GREAT-ER

Quarterly progress report: February - May 1998

A. Young

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Institute of Hydrology
Crowmarsh Gifford
Wallingford
Oxfordshire
OX10 8BB

Tel: 01491 83800
Fax: 01491 692424
Telex: 849365 Hydrol G

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1. Summary of Progress

1.1 OBJECTIVES FOR THE REPORTING PERIOD

This report presents the activities undertaken by the Institute of Hydrology during the period 1 February to 31 May 1998 as part of the GREAT-ER project. The overall work schedule for the project is presented in Figure 1.1. The specific objectives to be undertaken during the reporting period have been to:

1. Complete the application of the revised Micro LOW FLOWS to the Don, Rother and Went catchments and to deliver the finalised model to the University of Osnabrueck

2. To continue the provision of flow estimates to support monitoring studies within the selected UK pilot study catchments;

3. To review the costs of developing suitable hydrological models for new member states and to participate in the data sub-group meetings.

4. To cost out a range of requests made by members of the ECETOC core management group in addition to the hydrological work required to support the Lambro pilot study catchment. The objective of this exercise is to enable the ECETOC core management group to identify how the Institute of Hydrology should proceed within the constraints of the remaining budget.

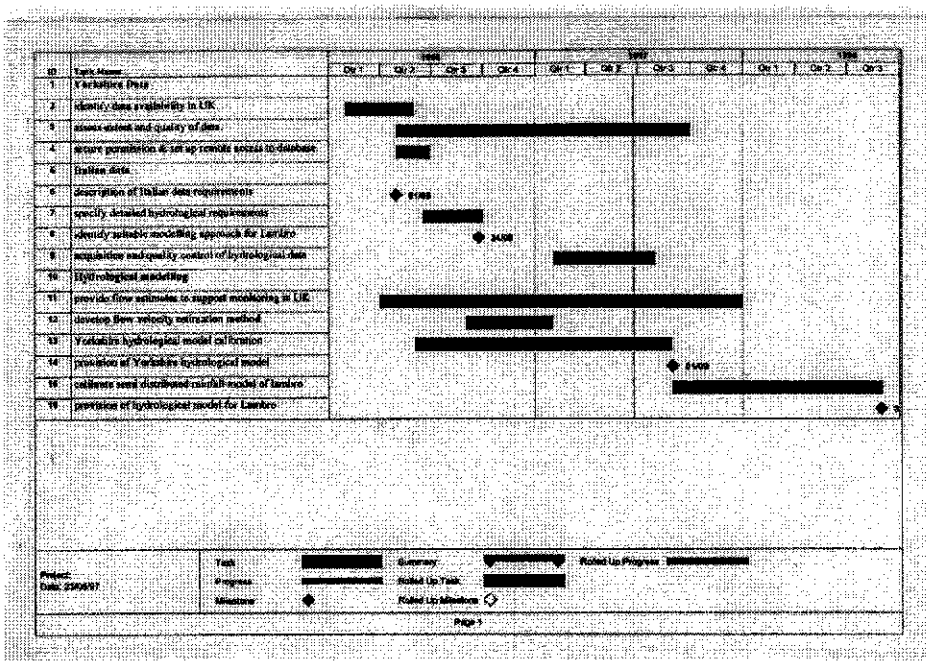

Figure 1.1 GREAT-ER work schedule

In light of 4 the remaining tasks (and associated time scales) in Figure 1.1 should be regarded as provisional. The progress made against these objectives is discussed with the subsequent section.

1.2 PROGRESS DURING THE REPORTING PERIOD

Within the reporting period the application of the revised Micro LOW FLOWS to the Don, Rother and Went catchments has been completed and the model data sets have been passed to the University of Osnabrueck. The provision of flow estimates to support the UK monitoring programme is up to date. A further tranche of estimates will be provided for the last three months of the programme once details have been passed to the Institute.

A working note (No. 9) was submitted to the data sub-group describing typical costs associated with developing a set of multivariate models of the type embodied within Micro LOW FLOWS for a member state. This working note is attached to this progress report as Appendix 1for reference.

The remaining contracted activities for the Institute of Hydrology Work Package relate to developing the hydrological model to support the Italian pilot study catchment. The Institute also has a remaining commitment to provide flow estimates to support the UK monitoring exercise. This is a additional task being undertaken by the Institute at no added cost to the project. The Institute has already undertaken a major additional piece of work relating to velocity estimation.

