



## D40: Strategies

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Lead contractor:	WUT
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Strategic leader:	Marek Nawalany (WUT)
Responsible task leader:	Marek Nawalany (WUT)

<b>Main contributor involved:</b>	<b>Organisation and E-Mail</b>	
Marek Nawalany	WUT	marek.nawalany@is.pw.edu.pl
Günter Fehr	FuN	g.fehr@funumweltconsult.de
Michael Becker	FuN	becker_@web.de
Johannes Post	HYD	post@hydromod.de
Helmut Baumert	HYD	baumert@hydromod.de
Malgorzata Loga	WUT	malgorzata.loga@is.pw.edu.pl
Matthew O'Hare	UoG	mohare@geog.gla.ac.uk
Adeline Kroll	IPT	adeline.kroll@jrc.es
Eckard Hollan	ISF	eckard.hollan@lfula.lfu.bwl.de

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## 1 EXECUTIVE SUMMARY

Inhabited by large populations, **catchment areas of large deep European lakes form specific European regions** where social and economic activities are naturally concentrated and are lake-dependent. These lakes also are valuable ecosystems and an important water resource. In particular, water uses and the state of ecology within their catchment areas are strongly linked to the lakes' good (or bad) status. Being large and deep these lakes have physical and biological characteristics, which are considerably different (specific and unique) from the characteristics of small or shallow lakes. Most specific is the existence and **long-term persistence of the lakes' two distinct parts**: the upper part (epilimnion) with intensive and "quick" dynamics and the deep, voluminous lower part (hypolimnion) with "very slow" dynamics.

The exchange of mass and energy between the two parts is only occasionally intense. Because of such a structure and dynamics, **these lakes** (especially the deeper part) **become a storage that holds mineral and organic matter originating from the catchment area**.

Although at present the major European large deep lakes are in rather good state their slow dynamics can cause an undetected drift from good or acceptable status to one of "bad" status. If deep-water dynamics is not sufficiently monitored and precautionary approach is not taken, the bad status can even turn into a "bad and unrecoverable" one. In order to avoid this situation, special care and a special political status of the large deep European lakes have to be drawn up. Such a programme/commission exists for example, for the Great Lakes in Canada and the USA, and the Danube and the Rhine rivers in Europe.

Since the wealth and well-being of many large populations in Europe depend on the "good status" of large deep lakes, the *cautious approach has to be applied*. The lake communities must recognise that although they are legally entitled to decide upon the uses of the lakes, **certain basic principles, derived from general experience and general knowledge about the behaviour of large deep lakes, must be respected**.

The objectives of the work package 28 ("Strategies") were:

- a) to define the *goals* of water management in large deep European lakes and their catchment areas taking into account their relevance for achieving the objectives of the Water Framework Directive and their dependence on the scale to which management is to be applied,
- b) to indicate ways/methods (i.e. **strategies**) to achieve the goals,
- c) to specify *constraints* of the strategies,
- d) to estimate the resources necessary to realise the strategies,  
and
- e) to assess the *feasibility, risks and potential drawbacks* of each strategy.

The main results of the EUROLAKES project reflect the concerns about the future long-term evolution of large deep European lakes. There is the hope that these lakes will continue to serve the regional communities of Europe as they have for thousands of years.

On the other hand, there is fear that certain human *activities on the lakes or within their catchment areas threaten to „turn these lakes into bad or even bad and unrecoverable state in an unpredictable manner”*. It can be concluded from the research done within this project that *due to their unique dynamics, the large deep European lakes are particularly vulnerable to depositing organic and toxic substances within their water bodies. In view of our limited knowledge of complex, multi-scale dynamics of physical, chemical and biological processes within these lakes, the precautionary approach must be taken in any sensible strategy.*

As it has been observed, the actors and users of these lakes did not necessarily follow the best practices in the past. However, in the last years the status of these lakes shows considerable improvements mainly due to coordinated actions in management and monitoring undertaken by regional responsible authorities. Therefore, the way (or **strategy**) to maintain the “good status” of the lakes is to strengthen organisational and regulatory framework that will make it possible to monitor and control the lakes and their catchment areas in a coherent manner. As the regulatory basis for treating large deep European lakes with *special care* (because of their dynamic behaviour) **a large-deep-lake-extension to the Water Framework Directive is recommended.**

In addition to the definition of large deep lakes and its own justification a number of particular requirements must be formulated in the extension. These requirements will act as constraints for decisions and activities/uses that are or may be undertaken by the regional communities in the lakes and within their catchments’ areas. **Creation of the advisory group in each lake-region as the supportive body to the existing regional water authorities/institutions** introduces a desirable new actor, the one who will focus on controlling and maintaining the “good status” of the lake. It is recommended that on the European level the advisory groups in the lake-regions can form a network aimed towards exchanging experience and information. The European Commission might support the network.

These institutional improvements can be equally well realised by already existing regional water institutions *by adopting the concept of advisory groups* as by possibly newly created bodies/institutions once their creation is found useful. In both instances it is considered indispensable to create legal and financial conditions through which the European Commission can introduce necessary regulatory framework. It can be accomplished through extending the WFD with the large deep lakes paragraph, support logistically and financially the regional water management bodies in setting institutional framework aimed towards maintaining the “good status” of the large deep lakes and supervise activities of the regional advisory groups.

In general, the Strategies when known and accepted at the European and regional levels may be used as a departure point for achieving and maintaining “good status” of large deep European lakes on a long-term basis.

On the practical level of managing the “good status” of large deep lakes in Europe ***the Strategies offer a number of recommendations concerning monitoring, data processing, research, standardisation, exchange of information and decision-supporting methods specifically suited to these lakes.*** Necessity of exchanging experience and information applies to measuring, interpreting and modelling of relevant physical, chemical and biological processes in large deep lakes.

Within the deliverable “Strategies”, good examples of managerial and monitoring strategies of Loch Lomond, Lake Constance and Lac Léman are described. Water and catchment management combined with appropriate monitoring strategies of these lakes led to considerable improvement of the status of the lakes. It is expected that by learning from these examples one can improve the status of other large deep lakes in Europe.

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## 2 INTRODUCTION

### 2.1 BACKGROUND

“Good status” is a primary concern for all lakes in Europe. However, a number of observations and results of the EUROLAKES project lead to conclusion that the activities concerning the maintenance of the “good status” of *large deep lakes* need better scientific basis and more efficient co-ordination in terms of monitoring and management. The observations are listed below:

- The present WFD formulation does not take into account the particularities and complexities of large deep European lakes. Instead, large deep lakes are treated as other (“small or shallow”) lakes.
- The present WFD formulation does not take into account non-stationary drift caused by *external* (climate changes) or *man-induced causes* (changes in organic load from the catchment area).
- No selected groups of people exist that would be solely responsible for the integrated maintenance of the “good status” of large deep European lakes.
- Procedures that are used to gather, process and update information and knowledge about large deep European lakes are far from being sufficient, consistent or well integrated.
- Although the present knowledge about deep lakes’ physical, chemical and biological processes is considerable, understanding of many processes is far from satisfactory. Specifically, in view of “sensitive” dynamics of large and deep lakes extensive and thorough research on these processes is still required.
- This also applies to the state of knowledge concerning the relationship between the processes in the catchment area and the processes in the deep lakes.
- On a practical level, no transparent and accepted mechanisms exist that could integrate the information and knowledge about large deep lakes and link them to the ecological, social and economic consequences of decisions and actions taken within the lake catchment area.

These observations create the motivation for developing a scientific basis concerning the dynamics of large deep lakes through establishing *regional advisory groups* that can take the responsibility for monitoring (and, to some extent, maintaining) the “good status” of these lakes. Also forming a European network of the advisory groups should be considered. The main task of the network would be exchange of information, advice and guidance to regional organisations (advisory groups) as to maintenance of “good status” of these precious water resources and ecosystems.

## 2.2 MOTIVATION

Inhabited by large populations, catchment areas of large deep European lakes form **specific European regions** where social and economic activities are naturally concentrated and are lake dependent. These lakes are also valuable ecosystems and an important water resource. In particular, water uses and the state of ecology within their catchment areas is strongly linked to the lakes' good (or bad) status. Large and deep lakes in Europe have physical and biological characteristics considerably different from the characteristics of small or shallow lakes:

Most specific is the **long-term persistence of two distinct parts**: the upper part (epilimnion) with intensive and "quick" dynamics and the deep, voluminous lower part (hypolimnion) with "very slow" dynamics.

The exchange of mass and energy between the two parts is occasionally intense. As a result of such a structure and dynamics, these lakes (especially the deeper part) become a **storage that holds mineral and organic matter from the catchment area**. The slow dynamics can cause an undetected drift from what is presently a lake of good or acceptable status to one of "bad" status. If deep-water dynamics is not sufficiently monitored and precautionary actions are not taken the bad status can even turn into a "bad and unrecoverable" one. In order to avoid this situation, special care and a special political status of the large deep European lakes has to be drawn up. Such a programme / commission exists for example, for the Great Lakes in Canada and the USA, and the Danube river and the Rhine river in Europe.

