SUSTAINABLE WATER MANAGEMENT IN THE BALTIC SEA BASIN

3

RIVER BASIN MANAGEMENT

EDITOR:

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The Baltic University Programme - Uppsala University

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Sustainable Water Management in the Baltic Sea Basin

Book III.

River Basin Management

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Foreword

Water and water management has a very special place in the efforts of countries in the Baltic region and universities participating in the Baltic University network. A concern for our common water, the Baltic Sea, was almost the only unifying point of departure when we met for the first time during the break up of the old system. It will remain to be an important dimension of our work as illustrated by declarations of prime ministers in the region and intensification of activities e.g. within the Helcom cooperation. When work to improve the environmental situation started on a larger scale a few years later, water was by far the most important point on the agenda. In 1995, for example, the Latvian investments in the environmental field was to 95 % directed to water issues, especially wastewater treatment. Reducing emission to air, soil remediation and natural protection were all second to water. The situation was similar in other countries in the newly independent states in Central and Eastern Europe. On the western side of the region investments to improve water quality have been substantial during several decades which happily have given some good results.

This is not difficult to understand. We, as all lifeforms, all depend on water for our daily life and well-being. We drink it, we wash ourselves in it, we enjoy to see it flowing by, enjoy to live in the beautiful ”waterscape” of our Baltic region. To have good and clean water is a first priority, as it always was.

The Baltic University Programme has selected water management for the first master level course on issues of sustainable development. In this context water has a special role. It is a renewable resource, and the access to this resource is quite well defined, not only globally or regionally but also locally, based on the drainage area concept. It will also be the first resource to be managed on the basis of this concept, since European Union directives recommend drainage area based water administration. Sustainable water management is a first goal in our development towards a sustainable society.

The course material on Sustainable Water Management is, as all Baltic University course material, not disciplinary in its approach. Instead we strive to show the complete picture of the ”problematique” of water management. This transdisciplinary approach is intended to give the students, regardless of background - natural scientists, engineers, social scientists etc. - a platform for work with water issues in their professional carrier. It treats the system rather than its components and of course all specialists will be disappointed with the treatment of ”their” specialities. The objective is rather to connect the specialities than to teach them.

The books are the result of the combined effort of more than 50 researchers/ teachers in some 10 countries. They could not have been written by any single person, university or even country. They are the true result of the network and hopefully they will be used and studied in the entire Baltic region.

Uppsala January, 1999

Lars Rydén
Director, the Baltic University Programme

PREFACE

The textbook series

The current textbook volume is the third in a series of three on sustainable water management. The prime purpose of the textbook series is to serve as reading material on the Sustainable Water Management courses co-ordinated by the Baltic University. The series build on the input from teachers and students from the pilot course given in 1998 and the second course in 1999, involving some 30 universities and 300 students in the Baltic region. However, the textbooks are quite general and may be useful on other courses on water management or as self-study material.

Although the focus throughout the series is the Baltic Sea basin, sustainable water management is a global issue and the ideas and problems are thus also introduced from a broader perspective, widening the scope of the books.

The "blue thread" of the series is carried forward by a multitude of authors, selected from a number of Baltic countries, and in some cases also outside the Baltic region. They all have the interest in the Baltic basin in common and they were invited to present their expertise views of the problems and processes.

It is thus up to the local course responsible teacher to guide the students along the main avenue, occasionally making excursions using texts describing local conditions and local problems. It is furthermore up to the students to form their own opinions and build their own understanding from the variety of presentations and view points presented. The discussions with the teacher and the fellow students should be central in this process. The video and Internet conferences complementing the course lectures are natural fora for this discussion.

River Basin Management

The third volume presents the principles and concepts of river basin management. Although most examples of legislation are taken from Swedish law, problems are general and similar examples from domestic legislation should be easy to obtain by students and teachers. Sweden enforced a new Environmental Code on 1 January 1999 and both Poland and the Baltic countries have recently changed environmental legislations.

Many of the chapters are based on a preliminary English translation of booklets in the series "Water Planning[1] ". The permission, from the Swedish Environmental Protection Agency and the Swedish Board of Housing, Building and Planning, to use the material is gratefully acknowledged. The original English text has been edited and expanded by the editor and chapter co-authors.

Different aspects on activities in the waterscape are presented in *Part I*. The focus is here not on water as such, but more on the functions, such as fishing and boating, provided by the water body and the catchment.

In *Part II*, the management of these activities and the measures needed to ensure good management of the waterscape are penetrated. River basin management, including the management of groundwater and surface water in the catchment and the coasts defines the centre of mass in the book.

In order to guarantee a good management of resources institutions and legal instruments are needed. This is the issue for *Part III*. International water policies, the EU Water Framework Directive, examples of environmental legislation from Poland and Sweden, as well as principles for water normation are discussed.

Having the overview needed, the legislation background and the principal knowledge on tools for water management, *Part IV* is intended to present strategies and practical knowhow in order to be able to make things happen. This very practical part will hopefully be followed by a successful career as water manager, broadly speaking, for the students that follow this course.

L-C Lundin

[1] Carlsson, S.-Å. & Gunnarsson, J., 1996. Vattenplanering, Swedish Environmental Protection Agency and the Swedish Board of Housing, Building and Planning. (In Swedish). The Swedish Environmental Protection Agency has not approved the translation of the texts and is therefore not responsible for this version of the edition.

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Part IV
Management Strategies

Photo, Lars Rydén.

Standing in the rain on the European continental divide you can raise your left arm and say, “This rain goes to the Baltic Sea.” Then raise your right arm and say, “That rain goes to the Mediterranean Sea.”

In fact, wherever you stand in the river basin, the water released at that point will travel in a predictable direction. This direction is called downstream if the release is made to surface waters. The same principle applies for groundwater, whereas soil water will normally, if unaffected by evapotranspiration, travel downwards, until it reaches the groundwater table.

These simple reflections are the basis for river basin management. Release water, or a water-soluble substance, at one point and you can count on it to show up at a downstream point later on. As a river basin citizen, you must be fully aware of this.

Upstream and downstream are thus fundamental, important, directions in the river basin perspective. But also fundamental in a literal sense, in that you can identify them by simply looking at the flowing water in the river, or feel which is which, just by putting your hand or foot in the water. No sophisticated devices are needed to tell upstream from downstream.

The upstream-downstream concept is very important for all life on land. There is an element of time in the concept, since downstream comes after upstream, and an element of transportation, since matter, water, and boats are automatically, without any input of external force, transported downstream. Solar energy provides the basis for the free downstream ride in instigating evaporation and precipitation, refuelling the downstream-transport system.

Responsibility lies with the upstreamers to care for the downstreamers and keep the water as it travels downstream in good condition, e.g. through good water management. The downstreamers have a similar responsibility to see to it that the upstreamers get the resources they need to live up to their responsibility.

Time-scales may vary but the direction is predetermined. This means that environmental impact has a direction and a predetermined path. The role of river basin managers is thus to distribute available resources along these predefined paths, in order to mitigate effects, modifying pollutant paths and, most importantly, avoid polluting activities in regions where potential pathways cause environmental threats. This is how we would like to see management and responsibility to be connected.

Lars-Christer Lundin

Uppsala University

WATER

W. Szymborska

A drop of rain fell on my hand
condensed from Ganges and the Nile,

from the heavenward ascending hoarfrost on the whiskers of a seal,
from the water of broken jugs in the cities of YS and Tyre,

on my index finger
the Caspian Sea is the open sea,

and the Pacific meekly flows into the Rudawa,
that very same river that floated as a cloud over Paris

in the the year seventeen hundred and sixty four
on the seventh of M   ay at three in the morning.

There are no lips enough to utter
your fugitive names, O water.

I would have to name you in all the languages
uttering all the vowels all at once

and at the same time keep silent - for the lake
which vainly has awaited any name

and does not exist on earth - just as for a star
that in the sky finds reflection in it.

Someone was long ago and that was yesterday.

Houses you extinguished, houses you carried off
like trees, forests like towns.

You were in baptismal fonts and in the baths of courtesans.
in shrouds, in love-enshrouded kisses.

Eating away at stones, nourishing the rainbows.
In the sweat and dew of pyramids, of lilacs.

How much lightness there is in a deep of rain.
How delicately does the world touch me.

Whatever whenever wherever has happened
is written on the water of Babel.

1.

Cities on water

WATER AND URBAN SPACE

Dorota Włodarczyk

Human settlements and water

Water has always been an element integrated in human societies and human life. The first civilisations grew up on riverbanks, on floodplains and in deltas. The seasonal fertilisation of the areas allowed a sustained crop production and development of agriculture. The Indus River, the Mekong River, the two-river country at the River Euphrates and the Tigris and the Nile Rivers are all examples of rivers that have fostered civilisations, some of them as long as 10 000 years ago.

The most spectacular wetland areas in the Baltic region, the deltas where the large rivers entered the Baltic Sea, and the confluences of the large rivers, also became the sites of the earliest cities. Where the Wisła River enters the Gulf of Gdansk, the city of Gdansk grew up 1 000 years ago. Where the Daugava River, called the Dvina River in Russia and Belarus, enters the Gulf of Riga, Riga was built 800 years ago. Where the Neva River enters the Gulf of Finland, St. Petersburg is now situated.

There are several reasons for this concentration of cities by water. The large rivers were important waterways for transportation, trade and travel and the deltas, being the gates to the inland, became politically important to control. But long before political arguments became decisive, humans settled close to water. Here they found food from fishing and hunting – in the Baltic Sea seal hunting was always important – as well as other necessities.

This preponderance of settlements close to water continues today. On a global scale, it can be observed with satellites. At night the coasts of the continents are outlined by a band of illuminated cities. In the Baltic region the population is concentrated along waters, especially the coasts of the Baltic Sea. Economy adds to the picture. Properties close to water are much more expensive than those inland. And it is better if the water is clean: Ecological economists have demonstrated the enormously decreased values of properties due to pollution of the Baltic Sea. In fact, increased property values of the coastal states would alone suffice to finance a clean-up programme for the Baltic Sea (Markowska & Zylicz, 1996; Zylicz, 1997).

The Baltic region is rich in waterfronts

Although the best-known waterfront cities may be Venice, Amsterdam and Hong Kong, the Baltic region has many cities with spectacular waterfronts. Stockholm is richly blessed with beaches, streams, lakes and seafronts, situated, as it is, where Lake Mälaren meets the Baltic Sea. Tsar Peter I designed St. Petersburg, similarly situated in the Neva River delta, once with some 70 smaller and larger islands, with Amsterdam as a model. He wanted the Vassilij Island to have canals, which, however, never materialised. Gdansk, with its canals and streams, boasts beautiful waterside promenades.

Inland cities with beautiful water views are found at the large lakes in the northern Baltic region. Many, from Petrozavodsk at Lake Onega to a series of cities along Lake Mälaren in Sweden, are famous for their waterfronts. A long list of cities situated at rivers, typically with their old castles at the riverbank, can be enumerated: The castle in Krakow, Wawel, is situated at the Wisła River; in Riga the castle is found at the Daugava River; and in Kaunas at the confluence of the Nemunas and Neris Rivers. The situation is similar at many smaller cities all around the region.

Originally, many of the most prestigious buildings were built close to the water – the Winter Palace in St Petersburg and the City Hall in Stockholm are just two examples – while the common people had to be content with areas further away. But there was also the need to build ports, warehouses and industries at the waterfronts. In many cases these have been turned to new uses.

Functions of urban water

It is obvious that water was appreciated both for its function and its form. Earlier fishing, transport and defence considerations were important. Rivers were also a source of energy and provided potable water. Today we undeniably need water to live. We have to think of providing the city with water; up to about 200-400 litres per day and capita. The largest consumption of water for domestic purposes takes place in the bathroom (Hough, 1995). And we assume without hesitation that, regardless of its use, water is to be of drinking quality. Thus water used in fire fighting, car washing and irrigation is of potable standard. Consequently we need to get rid of equal amounts of wastewater. A sewage treatment system with technological solutions is employed to remove the disposal from the city. The rainwater runs underground in sewers to be disposed of, while it is essential to notice it as a resource to be recycled and reused. Recycled wastewater can be used in the WC or for gardening.

In 1762, Nicola Salvi, the architect of the Trevi Fountain, one of the most spectacular fountains in Rome, intended it to symbolise the water cycle. He wrote: "The sea is, so to speak, a perceptual source which has the power to diffuse various parts of itself, symbolised by the Tritons and the sea Nymphs, who go forth to give necessary substance to living matter for the productivity and conservation of new forms of life, and this we can see. But after all this function has been served, these parts return in a perceptual cycle to take on new spirit and a new strength from the whole, that is to say from the sea itself." (Moore, 1994).

In earlier times, the purification of wastewater was simply neglected, resulting in terribly polluted and badly smelling rivers and seasides. This is still the situation in some places. In the Neva River, the water leaving the city contains considerable amounts of untreated wastewater. Riga is still struggling with its sewage system to avoid direct channelling of wastewater to the river. Much runoff from streets and other paved surfaces is going directly to the closest surface water.

The revival of poisoned rivers is, however, already well known. By the middle of the nineteenth century the Thames River was so polluted due to the rapid expansion of the population, that all fishes were eradicated. The concern for rehabilitation of the river caused the installation of improved sewage treatment and aeration equipment. As a result, in the revived Thames River, 86 species of freshwater and marine fish had been identified in 1975. In Stockholm, it is possible today to swim in the centre of the city and regularly large salmons are caught along riverbanks in the centre, proving the success of several decades of work with wastewater treatment.

Water shaping the form of the city

Cities on rivers

The way settlement meets the water creates the character of the city by water. There are specific conse-

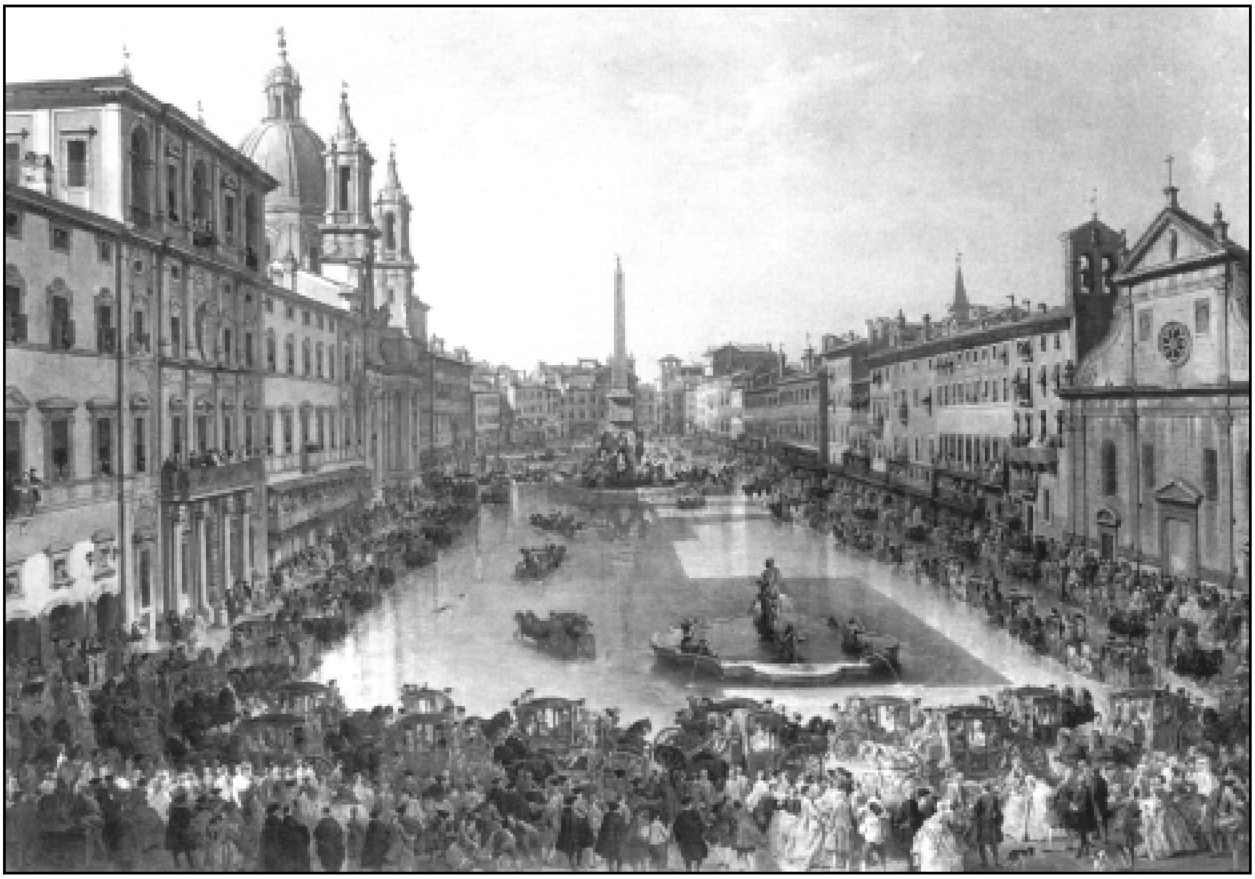

Figure 1.2. Piazza Navona in Rome in the 18th century. At weekends in August, it was the custom to block the fountain's drain and flood the square, providing an unusual stage for the carriage-rides. Painting by Pannini (1756).

quences of how this meeting takes place. A great number of towns were originally located on only one bank of a river. In ancient Egypt, settlements were built on the east bank of the Nile, as required by the religion. In Chinese cosmology, facing south was important. Common-sense issues like the patterns of water flow, the productivity of the basin land, consideration of defence and the convenience of river transport were also taken into account when choosing the location for city development.

In Medieval Europe, cities located on one bank of the river evolved into bridge-cities. With the original settlement on one bank, typically a walled smaller district formed a suburb on the other bank. A bridge through the main gate to the original settlement joined them. The bridge between the two settlements was sometimes fortified, and often lined with houses and shops.

The river below was used mainly as a waterway, source of drinking water and source of power for operating grain mills; its aesthetic dimensions were not appreciated. It was not until the 14th century that the picturesque values of water were noticed in Europe. An early example is Ponte Vecchio in Florence, where the middle part of the bridge was left open to allow passers-by to enjoy the view along the Arno River.

