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# Hydroinformatics in 1999: what is to be done?

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## ABSTRACT

Some possible directions of future evolution of hydroinformatics as seen from the recently observed social demand point of view are indicated. Among key issues concerning water resources management, hydroinformatics can contribute by defining a coherent methodological approach for negotiation of the most relevant water-related conflicts. The latter require however equitable access of all stakeholders and parties in conflicting situations to reliable information and objective tools allowing assessment and evaluation of a family of feasible solutions. Rapidly changing Information and Communications Technologies (in particular Internet applications) will have also their impact on the way water-related industry will use the modelling software and an appropriate experience.

**Key words** | DSS, future of hydroinformatics, modelling, telematics for environment, water resources management conflicts, water industry

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## INTRODUCTION

This paper is written for the especial benefit of the *Journal of Hydroinformatics* and, more specifically, for its first issue. The very term *hydroinformatics* has many definitions and covers many ideas, according to who attempts to define it. Nevertheless, there is a consensus that hydroinformatics, considered as a technological activity, cannot be defined as a 'hard' science. To the contrary, it is regarded as a bridge that aims to close at least several gaps between 'hard', water-oriented sciences, technologies and activities on the one hand, and such 'soft' social requirements as sustainable development, legal regulations and political aims on the other. The concept of citizen-oriented technology development, or of information-society technologies (ISTs), has appeared with more recent intrusions into everybody's life of exponentially growing communication and information technology applications. It is interesting to note that this phenomenon, historically unique in terms of its acceleration and the speed of its diffusion, is considered in different ways in Europe and elsewhere, e.g. in the USA. The United States is considered more advanced compared with Europe because, in very pragmatic ways, new technologies are adopted, used and applied on a very large scale, mostly as convenient tools, 'without questions asked'. Market-driven developments are applauded (except for the Microsoft anti-trust lawsuit) and the creation of hundreds of thousands of new jobs thanks to these initiatives provides a positive feedback to the initial momentum. The European approach, as expressed and shaped by the 3rd, 4th and 5th Framework Research and Development Programmes funded by the European Union (EU), is more 'intellectual' (or should we say 'Cartesian'?). It tries to define general trends and currents, providing an overall profile of the future as shaped by the new information revolution. It hopes to lay wider societal bases and to achieve, through more synergy-oriented actions and incentives, a qualitative jump *integrating* new technologies *with* human activities.

Applications in the domain of telecommunications, television, multimedia educational tools and citizen-oriented activities financed by the 4th and 5th EU Framework Programmes are typical examples of this more European approach and way of thinking. The applications are often supply-side or 'upstream' conceived, intellectually planned and less spontaneous than in the USA, where industry and citizens take and use as such whatever appears on the market without 'upstream' changes in their behaviours and organisations.

Everyday telematics applications oriented towards the large public can indeed be directly market driven, in the American way. They are explicit for the end-user, the consumer, who uses the telephone continually, views television every day, buys a computer and links it to the Internet and so on. All this is done quite naturally without having any knowledge about the technical solutions, problems and difficulties. These, including the future integration of Internet and television and the formation of a global telecommunications network, are solved by producers and offered in a turnkey fashion by suppliers. The telematics applications industry knows the end-user language and the market; the profit margins are so big that to find money for necessary investment and marketing is no problem. Governments can never resist very long in the face of such market forces in Europe just as in the USA. The example of the number of digits allowed in French message encryption is eloquent: the French government, evoking national defence interests, resisted less than a year before allowing the total liberalisation of this issue.

The domain of water supply, civil-engineering works, planning and project concept and development, is closely related to environmental problems and hence to politics and citizens. Budgeting for these developments in Europe, at least, is nearly exclusively administered by governmental agencies and it is very far from being governed by the market alone. It is then not surprising that the hydroinformatics concept has been born within this field of activities, and in Europe, because it deals precisely with integration and linking of various domains, the rise of such concepts from conventional market activities alone would be difficult. There is an analogy between this situation and that of computational hydraulics and numerical simulation some 25–30 years ago, when European advances compared with American civil engineering practice was based on an overall integrated reflection rather than on the simple applications of market-available tools to traditional methods. Nevertheless, the concept of hydroinformatics is spreading rapidly and any novelty is today of very short duration. Current global information network systems see to that!

However, there is the question of the near future. What will become of hydroinformatics: how will it be transformed and in what directions, taking account of the fact that it was built originally upon the foundation of numerical modelling of hydraulics and hydrological phenomena? And 'What is to be done in the way of further developments and applications?': a question that the hydroinformatics professional community, as well as other communities interested in water-related problems, should ask today. We do not have the ambition to supply a credible answer to this question here, and even less the ambition to influence the future in a serious way.

