turbine flow and the residual flow requirements of the river. This information is then combined with the flow-efficiency curves of the selected turbines to derive estimates of maximum and average annual power output.

A workshop to publicly launch the UK version of the software is to be held on 20-21 March, 1997 at Water Training International, Tadley Court, Near Reading, Berkshire. The workshop will provide a comprehensive introduction both to the HydrA software and the principles of estimating hydropower potential. Speakers from the European Union, ESHA and the UK Environment Agency will relate the overall aims of the HydrA project to global, European and national policies on renewable energy.

HydrA is the outcome of a three year applied research project undertaken by a consortium of partners including the Institute of Hydrology, Wilson Energy Associates Ltd. (UK) and INTECSA (Spain). The next development phase, which is already under way, will see HydrA developed over the next three years in other parts of Europe. The generic nature of the methods used means that similar applications could be developed beyond the European Union. Countries which have shown early interest include Albania, Lithuania, Slovakia, India, Nepal, Fiji and the Philippines.

Further information concerning the software or the workshop can be obtained from the:
Software Helpdesk
Institute of Hydrology,
Wallingford, Oxfordshire,
OX10 8BB, United Kingdom;
tel: +44 (0)1491 838800;
fax: +44 (0)1491 692424;
E-mail: softdev@ioh.ac.uk

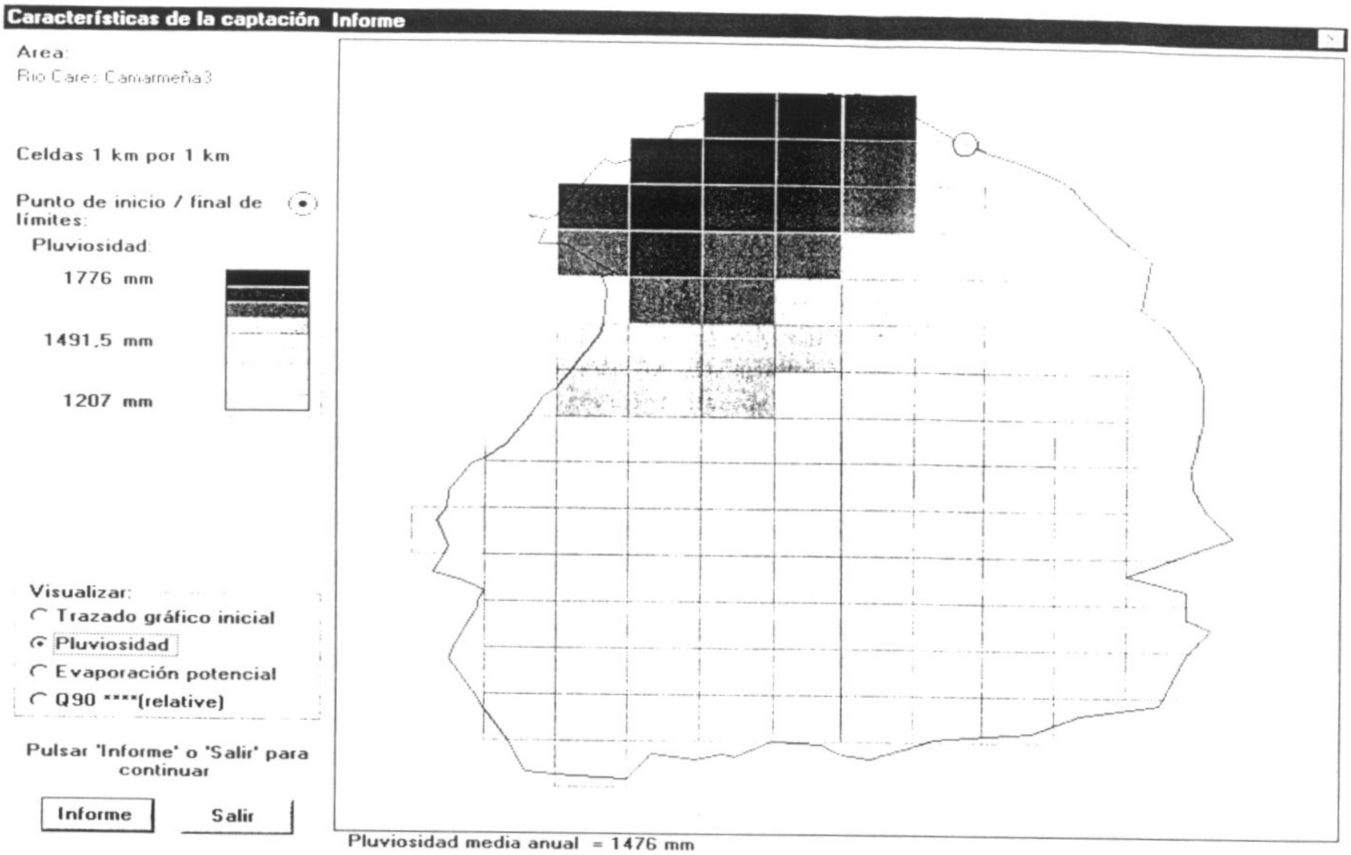


figura 1

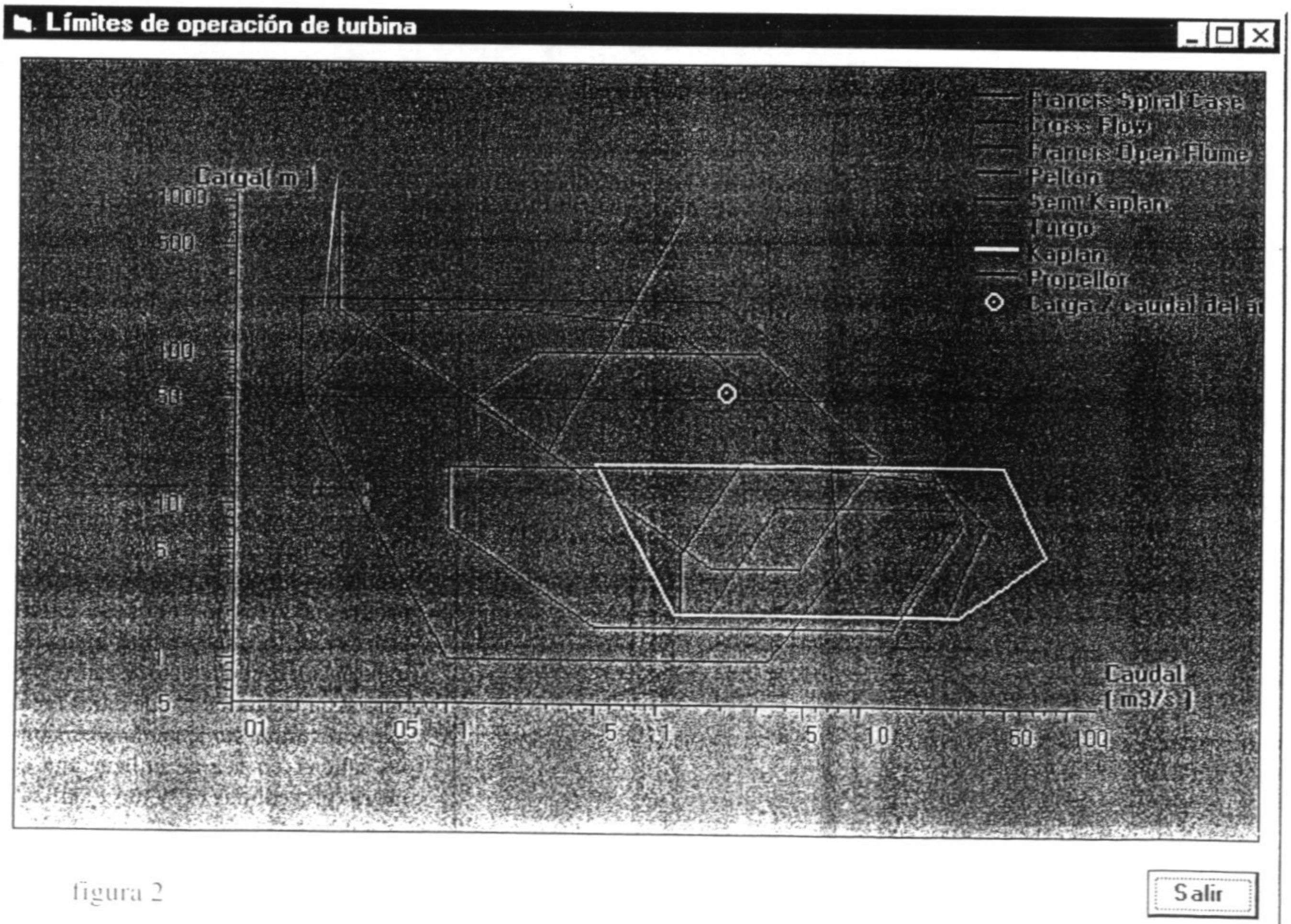


figura 2

ATLAS EUROPEO DE RECURSOS MINIHIDRÁULICOS

La versión para España del Atlas Europeo de Recursos Minihidráulicos es ya operativa. La ultima versión beta ha sido ensayada con éxito y en breve se procederá a su lanzamiento comercial. Para ello se celebrarán en breve, unas jornadas de trabajo, en lugar y fecha aun no determinados. En dichas jornadas, cuyo objetivo es difundir el programa a la mayor escala posible, se explicaran las hipótesis y métodos de calculo utilizados en su desarrollo y se mostrará como funciona.

El Atlas, ha sido desarrollado para ESHA (European Small Hydropower Association), por el Instituto de Hidrología del Reino Unido, como un paquete de software con menús desplegables, llamado HydrA. Wilson Energy Associates Ltd., G.B. ha coordinado el proyecto, financiado con fondos de la Dirección General de Energía (DG XVII) de la Comisión de las Comunidades Europeas, en el marco del Programa ALTENER.

El software se suministra en disquetes de 3.5" D.D., y ha sido diseñado para funcionar en un Ordenador Personal trabajando en entorno Microsoft Windows™, versión 3.1 o superior, con los siguientes requisitos mínimos:
Memoria: 2 Mb,preferiblemente 4 Mb
Procesador: 80386 a 20 MHz
Disco duro: 20 Mb
Tarjeta Gráfica:VGA, EGA o compat.
Unidad de disquete: :3" DD

El espectro de usuarios potenciales se extiende desde las grandes empresas consultoras hasta aquellos ingenieros no familiarizados con el diseño de aprovechamientos hidro-eléctricos, pero con cierta práctica en el uso de ordenadores.

El software se ha diseñado para que sea robusto, compacto, tanto por el número de disquetes de instalación como en las exigencias de memoria, fácil de instalar, utilizando un proceso de instalación controlado por menús y disponible en varios idiomas (por el momento inglés y español)

El objetivo del programa es evaluar el potencial de generación de un aprovechamiento utilizando tres procesos consecutivos: evaluación de las características de la cuenca, calculo del régimen de caudales y estimación de potencia instalada y electricidad generada en año hidráulico medio.

El usuario empieza por definir el perímetro de la cuenca correspondiente al aprovechamiento objeto del estudio, introduciendo una serie de pares de coordenadas (en nuestro país cordenadas UTM).

El módulo de características de cuenca, superpone este perímetro sobre cada una de las bases de datos celulares (celdas de 1 kmx1 km), correspondientes a precipitación, evaporación y constitución del suelo (figura 1), y calcula automáticamente el caudal medio y la respuesta hidrológica de la cuenca

El módulo de evaluación del régimen de caudales selecciona, a partir de la respuesta hidrológica, la curva sintética de caudales clasificados (CCC) que caracteriza el aprovechamiento, curva que es escalada con el valor del caudal medio. El programa permite en este estadio, calcular el caudal para una probabilidad de que sea igualado o excedido, y viceversa

Introduciendo el valor escogido como caudal de diseño, y la altura del salto, el programa situa el punto definido por ese par de valores sobre el gráfico(figura 2) de envolventes operacionales de cada una de las turbinas soportadas por el programa y determina cuales de entre ellas pueden utilizarse en esa hipótesis.

El programa soporta las siguientes turbinas:

- Cross Flow (o Banki)
- Francis de cámara abierta
- Francis de cámara espiral
- Kaplan
- Semi-Kaplan
- Helice
- Pelton
- Turgo

El módulo de potencial energético calcula la potencia nominal de cada turbina y su producción anual, basandose en el agua turbinada que viene definida por la parte utilizable de la CCC: caudal de diseño, curva , caudal ecológico y caudal minimo técnico - uno u otro según sea el uno mayor o menor que el otro (figura 3).

El Manual del usuario que es tambien un libro de referencia técnica, esplica en detalle las hipótesis en que se apoya el programa y los metodos de cálculo utilizados, lo que permite al usuario trabajar con conocimiento de causa, sobre todo si quiere hacer uso de datos locales que le permitan aumentar la precisión de las salidas, en vez de utilizar una caja negra (procedimiento siempre utilizable en todo caso).