As the city grew, the pattern of a water-city composition developed. The layout of streets evolved as a consequence of the configuration and flow of water. Grids parallel to the river extended into the city and became the streets and blocks. In cities of central Sweden, streets were originally parallel to the water and narrow passageways led down to it. Pittsburgh, Pennsylvania is the best example of a city rising from the triangular plot between three rivers. The three grids, each connected to a different river, come together at an angle in the city centre.

Coastal cities

The urban form of the cities at coasts developed as a response to their closeness to the water. In Antiquity, Ostia (at Alexandria) is worth mentioning, where church towers, high domes, temples and the Colossus of Rhodes (one of the Seven Wonders of the World) were scaled to the infinity of the sea and were supposed to be admired from a distance.

In Europe, up until the 18th century, the link to the sea was vital for economic and industrial growth. Maritime ports with shipyards and warehouses formed disorderly clusters of structures. Aesthetically unified designs for seafronts of cities were not then seen as important, but rather as counterproductive.

The 17th century marked the emergence of rational port city planning, first seen in France, Sweden and the Netherlands. This produced an urban network suitable for the exploitation of the sea. The waterfront had to be planned around arsenals, armouries and warehouses, rather than representational public buildings. In the next century, this way of building developed to include planning for architectural values. In Bordeaux, Jacques Gabriel, Louis XV's chief architect, designed a splendid series of formal squares. These squares, defined by housing and public buildings, were built over the water. At the same time, a similar scheme was proposed and partly executed in London.

In the late 18th century, the first seaside resorts were built. Brighton, England was a pioneer. On the Baltic Sea coasts, Saltsjöbaden, Sweden, Sopot, Poland and Hapsalu, Estonia were among the earliest. The area for access to and along the water body became important and flourished with impressive promenades, piers, boardwalks and decks. Characteristic for these forms is that the edge of land is extended to a point of immediate contact with water. In some cases, boardwalks run parallel to the beach, sometimes just out into the bay. The elongation of the pedestrian network of a city is usually organised as a wooden floor elevated slightly above the water level, with very little enclosure provided by street lamps, benches and railings, which allows us to admire distant views. Similarly, nowadays, bicyclists' and joggers' paths are built along scenic banks.

Recently, port cities have evolved away from shipping, industry and railway yards. The changing technologies have made much of these constructions obsolete and instead we see new residential and recreational uses for them. Sometimes it is possible to preserve old buildings; the reuse of historic structures retaining some of the maritime and cultural heritage of waterfront areas is an excellent opportunity for maintaining genius loci of the urban space. In London the popular "London Docks" residential area illustrates this. In Stockholm, Hammarby Sjöstad, where some port activities are still going on, has become a success. In all these cases, the sea itself gives a very special character to the area. The distinctive feature of a waterfront city is that the surface of the water provides a foreground for an impressive townscape and a dramatic skyline with unique landmarks, which may be admired from a distance.

Water shaping urban space

Streets and squares are the main components of urban space. Streets are perceived as kinetic phenomena – always associated with movement – in contrast to squares, which are static – associated with relaxation and celebrations. The influence of water on the form of streets and squares is of great significance.

Some streets in the world – in Copenhagen, St. Petersburg, Amsterdam, Bruges, Venice, Bangkok, etc. – are designed as man-made waterways – canals. The flow of water along them enhances their kinetic qualities and strengthens their connection with the outside world. Their currents, in contrast to asphalt lanes, carry the imagination beyond the town, into the sea.

Many canal cities began as towns ringed with circular moats, walls and towers, to defend against invasion. Medieval Bruges, in Belgium, was once built entirely within the canal-moat. Over time, canals were excavated from the main moat to allow access to the inner parts of the town. Today, urban space in Bruges is the composition of streets and narrow waterways. Venice, with its organic network of interconnected capillaries, is the premier canal city. Water is present everywhere in Venice, and in each neighbourhood, where buildings are packed tightly between the labyrinth of waterways, passages, squares, bridges and sidewalks. The streets in Venice represent a dual circulation: boats on the canals, pedestrians on flanking walkways and bridges. In some places, such as in the Grand Canal, buildings grow up out of the water and there is no place to walk.

In contrast to the subtle canal layout of Venice or Bruges, Amsterdam has a more regular pattern, described by Kostof (1992) as a rigid, semicircular spider's web of canals and dams. In the beginning, Amsterdam was a town around the dam, but as the town grew, canals were built successively in a series of concentric arcs. In many Dutch towns, the constituent elements of canal streets are the quays for loading and unloading. The streets are experienced as more narrow and tightly defined because of the height and rather modest width of the buildings that line them, and the changes of levels of the floor, from water surface to the street walks. Additionally, a sense of enclosure is created by lines of trees and bridges at higher levels than the walkways, as well as boats and barges. The width of the waterways is crucial for the perception of the street; if it is too wide to be crossed by a simple bridge, the buildings on the other side become isolated and the urban effect is lost. Channels of water are excellent devices for unifying complicated architectural arrangements and provide an element of continuity within the city. The reflective quality of water is worth noticing here. The townhouses along the canals of Venice and Amsterdam gain elements of fantasy; while reflecting light, water is transforming the solidity of their shadows. St Petersburg provides another remarkable example of this, as the church of "Saviour of the Blood" (Spas na krovi) is viewed from the Griboedov canal.

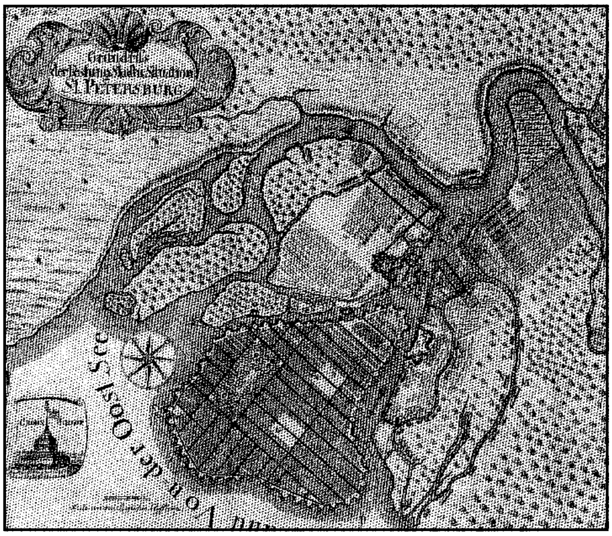

Figure 1.3. This city map of St Petersburg from 1720 reflects the Swiss-Italian architect Domenico Trezzinis unfulfilled plans for the Russian capital. The canals on Vassilij Island, inspired by Amsterdam's city plan, were later realised as streets, so-called "lines" (from F.Chr. Weber, *Das veränderte Russland)*.

Bridge-streets have prominent urban positions in river cities. To maximise precious urban space, they were sometimes formed as streets, bearing buildings on their decks. Contact with water is also essential for such important urban interiors as squares. Piazza San Marco in Venice is not only open towards the sea, but its floor is physically connected with it. While the high-tide floods the surface of the square, it changes naturally into a reflective pool and gives the surrounding buildings and monuments an unusual charm. Another example of a square which floor was filled with water is Piazza Navona in Rome. The remarkable setting of Bernini's Four Rivers Fountain in the 17th century became a fashionable place for festivities, which regrettably now belong to the past. Usually at weekends in August it became the custom to block the fountain's drain and flood the square. The cool environment was appreciated by rich citizens and provided an unusual stage for the carriage-rides. In defining edges of urban space, the sensitive design of the City Hall in Stockholm, by Ragnar Östberg, in 1913, is worth mentioning here. The mass of the building articulated with arcades creates not only well-proportioned open spaces in the form of squares, some just by the water, but the enclosure and continuity of the building, equipped with the tower (an important visual landmark), is extremely important in framing the waterfront. The citywide focal point can be observed from many different locations in Stockholm, contributing to defining the significant urban water interior.

Water in the city – meanings and aesthetics

The well, spring or pump was always the social focus in a settlement. The women living close by went there to fill their buckets and bottles with water, and stayed to talk to neighbours. Similarly, riverbanks used for cleaning or washing clothes became public space for socialising. All this is, of course, gone in modern life, although its symbolic value may remain in other contexts, just as the sanctified "holy" well, the natural centre for worship and spirituality, remains in the use of water in religion.

Water, in its wide variety of forms on the largest and smallest scales, is an attractive material, enriching the form of urban spaces. In the city, it is used not only as functional water, as canals, reservoirs and drainage systems but also for purely decorative reasons such as fountains, cascades and pools. In the light of psychoanalytic evidence, frequent contact with water may bring a person closer to the unconscious processes in his life and has a positive therapeutic effect connected to its religious meaning. Moorish, Indian, Persian and various other cultures have appreciated the cooling and aesthetic features of water underlying its symbolic significance.

Water has its own identity and very special qualities of movement and variation under the influence of wind and light. It changes colour and texture according to weather conditions. In the past, fountains were often accompanied by sculptural compositions. The combination of water and sculpture makes for an interesting effect. It is, however, important to decide which motif is to dominate. In the composition, the sculpture should be entirely dry or entirely wet. Originally, gravity and supply of water governed fountain design. Today, the form and arrangement of fountains have changed dramatically. Sometimes water appears in parks and squares in unique steel, concrete or ceramic arrangements. The direction and rate of flow of water is very important. Sometimes a series of jets, which rise and fall at intervals, controlled by a prearranged programme, may often be accompanied by music. The jets of water are most spectacular when they appear luminous, so the fountains should be located between the spectators and the sun. Fountains may, in addition to conveying decorative functions, have an ecological role through their possibility of aerating the water.

Water affects not only sight, but also other senses through its sound, smell and texture. If these qualities are used intelligently, water has the potential to

Figure 1.4. One of the waterfronts of Stockholm. The City Hall (architect Ragnar Österberg) on the shore of South Mälarstrand (left below) (photo, R. Ryan).

influence and modify the form of urban space. By communicating sensory clues, it can create a focal point and give distinct quality to a part of a city. We are all engaged in identifying the features of the space that surrounds us; we define its elements, organise it into images and associate it with our memories. As observers, we seek to define patterns of attention, which we can recognise and remember. In this context, water has a magnetic charm and the ability to become the centrepiece of urban interior design. The Four Rivers Fountain, with underwater lights creating the illusion that figures move, became one of the Rome's landmarks and a well-known meeting place. The Trevi Fountain in Rome is another gathering place, extensively visited by tourists, who ritually drop coins into its water with the wish to return to the city. The Trevi Fountain is perhaps the best example of a relationship between water and architecture. These also provide an unusually clear illustration of how we unconsciously relate to water as of central importance in our life.

The sense of hearing conveys the shape of space. The sound of falling or running water may hypnotise the observer and block out unwanted sounds, creating an additional subspace, characterised by its own melody. The designer can use water as a device to change the perception of small, enclosed urban interiors. Liquid parts of squares in the middle of crowded cities may create special spaces characterised by emptiness, too rare sometimes, in the urban landscape. The flat surface of water naturally seeks an embellishment for composition. The pools clear out a space in front of buildings so we can view them free of other components of the urban fabric. Small squares can be furnished with water for climatic reasons or small pools in a dark place may serve to add light by reflecting the sun and the sky. The reflective quality of water increases when the surface is still and the bottom is dark or deep. The image to be seen in water can be calculated geometrically. Such features of water as reflection, depth or the comparatively large surface can be used to expand personal space, hypnotically drawing attention or guiding our eyes into the sky or opening with spacious landscape.

Figure 1.5. In the summer residence of Peter the Great, Peterhof, outside St. Petersburg, a multitude of fountains delight visitors (photo, Lars Rydén).

Urban open spaces enhance hydrological processes in the city

The residential parks, playgrounds and city forests associated mainly with recreation also play important roles in re-establishing the ecological balance. The storage of stormwater is one of the significant issues. The ecologically oriented design of urban development can reduce costs and be beneficial to the environment. Parking lots, cemeteries, parks, playgrounds and even flat roofs can, in addition to their basic function, be designed to provide temporary storage for rainwater and snow. The city forests, wetlands and garden plots, which create low-maintenance landscapes, so much needed in the city, serve the same hydrological function.

Water in all its forms may be exposed and preserved in the shape of small ponds, pools, reservoirs and streams. The aboveground lakes and canals in residential areas provide not only distinctive visual amenity, but can serve as permanent retention containers, improving water quality. The fountains in the water can cool the environment on hot summer days. In a park, a fountain in a pond or lake may discourage activities such as paddling. Most pollutants in rainwater coming from roads, paved surfaces etc. to permanent ponds are attached to sediments. When these settle to the bottom, the pond works to purify the water.

In neighbourhoods where there is a scarcity of area, temporary retention ponds may enrich common parks and greenery, serving multiple functions. They can provide opportunities for understanding hydrology in cities, bringing children closer to the water cycle. In the winter, the temporary retention ponds may become skating rinks, and in the summer, when

Figure 1.6. Children are playing by the “bächle” in Freiburg, Germany. The “bächle” are small open water channels that follow the streets downhill to the river.

filled with rain, they may serve as a place for sailing small boats and playing with water. The hard bottom surface of a pond may be used for skateboarding, biking and roller-skating during dry periods.

There is a common practice that in the urban setting, running water – brooks and streams – are paved over and forced underground and water reservoirs are covered and fenced. These practices may be questioned on some grounds. The rainwater can be allowed to gather from rooftops into small pools or be collected in open gutters where it can flow above ground along pedestrian paths. As water attracts birds and animals, it may enhance the formation of wildlife corridors. The natural surface drainage is appropriate for low- to medium-density developments and local streams, lakes or retention ponds may collect its water. This alternative to traditional storm sewers has proved to be more economical and more beneficial to water quality.

Water is an important element of contemporary cities. It significantly influences the urban structures and natural processes of all of them, not only of those located along waterfronts. It should be remembered, however, that regardless of its function – not to cause distaste or disaster – water requires constant care, maintenance and conservation.

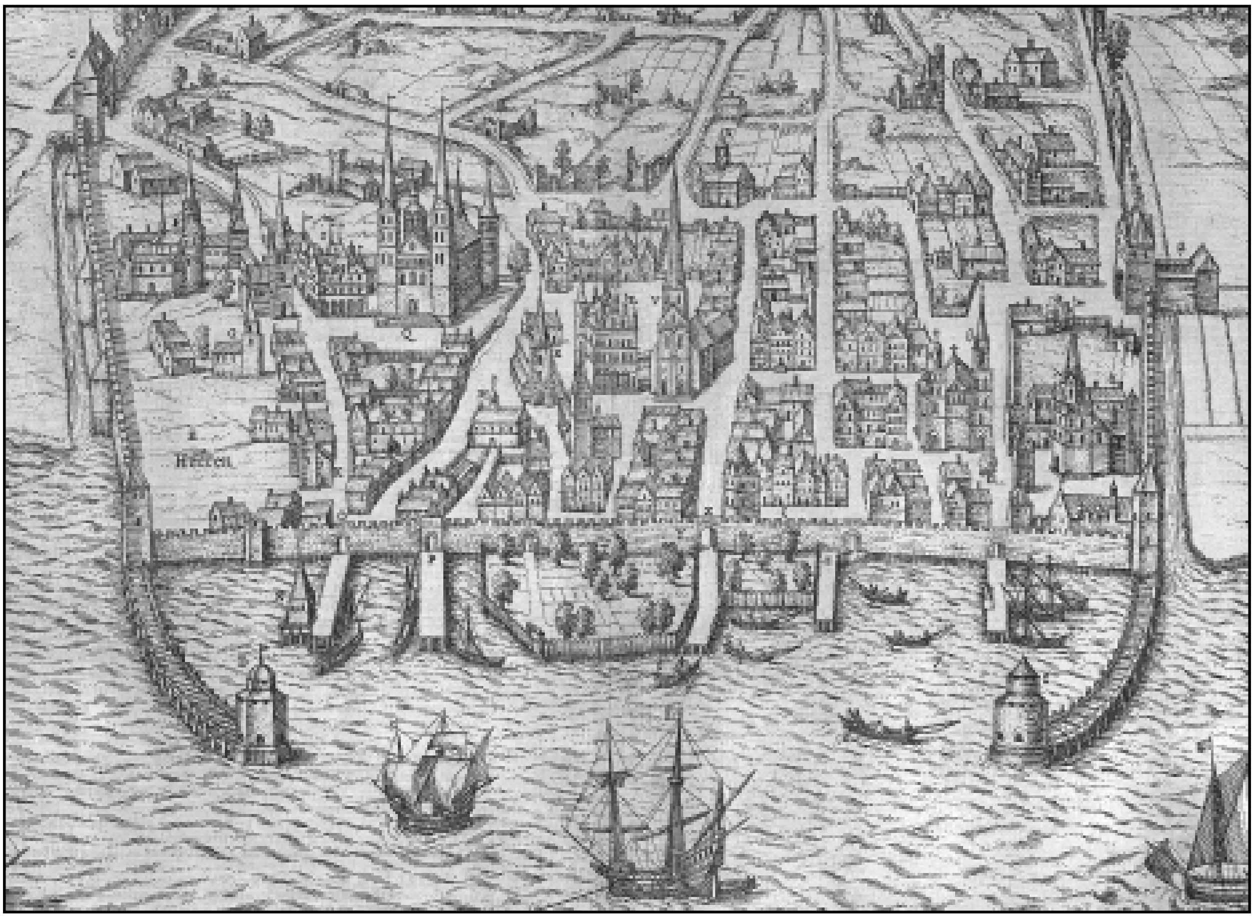

Figure 2.1. In Hanseatic times, Visby had one of the most important harbours in the Baltic Sea. Still, shipping was small compared to today (courtesy of Uppsala University Library).

2.