The large deep lakes in Europe must satisfy the general principle of "good status". However, it must be recognised that the **"good status of the large deep lake"** is to be realised as a part of regional sustainable development. Communities within the lakes' catchment areas decide upon the uses of the lake and the catchment area and hence impose pressures on the lake. These pressures cause a departure of the lakes' status from its "natural" evolution, i.e. the evolution that could take place if there would be no human intervention. The "human-generated" part of the lake evolution is frequently considered as leading to deterioration of the lake's status or, at best, as neutral. When the status of the lake is considered as "bad" all kinds of actions are undertaken to "improve the situation". Although in most cases these actions indeed improve the situation, from the long-term perspective they may be perceived as having "ad hoc" character as they all are based on "incomplete" knowledge about functioning of large deep lakes. The major assumption for the strategies proposed by the EUROLAKES project is to speed-up gathering of knowledge about the large deep lakes through specific actions. It is hoped that by making an effort to make the knowledge *complete, consistent and known to communities* the decisions taken in the lakes' catchments (and in the lakes themselves) will not cause long-lasting detrimental effects on the lakes' status.

The wealth and well-being of many large populations in Europe depend on the "good status" of large deep lakes. The lake communities must recognise that although they impose most of the pressures on the lake and they are legally entitled to decide upon its uses, certain basic principles, derived from general experience and general knowledge about the behaviour of large deep lakes, must be respected.

Being under external political (European policies) and economic influences (global economy) ***catchment area communities living along large deep lakes can essentially influence the lake-related part of the regional sustainable development if***

- they are conscious that “the good status of the lake and its catchment area” is a necessary condition for improving the quality of their lives on the long-run,
- their activities within the regions incorporate the “good status of the lake and its catchment area” as an indispensable ingredient,
- the organisational form they choose for the purpose (advisory groups, networks etc.) will be effective and sustainable in itself,
- they are consistent in their efforts,
- helped and guided by European policy in this respect.

## 2.3 OBJECTIVES

The main objectives of the WP28 are:

- to define the *goals* of water management in large deep European lakes and their catchment areas taking into account their relevance for achieving the objectives of the Water Framework Directive and their dependence on the scale to which management is to be applied,
- to present examples of the strategies applied at the selected large deep lakes in Europe,
- to formulate ways / methods (i.e. ***strategies***) to achieve the goals,
- to define *constraints* of the strategies,
- to estimate the *resources* necessary to realise the strategies and
- to assess the feasibility, risks and potential drawbacks of each strategy.

## 2.4 METHODOLOGY AND SCIENTIFIC ACHIEVEMENTS INCLUDING CONTRIBUTIONS FROM PARTNERS

The methodology applied in this work package is based on a system analysis approach which is very well suited for analysing the complexities of the subject, finding the relevant strategies for water management and assessing the consequences of realising these strategies. A distinction is made between long-term and short-term goals of water management on two scales: the *European scale* and the *regional scale*. Two scales and two time horizons define four groups of goals to be achieved and generate a number of strategies that may lead to the achievement of the respective goals. Work packages from almost all of the partners of this project have been used/utilised in formulating the goals and the corresponding strategies. In deliverables D19, D20, D21, D33, D34 and D36 several strategies have been already formulated explicitly. They are generalised in this Deliverable D40. Their relevance in achieving and hence preserving the “*good status*” of large deep European lakes is highlighted. Maintenance of “good status” should be considered as the primary goal to all other goals.

## 2.5 SOCIO-ECONOMIC RELEVANCE AND POLICY IMPLICATION

By considering *local communities as the main addressee*, the work package “Strategies” focuses on the goals and methods, which are relevant and feasible for each lake. No strategy can be effectively realised unless the *economic context* of the water management activities within the lake catchment area is taken into account and there is *social consent* as to the goals to be achieved and the strategies to be realised. The availability of relevant information concerning the lake and its status, its transparency and accessibility is considered within this Package as the prerequisite for implementing the proposed strategies.

Just as socio-economic conditions change, so must strategies evolve with time. Three conditions must be fulfilled in order to make the “strategic drive” towards the agreed goals unstoppable:

- a) using scientific approach to interpreting cause-effect relationships between processes in the lakes and their catchments,
- b) updating the lake-oriented information and knowledge bases  
and
- c) discussing of the necessary changes in water policy with the regional communities.

The former requires creating at each lake region *the advisory group*, which would take continual care of the “good status” of the lake. Preferably, the advisory group should consist of three types of specialists: limnologists / ecologists, information specialists and public relation specialists.

Depending on the changes in pressures imposed on the lake catchment area and the growth of knowledge about the processes in the lake, the scientific advisers should be

allowed to reformulate the definitions of “pressure” and “impact” indicators as needed. In order to communicate the issues concerning the “good status” of the lake to the local community, industrial/agricultural actors and the decision-makers (the local authorities), as well as water management specialists need to be included into the *advisory group*. The concept of *advisory group* results from the observation made within this project, i.e. “*in order to keep the good status of large deep lakes*” specific information about the lake must be continually gathered, elaborated and highly specialised knowledge utilised for the purpose of data interpretation. Necessarily, information and knowledge must be subjects of transparent discussion between decision-makers and the local communities before adopting major changes in water policy.

## 2.6 CONCLUSION

Improving strategies concerning long-term water management, short-term pollution control, integrated monitoring and data processing will be accomplished by using and extending available local experience as well as integrating the lake-related information and knowledge with planning and water management decision-making processes. In order to achieve the ultimate goal of “*good status of the lake*” the relevant strategies should be realised through consistent and transparent consultation procedures with local communities and the major actors within the lake catchment area.

### 3 DEFINITIONS

Before defining *Strategies* concerning large deep European lakes, the following definitions are formulated to help understanding the notions and terms used in this Report:

- A **Goal** is what one wants to achieve.
- A **Strategy** is a way of achieving the defined goal within a finite interval of time using finite resources and respecting imposed constraints.
- If there is at least one strategy, which permits the goal to be reached, then the **goal is considered achievable**. Otherwise the goal is *non-achievable*.

There is a number of general consequences arising from the above definitions. They are listed below. Some of these consequences will be seen later when the definitions are applied within the context of large deep European lakes:

i) Goals can be defined by individuals, groups of people who are not necessarily the ones who will realise the strategy. Some **people undertake the** realisation of a **strategy because they are driven by the belief that the goal is worth achieving**. Others are motivated **by the fear** that if the goal is not achieved, this may lead to detrimental consequences. Goals can be, and usually are, conflicting.

ii) **The realisation of any strategy takes time and diminishes the available resources**. A major fallacy concerning the notion of “strategy” is the belief that some goals can be achieved without losing *opportunities*. In fact, any strategy is based on a compromise of “opportunities” versus “time”, i.e. to achieve the goal within a certain time span, one has to concentrate on the realisation of a given strategy and accept that certain “opportunities” will be lost forever.

iii) If the goal is non-achievable within a given time span because the time available is too short or the resources are not sufficient, one should consider *extending the time* that is available or of *getting additional resources*. However, **the cost of getting the additional resources or time cannot be higher than the losses that result from not achieving the goal**.

iv) Choosing one strategy from a set of possible strategies to achieve a given goal, requires setting **a criterion** for making the choice between strategies.

v) The realisation of any strategy should be supported by a set of well-defined **indicators** that can help to measure the progress / regress made towards / from the goal or the assumed strategy.

vi) **For multiple goals there is no single strategy** that can lead to achieving all of them. Real life strategies within the multiple goals context are based on partially sacrificing the realisation of some goals. This frequently results in a situation where none of the goals is achieved 100%.

## 4 GOALS

### 4.1 GENERAL GOAL

The accumulated experience, together with the precautionary approach, common sense and compatibility with the Water Frame Directive leads to the following **General Goal**:

***"The good status of large deep European lakes should be achieved and maintained on a long-term basis."***

Based on the research carried out and the results obtained within the EUROLAKES project, the selection of the above formulation of the General Goal is justified. When considering strategies leading to the achievement of this General Goal, the following aspects must be taken into account:

1. **Perception / recognition of the goal levels:**

- a) European Community level
- b) Regional local level

2. **Time scales:**

- a) "Short-term" = up to 5 years
- b) "Long-term" = 5 years and more

3. **Aspects of sustainable development:**

- a) ecological
- b) social
- c) economic

4. **Main beneficiaries:**

- a) Regional communities
- b) Nature (lake ecosystems)

### 4.2 SPECIFIC GOALS

Formulation of the *General Goal* does not implicate how many and what types of actions have to be undertaken to achieve the goal itself. Therefore, a number of *specific goals* have been defined within the EUROLAKES project. Their choice is based on general knowledge, the results of this research and the experience gathered about large deep European lakes.