El programa está actualmente disponible para el Reino Unido y para España. ■

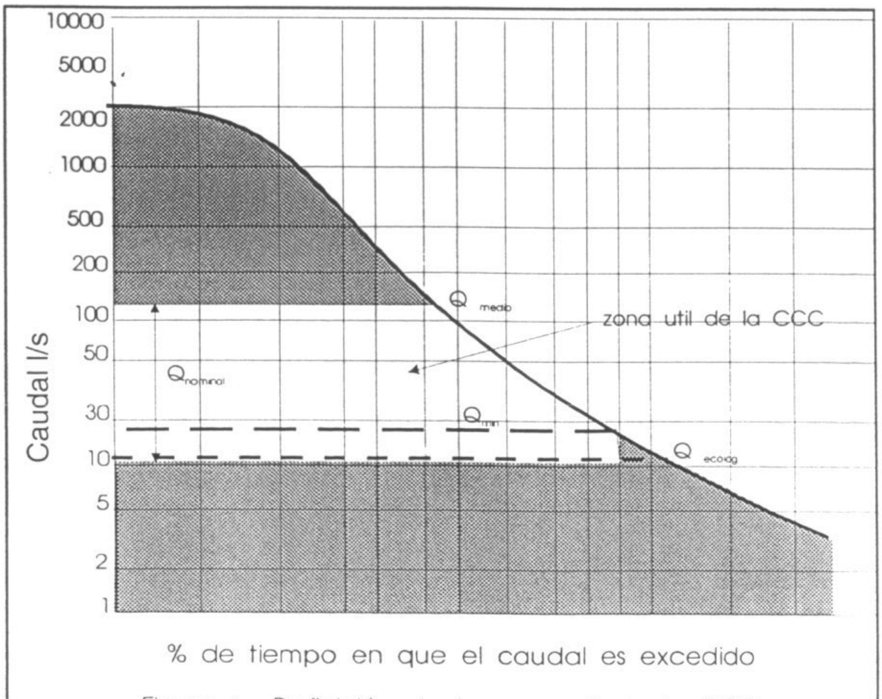


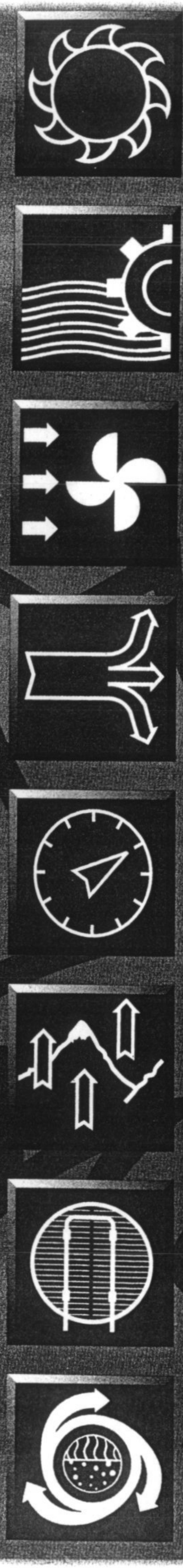
Figura 3 Definición de la zona util de la CCC

Memoria: 2 Mb,preferiblemente 4 Mb
Procesador: 80386 a 20 MHz

El módulo de características de cuenca, superpone este perímetro sobre cada una

Hélice
Pelton
Turgo

El módulo de potencial energético calcula la potencia nominal de cada turbina y su producción anual, basandose en el agua turbinada que viene definida por la parte utilizable de la CCC: caudal de diseño, curva , caudal ecológico y caudal minimo técnico - uno u otro según sea el uno



THE WORLD DIRECTORY OF RENEWABLE ENERGY SUPPLIERS AND SERVICES 1997

JAMES X JAMES

HYDRA – RAPID ASSESSMENT OF SMALL SCALE HYDROPOWER POTENTIAL

ARTICLE

Gwyn Rees

INTRODUCTION

A team at the Institute of Hydrology, Wallingford, UK, has recently completed the development of a software package that can estimate the small-scale hydropower potential (<5MW) at any location in Spain or the UK. The software, named HydrA, was developed on behalf of the European Small Hydropower Association (ESHA) with funding from the Commission of the European Communities' ALTENER Programme (DG XVII). Aimed at hydropower consultants, electricity utilities, environmental agencies and potential investors, the package will enable the user to rapidly assess the feasibility of proposed small-scale hydropower schemes at gauged or ungauged sites.

DESCRIBING THE HYDROLOGICAL REGIME

To develop a hydropower scheme, it is essential to determine whether there is sufficient discharge, or flow, in the river to drive the turbines. An effective technique to characterize the temporal variation of flows is the flow-duration curve. This identifies the proportion of time a given flow is exceeded and provides a means of determining how much of the available water resource can be used by turbines of different sizes. Where long records of measured river flows are available at, or near, the site, HydrA allows the observed flow-duration curve to be entered directly. However, at many proposed sites, no flow records are available and therefore a method of deriving a synthetic flow-duration curve is required. HydrA incorporates a regional flow-estimation model which allows the flow-duration curve to be estimated at any ungauged site in Spain or the UK. The model is derived from extensive statistical analysis of national river flow data and catchment characteristics.

Previous studies at the Institute of Hydrology[1] indicated that the physical properties of soils, by controlling the storage and transmission of water, are very important in influencing the hydrological characteristics of a catchment. It was found that UK soils can be categorized into 29 discrete groups to represent their hydrological response. The classification system, referred to as the Hydrology of Soil Types (HOST) classification, was developed into a national database containing the proportion of HOST class for every cell of a 1 km^2 grid for the UK. Subsequent research, published in IH Report 108,[2] related HOST to the low-flow response of gauged catchments. This work revealed that the Q95 (the flow exceeded for 95% of the time), when standardized (i.e. expressed as a percentage of the mean flow), could be used as the key low-flow statistic for estimating the flow-duration curve at an ungauged site. Multivariate regression models, derived by relating the observed Q95 to the proportion of HOST in 727 UK catchments, were then used to estimate the standardized Q95 for each 1 km^2 grid cell in the UK. A new version of the Q95 grid, based on an improved HOST classification[3] and longer time-series data, is incorporated in the UK version of the HydrA software. Similar multivariate regression relationships were derived in mainland Spain by relating the observed Q90 low-flow statistic and the soils for 198 catchments. The relationships were used to derive a 1 km^2 grid of standardized Q90 for mainland Spain, which is incorporated in the Spanish implementation of the HydrA software.

IH Report 108[2] also showed that the gradient of the flow-duration curve is controlled by the catchment low-flow re-

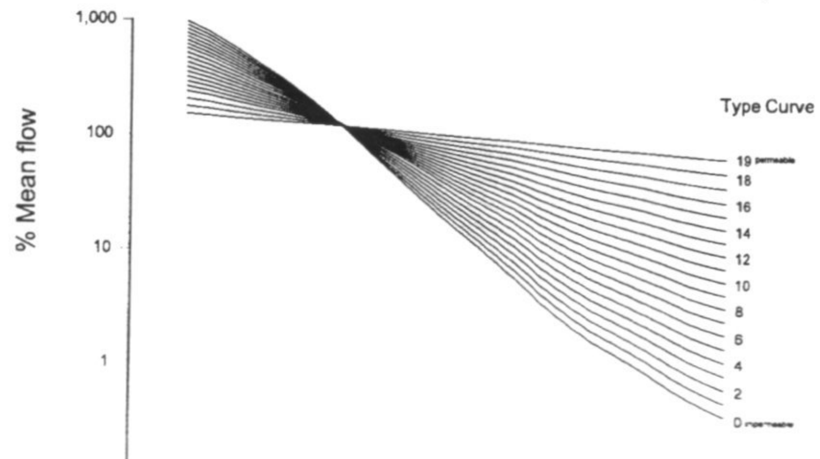


Figure 1. Flow-duration type curves – UK

sponse as represented, in the UK, by the magnitude of the standardized Q95 flow (or Q90 for Spain). For example, a catchment having a high Q95 value relative to the mean flow would have a gradually inclined flow-duration curve, typical of a permeable catchment; whereas a catchment having a low Q95 value would have a steep flow-duration curve, which is characteristic of an impermeable catchment. By pooling the flow-duration curves from gauged data, 20 typical standardized type curves were generated for the UK (Figure 1). In Spain, two sets of type curves were defined: one set for the wetter, northern regions of the country; the other for the drier, southern parts. The standardized type curves are incorporated in the HydrA software, together with the grids of hydrological response (Q95/Q90).

HydrA enables the estimation of a flow-duration curve by superimposing a catchment boundary onto the hydrological response maps. Once the user has entered the points defining the upstream catchment boundary into the software, HydrA will overlay the boundary onto the grids (of hydrological response) and provide an estimate of the standardized Q95 for the site (or Q90, in Spain). When this estimate is referred to the type curves, a characteristic flow-duration curve for the site is obtained which is expressed in percentage terms of the mean flow. In the case of a gauged site, HydrA provides a facility to enter the ordinates of a flow-duration curve derived directly from observed data.

CALCULATING THE MEAN FLOW

The estimated flow-duration curve is standardized by the mean flow. For an ungauged site it is necessary, therefore, to estimate the mean flow and scale of the flow-duration curve. The software incorporates 1 km^2 grids of standard period average annual rainfall (SAAR) and potential evaporation (PE). The mean flow is calculated using a catchment water-balance method, in which the mean flow, expressed in terms of the long-term average annual runoff, is the difference between SAAR and the actual evaporation (AE). Catchment values of SAAR and PE are obtained within the software by overlaying the catchment boundary onto the respective grids (Figure 2). The AE is calculated by relating the SAAR to the PE. For the UK, a relationship between the actual and potential evaporation was determined through the regional analysis of gauged flow data and catchment average rainfall.

If the simple water-balance approach is assumed:

$$\text{Runoff} = \text{SAAR} - \text{AE} \quad (1)$$

where AE is given by the equation:

$$\text{AE} = r.\text{PE}. \quad (2)$$

the runoff may be expressed as:

$$\text{Runoff} = \text{SAAR} - r.\text{PE}. \quad (3)$$

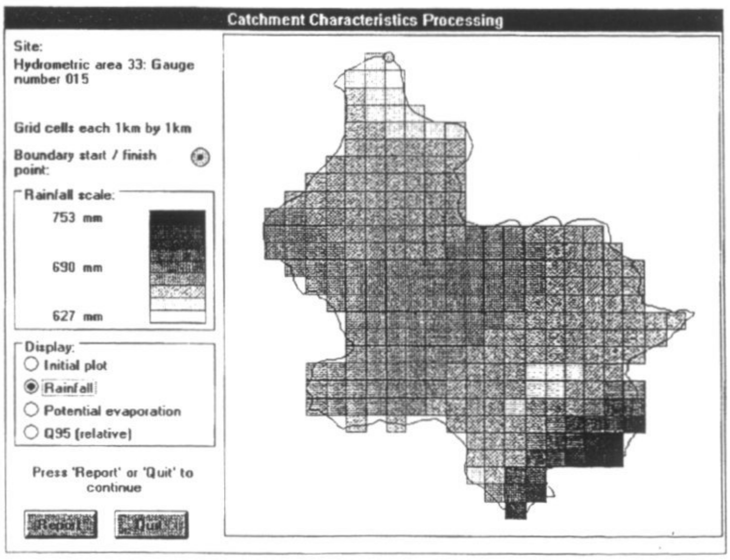


Figure 2. Catchment overlay

Power Potential Report

Site: Hydrometric area 33: Gauge number 015
Run Date / Time: Wednesday, February 12, 1997 at 15.21

Mean Flow: 1.82 m3/s
Provisional Rated Flow: 1.82 m3/s
Residual Flow: 0.50 m3/s

Rated Flow: 1.32 m3/s
Gross Hydraulic Head: 10.00 m
Nett Hydraulic Head: 9.30 m

Applicable Turbines	Gross Annual Average Output	Nett Annual Average Output	Maximum Power Output	Rated Capacity	Minimum Operational Flow
Francis Spiral Case (mgnl)	408.0	387.6	110.6	106.1	0.90
Propellor	324.0	307.8	105.4	101.2	1.36
Crossflow	377.0	358.2	96.3	90.2	0.70
Kaplan	411.8	391.2	107.5	100.7	0.76
	MWh	MWh	kW	kW	m3/s

Marginally-applicable turbines indicated by '(mgnl)'

Flow Regime Results File: c:\hydra\data\demo.fri

Plot Power / Flow Graphs   Plot Flow-Duration Curve

Figure 3. Power potential report

It was found that, for the UK, r could be defined by the equation:[5]

$$r = 0.00061\text{SAAR} + 0.475 \quad \text{where SAAR} < 850 \text{ mm} \qquad (4a)$$

$$r = 1.0 \qquad \text{where SAAR} \geq 850 \text{ mm.} \qquad (4b)$$

For Spain, an alternative approach using a calibrated form of the Budyko equation was used (Budyko and Zubenok, 1961, referenced in Dooge[5]) where the AE is related to SAAR and PE by:

$$\text{AE} = \text{SAAR}[1 - \exp(-\text{PE}/\text{SAAR})]. \qquad (5)$$

Thus, the equation for runoff becomes:

$$\text{Runoff} = \text{SAAR} \,.\, \exp(-\text{PE}/\text{SAAR}). \qquad (6)$$

HYDROPOWER ESTIMATION

Having established a characteristic flow-duration curve for the site, the software then determines how much of the water can be used for power generation. First, the residual flow, or the minimum flow that is to be left in the river, must be entered by the user. Any flow above this value could be used for generation. However, no turbine is able to operate efficiently in all conditions. Many can only operate upwards from about 60% of their design (rated) discharge.[6] The larger the rated discharge chosen, the larger the cut-off at low flow. Within the software, the rated discharge is provisionally set at the level of the mean flow, although this can be altered by the user. The user is also required to enter the head conditions available at the site. The software contains typical operational envelopes and flow–efficiency curves for eight common types of turbine. It identifies which operate under the stated conditions and then calculates the energy production of each selected turbine by integrating the usable area under the flow-duration curve with the flow–efficiency curves and the nett head conditions. The primary output from the software is a single sheet report giving estimates of gross and nett annual average output (MWh), maximum power output (kW) and rated capacity (kW) for each selected turbine type (Figure 3).

