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Water Institutions in the New Era and the Outstanding Aspects of Water Problems

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Abstract: Water problems are now very complex, due to the high number of aspects interrelated each other and to the great quantity of data necessary for their solution. Science and technology have provided several tools, able to handle the large amount of data and to propose suitable solutions. To achieve the proposed goals an appropriate institution is necessary in form of a public agency, expression of the people involved by the problems. Its responsibility should be preferably at the catchment scale, in terms of a water authority acting as a technical advisor to the governing structures, to which it has to install a well-defined tie. Planning is the most important activity of this institution, taking into account the hydrology and all the other vital aspects in the area.

Key words: Water policy, water resources, catchment area, drought, flood, water management, water planning, environment protection, water authority

1. WATER AS A VITAL ELEMENT

Water is essential for life and water problems are strictly related to the present and future living conditions in the world. It is universally recognised that the world population increases tremendously, but the amount of water on earth remains constant. While some global estimates in 1970 gave a per capita average annual run-off value of 12,900 m³/pers, estimates of 1995 indicate a value of 7,600 m³/pers. The quantity of water potentially usable is much less and strictly dependent on several factors that condition its presence in time and space. The occurrence of long period of scarce precipitation is becoming very frequent, with the impossibility of having water when and where it is necessary. Moreover, the quality of the natural bodies deteriorates as an effect of the increasing pollution that hampers in particular the potable use, and the effective per-capita availability further decreases. Such a situation, valid for the present time, is expected to worsen in the future.

Table 1. Estimated and forecast global water withdrawal (km³/year)

	1900	1940	1960	1990	2000	2010	2025
Europe	38	96	226	482	463	535	559
North America	70	221	410	653	705	744	786
Africa	41	49	89	203	235	275	337
Asia	414	682	1.163	2.114	2.357	2.628	3.254
South America	15	33	66	152	182	213	260
Australia and Oceania	2	7	15	29	33	36	40

An estimate of water demand is always difficult and doubtful. Concerning the total withdrawal from surface and underground bodies, an order of magnitude is reported in Table 1, referred to the largest geographical aggregations (Shiklomanov, 2000). The expected values for Asia, mostly connected to a foreseeable population growth, are overwhelming. In any case, the indicated high values stress the importance of water and its related problems. Facing and solving the actual and future water problems is one of the principal commitments in the European continent (European Union, 2000; Correia, 1998; Suzenet, 1997).

Not only water is necessary for maintaining the natural equilibrium of the living species on the earth, but is essential for the uses that characterise the man's life. As shown in Fig. 1, the world water withdrawal is expected to increase to meet the demand for the various forms of use, in particular for agriculture and industry. The municipal use, which largely includes the potable supply, is also expected to grow.

One of the principal aspects of present and future water problems is the rational utilisation of the existing surface and underground resources, in order to satisfy the demand that is strictly connected to all the intrinsic aspects of human living and civilisation.

Another important aspect concerns the protection of land and human settlements from the inundation and damage caused by flood in rivers and streams and from the erosion in coastal areas and lakes shore. This aspect is closely related to the climatic change clearly identified during the last decades. Extreme events of very high precipitation intensity, after long periods of scarce rainfall, are now more and more frequent. In many parts of the world hourly rainfall up to 150 mm is very often recorded, while short periods of a few days have the amount of rain that usually fell during a long part of the year.

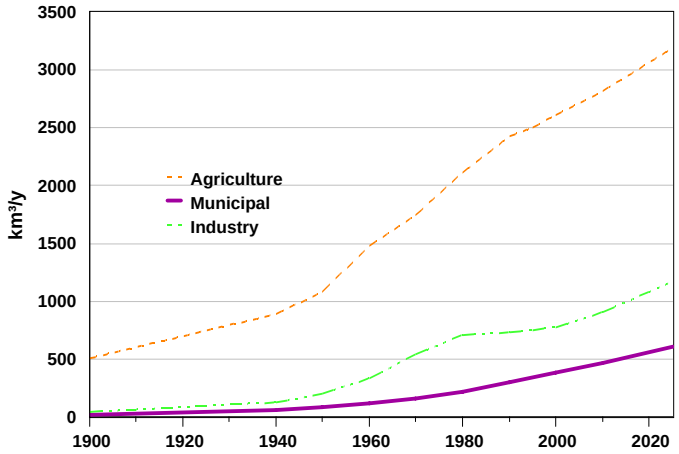

Figure 1. Estimates of the global annual withdrawal to meet the demand for the various uses.