*Specific goals* cover all the aspects mentioned above. Once achieved they are expected to create the conditions, which can be equivalent to achieving the General Goal. The specific goals themselves can be achieved through a series of meaningful actions (strategies) that have to be undertaken by the communities inhabiting the European re-

gions of large deep lakes. Because of the continental importance of addressing the issues and problems of large deep lakes, the involvement of the European Commission is desirable.

The General Goal can only be realised if the actions / strategies related to *Specific goals* are coherently undertaken at both levels - the regional and the European ones. The table below contains the *Specific goals* arranged into two categories: short-term and long-term goals and subdivided into the regional and the European issues.

Tab.1. Table of *Specific goals*

	<b>Short-term</b>	<b>Long-term</b>
<b>European level</b>	<ul style="list-style-type: none"> <li>• <i>WFD extended</i> with respect to the maintenance of the “good status” of <i>large deep European lakes</i></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Support and control of the “good status“ of large deep European lakes set and executed</i> in Europe</li> </ul>
<b>Regional level</b>	<ul style="list-style-type: none"> <li>• <i>Indicators</i> (of pressures and the state) for the lake <i>defined</i> together with their measures</li> <li>• <i>Information and knowledge</i> on the lake and its catchment area consistently <i>gathered</i></li> <li>• <i>Regional specification of the “good status“</i> of the large deep lake <i>set</i></li> <li>• <i>Actual status</i> of the lake <i>assessed</i></li> <li>• <i>Actions</i> (e.g. pollution control) towards the improvement / maintenance of the “good status“ of the lake <i>undertaken</i> within the lake catchment area</li> </ul>	<ul style="list-style-type: none"> <li>• <i>Transparent mechanisms</i> aimed to maintain a good status of the lake <i>set and executed</i> within the lake catchment area</li> <li>• <i>Effective and stable institutional solutions in place, i.e.</i> <ul style="list-style-type: none"> <li>a) monitoring and maintaining the good status of the large deep lake</li> <li>b) updating information and knowledge about the lake</li> <li>c) revising and modifying the list of indicators and the definition of good status itself</li> <li>d) communicating the lake-oriented information and knowledge to Regional communities</li> <li>e) Influencing the decisions of major actors in the lake catchment area</li> </ul> </li> </ul>

## 5 STRATEGIES

### 5.1 CONCLUSIONS FROM THE RELATED INDIVIDUAL WORK PACKAGES

In this section, individual work packages' "strategic" conclusions have been integrated in order to formulate more general recommendations that can be used on the European and regional levels to achieve and maintain the "good status" of the large and deep lakes in Europe.

Important work package (WP) 14 has gathered local information and data from four lake sites: Lake Constance, Lac Léman, Lac du Bourget and Loch Lomond. At all four lakes' sites the aim of **water resources management** is to guarantee good quality of water resources. Main threats to good water quality come from overuse and from different sources of pollution. These threats can be handled through a better understanding of the system dynamics and the key processes followed by developing long-term solutions. From a management point of view it is of interest to define objectives for long-term solutions in terms of indicators such as the phosphorous content for water quality. It was an important task of the EUROLAKES project to identify the most suitable indicators and to link key process dynamics to these indicators. WP14 demonstrates that at present the management tools are not yet everywhere at a level which will guarantee the long-term sustainable development of the lake/catchment system. However, strong efforts in this direction are being made at all lake sites. While no reference status, as proposed by the European WFD, has been defined at any of the lake sites, the objectives of the present management concept at all lakes essentially imply such a reference status. There appears to be a wide interest to consider and integrate new findings and proposals, which may come out of focused activities such as EUROLAKES. In this respect, well-adapted models can be helpful and efficient tools.

As to the **monitoring programmes** that have been carried out in the past at large and deep European lakes experiences were the subject of WP23 ("Existing monitoring strategies") and WP30 ("Site characterisation"). These work packages conclude that despite of the lack of co-ordination between the monitoring programmes for deep European lakes, there were several common indicators of the lakes' status, which have been used in these programmes for a long time. It has been concluded that all the EUROLAKES sites have monitoring programmes of considerable length. The programmes show a high degree of integration. They are all suitable for interdisciplinary analysis although routine monitoring of the movement of water within the lakes is lacking. Despite the obvious differences, there is clearly an agreement that monitoring of both the littoral and open water is necessary as well as monitoring of the catchment. Additionally, for very deep lakes the inevitable habitat to monitor is deep hypolimnion, so called abyss monitor (with much lower frequency than pelagial or littoral) - see also D38.

Long-term records (circa 30 years) are available at least for some parameters on all of the four main lakes. From the description of the monitoring programmes, two groups of lakes can be distinguished, one including the Loch Lomond alone and one clustering the three other lakes. Monitoring programmes on Loch Lomond focus more on ecological habitats and give an equal importance to lake and to near shore landscape. So far, eutrophication there is not a central problem. Main aims of the survey are fisheries (angling), conservation, nature preservation and prevention of eutrophication. Monitoring programmes on Lac du Bourget, Lake Constance and Lac Léman mainly focus on pelagic communities and eutrophication. Long records are available for Lake Constance and Lac Léman including some information on benthic communities. This is not the case for Lac du Bourget where data records were incomplete. Monitoring programmes for this group are now gradually turning to a higher importance given to ecotoxicological aspects, to structure and conservation of littoral areas and to management of catastrophic scenarios (pollution coming from road traffic, for example). With respect to this the Lake Constance is ahead because of the long time concern of local management about the lake's shore restoration. From this standpoint Lac Léman follows and Lac du Bourget is the third.

Generally, the data concerning the impact of contaminants at the four EUROLAKES can not be used for reliable assessment of potential harm to the aquatic environment. In Lac du Bourget, for example, nothing can be said with certainty about the concentrations of the used pesticides in the water and sediment or in the mouths of some important tributaries. In all cases even less information exist about the joint effect of different substances on the lakes' status. These issues are discussed in D36 and D5 reports.

In work package 22 ("Long-Term Managerial Studies") it has been concluded that because the simulation models (used to describe processes in deep lakes) are mainly deterministic, it is not possible to use conceptual indicators in the sense of the Work package 18. Consequently, more effort should be directed to the development of this kind of applications. A lack of input data for sophisticated modelling purposes (management planning options) is a fact in almost all European deep lakes. In addition to the routine monitoring there is a need to scope the lake monitoring and the catchment monitoring more carefully. Similarly from WP25 ("Monitoring model studies") it can be concluded that the monitoring needed in modelling of lakes and their catchments may essentially differ from the monitoring strategies presented in the WFD. In the monitoring strategy of the WFD, the main emphasis is on detecting whether the status of a lake (or other water formation) is good or not. However, *for assessments made by means of models this kind of monitoring strategy is not sufficient. More focused monitoring is needed.* The models applied in this project can be used as tools to estimate how suitable the present monitoring programmes are for modelling purposes. In addition, models can be applied in analysing and improving the present monitoring programmes.

The most important large deep lakes in Europe have their own management and monitoring strategies to control the status of the lakes. The strategies have already been implemented by a number of national or international organisations that operate in the lakes' catchments. In the next paragraphs these *strategies and their effects* are

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shortly described. In most cases the effects of implementing the strategies are positive and hence they can be taken as a departing point in formulating *general strategies* for large deep lakes in Europe. The strategies and effects of their implementation in Loch Lomond, Lake Constance and Lac Léman described in next paragraphs are formulated as concise answers to the following questions:

### **“Management strategies”**

1. What are the major uses of the lake?
2. What kind of human practices / natural processes (in the lake or catchment) endanger the “good status” of the lake and thus the uses?
3. How are these practices (or have been) counteracted?
4. To what extent are (or have been) the counteracting practices effective?
5. How to make the counteracting practices more effective?
6. Who takes care for overall management of the lake?

### **“Monitoring strategies”**

1. What parameters are routinely measured / monitored in the lake?
2. How are they related to parameters defined in the Water Framework Directive?
3. How many measuring points (space distribution) are used in the routine monitoring system on the lake?
4. What frequency for the monitoring measurements is applied?
5. Is the time frequency and space distribution of measuring points adequate for assessing long-term behaviour of major status indicators within the lake?
6. What can be improved with respect to present ways of lake and catchment monitoring?
7. Who is doing the lake monitoring?

## 5.2 EXAMPLE OF LOCH LOMOND

### 5.2.1 Management strategies

- *What are the major uses of the lake Loch Lomond?*

Major uses are:

- Drinking water supplies for central Scotland.
  - Tourism (leisure attraction for the neighbouring City of Glasgow).
  - Natural heritage resource of national importance (Loch Lomond catchment lies within the boundary of the „Loch Lomond and Trossachs National Park“).
  - Only in the southern catchment of Loch Lomond agriculture has a certain importance.
  - Fishing and yachting is present but of minor importance.
- *What kind of human practices / natural processes (in the lake or catchment) endanger the “good status” of the lake and thus the uses?*

A list of threats can be found in the Catchment Management Plan (CMP). Some of the more important activities that endanger the natural functioning of the loch include those that contribute to eutrophication, the regulation of loch-water level and intensive recreational use. During summer there are several thousands of tourists per weekend which are visiting the Loch Lomond catchment and which cause a certain impact (sewage and litter). Mainly in the southern catchment of Loch Lomond agricultural activities regarding fertilisers to improve plant growing and sewage from cattle breeding has a certain impact. Land and boat traffic as well as fishing activities have a minor impact. However, the import of foreign species by boats and fishermen is a potential danger for the lake's eco-system.