CONCLUSION

HydrA is a PC-based package which runs under Microso Windows version 3.1 or above. It is the product of a three-year applied research project undertaken by a consortium of partners including the Institute of Hydrology, Wilson Energ Associates Ltd (UK) and INTECSA (Spain). The next devel opment phase, funded by the European Union's ALTENER programme, will see HydrA developed in Austria, Belgium Italy and Portugal. The generic nature of the methods mea that similar applications could be developed elsewhere. Countries which have shown early interest include Albania, Lithuania, Slovakia, India, Nepal, Fiji and the Philippines.

With ALTENER aiming to increase the uptake of renewable energy sources in the European Union, the HydrA software will be publicly available from 20 March 1997 at a su sidized price of ECU 400 (£330). Further information can be obtained from the Software Helpdesk at the Institute of Hydrology, Wallingford, Oxfordshire, OX10 8BB, UK; Tel. +4 1491 838800; Fax +44 1491 692424; Email softdev@ioh.ac.u

REFERENCES

1. Boorman DB, Hollis JM (1990). Hydrology of Soil Types. A hydrologically based classification of the soils of England and Wales. Ministry of Agriculture, Fisheries and Food Conference for river a coastal engineers, Loughborough University.
2. Gustard A, Bullock A, Dixon JM (1992). Low flow estimation in the United Kingdom. IH Report No. 108, Institute of Hydrology, Wallingford. 88pp.
3. Boorman, D.B., Hollis, J.M.K Lilley, A.. (1995). Hydrology of Soil Type – a hydrologically based classification of the soils of the United Kingdom. IH Report No. 126. Institute of Hydrology, Wallingford. 137p
4. Gustard A, Irving K, Rees G, Young A (1995). Hydrological models small scale hydropower assessment. Conference proceedings Hidroenergia 1995. Milan.
5. Dooge JCI (1989). The role of the hydrological cycle in climate. In Berger et al. (ed.). Climate and Geo-Sciences. pp. 355–366. Kluw Academic Press. Dordrecht. The Netherlands.
6. European Small Hydropower Association (1994). Layman's Guidebook on How to Develop a Small Hydro Site. Commission of the Europe Communities, Directorate General for Energy (DG XVII).

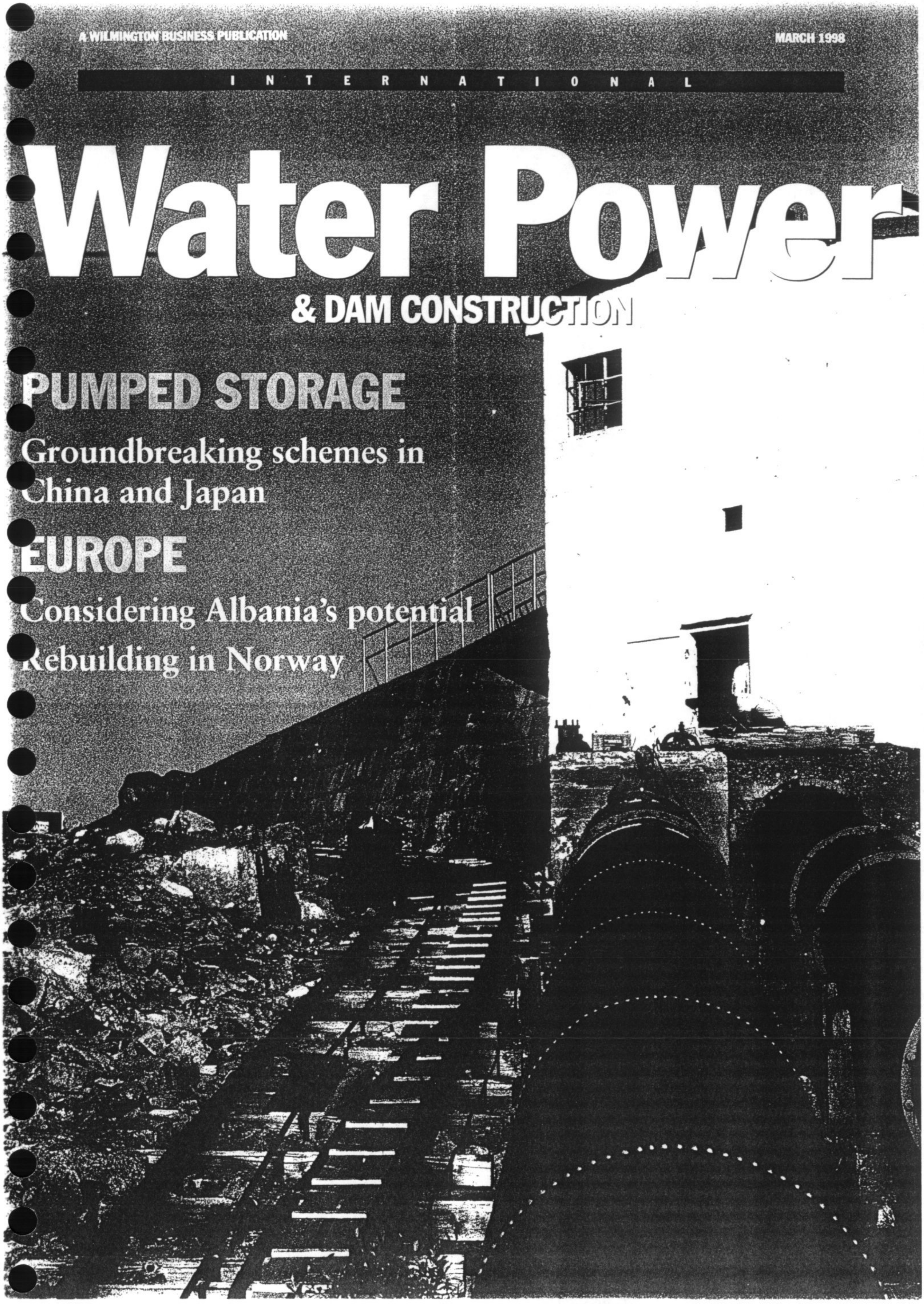
Guyn Rees is Project Leader at the Institute Hydrology, Wallingford, Oxon OX10 8BB, U

A WILMINGTON BUSINESS PUBLICATION
MARCH 1998

INTERNATIONAL

Water Power

& DAM CONSTRUCTION



PUMPED STORAGE

Groundbreaking schemes in China and Japan

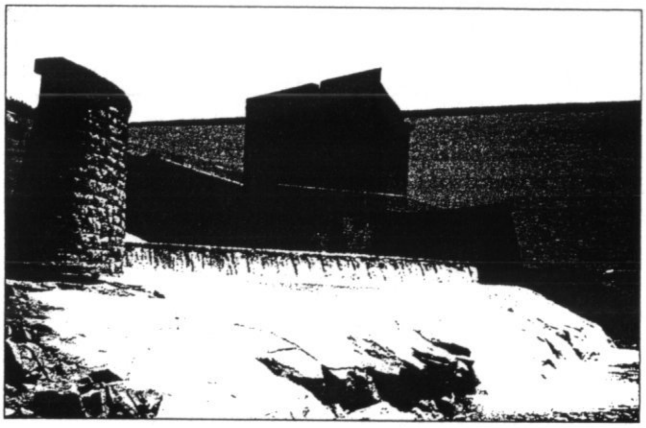
EUROPE

Considering Albania's potential

Rebuilding in Norway

Software package puts small hydro on the map

The Institute of Hydrology in the UK has developed a software package to assess the hydrological and power potential of small hydro sites across Europe. Karen Croker and Gwyn Rees explain the principles behind the program called HydrA.*



The Altener Committee of the European Union and the European Small Hydro Power Association (ESHA) are keen to promote investment in small run-of-river hydro power schemes. Such schemes can provide a reliable source of energy, especially in remote areas, provided that the hydrological conditions are suitable. However, in such remote locations, the availability of reliable measured flow records is severely limited.

To address this problem a software package has been developed by the Institute of Hydrology on behalf of ESHA, providing an automated procedure for assessing the hydrological potential of a site. Once the hydrological characteristics have been determined, the feasibility of developing small hydro schemes in these areas can be evaluated. The software is currently operational in the UK and Spain and a version covering Italy will be available in 1998.

Called the Hydro Power Atlas (HydrA), the software is a menu-driven package which incorporates regional flow estimation models and databases of climate and hydrogeological response characteristics. The automatic estimation procedures are ideal for the rapid hydrological assessment of sites for regional planning and for hydropower assessment at gauged and ungauged locations. The program enables the user to:

- Compare the power output for different turbine types at different locations.
- Suggest preliminary designs for the sites, including the most suitable turbine and capacity.
- Select key sites for more detailed investigation.
- Potentially reduce expenditure on unnecessary hydrological surveys.

Various hydrological principles are incorporated into HydrA. The hydrology of a catchment is an important factor when considering whether a site is a suitable location for a small hydro power scheme — there must be a reliable source of water to drive the turbines. Within a catchment, the rainfall and evaporative losses are important in determining the total available water resource, while the soils and underlying geology will influence the way in which the catchment responds.

A generally accepted method for characterising the hydrological regime is to determine the cumulative frequency distribution of flows expressed as a percentage of time that the specified flows are equalled or exceeded. This relationship is more commonly referred to as the flow duration curve and, although it does not convey any information about the sequence of flows, it graphically represents the complete range of flows from low to flood.

The flow duration curve can be derived directly from daily flow data by assigning daily flow values to class intervals and counting the number of days within each class interval. The proportion of the total number of days above the lower limit of any class interval is then calculated and plotted against the lower limit of the interval. If the flows are normally distributed, plotting the points using a normal probability scale for the frequency axis and a logarithmic scale for the flow axis, will define the flow duration curves as a straight line. In addition, plotting the flow axis as a percentage of the mean flow enables catchments of different sizes and with different climatic conditions to be compared.

In the areas that might be suitable for hydro power development, such as remote upland areas, gauged flow data is not available for deriving the flow duration curve – alternative techniques are required.

The shape of the flow duration curve is a function of the catchment hydrogeology. This observation has been used to form the basis for developing an estimation procedure at ungauged locations.

Previous studies have identified that the key flow statistics required for the estimation of the flow duration curve at an ungauged location are the mean flow and a standardised low flow statistic (expressed as a percentage of the mean flow). In the UK, the Q95 flow (the flow equalled or exceeded for 95% of the time) is the low flow statistic most commonly used by the water industry. However, in drier countries such as Spain and Italy, the Q90 provides a more reliable low flow statistic (the Q95 in these countries is often zero).

Ungauged locations

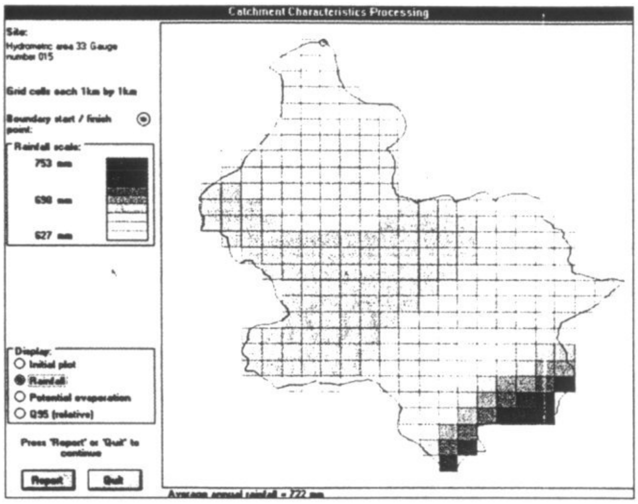
In order to be able to implement the design procedures in ungauged locations, it is first necessary to identify the extent of the catchment, by defining a catchment boundary, and to determine the physical characteristics of the catchment. The catchment boundary is overlain onto maps of the relevant catchment characteristics. Average values of rainfall and evaporation can easily be calculated and the fractional extent of each soil class within the catchment can be determined. The soil classes can then be grouped into hydrogeological units, based on similar characteristics and similar low flow responses.

At ungauged locations, the long-term mean flow can be estimated directly using a simple relationship incorporating the annual average rainfall and the potential evaporation, scaled by the catchment area. A simple linear model relates the standardised low flow statistic to the fractional extent of each hydrogeological unit.

Since the shape of the flow duration curve is controlled by the hydrogeological response of the catchment, by grouping together flow duration curves derived for gauged locations with similar hydrogeological characteristics, a family of flow duration curves can be derived. These curves represent the typical response of catchments with different geological characteristics. Therefore, at an ungauged location, the selection of appropriate curves can be determined based on the magnitude of the standardised low flow statistic.

The principles of hydro power estimation

Once the overall flow conditions have been determined for the site of interest, either from gauged data or estimated from catchment characteristics, the designer of a small hydro plant must choose the turbine types that would be appropriate for the site, then identify the range of flows within which the turbines can be operated.