Taking as a departure point our understanding of hydroinformatics as driven by end-user requirements, Information & Communications Technologies (ICTs) applications in the water area ('the proof of the pudding is in the eating'), an effort can be useful to try to enumerate at least some causes of change, some emerging trends and premises, and some possibilities that are seen today, such as:

- water-related conflicts, decision making and hydroinformatics;
- hydroinformatics and industry (water industry, consulting and contracting companies, software developers): strategy, possible changes and trends;
- current technical and conceptual developments and trends for the near future.

That is the purpose of this paper in which several of these aspects are discussed.

## CONFLICTS, WATER AND HYDROINFORMATICS

It is likely that water-related problems will be in the near future (with a timescale of, say, ten years) the essential and main source of difficulties and conflicts, all over the world. Why water? Because, even if most people do not realise the situation today, the scarcity of water will probably become an acute reality to them before the scarcity of oil or of breathable air.

There is a near certainty that several water-problem-triggered, serious political conflicts will occur within a short time. It is only a question of where it will begin, but the locations of focal points in the Middle-East, Africa, South America and Asia are well known to everybody; there is no need to enumerate them. How long will it take before Clausewitz's definition of war as 'politics carried out with other means' will become true in the field of water politics and lead to a danger of armed conflicts?

However, even without going into even these not-so-distant futures, one witnesses, on every economic level, a continuous procession of political and economic conflicts linked to water scarcity and water quality and, sometimes, on the other boundary of the scale, of water fury (inundation, flash floods, etc.). Let us mentioned just a few of these.

## Agricultural pollution by nitrates and pesticides

The degree of pollution of groundwater reserves and the timescale of the consequences have only begun to be understood by the population of European countries. The consciousness of the irremediable catastrophic effects that will be felt during scores of years because of the slow rate of underground water transport only now begins to penetrate people's minds. In France, for instance, we observe political and violent demonstrations of farmers *against* proposed taxes on water polluters (i.e. fertiliser and pesticide users) *and*, at the same time, *for* governmental financial aid to farms which cultivate biologically 'clean' products rather than the 'production-efficient' farms, privileged by an EU subvention policy, which use pesticides and fertilisers intensively and extensively.

## Dams and reservoirs

There is no way in France to build a dam, even if the purpose is to ensure water supply to the cities or to a maintain minimum quality in the river downstream, or to protect the valley against floods. Political conflicts, local and national, over the preservation of existing valley landscapes make the decision process not only continue for decades but most often lead to a political deadlock. A typical example is the river Loire and its tributaries and the quarrels (which have now lasted for 15 years) over two dams: Chambonchard on the Cher river and Veurdre on the Allier river. It is doubtful that they will ever be built, unless there occurs an exceptional flood causing so much loss of life and so much material damage that sheer terror will make people change their views; and the result in that case may not necessarily be better than the current 'do nothing' attitude. Some years ago in Southern France during a summer drought, there were two demonstrations within only a 3 week interval: one against a proposed dam (because of its ruining the landscape) and another for the same dam because the summer was very dry and the river transformed itself into a stinking sewer killing all fish; a dam, if built, would at least have maintained a minimum discharge.

## Financing the structures

Water systems ask for important investments, and the acquisition of the funds necessary for these investments is a key problem in the decision process. Funding is paradoxically more and more dependent not so much (or not only) upon banks but also upon groups of citizens, their associations, environmental organisations and other such bodies. This phenomenon is international and the conflicts over the decision 'to build or not to build' are more and more frequent. The first well-known example is the Narmada Dam (in India), a saga continuing over the past 5 or 7 years: the World Bank, under the pressure of public opinion, attached several conditions of an 'environmental' type to its offer to finance the dam. The Indian Government preferred not to accept the financing rather than change its own views, thus making the financing of the dam more difficult. The expression of 'citizen power' in this case was rather crude and went so far as throwing stones at the World Bank's office windows during demonstrations in Washington, DC. Another case dates from March 1999 and concerns the financing of the Three Gorges Dam in China. The financing of the second phase of the project comprises several loans from American banks amounting to a total of around US$ 3,000 million. Several clients of these banks have declared that they will close their accounts and change their banks because the Chinese project is considered unsound from environmental and social points of view. The banks have withdrawn their offer to lend money to finance the Project.