Shipping

boats, harbours and people

Peter Norberg, Allan Nilsson, Pia Westford, Yngve Malmquist & Lars Rydén[1]

Ship traffic in the Baltic Sea region

The Baltic Sea and rivers and lakes in its basin have been trafficked by boats and ships since the earliest of times. Even if Viking dragons, Hanseatic cogs and large sailing-ships are all part of our history, they constitute a small amount of activity compared to what we have today. Shipping increased dramatically after the invention of the propeller by Swedish John Eriksson in the 1850s and the diesel engine by the German Diesel Brothers 40 years later. But, just as trade and commerce increased in scale after the 1950s, so did shipping. Today it is larger than ever, even if many of the ships are registered under foreign flags.

Shipping has always accounted for the largest share of trade by far compared to other means of transport. The great majority of all transport to, from and between the countries in the region occurs on ships. In Sweden, the share of freight imported by ship in 1993 corresponded to 80 % of the transport work, when calculated as kilometres per tonne. If freight in trains and trucks on ferries are included, the share was 95 %. The corresponding numbers for export were 53 % on ship, 72 % if ferries are included. In 1993, shipping was responsible for 12 % of the total domestic freight, when measured as kilometres per tonne.

In addition to transport of goods there is a considerable passenger transport, which has increased dramatically after the systems changes in 1989-91. The ferry routes over the Baltic Sea carry tens of thousands of passengers every day. The most important routes are between Helsinki (Finland) and Tallinn (Estonia); Helsingborg (Sweden) and Helsingør (Denmark); and Rødbyhavn (Denmark) and Puttgarden (Germany), but many more contribute to the enormously increased mobility and exchange between our countries.

A considerable part of the merchandise transported consists of natural products of large tonnage and volume: ore and steel from northern Sweden; timber, pulp and paper from Sweden, Finland and Russia; coal from Poland; and oil from Russia. On a worldwide basis, close to half of all tonnage is oil. Oil transport in the Baltic Sea is also considerable. Oil tankers come from the North Sea oil fields to harbours in the Baltic Sea and oil from Russian oil fields is exported from harbours in Russia, Estonia, Latvia and Lithuania. The rest of the goods are transported on ROR ships, container ships or smaller ships.

Trade shipping and shipping lanes

The infrastructure of shipping consists of the shipping lane system, typically maintained by the State and the harbour service. Shipping lanes connect the harbours and give prerequisites for shipping through the supplied service of nautical charts, marking of lanes, piloting and ice breaking.

Shipping may be divided into open-sea shipping, coastal shipping, river shipping and inland shipping. The river traffic, mostly with barges, is considerable on many of the larger rivers in the region and in continental Europe, among them the Rivers Wisła, Odra, Elbe, and Rhine. Similarly trafficked lakes further north are the Lakes Onega, Ladoga, Mälaren and Vänern with the rivers or channels that connect them with surrounding waters.

Along the coasts traffic is focused in the shipping lanes close to the ports. Little commercial shipping is therefore performed in the protected fairways along the coasts, especially in the sensitive archipelago areas of Sweden and Finland.

The traffic from the Baltic Sea to and from the North Sea and the oceans has to pass the Danish Straits or the Kiel Canal. There is thus a limit to the size of the ships in these waters. The largest ships are not seen in the Baltic Sea.

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[1] The chapter is based on a preliminary English translation of a booklet in the series "Water Planning", published in 1996 by the Swedish Environmental Protection Agency and the Swedish National Board of Housing, Building and Planning. The original English text has been edited and partly expanded by Lars Rydén.

Figure 2.2. The Baltic Sea has many important ports (photo, Lars Rydén).

The marking of fairways on open-water entrances and over fjords and bays is normally narrow. The fairway widths in these areas must therefore be dimensioned with consideration to the comparatively poorer conditions for the ships to determine their positions and to follow specific coastlines. A number of factors, such as vessel size and manoeuvring ability, traffic intensity, exposure to weather and wind and the over- and underwater topography, affect the widths of the fairways. The use of the archipelago fairways is limited by water depth.

The traffic separation system is a route system approved by the International Maritime Organisation (IMO), the Sea Security Agency of the United Nations. The traffic separation system is marked on nautical charts. It is mainly used by coastal and through traffic. Ships longer than 20 metres shall, according to the shipping rules, use traffic routes. Smaller ships are obliged to use the water between land and the actual traffic separation system. The purpose with the system is to direct oncoming traffic to different traffic routes.

Smaller fishing boats exhibit a transport pattern between the open sea and the port that largely agrees with trade shipping. The home harbour of fishing boats often differs from the port where the fish is unloaded. There is therefore traffic between these sites. When weather conditions are unfavourable, the fishing boats use the protected archipelago fairways along the coasts. Coastal fishing and fishing in the archipelago using boats for shallow waters often utilise older unmarked fairways and occasional shortcuts in order to reach the actual fishing area.

Harbours, ports and coastal infrastructure

Practically all cities on water, inland or on the coasts, have harbours. The larger cities on the coasts and many of the smaller ones are important port cities. Some of the largest ports are found in: St Petersburg and Kaliningrad in Russia; Helsinki and Turku in Finland; Luleå, Sundsvall, Stockholm, Norrköping, Karlskrona, Malmö and Gothenburg in Sweden; Tallinn in Estonia; Riga in Latvia; Klaipeda in Lithuania; Gdansk, Gdynia, and Szczecin in Poland; Rostock, Lübeck, Kiel and Hamburg in Germany; and Copenhagen in Denmark. All of these cities have famous ports. Naturally favourable conditions to build a port were in fact the reason for the location of several of these cities.

Harbours for proper trade receive freighters, cargo ferries, and combined ferries. Harbours for ferries in passenger traffic should also be mentioned: A large number of passengers in international and domestic traffic are transferred over the regular harbours. Moreover, there are industrial harbours or loading sites with a turnover of approximately 100 000 tonnes per year. Special harbours for energy supply are also of interest to shipping. Several very large new oil terminals have been built in the Baltic Sea, like Buttinge in Lithuania, close to the Latvian border.

Authorities responsible for shipping activities

International – The UN International Maritime Organisation, IMO
Security and environmental issues related to shipping are continuously treated within the framework of the UN shipping organisation, the International Maritime Organisation (IMO). The work concerns, among other things, measures to reduce the negative impact of shipping on the environment.

State level – the State Maritime Administration
The main objective of the activities of the Swedish Maritime Administration is to enable safe and efficient shipping in Swedish waters. The goals include good and suitable navigability in Swedish waters, and security work focusing on preventive measures.

The Swedish Maritime Administration is both a security authority and an environmental authority within the area of shipping that comprises trading, recreational boating and other activities. Moreover, the Administration itself has sea-borne activities. The Swedish Maritime Administration is also responsible for the control of measures in water areas that may obstruct or hinder public shipping.

According to the shipping legislation, the County Administrative Board can, in consultation with the Swedish Maritime Administration and in some cases with the National Board of Fishery, make certain decisions on traffic within a water area. These decisions concern speed limitations, prohibition of anchoring, and limitations in the access of water areas in order to protect birds, fish farms and other activities.

Examples of shipping interests in the basic material of the Swedish Maritime Administration:
- Conceivable new shipping lanes
- Sites of deep harbours
- Shipping lane constrictions
- Areas for traffic separation
- Sites for offshore platform work
- Laying up of ships out of operation

County level – The County Administrative Boards
The County Administrative Boards are responsible for ancient remains above the water level, for shipwrecks and for some marine remains under water.

Municipalities
Municipalities may formulate their own shipping objectives based on individual concerns and prerequisites. The municipalities shall obviously pay attention to the national objectives in their comprehensive planning and actively participate in order to meet them.

Harbours regularly have appointed sites for anchoring. Some anchoring sites are of great importance in security anchoring, while waiting for a quay berth or for sea-borne loading and unloading.

Trade shipping may be a part of the contingency planning of the total defence. Contingency fairways and emergency loading sites are prepared and are to be considered in the planning of the municipalities.

In the Nordic countries, the harbour system is the responsibility of the municipalities. In Sweden, the harbour service is made up of approximately 50 harbours and a lower number of private industrial loading places well spread out along the coast.

Finally, one needs to mention harbours and vessels belonging to the navy. The largest might be Baltijsk (formerly Pillau), some 40 km outside Kaliningrad, Liepaja on the Latvian coast and Karlskrona on the Swedish coast. However, the activities in these navy ports decreased considerably during the 1990s, and Liepaja was in practice closed in 1994.

Canals are also part of the shipping infrastructure. The interests regarding canals for trade shipping is not limited to the canal itself. Surrounding banks, constructions and machinery associated with locks, security devices, possible meeting places etc. are important.

In the coastal range, there are buildings, fishing villages, lighthouses, pilot sites, ancient remains, etc. that directly fall under the legislation of the protection of the cultural environment. Ancient underwater remains include shipwrecks and other marine remains. A wreck that has been on the sea bottom less than 100 years is normally still considered to have an owner and is not included in the legislation for ancient monuments and findings.

Dredging and dumping of dredged material

Dredging is performed in order to deepen water areas in harbours and shipping lanes and also to remove especially contaminated sediments. Dredging is carried out through digging, use of explosives or flushing of sediments. The dredged material is

A CASE OF CONFLICT OF INTEREST BETWEEN SHIPPING AND OTHER ACTIVITIES

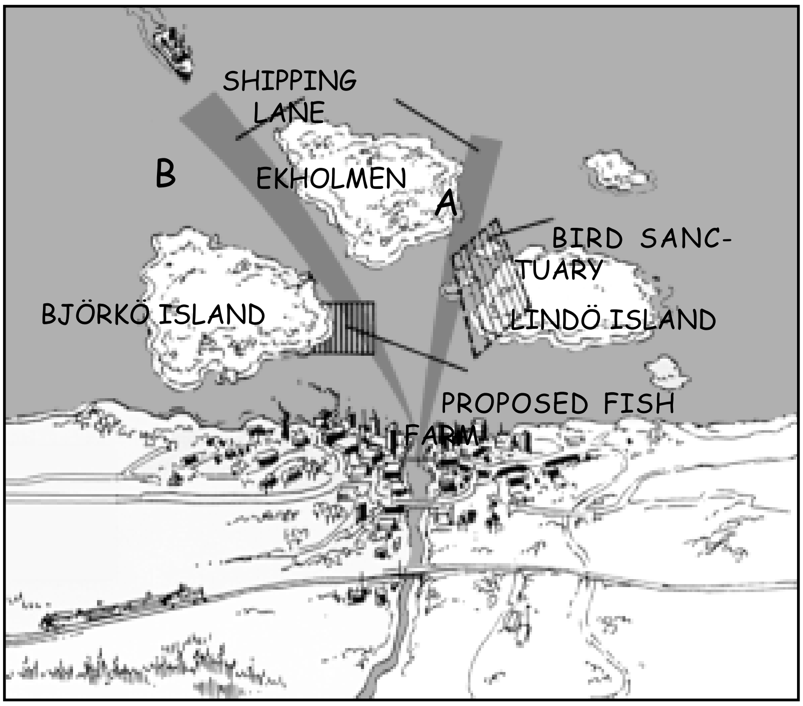


Figure 2.3. Modified from a drawing by Nils Petersen.

The fictitious map above describes how the total demands on land and water can be accounted for. Accounts of total demands on land and water should include

- Conflicts with other demands
- Combined effects with other demands
- Measures that can be taken in order to reduce negative or increase positive effects

The map shows two alternative sites for a shipping lane: the present shipping lane (A) and a proposed alternative (B).

The present shipping lane causes disturbances in the bird sanctuary on Lindö Island. Increasing traffic of freighters and larger ships causes intolerable conditions for the bird-life. The effects can be reduced through lower velocities and smaller ships but such restrictions would damage the harbour industry and deteriorate the ability of shipping to compete with other types of traffic. Another measure would be the construction of breakwaters, but this would bring about difficulties for the largest ships in passing the already narrow passage.

It has not been investigated if favourable conditions for the bird-life could be created somewhere else but it is considered very difficult to do. Moving the shipping lane to a new location (B) seems, in this case, to be a better alternative. However, even here demands exist that have to be considered – the construction of a fish farm. The fish farm, however, can be relocated to another site with only slightly poorer prerequisites. Another negative effect of a shipping lane in location (B) is the erosion of shores, especially on Björkö Island and Ekholmen. This effect could be reduced using breakwaters.

The combined positive effect of alternative (B) is that the water area outside Lindö Island and Ekholmen that had at one time been used for fishing would again be available as nearby fishing water. No negative effects except for the remarking of shipping lanes and administrative work can be predicted with this alternative.

Figure 2.4. Small-boat harbour at Revsudden near Kalmar, Sweden (photo, Lars Rydén).

taken care of in different ways. Usually it is dumped into water but it may also be deposited on land or in an area surrounded by a seawall.

Dredging and dumping activities are common during the construction and maintenance of marinas. The dredging is normally small-scale and often concerns relatively clean sediments. Dredging and dumping activities on a larger scale are performed during upkeep and expansion of harbours for trade shipping. This dredging often concerns sediments with contaminated surface layers.

Substances that demand special attention are mercury, cadmium and PCB, but also nutrient and organic material. Other substances that can be important in this context include arsenic, zinc, copper, lead, nickel, chromium and oil. Pollutants can be found especially in areas that have received industrial discharges and in harbours.

Small- and pleasure-boat traffic and marinas

In contrast to other forms of shipping, pleasure-boat traffic is concentrated to the warmer seasons. Pleasure-boats are found all over the region, although more in the archipelago areas than anywhere else. During transport over longer distances, the fairways shown in the nautical charts are normally used. When sailboats sail windward they use the whole width of the fairway, which may cause traffic problems.

There are millions of small private boats in the region. Since there is no compulsory registration for such boats, exact statistics are lacking. Belonging to this sector are the harbours for smaller boats, marinas. In Sweden alone, there are approximately 1 500 marinas. Boat clubs run most of these. Since Sweden has about 35 % of the Baltic Sea coast, it is likely that these 1 500 represent a major part of the existing marinas in the region.

Within the pleasure-boat traffic, different forms of competitions are arranged. Racing-boat competitions, which often place high demands on the regulation of other boat traffic within the competition area, are one example. In Sweden, water-scooter traffic, a minor part of this, has been restricted to special areas since 1994.

Small-boat traffic has a considerable negative impact on the environment and the surface water. Estimations are that more than 95 % of all pollution by oil or oil products to the Baltic Sea comes from small boats, through oil spills or leakage from tanks and motors. Underwater emissions of fumes from two-stroke engines have recently been shown to have very negative effects on fish. Investigations have demonstrated several biological effects, such as damage to the genetic material DNA and reduced function of the immune system. Fumes

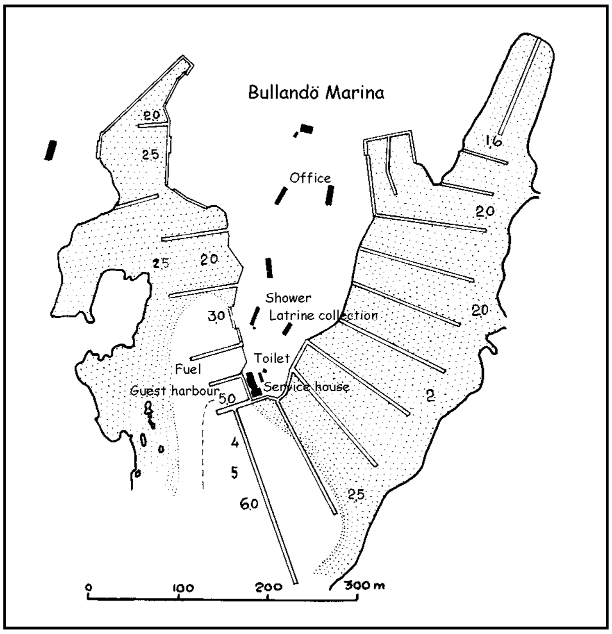


Figure 2.5. Map of the marina at Bullandö in the Stockholm Archipelago. Observe the arrangements for waste disposal and refuelling at the tip of the peninsula.

from two-stroke engines give rise to significant emissions of hydrocarbons.

Environmental impact of shipping and harbour activities

Shipping represents a major threat to the environment, nature and biological life. This is due to its infrastructure, in particular harbours, to boat traffic itself and to exhausts and spills from ships and harbours. Some of the major hazards are:

- *Presence*
  - Disturbance of wildlife, in particular bird-life, in sensitive coastal areas, through boat traffic, landings and spills
- *Physical impact*
  - On coasts, shorelines and bottoms by wave actions, anchoring, etc.
  - On coastal areas during construction, in particular dredging
- *Waste/solid-waste*
  - Solid-waste disposal in sensitive waters and along coasts
  - Disposal of toilet and kitchen wastes
- *Chemical pollution*
  - Deliberate oil-spills along coasts and in open waters
  - Oil leakage from motors and fuel tanks
  - Major accidents, especially involving oil tankers

One might believe that tanker accidents constitute the major threat but, in fact, they represent at most a few percent of the oil spills in the Baltic Sea. In the area where they occur, however, consequences are serious and long-term. Important factors are the cold climate and the brackish water of the Baltic Sea, which make biological processes comparatively slow. The less well-recognised daily leakage from motors from small boats is by far the largest threat to surface water from shipping.

In general, there are strict rules regarding shipping to limit pollution. The possibilities for authorities to survey these rules are not efficient for the time being and need much improvement. Several of the environmental hazards will be outlined below.

Ships cause erosion of the shorelines

Erosion caused by ships is, like natural erosion, the result of wave action and currents. The currents are produced when large water masses are pushed rapidly during the forward movement of the ship. The impact of the waves depends on the slope and the material of the shore, while the bottom topography and the cross section area of the fairway mainly determine the impact of currents.

It is very difficult theoretically to estimate the erosion effects of a specific shipping traffic in a specific area. Factors like ship speed, displacement and wave formation may be known and controllable. The effects of nature, however, are controlled by partly unknown and often completely uncontrollable factors, such as natural waves created by the wind, changes in the current situation caused by water-level variations that are affected by the appearance of the shoreline and the cross section area. Due to these variable factors, theoretical erosion models are too rough.

Shores can be roughly divided into two categories, soft shores and hard shores. Hard shores can be considered more or less immovable. Hard shores include steep and flat rocky shores, boulder shores without finer materials and shingle shores. Soft shores include steep and flat, non-washed, moraine shores, sandy beaches and other fine-grained shores.