In the Windows environment, HydrA can give an estimation of catchment average rainfall

Manufacturers produce operating envelopes for different turbine types, which indicate the range of head and flow conditions within which the turbines will operate. For the proposed site, the selection of the appropriate turbine types can be determined from the operating envelopes based on the head and flow conditions.

The range of operational flows for turbines is determined by an environmental minimum flow (which must be maintained in the river to sustain fish life) and the requirements of downstream users. In addition, the minimum operating flow of the turbine needs to be taken into account. No turbine can operate efficiently in all conditions — below a certain percentage of the rated flow, the turbine efficiency decreases rapidly as the discharge increases. The rated flow and minimum turbine or environmental operating flow (whichever is greatest), when marked on the flow duration curve, define the usable part of the flow range. A first approximation of the average annual energy output and power potential can be determined by integrating the usable area under the flow duration curve.

The way in which this can be achieved is to divide the usable part of the flow duration curve into vertical incremental strips, for example at 5% intervals on the probability scale. The gross energy for each strip can be calculated, incorporating the flow, the specified head and the known efficiency characteristics of the turbine and the individual components (ie gearbox, generator and transformer). The gross annual average energy output is then the sum of the energy contributions from the individual strips.

However, the net energy output will be lower, to take into account periods when the turbines will not be operational, due to maintenance and repairs. A similar approach can be adopted to calculate the annual average power.

By comparing the energy, power output and capacity, the designer can then determine the optimum turbine type and capacity for the site.

HydrA has been designed to run on a PC with Microsoft Windows. Within the software, the estimation of catchment characteristics, the derivation of the flow duration curve, the selection of the turbine types and the calculation of the power potential are undertaken separately through a series of modules.

The software incorporates raster databases of rainfall, potential evaporation and the hydrological response of soils, plus regionally derived models, which enable the physical and hydrological characteristics of the catchments to be identified automatically. This capability is of particular benefit to designers with little hydrological expertise.

The only pre-requisite for the estimation at an ungauged site is for the user to define the catchment boundary from topographic maps and input the co-ordinate pairs into the software. An example of the estimation of catchment average rainfall is illustrated in the diagram above.

The software also incorporates recognised operational envelopes and efficiency criteria for eight turbine types: cross flow; Francis open flume; Francis spiral case; Kaplan; semi Kaplan; Pelton; propellor; and Turgo.

Automatic estimation procedures can be applied to all user-defined sites. Once the catchment boundary has been defined, each of the modules can be run sequentially. However, where gauged climate statistics or flow data are available, the catchment or flow analysis modules can be bypassed and the next module can be run using the available data. Each module can be accessed through icons from a toolbar or from pull-down menus.

Data can be entered and edited interactively by the user through a series of dialogue boxes and templates, or it can be retrieved from an existing file.

The results from the separate analysis modules are displayed on the screen and can be printed or written to a file for use in the other modules and applications. Such a flexible approach means that the results can be transferred to different software packages for further investigation, such as exporting the power results for economic analysis.

The output is presented such that it is possible to compare the energy, power and capacity output for each of the selected turbine types, thus enabling the designer to determine the optimum turbine type and capacity for the site. This means that the initial assessment of the potential of selected sites for small hydro power schemes can be achieved rapidly and efficiently.

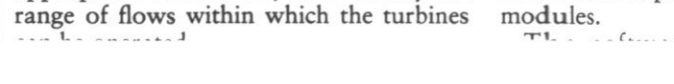
HydrA was formally launched in March 1997, and since then has been used by consultants, regulatory bodies and universities throughout the UK and Spain. Regional models for use in Italy were completed during 1997 and have been incorporated into the program. Documentation for the software is currently in preparation, and it is anticipated that the new package will be released later this year.

Similar applications

Due to the general nature of the design models, similar applications can be developed for any country. Within the current phase of the project the coverage of the Hydro Power Atlas is being extended to include Austria, the Republic of Ireland, Belgium and Portugal.

Additionally, current plans include development of the software in India and Nepal, and interest has been shown by organisations in Albania, Slovakia, Fiji and the Philippines.

**Karen Croker and Gwyn Rees work at the Institute of Hydrology in the UK. Tel: +44 1491 838800, Fax: +44 1491 692424.*



In the Windows environment, HydrA can give an estimation of catchment average rainfall

designer of a small hydro plant must choose the turbine types that would be appropriate for the site, then identify the range of flows within which the turbines

determine the optimum turbine type and capacity for the site.

HydrA has been designed to run on a PC with Microsoft Windows. Within the software, the estimation of catchment characteristics, the derivation of the flow duration curve, the selection of the turbine types and the calculation of the power potential are undertaken separately through a series of modules.

March 1997, and since then has been used by consultants, regulatory bodies and universities throughout the UK and Spain. Regional models for use in Italy were completed during 1997 and have been incorporated into the program. Documentation for the software is currently in preparation, and it is anticipated that the new package will be released later this year.

Similar applications

CALENDAR

3-7 February
An international conference **Renewable Energy - Small Hydro** is to be held in Hyderabad, India, organized by the International Association for Small Hydro and sponsored by CBIP.

Contact: C V J Varma, Member Secretary, Central Board of Irrigation and Power, Malcha Marg, Chanakyapuri, New Delhi 110021, India (Tel: +91 11 301 5984; Fax: +91 11 301 6347; E-mail: cbip@cbipdel.uunet.in).

10-14 February
A **Symposium on Gases in Aquatic Ecosystems** is to be held at Santa Fe, New Mexico, USA, as part of the annual meeting of the American Society of Limnology and Oceanography. The two one-day sessions will cover: Sediment-Water Interactions; and, Water-Atmosphere Interactions.

Contact: Dr. Robert G. Streigl, USGS, Box 25046 Mailstop 413, Denver, CO 80225, USA (Tel: +1 303 236 4993; Fax: +1 303 236 5034; E-mail: rstriegl@usgs.gov).

24-28 February
The **Fifth Nile 2002 Conference** will take place in Addis Ababa, Ethiopia.

Contact: Habib Khoury, Hydrosult Inc., 333 Cavandish Blvd, Suite 410, Montreal, Quebec H4B 2M5, Canada (Tel: +1 514 484 9973; Fax: +1 514 484 5298).

27-28 February
A workshop on **Repair of Ageing Concrete Structures** is to be held in Montreal, organized by the Canadian Electrical Association.

Contact: CEA Repair of Ageing Concrete Structures Workshop, 1 Westmount Square, suite 1600, Montreal, Quebec H3Z 2P9, Canada (Tel: +1 514 937 6181; Fax: +1 514 937 6498).

28-29 February
Powerful Strategies for Acquiring Foreign Energy Assets will take place in New York City, USA.

Contact: Registration Dept., Center for Business Intelligence, 70 Blanchard Rd., suite 4800, Burlington, MA 01803, USA (Tel: +1 617 270 6200; Fax: +1 617 270 6216; E-mail: registrar@cbinet.com).

11-12 March
The 2nd Annual conference on **Successfully Developing Private Power in India** will be held in Washington DC, USA.

Contact: Registration Dept., Center for Business Intelligence, 70 Blanchard Rd., suite 4800, Burlington, MA 01803, USA (Tel: +1 617 270 6200; Fax: +1 617 270 6216; E-mail: registrar@cbinet.com).

12-13 March
A **WEC Regional Energy Forum** is to held in Strasbourg, France, entitled: "Is Europe going to be short of energy? Securing energy supplies for Western Europe: what risks? What strategies?"

Contact: WEC French Member Committee, Madame J. Cauro (Tel: +33 1 4042 6526; Fax: +33 1 4744 5673).

19-21 March
The 18th IAHR International Course - Inverse and Stochastic Groundwater Modelling is to be held in Zurich, Switzerland.

Contact: Dr. F. Stauffer, Institute of Hydromechanics and Water Resources Management, ETH-Hönggerberg, CH-8093 Zurich, Switzerland (Tel: +41 1 633 3079/ 3075; Fax: +41 1 633 1061; E-mail: stauffer@ihw.baum.ethz.ch).

20-21 March
Successfully Developing Private Energy in Colombia will be held in Miami, Florida, USA.

Contact: Registration Dept., Center for Business Intelligence, 70 Blanchard Rd., suite 4800, Burlington, MA 01803, USA (Tel: +1 617 270 6200; Fax: +1 617 270 6216; E-mail: registrar@cbinet.com).

20-21 March
An **International Conference on Ground Anchorages and Anchored Structures** is to be held in London, UK.

Contact: Carol Chin, Thomas Telford Conferences, ICE, 1 Great George Street, London SW1P 3AA, UK (Tel: +44 171 839 9803; Fax: +44 171 233 1743).

20-21 March
A technical workshop to promote small hydropower and the use of a new software package to assess potential schemes ("PC Hydropower Atlas for UK & Spain") will be held in North Hampshire, UK.

Contact: Institute of Hydrology, Software Helpdesk, Wallingford, Oxon OX10 8BB, UK (Tel: +44 1491 692432; Fax: +44 1491 692424; E-mail: softdev@ioh.ac.uk).

25-29 March
The **6th International Conference on Geosynthetics**, will be held in Atlanta, GA, USA.

Contact: Danette R. Fettig, IFAI, 345 Cedar Street, Suite 800, St. Paul, MN 55101-1088, USA (Tel: +1 612 222 2508; Fax: +1 612 222 8215).

26-27 March
The Fourth Central and Eastern European Power Industry Forum, **CEEPIF 97**, will be held in Warsaw, Poland.

Contact: CEEPIF 97, Elly Kreijkes/ Marije Groenenboom, PennWell, Kaap Hoorndreef 30, PO Box 9402, 3506 GK Utrecht, The Netherlands (Tel: +31 30 26 50 963; Fax: +31 30 26 50 928; E-mail: elly@pennwell.com).

7-8 April
Successfully Developing Private Energy in Mexico will be held in New York City, Florida, USA.

Contact: Registration Dept., Center for Business Intelligence, 70 Blanchard Rd., suite 4800, Burlington, MA 01803, USA (Tel: +1 617 270 6200; Fax: +1 617 270 6216; E-mail: registrar@cbinet.com).

7-10 April
A conference on **Maintenance and Refurbishment of Large Motors and Utility Hydro- and Turbo-Generators** is to be held in Florence, Italy.

Contact: Jan Stein, EPRI, 3412 Hillview Avenue, Palo Alto, California 94304-1395, USA (Tel: +1 415 855 2390; Fax: +1 415 855 8759).

12-17 April
The **World Tunnel Congress 97** and Exhibition, with the theme "Tunnels for People", including the 23rd ITA Annual Meeting, will take place in Vienna, Austria.

Contact: ICOS Congress Organisation Service, Johannesgasse 14, A-1010 Wien, Austria (Tel: +43 1 512 8091; Fax: +43 1 512 9091-80).

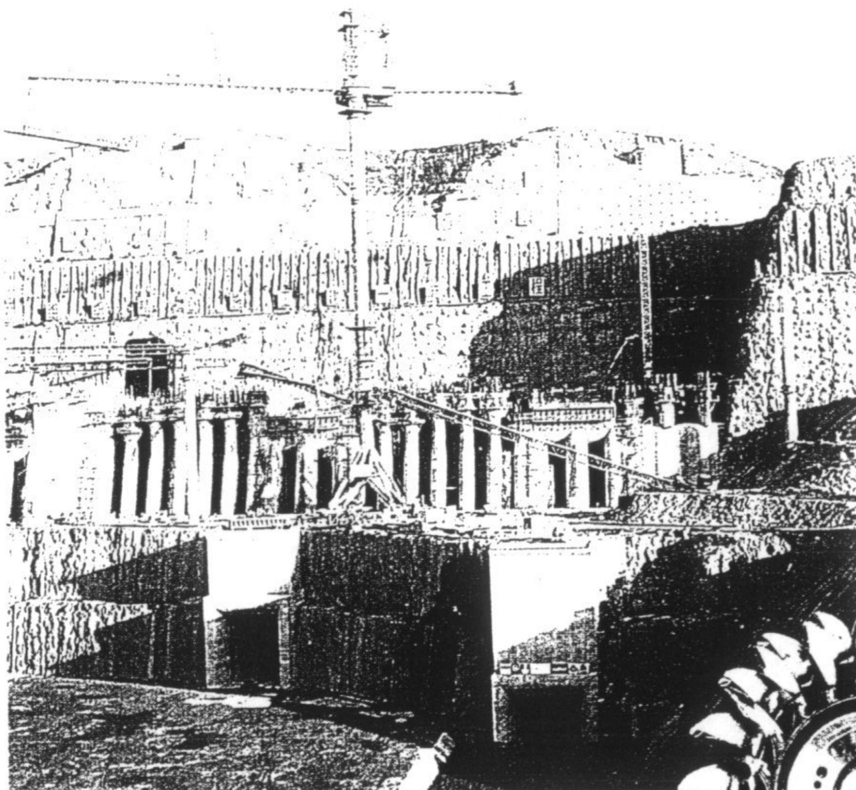
15-17 April
An **International Symposium on Ground Freezing and Frost Action in Soils** is to be held in Luleå, Sweden.

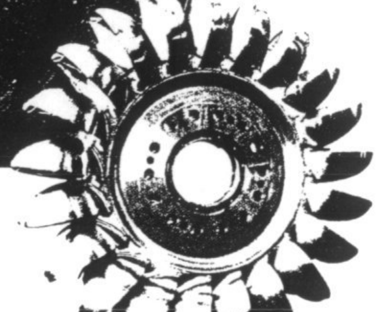
Contact: Prof. Sven Knutsson, Luleå University of Technology, Dept of Civil Engineering, S-971 87 Luleå, Sweden (Tel: +46 920 91332; Fax: +46 920 72075).