The introduction of non-native fish species as live bait by anglers has threatened the powan, an endemic fish species. EUROLAKES research has suggested that temperature is a key regulator of production in the loch and that climate change may have profound impacts on loch function.

- *How are these practices (or have been) counteracted?*

The Scottish Environment Protection Agency (SEPA) is responsible for the control of any new application for septic tanks within 100 m of a water course in the catchment. So in effect most housing developments within the catchment are reviewed by SEPA. The recent foundation of the National Park provides a park management with rangers (a kind of park police) which take care of the protection of the environment within the catchment and watch the activities of tourists visiting the park.

For each potential impact on the loch the CMP identifies action(s) to be taken to prevent damage and a suitable actor(s) to carry out the action. The Scottish Environment

Protection Agency (SEPA) has put in place an action plan to counteract eutrophication and is encouraging stripping of phosphate by sewage treatment works. Scottish Water in conjunction with riparian owners has altered its regime of water level management to reduce impact on the shore zone. Angling associations are working together to prevent the use of live bait. The new National Park has invested heavily in recreation management.

- *To what extent the counteracting practices are (or have been) effective?*

Within a recent report (West Region Water Quality Review; 2000) SEPA published the following statements: "Between 1996 and 1999, some 97 % of river lengths in the West Region have remained in the excellent/good or fair river water quality categories and less than 0.25 % remain as seriously polluted waters."

And furthermore: "Since the 1996 baseline year, additional monitoring led to the identification of further 226 km of river lengths in the poor quality class. These additional poor quality river lengths are being added, where appropriate, to improvement plans over the next five years."

Regarding the Freshwater Lochs following statement is given in that report: "Of the 30 freshwater loch units (lake with it's catchment) assessed in SEPA West Region for the 1995 loch classification scheme, 22 were found to be in the excellent to good categories, 6 lochs were of fair quality and 2 lochs were of poor quality."

Freshwater lochs are classified on a 5-year basis and the recent monitoring for the next classification shows a clear trend to a higher percentage of excellent to good lochs.

Many of the measures put in place by the CMP are prophylactic. The absence of impact attests their success. SEPA's anti-eutrophication measures are still being put in place but their routine monitoring shows water quality in the loch to be good. The riparian owners association is content with the new arrangements for loch level management. New arrivals of non-native fish species continue, but given the size of the loch it is highly likely that they arrived before measures were put in place to prevent their arrival.

- *How to make the counteracting practices more effective?*

For most impacts on the loch existing measures are sufficiently effective. Communication between actors is for the most part excellent. Increased investment in management and research would definitely help in identifying the most serious threats. Capital investment in improved sewage treatment works and a change in land use practices would definitely reduce the threat of eutrophication. In draft strategic documents the National Park makes it clear that it is aware that it will need to be committed to the implementation of the WFD.

The park has recently reviewed economic activities within its limits. There is the intention to manage all of them as sustainably as possible. It is clear that some traditional economic activities, such as hill-sheep farming are not doing well. Alternative ways of managing the land may be sought by the National Park. For example, the low intensity of hill farming helps sustain wildlife which is under threat elsewhere. Recognising this service and paying farmers for maintaining biodiversity may be a sustainable alternative means of income. Such policies have potential benefits for SEPA and it's responsibility for the water quality, too.

- *Who takes care for overall management of the lake?*

At present the loch is managed by a number of different organisations, which co-ordinate their activities through the Loch Lomond Catchment Management Plan, and a variety of other committees. Due to the fact that Loch Lomond is a major part of the recently founded National Park the park authority will play a major roll in the overall lake management. However, for certain types of planning applications organisations with expertise in freshwater management are consulted; Scottish Water, the Scottish Environment Protection Agency and Scottish Natural Heritage. SNH is not normally consulted unless a development is likely to directly impact on an area with a natural heritage designation, although at Loch Lomond this is often the case. SEPA is consulted more frequently with regard to the protection of the environment and with regard to maintain a good water quality.

### **5.2.2 Monitoring strategies**

- *What parameters are routinely measured / monitored in the lake?*

SEPA is monitoring continuously the water quality of the loch. This is done by four different monitoring programmes:

- Loch Mid Line Survey: monthly measurements and water sampling at 8 fixed locations on the length axis of the loch.
- ECN sites: Invertebrates are sampled at the sites for chemical sampling. Some invertebrate samples are taken at the two long-term Environmental Change Network (ECN) sites, as are plankton and macrophyte samples.
- Littoral & Main Bay sites: Monitoring 4 to 8 times per annum with a spatial coverage of 22 locations in the littoral zone. About 8 parameters (plus) are monitored.
- Catchment monitoring every 2 months at 23 locations / sites where 8 parameters (plus) are monitored.

The report for WP23 “Existing Monitoring Strategies” gives all this information in detail. In the loch nutrient levels and chlorophyll-a levels are monitored monthly. In addition, pesticide residues, heavy metals and PACs are monitored. Benthic invertebrates are surveyed and there are two ECN monitoring sites in the loch which are subject to intensive survey annually. Water level is also routinely monitored. The table below presents the parameters measured in Loch Lomond and its catchment (inclusive rivers).

**Tab. 2: Measured parameters in Loch Lomond and its catchment**

Parameter	Detection limit	Loch Mid line Sites	ECN sites	Littoral and main bay sites	Catchment Rivers
Invertebrates			X	X	X
Chlorophyll-a		X	X	X	
pH		X	X	X	X
Alkalinity		X	X	X	X
DO	0.1 mg/l	X	X	X	X
BOD		X	X	X	X
Temperature	1°C	X	X	X	X
Secchi depth		X			
Suspended solids		X	X	X	X
Total Nitrogen	0.01 mg/l		X		
Ammonium (as N)	0.01 mg/l	X	X	X	X
Nitrate (as N)	0.01 mg/l	X	X	X	X
Nitrite (as N)	0.01 mg/l	X	X	X	X
Alkalinity	0.02 mg/l		X	X	X
Chloride	0.05 mg/l		X	X	X
Total organic carbon	0.1 mg/l		X		
Particulate organic carbon	0.1 mg/l		X		
Phosphate (soluble reactive)	0.005 mg/l		X		
Total phosphate	0.005 mg/l	X	X	X	X
Orthophosphate	0.005 mg/l	X	X		
Silicate	0.01 mg/l	X	X		
Sulphate	0.005 mg/l		X		
Sodium	0.01 mg/l		X		
Potassium	0.01 mg/l		X		
Calcium	0.01 mg/l		X		
Magnesium	0.01 mg/l		X		
Aluminium (total)	10 µg/l		X		
Manganese (total)	50 µg/l		X		
Iron (total)	50 µg/l		X		
Mercury	0.1 µg/l		X		

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Organochlorine pesticides	< 10 µg/l	X
Organonitrogen pesticides	< 10 µg/l	X
Organophosphorus pesticides	< 10 µg/l	X
Polyaromatic hydrocarbons	< 10 µg/l	X

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- *How are they related to parameters defined in the Water Framework Directive?*

The ECN suite of parameters covers zooplankton, phytoplankton, invertebrates and macrophytes, all groups required to be monitored by the WFD. Monitored annually, they could be regarded as sufficient to meet WFD requirements for surveillance monitoring although it is likely SEPA will apply a tailored monitoring programme for these elements to all of Scotland, including Loch Lomond. Most of the elements intensively monitored are regarded as supporting elements to the Directive. It is yet to be established whether chlorophyll level will be accepted as a suitable surrogate for phytoplankton abundance and composition as required by the WFD.

- *How many measuring points (space distribution) are used in the routine monitoring system on the lake?*

There are 8 sampling points along the mid line of the loch with additional sites closer to shore.

- *What frequency for the monitoring measurements is applied?*

For most parameters, full depth profiles are taken once a month.

- *Is the time frequency and space distribution of measuring points adequate for assessing long-term behaviour of major status indicators within the lake?*

EUROLAKES reports confirm that the existing sites are suitable. Fortnightly sampling during the growing season would be beneficial.

- *What can be improved with respect to present way of lake and catchment monitoring?*

Integration of loch and catchment sampling programmes, especially the synchronisation of sampling in the loch and in feeder rivers, would enormously improve our capacity to understand the system.

- *Who is doing the lake monitoring?*

SEPA, Scottish Water.