It goes without saying that on the basis of the known data there is no way, in all the above-mentioned cases, to

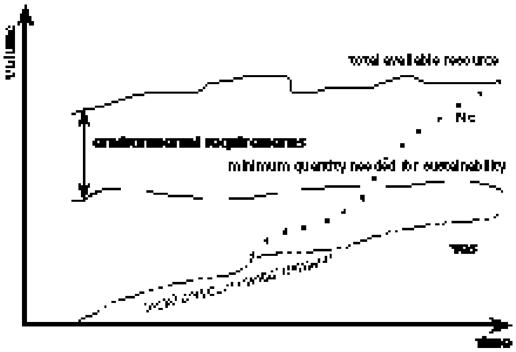


**Figure 1** | Post-industrial era and sustainable development: to allocate, means to share information and to arbitrate through consensus (Matthews 1996).

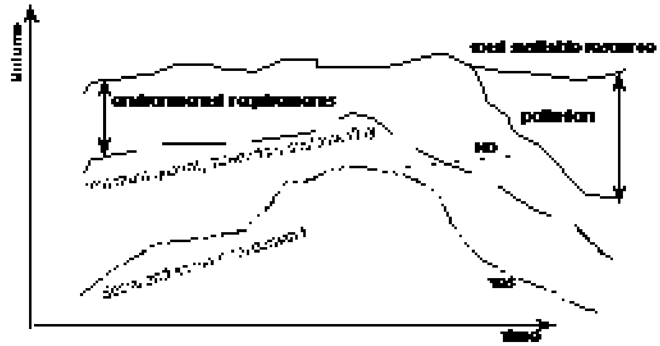


**Figure 2** | To allocate, means to produce information, to be able to forecast consequences of our actions (e.g. pollution) (Matthews 1996).

be sure who is right, who is wrong, whose position or solution is less (or more) acceptable than others, etc. Intuitively it seems clear that there is no solution satisfactory to everybody. These situations are summarised in Figures 1–3 (from Matthews 1996) based on the obvious axiom that there are two limits as far as water resources are concerned: absolute quantity of water resources available on the planet, and the minimum quantity needed for the sustainability of acceptable conditions of life on the planet.

Subtraction of the latter from the former gives a limit, not to be crossed by consumption, to satisfy socio-economic requirements. These requirements must be modified simply because the available resource is limited and variable in time: it can decrease because of human activities (e.g. agricultural pollution of groundwater) or because of climatic constraints (e.g. droughts).

There is a necessity to share a limited resource. In such a situation, if things are left to their own, conflicts (local, global, political, social, violent, etc.) can only multiply until we cross the border of sustainability, engage in quasi-religious wars of extermination, or are forced to compromise.

## DECISION MAKERS, OBJECTIVE TOOLS, HYDROINFORMATICS

Thus, when water problems are concerned, we are living in a conflicting world where the stakeholders, players and decision makers are not only, as was the case 50 years ago, engineers, but also others, including whole ranges of citizens and their associative and political emanations as well as the information carriers (media). As said above, the most dangerous and important conflicts and problems within the next 25 years will be those of pollution, environmental quality, and resources scarcity (including water, but also energy and agriculture). All are in one way or another water-oriented. It is of capital importance to every stakeholder, to every actor in this play, to understand that eventually only negotiated solutions are acceptable, even if they cannot be completely satisfactory for all involved. We are in the situation where the rules of allocation of limited resources under constraints are sought. Thus, if armed solution is excluded, for every specific situation the stakeholders, willy-nilly, will have to search for a