17-18 April
A European Workshop entitled **Low-Head Hydropower: New approaches & Innovative technologies** will be held in London, UK.

Contact: IT Power Ltd., The Warren, Bramshill Road, Eversley, Hants RG27 0PR, UK (Tel: +44 118 973 0073; Fax: +44 118 973 0820; E-mail: hydro@itpower.co.uk).

THE INTERNATIONAL JOURNAL ON HYDROPOWER & DAMS





DAM ENGINEERING
HYDROPOWER MACHINERY
WATER RESOURCES MANAGEMENT

Volume Five, Issue One, 1998

the most effective, and will usually dry out a small high speed machine in a few hours. A 1 MW 10 pole machine might take 12 hours.

Manufacturers have different strategies for dealing with an alternator which has been flooded, as opposed to merely exposed to condensation. The bearings must obviously be renewed. Some recommend cleaning and drying using hot air, and others prefer the machine to be returned for steam cleaning and drying.

The long-term reliability of a mini hydro alternator depends on appropriate management of condensation in the alternator. Even anti-condensation heaters will often be no guarantee of safety for shut downs of more than 72 hours in severe conditions. To avoid costly mistakes such as the examples described here, maintenance procedures must clearly set out when and how insulation tests should take place, and how drying should be carried out. - *Andy Brown, Dulas Ltd, Machynlleth, Powys, UK.*

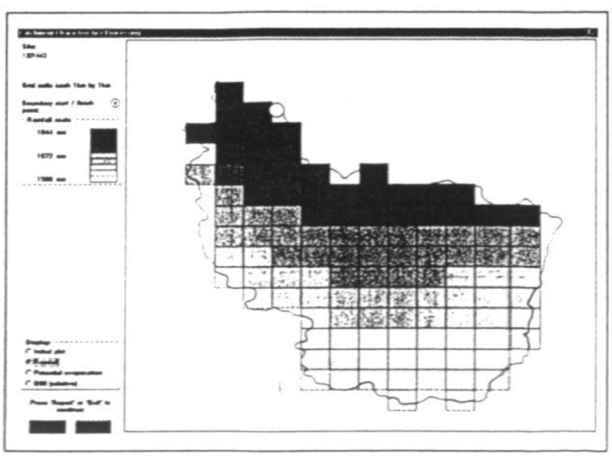
Rapid assessment of small hydro potential

A new software package is available which is designed to assist local authorities, consultants, electricity utilities and potential investors in assessing the feasibility of developing hydropower schemes. Designed on behalf of the European Small Hydropower Association (ESHA), by a consortium of partners including the Institute of Hydrology, Wilson Energy Associates Ltd (UK) and INTECSA (Spain), the 'European Atlas of Small Scale Hydropower Resources' enables users to obtain estimates of catchment details, flow characteristics and the generating potential for a site rapidly and efficiently. Software packages for the United Kingdom and Spain are already available and a package for Italy will be available shortly

Available as a menu-driven software package named HydrA, and designed to run on any personal computer running Windows 3.1 or above, it incorporates grids of standard period average annual rainfall, potential evaporation and low flow statistics (Q_{95} in the UK and Q_{90} in Spain). Regional models are used to enable designers with little hydrological expertise to obtain climate characteristics and synthetic flow duration curves for locations in the UK and Spain. The models have been derived from extensive statistical analysis of national river flow data and catchment characteristics.

Where gauged flow data (the coordinates of the flow duration curve) and climate statistics are available, then the flexibility of the software allows these values to be used in the calculation of power output instead of the estimated values.

Example of a screen image from the HydrA system, showing rainfall distribution in Spain.



When the flow conditions for the site have been determined, the next step is to calculate the generating potential for the site. The rated discharge is provisionally set at the level of the mean flow, although this can be altered by the user. In addition, values of minimum flow and design head defined by the user are required for the identification of suitable turbines for the site.

The selection of turbines is done automatically within the software, using recognised operational envelopes for eight different turbine types. Standard procedures are implemented within the software for calculating the power output and generating capacity from the usable part of the flow range for the selected turbines. The final output from the software is a report giving estimates of gross and net annual average output (MWh), maximum power output (kW) and rated capacity (kW) for each selected turbine type, with the option to display the turbine flow efficiency curves. At all levels within the software, the data can be output to a file for export into other software packages, and the graphical information can be output to a printer.

The European Union's ALTENER programme, which is committed to increasing the uptake of renewable energy sources in the European Union, has funded the second stage, which is about to produce HydrA for Italy and will go on to see HydrA developed in Austria, Belgium, and Portugal. The generic nature of the methods means that similar applications could be developed elsewhere. Countries that have shown interest include Albania, Lithuania, Slovakia, India, Nepal, Fiji and the Philippines.

With funding from the UK Department for International Development, The Institute of Hydrology, in collaboration with the Alternate Hydro Energy Centre (Roorkee), and the International Centre for Integrated Mountain Development, will embark over the next financial year, on a project to develop regional flow estimation techniques for hydropower assessment in India and Nepal.

A workshop aimed at existing and potential users of the HydrA software will be held at the Water Training International Conference Centre in Tadley, UK, on 4 and 5 June, 1998. This will give an overview of the hydrological and technical procedures necessary to estimate a site's hydropower potential. The HydrA software is available at a subsidized price of ECU 400. Further information can be obtained from the Software Helpdesk at the Institute of Hydrology, UK. Fax: +44 (0)1491 692424; E-mail: softdev@ioh.ac.uk.- *G.Rees and K. Croker, Institute of Hydrology, Wallingford, Oxon, UK.*

References

Dooge, J.C.I, " The role of the hydrological cycle in climate". In: Berger et al. (eds.), Climate and Geo-Sciences, 355-366. Kluwer Academic Press; 1989.

ESHA, "Layman's Guidebook on how to develop a small hydro site", Commission of the European Communities, Directorate General for Energy (DG-XVII); 1994.

Gustard, A., Bullock, A. and Dixon, J.M., "Low Flow estimation in the United Kingdom", Report No. 108, Institute of Hydrology, UK; 1992.

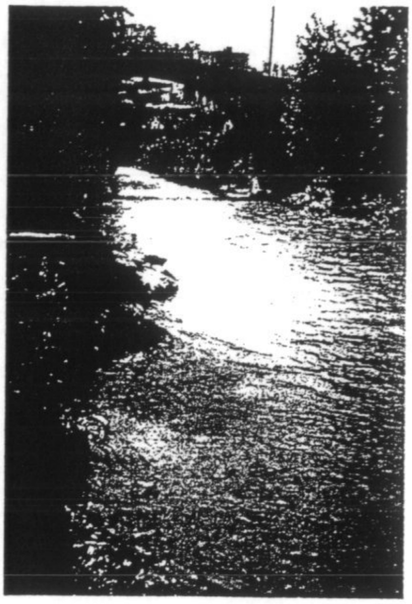
Gustard, A., Irving, K., Rees, G. and Young, A., "Hydrological models for small scale hydropower assessment". Hidroenergia 1995, Milan, Italy; 1995.

This supplement is funded by the Environment, Forestry and Energy Section, Swiss Development Cooperation.

1995/96 highlights

Lebanese Hydrometry (for Litani River Authority and British Partnership Scheme). Advice on rehabilitating river flow monitoring and data processing facilities for the Lebanon, plus provision of computer database software and assistance with publication of a national hydrological databook.

Contact: Kevin Sene



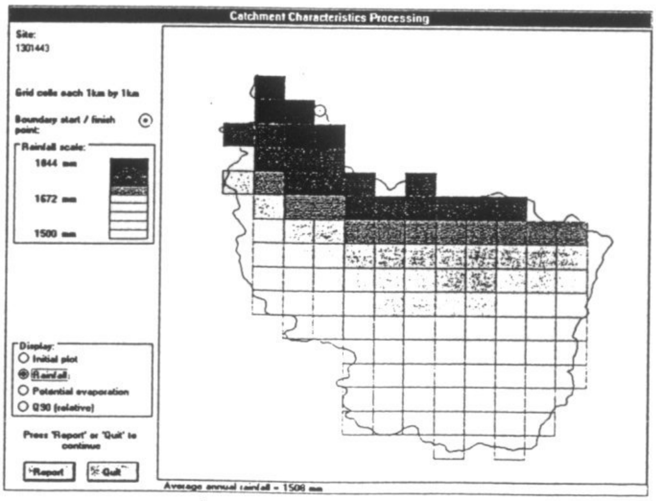
A flow gauging station near Beirut

Combining hydraulic design and environmental impact assessment for flood defence schemes for MAFF involved the integration of the physical habitat model PHABSIM with standard hydraulic design models including ISIS, HEC-RAS and Mike-11. The PHABSIM software has also been enhanced and further objective techniques developed for the Environment Agency to select representative PHABSIM study reaches.

Contact: Craig Elliott

Naturalised river flow records. The development of a consistent automated method has been developed for the Environment Agency's Anglian Region, initially for assessment of the yield of the Ely Ouse transfer scheme.

Contact: Andy Young



Catchment average rainfall derived with the HydrA software

European atlas of small-scale hydropower (for EU Altener Programme). HydrA, the software implementation of the atlas, has been completed, providing a tool to estimate low flows and hydropower potential at any site in Spain and the UK.

Contact: Gwyn Rees

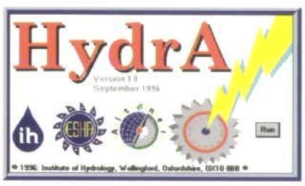
Software Newsletter

Autumn 1996

Institute of Hydrology

Contents

New hydropower package
WIS in Malaysia
HYDATA news
Software Open Days
Launch of RIVPACS III
PC-Quasar news
Micro-FSR update
Land Ocean Interaction Study (LOIS)
Software & support survey



New hydropower package

A new PC Software package is available for planning new hydropower shemes. The European Small Hydropower Association (ESHA) has asked IH to disseminate the software in the UK and Spain. The package, called HydrA, incorporates methods for deriving flow duration curves at ungauged sites and provides a means of using these curves to assess the feasibility of developing small hydropower schemes.

HydrA workshops will be held in March 1997.

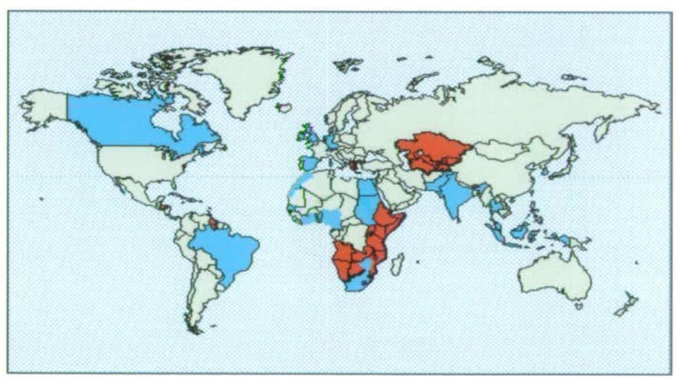
WIS in Malaysia

The Malaysian Drainage and Irrigation Department has commissioned a new hydrological information system from consulting engineers Syed Mohammed Hooi dan Binnie (now called SMHB). The Institute of Hydrology will be undertaking the design work and UTM, the Technical University of Malaysia will undertake the programming. The design work will be based upon IH's Water Information System (WIS), which is a highly generalised system for handling spatial and time series data, and it is already being used for the LOIS project.

For further information about this project, please contact Roger Moore at the Institute of Hydrology.

HYDATA news

HYDATA is now in use in the former Soviet Republics and a Russian version of HYDATA is being prepared. Meanwhile HYDATA (and other IH software) is also moving into South America. Kevin Down from IH has been to Brazil to provide training and technical support for new users. This has enabled a regional training centre to be established at the Instituto de Pesquisas Hidráulicas. The software has been translated into Portuguese and Spanish.



Project data bases — *National databases*

Current global use of HYDATA

The HYDATA utilities (HYMERGE, HYDOUT and HYTRAN) will soon be available as a set — at a discount price. They will of course still be available singly.

Software Open Days

Software Open Days will be held at the Institute of Hydrology on 30 and 31 January 1997. There will be presentations, software demonstrations and the chance to order software at a discount. Information about this will be available on the WWW and full details will be sent to all IH software users nearer the time. Contact us now to ensure your invitation.

RIVPACS III

River InVertebrate Prediction And Classification System (RIVPACS) III is the latest version of a PC-based software package providing biological assessment of rivers. It is produced by the Institute of Freshwater Ecology and based on a classification of over 600 reference sites. RIVPACS III offers site-specific predictions of the macro-invertebrate fauna based on environmental features and sets a "target" for the fauna to be expected in the absence of environmental stresses such as pollution or habitat degradation. The software has applications in river management, conservation and environmental impact studies. It will be available via the Institute of Hydrology.

PC-Quasar

Beta testing of this PC-based water quality and flow model for river networks is almost complete and the software should be available for Winter 1996.

PC-Quasar is designed for use by river regulatory authorities and water and sewerage companies for setting and monitoring River Quality Objectives. It can model river flow, nitrate, biochemical oxygen demand, ammonia, temperature, conservative pollutant or tracer, pH, *E. Coli* and dissolved oxygen.