## 5.3 EXAMPLE OF LAKE CONSTANCE

### 5.3.1 Management strategies

- *What are the major uses of the Lake Constance?*

Major uses are:

- Drinking water supplies and sewage outfalls
- Fishery
- Water sports
- Tourism and long-term residence of retired people as well as vacation residences of well-off people

- *What kind of human practices / natural processes (in the lake or catchment) endanger the "good status" of the lake and thus the uses ?*

Discharge of sewage as cleaned sewage plus rain water from rain water reservoirs after being filled due to strong precipitation events, pressure of settling and residence on the lakeshore and near hinterland, diffuse discharge from agricultural cultivation in the catchment, natural separation of the eastern region, the Bay of Bregenz, by sedimentation of the Alpine Rhine in transverse direction away from its artificial mouth since 1900, traffic accidents by ships, air planes and cars driven along the roads near the shores as well as railway accidents in regions close to the lake shore and tributaries, oil pipe line very close to the lake shore at the eastern end running from Italy to Ingolstadt as one of the main former supplies for southern Germany.

- *How are these practices (or have been) counteracted?*

A network Construction of sewage plants in the whole catchment: a few large scale ones, e.g. at Ravensburg and Konstanz usually designed for high cleaning degree as rank 3 or 4, a lot of smaller scale sewage plants of less rank, guide lines of the IGKB for keeping Lake Constance clean and general environment protection of this lake water body: novel versions since the last complete edition from 1987, improvement of public access to the lake shore, construction of a bicycle way around the lake, long-term construction of the mouth of the Alpine Rhine in order to divert the main direction of this inflow longitudinally into the deep central basin, political desistance from the construction of a motor highway (Autobahn) along the northern hinterland of Lake Constance as connection between the western Autobahn end near Stockach and the eastern Autobahn near Lindau, stop of oil pumping through the eastern pipe line since around 1999 due to commercial reasons but with an essential effect to remove severe risk conditions of oil spill for the sake of Lake Constance, etc.

The total costs of the construction of all the sewage plants in the catchment for saving the good limnological state of Lake Constance amount to four billions of Euro since the 1960'ies until the end of the twentieth century ( four thousand millions Euro). The ranking degree of the cleaning methods means: 3 corresponds to mechanical, biological and chemical cleaning, while 4 includes additionally a flocking filtration method.

- *To what extent are (or have been) the counteracting practices effective?*

Reduction of input of phosphorus compounds from 87 mgr/cbm in 1979 to 12 mgr/cbm in 2003, coordinated recommendations for measures to reduce diffusive discharge of nutrients and other impairing substances as well as other protection measures, completion and improvement of sewage cleaning plants covering utmost the whole catchment, restoration of lakeshore segments by the method developed in the ISF and meanwhile adopted by the other bordering nations around the lake including a general agreement for the procedures, which is just being elaborated, mutual information obligation concerning large scale projects in the catchment with aftermath on the state of Lake Constance, etc.

- *How to make the counteracting practices more effective?*

Continuation of the above measure and information tools, current deliberation of strategies and concepts, current control of the lake's reaction and adaptation, adaptation of the monitoring programme, public relation programme to inform about the control, improvements and recommendations.

- *Who takes care for overall management of the lake?*

The International Deputie's Conference of the Fishery in Lake Constance (Internationale Bevollmächtigtenkonferenz für die Bodenseefischerei), IBKF (Internationale Bodensee Konferenz für Fischerei), AWBR (Arbeitsgemeinschaft Wasserwerke Bodensee-Rhein), national administrations of water affairs and environment of Austria (State of Vorarlberg), Germany (States of Baden-Württemberg and Bavaria), Switzerland (Kantons of Graubünden, St.Gallen, Thurgau and in official replacement of the State of Liechtenstein), IBK - Internationale Bodensee Konferenz as governmental commission for joint affairs of the Lake with direct political deputies of each bordering government, etc.

### **5.3.2 Monitoring strategies**

- *What parameters are routinely measured / monitored in the lake?*

Plant nutrients, microbial measurements of sewage indicators, phytoplankton, zooplankton, macrophytes, zoobenthos, phytobenthos, harmful substances selectively, temperature and electrical conductivity, transparency (Secchi disk), meteorological data from the German Weather Service (DWD), current investigations of the fishery management.

- *How are they related to parameters defined in the Water Framework Directive?*

According to WFRL the quality status of the lake is determined on the basis of the data mentioned in B1, the bathing water quality at the huge public bathing places on the lake shore is controlled according to the EU-bathing water guide lines by the health authorities and reported by them to the EU (Switzerland applies a similar system merely on national level).

- *How many measuring points (space distribution) are used in the routine monitoring system on the lake?*

Presently, five routine stations: Bregenzer Bucht, Seemitte Fischbach-Uttwil (midlake at greatest depth), Seemitte Lake Überlingen (midlake off Überlingen), Zeller See and Rheinsee (midlake Zeller basin and southern basin Rheinsee both in lower Lake Constance).

- *What frequency for the monitoring measurements is applied?*

Every four weeks.

- *Is the time frequency and space distribution of measuring points adequate for assessing long-term behaviour of major status indicators within the lake?*

Long experience has shown that the present monitoring programme is adequate.

- *What can be improved with respect to present ways of lake and catchment monitoring?*

Running of automatic observational stations at the inflows of the important tributaries, increase of time and vertical measurement resolution in the deepest layers of the main basin along with appropriate higher precision seasonally at least during wintertime and early springtime.

- *Who is doing the lake monitoring?*

IGKB with main focus charge on ISF since 1961, additionally: Environmental Institute of the State of Vorarlberg (Austria), AWBR in terms of BWV (Water Supply of Stuttgart) for Lake Überlingen, tributary monitoring of the Austrian inflows by the Austrian Hydrographical Service, hydrological and water quality monitoring of the Alpine Rhine at the station Schmitter just upstream the mouth by the Swiss Federal Hydrological Service (Landeshydrologie in Bern), about every decade there is an intensive annual measurement programme of water quality of the main tributaries, which is carried out at the German side mainly by the ISF by order and charge of the IGKB for a general control and calculation in detail of the quality state of Lake Constance.

## 5.4 EXAMPLE OF LAC LÉMAN

## 5.5 MANAGEMENT STRATEGIES

- *What are the major uses of the Lac Léman?*

Major uses are:

- Drinking water intakes and sewage outfalls
- Fishery
- Tourism (beach and boat travel)

- *What kind of human practices / natural processes (in the lake or catchment) endanger the “good status” of the lake and thus the uses?*

There are no natural processes, which endanger these uses. The principal danger comes from water pollution. So far, pollution was mainly due to the oversupply of phosphorous through sewage and diffuse sources in agriculture, which enter through rivers. More recently, heavy metals and micro-pollutants such as endocrine disrupters and hormones become important.

- *How are these practices (or have been) counteracted?*

A network of sewage treatment plants has been built and since 1972 they have been progressively equipped with elimination of phosphorus. Phosphorus was banned from detergents in Switzerland in 1985. For Lac Léman and the catchment, the total number of sewage treatment stations is 221. 98.9 % of the population is connected to these stations. The CIPEL controls each year randomly at least 50% of these stations for their efficiency. Farmers have been alerted to the proper use of fertilizers in order to reduce the load by diffuse sources.

- *To what extent are (or have been) the counteracting practices effective?*

The total amount of phosphorus in the Lac Léman has been reduced from almost 90 mg/l in 1975 (peak value) to less than 40 mg/l today and the trend is towards further reduction.

- *How to make the counteracting practices more effective?*

In addition to the publication of its annual reports which have been provided since 1960 the CIPEL has defined for the period 2001-2010 a management and action plan. Details are provided in dash boards. Before enacting this plan, CIPEL has held public hearings about it in several locations around the lake. This was done to alert the public to the state of the Lake and the plans to further improve it. The feedback input from

these hearings has been integrated in the plan. The dashboard concept allows an efficient evaluation of the progress of the actions with respect to the initial concept.

- *Who takes care for overall management of the lake?*

The International Commission for the waters of the Lac Léman (CIPEL). Both the Swiss and the French governments mandate CIPEL. All local state governments surrounding the lake and the catchment are members of the CIPEL.

### 5.5.1 Monitoring strategies

- *What parameters are routinely measured / monitored in the lake?*

Profiles of physico-chemical parameters are measured with a multi-parameter profiling instrument. Parameters are: temperature, electric conductivity, dissolved oxygen, pH, turbidity and chlorophyll *in vivo*.

The following chemical substances are evaluated from bottle profiles: N-NH<sub>4</sub>, N-NO<sub>2</sub>, N-NO<sub>3</sub>, N<sub>tot</sub>, P-PO<sub>4</sub>, P<sub>tot</sub>, Si, Cl, SO<sub>4</sub>, Na, K, Ca, Mg, Al with a standard error of about 5%. Also monitored are seven heavy metals and a number of organic micropollutants.