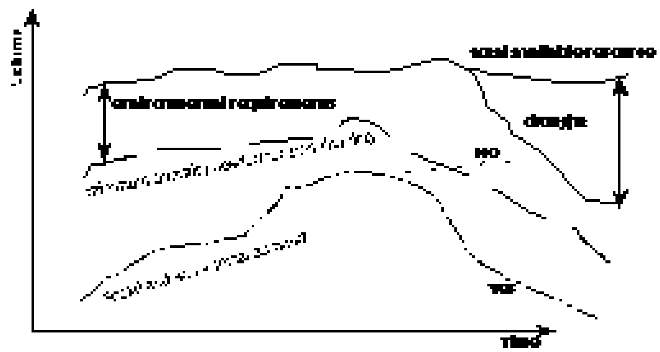

**Figure 3** | To allocate scarcity, means to share information (Matthews 1996).

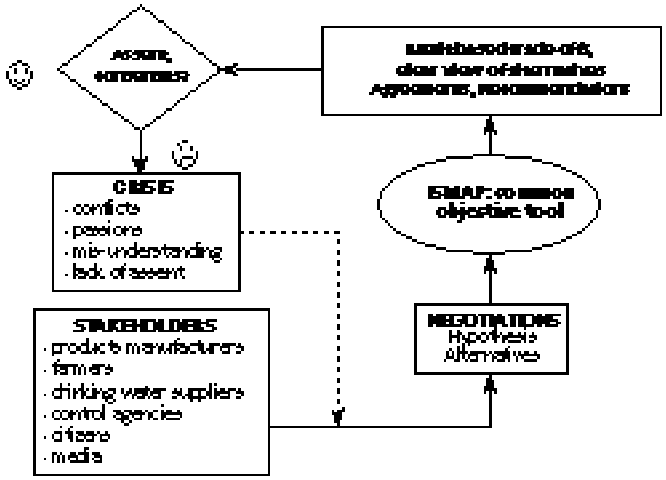

**Figure 4** | 'Loop of Consensus': ISMAP/EUREKA Project.

compromise solution. And, once the choice of a solution is made from several possible solutions, its implementation has to be done as an *engineering* solution because that is the traditional purpose of engineers: to build, to implement, to organise workable structures and solutions which are *ad minima* satisfactory to meet social requirements within the available budget.

A rational search, if not for consensus then at least for compromise, is difficult to imagine without two conditions:

1. Elaboration and presentation to all interested parties of the *information*, so as to share information in an equitable way, i.e. so that it is identical in content and intelligible to all parties – a task impossible without objective tools.
2. Use of *objective* tools (methodologies, processes) allowing for the confrontation of consequences of various potentially possible scenarios and solutions as well as for an iterative approach of the final choice.

At this stage it is necessary to explicate the terminology. Let us stress the difference between *data* and *information*. The *data* may be collected in the field (e.g. measurements of physical quantities such as water level, degree of pollution, etc.); satellite imagery, optical or radar, are also data, although of a different kind; state variables defining ecosystem or biodiversity, their evolution, location of houses, regulations and laws – all are data that can be measured or collected in the field or which may result from projections, extrapolations and modelling. The *information* is elaborated from the data under a form that should be intelligible to the stakeholders. If the information is to provide an equitable basis for seeking a *consensus*, it must be supplied *under the same form for all stakeholders* and must be considered by all of them as *objective*. That means that the tools and the ways in which the data is fused and transformed into the information must not be partial, subjective, suspected by some stakeholders: there is a need for *objective* 'data→information' transformation tools.

An objective tool (modelling software, risk management system, knowledge base and its content, information system, communication network) is a tool that is considered by all concerned stockholders as valid (Cunge 1998). That means that all concerned regard the outputs of the tool as valid consequences of the inputs, whatever are the inputs, the latter representing hypotheses proposed by stakeholders. This 'tool' can be 'immaterial', e.g. a methodology, or a model, or a data and information processing system. The essential point is that its credibility be accepted by all concerned. Thus if an output (e.g. the degree of groundwater pollution) is unacceptable to a stakeholder, it means that for him or her the corresponding input hypothesis (e.g. quantity of pesticide per area) is unacceptable. Such a tool allows negotiations based on merit, not on passion – it is an essential link in a loop of consensus as shown in Figure 4, supposing that consensus is possible.

Obviously, the only way to arrive at such a situation is to involve all those concerned in the development of requirements for the tool in the development of the tool itself and in its validation. And, as mentioned above, the presentation of the information in a form that is equitable, intelligible and identical for all concerned is an essential point in this 'objective' approach. The most obvious and practically proven way to develop such 'objective' tools is to finance and control such developments by a common investment effort by the interested stockholders. The example of the French–Italian–British EUREKA–ISMAP project (Aboujaoudé *et al*. 1994) is instructive: governmental funds covered roughly 40% costs, while the other 60% came directly from the stakeholders. The latter included fertiliser and pesticide manufacturers, the Vivendi (former Compagnie Générale des Eaux), which must clean water polluted by these products, French Basin Agencies, who tax the polluters and finance water cleaning, farmer associations, etc. The development was done by independent consultants and controlled by a steering and a scientific committee composed of the stakeholders. The result was that after a first stormy period of co-operation there was unanimous agreement that the developed tools were objective and could be used to seek overall consensus concerning this application.