The flood events and the consequential inundation related to such an unusual precipitation pattern are a serious threat to the ordinary living conditions, keeping into account that the effects are now much disastrous than in the past and are expected to be worse in the future. Many man's interventions, also related to the population growth, have modified the original rainfall-runoff mechanism, enhancing the generation of high peak flow in streams and rivers, with a lesser possibility of attenuation along the watercourse.

Finally, the increasing pollution due to uncontrolled discharge of wastewater threatens the natural quality of receiving bodies, giving rise to serious environmental problems. It is not unrealistic to assess that such a situation, connected to the water shortage previously mentioned, puts at risk the future life of the Planet.

To maintain the water quality in rivers, streams, lakes, aquifers and coastal areas, in accordance to the environmental requirements, is now mandatory for mankind.

For all the above reasons, all the actions concerning water management, protection and control are becoming more and more important and require the greatest attention.

2. THE MAIN PECULIARITIES OF WATER PROBLEMS

The water problems have become very complex because of the particular nature of the involved phenomena and of the interference with the human activity, which is not always easy to understand. Some points can be considered predominant, namely:

- The presence of several components, or aspects, related to various disciplinary approach, which are strictly one another related
- The large amount of data, of various natures, that are necessary to bring a problem to a solution.

Another peculiarity of water problems is a sort of "inertness", or, in other words, the difficulty of perceiving promptly the innovation and the results of science and technology. Also for the most advanced management agencies it takes a long while to acquire the breakthrough of research institutions and put it into operation. In the United States, even with very efficient structures like the Corps of Engineers or the Tennessee Valley Authority, some years are necessary in order to apply completely the output of a scientific institution. Conversely, in the Silicon Valley a research output is entirely consumed in a six-months term by the electronic industry. Such an aspect is not necessarily due to the fact that water falls almost completely in the public domain while the electronic industry is private and governed be strong market impositions. Normally the public institutions still maintain predominant bureaucratic characteristics, which increase the complexity already described.

To achieve a solution of water problems various subjects have to be employed, with the best expertise able to understand the intrinsic aspects, keeping in mind that the innovation continuously proposed by the scientific world remains the most valuable help. The way a water problem is tackled and brought to solution is sketched in Fig. 2. It must be kept into account that there is always the possibility of restarting with new aspects and a new order of problems can arise, in a continuous process that, if correctly performed, should bring solutions improved and closer to the reality, which is also in a continuous evolution.

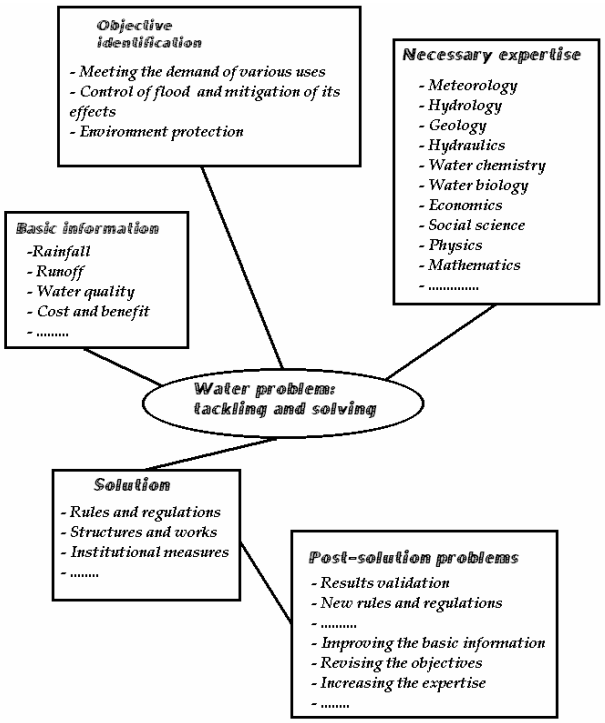

Figure 2. Layout of a water problem.

3. WATER AS A COMMODITY

Water is a public entity and property of the whole community, following a basic concept now recognised by all the most economically and technologically advanced countries (Howsam et al., 1996). Such a statement involves the overall consequence that the community has the responsibility to prevent that water becomes a useless stuff or a source of threat. The community has therefore the

duty to intervene for the solution of water problems with all the suitable tools, and to provide for the necessary financial means.