A beach that is not subject to erosion caused by ship traffic is always in a state of equilibrium regarding the material composition of the shore. Particles of a size up to the limit that can be moved by the maximum water movements will be transported away, usually a relatively short distance. The composition of the remaining washed material depends on the energy in the highest water velocities.

Shingle shores formed in exposed locations represent clear examples of shores in balance. Such shingle shores are made up of well-sorted, fist-sized

Comprehensive-planning considerations

Interests and demands are described and given priority on the basis of knowledge and the national and municipal objectives. Demands on water and land and the conflicts and concurrent effects expected are normally accounted for in a special document. It is very important that the demands are clearly expressed in text and on a map. Alternative demands on land and water within each sector are accounted for such that any possible order of priority is obvious.

It is important that basic material of relevance to the adjustment between the interests of shipping and other interests is used and accounted for. It may, for example, regard communication investigations in the municipality or the transformation of harbour areas to other types of activities.

The consequences of different demands and priorities should be analysed. As an example, constrictions in archipelago shipping lanes where a specific surface can be available between the lane and the shore can be mentioned. The conditions associated with such constrictions are often unfavourable for other activities.

The measures used can be of decisive importance for the consequences of a planning proposition. Examples include protective measures or changes in activities. It is therefore urgent to account for possible measures early in the planning process. Measures can also be accounted for on a map, the major tool used in giving a good overview of the planning situation. Measures can aim at both reducing negative effects of shipping and strengthening the positive effects of the planning alternative.

Interests of shipping that should be accounted for in a map:

- All shipping lanes – ferry lanes, passages used by the public and smaller lanes – and their approximate widths can be marked on the map
- The area's demands for anchoring sites
- Harbours and harbour areas including fishing harbours. Harbour areas refers to the areas within which the harbour order, appointed by the County Administrative Board, is valid
- Harbour area for cargo or larger fishing harbours
- Important marinas for pleasure- and fishing-boats
- National interests of shipping
- Lay-up sites for ships out of operation
- Possible shipping lanes and harbour sites for deep-going ships
- Anchoring and mooring sites for offshore platforms
- Permanent reloading sites
- Traffic separation systems
- Dredging and dumping sites. In order to maintain shipping, dredging of shipping lanes may have to be carried out

Interests of shipping that should be accounted for in writing:

- Type and extent of traffic
- Existence of environmentally hazardous cargo
- Presence of lighthouses in the shipping lane and knowledge of the special demands associated with them

stones, but were originally comprised of an unsorted moraine material with finer fractions. These beaches have reached a state of equilibrium and will not change until being worked on by energy levels higher than that of the water. At these higher energy levels, a new sorting will start and the result will be an increase in the average size of the stones. In summary the erosion risks due to ship traffic are connected to the material composition of the shore, the exposure of the shore to natural erosion, determined by the location towards open waters, exposure to ship-generated waves and probable direction of the attack by ship-generated waves. If these act in an angle unnatural for the shoreline there is a risk of erosion. Exposure to suction effects from the ships also increase erosion.

A shore that is subject to erosion caused by ship traffic is given a sudden and persistent addition of energy. The shore must thus renew its state of equilibrium. During this time, changes can be great, obvious and disturbing to the human eye. Land will disappear, vegetation will be wiped out and the material composition of the shore will change. All this can happen in a short period of time. When the shore has reached its new state of equilibrium, and if no new increases in energy levels occur, the shape of the shore will be lasting.

An investigation on backwash from pleasure-boats and smaller ships shows that problems with backwash and the risk of damage on shores and to vegetation can also occur in areas trafficked only by smaller boats.

Table 2.1. Compilation of shipping matters that may need to be treated in a Municipal Comprehensive Plan

Object	Responsible Authority or organisation
Public shipping lane	State Maritime Administration
Anchoring demands at important anchoring sites	State Maritime Administration
Harbours and harbour areas	Municipality, harbour board
Fishing harbours	Municipality, harbour board
Marinas	Municipality, office of recreation
Conceivable new shipping lanes and harbour sites for deep-going ships	State Maritime Administration
Sites for laying-up ships out of operation	State Maritime Administration
Anchoring and mooring sites for offshore platforms	State Maritime Administration
Traffic separation system and areas with regulated traffic	State Maritime Administration
Reloading sites	Municipality, harbour board
Fairways outside the shipping lanes trafficked by fishing boats	Regional fishing federation, Fisheries Board
Fairways outside the shipping lanes trafficked by pleasure-boats	Local boating organisations
Different types of competition tracks for sailboats, water skiing and rowing	Local boating organisations, sailing federations, special federations
Especially designated areas for wind-surfing and water-skiing	Municipality, office of recreation
Ferry lanes	State Maritime Administration
Historic conservation	Board of national antiquities, County

The discharge to surface water from ships in shipping lanes

There are many types of discharge from ships that are prohibited and regulated, with the support of the Act on measures against water pollution by ships. Discharge of the following substances from ships is prohibited:

- oil
- large volumes of hazardous liquid substances
- packed hazardous substances
- toilet waste
- solid waste

In principle, only one type of oil discharge is allowed in fairways close to land. This concerns the discharge of cleaned oily bilge water that has to be pumped out. Before such a discharge can be carried out a number of demands have to be met (see Box overleaf).

The discharge of large volumes of hazardous liquid substances is divided into four categories on a falling scale: A, B, C and D. Category A includes poisonous substances that, if discharged into the sea in connection with tank cleaning or ballast cleaning, would constitute a severe risk to marine resources or human health or would constitute a cause of serious damage to both the beauty of nature and to recreational values. Category B includes hazardous liquid substances that may constitute a risk to marine resources. Category C includes less hazardous liquid substances. Category D includes substances that are practically harmless to life in water. These substances do not result in any grave risks to human health or disturb the use of public beaches; due to persistent, foul smelling or irritating characteristics that cause moderate decreases in the beauty of the area or of recreational values.

The discharge of all substances listed within categories A-D is prohibited except under certain premises and never closer to land than 12 nautical miles.

The discharge of packed hazardous substances is prohibited. The Swedish Maritime Administration may prohibit the transport of a hazardous substance that is allowed to be transported by ship, if the substance, in the case of a discharge, would pose great risks to the marine environment.

Rules for the discharge of toilet waste are valid for ships from countries under the Helsinki Commission (the Baltic countries), if the ship has a gross weight of 200 tonnes, or more than ten persons on

Regulations of discharges to water from ships

Discharge of oily bilge water is only allowed if:

- It does not originate from cargo pump rooms
- It is not mixed with remains of shipped oil
- The ship is running
- The ship has treatment facilities that can reduce the oil content to below 15 ppm
- It is not performed from oil tankers
- The ship has a gross weight of at least 400 tonnes

Discharge of toilet waste is only allowed if:

- The ship has a gross tonnage of less than 200 tonnes
- There are less than 10 persons on board
- The toilet waste is ground into finer particles and disinfected
- The discharge is done more than 12 nautical miles from the nearest land

No discharge of solid waste is allowed for ships within Swedish territorial waters.
Solid waste includes:

- Plastic materials
- Other solid waste, for example paper products, rags, glass, metal, bottles, china, wooden boards and covering and packing materials. The discharge of leftovers should be done as far away from land as possible and at a distance of at least 12 nautical miles

board. The rules imply that ships are only allowed to discharge toilet waste if, among other things, the waste is ground into finer particles and disinfected. The discharge must be made more than 12 nautical miles from the nearest land.

Discharged, untreated toilet waste that can be found in a fairway close to land thus originates from ships registered in other countries (see above) and from ships of less than 200 gross tonnes, including pleasure-boats.

Protection against discharges of oil and chemicals

Responsibility concerning protective measures against the discharge of oil and chemicals is spread out over many different authorities. The Swedish Environmental Protection Agency has the overall responsibility regarding the impact on the environment caused by oil and chemical accidents in the sea, while other authorities are responsible for the operational efforts. The Coast Guard is responsible for the fighting of oil and chemicals in the sea. The municipalities are responsible for fighting oil on land, cleaning the shore and for taking care of the oil remains. The National Rescue Services Board is responsible for supervision and the co-ordination of the rescue service, research, development, education and material support to the municipalities. The County Administrative Boards are responsible for the co-operation of the national and the regional rescue services in the case of accidents and for questions regarding environmental protection and conservation. Finally, the Swedish Maritime Administration is responsible for measures onboard ships, ship construction and inspection, security at sea and shipping lanes. The Swedish Meteorological and Hydrological Institute is responsible for weather forecasts and prognosis of the drift of oil.

An environmental station for attending to waste from ships should be available as close as possible to the quay. Such an establishment should be able to serve many quay sites. The environmental station should include at least one garbage container for combustible waste and three containers with plates equipped with borders for barrels and other waste that may leak. One of the plates should be for barrels and cans containing oil, for example in order to leave used engine oil for further treatment. Another plate should be supplied with a funnel leading into a barrel where remains of solvents and similar substances can be emptied, plus a barrel with a lid for oily rags and cotton waste. A third plate is needed for lead batteries and accumulators. An environmental station should also have devices to take care of oil waste from ships and oil originating from discharges in the sea. Large volumes of oil waste from engine rooms etc. is produced in ships. Investigations have shown that the average volume of oil waste that ships wish to hand in varies between 15 and 20 m^3. In practically every Swedish harbour, a truck, through septic pumping directly from the ship, collects this oil waste.

Emission of fumes from ships

Sulphuric and nitric oxides constitute the dominating portion of exhaust gas emitted by ships. They participate in acidification; the emissions thus give rise to a negative impact on the environment. Regarding the emissions of sulphuric oxides, it can be stated that shipping is responsible for two-thirds of the emissions within the transport sector. In this matter it is also important to mention that Scandinavia is more susceptible to acidification than the rest of Europe. The reason is that the Fennoscandian primary rock provides considerably less protection against acidification than the bedrock in the rest of Europe. It should be mentioned, however, that nowadays equipment is available that may reduce the emissions of nitric oxides by up to 95 %.

Planning of shipping lanes and shipping infrastructure

The width of shipping lanes and the surface demands of shipping are of importance when balancing the use of a water area against other interests. It is important to have a survey for the comprehensive planning along coasts and in archipelagos and their outskirts, in order to quickly see if a new activity is in conflict with the interests of shipping. The shipping lane standard of the State Maritime Administration can lend support in the determination of necessary widths of shipping lanes.

Each County Administrative Board is responsible for providing basic data to the municipalities to be used in the planning activities according to the legislation concerning ancient monuments and findings etc. The County Administrative Boards can initiate inventories of Swedish coastal and sea areas with the objective of defining especially valuable areas for the marine conservation of relics of culture. This is especially important for areas with a high number of shipwrecks, as in southern Skåne, the Blekinge Archipelago, the areas around Gotland and Salvorev, the Stockholm Archipelago and larger lakes such as Lakes Mälaren, Vänern and Vättern.

An example of how shipping lanes can be accounted for as a basis for municipal planning is shown in the Case box. This should be seen as a schematic basis for the planning and is not binding regarding the width of the shipping lanes. This is emphasised by the fact that the shipping lanes are shown in raster without borderlines. It may also be necessary to consider shipping outside the marked shipping lane areas. For such areas, if of importance to shipping, a more detailed account of the interests of shipping than provided by the State Maritime Administration may be necessary. These accounts should be made in a co-operation between the shipping area, the County Administrative Board and the municipality.

3.

FISHING AND AQUACULTURE[1]

Fishing

Fishing has always been of great importance to the people living near the Baltic Sea. At one time it contributed a fair share to the protein intake. Medieval herring markets at Skanör, in the south, were classic signs of an enormous richness of fish. Today the large production of fish in the Baltic Sea itself is complemented with fish from aquaculture, especially in Norway, and inland fishing, not the least of which occurs in the north. Both subsistence fishing and recreational fishing are performed in the Baltic Sea, along the whole Baltic Sea coastline, from the Bothnian Bay to the Atlantic environment in Kategatt and Skagerakk and in many different types of inland waters, lakes and rivers.

When compared to most other areas in Europe, the Baltic region provides very rich and variable possibilities for fishing. Commercial fishing is mainly performed in the open sea, with some taking place in the larger lakes, in mouths of rivers and along the coasts. The most important species for commercial fishing are cod, herring, and sprat. In the Baltic Sea these account for 90 % of all catches. Other economically important species are salmon, sea trout, plaice and turbot; catches include 29 species in all (HELCOM, 1996). Thus coastal commercial fishing includes vendace and whitefish in the Bothnian Bay,

Figure 3.1. Fishing for pleasure and providing variation in the menu was once very common on many farms in the Baltic Sea countries (photo, Lars Rydén).

[1] The chapter is based on a preliminary English translation of two booklets in the series "Water Planning" published by the Swedish Environmental Protection Agency and the Swedish National Board of Housing, Building and Planning in 1996. The original English text has been edited and partly expanded by Lars Rydén.

perch, pike and pikeperch, along the entire Baltic Sea coast and flounder and eel along the southern coasts. In the North Sea and on the Swedish west coast, mackerel, coalfish and haddock are important species, as are shrimp and Norwegian lobster.

The fish stock varies considerably. During the peak period of 1973-1995 the average catch in the Baltic Sea was 760 000 tonnes with a maximum of 940 000 tonnes in the early 1980s. Today, however, the cod population is small. The decrease is due both to over-fishing and to low reproduction caused by oxygen deficiency and low salinity in the reproduction areas. Herring and sprat populations, conversely, have increased, helped by eutrophication. Environmental impacts have negatively influenced eel, flounder and salmon. Moreover, at the moment, the disease M74 casts a shadow over the future of the salmon in the Baltic.

In inland waters, commercial fishing is mainly focused on the large lakes, but also occurs in the mountain lakes of Lapland and in rivers in the southern Baltic regions. Important species include salmon, char, pikeperch, perch, pike, eel, vendace and whitefish. In Sweden alone the total catch in inland waters amounts to approximately 2 000 tonnes annually.

Questions regarding fishing claims, conflicts with other interests and measures that can be recommended for the protection of fish stocks are important for comprehensive planning. Exploitation of areas outside the coastal zone, e.g. oil platforms or wind-power stations, is at the moment very small in the Baltic Sea. Neither is it an immediate concern for river basin management. This chapter is thus focused on fish, fishing and aquaculture in coastal and inland waters.

Recreational fishing

Recreational fishing in inland waters aims at the same species as commercial fishing, although with a greater focus on perch and pike. Along the Baltic coasts, fishing for whitefish, herring, perch, pike and pikeperch dominates while sea-run brown trout is of major importance along the Swedish coasts of Skåne and Halland.

Recreational fishing has grown strong over the last few years, and hundreds of thousands of fishing amateurs are found in every country. Trolling for salmon and pike as well as more advanced angling for species of no commercial value are newly introduced, fast-growing fishing methods. The annual catches within subsistence and sport fishing, dominated by perch and pike, are estimated at 40 000 tonnes in Sweden alone. The economic importance of recreational fishing cannot be calculated as precisely as the yield of commercial fishing, however, the recreational value itself justifies a high price per kilo, especially when more desirable species like trout, char, salmon and pike are considered.

Conditions needed for fish and fishing

Commercial and recreational fishing exhibit different demands on comprehensive planning. Commercial fishing is performed as large-scale open-sea fishing cruises or smaller-scale coastal and inland water fishing activities. Recreational fishing, on the other hand, is performed as subsistence- and sport-fishing. For both commercial and recreational fishing, it is important that certain physical prerequisites are met in order to ensure a persistent condition.

A persistent fishing demands:

- That water and sediments are free from pollutants
- Sufficient oxygen concentrations in the water
- Intact spawning and growth areas in shallow waters, in running waters and in the sea
- Intact migration paths
- Accessibility to fishing waters
- Infrastructure

The demands of fishing are generally in accordance with other environmental protection demands regarding the protection of waters from pollution.

The bottleneck for many fish stocks is the availability of suitable spawning areas. This is especially valid for salmon, trout, grayling and whitefish spawning in running waters but also for many marine species that utilise shallow water areas. Generally, care should be taken to protect spawning and growth areas since they are already so affected that the production of species of importance to fishing is limited. Shallow and protected areas with stable temperature and nutrient conditions form the most important environments, i.e. shallow bays in the sea and in inland waters. Many species are favoured when these environments are in close connection to flooded land areas. Small running-waters are often very important, and in exposed coastal areas they constitute the dominating production areas for fish fry. Small running-waters may also offer spawning and growth areas for salmonids.

Most fish stocks use different areas for spawning and for growth. The possibility of migration between these areas is therefore necessary. It may concern the migration of eel along the coasts and into freshwater, the migration of flatfish to shallow spawning areas or the migration of char in mountain watercourses.

The natural and environmental prerequisites vary largely in the region, creating regional characteristics of fishing. Commercial fishing for certain species is directed towards areas with the strongest stocks. This is not always true of recreational fishing. One example in sport fishing is trout, always highly valued, even if the local stocks are small. In comprehensive planning, regional aspects always have to be considered.

Fishing together with other water uses

Commercial fishermen rarely make strong demands on the surrounding environment during fishing. For recreational fishermen, especially in sport and tourist fishing, this can be of great importance for the quality of the fishing.

In coastal areas, commercial fishing often has to share space with other activities demanding large water areas, i.e. boating, location of industries, dredging and in-filling. The yield of fishing is low compared to the yield of aquaculture since fishing is performed on natural stocks. A direct consequence of the use of natural fish stocks in fishing is the demand on large water areas. Commercial fishing demands navigable fairways, harbours, landing places, cold storage and freezing, service workshops and good transportation routes.

Fishing is very sensitive to changes in infrastructure. Special consideration has to be taken in the location of commercial fishing owing to its demands on navigable routes, harbours and landing places. The common service level on land is very important when developing new fishing industries.

In the Comprehensive Plan of a municipality, the demands of fishing can be accounted for on a map. Important existing and potential reproduction sites for all important species should be shown. The shallow water areas are especially important to many fish species.

