Integrated water management is a perspective for effective and efficient protection and utilization concepts for water. On the one hand, individual demands, such as water quality or flood protection, need to be coordinated and optimized; on the other, integrated water management deals with ecological-economic optimization of specific uses such as hydroelectric power generation. This article presents some basic principles and tools to implement integrated water management.

Development of Water Utilization

Aquatic ecosystems have become subjected to permanent change due to a large extent from ever changing and increasing demands for utilization. Since the 19th century, laws governing fisheries, flood protection, stream corrections, hydroelectric power generation, and water protection have been established with each law covering a specific sector of all the different aspects defining a stream. Many activities, such as farming, community development, road construction and combustion processes, have an indirect impact on streams. For a long time, these impacts were mostly ignored. Even water protection itself has become segregated into areas that have developed independently. Despite the ongoing trend for management approaches to cover wider aspects of problems (Fig. 1), stream protection still strongly reflects its historic roots. Preventative, cause-oriented approaches are still poorly developed when compared with “end-of-pipe” solutions. Positive examples of exceptions are the ban on phosphate in detergents (1986) and the promotion of low-pollution production processes in industry. The introduction of market economy tools in environmental politics (e.g., financial incentives, environmental tax reform) still faces resistance. Where – in view of the new challenges – lie the problems in the historically established way we deal with streams and the corresponding legal and administrative structures?

Starting Point for an Integrated Approach

Ideally, integrated water management would take into account all impacts, all forms of utilization, and all protection needs as well as predominating political, legal, institutional, economic, social and cultural aspects. Is this goal attainable in the real world?

The primary goal of integrated management is the sustainable use of water, i.e., guaranteeing that the essential forms of utilization can be maintained over long periods of time. This includes supplying drinking water, water for food production, hydroelectric power generation, flood protection, maintaining a healthy ecosystem, and also providing emotional values.
The priorities among all these demands may vary depending on the particular set of problems in a given situation [1]. Priorities will also depend on the culture, the dominant socio-economic factors of a country or a region, and administrative and legal structures [2]. Figure 2 illustrates the typical demands on water management for developed and third-world countries. Problems related to water resources are by nature highly complex and specific. This leads to an apparent paradox: each of the problems is difficult enough to handle by itself, and now the interactions among the major aspects of water use need to be considered.

Connected aquatic ecosystems: Aquatic ecosystems are closely linked with one another and with their environment (see article of U. Uehlinger, p. 16). The condition of individual ecosystems is determined by interactions within this entire network and by anthropogenic influences. The processes occurring in the system are extremely complex and dynamic and may be described and predicted only to a limited degree.

Connected environmental problems: Human activities that cause water problems lead to numerous other environmental problems. Conversely, a number of human activities are often responsible for a particular problem, e.g., excessive nitrogen accumulation in the environment (Fig. 3). Each activity (such as agriculture) should therefore be optimized within an overall environmental context, and not only with regard to water [3–5].

Large spatial and temporal scales: Biological elements and ecological processes relevant in aquatic ecosystems occur on wide spatial (m² to km²) and temporal (days to centuries or more) scales [6]. The same can be said of anthropogenic impacts. In minimizing environmental impacts of hydroelectric power generation, for example, the stream fauna is sensitive to the daily and weekly rhythm of residual flow volumes, while a flood plain responds to rhythms spanning decades. It is therefore very difficult to perform cause-effect analyses and to determine the effects of actions relevant for water condition [7].

Execution at different levels: Additional complexity is introduced by the fact that responsibility for different kinds of problems and decisions falls to entities that are subjected to different hierarchical and spatial levels. The entities involved comprise of governing bodies ranging from the community all the way up to international level, a suite of administrative offices, (e.g., for water use, energy, agriculture, water and environmental protection), and other groups who need to provide input, such as certain business sectors, professional associations, citizen organizations, NGOs and more.