Water can be abstracted from a natural body and purchased by a private user, becoming a private commodity. In such a new requisite it can be transformed into other goods or referred to other entities, for which the user can claim full property. This is the typical case of the industrial use when water enters the final output of the factory. In the context of water resources it is consumed and never returns to the original body.

Vice versa, if it is not consumed, the abstracted water is returned to the natural bodies and comes back into the public domain.

Every user cannot neglect the requirements of other actual or potential users, which claim their rights to abstract and purchase water from the same natural body. There is then a competition, sometimes a conflict, exacerbated when water is scarce and the various requirements are high. Subtracting water from a natural body, even though temporarily, has always a negative effect to the community, in particular if the environmental requirements have been taken into account. The community reacts imposing severe constraints, also in terms of fees, in order to guarantee its benefit. In a similar way must be considered the problems related to flood control and soil protection.

4. CONNOTATION OF AN INSTITUTION RESPONSIBLE OF WATER PROBLEMS

The above considerations underline the need of a suitable structure having the adequate power to intervene. First requisite of such a structure is to be equipped with a staff having the best experience, always abreast with the scientific progress.

A unique structure responsible for all water problems seems to be the best solution and good examples in many countries confirm its validity. If properly and efficiently working, it could cover all the various fields of the problems, avoiding duplication and reducing the conflict that can arise if the same responsibility has to be shared by different institutions.

A structure responsible for all the water problems is not a feasible task particularly in the industrialised countries, where electricity generation normally belongs to specific institutions, either public or private, irrigation schemes are in the hands of farmers and water quality preservation is responsibility of public health authorities. All these institutions have great power in their respective field and are not always willing to interact with the others. The solution seems to be a structure that does not absorb the existing institutions, but exerts a sort of supervision putting them together and harmonising (Intern. Water Supply Assoc., 1997a and 1997b).

A unique structure responsible of several different aspects might be easier in a developing country, where all these considerations start practically from zero and there is more freedom to intervene.

5. TERRITORIAL JURISDICTION OF THE INSTITUTION

The structure responsible of water must be a public agency, in a close contact with the government's institutions, which are the direct expression of the involved community. In such a context, it has eventually to report to the government, but it can benefit from the possibility of being financed through the taxes imposed to the people.

An essential point is the territorial extension on which the structure is responsible. There are several possibilities, but a responsibility at the catchment scale is fundamental. The catchment area is the only reliable territory on which water complies with rigorous rules imposed by nature. Also groundwater protection and exploitation can be justified considering the surface-groundwater interaction in the catchment context.

There are several definitions of the catchment area. The European Water Framework identifies it as *the territory from which all the surface water, through watercourses, rivers and sometimes lakes, reaches the sea converging into a unique outfall, either in form of estuary or delta* (European Parliament, 2000).

Table 2. The most important European rivers and their catchments.

River	Length (km)	Catchment	
		Area (km²)	Location
Volga	3.688	1.350.000	Russia
Danube	2.860	817.000	Central-East Europe
Rhine	1.326	160.000	Central Europe
Rhone	812	98.420	Switzerland-France
Seine	776	115.120	France
Po	652	74.970	Italy
Garonne	647	56.000	France
Tiber	405	17.169	Italy

The role of the catchment is not restricted to the rainfall-runoff mechanism, but is characterised by several other aspects, not necessarily bound to hydrology. Particularly for the largest rivers, the catchment identifies also the area on which the life of the involved people has many common issues. The divides between contiguous catchments are very often an impervious separation of tradition, language and economical activities.

The main European catchment area is indicated in Table 2. The largest catchment includes territories belonging to different countries. In this case, water problems trespass the political boundaries. Typical is the case of Danube, the catchment of which covers an area of 817,000 km² belonging to 18 different sovereign countries and involves more than 82 Million people. In this case the national governments have to comply with rules dictated by the hydrological conditions and are obliged to shape their policies taking into account what happens upstream and downstream along the river stretch that crosses their respective territory.

Nevertheless, a unique institution having direct responsibility on all this area is hardly conceivable. In this case, an international advisory committee seems to be more appropriate, leaving the decision role to the national governments and institutions.

Similar problems, although at a smaller scale, occur where two or more river basins belong entirely to the same country. A different pattern of hydrology and living conditions identifies very often realities that are different from other areas, even contiguous, belonging to the same country.