Conflicts between fishing and other interests

Many old and new conflicts exist within fishing, the classic battle between sport fishing and commercial fishing regarding trout and salmon resources being one example. Fishing is now confronting other problems, including damage to

Information required for planning of fishing activities

An overview picture of the fishing within the municipality with a special emphasis on spawning and growth areas, migration paths and fishing areas should form a basis of planning. In addition, possible conditions in the law of fishing regarding protected areas should be included. Moreover, for coastal municipalities, the area from the sea to the first definite freshwater migration obstacle should be identified. Most fishing regulations promulgated by the State Fishery Authorities are normally valid up to the first migration obstacle from the sea. Above this point, the local fishery administrations or the owners of the fishing rights make their own decisions. Good basic knowledge is required to present well-supported standpoints and recommendations when arguing for a plan for fishing areas.

Information should include the following:

Type		Source
1.	Fish inventory: Existing species	County
2.	Catching areas, statistics on catch	County
3.	Recreational and commercial fishing	National Board of Fishery
4.	Existing protected areas	County
5.	Areas of interest to fishing according to the Swedish Environmental Code	
6.	Waters of importance to fishing:Inventories, spawning, growth, migration paths	County
7.	Ecologically sensitive stocks: Threatened species, strains, other species	County, NGO:s,
8.	Ecologically sensitive environments: Shallow water areas, river mouths, rapid flowing waters etc.	Municipality, County, Maps and inventories
9.	Competing interests: Receiving waters, outdoor life etc.	County, Municipality
10.	Water quality: Oxygen, pH, metals, organic pollutants etc.	County, Municipality
11.	Existing conservation of the fishery: Restoration etc.	County, Local Fishing Organisations, Municipality

equipment and catch by cormorants and seals and the competition for resources. Trawling on sensitive bottoms may cause damage to plants and animals. Too heavy a pressure from fishing may threaten the growth of important stocks.

The load of nutrients and environmental pollutants to receiving waters is also a threat. The watershed is changed through underground drains, forest drainage ditching, construction of culverts etc. causing changes that almost always damage fish stocks and fishing. Even though it often concerns small stocks of little interest to commercial fishing, they may be the backbone of an extensive recreational fishing. Not only the interests of the fishing industry but also the importance of fishing in recreation and tourism should be considered.

The use of surface waters for irrigation often creates problems, especially if measures have been taken to enhance the drainage of the irrigation area.

Industries and municipalities use waters as receiving waters for effluents and process water, having influence on the water quality demanded for a persistent fishing.

Many physical operations are performed in shallow areas along the shores and coasts and in the watercourses. Dredging, in-filling, port constructions, pits, road constructions, power-plant dams etc. can all have negative effects on fish reproduction, growth and migration.

The conflict situation needs to be analysed properly in order to make well-supported decisions and priorities between fishing and other interests. The opposite interests should be described in text and on a map. An analysis should be made in order to see if the interests can be co-ordinated or if one part should be given precedence. Light may have to be thrown upon the consequences of the carry-through of the different alternatives.

Conditions to be taken into account when planning for fishing

In the watershed:

- Digging of drainage ditches may cause leakage of nutrients and humus and sediment transport affecting water quality and bottom conditions negatively.
- The use of acidifying fertilisers in forestry as well as the use of fertilisers and pesticides in agriculture, affects water quality and fishing negatively, especially if performed close to surface waters.
- Protective stands of forest or other protective zones along watercourses can have positive effects on fish through shading of the water surface, thereby reducing the risk of excessive growth of vegetation, stabilising the shorelines and acting as a buffer for nutrients from the surrounding land areas.
- Irrigation may threaten fish stocks through the reduction of water volumes, causing a reduced dilution of pollution. Irrigation should be tried according to the Environmental Code.
- Digging of drainage ditches and lowering of water levels often affect fish stocks negatively through negative effects on water quality, temperature and oxygen conditions and may therefore have negative effects on fish spawning sites.
- Transportation of environmentally hazardous substances by truck or train close to surface waters implies an increased risk of pollution in the case of accidents.

In lakes and running waters:

- Migration obstacles may make it difficult for or prevent migrating fish from reaching their spawning and growth areas.
- Short-time regulation normally affects fish negatively, since it often causes fluctuations in water quantity and quality and the erosion of beaches and bottoms.
- The construction of channels and cleaning of ditches may, among other things, affect bottom structure and water quality.
- Liming and the following changes in pH may have negative effects on fish.

In shallow marine areas:

- Areas with a depth between zero and three metres are highly productive spawning and growth areas and are therefore especially worthy of protection.
- Small boats may spill oil and cause erosion of important spawning bottoms. Mooring to buoys may also damage sensitive bottoms through the wearing of anchor chains.
- Areas that appear to be suitable for the building of marinas are often important for fish reproduction and growth as well.

Fishing in Tjörn municipality - a case

In the Comprehensive Plan of Tjörn municipality on the west coast of Sweden, there is a map showing the different interests related to fishing and their geographical distribution. The municipality has accounted for areas of national and regional interest for commercial fishing and outdoor life connected with fishing. Ecologically sensitive areas regarding the interests of fishing and potentially interesting areas are also shown.

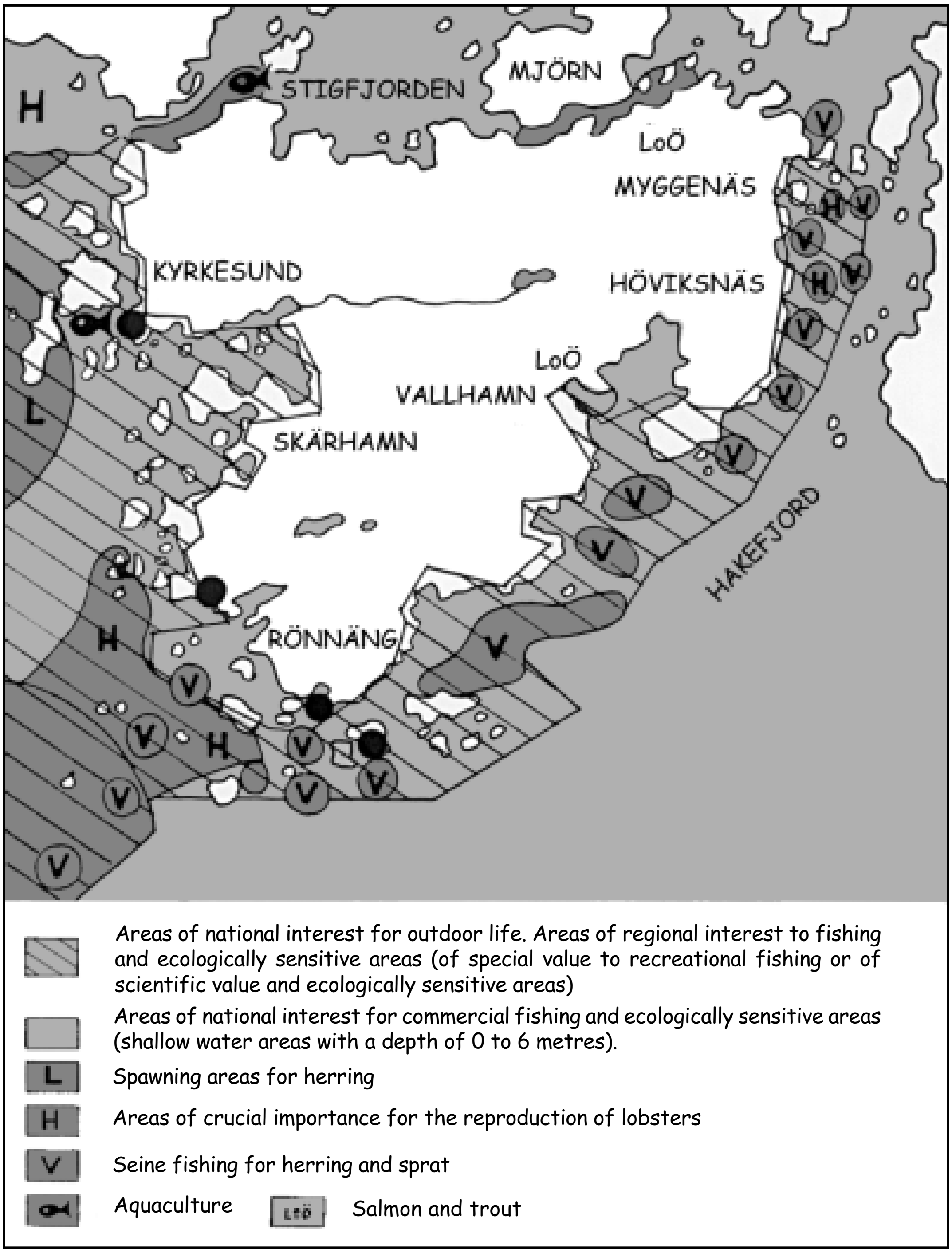


Figure 3.2. Areas of interest related to fishing (Freely drawn by Nils Petersen after the comprehensive plan of the Tjörn municipality).

Comprehensive planning for fishing areas

Fishing may be included in a Comprehensive Plan for a coastal, lake or river area. Objectives for the planning may include geographical, environmental, economic, and especially, water quality, to enable people to live and work both along the coasts and the larger lakes. To achieve these goals, measures to improve fishing are often necessary as fishing often forms a central element for survival in these communities. The objectives often have to be specified and divided in order to make measures realistic and possible to carry through.

In order to favour fishing, disturbing activities should be localised to areas of little interest to fishing. This means that disturbances like discharges, dredging, and fills should be avoided in important spawning and growth areas. Environmental impact assessments shall be established for larger works, i.e. in-fills.

Areas suitable for restoration should be stated in the Comprehensive Plan. These measures are meant to restore important spawning and growth areas, migration routes and fishing-waters through changes in roads, dams etc. or through the recreation of natural environments for fish in drained and in straightened watercourses.

Other areas that are suitable for measures aimed at an increase in the strength of fishing can be pointed out. The municipality may, in its Comprehensive Plan, mention water areas where liming is needed. It is also important to save existing wetlands and aim to create new ones in order to increase the retention of organic material and nutrients (wetlands also exhibit other positive effects on the environment) and save and create protected areas for bushes and trees. The municipality may also point out areas where special consideration should be taken regarding the regulation of water flows and water levels and identify areas with different types of migration obstacles that may and should be considered.

Areas of special interest to fishing where special consideration should be made regarding the progressive use of land and water can be pointed out. It may, for example, regard recommendations of the municipality to keep protected zones surrounding watercourses, requirements of consideration regarding use of manure, fertilisers or the use of chemicals in agriculture or forestry in sensitive areas.

If areas suitable for different measures are pointed out in the Comprehensive Plan, a programme should be prepared describing how the measures are to be carried through and who is responsible. The Comprehensive Plan can refer to existing or future fishery conservation programmes, water conservation programmes etc.

Certain areas of great interest to fishing may need to be protected according to the Environmental Code, such as nature reserves. The municipality may take an initiative to propose this.

Instructions for the continuous planning should be given in the Comprehensive Plan. The municipality may, for example, state that a local plan should be established for a specific area and that special consideration should be taken within the local plan regarding accessibility to boathouses and landing grounds.

The municipal Comprehensive Plan may have to be focused in a local plan in areas with many contradicting interests, such as “overheated” coastal areas in the vicinity of big cities, in order to clarify the planning questions.

Aquaculture

Aquaculture is the breeding of organisms living in water where you can control production by different means, such as feeding and protection against predators. Aquaculture can be extensive or intensive: Supply of extra food to the species makes the cultivation intensive otherwise it is extensive. Species involved in aquaculture include fish, mussels and crayfish.

The production of salmon in aquaculture is considerable, especially in Norway, where the annual production is more than 300 000 tonnes per year. In the Baltic Sea, aquaculture and fish farming is still limited, and mostly concentrated to the Finnish and Swedish archipelagos. Further south, fish farming in lakes has a long tradition. Poland produces an annual 40 000 tonnes of carp and 30 000 tonnes of salmon in fish farms. In Sweden much farmed-fish are used for planting in natural or regulated waters.

Fish cultivation can be land-based, using ponds, pools, troughs etc. or take place in net cages in open water. The latter is the most common form in Norway and Sweden. The foodstuff used is usually dry fodder, no more than 10 % water, with a high-energy content.

In many areas aquaculture developed as other trades, e.g. fishing, forestry and agriculture, have diminished in economic importance. Especially during the 1970s aquaculture was viewed as an interesting way of making a living in scarcely populated coastal areas, and new aquaculture-companies were supported in different ways. This optimistic view has been hampered, due to lower profits and negative environmental impacts from the farms. Enhanced control and production of environmentally better fodder has, however, led to drastically reduced discharges, mainly of phosphorus from fish farming.

Basic information for planning an aquaculture

There is knowledge to gather from the considerations given aquaculture in comprehensive planning. It can also be found at central authorities, as well as on the regional and local levels. An example of a good base is the environmental report, which is delivered annually to the local authorities by existent facilities. From this report it is possible to calculate the level of pollution. For planned facilities these calculations can be made from the Swedish Environmental Protection Agency's guidelines.

The use of chemicals and medications varies a lot. However, it is usually very small at Swedish facilities.

Examples of useful sources of knowledge:

- Maps over bottom conditions, charts, etc.
- Maps over water circulation
- Surveys of water quality, river outflows and natural populations in the area
- Commercial fishing interests
- Information from regional environmental plans
- Environmentally orientated programmes and reports from the local authorities
- Programmes for control of the receiving water
- Interviews with local fishermen etc. and co-operation with local authorities
- Reports of profitability, number of employees etc. from existent facilities in the region

Requirements on areas for aquaculture

Areas suitable for net-cage cultivation of fish should meet certain demands. They must have good water circulation to keep effects on the local environment low. The lake/sea needs to be sufficiently deep for the cages to be placed and anchored properly. Temperature layers in the water should also be considered. The position must be protected, not exposed to wind or strong currents, and ice conditions must be good.

Good water quality is also important, so that the fishes remain healthy, grow well and are suitable to eat, and the effect on the receiving water must be as low as possible. In addition, good bottom conditions, without distinctive accumulation bottoms, are desirable.

It should also be relatively easy to reach the location, which demands docks, ports and/or roads. Areas with restricted access, such as bird protection areas, should be avoided. If a new facility is to be opened, it is necessary to obtain a permit from the local authorities. Access to service facilities such as storehouses and refrigerators are a plus.

Areas for net-cage fish farming should have:

- good water circulation
- suitable depth
- high water quality
- good bottom conditions
- a suitable location
- access to service facilities

Environmental impact of aquaculture

It is mainly net-cage cultivation of fish that can have a large effect on water quality, bottom conditions and the supply of plant nutrients in the area. Net-cage fish farming is an open system with direct contact to the surrounding water and bottoms and with scant possibilities of sewage treatment.

Effects arise from faecal matter and bacteria from the fish, and surplus fodder, which affect the water quality and bottom conditions. These products contain plenty of nitrogen and phosphorus; important nutrients that can increase production of attached algae and phytoplankton in the area.

If there is an accumulation bottom beneath the net-cage, waste is accumulated right under the cage, which can lead to lack of oxygen and the production of highly toxic hydrogen sulphide. This can affect not only the cultivation, but also the entire surroundings.

Fish farming can affect or change:

- water quality
- bottom conditions
- supply of plant nutrients
- dispersion of bacteria, diseases and genetic defects
- ship routes
- landscape
- smell
- noise
- light conditions in the receiving water

If the cultivation is land-based, there are better possibilities for sewage treatment of different types.

Introduction of cultivated fish with small genetic variation is a threat to wild populations.

Mussel cultivation also affects bottom conditions by the accumulation of shells and faecal matter beneath the cultivation place, but since they are filter feeders and use food already available in the water, one does not have to worry about surplus fodder.

Aquaculture and conflicting activities

The possible conflicts of interest can arise when the aquaculture facility demands a certain environment, which is threatened by some other project, or when the cultivation's effects have a negative influence on some other enterprise.

Threats against aquaculture activities consist mainly of discharges from industry and drains, which brings polluted water to the vicinity of the fish/mussel, thereby damaging it, or making it unsuitable for consumption. Damage upon fish-farming facilities can also be caused by boat traffic.

Aquaculture can, by its demands and effects, come into conflict with several other interests. An area suited for aquaculture can also be of interest for recreation, fishing and nature conservation. Interests that can come into conflict with aquaculture include:

- industrial discharges
- discharges from sewers
- boat traffic
- fishing
- recreation
- nature conservation

Comprehensive-planning considerations

Environmentally adapted aquaculture may be developed if the location and scope of facilities are determined on the basis of water-use planning and water quality, and if fish fodder with the lowest possible environmental impact is selected. Due to the effect on the water quality caused by net-cage cultivation, the location is of great importance. Along the coast, the contribution from aquaculture to the grand scale eutrophication of the sea must be considered, which makes things even more complex. A well-situated fish-farming facility has only limited effects on the receiving water.

Local objectives for the aquaculture should be presented in the Comprehensive Plan, so that everyone might understand the intention of the Plan on this issue. The objectives may be geographical, qualitative, operational or environmental; water quality, for example, is important. Such objectives may state that a given lake should be useful for swimming and recreation, or that the influence on water quality should not pass a certain criteria.

Base material for the planning should be put together so that an all-round and all-covering picture of the possibilities of the area is obtained. A compilation of existing enterprises, which affect the area, e.g. effluent sources, which already burden the receiving water, should be done. The environmental consequences of the fish/mussel cultivation in form of pollution and other disturbances should be estimated, and opposing interests described.

In the Comprehensive Plan, the local authorities can point out those areas considered inappropriate for aquaculture, where opposing interests are considered to be stronger and incompatible with cultivation interests (see Box overleaf). This gives a clear signal to potential fish/mussel-farmers. The farmer's personal choice is often governed by forces unknown to the local authorities, such as deals with landowners and proximity to the farmer's house. If the local authorities instead choose to point out areas where fish/mussel cultivation is appropriate, the basic planning should be complemented, such as with an investigation of how a project can affect other interests by transports, discharge of nutrients and constructions on the beach. Some interests that can come into conflict with aquaculture include bathing, drinking water supplies, fishing and shipping.