Utilization conflicts and discrepancies in values: Even within a relatively homogenous cultural context, problems caused by water utilization can be valued very differently by various interest groups (e.g., protectors of the environment vs. protectors of jobs). This can lead to irreconcilable differences because the priorities and the remedies are determined within different value systems. The situation can be aggravated even further since the values and needs related to water use can change relatively quickly.

Synergisms between different usage modes: Opposing demands on water use usually restrict the options for action, but in some cases they may even turn out to be mutually beneficial. The certification of green electricity, for example, (see article of C. Bratrich, p. 20) can lead to conflict resolution and support integrated stream rehabilitation [8]. The opposite is done for agricultural practices which crank up the nitrogen cycle, and thus are difficult to reconcile with technological improvements in wastewater treatment [3–5].

**General Directions and Principles**

Our discussion so far illustrates that the goal of all-inclusive, integrated water management in the idealistic sense is not realistic.
So where are the solutions that will bring us closer to sustainable water management by using the potential of synergisms and efficiency improvements?

The new EU Water Framework Directive (WFD, see article of J. Leentvaar, p. 18) stipulates that integrated water management be implemented on the scale of entire watersheds. The directive formulates general goals and principles that must be translated into national law, and applied in specific action plans. This step-by-step application of generally accepted principles can enhance integrated approaches to water management. Another important intention of the WFD is to integrate issues related to water and environmental protection into sectors like agricultural policies and urban planning (see article of H.P. Willi, p. 26).

But even with the best intentions, the inherent complexities and uncertainties in water management cannot be overcome. Simply for practical reasons, it must be assumed that individual approaches for different aspects of water management (e.g., wastewater treatment, water supply, flood protection, restoration) and that tailor-made solutions for certain uses (e.g., hydroelectric power generation, agriculture) will continue to play an important role. What will be new, however, is that these approaches will not be worked out individually for each aspect, but will be coordinated with one another. The following principles – as they are, in part, also stated in the WFD introduced by the EU – are meant to provide general guidelines for the practically oriented definition of integrated water management in a range of different contexts.

**Design water use in accordance with sustainability:** The long-term regeneration of water resources is the highest principle for all actions. Irreversible impacts have to be avoided.

**Choosing appropriate incentives and acting upon cost/benefit evaluations:** The effectiveness of a certain measure is often crucially dependent on its acceptance by the affected parties. In finding practical solutions, we must consider how much room these parties have to maneuver, and we have to include cost effectiveness in the evaluation process. We must go beyond traditional ordinances and should increasingly resort to financial incentives, voluntary agreements, information transfer and education, and support of innovative solutions and cooperation among the various parties. The general understanding of the problems and the capacity for solving them will grow, while local initiatives will become increasingly more important.

**Taking into account interactions between different spheres of interest:** We should attempt to overcome the traditional antagonism between protection and usage interests and identify and promote possibilities for synergisms. Optimizing the amount of fertilizer used in agriculture, for example, can have environmental as well as economic benefits. An example of what we should not attempt to do would be pushing wastewater treatment to its absolute technically feasible optimum, since we might create new environmental problems in the process. The necessary coordination could be provided by interdepartmental committees who would examine proposed regulations as well as action plans for duplication or inconsistencies.

**Participatory decision-making processes:** The high level of complexity in water use and protection issues requires active participation of the various interest groups, for example in the permitting process for hydroelectric power plants. Involvement of all interested groups from the beginning can reveal synergisms early on and will place decisions on a broader basis, which will reduce opposition during the later phases of the process. Early involvement of all interest groups will also tend to reduce overall costs and shorten the planning and permitting process.

**Flexible approaches which allow a learning process:** Flexible management, control and correction mechanisms are needed since natural and social processes are very complex, and the effect of any particular action is difficult to predict. Actions should be conceived as experiments that will periodically be evaluated and adapted. Flexible approaches that leave some room for error are particularly important for installations with a long life time, as for example, in wastewater disposal. Technical solutions should ideally provide flexibility and options for design modifications for a long period after initial construction.