Fig. 3 refers to the Po river catchment, in northern Italy, for which a responsible institution, the Po River Authority, is now in operation and has carried out a successful activity.

The Po River is the largest in Italy, where it covers about one third of the entire national territory, with about 15 Million inhabitants and characterised by an intensive economical activity (Autorità di Bacino del Fiume Po, 1999).

As a quite general consideration, all the economical and vital aspects, in a country or in an administrative area, are developed in a way that is consistent with the catchment area of the rivers that flow in its territory.

A rational and efficient structure responsible of water problems should be therefore authority acting at the catchment area. On this assumption the majority of sovereign countries have activated the “River authorities”, which are now an ordinary part of their relevant administration machinery.

Somewhat different is the situation of tiny rivers that belong entirely to a unique administrative territory. This is normally the case of the coastal area of some Mediterranean country. To devise an independent structure for each catchment could be a pretentious claim, but there are always some characteristic justifiable only within the catchment concern, which suggest even a unique structure to split its attention to different realities. The experience matured in different countries suggests to

put all them together under a unique *regional water authority*, which can take care of them simultaneously, sharing and using its facilities and resources.

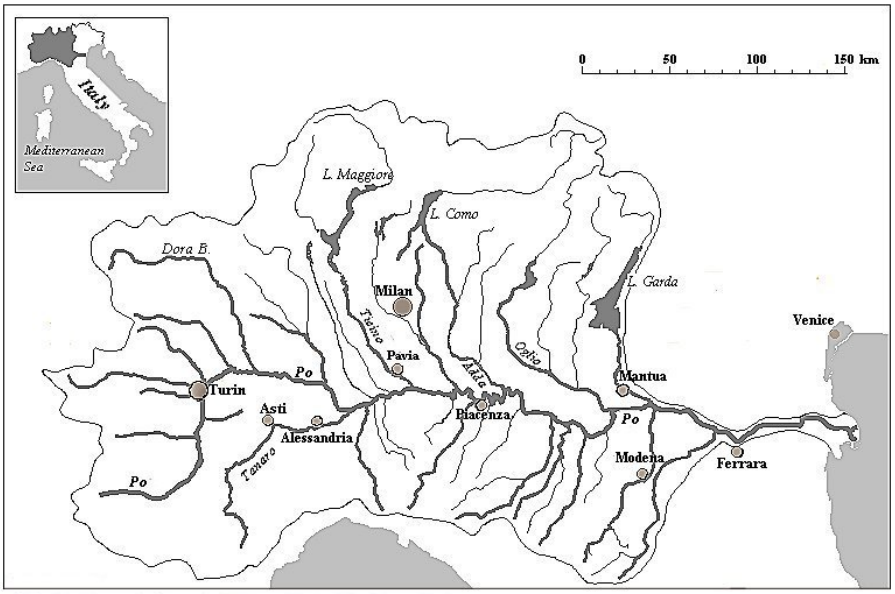

Figure 3. The catchment of the Po River in Northern Italy.

6. THE PLANNING ACTIVITY

The most important activity of a river authority is planning the catchment's water, to achieve the overall objectives of (1) best resources management, (2) protection of land against flood and slides, and (3) environment preservation for present and future generations.

Water planning does not take into account only hydrology, but all the vital aspects in the catchment. Moreover, it should refer to all the other plans existing or foreseeable for the same area of interest. There is a quite general requisite that the works for the correct water management and protection must not be in conflict with those relevant to the development of living quarters, the improvement of agriculture and the efficiency of roads and railways network.

A plan normally consists of several actions that can be grouped into some more general steps, as sketched in Fig. 4.

First step involves the *recognition* of existing situations, focussing on the main aspects of the problems.

Second step is the *interpretation* of the various phenomena. It requires the deepest knowledge of the involved mechanisms, with the application of the best available methodologies. This step is closely associated with that of *definition of measures*, in which the solutions of the problems are outlined and examined. Several procedures can be adopted, among which the *models* provide the best chance to understand the evolution of the various components, with the possibility of analysing the effects of a man-made intervention.

The final step is the *implementation of measures*. It involves also professional institutions outside the authority, which has to analyse the effects and the reactions resulting from the interventions.

At this point, also in accordance to the general philosophy of water problems already mentioned, the planning activity is not "finished", but other aspects have to be considered, taking in due account the effects of the measures suggested by the previous steps. A new planning sequence can be started.