Following on from the Duesseldorf taskforce meeting IH were actioned to provide a revised proposal for the hydrological modelling activities in Italy and and to provide costed proposals to meet a number of additional requests made by the ECETOC core management group. The costed proposals for these activities are presented in the following section.

At the Duesseldorf data meeting in May IH were actioned to provide a form of words for the GREAT-ER licence agreement to protect third party data sets. A copy of the licence agreement for Micro LOW FLOWS sales is presented in Appendix 2. This licence agreement is a blanket coverage for code, data and documentation and could form the basis of a GREATER licence agreement. It should be noted that this licence has been written with reference to the UK legal system.

2. Proposals for potential future activities

2.1 HYDROLOGICAL MODELLING WORK TO SUPPORT THE LAMBRO PILOT STUDY

This proposal has been developed in collaboration with the University of Milan. The river network has not been fully digitised within and below Milan. Consequently it is not possible to implement a network based model below the Milan. As the pilot study is focusing on the river between Moreno and Milan it is proposed that hydrological modelling activities are focussed within the catchment above Milan and will consider the flow records for the Biassono San Giorgio, Bevera a Colombaio, Lambrugo and Casilino d' Erba gauging stations. Flow statistics from these stations will be extrapolated to ungauged stretches within the digitised river network on the basis of geological, rainfall and area considerations. The primary issue related to differing periods of record for the gauging stations. This is an important issue as a consequence of the large temporal variability in precipitation generally observed in southern Europe. The main tasks will be to:

- fully quality control the available flow data using contemporary rainfall and temperature/ evaporation data;
- calibrate and evaluate a conceptual rainfall runoff model on the available flow data using contemporary climatic data;
- use long term climatic data to extend the period of record data at each gauging station through simulation;
- select a suitable period of record for analysis and statistically summarise the flow regimes at each station using mean flow and Q95 as descriptors;
- extrapolate statistics to ungauged river reaches using a similar framework to that reported for the incorporation of local data within the Yorkshire pilot study catchments;
- export the digital river network and associated flow estimates to the University of Osnabrueck using the agreed Micro LOW FLOWS based formats.

The risks in this strategy relate to the quality of the flow data and the quality and availability the climatic data (daily rainfall and monthly, weekly or daily temperature data) over and above that already supplied by the University of Milan. It is anticipated that a member of the Institute's staff will work under guidance from University of Milan on sourcing these data.

It is anticipated that this work will require approximately 60% of the remaining budget for the Institute of Hydrology and would take approximately five calendar months to complete.

2.2 CONFIGURATION OF MICRO LOW FLOWS FOR THE UK USING THE EEA/BARTHOLEMEWS 1:1M RIVER NETWORK

At the data subgroup meeting the Institute was asked to quote on configuring Micro LOW FLOWS for the Yorkshire area using the 1:1 000 000 scale river network prepared by the Institute of Hydrology as part of the Institute's involvement in the Inland Waters Topic Centre. The network is obviously sparse in comparison to the 1:50,000 network used in Micro LOW FLOWS and it is our opinion that undertaking such an exercise solely for Yorkshire would not be that useful. It is proposed that the Institute should setup the natural version of Micro LOW FLOWS for the whole of the UK based upon the 1:1 000,000 river network and incorporate the artificial influences for Yorkshire in the same way as they have been for the detailed 1:50,000 implementation in Yorkshire. This data set could be exported to Osnabrueck in exactly the same way as for the 1:50,000 network. In addition to the mechanics of undertaking this exercise the Institute would also assess the consequences of this change in scale on a regional stretch based distribution of Mean Flow and Q95 Flow across the whole of the UK through comparison with the 1:50,000 scale implementation Micro LOW FLOWS. This analysis would provide a useful indicate of the impact of changing scale on regional PEC values. It is anticipated that this work will require approximately 35% of the remaining budget for the Institute of Hydrology and would take approximately three calendar months to complete. The remaining 5% of the budget would be retained to fund the provision of flow estimates to support the UK monitoring programme.

The base river network is the copyright of Bartholemews, however the EEA are licenced to provide the network, node matched by IH, to contractors who are undertaking EEA work. The Institute is licenced to use the network within the research context. A licence for the base networks can be purchased for about £1000 from Bartholemews, although the issue of subsequently distributing the networks as part of the GREAT-ER CD would have to be discussed with them. If ECETOC purchase a licence from Bartholemews the Institute, subject to EEA approval, would be able to provide a copy of the entire European network to ECETOC for incorporation into GREAT-ER.