What now is the reason why hydroinformatics can and should play an essential role in building and applying such tools and not, for example, ICTs alone? It is because in a conflicting world it is of the utmost importance to have an end-user oriented approach to be able to construct interfaces between the technology (which is unintelligible to most of the end-users) and the end-users (stakeholders) themselves. The word interface means here the capacity to understand the end-user problems, to be credited by the stakeholders with good technical understanding of the problems and with the capacity to assess the technical feasibility (*not a preference!*) of the proposed solutions. And hydroinformatics is precisely such an activity: simply to apply ICT tools to existing hydraulics and hydrological methods would not satisfy at all the basic requirements that come into play here. The decision makers are today politicians, elected bodies, media, public opinion, associations, etc. But whatever they decide and whenever we talk about the water-related realm, the engineers are supposed to carry out their decisions. Hydroinformatics should seize the chance and the leading role because of its particular position, because of its experience of ICT tools applied to numerical modelling, thanks to its links with hydraulics and hydrology and to engineering and because of its expertise in water problems. If hydroinformatics-oriented institutes and companies do not show the way, somebody else will appear to do something that outwardly resembles hydroinformatics simply because there is such an obvious historical, material and social set of requirements for such an activity.

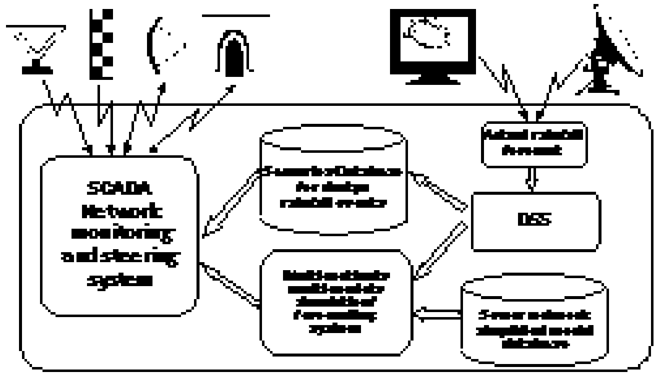


**Figure 5** | Encapsulation principles for large size sewer network management systems.

It is difficult, maybe impossible, even to sketch the more distant future of hydroinformatics. It is interesting, however, to describe the tendencies and certain obvious directions that are being taken by some of components of what we call today hydroinformatics activities.

## MODELLING, WATER-RELATED INDUSTRY CONSULTING, AND HYDROINFORMATICS

Hydroinformatics has been built around and upon hydraulics and hydrology, and at its heart was numerical modelling and computational hydraulics. It is because of its links and interwoven developments with ICT that it widened its horizons and perspectives, building bridges towards biological and social sciences but, first of all, towards water industrial and water resources management. The current positions of hydraulics and hydrology (including their modelling software) is most often that of supplying the results of modelling to larger water industry systems (such as water supply or wastewater, sewerage systems) or to carry out nearly standard calculation procedures used or subcontracted by civil and engineering-works contractors. One of the possible futures is that hydraulics/hydrology encapsulated components will become parts of the larger management systems. Figure 5 schematises the place of these technologies and scientific-related activities in large urban water industry systems and it is obvious that their financial or administrative weights are negligible compared with the whole. They are becoming more and more encapsulated and used as components of a puzzle.

This situation has already been pointed out several years ago (Cunge 1997) and since then the trend has continued. The qualities of hydraulic modelling and of the hydrological aspects are of utmost importance to the success of the perennial functioning of whole systems. Consider such problems as the recirculation of warm (or cold) outfall water, pollutant dilution, and estimates of the project flood discharges necessary to define evacuators. It is easy to realise that if errors are made at that level, whole systems, whatever their cost and complexity, might well lose their usefulness. Nevertheless this situation does not seem to trouble the decision makers or contractors, mostly because they do not understand this risk and, in the absence of an evaluation of uncertainty and error margins, they assess the risk exclusively in terms of the cost of the hydraulic/hydrology component, which of course is negligible compared with the whole system or structure.

The importance of the problem is real and of a different order of magnitude than usually assessed. Because of this, the consciousness that interfaces (in the sense defined above) are necessary will emerge sooner or later—either in the wake of technical failures or as consequence of political processes. A forerunner example is the Öresund bridge and tunnel in Denmark, which would never have been built if such interfaces had not been developed and made available to the public. It must also be mentioned that the bridge could have been an environmental failure without new progresses in modelling which were in turn prompted by the need to develop general citizen-oriented interfaces.

One possibility is that such interfaces will be developed by the *water industry*, in which case independent developers of hydroinformatics software systems as well as expert consulting activities on this field might disappear, absorbed by water industry companies. Another possibility is that these interfaces will be developed by modelling software suppliers through hydroinformatics activities, which have their origins in water-consulting engineering activities.