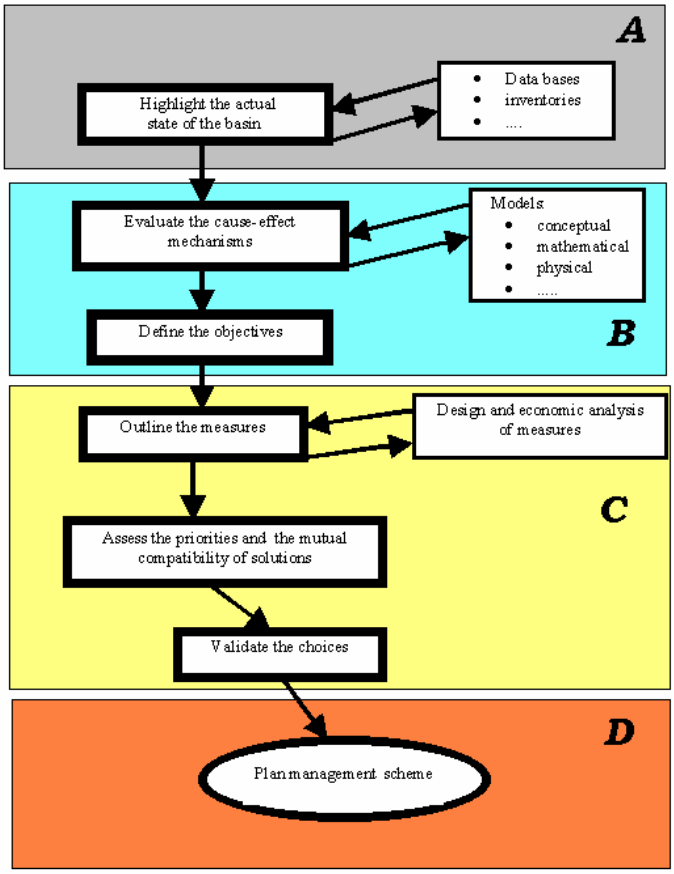

Figure 4. The sequential structure of a plan
(A = recognition; B = interpretation; C = definition of measures; D = implementation of measures).

7. FINANCIAL GUIDELINES

The water authority must be a public institution inserted in the government mechanism, which should control the activity and provide the necessary financial support. This is in particular necessary when a conspicuous intervention, with massive works, has been devised, the cost of which could be hardly born by the authority itself.

Nevertheless, for the ordinary operations, a direct income should be recommended to cover the expenditures and reduce the authority's dependence on non-return government grants. The water authority has the opportunity to ask the interested community for a direct contribution, in form of fees, justified by the improvements it is able to guarantee.

The interested people are not reluctant to pay for these fees if the authority proves to be efficient and not a useless money-wasting burden. It is another challenge for the authority, which is then stimulated to do its best.

One of the main duties of an institution responsible of water problems is to *enhance the public participation* in its jurisdictional area. This should be considered as a mandatory task, because the people that can be affected directly or indirectly by water events are not only the main object to protect but also the only subject entitled to make the final decision.

Such a task is now very important, because there are several aspects to which people usually pay very poor attention, at least as far as an unexpected event, able to involve them seriously, does not occur. Flood, to which very few interests are paid when there is no impending emergency, is an example. Consequently, in case of a sudden flood the majority of people are not prepared to face such an event and undergo serious damages.

8. INTERNAL ORGANISATION OF THE RIVER AUTHORITY

The authority responsible for water use, protection and control is essentially a technical institution, which co-operates with the authorities and institutions in charge of political and administrative aspects of the territory involved. In this framework it has to be provided with staff having high technical qualification in the various water-related disciplines. A skilled engineering support should care for the design and implementation of the necessary works.

If the authority is not always able to hire a numerous staff, particularly in the very common case of restricted financial budget, it has to rely on external professional structures, to which the problems have to be presented in very clear terms. The authority should be provided at least with an internal expertise able to evaluate the substantial aspects of the problems and appreciate the solutions proposed from outside.

Skilled people are necessary to direct the authority. They have to run it through the various constraints imposed by the governing structures, which are the only subject entitled to make decisions. For this reason, the top management level of the authority should have direct access to the government and regional institutions.