Nine taxa of phytoplankton (micro and nanoplankton) with more than 30 species are monitored from bottle profiles, as well as the zooplankton, and the bacterioplankton. Evaluated are their presence or absence, their estimated stock and depth distribution and the population succession.

On the next level of the food chain, the six most important species of fish are surveyed in a separate programme with a monthly resolution. Parameters are the estimated total stock, the size distribution and the stomach content.

- *How are they related to parameters defined in the Water Framework Directive?*

This aspect is not applicable to Switzerland.

- *How many measuring points (space distribution) are used in the routine monitoring system on the lake?*

Two: one in the centre of the deep lake basin (*grand lac*) and one in the centre of the small lake basin (*petit lac*).

- *What frequency for the monitoring measurements is applied?*

From experience, the frequency of the monitoring is adapted to the biological cycle of the lake. For most parameters, full depth profiles are taken once a month. They are taken twice a month during periods of high biological activities or strong gradients. For bottle profiles, the following depths have been chosen:

Deep lake basin:

0-2.5-5-7.5-10-15-20-30-50-100-150-200-250-275-290-300-305-309 m.

Small lake basin:

0-2.5-5-7.5-10-15-20-30-50-70 m.

- *Is the time frequency and space distribution of measuring points adequate for assessing long-term behaviour of major status indicators within the lake?*

Long experience has shown that the present monitoring programme is adequate for those parameters for which sufficient knowledge about their behaviour and the means and techniques for their elimination exists. For those “new” pollutants, CIPEL may mandate specialists to evaluate the situation and the risks and determine the monitoring programme accordingly. The monitoring strategies are reviewed every 5 years by a technical and scientific commission of the CIPEL and may be adapted if considered necessary.

- *What can be improved with respect to present way of lake and catchment monitoring?*

Based on the long-term experience and the good results, which are evident, the Swiss government considers the present monitoring strategy adequate. This is also a question of budget made available by the federal government for the monitoring programme. For the time being, the Swiss government has no intention to change the monitoring even if the Water Framework Directives propose a different strategy. In particular, the Swiss government is opposed to implementing any WFD monitoring strategy, which may require additional funding.

- *Who is doing the lake monitoring?*

Both the Swiss and the French governments define the monitoring plans and the strategies are mandated by CIPEL. Qualified (certified) local laboratories on behalf of the CIPEL carry out the actual monitoring. Each year, the person / persons in charge of a specific monitoring task write a *status report* based on the monitoring of that year and evaluate the long-term trends for each parameter. This report becomes part of the annual report of the CIPEL. On demand by the CIPEL, all status reports are reviewed by (outside) specialists before being accepted for publication in the CIPEL annual report.

## 6 THE EUROLAKES STRATEGIES

### 6.1 MONITORING

- **As the** processes that determine status of the lake (**key processes**) within large deep lakes **are characterised by their zonal structure, sampling points** of any monitoring system **should follow the zonal pattern of the processes**. In particular, **additional sites closer to shore** are strongly advisable, as the impacts made by the local stresses are “visible” mostly in these zones.
- Present situation at major large deep lakes in Europe indicate that **3-5 measuring points located at littoral and pelagial supplemented by measuring points at the mouth of effluent rivers** can be considered as minimal set.
- **Sampling frequencies of particular processes should follow the dynamics of these processes**. In particular, integration of catchment sampling programmes with the lake’s sampling, especially the synchronisation of sampling in the lake and in feeder rivers is crucial, as it will enormously improve our capacity to understand the system. For the lake, an advisable **monitoring interval is monthly**, however, **fortnightly sampling during the growing season would be beneficial**.
- **Standardisation of the monitoring methods** especially as to the measurable biological parameters specific to deep lakes (e.g. benthic invertebrates, bacteria loop) is required.

### 6.2 MANAGEMENT

- Because of specificity of their dynamics, large deep European lakes form a special set of lakes in Europe, distinct from remaining (smaller and/or shallower) lakes. **Therefore, it is strategically important to adopt water management methods, list of indicators and monitoring practices specifically suited to these lakes**.
- As the large deep European lakes are particularly vulnerable to depositing organic and toxic substances within their water bodies (see Key Processes recommendations) **maintaining the “good status” of these lakes can be achieved by limiting deposition of organic and toxic substances into the lakes**, (i.e. by controlling fluxes of these substances to the lakes).
- Because of diversity of actors and their interests, interdependencies of processes in the large deep lakes and complexity of decision-taking, **rapid introduction of modern decision support tools** (like those proposed by the EUROLAKES project) in the lakes’ catchments management **is advisable**.

- It is highly recommended to communicate by regional authorities the lake-oriented information and knowledge to the local community and ***discuss publicly decisions that may have an impact on the “good” status of the lake.***

### 6.3 INSTITUTIONAL STRENGTHENING

Although the present status of major large deep lakes in Europe can be considered rather good, the results of the EUROLAKES project reflect a concern about the future long-term evolution of these lakes. There is a hope that these lakes will continue to serve the regional communities of Europe as they have for thousands of years. On the other hand, there is a fear that certain human activities on the lakes or within their catchment areas may threaten to „turn these lakes into bad or even bad and unrecoverable state in an unpredictable manner”.

It can be concluded from the research done within this project that due to their unique dynamics, the large deep European lakes are particularly vulnerable to depositing organic and toxic substances within their water bodies. In view of our limited knowledge of complex, multi-scale dynamics of physical, chemical and biological processes within these lakes cautious approach has to be applied together with any sensible strategy.

As it has been observed, the actors and users of these lakes were not necessarily cautious in the past. There is also no guarantee that they will be cautious in the future. Therefore, the only way to maintain the “good status” of the lakes in the long run is to establish some sort of organisational and regulatory framework that will make it possible to continually monitor and control the lakes and activities within their catchment areas.

Once accepted, the lake-region communities will soon perceive these organisational and regulatory innovations as a normal part of their lives. As the regulatory basis for treating large deep European lakes with special care (because of their dynamic behaviour) establishing a large-deep-lake-extension to the Water Framework Directive should be considered.

The extension should contain:

- a) definition of large deep lake,
- b) justification of the extension itself and
- c) a number of specific requirements concerning management and monitoring applicable to large and deep lakes.

These requirements will act as constraints for decisions and activities / uses that are or may be undertaken by the regional communities in the lakes and within their catchments’ areas.

Creation of the advisory group in each lake-region as the body supportive to the existing regional water authorities / institutions introduces a desirable new actor, the one who will focus on controlling and maintaining the “good status” of the lake. It is recom-

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mended that on the European level the advisory groups in the lake-regions can form a network aimed towards exchanging experience and information. The European Commission might support the network.

These institutional improvements can be equally well realised by already existing regional water institutions by adopting the concept of advisory group as by possibly newly created bodies / institutions once their creation is found useful. In both instances it is considered indispensable to create legal and financial conditions through which the European Commission can introduce necessary regulatory framework. This framework will be based on extending the WFD with the large-deep-lakes paragraph, logistic and financial support to the regional water management bodies and supervision of activities of the regional advisory groups. In general, the Strategies when known and accepted at the European and regional levels may become a good departure point for achieving and maintaining “good status” of large deep European lakes on a long-term basis (*general goal*). If additionally supported by the regional communities, regional water institutions and by the European Commission they have a good chance to succeed.

On the practical level of managing the “good status” of large deep lakes in Europe the Strategies offer a number of recommendations concerning monitoring, data processing, research, standardisation, exchange of information and decision-supporting methods specifically suited to these lakes. Necessity of exchanging experience and information applies to measuring, interpreting and modelling of relevant physical, chemical and biological processes in large deep lakes.

Within the Deliverable “Strategies” good examples of managerial and monitoring strategies of Loch Lomond, Lake Constance and Lac Léman are described. Water and catchment management combined with appropriate monitoring strategies of these lakes led to considerable improvement of the status of the lakes. It is expected that by learning from these examples one can improve the status of other large deep lakes in Europe.

The strategy of achieving or maintaining “good status” of the lake through institutional strengthening is summarised below in bolds and further presented in two scales: in the European scale and in the regional scale (Table 3).

- Since **the large deep European lakes** serve large populations, possess unique features in their dynamics and pose the risk of “turning into bad or even bad and unrecoverable state in an unpredictable manner,” they **require special care and a special political status** (such as has been established for the “Great Lakes” in Canada / USA, and the Danube river and Rhine river in Europe).