3. Future work

The future work programme is dependent upon the decision of the core management group on the items for future presented in section 2.

Appendix 1

GREAT-ER Working Note No. 9

GEOGRAPHY-REFERENCED REGIONAL EXPOSURE ASSESSMENT TOOL FOR EUROPEAN RIVERS: GREAT-ER

TECHNICAL REQUIREMENTS DOCUMENT HYDROLOGICAL MODELLING: PHASE II

Working Note No. 9

A.R.Young

April 1998

Institute of Hydrology
Crowmarsh Gifford
Wallingford
Oxfordshire
OX10 8BB
UK

Tel 01491 838800
Fax 01491 692424

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1. Introduction

This document presents technical and financial requirements for the hydrological modelling component of GREAT-ER PHASE II. The requirement is based around the development of country specific statistical hydrological models for predicting natural mean flow and flow duration statistics with the models implemented within the Institute of Hydrology's river network based software package Micro LOW FLOWS V3.0 (name subject to revision). Micro LOW FLOWS V3.0 is the Windows95/NT compatible rewrite of the Micro LOW FLOWS V2.1 software used within Phase I of GREAT-ER.

The costs within this document reflect the Institute's experience in the acquisition, processing and modelling of European hydrometric and spatial data. These costs should be treated as guidance costs that should be considered when letting model development contracts. This document does not consider software costs as the Micro LOW FLOWS V3.0 hydrological modelling shell will provide all of the required functionality for the hydrological model. It should be remembered that ownership of Micro LOW FLOWS V3.0 will lie jointly with the Institute of Hydrology and the UK Environment Agency with the majority of the Intellectual Property Rights (IPR) held by the Institute. The costs associated with compiling requisite data to describe the impacts of artificial influences (surface and groundwater, abstractions, discharges, reservoirs, canals, inter-basin transfers) is also not considered within this document. The availability, quality and costs associated with these data will vary greatly both between European member states and between specific regions of a particular member state. It is proposed that a review of these data should be undertaken when assessing the feasibility of extending GREAT-ER coverage to a new member state.

The Institute of Hydrology has, through the project "European Atlas of Small-Scale Hydropower Resources" developed statistical models for Italy and Spain and will be developing similar models for Belgium, Ireland, Austria and Portugal. This project has been funded by the Alternative Energy (ALTENER) Committee of the CEC who hold the IPR associated with the models. It should be noted that the development of these models has been resource constrained and thus the development has tended to focus on those parts of the country that are suitable for hydropower production. These areas, by definition, tend to be upland areas. If any of these models were to be used in GREAT-ER consideration should be given to improving the representation of lowland areas within the models.

The tasks required to develop a model for a member state include the development of a river flow and spatial database, deriving relationships between river flows and catchment characteristics and the implementation of these methods within a software environment. The software environment is required to facilitate the estimation of both natural and artificially influenced (or actual) flow statistics at any point within a digital river network of an appropriate resolution. The technical tasks are outlined in sections 2 to 6, the implementation and a proposed management structure, including example budgets, are presented in section 7.

2. Overview of the Development and Implementation of a Model for a Member State

This section summarised the steps in developing a hydrological model of the type employed within Micro LOW FLOWS and used within the Yorkshire Pilot Study area. These steps cover the compilation of requisite data sets, and overview of the modelling procedure and the feasibility of developing a Pan European version of Micro LOW FLOWS. The Institute of Hydrology submitted a report to the GREAT-ER core management committee on the availability of relevant data sets across Europe at the Wallingford Enlarged Taskforce Meeting in 1997.

2.1 RIVER FLOW DATABASE

The basic requirement for the development of statistical relationships between the flow regimes and the catchment characteristics is to establish a database of river flow data of acceptable quality. The key steps in the development of a coherent, high quality database are listed as:

1. The selection of gauging stations in each country which satisfy the following criteria: catchment size less than 2000 km^2 (depending on the proposed scale of the model) good hydrometric quality; minimal artificial influences; complete daily flow records of 10 years or more (depending on inter-year climatic variability). As a rule of thumb, flow records for 200 or more sample catchments are required to develop the regional model in the larger European countries (e.g. Germany, France, UK, Spain, Sweden) and 100 or more for the smaller countries (e.g. Portugal, Denmark, Ireland). Obviously the quality of the model will improve as the sampling density increases. Note that the UK model with Micro LOW FLOWS is based on approximately 700 gauged flow records.