**Tools for Integrated Management**

In order to apply the principles described above in the real world, we need new concepts and tools. However, the scientific basis for those is often not available in a form that is directly applicable. Science needs to increase its effort to synthesize information and to present and communicate it in a generally accessible form. Furthermore, close cooperation between science and professionals on the application side will support the development of new approaches in water management.

**Early identification of risks:** Scientific based knowledge plays a crucial role in the early recognition of problems and in the subsequent development of remedial actions. Scientific knowledge as well as projections of risks, however, are always associated by some degree of uncertainty. It is important to openly discuss these uncertainties; ignoring uncertainties or exaggerating them can have equally fatal consequences. This type of information has to be transmitted to the public in an appropriate and understandable form, which requires the scientific community to find new ways of communicating.

**Procedures for ecological assessment and evaluation of action plans:** In order to develop effective responses to problems, we need to develop and apply procedures that characterize and evaluate environmental problems in appropriate ecological terms (see articles of A. Peter, p. 7, and N. Schweigert, p. 10). Such procedures need to be scientifically based and broadly accepted, and be easy to integrate in the decision-making process. Decision-support systems (e.g., analyses of cost effectiveness) will become increasingly more important (see article of W. Meier, p. 13). Figure 4 compares the costs and the affects of reducing nitrogen emissions in Switzerland [4]. Open discussion of uncertainties is important in this type of evaluation, too. We have to explicitly state how different value systems will lead to different responses to a given problem. When trying to demonstrate the need for remedial action, for example in flood protection or stream restoration, it is critical that different segments of the public provide their own risk perception. The degree of risk one is willing to accept has to be an explicit, adjustable parameter within the problem analysis framework.

**Development of new technologies:** At the center of our efforts are both the reduction of the amount of water used and the reduction of contaminant release into the environment. Target sectors are agriculture, industry, households, together with other areas of our society and economy where water plays an important role. We must be open to radically new socio-technical solutions and seriously evaluate their viability. Innovative technologies should not be based solely on technological considerations; the full potential of innovative technology is only realized when it is accompanied by the development of new usage patterns and institutional structures.

**Promotion of efficient institutions:** In some areas of water management, institutional reforms are believed to offer the largest
potential for improvements. In the public sector, such reforms have been dominated over the past few years by various forms of liberalization and privatization. We have had to realize, however, that such reforms must be thought out very carefully in order to avoid the creation of new problems. The one indisputable principle emerging from our experiences is that the competence to make decisions should be placed with the institutions or authorities which have physically to deal with the relevant problems.

**Perspective**

Integrated water management, which is able to simultaneously analyze, evaluate and solve all problems in an all-inclusive form, is a hypothetical goal that is not attainable in the real world. It is important, however, to remain focused on the basic requirements for integrated approaches when developing new concepts for water utilization and protection. We need to be aware of the connections between different kinds of problems and to coordinate between different sectors of action. This is important when dealing with whole watersheds and also when optimizing specific water uses. One important factor in mastering this task is a consistent political framework that recognizes the links between individual sets of problems and creates incentives for initiatives to be proposed by the various players and affected parties (Fig. 5).

This article discussed some of the fundamental principles and tools towards integrated water management. We would like to emphasize once more how complex the natural and social systems are that we have to deal with. Therefore, it is important to keep the decision-making process transparent, explicitly state uncertainties, and to create an open and participatory atmosphere. Only in doing so will we make the best use of synergisms, minimize friction, and maximize efficiency and efficacy of the actions that are to be taken.

EAWAG has proposed a number of initiatives over the last few years, aimed at supporting specific areas within the framework of integrated water management. It was the goal of the Information Day 2000 to present the larger context of the various projects and to show how integrated water management might look in the future.

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**Fig. 5: Management framework for integrated water management.**

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