- **By adopting a concept of the advisory group**, the local water management authorities will concentrate activities related to “good status” of the lake in one hand. The following responsibilities can be envisaged for the advisory group:
  1. **Continuous measuring of major physical, chemical and biological parameters and indicators of the lake and its catchment.**
  2. **Continuous upgrading, interpreting and processing of information and knowledge** on the lake and its catchment area.
  3. **Setting regional specification of the “good status”** of large deep lakes.
  4. **Defining the indicators** (of pressures and the state) **specific for the lake** together with their measures and assuring that the list contains indicators included in the Water Framework Directive.
  5. **Assessing the actual status of the lake.**
  6. **Initiating and organising activities** towards the improvement and maintenance of the “good status” of the lake.
  7. **Setting the Lake Catchment Management Plan** as the obligatory document that integrates all activities and measures concerning the lake and its catchment.
  8. **Exchange of experience in the lakes’ management between regional advisory groups and the “quality control” of their activities** as to the maintenance of “good status” of the large and deep lakes **is also recommended**. Necessity of exchanging experience and information also applies to **measuring, interpreting and modelling of relevant physical, chemical and biological processes in large deep lakes**. Modern tools of the **system analysis, environmental economy and mathematical modelling** methods for prediction and risk assessment, decision making etc. need to be used for the purpose.

**Tab. 3. General Strategies in institutional strengthening for large and deep European lakes**

	<b>Short-term</b>	<b>Long-term</b>
<b>European level</b>	<ul style="list-style-type: none"> <li>• <i>Formulation of an extension of the “Lakes” paragraph of the WFD with respect to large deep lakes</i></li> <li>• <i>Concerted actions undertaken by limnologists at the regional and European level aimed at introducing the necessary extension of the WFD. The extended WFD should allow and facilitate the maintenance of the “good status” of large deep European lakes</i></li> <li>• <i>Establishing the legal and financial conditions for networking between the water management bodies along large and deep lakes</i></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Supporting networks of advisory groups. Also controlling whether their activities are executed according to extended WFD and are dedicated to maintaining the “good status” of large deep European lakes</i></li> <li>• <i>Revising periodically and, if required, modifying the regulatory instruments concerning the preservation of the “good status” of large deep lakes in Europe</i></li> </ul>
<b>Regional level</b>	<ul style="list-style-type: none"> <li>• <i>Setting the Advisory Group at the local water management authority where necessary. The AG should be responsible for:</i> <ol style="list-style-type: none"> <li>1) <i>consistent gathering of information and knowledge on the lake and its catchment area</i></li> <li>2) <i>setting regional specification of the “good status” of large deep lakes</i></li> <li>3) <i>defining the indicators (of pressures and the state) for the lake together with their measurements</i></li> <li>4) <i>assessing the actual status of the lake</i></li> <li>5) <i>initiating and organising precautionary actions towards the improvement and maintenance of the “good status” of the lake</i></li> </ol> </li> </ul>	<ul style="list-style-type: none"> <li>• <i>Maintaining the stable existence and high technical status of the Advisory Group using economic instruments but at the same time:</i> <ul style="list-style-type: none"> <li>- <i>Controlling the transparency and efficiency of the AG activities using legal and political means</i></li> <li>- <i>Employing knowledgeable people by the AG who can combine theoretical knowledge and practical skill with the single aim of controlling the “good status” of the lake</i></li> <li>- <i>Running educational and cultural programmes in the region to promote the idea of keeping the “good status” of the lake</i></li> </ul> </li> </ul>

## 7 TOOLS AND METHODS

A number of tools, methods and procedures need to be considered as useful to realise the Strategies concerning the maintenance of the “good status” of large deep lakes in Europe.

They can be subdivided into two groups:

- a) information technologies and
- b) managerial (and policy) tools and methods.

### 7.1 INFORMATION TECHNOLOGIES

Modern tools and methods allow and facilitate the gathering of knowledge and data concerning the status of large deep lakes in well-organised manner. The lakes’ monitoring systems and procedures, data banks, decision support systems, mathematical models of large deep lake phenomena, dashboards etc. are examples of these tools. Water managers and decision-makers (regional authorities) are to be the targeted users of the tools.

In particular, the decision support systems developed for Lac du Bourget and Loch Lomond have been developed with the decision-makers in mind. The two Decision Support Tools are not only generically prepared to gather complex (spatially distributed) data concerning the lakes and their catchment areas but also allow simulating pre-prepared scenarios of the different uses of the lake and its catchment area.

For the purpose of simulating large deep lake hydrodynamics, several numerical models have been developed within the EUROLAKES project including two major 3-dimensional numerical models (Hydromod model, EPFL model and Telemac of Sogreah). Because of their dimensionality and complexity, the 3D-models could have been applied only in the “off-line” mode. Nevertheless, the 3D-models have proven to be indispensable, especially when dynamics of selected Key Processes (WP9) have been investigated in detail.

In addition to the number-crunching models, the post-processing software equipped with graphical outputs has also been developed or adopted. The GIS packages (ArcView and MapInfo) have been implemented into the Decision Support Tools allowing a visual assessment of the results.

In the WP 21 (Short-term management studies) report it is concluded that despite known limitations modern high-resolution hydrodynamic models are invaluable tools in research and management studies. They can help scientists and water managers to gain deeper insight into specific features of physical processes, like currents and waves, spreading of river plumes, drift and dispersion of pollutants and so on.

To “translate” the modelling results to the language of managers and decision-makers the joint expertise of modellers, physicists, limnologists, biologists and ecologists is required. Partially this task has been undertaken in D38 (report on “Key Processes”). Clearly, the information technologies adopted or developed within the EUROLAKES project have proven their usefulness when tested as a modern tool for the lakes’ water managers.

## 7.2 MANAGERIAL TOOLS AND METHODS

In addition to technological tools also operational, system analytic and logistic methods must also be mastered and made available in order to make the proposed Strategies work. In table 4 major initiatives and programmes are listed. They are aimed to support both European and regional levels of the Strategies in a complementary fashion, e.g. actions that will support the *extension* of the Water Framework Directive or the creation/operation of the advisory group network at the European level.

Tab.4. Managerial tools and methods

	<b>Short-term</b>	<b>Long-term</b>
<b>European level</b>	<ul style="list-style-type: none"> <li>• <i>Organising a series of presentations on the EUROLAKES project results at regional and European forums. It must be made known that if applied to large deep lakes the WFD can not be effective unless the particularities and complexities of these lakes are taken into account explicitly</i></li> <li>• <i>Funding a (post-EUROLAKES) project on formulating the EC regulatory procedures promoting the control of the “good status” of large deep European lakes</i></li> <li>• <i>Setting a financial basis for the advisory group network</i></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Financing and executing the EC Programmes that stabilise the EC regulatory procedures of controlling the “good status” of large deep European lakes at the regions</i></li> <li>• <i>Initiating consultations / seminars on guidelines and good practices of maintaining the “good status” of large deep lakes</i></li> </ul>
<b>Regional level</b>	<ul style="list-style-type: none"> <li>• <i>Setting a financial basis for the advisory group</i></li> <li>• <i>Set-up of a <u>modus operandi</u> for the advisory group</i></li> <li>• <i>Equipping the advisory group with:</i></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Supporting the stable operation of the advisory group by regional authorities</i></li> <li>• <i>Employing knowledgeable staff by the advisory group. The personnel should combine the following <u>theoretical knowledge</u> in:</i></li> </ul>

	<p>a) <i>instrumentation</i> for measuring the lake and the lake catchment area parameters</p> <p>b) <i>Equipment for information and data processing</i> (databases, DSS, mathematical models of processes, dashboard, etc.)</p> <p>c) <i>the capacity to undertake meaningful actions</i> within the lake catchment area aimed at keeping the “good status” of the lake</p>	<p>a) processes, parameters and indicators in lakes and their catchment areas</p> <p>b) monitoring/measuring methods and technologies</p> <p>c) informatics and data processing</p> <p>d) mathematical modelling of physical and biological processes</p> <p>e) system analysis methods (prediction methods, risk assessment etc.)</p> <p>f) public relations techniques</p> <p>g) basics of environmental economy</p> <p><b>with <u>practical skills</u> in:</b></p> <p>a) operating a monitoring system for controlling/measuring the state of the lake and the state of its catchment area</p> <p>b) processing information and knowledge about the lake</p> <p>c) using scientific methods to verify, revise, modify and update the list of indicators and also (re)-define the “good status” of the lake</p> <p>d) initiating public debates concerning the “good status” of the lake</p> <p>e) communicating the lake-oriented information and knowledge to the Regional community</p> <p>f) discussing publicly decisions that may have an impact on the “good status” of the lake</p> <p>g) maintaining the “good status” of the lake by influencing decision makers and major actors in the lake catchment area</p>
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## 8 RESOURCES AND CONSTRAINTS

Table 5 below lists the Constraints (C) and Resources (R) required for the realisation of the proposed Strategies. The listed (R) and (C) reflect typical situations encountered in the EUROLAKES project. Clearly, at each large deep European lake, the resources and constraints may differ from the resources and constraints at other lakes.