2. Compilation of a master list of gauging stations including the following details for each of the stations selected in 1: river name; site name; location in an appropriate coordinate system (usually UTM); catchment area; mean rainfall.

4. Transfer of the flow data in a standard format to the database at the Institute of Hydrology (or alternative contractor);

2.2 SPATIAL DATABASE

A central component of estimating catchment characteristics is the ability to overlay digital catchment boundaries for the selected gauging stations over raster thematic maps of catchment characteristics. Catchment characteristics that would be significant for the development of procedures include:

(i) The hydrological response of a catchment (e.g. soils/geology, topographic characteristics (mountainous areas));
(ii) Rainfall (annual & seasonal);
(iii) Potential/Actual Evaporation (annual & seasonal);
(iv) Temperature (annual/seasonal) where sub-zero temperature commonly occur in winter;
(iv) Topographic catchment boundaries.

2.3 RELATIONSHIP BETWEEN RIVER FLOW AND CATCHMENT CHARACTERISTICS

The current statistical hydrological model is primarily based on a multivariate regression model for predicting a specified low flow index coupled with a water balance model for estimating mean flow. The UK model has been fully described within the Institute of Hydrology reports on GREAT-ER Phase I, a summary of the core of the UK model is presented here. In the multivariate model an appropriate low flow index, calculated from the flow records, is regressed against the proportional extent of key catchment characteristics within the topographic catchment boundary for selected gauging stations. This analysis yields a relationship between the low flow index and catchment meterological & geological characteristics. These relationships can be applied on a regional basis to estimate the low flow index. Further pooling analyses use the estimated index value to predict the full flow duration curve. The mean flow model is also calibrated against the mean flow values for the selected gauging stations.

It is important to note that the important aspect of the multivariate modelling is to construct a conceptual model describing the hydrological functioning of the system and then to statistically model the system, using the results to refine the conceptual model as appropriate. Note that the conceptual model structure, and hence the structure of the statistical model may vary from hydrological regime to hydrological regime. For example seasonality of rainfall is not a prime component of the UK model as the UK rainfall climate is not strongly seasonal, with the inter- year variability in rainfall being of the same order as the between year variability. This will not be the case in Mediterranean Europe where the seasonality of rainfall is important. Also the statistical tools used to build relationships will also vary as research continues.

2.4 IMPLEMENTATION WITHIN A RIVER NETWORK FRAMEWORK

The implementation of natural hydrological models within a river network framework and the associated incorporation of the impact of artificial influences and local hydrometric data is described with the Institute of Hydrology's reports on GREAT-ER Phase I. The UK implementation of Micro LOW FLOWS uses digital rivers derived by the Institute of Hydrology from the UK Ordanance Survey 1:50,000 map series.

The status of the availability of digital rivers in Europe was discussed in the IH report on pan

European data availability. The compilation of the 1:1000,000 scale digital rivers data set for Europe discussed in the report has now bee completed at the Institute. The estimation of catchment boundaries using the USGS Digital Elevation Model proved to be unsuccessful due to coarse resolution of the DEM. To generate the catchment boundaries the river networks have been imported into the Micro LOW FLOWS frame work and the two dimensional catchment area estimation method used within Micro LOW FLOWS is currently being used to derive the 1000 largest catchment boundaries. This demonstrates the utility of the Micro LOW FLOWS approach at the Pan European scale.

3. Schedule of Technical Activities, Manpower Inputs and Example Costs

This section summarises the manpower requirement to compile, develop and implement the natural hydrological model for two hypothetical EEC member states. There are 28 distinct tasks that have to be undertaken when developing an model of this type for a member state. These tasks form 4 distinct groups:

1. Project management
2. Establishment of the river flow database
3. Establishment of the spatial database
4. Regional hydrological modelling and implementation of the models in the a river network based software modelling shell (Micro LOW FLOWS in GREAT-ER Phase 1).

The manpower requirements and associated costs for a medium size member state with generally centralised hydrometric data of reasonable quality are presented in Table 3.1. The manpower and associated costs for an equivalent member state where data availability is poor and of dubious quality are presented in Table 3.2. Note that these figures should be regarded as guideline figures only and that the manpower inputs are expressed in man weeks over a two year project duration. A manpower cost of 46.6 ECU/hr and a 7.4 hour day were used in estimating costs.