As far as the *consulting* water-related industry is concerned one can distinguish today, with respect to hydroinformatics and modelling, three categories or streams of company and institute, as shown in Figure 6:

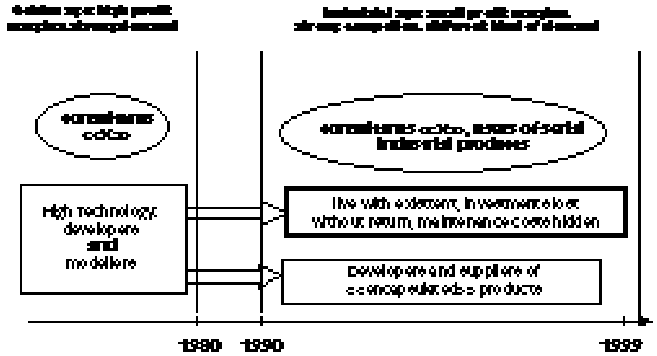


**Figure 6** | Past evolution.

- ‘traditional’ consulting companies employing ‘standard’ market-available tools without particular ambition to acquire an expertise in the field of hydroinformatics;
- consulting companies having a specific expertise in the field of applications of hydroinformatics tools, employing this expertise for their own projects and studies as well as for advising the water industry, contractors and the former stream of companies ;
- consulting companies and institutes who are also developers of hydroinformatics and modelling software, the latter being put on the market and made commercially available to the two previous streams.

This emergence of the three categories is not accidental. The reasons are market-driven. Within the population of developers–consultants existing at the end of the 1980s and the beginning of the 1990s, a differentiation occurred, mainly because of strategic decisions made and applied by some consulting companies and then consolidated by the difficulty (impossibility?) for others to find the funds necessary to be invested to catch-up.

This trend is being favoured by the emergence of electronic commerce through the Internet: a consultant will now be able to buy through the network the software and modelling services she or he needs for a specific

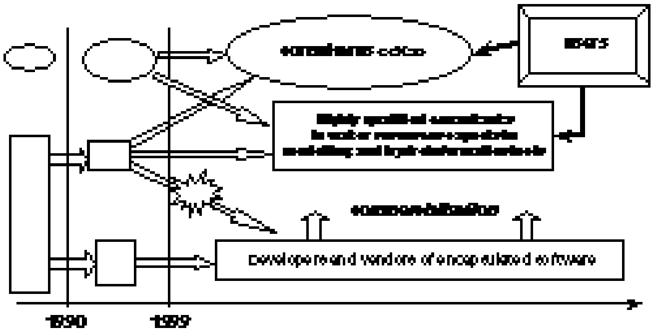


**Figure 7** | Likely future evolution.

project from a developer (and also to buy on the network) for the same project modelling services and/or advice and expertise from a consultant categorised in the second stream (as is being tested in the framework of EC ESPRIT programme *ELTRAMOS* project (ELTRAMOS 1998)). This will make it easier for the first stream companies to avoid errors and misapplications due to their limited expertise in modelling but, at the same time, it will make the fences between the streams even higher and stronger.

The situation described is new. Traditionally it was thought that there was no room for the 'second stream'. Obviously, it can be strategically more 'noble' to be both a developer and a consultant – modelling expert than to be the latter only. This, however, is not possible for all. If a company has not such a position today, the investments necessary to catch up with existing development capacities are so great that in practice no outsider can dream of it. It is known, moreover, that profit margins in the business are rather narrow and if such investments were made today a positive return on them would be doubtful (Figure 7).

On the other hand, there is no need today for a consultant to be a developer, to be an expert in modelling. The qualifications and level of expertise depend on a focusing on the basic trade (e.g. water-orientated engineering, structures, applications) and knowledge of how to apply tools from various origins, how to choose them as functions of the physical and engineering problems at hand, how to interpret the results and how to create appropriate information, based on the modelling results, for the client and end-user. This 'tool user' must of course know the basic algorithms and limits of market-available hydroinformatics tools, but does not need to develop them in-house. But, then, this user still has a privileged position in advising civil engineering contractors and the water industry, because there are no links with the tool makers.

Indeed, at that point one should not forget the *contracting and civil works industry* which essentially is and will be a *user* of hydroinformatics and modelling systems, either market-available or customised. However, when important projects or the updating of their own systems are concerned, this industry needs the advice and expertise coming from the consultants, independently of the developers, i.e. of companies belonging to the second or the third streams.

## CURRENT AND NEAR-FUTURE TECHNICAL DEVELOPMENTS AND APPLICATIONS

We shall limit ourselves only to a very few examples, without even pretending to give a representative sample of what can be expected or of what is going on. The examples are purposefully taken from domains linked very much to the more traditional activities of consultants, managers, modellers and hydraulics/hydrology software developers – to show that new applications and developments of these activities are to be expected from the spread of hydroinformatics activities.