The internal structure of a water authority depends largely on the size of the catchment and the importance of the problems. Some specific lines are of general evidence and should direct the various sections and the relevant offices. A typical organisation chart of a water authority is sketched in Fig. 4.

The high-level decision body of the authority is the *institutional board*. The executive role is given to a general manager or general secretary, in charge of the ordinary activity. He can benefit from the advice of a technical and scientific committee, made up by qualified experts coming from professional and research institutions.

The specific offices, in charge of the various sectors of activity, act under the directions of the general secretary.

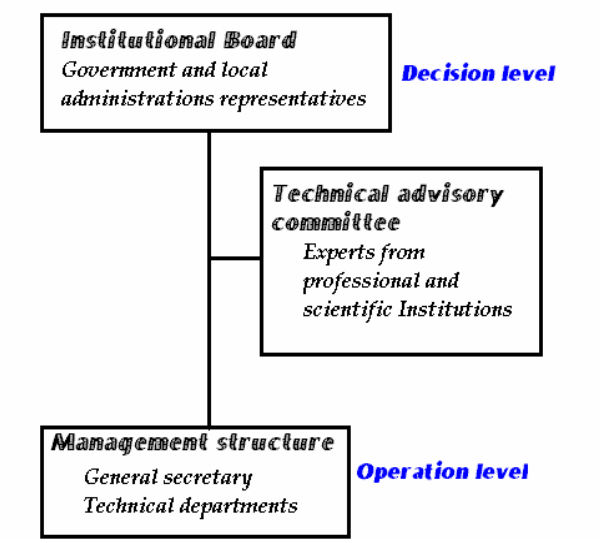

Figure 5. Layout of a water management institution.

9. OTHER ORDINARY DUTIES AND TOOLS

To implement the institution's mandatory activity, particularly that of planning, some daily commitments have to be considered.

Correct *information* is always necessary, in particular to enhance the public participation, with the help of the current media. The reaction of the interested community can be perceived through *public hearing*, where the authority shows the interventions and their expected effects.

An appropriate *education* for the interested communities is also an efficient tool, starting from the primary school, to develop a proper consciousness on the water problems.

An active public participation is essential when the resources are scarce, as during the frequent occurrence of drought phenomena. The authority has to convince people to save water and reduce the demand. Saving water during a drought period entails *rationing* some use, even the potable one, and the users must be prepared to rely only on a restricted quantity of water.

The occurrence of flood affects a community very deeply with damages and even casualties. A strong tie between authority and people is therefore necessary, not only to remedy in case of emergency, but also to provide the *proactive* measures that can be useful if the flood will occur.

Both flood and drought are extreme events to be frequently expected and the authority should devise all the measures that can be useful to mitigate the foreseeable effects. Measures can be structural, as the construction of reservoirs or the opening of a diversion channel, but also non-structural, as an *evacuation plan* in case of a foreseeable inundation.

A practice recently adopted by some river authorities is requesting people to take out an *insurance* for the expectable damage that could be caused by flood.

10. SOME LONG TERM INTERVENTIONS

Normally an institution like the water authority does not deal directly with service like potable supply, which is left to specific agencies. The authority acts as a supervisor during the negotiation between the supplier and the users. In such a context the authority can promote the adoption of a suitable *tariff* for the users, which can be a useful tool to control the subtraction of water from the natural bodies, particularly if a convenient flow has to be maintained in a river for the preservation of aquatic life.

A precise duty of the water authority is to identify the *minimum acceptable flow* in a river and devise the way the governing institutions have to intervene in order to harmonise all the water uses that subtract water from rivers, streams and lakes.

The management of water resources requires to evaluate the quantity of water naturally available. The authority has to promote efficient *data collection, storing and retrieval* for

- precipitation,
- level and flow rate in rivers, streams and lakes,
- depth and yield of groundwater.

Because there are in the present time many restrictions on water availability caused by an appreciable climatic change and the occurrence of droughts is expected to increase in the future, particular considerations are necessary about the meteorological alternations.

A very important institutional duty is the *revision of water demand* for the various uses, according to their specific characteristics.

The scarcity of freshwater naturally available can induce the authority to take into consideration *non-conventional resources*, like low quality water, that can be used for particular purposes after an appropriate level of treatment. Seawater can be used directly for cooling processes and, after desalination, also for some other purposes, including potable supply. If there are no chances to have usable resources in the catchment, the authority can suggest to *import water from another area*, following appropriate inter-catchment agreements.