There are several measures, which can be used in order to reduce pollution from fish cultivation facilities. An important step for already existent facilities is the use of as environmentally good fodder as possible. In some cases, if the effects on the local body of water are great, moving the facilities to a more tolerant location, perhaps even up on land, should be considered. Land-based facilities can be very expensive, but sewage treatment is much easier. It can be necessary to create an action programme. The Comprehensive Plan can give information on existing or planned action programmes.

The need for an extensive investigation when planning a location has been described earlier. In the Comprehensive Plan, directives for further planning can be given. For areas with opposing interests, it can be necessary to make a more detailed Comprehensive Plan. The example of fish cultivation in a strait (see Box above), could have originated from such a plan.

In the Comprehensive Plan, it is possible for the local authorities to give directions for the work with a detailed plan or area regulations. This could, among other things, make it possible to limit disturbances in the landscape and give noise high priority.

In the Comprehensive Plan one can also point out the need for further investigations, such as those concerning the environmental situation in certain areas.

AQUACULTURE IN COMPREHENSIVE PLANNING - AN EXAMPLE

In the following example the local authorities wished to determine whether it was appropriate to locate a net-cage fish farm in the strait of a bay (see Figure 3.3).

Material used in the investigation included chart material over bottom conditions and water dynamics; the local nature conservation programme; register leaflets for agricultural areas; city architect's survey of second homes; and information from water treatment plants

The investigation showed that the intended place met the needs of natural conditions and accessibility well. On the other hand, the inner parts of the bay were already polluted. Large parts of the bottom consisted of accumulation bottoms with low amounts of oxygen and occasional formation of hydrogen sulphide. There were also productive shallow bottoms of importance for the fishing in the bay. Nutrients from second homes with poor sewage treatment loaded the bay, causing deterioration in recent years. Calculations showed that the fish cultivation facility would lead to a significant increase in this loading.

The local authorities decided that they wanted to keep water quality and biological values intact rather than exploit the possibilities of aquaculture.

In the Comprehensive Plan it was stated that the burden on the inner water area must not increase, but rather decrease in the long run. Improving sewage treatment, both in the second homes and in the main water-treatment plant, and avoiding any aquaculture in the strait can achieve this. However, west of the bay there was a promising area that was found worthy of further investigation.

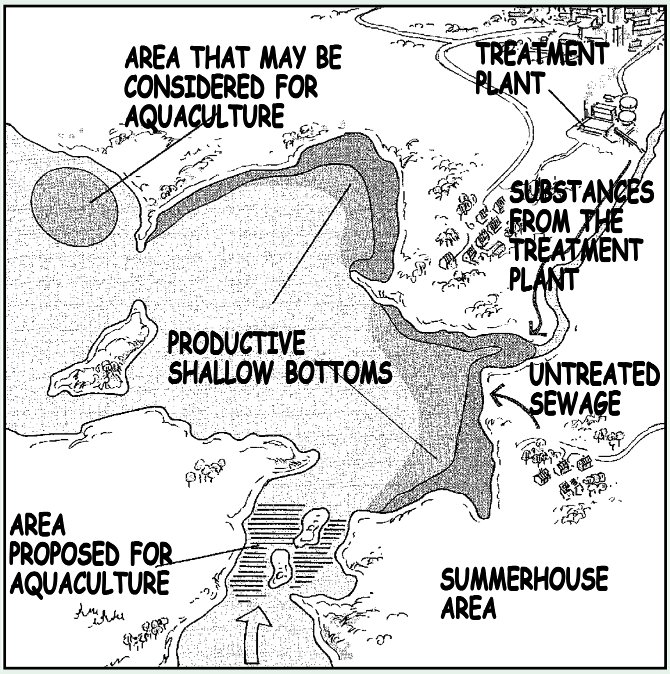


Figure 3.3. Modified after drawing by Nils Petersen.

Figure 4.1. Today hydropower is often only associated with electricity, but water as a source of power has been used for many purposes. Many years ago, local farmers came with their grain to this mill but today it stands by the small stream, empty and silent (photo, Inga-May Lehman Nådin).

4.
HYDROPOWER

Inger Brinkman, Yngve Malmquist, Tomas Kåberger & Lars Rydén[1]

The history of waterpower

Streaming water has always been taken into service to power machinery. A wheel positioned in the streaming water constituted the means by which water mills, saw mills, sledge hammers, pumps etc, were turned and used in the service of agriculture, forestry and mining for hundreds of years, long before the advent of steam engines, generators and the diesel motor. Today, hydropower is used exclusively for generating electricity but it still has an equally general role since the electricity is used for all purposes, including the industrial sectors mentioned.

The ancient use of streaming water was small-scale and did not much disturb the rest of the river being used. The modern production of hydroelectric power is, on the contrary, done in enormous power stations and is critically dependent on large-scale regulation of the streams and even entire river basins. It constitutes by far the most profound impact of humans on water and river basins, surpassing shipping, fishing, agriculture, etc.

The best sites for hydropower in the Baltic region are found in the mountainous northern areas. The first hydroelectric power stations in the region were built in the rivers in northern Sweden and Norway at the end of the 19th century, as the technology for the transfer of electricity over large distances developed. The development of large-scale power stations continued in these areas up to the 1980s. In comparison, the landscape in the south, where large geologically "older" rivers are found, is very flat. The Wisła River in Poland has thus only one large power station at Plotsk, while the Daugava River has two power stations, one in Salaspils, Latvia, and a small one in Belarus. Recently, the construction of a large power station in northern Finland has been much debated, as have further developments of hydroelectric power along the Wisła River.

As the result of a century of exploitation of large rivers, Norway has the world's largest production of hydropower electricity per capita. In Sweden, 50 % of all electricity comes from hydropower plants. In Finland hydropower is very important as well.

Completely different ways to extract the energy content in water, such as wave-power stations, have not been successfully developed so far. It may be mentioned that wind-power stations are much more efficient and less disturbing on water than on land. Thus wind-power stations outside coasts might in the future become a significant source of renewable energy.

Dam buildings

A large hydropower station requires a large dam upstream to provide a better fall height and a more controlled and continuous supply of water. The effects on rivers are therefore threefold: a reduction in seasonal variation; the permanent formation of large dams, even enormous lakes, upstream; and an often considerable reduction of water volumes downstream.

The environmental consequences of this are dramatic. The seasonal flooding of floodplains disappears, and with them a whole biotope. Species dependent on seasonal variation are affected, as are migrating fish such as the salmon, which is no longer able to swim upstream to spawn. In addition, large aesthetic values are lost. The romantic and comparatively unaffected scenery of water falls, streams and desert-like areas where the old riverbed lays barren substitute floodplains. Changes in water flows may have negative consequences for groundwater levels, which affect the local water supply and irrigation.

The social and economic effects may be substantial. Valuable farm- and forestland may be lost when the dams constructed block the water reservoirs. Sometimes whole valleys are set under water and homes and even entire villages may have to be relocated. These effects, however, have to be compared to the benefits the hydropower plant brings, such as electrification and regulation of the river flow as pro-

[1] The chapter is based on a preliminary English translation of a booklet in the series "Water Planning", published in 1996 by the Swedish Environmental Protection Agency and the Swedish National Board of Housing, Building and Planning. The original English text has been edited and partly expanded by Lars Rydén. The section on the technology of hydropower is based on a text by Tomas Kåberger in the series "A Sustainable Baltic Region from the Baltic University Programme", 1997.

tection against devastating floods. Important environmental benefits such as little or no air pollution should be taken into account as well.

Because of the negative effects of large-scale hydropower, it has become less viable as an energy source in our part of the world. While some undeveloped rivers remained in the northern parts of Finland, Norway and Sweden, strong public opinion against using these rivers for hydropower developed during the 1970s. In Sweden this led to a new Water Act, passed by Parliament in 1983 (later merged into the Environmental Code), where the four remaining large rivers in the north were protected against exploitation. These are the Rivers Torneälven (the border river between Sweden and Finland), Kalixälven, Piteälven and Vindelälven.

The technology of hydropower

Hydroelectric power is renewable and in this way constitutes a sustainable source of energy, in contrast to the combustion of oil, gas and coal, which dominate electricity production in the southern and eastern part of the region.

Hydropower is a very well established technology. The production costs of hydroelectricity depend on the geographical conditions at the site of the plant,

The Swedish Parliament on Hydropower Development

According to the decision of the Parliament in 1975 (81), hydropower will be allowed to expand to 66 TWh per year. One objective for the energy production is to be able to continue to use hydroelectric power in an efficient way, while decreasing its negative effects and getting maximum environmental use for a minimum amount of money.

Today only a few streams and rivers flow naturally with waterfalls. Therefore, it is of utmost importance to preserve these waters, including the rivers that were saved from regulation by the decision of Parliament. These waters should also be actively protected against other kinds of influence or exploitation. The environment in regulated waters should, if possible, be improved in order to increase biological diversity, recreation and fishing conditions.

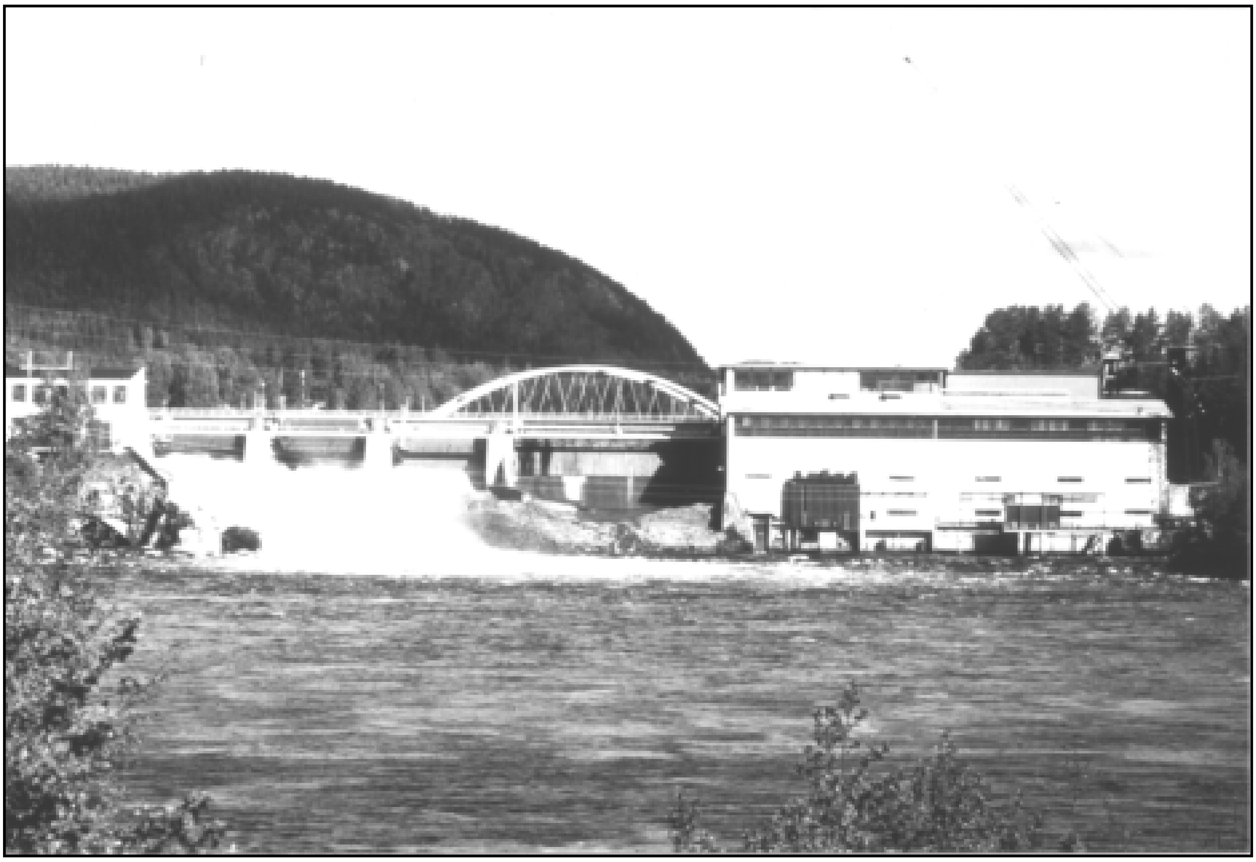


Figure 4.2. The Hammarforsen hydropower station in Sweden (Swedish Hydropower Association).

which determines the construction or capital costs. They are also dependent on the plant's load factor, i.e. how it is utilised in the integrated power system. At favourable conditions, i.e. low capital costs and a high load factor; hydropower is one of the cheapest ways to produce electricity. It is also one of the most efficient; at optimal conditions efficiencies of 95 % can be achieved.

An important advantage of hydropower plants is that they can be used to store energy. Water is stored in dams as a reserve energy source to meet sudden changes in demand. In northern Europe, water is typically stored during spring and summer, when electricity demand tends to be lower, and is used to produce power later in winter, when electricity demand is high.

Another way to store energy is through the use of pumped storage systems. In pumped storage systems, electrical energy is converted into gravitational potential energy by utilising the surplus power from a thermal or a nuclear power station at low demand to drive a pump that raises water into a reservoir. The water in the reservoir can then be used to produce electricity in a hydropower station at times of peak demand. At present, pumped storage systems are the only practicable solution to storing electrical energy in large quantities.

Small-scale hydropower

Small-scale hydropower, i.e. power plants with a capacity below 5 MW, is today a promising alternative. There is still a significant potential for small hydropower stations in the Baltic region. In the past 50 years or so, the number of small-scale hydropower plants in industrialised countries has declined as power companies have invested in larger, more profitable electricity production systems. However, the conditions for small-scale electricity generation are slowly improving again in Europe. One reason for this change is the deregulation of the electricity market, which in some countries includes better provisions for independent producers. Another reason is a revived interest in developing domestic energy sources in order to reduce the dependence on electricity imports. In Latvia and Poland, small hydropower stations that have been idle since World War II are now being put into operation again.

In Sweden alone there were about 4 000 small hydropower stations some 50 years ago, typically of some 100-1 000 kW each. Today 1 200 of these are still in action, producing a total of 1.5 TWh yearly. Small companies or private persons often own them. A recent estimate is that about 2 400 new small stations could successfully be developed. These will preferably be installed at already existing dams, e.g. such dams that earlier were used for mills or iron works, sometimes hundreds of years old. Today it is possible to install computers to regulate the function and the water level automatically.

Effects of regulation of watercourses

- Different obstacles block the way for salmon and other migrating species.
- Varying water level removes large parts of beach flora, bottom vegetation and bottom fauna.
- Increased isolation reduces biological diversity.

Conflict of interest for hydropower

The interests that can come into conflict with regulation projects are nature conservation, fishery and recreational activities in connection with water and cultural history preserving.

Dams in regulated waters hinder salmon, trout and other species that migrate up the streams. For a long time there have also been obstacles in the form of mills, etc. along the streams.

The regulations have eliminated many of the genetically distinct variants of salmon and trout that were tied to a certain stream or river. In many of the regulated rivers the natural production of salmon has been replaced with cultivation of these fish, which has often resulted in a genetic mix.

In the water reservoirs of regulated rivers, the water level tends to vary greatly, often in a rhythm completely different from the natural one. This removes a large part of the beach flora, bottom vegetation and bottom fauna. Similar changes have also been noted along the regulated parts of rivers. Where streams have been dammed into reservoirs, the typical river fauna has, to a large extent, disappeared. It has been partly replaced with lake species.

In regulation reservoirs as well as along regulated rivers, hydropower, more than any other human activity, has reduced biological diversity. The expansion of hydropower has caused many habitats, such as waterfalls and flooding areas, to become scarce or to disappear completely. In addition, many species have been reduced in number and have had their populations broken. Increased isolation leads to increased risk of extermination.

When water reservoirs are created, humus, nitrogen and phosphorus are set free, which raises the tro-

Regulations of hydropower in comprehensive planning

Hydropower expansion in the Gideälven River

The municipality of Örnsköldsvik treated hydropower expansion in the all-municipality Comprehensive Plan of 1990 and in the Comprehensive Plan for the coastal areas of 1991. Concerning hydropower expansion in the Gideälven River, the municipality decided as follows:

- A recommendation for Lakes Gissjön and Bodumsjön
- No further regulation of the lake should be allowed, especially not short-term
- Planting of foreign species should not be allowed
- The water quality of the lake should be maintained

The Gideälven River upstream from the dams of the power plant at Björna is of national interest, both as an energy source and for its environment. This practically unregulated stretch of river is typical of a forest river, still quite unaffected. Together with upper Mo River, this river stretch is the last untouched in the region. Some parts of the river, especially the delta near Locksta, are of great geomorphologic interest. The populations of river pearl clam and grayling are also valuable.

The water verdict concerning the reservoir at Skinnmuddselet forces the power company to conduct massive liming measures to prevent damage to areas downstream. This area is already severely affected though, since regulations upstream sometimes cut off as much as 75 % of the original flow.

Most of the Hemlingån River has been designated as natural preserve to protect the otters; the government, however, cancelled the part of the preserve that affected the Gideälven River in 1989.

The municipality views the environmental interests as of greater importance, and believes that no regulations that threaten these values should be allowed.

Recommendations for the Gideälven River, upstream of Björna:

- No regulations that threaten environmental values should be allowed.
- The water quality of the river should be maintained.

If power expansion is allowed in spite of this, as much as possible of the remaining waterfall should be preserved. Short-term regulation should be avoided. The preserve of the Hemlingsån River will be increased with the entire drainage area of the Flärkån River (which contains many otters), to make sure that there are enough waterfalls to sustain the otter population. This is to compensate for the areas that were removed when the preserve was shrunk.