### Data mining and information

We are at the very beginning of the era of data mining, the technique that exists both in the search for data and transformation of data to knowledge and which is seen as the step that performs knowledge discovery (Fayyad *et al.* 1996). The data are today raw and abundant resources, not exploited because of a lack of tools, a lack of the means to transform them into information and a lack of a developed market. Although the highly successful businesses built around Internet search engines (e.g. Yahoo!) are available today, still, searching for data is at the low/primitive end

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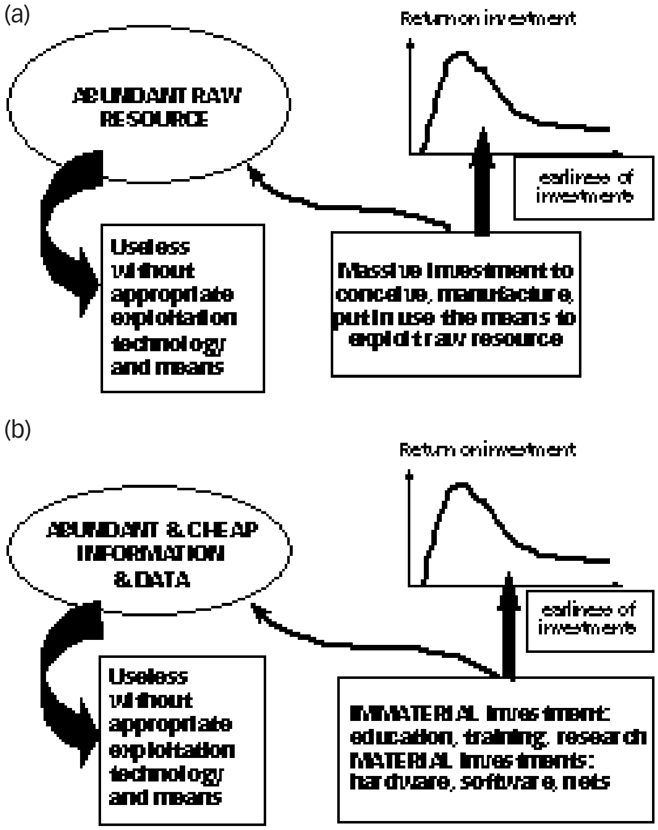


**Figure 8** | (a) Petroleum in 19th century; (b) information today: raw resource of constantly increasing availability and decreasing cost.

of the products (search engines provide only where data are to be found, but they say nothing about its relevance, nor do they provide any sort of interpretation). As shown in Figure 8a, b, one can compare the situation to the one of petroleum at the beginning of 19th century, with possible similar economic consequences, but most likely within a much shorter span of time.

Important to us is the emergence, even in an embryonic form, of tools for exploiting the existing veins of data, which are already available as databases and information sources. What is needed is to transform these data into information. Once the data are interpreted, one can hope for a serious pay-off (both scientific and commercial). Refined knowledge is more valuable than raw material (data). There are some first experimental systems able to look for the data *and* transform them, such as developed in the E-MAIL and REMSSBOT Projects of the Telematics Applications for Environment Sector of the European Commission's 4th Work Programme (EC/DGXIII, Catalogue of TA ENV Projects, 1998). Another example is the D2K project (*http://projects.dhi.dk/d2k*), currently the only large-scale data mining effort in hydroinformatics. There are also scientific numerical methods that can be considered as basic tools for systems: new generations of Artificial Neural Networks (ANNs) tools, Evolutionary Algorithms (EAs) method approaches allowing for recovery of the form of physical laws from the raw data, etc. They have been already applied in water related problems (Babovic & Abbott 1997*a*, *b*).

## Risk and emergency management systems

When trying to perceive current technical trends of hydroinformatics there are two interesting components of such systems: *modelling-forecasting* and *information* systems for the management of emergency situations.