If water has to be used for various purposes, it is necessary to assess the quality of available resources. Such a quality is principally an effect of the discharge from previous utilisation. An *inventory of the discharges* on the interested water bodies is therefore mandatory of the authority.

In the general concern of water management other uses are becoming more and more important, among which the *recreational* use, consisting of water for bathing, fishing and boating, is strictly tied to the level of economical income. The *internal navigation* in rivers and lakes can greatly help to solve the problems related to transportation, and *hydropower generation* can be still a promising economical enhancement.

An important task is the evaluation of the damage to the interested people, in monetary terms, due to inundation of residential areas, industrial settlement and cultivated land. It is normally connected to the *risk*, to be considered as the probability of having an event that causes an appreciable damage, like the destruction of a residential zone or the interruption of a productive activity.

A methodology has been developed for this purpose, based on the identification of "hazard areas" relevant to the river. As sketched in Fig. 6, around the river channel that is interested by the ordinary flow, a "flood hazard area" is considered, on which the most frequent floods can cause inundation. Outside this area there is "the catastrophic hazard area" that can be inundated by the highest foreseeable flood. To identify such areas, suitable statistical interpretations must be done of the available data (Autorità di Bacino del Tevere, 2000).

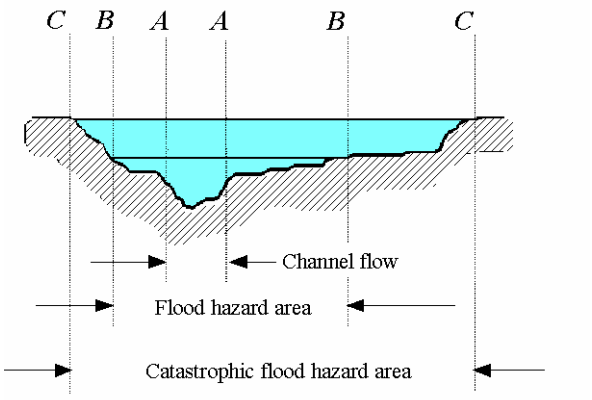

Figure 6 Definition of "hazard areas" around a river with risk of flood.

The identification of "hazard areas" allows to set up the priority of intervention and the evaluation of the possible damage. This is also a compulsory step for urban and transportation planning.

Problems relevant to water quality protection deeply engage the institution responsible of water problems. The water authority has to identify the *quality indicators*, characteristic of the water bodies and connected to the effluents from the various forms of utilisation. For this purpose it relies on appropriate analytical facilities, always abreast with the technological progress, taking in due account that the number of substances able to alter the water quality in a receiving body is increasing continuously. Attention must be given to the chemical compounds present at a very low concentration (*micro-pollutants*), which can be harmful for human health.

An acceptable quality in the natural bodies requires a strong control of the wastewater discharged from urban and industrial zones.

Water coming from the cultivated land, both in form of natural runoff or as an effect of irrigation, is a worrisome surface and groundwater polluter. To abate this form of pollution, the water authority has to give directions to the farmers on how to use fertilisers and pesticides, promoting agricultural practices based essentially on the natural characteristics of crops.

Controlling groundwater pollution, very serious and normally considered irreversible, is an obligation of the water responsible institution, as groundwater is a precious source primarily for the potable use.

To abate the pollution and improve the water quality, the water authority has to promote a skilled engineering support, able to identify the best form of intervention. Wastewater treatment is not sufficient for the receiving body to recover its environmental conditions completely, therefore the authority has to stimulate the reduction of polluting emission at the source, promoting *clean technology* in the industrial sector and fostering the reduction of chemicals in agriculture.

11. CONCLUSIVE REMARKS

The complexity of water problems is a characteristic of the present time, destined to increase in the future. It affects all the vital aspects, with an eventual impact on the possibility of safeguarding the life on the Planet. Meeting the demand of the various uses is an essential goal, to be achieved without interfering with the environment preservation, which in turn is another primary objective inserted in the water problems. Prevention of the effects of natural extreme events, both in terms of drought and flood, is also a problem expected to be crucial for the future generations.

The solution of water problems will be possible only if a suitable institution is outlined and put into operation, able to appreciate the basic phenomena and devise the most appropriate tools.

The success of such an institution is conditioned, first of all, by its capability to understand the needs of the involved people, with an internal structure made up with the best available expertise, in a close contact with the scientific community.

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