The management structure adopted is one of a Hydrological Consultant (HC) managing the data acquisition, development of the model and the implementation. The implementation is based on Micro LOW FLOWS V3.0 being available for use on the project and thus excludes cost of the development of an equivalent system if required. The HC would work in parallel with a National Hydrological Organisation (NHO) within the target member state who would undertake the sourcing of data in accordance with quality guidelines defined by the Hydrological Consultant. Having an NHO involved in at least the data collection issues is regarded as being essential. The breakdown of costs for a medium size EEC member state where data availability is good and the data are of good quality is given in Table 3.2. These are guideline costs based on the Institute's experience in developing the European Small Hydropower Atlas for some member states.

Table 3.1: Medium sized member state where data is readily available and of reasonable quality

TASK	Man Power Weeks		Costs	ECUs
PROJECT MANAGEMENT	NHO	HC	NHO	HC
Appoint National Consultants		1		1433
Progress meeting	2	2	12866	2866
Progress reports		2		2866
Final Report		2		2866
ESTABLISH FLOW DATA				
Master list of gauging stations	1	1	1433	1433
Gauging station selection	3	1	4299	1433
Process of flow records	4		5732	
Transfer of data to HC		1		1433
Quality control of flow data		3		4299
ESTABLISH SPATIAL DATA				
assemble maps & draw catchment boundaries	6	1	8599	1433
Digitise boundaries	5	1	7165	1433
Assemble climatalogical maps	3	1	4299	1433
Assemble physiographical maps	2	1	2866	1433
Digitise clim & physio. Maps		4		5732
Process clim. & physio. Maps in GIS		3		4299
Load boundaries into GIS		2		2866
Overlay catchment boundaries		3		4299
Database of catchment charact.		2		2866
REGIONAL ANALYSIS				0
Development of conceptual model		3		4299
Analysis of Clim. & Physio. Maps		2		2866
Development of model		11		15764
Incorporation Into Micro LOW FLOWS		3		4299
Evaluation and uncertainty analysis	2	2	2866	2866
Total manpower costs			50127	74521
Computing & consumables				10290
T&S				5000
Total costs				**139938**

Table 3.2: Medium sized member state where data is not readily available and is of poor quality

TASK	Man	Power Weeks	Costs	ECUs
PROJECT MANAGEMENT	NHO	HC	NHO	HC
Appoint National Consultants		1		1433
Progress meeting	3	3	4299	4299
Progress reports		2		2866
Final Report		2		2866
ESTABLISH FLOW DATA				
Master list of gauging stations	2	1	2866	1433
Gauging station selection	6	1	8599	1433
Process of flow records	6		8599	
Transfer of data to HC		1		1433
Quality control of flow data		5		7166
ESTABLISH SPATIAL DATA				
assemble maps & draw catchment boundaries	6	1	8599	1433
Digitise boundaries	5	1	7165	1433
Assemble climatalogical maps	4	1	5732	1433
Assemble physiographical maps	4	1	5732	1433
Digitise clim & physio. maps		4		5732
Process clim. & physio. maps in GIS		3		4299
Load boundaries into GIS		2		2866
Overlay catchment boundaries		3		4299
Database of catchment charact.		2		2866
REGIONAL ANALYSIS				0
Development of conceptual model		3		4299
Analysis of Clim. & Physio. Maps		4		5016
Development of model		15		24363
Incorporation Into Micro LOW FLOWS		3		4299
Evaluation and uncertainty analysis	3	3	4299	4299
Total manpower costs			55891	91003
Computing & consumables				10290
T&S				5000
Total costs				**162183**

To place these costs in context, the total development cost of developing and implementing the models within Micro LOW FLOWS over the last seven years for the whole of the UK (excluding software costs and the incorporation of artificial influences) amounts to approximately 742,000 ECU. As there are more than 300,000 river reaches in the UK this equates to <2.5 ECU per stretch for a flow duration curve.

Appendix 2

Micro LOW FLOWS LICENCE TERMS AND CONDITIONS

N.B. In this agreement "you/yours" refers to you, the Licensee and "we/us/ours" to the Licensors and "the Program" the package named overleaf which normally comprises the executable program files, data and installation files on magnetic or optical media, and user manuals.