The model was originally developed for DEC VAX machines; existing VAX users can readily convert their data to run under PC-Quasar.

Micro-FSR update

A program update for Micro-FSR was sent out in June this year. It contains a number of bug fixes and user-requested enhancements. It is being sent to all users of Micro-FSR software under maintenance (i.e. under a maintenance contract or purchased within the last twelve months).

Land ocean interaction study (LOIS)

The £30M LOIS project is looking into the movement of chemicals from the land out into the deep ocean, with the aim of understanding flux and acquiring the ability to predict the nature of environmental change. This project is creating an integrated database of hydrological, chemical, biological, geological and other characteristics across the land, estuarine, coastal, ocean and atmospheric components of the environment.

As part of this, a Rivers Data Centre has been set up at IH. This data centre has created a major database containing various data for the LOIS region (which consists of the east coast of England and the edge of the continental shelf to the west of the Outer Hebrides). At the end of the study the data will be available on CD-ROM as well as being published conventionally. In the meantime the data can be accessed by, or supplied to, interested parties.

For further information about WIS, the LOIS datasets or the IH spatial datasets, please contact Mrs Anne Roberts or Miss Isabella Tindall at the Institute of Hydrology.

More information

For more information about IH software please contact Software Sales & Support at:

Institute of Hydrology
Wallingford
OXON OX10 8BB
Tel: +44 (0) 1491 838800
Fax: +44 (0) 1491 692424
E-mail: softdev@ioh.ac.uk

or visit us at our World Wide Web pages:
http://www.nwl.ac.uk/ih

Feedback

IH Software Sales Support & Marketing team would like to hear from the users of our software. We'd like to know how you view our software and service and what you would like to see from us in the future. If you are a user of IH software, please take a few moments to fill in the enclosed questionnaire. We hope that you'll appreciate the opportunity to comment in whatever way you wish, rather than just being given a sheet of tick-boxes to fill in. We'll give an *exclusive* IH mousemat (pictured right) to the first 100 respondents.

Software & Support Survey Update

Around 250 surveys were sent out — 42 were completed and returned to IH.

Thank you to everyone who completed and returned the Software Sales & Support survey. You should all have received your *exclusive* IH mousemat.

Here are some of the survey findings:

Almost all of you said you would wish to continue receiving the newsletter in the future. Likewise, about half of you wanted more information on current IH software offerings — so a current software list will be included with this newsletter. Some of you provided some good ideas for future newsletters and we will bear these in mind.

Over 70% of you rated the level of service provided by the Software Support section as good. However this does *not* imply that the other 30% gave an "unacceptable" rating — it's just that quite a few did not comment either way, but we hope to improve on those figures anyway.

Over half of you expressed an interest in contributing suggestions or comments on future development of products, while over 60% were interested in joining a user group. We were very pleased at this level of interest and will be considering how best to respond.

Interestingly, despite all the media focus on e-mail and the Internet, the vast majority of you expressed a preference for using the post rather than electronic communication, for both receiving newsletters and participating in user groups, so that is what we will continue to use.

More information

For more information about IH software please return the coupon below or contact Software Sales & Support at the address opposite.

Institute of Hydrology
Wallingford, Oxfordshire OX10 8BB
Tel: +44 (0) 1491 838800
Fax: +44 (0) 1491 692424
E-mail: softdev@ioh.ac.uk

or visit us at our World Wide Web pages:
http://www.nwl.ac.uk/ih

Mailing list update (cont'd)

Please indicate your area(s) of interest below

- Agrohydrology ☐
- Climate change ☐
- Engineering hydrology ☐
- Floods ☐
- Groundwater (including soils) ☐
- Hydro-ecology ☐
- Hydropower ☐
- Hydrometeorology ☐
- IT (archives, etc.) ☐
- Remote sensing ☐
- Urban hydrology ☐
- Water quality ☐
- Water resources (droughts, low flows) ☐
- Other ....

Request for information

Please send me a brochure for

.... software ☐

Please provide further information about software products for higher education

(i) all products ☐

(ii) specific product .... ☐

Software Newsletter

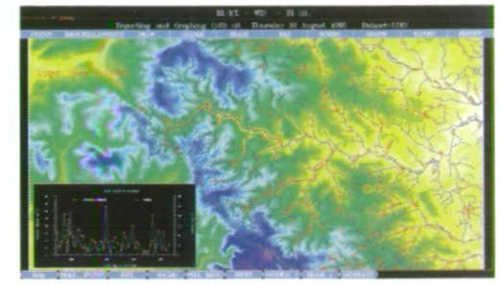
Winter 1997

Institute of Hydrology

Contents

- LOIS — forthcoming CD-ROM series
- HYDATA — Windows version & training
- Brochures on the World Wide Web
- Windows Micro-FSR — flood estimation
- Launch of IHACRES — new product
- Micro LOW FLOWS — retrieval service
- IH software with Windows 95 & NT
- River Flow Forecasting System (RFFS)
- New software deal for higher education
- SWIPS — release of Version 2.0
- HydrA — Hydropower assessment
- Software & Support Survey results

New LOIS CD-ROMs



A new series of CD-ROMs containing the major findings from one of NERC's largest thematic programmes — the Land Ocean Interaction Study (LOIS) — will be available around April next year. The project has studied the movement of chemicals from the land out into the deep ocean, and has assembled a major collection of environmental data spanning the terrestrial, freshwater, marine and atmospheric components of the biosphere. There will be one CD for each component of LOIS, plus one of selected model results. The data on each CD will be assembled into a simple file structure with numerical data presented in widely-used file formats. Documentation files will accompany the data files.

One of the aims of LOIS is to model processes that cross traditonal component boundaries. The outputs from river models can form the inputs to estuarial models. Model results are included to allow work in the area to continue after LOIS and so that future modellers can compare results with those achieved now.

HYDATA Hydrological Database and Analysis Package

Windows version

Work on the Windows version of HYDATA is now at the beta-testing phase and the software is due to go on general release by early 1998.

The initial release will include most of the functionality of the current DOS version as well as some completely new features, including:

- total flexibility in data types, intervals and units
- option for map-based access to the data
- improved rating editor
- greatly improved reporting facilities

HYDATA in the Caribbean

A Regional Training workshop in Barbados for all the Caribbean countries is being planned for September 1998. Some funding has already been promised by WMO and IH will coordinate a further approach to DFID for the balance of the funds after the launch of the Windows version of HYDATA.

A DFID-funded project has already enabled IH to upgrade the copy of HYDATA in St Lucia to version 3.21 and provide a one-week training course. The project also includes a later upgrade to the Windows version.

Institute of Hydrology

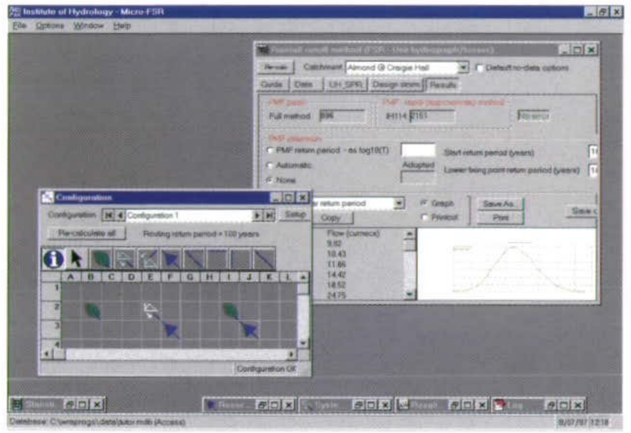
Brochures for some of the Institute's software products can now be be downloaded from our recently updated World Wide Web pages — http://www.nwl.ac.uk/ih

Centre for Ecology & Hydrology

Windows Micro-FSR

Flood estimation package for UK rivers

The Windows version of Micro-FSR is making progress. It is hoped that the software will be on general release in 1998.



The new version of the software provides a number of improved features:

- rapid and semi-automatic recomputation
- rapid access to assumptions and estimates
- pictorial configuration allowing catchments, channels, reservoirs etc to be linked to represent real-world situations.

Micro LOW FLOWS retrieval service

Low flow estimation service at gauged and ungauged sites in the UK

This new, low-cost, service is now available, enabling individuals, companies and consultants to obtain estimates of catchment characteristics and natural low flow estimates for gauged and ungauged locations in England, Wales and some parts of Scotland, without the need to purchase or install Micro LOW FLOWS software. The same service for the rest of Scotland plus Northern Ireland will be available next spring.

Our Web site will soon have more information about what the service comprises. Alternatively contact us direct for further information and costs.

Launch of IHACRES

New software for catchment rainfall-streamflow modelling

IHACRES (Identification of Unit Hydrographs and Component Flows from Rainfall, Evaporation and Streamflow data) employs a transfer function / unit hydrograph (UH) approach to catchment-scale (lumped) rainfall-runoff modelling, developed jointly by the *Institute of Hydrology* and the *Centre for Resource and Environmental Studies* at the Australian National University. IHACRES is a Windows 3.1 compliant application with easy-to-use Windows-style menus and dialogue boxes. An extensive range of graphical data presentations is available along with a summary and general results.

Institute of Hydrology

IHACRES will assist hydrologists and water resource engineers. Applications include investigations in small catchments instrumented for special studies, regional studies using readily-available data for large catchments, quality assurance of strategically important streamflow and rainfall records and use in higher education as an aid to teaching unit hydrograph theory and application.

Notice to Windows 95 & NT users of IH Software

Users who are migrating to new Windows operating systems may experience problems when reinstalling our older software products. In particular, transferring the software copy protection system and installing DOS-based packages have caused problems for some users. We think we know all the answers now, so please call the Software Support Help Desk if you are in difficulty!

River Flow Forecasting System (RFFS)

The Institute has undertaken to produce a generic full function Graphical User Interface for its RFFS. The intention of this work is to make the RFFS more of an "off the shelf" product, although the complexity of the system means that most users will still require some assistance with installation, configuration and calibration.

Contact R. J. Moore for further details

New software deal for higher education

Since 1 October 1997, most IH software is very easily and inexpensively accessible to universities and other academic institutions, thanks to a major restructuring of IH software pricing policy.

The software will allow a number of simultaneous users, making it suitable for teaching groups, whole classes at postgraduate or undergraduate level, or individuals involved in postgraduate study.

However these software licences are strictly for use as teaching and research tools. Commercial use of any kind is not allowed under the terms of the licence.

Please contact us for prices and availability.

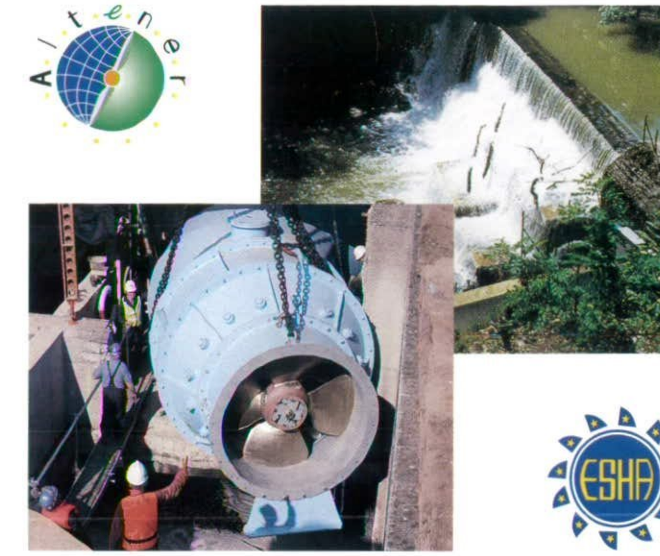
SWIPS — Soil Water Information Processing System

Version 2.0 of SWIPS, including much improved graphics, will be available shortly and will be issued automatically to users under maintenance.

HydrA

Hydropower assessment software

Altener



ESHA

A technical workshop was held in March 1997 to launch the UK version of the hydropower assessment software, HydrA. The workshop was well attended, and copies of the software have been sold to consultants and educational establishments. HydrA is soon to be launched in Spain.

The development of HydrA is continuing, with an Italian version expected next year. A research programme is underway to extend the coverage of the Atlas to include several other European Union countries over the next three years.

If you would like HydrA to be developed for your country, please let us know.

Mailing list update

Institute of Hydrology

If you would like to amend your entry in our records, please complete, detach and return this form:

To:
Software Section
Institute of Hydrology
Wallingford
Oxon OX10 8BB

Tel: +44 (0) 1491 838800
Fax: +44 (0) 1491 692424

E-mail: softdev@ioh.ac.uk

Name ....

Job title ....

Organisation ....

Address ....

....

....

....

Telephone ....

Fax ....

E-mail ....

Institute of Hydrology

Scientific Report 1997-98

Centre for Ecology & Hydrology
Natural Environment Research Council

Understanding and modelling hydrological processes are essential for estimating the spatial and temporal distribution of freshwater resources. A wide range of innovative commissioned studies has been carried out throughout the world, including resource assessment at the continental, country and basin scale, hydropower design, habitat assessment and estimating river flow distributions at the European scale. In response to resource and environmental pressures on permeable systems, new initiatives have focused on understanding both water quality and quantity pathways between ground and surface water systems.