**Table 5. Resources and constraints**

	<b>Short-term</b>	<b>Long-term</b>
<b>European level</b>	<p>( R )</p> <ul style="list-style-type: none"> <li>• EC funds directed to regional development</li> <li>• Experienced limnologists and water management specialists (Europe-wise)</li> </ul> <p>( C )</p> <ul style="list-style-type: none"> <li>• Psychological tendency to simplify lake dynamics by the lake catchment area actors involved</li> <li>• Reluctance to make changes in daily routines</li> </ul>	<p>( R )</p> <ul style="list-style-type: none"> <li>• Regional environmental funds</li> </ul> <p>( C )</p> <ul style="list-style-type: none"> <li>• Possible conflicts with national Environmental Authorities over water <b>sovereignty</b></li> <li>• Legal complexities</li> <li>• Long duration of introducing changes in law</li> <li>• Lack of funds</li> </ul>
<b>Regional level</b>	<p>( R )</p> <ul style="list-style-type: none"> <li>• Extensive basic information about the lake</li> <li>• High level of expertise</li> <li>• Qualified persons</li> <li>• Basic technologies</li> <li>• General societal acceptance of the idea of keeping the “good status“ of the lake</li> </ul> <p>( C )</p> <ul style="list-style-type: none"> <li>• Limited financial resources</li> <li>• Unknown factors in science, nature, social processes and economy</li> <li>• Existing institutions and their relationships</li> <li>• Reluctance of major actors to collaborate</li> <li>• Complexity of a start-up of the Advisory Group</li> </ul>	<p>( R )</p> <ul style="list-style-type: none"> <li>• Water resources taxation</li> <li>• Good technological environment</li> <li>• Good exchange of information and knowledge</li> </ul> <p>( C )</p> <ul style="list-style-type: none"> <li>• Difficulties in influencing decision makers and major actors to maintain the “good status“ of a large deep lake and its catchment area</li> <li>• Difficulties in overcoming cultural and social habits</li> </ul>

## 9 FEASIBILITY VS. RISK

Table 6 below assesses the Feasibility (F) and Risks (R) that may accompany the realisation of the proposed Strategies. The listed (F) and (R) are based on typical situations observed while doing research within the EUROLAKES project. At each location the feasibility and risks are different. However, certain likely situations can be envisaged and later used when the Strategies are initiated.

**Table 6. Feasibility and risks**

	<b>Short-term</b>	<b>Long-term</b>
<b>European level</b>	<p>( F )</p> <p><i>The necessary resources which are available:</i></p> <ul style="list-style-type: none"> <li>• Extensive basic information about the lake</li> <li>• High level of expertise</li> <li>• Qualified persons</li> <li>• Basic technologies</li> <li>• General social acceptance of the idea of keeping the “good status” of the lake               <ul style="list-style-type: none"> <li>• <i>A fraction of the regional development funds from the EC would be sufficient to support the creation of the postulated advisory groups within the lake-regions</i></li> </ul> </li> </ul> <p>(R)</p> <ul style="list-style-type: none"> <li>• Schedules of creating new directives by the EC may not favour the fast introduction of the postulated extension of the Water Frame Directive “on large deep lakes”</li> <li>• Consequently, the creation of the advisory group network may be postponed</li> </ul>	<p>( F )</p> <p><i>The necessary resources, which are available:</i></p> <ul style="list-style-type: none"> <li>• Good technological environment</li> <li>• Good exchange of information and knowledge concerning large lakes</li> </ul> <ul style="list-style-type: none"> <li>• <i>A fraction of the funds assigned to water protection in Europe would be sufficient to support activities of advisory groups network in Europe</i></li> </ul> <p>(R)</p> <ul style="list-style-type: none"> <li>• <i>Change in EC water policy</i></li> </ul>
<b>Regional level</b>	<p>( F )</p> <ul style="list-style-type: none"> <li>• <i>Necessary resources</i></li> <li>a) Extensive basic information about the lake</li> <li>b) High level of expertise</li> <li>c) Qualified persons</li> <li>d) Basic technologies</li> <li>e) General social acceptance of the</li> </ul>	<p>( F )</p> <ul style="list-style-type: none"> <li>• <i>Necessary resources</i></li> <li>a) A fraction of the water resources tax collected in the lake regions would be sufficient to support the basic activities of the postulated Advisory Groups</li> </ul>

	<p>idea of keeping the “good status“ of the lake</p> <p>( R )</p> <ul style="list-style-type: none"> <li>• <i>Sufficient resources for creating the advisory group may not materialise due to:</i> <ol style="list-style-type: none"> <li>a) Limited financial resources of the regional water authority</li> <li>b) Uncontrolled factors in science, nature, social processes or economy</li> <li>c) Reluctance of major actors to collaborate</li> </ol> </li> </ul>	<ol style="list-style-type: none"> <li>b) Good technological environment</li> <li>d) Good exchange of information and knowledge <i>available</i></li> </ol> <p>(R)</p> <ul style="list-style-type: none"> <li>• <i>Sufficient resources for the AG operation may not materialise due to:</i> <ol style="list-style-type: none"> <li>a) Unfavourable social and economic factors within the lake region</li> <li>b) Natural disasters</li> <li>c) Difficulty in assessing the benefits resulting from the activities of the Advisory Group may put its existence in jeopardy</li> </ol> </li> <li>• <i>Transparency and/or people’s participation in the lake-related decisions may be obscured by regional groups of interest</i></li> </ul>
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## 10 CONCLUSIONS AND RECOMMENDATIONS

After having outlined the Strategies, the resources, tools and methods that may make them work, the following general *conclusions* can be formulated:

- ***On the practical level*** of managing the “good status“ of large deep lakes in Europe the ***Strategies recommend to adopt indicators and monitoring methods specifically suited to these lakes.***
- ***As the*** processes that determine status of the lake (***key processes***) within large deep lakes ***are characterised by their zonal structure, sampling points*** of any monitoring system ***should follow the zonal pattern of the processes.*** In particular, ***additional sites closer to shore*** are strongly advisable, as the impacts made by the local stresses are “visible” mostly in these sites.
- Present situation at major large deep lakes in Europe indicate that ***3-5 measuring points (vertical measuring profiles) located at littoral and pelagial zones supplemented by measuring points at the mouth of feeder rivers*** can be considered as minimal set
- ***Sampling frequencies of particular processes should follow the dynamics of these processes.*** In particular, integration of catchment sampling programmes with the lake’s sampling, especially the synchronisation of sampling in the lake and in feeder rivers is crucial, as it will enormously improve our capacity to understand the system. For the lake, advisable ***monitoring interval is monthly***, however, ***fortnightly sampling during the growing season would be beneficial.***
- ***Standardisation of the monitoring methods*** especially as to the measurable biological parameters specific to deep lakes (e.g. benthic invertebrates, microbial loop) is required.
- Since ***the large deep European lakes*** serve large populations, possess unique features in their dynamics and pose the risk of „turning into bad or even bad and unrecoverable state in an unpredictable manner”, ***they require special care and a special political status*** (such as has been established for the „Great Lakes” in Canada/USA, and the Danube and Rhine rivers in Europe).
- Being under external political (European polices) and economic influences (global economy) catchment area ***communities living along large deep lakes can essentially influence the lake-related part of the regional sustainable development*** if
  1. they are conscious that the “good status“ of the lake and its catchment area is a necessary condition for improving the quality of their lives in the long run.

2. their activities within the regions incorporate the “good status“ of the lake and its catchment area” as an indispensable ingredient.
  3. the organisational form they choose for the purpose (**advisory groups, networks** etc.) will be effective and sustainable in itself
  4. they are consistent in their efforts
  5. helped and guided by European policy in this respect.
- If not yet in place, a **regional / catchment advisory group** could help local water authorities in determining monitoring programmes, filling knowledge gaps and choosing indicators. This group could be instrumental to act as a platform for information exchange on the **lake, its users, its managers and the researcher**.
  - The above recommendations can be equally well realised by already existing regional water institutions by **adopting the concept of advisory groups** as by possibly newly created bodies / institutions once their creation is found useful. In both instances it is considered indispensable to create political and financial conditions through which the European Commission can:
    1. introduce necessary regulatory framework (by extending the WFD with the large deep lakes paragraph)
    2. support logistically and financially the regional water management bodies in setting institutional framework aimed towards maintaining the „good status“ of the large deep lakes and
    3. supervise activities of the regional advisory groups network.
  - The standardisation of the mentioned methods, exchange of experience and information between regional advisory groups and the “quality control” of the regional activities as to the maintenance of “good status“ of the large and deep lakes is also highly recommended. Necessity of exchanging experience and information applies to measuring, interpreting and modelling of relevant physical, chemical and biological processes in large deep lakes.
  - Large deep lakes are also characterised by a diversity of actors with sometimes conflicting uses and interests. The complexity of such lakes, in terms of both natural processes and uses, could be managed using a **decision support system**, such as DPSIR<sup>1</sup> or the *Decision Support Tool* developed within the EUROLAKES project.

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<sup>1</sup> The causal framework for describing the interactions between society and the environment adopted by the European Environment Agency: driving forces, pressures, states, impacts, responses (extension of the PSR model developed by OECD). <http://glossary.eea.eu.int/EEAGlossary/D/DPSIR>

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