We provide the Program and we hereby license you use it. You are responsible for how you use the Program to achieve the results you intend, and for the results obtained.

Terms and Conditions

1. The Program is our proprietory product and thus protected by UK Copyright Law. We reserve all rights of ownership and copyright in the Program.
2. In consideration of the licence fee paid (if any) we grant you a personal, non-exclusive, non-transferable licence to use the Program.

3. **You may:**

3.1 install and use the Program on a computer which includes the Central Processing Unit (CPU) identified by the unique number or code (if any) shown overleaf. This computer system should not generate more concurrent executions of the Program than the Number of Concurrent Runs allowed in this licence agreement and we reserve the right to check this.

3.2 transfer the Program onto another computer provided that at any one time your computers are nor running more copies of the Program than the Number of Concurrent Runs allowed in this licence. If your licence specifies a CPU number you must notify us of the new number.

3.3 make full or partial copies of the Program for back-up and archive purposes only, provided you label such copies clearly with our name, the name of the Program and the date of this licence.

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4. **You may not:**

4.1 Transfer, assign, rent, lease, sub-license, sell, give or otherwise dispose of this Program except as stated in the licence.

4.2 Reverse compile, disassemble, or otherwise reverse engineer the whole or part of the Program.

4.3 Modify, adapt or translate the Program in any way.

4.4 Merge the whole or part of the Program with any other software other than that strictly required by the operating system stated in this licence agreement.

4.5 Reproduce, distribute or alter the Program documentation.

4.6 Export or re-export the Program without the appropriate United Kingdom or foreign government licences.

4.7 Reveal the source code (if supplied) to a third party.

If you do any of the foregoing without our express permission, this agreement will be breached and your licence automatically terminated. Such termination shall be in addition to and not in lieu of any other legal remedies available to us.

5. **Your responsibilities**

5.1 You are responsible for installing and commissioning the Program onto your computer system(s) unless we have agreed in writing to do so.

5.2 You must ensure that proper security precautions are followed to secure back up copies of the Program, and that an effective control is kept on the number of copies of the Program.

5.3 Beyond training specification contained in the schedule 1 you must train the staff that run this Program to understand its purpose, operations, and limitations. You are responsible for how you use the Program.

5.4 You are responsible for the interpretation of the results produced by the program.

5.5 You must treat this Program and its documentation as confidential. You must not disclose any part of it to another party without our permission, even after the licence has been terminated.

6. **Term**

6.1 You are licensed to use the Program for the duration specified overleaf, from the date of issue stated in this agreement.

6.2 You may terminate your licence and this agreement at any time by returning it to us together with the original media and user documentation of the Program.

6.3 This licence will terminate immediately if you fail to comply with any term or condition of this agreement.

In the event of any termination you must destroy all full or partial copies of the Program resident on your computer system(s) in any form and you agree to provide us on request a written certificate of such destruction.

7. **Warranty and Liability**

7.1 If a diskette or other media of the Program is defective we will replace it at no charge provided the defective item is returned to us within one year of the date of purchase.

7.2 We do not warrant that the functions contained in the Program will meet your requirements or that the operation of the Program will be either error-free or appear precisely as described in any documentation describing the Program. However we do warrant the functions meet the requirements specified in the schedule 1 and that any errors will be corrected in accordance with the procedure specified in the schedule.

7.3 We agree to indemnify you against any claim that the Program infringes the United Kingdom copyright of any Third Party except if the claim arises out of the use of the Program in combination with any equipment (other than your computer system(s)) or any other software. You must notify us immediately of such a claim and let us conduct any negotiations or

proceedings with the Third Party.

7.4 Subject to 5.3 and 5.4 above, we do not seek to limit or exclude liability for personal injury or death arising from our negligence.

7.5 Except for 7.4 above our entire liability for any breach of our duties, whether or not attributable to our negligence, is limited to the licence fee you have paid for the Program.

7.6 Except for 7.4 and 7.5 above, in no event will we be liable to you for any damages, including lost profits, lost savings or other incidental or consequential damages arising on your use or inability to use the Program even if we have been advised of the possibility of such damages.

8. **General**

Should any of the provisions in this Licence Agreement be ruled invalid under any law or Act of Parliament, they shall be deemed modified or omitted only to the extent necessary to render them valid, and the remainder of the Agreement shall be upheld.

9. **Governing Law**

This Agreement is subject to the jurisdiction of the English Courts