Freshwater resources

ESTIMATING WATER AVAILABILITY FOR SMALL-SCALE HYDROPOWER PRODUCTION

A key aspect of the design of a small-scale hydropower scheme is to determine the hydrological conditions at the proposed site. Many potential sites are in remote areas, where flow measurements — upon which an assessment could be made — are limited or unavailable. The Institute of Hydrology has recently developed a PC-based package, which allows not only the hydrological characteristics but also the hydropower potential to be determined at any site. The package, HydrA, is the result of a three-year research project funded by the European Small Hydropower Association (ESHA) through the Altener programme of the European Union (DGXVII)

The software builds on existing techniques for assessing hydrological regimes that have been developed by the Institute of Hydrology over many years. The techniques focus on the estimation of flow from catchment characteristics at ungauged locations and have previously been applied to the IH Micro LOW FLOWS software, a tool used extensively within the UK water industry for catchment management and water resource planning purposes. Through the development of HydrA, the techniques have been applied to other parts of Europe. The software has already been completed in Spain, Italy and the

New PC-based software to assess hydropower potential at any site

UK and is presently being developed specifically for Austria, Belgium, Portugal and the Republic of Ireland.

HydrA is presented as a menu-driven software package and incorporates regional flow estimation models and databases of climate and hydrogeological response characteristics, plus algorithms for calculating the generating capacities of turbines and annual power output for the site. The regional models are developed for each country based on available hydrometric, meteorological and physiographic data supplied by partner organisations in the representative countries. Statistical analysis of the data is used to identify models for estimating mean flow, low flow statistics and pooled flow-duration curves in each country.

The value of the method has been recognised for application in other parts of the world. The Department For International Development (DFID) is presently funding the Institute in a three-year research project to develop the software for two Himalayan regions in India and Nepal. The work is being carried out in collaboration with the Alternate Hydro Energy Centre in Roorkee, India, the International Centre for Integrated Mountain Development (ICIMOD) and the Department of Hydrology and Meteorology in Nepal. The development of regional low flow models in the Himalayan region poses a significant challenge because of the extreme relief and the seasonal effects of the monsoon.

Contact: Gwyn Rees

Figure 14. Irrigation releases from Tarbela Reservoir

MAINTAINING HYDROPOWER PRODUCTION AT TARBELA RESERVOIR, PAKISTAN

Tarbela Dam in Pakistan harnesses the waters of the Indus to provide about half of the country's irrigation needs, and one third of its electricity. However, the life-span of the reservoir is threatened by sedimentation and, since impoundment in 1974, the reservoir has lost over 20% of its gross capacity. Further, with each year's flood inflow, the sediment delta continues to approach the intakes to the power tunnels, threatening to cut off this huge source of energy to the country. IH has been working with TAMS Consultants Inc., New York, and with HR Wallingford to identify options for extending the life of this vital facility well into the next century.

IH provided long-term inflow series to a reservoir sedimentation simulation model operated by HR Wallingford. We then ran a system simulation model to predict the future irrigation and energy benefits which would be derived from the reservoir under either a

For **Italy**: Important obstacles arise for the autonomous production, as a result of the lack of coordination between the various fields of the national legislation and between the latter and the

local one. Considerable difficulties arise regarding the establishment of hydro plants, due to the opposition by local interest groups which take advantage in this case once more of specific unco-ordinated norms. As a result, they often succeed in blocking or delaying for long time periods the establishment of such plants (**UNAPACE**).

All aforementioned obstacles could be easily overcome by the establishment of a common general framework, within each Member State.
This framework could determine the licence procedures (building/operation) as well as the quali-fications to be satisfied by a plant for obtaining such a licence.

It was precisely that need i.e. for the existence of a general framework, that led CEC/DGXVII to the establishment of the new **ALTENER** Programme, aiming at a greater penetration of the renewable energy sources in the European Community and their integration into the internal market.

3. The role of the European Small Hydropower Association (ESHA)

In the perspective of the aforesaid further development of the small hydropower in the EC, the **European Small Hydropower (ESHA)** was established in 1989, as an initiative of the Directorate General for Energy (DGXVII) of the Commission of the European Communities.

The primary objective of this Association is to represent the interests of the small hydro equipment industry in Europe (i.e. to the general public, national governments, the EC and other organizations), to encourage the exchange of the relevant technology and promote the export of the european expertise throughout the world and finally to study and analyze the relevant environmental, legislative, technical and economic problems.
This objective involves the lobbying of local authorities, national governments as well as the Commission of the EC for the removal of the aforementioned bureaucratic obstacles and the standardization of the regulations, valid in the different Member States.

ESHA can then very well play the role of the promoter/ coordinator of the independent electricity production, inside and outside the European Community, regarding the small hydropower, in close collaboration with all national associations. The unanimous approval of all the EC Member States to re-introduce small hydro in Thermie 94 was achieved recently thanks to a timely co-ordination of all ESHA National Delegates and the submission of a proper argumentation to the CEC/DGXVII. This proves the ideal position of ESHA to be the unique lobby for the promotion of small hydropower inside EC.

If we consider the liberalization of the energy sector of the Eastern European countries and their current actual will to establish the independent electricity production, the importance of that role of ESHA for the small hydropower in Europe is clearly understood.

Thus, ESHA has been establishing contacts with Eastern Europe as well Thirld World countries (e.g. Rumania, Poland, Georgia, Brazil, Costa Rica...), supplying them with all the European expertise they need in their effort to establish or better develop the independent electricity production.

In this framework, ESHA established last year a close collaboration with the Ministry of Energetics and Fuel of the new **Republic of Georgia**.

Today ESHA has **300 full individual members** and some **100 full corporate members** throughout EC, as well as a dozen of associate members in the other countries. All existing national associations in EC are represented in its Governing Board.

Every two (2) years an international conference, called **HIDROENERGIA**, accompanied by an exhibition of small hydro equipment is organized in collaboration with the relevant national associations. It offers to participants from all over the world a unique opportunity for the exchange of experience in small hydropower, including appropriate technology transfer to the developing countries. All new developments in the small hydro field as well as the operation experience are reported and discussed in those conferences.

The first two conferences took place sucessfully in 1989 in Madrid and in 1991 in Nice, while the third is now taking place in Munich.

Furthermore, ESHA carried out for the account of the Commission of the EC a **Comparative Study** on the existing legislation for the small hydropower in the various Member States as well as the **Layman's Guidebook** on how to develop a small hydro site, while it has already elabo-rated the first phase of the **European Atlas** of Small Hydro Resources.

ESHA considered also the environmental impacts of the small hydro plants, one of the problems faced currently by small hydropower producers. In this connection, they adopted the DGB method (débit de garantie biologique) which was elaborated by Hydro M, a French engineering firm (already adopted and used by EAF) and submitted it to the CEC/DGXVII.

Furthermore, ESHA distributed to all national associations a special questionnaire on the various subjects which interest EC autoproducers/future investors (i.e. licencing procedures, tariffs, environmental constrainsts, etc) in their exchange of information. Close contacts with relevant associations in the EFTA countries (e.g. Switzerland, Sweden) will enlarge the scope of this information.

In addition, ESHA has recently submitted to the CEC/ DGXVII a proposal for a new study in the framework of the new **ALTENER** Programme, regarding the establishment of a common insti-tutional framework for the small hydropower in Europe. This should be realised through the development of a set of procedures-guidelines for the licencing of small hydroelectric plants.

A quarterly newsletter, the **ESHA Info**, is distributed in 2000 copies all over the world, promoting in the best way the European expertise in this energy sector.

El mensage de Jorge BABALIS

A word from George BABALIS

Le mot de Georges BABALIS

ENGLISH

The last Governing Board meeting of ESHA took place as foreseen in Brussels on 19th April 1993.
Dr Ch. Jehle of the Future Energies Forum was invited to represent the German organisers of the Hidroenergia 93 and to give exhaustive information regarding the organization of the Conference.
The course and activities of the Association as well as its financial situation were presented by Messrs H. Baguenier, President et G. Babalis, General Secretary.

Thanks to an efficient coordination of the work of all the national delegates who put pressure on the members of the Thermie Committee, the re-introduction of the small hydropower in the Thermie 94 programme was unanimously approved in Copenhagen on 28-30 April. On the occasion of a later meeting held in Brussels early in June, the Committee fixed the maximum installed capacity at 5 MW. The programme supports innovatory and dissemination projects. The call for tenders is expected to be issued by the end of July 1993. ESHA would like to thank the national representatives for their interest and help in this matter.

The first phase of the European Atlas of small hydropower has been completed and the final report has been submitted to the CEC/DGXVII. The DGXVII have asked Prof. Wilson to make a presentation of the Atlas project in the DGXVII premises. It took place mid July. This was also a good apportunity to present our arguments in favour of the second phase.

The Environmental Impact Study of Epsilon will finally be submitted to a workshop of experts on the initiative of ESHA. We remind you that this study has been commented by Mr Mustin (Hydro M) on behalf of ESHA thanks to financial support from EAF. This workshop will be organized jointly by ESHA and the DGXVII and will take place in their premises in Brussels by September. ESHA has already started to contact national associations and other individuals to draw up a list of experts to be invited.

The final programme of Hidroenergia 93 has been issued. It is presented in three languages : French, English and German and has been already distributed to all the members. A special registration fee of 990 DM is offered to ESHA members.

A questionnaire on the administrative procedures, tarifs/buy-back rates and environmental constraints in force in the different member-states has been sent to the national associations. Several answers have already been received. The exchange of this information will help the associations to strive for their interest more efficiently.

The Swiss Association of autoproducers (ISKB/ADUR) have declared their interest in organizing the Hidroenergia 95 in Switzerland. ESHA is awaiting the official proposal.

A delegation of the Swedish Association of auto-producers (SERO) led by their President, Mr Söderberg after having visited Bavaria also paid a visit to Scotland from 13 to 20 June. They were received by Messrs Tom Douglas and Douglas Henderson who informed them on the state of the independent electricity production from small hydro in Scotland.

Mr Jean Cayrol, the managing director of the company Argentine (France), took opportunity of his visit to Central America to meet the competent authorities for energy and informed them on the state of the small hydro in the EC as well as on the role of ESHA. He also represented ESHA in a meeting for the establishment of a small hydro association for Central America (FECAPPE). This association is grouping four countries until now : Costa Rica, Guatemala, Honduras and Nicaragua.

After having met with the representatives of IWB and the DGXVII officials in the premises of DGXVII on 23rd July 1993 on the subject of our study proposal in the ALTENER programme, it was finally decided that ESHA would sign the contract with the DGXVII and that the work of main-subcontractor would be assigned to IWB (through an internal contract). IWB would then be responsible of the choice of its partners.

Hidroenergia looks at world of opportunity

About 300 participants attended the Hidroenergia 95 Conference September 18-20, 1995, in Milan, Italy. The European Small Hydropower Association and the Italian Federation of Scientific and Technical Associations (FAST — Federazione delle associazioni scientifiche e tecniche) organized the fourth international conference. DG XVII, the European Commission's Directorate General for Energy, and others, supported the conference.

Participants heard reports on developments in small hydro and on operational experience, and discussed the future of small hydropower projects in Europe and around the world.

More than 40 papers were presented at the conference, which featured sessions on four aspects of small hydro: 1) economics and politics; 2) technology and engineering; 3) environmental effects; and, 4) the worldwide market, European programs, international cooperation, and financing. Most of the papers contained information specific to European sites, innovations, and strategies, although some papers did address topics involving Argentina, Brazil, India, Mexico, and Nepal.

One thought-provoking paper discussed a new way of assessing an apparently suitable site for development by using the "European Atlas of Small-Scale Hydro Potential" computer software developed for DG XVII. A non-technical developer using the software, in one hour, can obtain a good first estimate of installed capacity and annual energy production for any site on a river in Spain or in the United Kingdom. These countries are the first to be included in the system, which will be expanded to include Austria,

HIDROENERGIA 95

Belgium, Greece, Italy, and Portugal. Other conference presentations of interest covered accidents in small plants, mainly due to poor design or inadequate investigation, and a computer-assisted technique for the design of fish ladders.

Henri Baguenier, president of ESHA, was among invited speakers who addressed the conference. Others invitees included Brian Leyland of Leyland Consultants, New Zealand, and Ken Bovee of the United States Fish and Wildlife Service.

Baguenier spoke of his perception that the energy situation is changing. The quest for energy efficiency is a top priority, and Europe needs to diversify from fossil fuels, he added. While many businesses in the European hydro market are now working in developing countries, Baguenier said, conditions also are favorable for development of small hydro in Europe.

Twenty-five exhibitors displayed their products and services at a concurrent exhibition.

Proceedings are available for 200,000 Italian lirás (US$130) from FAST, Plazzale Morandi 2, Italie-20121 Milan, Italy; (39) 2-76015672; Fax: (39) 2-782485.

—By Eric Wilson, Wilson Energy Associates Ltd, vice president of the European Small Hydropower Association.

Peruca Dam Remediation draws international interest

More than 250 people attended the International Conference on the Peruca Dam Remediation September 20-23, 1995, in Brela, Croatia.

Croatian National Electricity (Hrvatska Elektroprivreda) and the Croatian National Committee on Large Dams organized the conference to disseminate detailed information to dam engineers about the remediation of the rockfill-type dam. In January 1993, former Yugoslav Army and Serbian paramilitary troops occupying the dam set off explosives in the dam's grouting gallery and on the spillway, damaging the dam. Remediation work began later that year, and was completed in September 1995.

Conference participants viewed a videotape that presented the dam's basic technical characteristics and the conditions under which the explosions occurred. Participants later visited the dam to view the scale of the remediation for themselves.