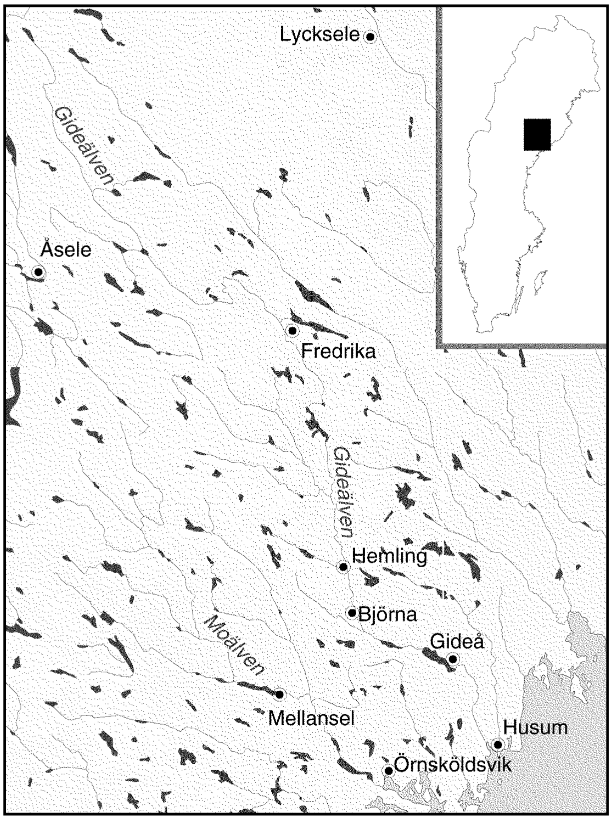


Figure 4.3. River Gideälven in Örnsköldsvik municipality. Map compiled by Patrik Steen. Map over hydropower stations in Sweden can be found at http://www.vattenfall.se/omvattenfall/epn/vat/vattenkraftverken.htm.

Hydropower expansion in the municipality of Ragunda

The main part of the hydropower potential in the municipality of Ragunda is already in use, and it is an important source of employment. Many of these facilities can be modernised and made more efficient; this process is underway.

There are nine hydro plants in the municipality today, and these produce a combined total of 6 TWh per year, representing a value of 600 MSEK ($US 75 million). The power plants are Midskog, Näverde, Stugun, Krångede, Gammalänge, Hammarforsen, Svarthålsforsen, Stadsforsen and Hölleforsen.

The remaining streams have increasing environmental and recreational values. Today the Environmental Code protects the Ammerån River from exploitation.

The Comprehensive Plan

In the municipality of Ragunda, the "Municipal Comprehensive Plan for the Valley of the Ammerån River" was developed in 1989, as a response to a proposal to regulate the lower regions of this river.

In the Plan, the Ammerån River is considered to be a huge, unused resource from a tourism point of view, mainly as a fishing and wilderness recreation area. The local authorities decided to turn the proposal down and instead turn the river valley into a reservation according to the Environmental Code. The Ammerån River was later added to the water areas that are protected by the Environmental Code, in which all regulations that cause more than negligible effects are forbidden.

From a general point, of view the local authorities of Ragunda consider the Ammerån River to have such great ecological and recreational assets, as long as it is left unregulated, that they are seen as the most valuable aspects of the area in the long term. The ecological and recreational assets are important both for supplying work and offering a pleasant environment. The timber floating that used to take place in the river has affected it somewhat, but not to a degree that threatens the above assets. The Swedish Parliament has in its decision assumed that a satisfactory minimum flow can be established. The minimum flow that has been discussed, and, likely, a significantly higher one as well, is considered by the local authorities to cause significant damage to recreational and ecological values, thus decreasing tourism opportunities severely. The local authorities think that the hydro-plants in the Indalsälven River can be reconstructed and expanded without taking water from the Ammerån River.

Considerations

The local authorities are very positive to the reformation of existing plants.

For several of these plants water permits were reviewed during the 1990s. Up until now, the local authorities have received compensation that is much too small compared to the heavy exploitation of the waters in the municipality. This compensation should be largely increased according to the reviews. Possible enhancements of the fishery and other measures that lead to a better use of the Indalsälven River should also be discussed.

The local authorities deem the remaining streams so valuable to the public, both recreationally and environmentally, that no further expansion of hydropower should be allowed in the municipality. This includes mini-plants, but not the very small facilities meant to supply some power to one or a few settlements.

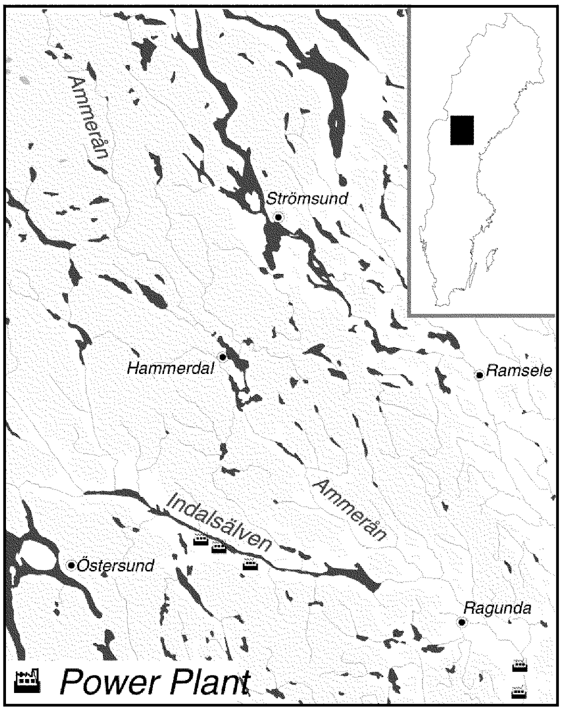


Figure 4.4. Hydropower in the municipality of Ragunda. Map compiled by Patrik Steen.

phy level of the water downstream of the regulation. But regulations can also have a positive effect on the environment, as phosphorus, nitrogen and humus can be retained in the reservoirs.

Effluents from the power plants into the water mainly consist of grease and oil. Electricity produced by hydropower causes no air pollution and, as mentioned above, only limited water pollution, compared to electricity produced by coal, oil or bio-fuels.

A response to the large environmental impact on the landscape of hydropower is technical developments. One such is the "salmon staircase" which allows migrating fish to pass the power stations. Another option is to develop double streams, such as in the Danube River on the border of Slovakia and Hungary, to allow for both ecological and technical requirements: One stream is the old river bed where even inundations are arranged yearly, the other is the canal for boat traffic. In the older stations, new concession rules might include the requirement of a small "natural" stream being maintained in the riverbed. Construction of larger, less environmentally provoking power stations is possible today, as more underground installations are used and more of the old streams are conserved.

Comprehensive planning

Demands on expansion of hydropower exist, and should be considered in comprehensive planning. These include national interests for the production of energy, but power companies may also have expansion plans.

For the hydropower plants that are operational, there are often possibilities to improve the environment. Comprehensive planning can be used to minimise the damages caused by the regulation of watercourses. Large projects affect areas quite some distance away, regarding flooding risks, settlement planning, ecosystems, water supply, landscape appearance and hindrances to migrating fish, reindeer breeding and recreation.

The position concerning regulation issues taken by local authorities in the Comprehensive Plans is very important when the Municipality Board and others decide their views on hydropower expansion. These positions are also important when a new water company applies in accordance with the Environmental Code, or in reviews concerning the environment, or expansion of existing plants and increased efficiency.

Most lakes and streams are affected by regulations of some sort. It can be the lowering of water levels, hydropower regulations, regulations for water supply or regulations to create reservoirs. No regulations can be made without damaging the environment. They create competition between different water demands and are often obstacles for migrating fish.

In the basic provisions of the Swedish Environmental Code, there are several sections that can be applied to rivers and lakes. One section concerns areas that are of national interest due to their potential for energy production. Some of the hydropower projects still running are considered to be of national interest.

5.

Tourism and recreation

Ebbe Adolfsson, Chatarina Holmberg & Beatriz Brena[1]

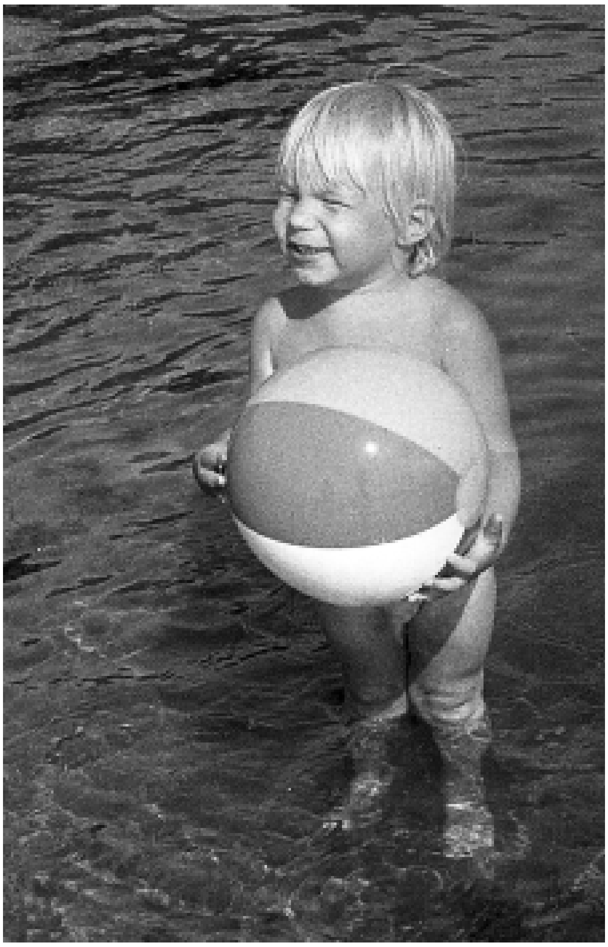
Recreation and water

The great importance to us of water is demonstrated more clearly than ever in our free time. During vacations and in general during leisure time, boats, beaches and baths are more popular than ever. On sunny summer days the coasts of the Baltic Sea and many of the lakes in its basin are lined with millions of happy people enjoying water or being close to water.

Today, tourism and recreation form a dominating part of the service sector, worth billions of dollars annually in the Swedish economy alone. The use of water by tourism and recreation is fully comparable to other uses of water, such as fishing, shipping, etc., in pure economic terms. The tourism and recreation sector clearly contributes to the well being of people and as such deserves as much care as the other sectors when planning for the best management of water and river basins.

Tourism, recreation and outdoor activities may also have more or less serious impacts on the living environment. Walking along the shoreline, swimming in the sea and skating on the lake in the winter normally have no negative effects on the environment. Facilities used in connection with these activities, such as roads, parking lots and overnight cabins, might, however, disturb nature and cause damage. These facilities, especially if inadequately designed or misplaced, most often have considerably more environmental impact than the simple activity itself. This may include a severe impact on water resources.

Outdoor activities and recreation require both land and surface water space. Some activities need water during certain time periods, while others have a year-round demand. In addition to natural access to surface water supply for summerhouses, tourist hotels and campgrounds have the same demand for fresh water as permanent settlements.



Photo, Lars Rydén.

Typical figures for summerhouses are 400 l/day and for campgrounds up to 300 l/day and family. When new facilities are planned, demands for groundwater may be raised. Some facilities for recreational activities have a great need for irrigation, e.g. golf lawns and ski resorts. Thus a golf lawn might use some 20 000-30 000 m^3 per year.

Planning should try to canalise and consider both the demands of the different recreational activities, such as a specified water quality, and measures to minimise disturbances to the environment.

[1] The chapter is based on a preliminary English translation of a booklet in the series "Water Planning", published in 1996 by the Swedish Environmental Protection Agency and the Swedish National Board of Housing, Building and Planning. The original English text has been edited and partly expanded by Lars Rydén. Beatriz Brena contributed the section on the quality of beach water.

The ”Golden beaches” stretching along the southeastern shores of the Baltic Sea represent significant tourist values but clean water is a prerequisite for increasing the number of tourists. Curonian Spit, Kaliningrad (photo, Lars Rydén).

Beaches and shores

Beaches for swimming are found throughout the region. Sandy or rocky shores make for the best beaches, but other kinds of shallow coasts are also possible to improve in different ways to make them suitable as public beaches. There should not be too much high vegetation, such as reeds. Optimally the lake or sea bottom should have a slope between 1:20 to 1:10. Streaming water should be avoided. The area required is often given as 10-20 m^2 per visitor. At larger and more frequently visited beaches, different kinds of service are often asked for, such as toilets, drinking water supply, and showers. If visited enough, a kiosk or cafe may be asked for. All this requires hygienic installations. For larger public beaches the risk of contamination of the water from restaurants, cafes and toilets should be taken into consideration.

Public beaches must meet certain criteria of water quality so as not to risk the health of the visitors, in particular children. Such beaches should not be situated close to sewage effluents due to the risk for disease-producing microorganisms. Microbiological tests should be carried out regularly. The minimum requirement is to monitor the level of *E. coli* bacteria, which is a good test of the influence of toilet waste. EU directives are available for use as criteria for the location of public beaches. The eutrophication of the Baltic Sea and its shallow bays is a special problem, as algal blooms typically appear during the warmer periods in the summer. Certain of the algae, such as cyanobacteria, are slightly toxic. If these algae appear in large quantities, the beach is required to close.

Public beaches give rise to disturbances of plant and animal life and should not be located too close to sensitive shallow waters. Conflicts between visitors, local residents and plant and animal life are commonplace, especially concerning loud music, boating, water-skiing, etc.

The quality of beach water

The main sources of pollution of beach waters

Accidental or intentional dumping of chemicals and solid waste may cause pollution in recreational waters. Although chemical pollutants, especially surfactants and oils, are sometimes present as contaminants in coastal waters, the major type of pollution comes from potentially dangerous microorganisms, such as bacteria or virus. The main origin of these health-threatening microorganisms is humans. For instance, pathogens from humans reach the wastewater system via toilets. Another

Summerhouses represent a significant part of the environmental pressure caused by the recreational sector. Cultivation of vegetables at a summerhouse close to the Swedish Baltic Sea coast (photo, Margareta Grauers Rydén).

source of potential human pathogens are pets and most commonly dog droppings that have been left on city pavements, which can get into the wastewater network through rainwater. Water in farming areas can also have this wash-off problem because manure from cows and pigs is spread onto the land as fertiliser. Certain industries, such as slaughterhouses, tanneries and farm-food processing plants also contribute to the microbiological pollution of waters.

Beach pollution may be due to discharges of untreated or only partially treated sewage into environmental waters. In many instances problems arise from rainstorms when the flow capacity of the sewer system is exceeded, causing combined-sewers overflows to discharge a mixture of stormwater and domestic untreated wastewater. Once pollution of waters has occurred, its impact is very different on cold and warm waters, on seawater or on fresh or inland water. The microorganisms and pathogens introduced into the receiving waters survive longer in warm waters and in waters of low salinity. UV radiation from sunlight adds additional pressure to the temperature and salinity effects, and it is more harmful to microorganisms when the wastewater is sufficiently diluted. This explains why inland waters are in general more vulnerable to discharges of wastewater than seawater.

The zone of the shoreline that is constantly washed by waves or tides is called the *swash zone*. When warm, moist organic matter in the interstices of sand particles of this zone may induce the multiplication of some pathogens. Subsequent resuspension of the sand and particles may cause the release of the pathogens into waters. Pathogen growth in the swash zone poses an increased risk to children who like to play and swim there.

The relevance of testing recreational water

Since a growing number of people are moving into coastal areas and pollution continues to threaten the waters in which they swim, there is a concomitant risk of illness. Epidemiological studies have consistently found a strong relationship between disease and exposures to polluted recreational water. However, we have no true measure of the overall magnitude of the problem. Certain people and children in general face a higher risk of exposure to the pathogens due to their lower immunocompetence.

The most common symptoms associated with swimming in faecally polluted waters are gastric-intestinal ones such as diarrhoea or vomiting. Contact with polluted water can lead to ear or skin infections, and inhalation can cause respiratory disorder or disease. Water pollution is also related to a number of

Conflicts of interest between recreational and other interests

A number of conflicts of interest have to be considered when dealing with tourism and recreation in relation to water.

Conflicts of localisation/occupation
Settlements, ports and boat-shelters are preferably situated in bays and other sheltered areas attractive for beach activities and sport fishing. Shore protection regulations have to be considered. The facilities may also negatively influence the water quality.

Excavation activities in water will damage bottoms used for reproduction. Examples of such measures are deepening of shipping lanes and dumping of dredging spoil as well as sub-aqueous sand and gravel extraction.

Water areas used for military activities, e.g. protected areas and areas for practice, are not available for sport fishing or other outdoor activities due to fishing or entrance bans.

Protected areas with restricted entrance enforced by nature conservation regulations, e.g. for seals or birds, restrict recreational activities.

Competition among fishing interests. Local conflicts of interest can appear between commercial fisheries, subsistence- and sport-fishing due to competition for fish as well as for fishing places.

Conflict with polluting activities
Eutrophication, caused, e.g. by sewage and process water discharge, affects the water quality and thus also the nutrient conditions. Especially fish but also mussel aquacultures contribute to an increased nutrient loading and thereby to a more rapid overgrowth of lakes. Macrophytes, soft bottoms and reed belts make it less pleasant to swim, bathe and enjoy beach life. It is also more difficult to fish from the shoreline. Perch and pike increase in number in nutrient rich lakes, which is not always popular among sport-fishermen.

Agriculture and forestry may, for reasons such as clear-cutting, drainage or ditching of wetlands, affect the water flow to and from lakes and other water systems. Fertilisation, leakage and pest-control in agriculture and forestry have negative impacts on the water environment and fish populations.

Liming and reed-control are examples of other activities that are harmful to sport fishing.

Water regulation conflicts
Establishment of hydropower plants may, through regulation of water levels in lakes and rivers, decrease the recreational value for canoeing, sport fishing and the like. Regulation of the water level in lakes will affect the nutrient supply and favour less attractive fish populations. Furthermore, shorelines and areas close to the water become less attractive for fishing from the shore due to obstacles under the water surface, which might destroy fishing equipment.

River regulations destroy fishing places in running waters and cause destruction of breeding areas for valuable fish species.

Traffic conflicts
Motorboat traffic should not occur in areas used intensively for canoeing or in areas with shores or places for sport fishing. Risks for clashes between motorboats and other water vehicles, e.g. sailboats, rowboats and wind-surfers, are high in narrow passages and in areas with intensive traffic.