*Modelling–forecasting* of floods seems to be one of the essential components for the management of risks and emergencies, but although scientifically and technically the problem can be considered as solved, operational on-site implementation encounters a resistance that hampers the seriously potential benefits of such progress. It is impossible to make a useful real-time flood forecast without appropriate simulation models. If the credible lead-time for a quantitative forecast of the rainfall is limited to something like one hour, there are tools to forecast the evolution of flows and levels in rivers as well as those at the outlets of watersheds due directly to the rainfall/runoff transformation. Model simulation is always marked by uncertainties in the knowledge of local physical characteristics, evaluation of experimental coefficients, etc. Some methods or models may be better adapted to the local situations than others, e.g. in different winter- and summer-season models, or even different methods might be used with better results than when using one method for both. Another element is subjective: some forecasters interpret the simulation results of some models with more success than the results of others, while some decision makers and engineers are for various reasons 'model patriotic' and would accept only 'their' models. A typical hydroinformatics approach to this problem is to develop 'multi-method, multi-model' systems allowing a hydraulic engineer or a hydrologist to choose a method, to choose the necessary data within a database and to build, in a user friendly way, several ensembles of models for a watershed and a river. These ensembles can then be used in operational real-time forecasting. The concept is that of an *object oriented architecture* of the system, the objects being methods, data sets, calibrated models and ensembles of models. For instance, such a system was developed and operationally implemented first on two important sites in China (Cunge *et al*. 1994; Rahuel *et al*. 1996) within the framework of industrial co-operation between China and the Commission of the European Communities (DGXIII, Information and Communication technologies). Afterwards, a very limited number of applications were done in France.

This novel concept will most likely transform itself into a new generation of systems: instead of *object oriented architectural* elements, which are connected by *fixed* interfaces, a new concept of multi-model multi-method systems having an object-oriented architecture the elements of which are *dynamically* linked by *intelligent software agents* is being born (Babovic 1991, 1996; Woolridge and Jennings 1994) and, more recently, a new approach to distributed decision support, which makes use of intelligent agents on the computer networks such as the Internet (Velickov & Price, personal communication 1999). And this is the real news: here is a potential trend (Figure 9).

Efficient *information systems for the management of emergency flood situations* are in their childhood today; they are almost non-existent. The reason for this is that the monitoring–forecasting part of the management is not integrated with emergency management on the terrain. Ideally the rescue and other terrain management operational teams should have been supplied in real-time with maps of current and future (in 1, 2, 3, 6, 12 hours) inundation situations as well as all other information concerning the evolution of the menace. Today they have nothing of the kind (except in catastrophe film fiction). The necessary picture and efficiency can come only through the fusion and synthesis (i.e. transformation into intelligible information) of all quantitative and qualitative available data which originates from remote and terrestrial sources. And then through the transmission of the results in graphical form superimposed upon GIS implemented on the portable mobile equipment of the emergency teams. The information is to be also made available in a transparent way to the citizens. The existence of such systems will make it possible to train emergency teams and to prepare citizens for a possibility of emergency during a crisis preparation phase.

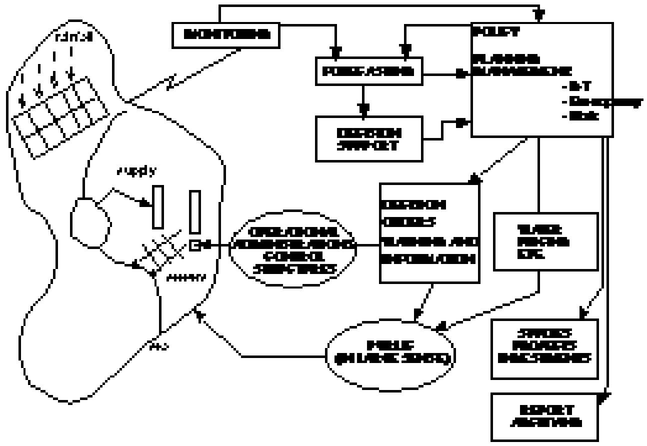

**Figure 9** | General control loop of water management.

## Network management systems

From a hydrodynamics point of view there are essentially two types of network that should, in the very short term, benefit from real-time operation using emergent methods and approaches: water supply networks and, most importantly, storm sewer networks. Both water quantity (discharges) and water quality are concerned.

The storm sewer network problem is important because of the short duration of events. The reactions must be very rapid (within 5 minutes from reception of information), the lead time is of the order of 30 minutes, the update of information every 10–15 minutes. Like flash flood real-time forecasting, deterministic models developed during the 1980s and 1990s most often do not allow the consideration of all hypotheses and risks. A new approach (such as represented on Figure 5) that is potentially prone to spread in practical applications is a scenario-based management approach (Auriaux *et al.* 1996; Erlich 1996) which is implemented already at a few sites and which is most interesting because it allows for taking into account several hypotheses, not just one.

On the other hand automatic control, and control and optimisation approaches and methods are being developed and no doubt will be applied, primarily because of systematic decreases in computing costs and increases in the speed of computing equipment.

## CONCLUSION

We are living in interesting times and hydroinformatics, understood as an activity bridging the gaps between various domains, either strictly water- or citizen-oriented, or both, has a promising future in the service of social requirements.

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