Peruca Dam, on the Cetina River in southern Croatia, is 63 meters tall and 450 meters long. It forms a reservoir that supplies water to a 40-MW powerhouse. Remediation work involved placement of a plastic concrete cut-off wall in the center of the dam, which features zoned cross sections. Both ends of the dam were reconstructed according to the dam's original design.

Conference work was organized into three sections. Session I included presentations on the project's role within the Cetina River power generating system, its occupation and attempted destruction, and the

REPSO VISION

RENEWABLE ENERGY

An Outreach Effort of India REPSO, Winrock International, New Delhi ISSN 0971-9296 Vol 3, April 1998

The Director Visualizes...

World's ' Ecological Capital' is being shared by 6 billion people inhabiting the earth, who are generating 30 trillion dollars of global GDP in their quest for a better quality of life.

It is doubtful whether the societies are following the principle of 'caring and sharing', in order to ensure a good quality of life also for our future generations. Regenerative potential of nature is not uniform and unlimited and so also its 'carrying capacity' and the 'assimilative capacity'.

In respect of energy needs of humanity it has to be realised that :

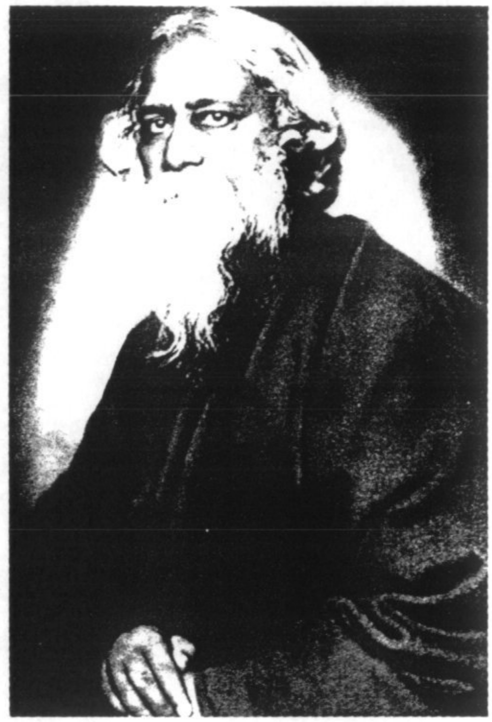
- Energy is required to make available man's fundamental needs for survival.
- Environmental stress on human communities due to deprivation of basic energy based facilities is simply unbearable. A cognizable segment of humanity dies of hunger, heat, cold, floods and droughts.
- Energy needs of man entail significant borrowings of natural resources and in turn refunding pollution and emissions.
- However, there are some forms of natural resources which are replenished by the continuum of nature's self-propelled phenomena like the hydrological cycle, tidal waves etc.

The intriguing question therefore is how best to borrow from the 'basic life support system' locally and preferably tapping the renewable streams so that the energy needs are met without irreversibly exhausting the 'resource base' and without impairing the global environment. At the present juncture, the world needs more environment doers and not merely environment lobbyists.

Revered Ramakrishna Paramahamsa used to say " Don't preach concept of God to a hungry man, feed him first '. Similarly, a poor man deprived of basic energy supply cannot be made to think of global environmental benevolence. For him the very survival of life comes first, then the improvement of quality of life.

A sustainable energy development strategy therefore would have to balance between the survival question of poor communities and the quality of life of not only the present day global population but also the coming generations. Decentralised renewable streams seem to hold local solutions with positive global ramifications.

Dr B.S.K. Naidu



" Trees are the Earth's endless effort to speak to the listening heavens"

- Rabindranath Tagore

(First Asian Nobel Laureate in Literature)

Earth Day (22 April) is an occasion for all of us to reflect on what we are doing to protect our environment. It is time to understand that to ensure a good quality of life for ourselves and future generations, we must act as responsible stewards of our air, our water, and our land, and be proud to pass along a safe, clean world to our children and our children's children.

The Earth is in Your Hands

Hydrology Of Ungauged Streams

India REPSO sponsored "International Symposium on Hydrology of Ungauged Streams in Hilly Regions for Small Hydropower Development" was organized by Alternate Hydro Energy Centre (AHEC), University of Roorkee on March 9-10, 1998 at New Delhi.

Welcoming the delegates, Dr J.D. Sharma, Director, AHEC

naugural Session of the International Symposium on Hydrology presided over by Dr Bharat Singh, x-Vice Chancellor, Univ. of Roorkee, along with AHEC nd India REPSO officials.

appreciated the foresight of India REPSO in sponsoring the symposium on this important subject.

Dr B.S.K. Naidu, Director, (REPSO) explaining the background of the Symposium, pointed out that complex hydrology of hilly streams coupled with scanty discharge data available is a constraint to conceive commercially viable small hydropower projects, which can be minimized by utilizing modern computer modelling techniques.

While introducing the theme and structure of the Symposium, Shri A.K. Goel, Program Manager (Small Hydro) expressed the necessity to bring associated development and research activities on a common exchange forum to assess the state-of-the-art in this sector.

Inaugurating the Symposium, Dr Bharat Singh, Prof. Emeritus, and Ex-Vice Chancellor, University of Roorkee emphasized that utilization of the modern techniques co-relating rainfall, run-off, catchment characteristics and the measured discharge data anywhere in the basin may minimize the risk of hydrology in setting up small hydro projects on streams having little or no observed discharge data.

The symposium was attended by 70 delegates from UK, Canada, Germany, Nepal and India including professionals from organizations like ICIMOD, NHPC, MNES, NIH, UPJVNL, AHEC, UOR, IITO, JNU, UNESCO etc.

Chairing the session on 'Small Hydro Power Potential Estimation', Dr Naidu reminded the international audience that India is a unique monsoon-blessed country near the tropics and at the foot of snowy Himalayas. Its rivers are influenced by monsoon (twice in some states) and snowmelt besides heavy sediment loads making the hydrology extremely complex.

Dr Alan Gustard of Institute of Hydrology, Willingford, U.K. in his presentation described the development of regional hydrological models, which can be used to estimate flows at sites where recorded data is not available.

Gwyn Rees of Institute of Hydrology, U.K. demonstrated HydrA software package, which allows the user to rapidly derive the flow duration curve. Dr S. Demutt of Institute of Hydrology, Germany threw light on issues of regionalization of low flows using a river network approach.

Mr Francis Vitez of LADCO, Kathmandu demonstrated hydrology software 'Hydest' developed for generating hydrological data and flow duration curve for small catchments in Nepal. While Mr Chris

Well-renowned experts from different parts of the world brainstorming on the uniqueness of Indian hydrology.

Kinsley of Canadian Center for International Studies & Cooperation, presented the software 'IMP' developed in Canada for hydrological estimation of ungauged streams.

In his concluding remarks, Dr S.M. Seth, Director, National Institute of Hydrology, Roorkee emphasized on technical co-operation amongst all concerned. The vote of thanks was proposed by Shri Arun Kumar of AHEC.

A tough time for small hydro

Janet Wood reports from IWP&DC's Small Hydro '98 conference

Small hydro is under pressure, Henri Baguenier said when he opened discussions at Small Hydro '98 (held in Athens, on 16-18 November). Baguenier, president of the European Small Hydro Association, noted that in Western Europe the electricity supply industry was mainly a grid market, and conditions were unfavourable to developing small hydro. The electricity price was set by the market, and this was dominated by fossil fuels which were becoming markedly cheaper and more efficient. Small hydro could not compete on a price basis with these other forms of generation.

Meanwhile, Baguenier said, there was less overt support within the European Union for small hydro. Other forms of renewable energy were given more resources and small hydro was in danger of being passed over in the Union's programmes. One important role of ESHA was to lobby for the small hydro community and ensure that this long-established and reliable source of renewable energy was not discounted.

Some other speakers also had warnings for the small hydro community. Hans Peter Hack, for example, noted that in his home country of Germany new regulations were about to be introduced on residual flow that were likely to affect the economics of small plants, and similar regulations were likely to be considered Europe-wide.

But despite these warnings, the mood of the delegates who met in Athens was positive. There were many small hydro plans to be discussed: in the host country, Greece, for example, Kostas Vasilikos from the Centre for Renewable Energies explained that an extensive programme was under way. Twenty projects together providing some 17.3MW were already completed, he said, and a further 110 — adding another 197.2MW — were at issue. It was evident that in Greece, at least, a traditional grid company was showing an interest in new forms of generation: the Public Power Corporation (PPC) had set up its own holding company to pursue renewable energies, according to PPC's representative John Stefanakos, and the company would also be pursuing small hydro.

A similar story was heard from other parts of the world. From Pakistan, Riaz Ahmad Khan of the Ministry of Water Power explained how small hydro power was being developed in the mountainous areas of the North West Frontier Province. Dikendra Raj Kandel of the Lamjung Electricity Development Co explained how his company was setting up projects intended to ensure that local people co-operated and had full involvement with the plant. In Lithuania, delegates heard from Miha Pisljar that while the number of small hydro plants had been decreasing until the mid 1990s, feasibility studies were now under way for up to 40 new plants.

If small hydro had some challenges in the short term, Baguenier said, in the long term its advantages were overwhelming. He said small hydro was 'still the first renewable energy used to generate electricity' and in evidence he cited the more than 10GW of capacity in operation in Europe, providing some 35TWh/y. In comparison, he noted, wind power capacity worldwide amounted to no more than 6GW, and he pointed out that 1kW of wind capacity provided considerably less energy than 1kW of hydro capacity. Small hydro's long history may make it appear to be an industry from the past, he said, but that could not be so, because it was vital in meeting the world's needs for renewable energy. In example, he noted that the European Union intended to double its renewable energy capacity by 2010: this would be impossible without a concomitant growth in small hydro.

But small hydro was similar to other renewables in one respect, Baguenier noted. In a privatised market it would need support, to ensure that investors would have a suitable rate of return. Market economics alone would not meet the objective of increasing the proportion of renewables in the energy mix.

Refurbishment opportunities

Speaking about the history of hydro power in Greece, PPC's Stephanakos noted that Greece had in fact had more small hydro projects in the past than are currently in operation. However, in the years after World War II these small projects had been bought by PPC and closed down in favour of large-scale central generation. Delegates from other countries told the same story: in Russia, for example, there were said to be more than 3000 small hydro projects that had been shut down in the past 40 years, representing an unknown capacity reserve. Several delegates had experience to relate about projects that were enabling long-disused plants to be brought back into operation, notably in Germany and Lithuania.

Delegates were optimistic about the opportunity represented by this huge reservoir of small hydro plants. Conference chairman George Babalis, previously secretary general of ESHA and now with PPC, explained why such apparently obsolete plant represented opportunities. 'The nightmare of small hydro investors is administration', he said, 'and the situation was getting worse and worse'. In France, for example, gaining authorisation for a small hydro project takes an average of six years. Refurbishment is not always free of this burden, he said, but in many cases the load is substantially lighter.

The future

After three days of discussion, delegates left Small Hydro '98 knowing that there was much work to be done to ensure that small hydro achieved its potential. But they left with positive news.

Although the EU had to be reminded of the value of this renewable resource, there was widespread support for reviving the many hydro plants now lying idle. Innovative new financing solutions were being examined, such as plans to operate 13 plants as a singe BOT project in Armenia, and the cost of developing new hydro schemes was being reduced by software tools such as the British Institute of Hydrology's hydro 'Atlas'.

Small hydro does need support, George Babalis said in his closing remarks to the meeting. And if countries are serious about their plans to introduce renewable energy they will have no choice but to give it the support it needs.

Small Hydro 2000

Delegates to Small Hydro '98 were still deep in discussion as the conference closed. The conference convenes again — for the eighth time — in October 2000. More than four years after the decisions were taken at Rio and Kyoto to increase the proportion of renewables used in energy production, we will have the chance to measure progress toward those goals and consider the best ways to ensure that small hydro can play its part. In many countries the pace of privatisation of the electricity supply industry will be increasing, and we will be able to pass on the experience from those operating small hydro plants in an open grid system. There will be new developments in technology, new ideas in financing, and new experiences from those building and reviving small hydro plants.

To register your interest and receive a Call for Papers, contact Jill Greenhalgh on tel +44 1322 277788, fax +44 1322 276474, e-mail: conferences@wilmington.co.uk

Annex F

List of customers who have purchased the HydrA software

UK

SEPA (North Region) (Dingwall)
SEPA (North Region) (Aberdeen)
British Waterways
Environment Agency (Midlands Region)
Scottish Agricultural College
Environment Agency (South West Region) (multiple copies)
Liverpool John Moores University
Oxford Brookes University
Sir Alexander Gibb & Partners
Derwent Hydroelectric Power Ltd
NEL
South West Water Services Ltd
Hyder Environmental
Dougall Baillie Associates
Newmills Hydro
ADAS
Hydro Energy Developments Ltd
Caledonian Energy Ltd
Dr R A Cotton
Dulas Ltd
Scottish Power (multiple copies)
Robert Cuthertson & Partners
Environment Agency South West (site licence)
Carnie Consultancy
National Power (site licence)

SPAIN

Aluminios Cortixo
Institut Catalan d'Energia
Hidroener
Hidroconsa

Centre for Ecology & Hydrology
Component Institutes
Institute of Freshwater Ecology
Institute of Hydrology
Institute of Terrestrial Ecology
Institute of Virology & Environmental Microbiology
Natural Environment Research Council