Canoeing tracks should not be located in fishing areas. Arrangements for canoeing tracks, e.g. cleaning of river bottoms, affect the environment of fish species living in running waters.

Water scooters are only allowed in certain, well-defined areas. It is very important that these areas are chosen with special care. The scooters are easily transported and can be driven in very shallow areas, which leads to special conflicts with people on the beach.

Very intensive snow-scooter traffic on ice may be a problem for skaters. If the problem is great, scooter driving may be banned by local regulations.

Ice breaking and driving motor vehicles on frozen lakes cause conflicts with winter fishing and skating activities. Cars and motorbikes bring sand and salt to the ice and destroy the ice surface and may pollute the water.

Tourism and recreation in Timrå municipality - a case

In the Comprehensive Plan for Timrå municipality in northern Sweden, the measures needed to secure the interests of recreation are described. In the map it is clearly shown how the municipality intends to develop, in order to safeguard different interests. For the coastal area at Tynderö, the municipality intends to develop a more detailed plan.

General recommendations

In this version of the Comprehensive Plan, there is only a broad description of the general interests connected with water areas and their use, and the Plan gives only general guidelines. Detailed adjustments between competing interests for the use of water areas will be dealt with later.

The use of the water areas for boating activities, sport fishing and beaches is favoured, but shipping, professional fishing and minor effluents are acceptable. When there is a risk of conflict, the outdoor activities should be favoured.

When concessions for development in or close to water are asked for, it must be shown that these do not give rise to any major negative consequences, firstly for boating life and beaches and secondly for professional fishing. Greater amounts of industrial effluents will not be accepted.

The different interests are normally combined without conflict. People on beaches or in motorboats should easily accept the professional fishermen's use of permanent, sedentary equipment. Only in cases where the permanent equipment lead to severe problems for beaches and boating will regulations be considered.

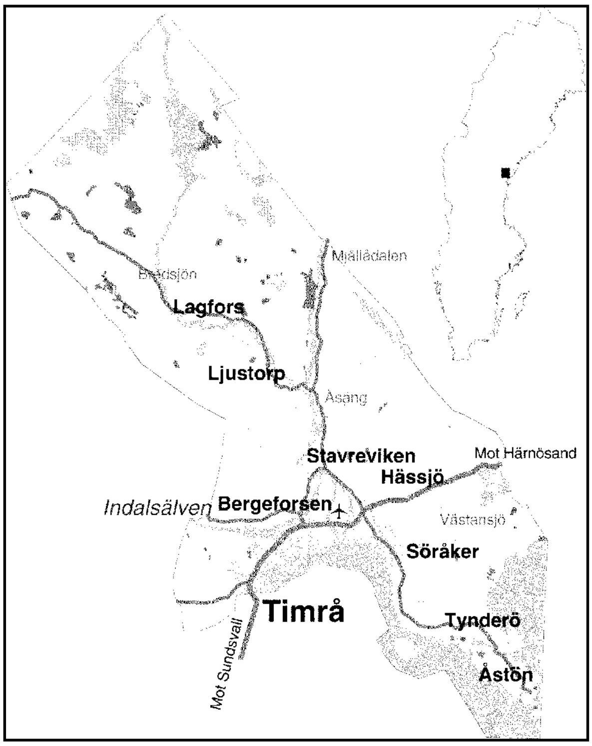


Figure 5.1. Map of Timrå municipality (compiled by Patrik Steen).

Water areas

For recreational areas including water systems, the following is written:

1. The coastal area Tynderö and the wildlife area around Lake Laxsjön have exceptional values as recreational areas, not only for the inhabitants of Timrå municipality, but for all people living in the greater region. Here forestry must respect recreational interests. Exact measures should be defined in a detailed Comprehensive Plan later, which should also contain directives for design and location of new settlements.
2. The delta area of the Indalsälven River is an area of national interest both for nature conservation and for recreation. Fishing is of high quality, as are canoeing, botanical and ornithological studies and enjoyment of the spectacular landscape. Adjustments between these outdoor activities and other interests, such as the airport with services, tourist facilities and traffic constructions, has been decided on in a detailed Comprehensive Plan for the delta area accepted in the spring of 1990.
3. The forest is the most important resource for outdoor activities outside settlements in the municipality, but in almost all areas a rational forestry has to be accepted.

Canoeing in bright sunlight in the Baltic Sea archipelago (photo, Lars Rydén).

serious health problems such as cholera, typhoid fever, dysentery, polio and infectious hepatitis. The pathogens responsible for these diseases are bacteria, viruses, protozoans, fungi, or parasites that live in the gastrointestinal tract and are released in the faeces of warm-blooded animals. Thus, water testing is an important tool that can help to warn a community of pollution and so prevent health problems.

Indicator organisms

Enterobacteria include *Escherichia coli* and other related bacteria known as coliforms. Coliforms are rod-shaped Gram negative bacteria defined by their ability to grow on certain media. They are found in high numbers in faeces. Due to the difficulties in analysing and detecting many possible pathogens or parasites, concentrations of faecal bacteria, including faecal coliforms, enterococci, and *Escherichia coli*, are used as indicators of faecal pollution. Elevated levels of indicator organisms, which in turn indicate the potential presence of pathogens, thus evidence pollution. The main properties that an ideal indicator must fulfil are:

- The indicator should be present in large amounts in the presence of the pathogens.
- The indicator should not be able to proliferate more than the pathogens in the water.
- The indicator should be more resistant than the pathogens to disinfectants and aqueous environments.
- The indicator should be easily identified and it must be able to grow readily on simple media.
- The growth of the indicator should not depend on the existence of other organisms that may be present in the sample.

Historically, total coliforms were the first indicator used, but since there are many coliform bacteria that are not of faecal origin, the procedures were modified in the seventies to detect only faecal coliforms. A decade later, the use of *E. coli* and enterococci was recommended for monitoring fresh and marine waters because of the evidence of a higher degree of association with outbreaks of certain other diseases than faecal coliforms.

The viruses from faecal origin known as enteroviruses include: polioviruses, hepatitis A-viruses, and rotaviruses. These viruses represent a problem because they usually are able to survive longer than bacteria in water and therefore they do not correlate well with bacterial indicators of pollution. In addition, enteroviruses are difficult to culture, which represents a problem for monitoring. Therefore, there is the need to develop viral indicators such as coliphages (virus of *E. coli*), which have the advantage of being easily culturable.

The standards are defined as a concentration of the indicator, above which the health risk from waterborne disease is unacceptably high. However, the existence of different indicators can lead to conflicting results and to inconsistent situations in which one state prohibits the use of recreational waters that have been considered safe by a neighbouring state.

Finally, several aspects of the science that supports monitoring programs need to be improved since:

- current indicator microbes are based only on faecal pollution and they may not be useful indicators of other pathogens,
- the present methods of microbiological evaluation are time consuming and do not allow real-time detection of the pollution, which makes it difficult to adequately report to the population,

Table 5.1. European Union legislation: The Bathing Water Regulations 1991. Quality and Additional Sampling Requirements in Compliance with Directive 76/160 EEC

Microbiological parameter	Upper limit	Minimum sampling frequency	Methods of analysis and inspection
Total coliforms	10 000/100 ml	Fortnightly	Fermentation in multiple tubes. Sub-culturing of the positive tubes on a confirmation medium. Counting according to MPN (most probable number) or membrane filtration, culturing on an appropriate medium, sub-culturing and identification of the suspect colonies.
Faecal coliforms	2 000/100 ml	Fortnightly	The incubation temperature is variable according to whether total or faecal coliforms are being investigated.
Salmonella	Absent in 1 litre		Membrane filtration, culturing on an appropriate medium, sub-culturing and identification of the suspect colonies.
Entero-viruses	No of plaque forming units in 10 litre		Concentration (by filtration, flocculation or centrifuging) and confirmation.

- more complete epidemiological studies assessing the risk associated with ingestion, inhalation, and skin contact with polluted waters are required.

Tables 5.1 and 5.2 contain information about criteria of microbiological quality of bathing waters from the European Union and the United States Environmental Protection Agency (EPA).

Summerhouses, second homes

Millions of summerhouses, dachas and second homes in general exist in the region. Impacts on the water quality from these, as well as from other facilities for tourism and recreation, are similar to that of permanent settlements. There is a risk for leakage, especially if the local sanitary systems are of low quality.

For building second homes close to a water system, restrictions may be given in the Comprehensive Plan of the municipality. Shore protection regulations may also exist in the State laws. In Sweden the Environmental Code prohibits the construction of new houses closer than 100 m to the shoreline. In some cases this has been increased by a County Board regulation to 300 m. These regulations may be overruled if there are special reasons for doing so.

People living in summerhouses or in second homes require water for swimming, fishing and boat life. As with any settlement there is also a need for water for household purposes as well as for irrigation. Second homes, similar to permanent settlements, also affect water by different effluents. New settlements lead to increased nutrient load to the surrounding waters as well as the need for some type of wastewater treatment. If permanent living becomes more frequent in the settlements, the standard of wastewater systems needs to be improved. In general, the requirements for protecting surface water are similar for second homes and permanent settlements.

When planning settlements in mountain areas, the infection risk of bacteria in cold water should be considered. This is also valid for campgrounds in mountain areas.

Table 5.2. EPA bacteriological criteria for bathing waters (full body contacts). No sample should exceed a one-sided confidence limit (C. L.) using the following as guidance: Designated bathing beach 75 % C. L., moderate use for bathing 82 % C. L., light use for bathing 90 % C. L., infrequent use for bathing 95 % C. L., based on a site-specific log standard deviation, or if site data are insufficient to establish a log standard deviation, then using as the log standard deviation: 0.4 for freshwaters or 0.7 for marine waters.

Type of water	Microbiological parameter	Geometric mean of at least 5 samples over a 30 day-period
Freshwater[1]	*E. coli*	< 126 per 100 ml
	Enterococci	< 33 per 100 ml
Marine water	Enterococci	< 35 per 100 ml.

[1] *Only one of the two indicators should be used.*

Boat life

Using boats and "living the boat life" is becoming increasingly popular. Most excursions by boat are done in sheltered coastal waters, from which a harbour may be reached easily if needed. It is, of course, best if the water is reasonably unpolluted and good for swimming.

There are several physical problems with small-boat traffic, which need to be addressed. Bridges and electric cables constitute obstacles for small boats.

Special care should be taken with cables mounted just above the water surface, as they constitute severe security risks. Aquacultures are another obstacle. Certain water areas are prohibited to visit as they have military installations. Regulation of the water level in lakes may also cause navigational problems.

Most problems, however, arise on shore. Waste is one such problem. In frequently visited places, garbage containers and dry toilets should be available. These facilities need to be emptied and looked after, which constitutes a problem, especially for islands. In home harbours and guest harbours, drinking water and toilets are necessary. In tourist areas hygienic service and showers are typically asked for.

When marinas for recreational purposes are planned, about 100 m^2 per place should be counted on, with a harbour depth of at least 2 m. There is often an advantage to co-ordinating harbours for small boats and other activities. The co-ordination may include service facilities such as sanitary systems, phones and food service, with boat-sheds in the winter.

Boating may cause many kinds of environmental imp acts (see chapter on shipping). Typically they are:

- Impacts from boat traffic itself, e.g. noise;
- Impacts in the marinas;
- Impacts from installations in the marinas.

Small-boat traffic in shallow and eutrophic waters affects the water quality negatively by resuspension of bottom sediments caused by the boat traffic. Sewage from on-board toilets is sometimes illegally let directly into the water. In areas with a high number of visitors, the concentration of impurities may reach levels where they cause problems and discomfort.

For animal life, mobile recreational boats are a special problem. They disturb bird colonies, nestlings, etc. They may pollute the water. Effluents from two-stroke outboard engines can be especially damaging in cold and sensitive water, harming the reproduction of fish and other water organisms. Another special problem is pathogenic microorganisms, such as the crayfish plague, which may be spread by boats to non-infected lakes.

In harbours, concentrated effluents of gas and oil may pollute the water. If the boat-sheds are close to the shoreline there is a risk of water contamination by chemicals and boat paints. Larger harbour areas will disturb animal life and cause degradation of some biotopes. Special care must be taken in fish reproduction areas.

When planning port facilities the following should be given special consideration:

- The areas worth protecting
- The conditions of dredged sediments and filling materials
- Turbidity during construction and running of the facilities
- Current conditions and turnover-time of water
- Pollution from gas and oil spill into the water
- Noise
- Cleaning

Canoeing

Waters used for canoeing should be fairly well protected against wind and currents. To be used for weekend tours, the length of the water systems should be at least 30 km. Even smaller river systems for shorter trips can be excellent waters for canoeing, with high recreational values.

The water should be clean enough for swimming and cooking. During the canoeing season, trails should have a water depth of at least 0.5 m and a width of two to three metres, both for convenience in paddling and to decrease the risk of damage from wear and tear. Obstacles, such as more narrow and shallow passages, dams or waterfalls, which require the canoe to be carried on land or by foot in the water for shorter distances, are acceptable.

Canoeing has caused considerable problems in certain areas. This is due mainly to the wear of shores, but to a certain extent even to damage. Planning of canoeing trails must take the protection of nature into consideration and be done in co-operation with the landowners. Cleaning of streams and other measures to improve the practicability of canoeing may affect the environment negatively for fish species breeding in running water (see also sport-fishing).

When canoes are moved from one water system to another, there is a risk of spreading the crayfish plague and other diseases to non-infected waters. Paddling can also cause damage to vegetation and animal life, especially in new areas.

Sport fishing

Sport fishing is a very extensive activity with millions of enthusiasts in all the countries in the region. The Swedish Sport Fishing Association is in fact the largest NGO in Sweden. Also economically sport fishing is of considerable significance.

Fishing requires good water quality. In some waters, however, eutrophication – a high content of nutrients – gives rise to a high production of perch and pike, etc. In natural fishing waters large areas are needed both to avoid over-fishing and to give the visitors a reasonable chance to catch fish.

In central Sweden, in the large Lake Mälaren, the yearly fish catch is more than 2 kg/ha and in Lake Hjälmaren more than 5 kg/ha. In an average lake, the yearly production of fish for sport fishing is around 5 kg/ha. It may be estimated that one sport-fisherman catches 0.5-1.0 kg/fishing activity. Thus a lake of 100 ha may meet the demands of 1 000 fishing days/year, i.e. one to three visits per day.

Sport fishing is a good example of an activity well suited for handicapped people. Adjusted jetties should be constructed. Sport fishing is performed from boats 80 % of the time and is thus co-ordinated with boat life. In sensitive areas, sport fishermen may cause disturbance and wear. If fishing spots or areas are planned for sport fishing, disturbances and wear can be controlled.

Shooting-ranges

Shooting-ranges can cause problems, since lead accumulation at the shooting-embankment can have effects on the groundwater. Thus, shooting-embankments should be cleaned regularly until lead-free ammunition is introduced. Monitoring measurements should be considered if there is a risk of contamination. In very valuable wetlands, the use of lead-shots is forbidden.

Winter activities

Skating is generally performed without demands for any special facilities. But sometimes it can be necessary to clear the ice from snow. Risk of thin ice should, of course, be taken into account. Skating may disturb bird-life, especially species that breed early.

To have a good environment for the scooter drivers to pass, careful planning is needed. The County Administrative Boards can assist the municipalities in this planning and with so-called scooter terminals. Snow-scooter traffic uses both frozen lakes and wetlands. Thus the scooter traffic affects the discharge conditions locally in wetlands. The effluents can affect sensitive lakes.

Planning considerations

Planning for tourism and recreation attempts to balance the interests of the tourism and recreational sector with other sectors and to minimise environmental impact.

The goals are, among other things:

- To find the best locations for each activity.
- To minimise travelling. Environmentally, it is important to stimulate less harmful means of transport.
- To stimulate environmentally-friendly activities, such as canoeing or sailing, instead of using motorboats. Information, plans and design should direct people to places that invite such activities. Complementary rules might be needed.

Balancing between different interests is often necessary in the recreational sector (see Box). One way of doing this is to set up a matrix in order to clarify different demands and from this to make adjustments.

To minimise the environmental impact, it is important to take into account what the land and water resources can tolerate and which activities they are best suited for. For example, most shores are attractive for recreation, but might not be good for developing the infrastructure required.

The result of the work is a Comprehensive Plan for the municipality, normally a map and written statements. These are to be used as instruments when deciding on various measures to be taken by the municipality. Since the Comprehensive Plan is not binding, the suggested measures must be secured in different ways, such as municipal regulations. It is important to describe in detailed plans or regulations how overriding laws, such as the Environmental Code, are implemented.


Nature values worth protecting at a small lake in the Kashubian area of northeastern Poland (photo, Lars Rydén).

6.

Nature conservation

Carl Erik Johansson, Ylva Rönning & Lars Rydén[1]

Nature - beauty, biology and productivity

We live in a time when mankind's influence on the natural world is more dramatic and far reaching than ever before. Even counted on the scale of life's history on Earth, the rate of species extinction is greater than ever before. Still, it is only recently that societies have started to realise the necessity of taking strong measures to conserve and protect nature and natural values.

The beauty, biology and productivity of the water biotopes and wetland areas in the Baltic Sea basin also need special measures to avoid deterioration and being lost to future generations. This seems obvious in the south where the population density is high and economic activities have a very visible environmental impact. But also further north, in areas vast and little touched by the sparse local population, the changes caused by man's activities are already a concern for many. In a water context, the large-scale impacts of the hydropower plants and increased tourism and mining might be mentioned. Obviously, here very large economic interests are in conflict with conservation interests.

When managing river basins and planning for the wise distribution of the many activities in them, natural protection should play a very important role in the scheme. Natural values quite often need to have priority over interests of exploitation and definitely should be considered even when setting the regulations in many situations. This chapter will form a basis for spelling out these regulations, indicate how to assess the natural values in a waterscape, summarise how to recognise the various threats to natural values and, finally, outline the means to protect them legally, physically and through information or educational efforts.

Nature protection goals

The nature conservation values of springs, rivers, lakes, wetlands, coasts and seas depend mainly on the water, the bottoms, the shores and the surroundings. Natural values include:

- Biological, geological and landscape diversity
- Natural resources, such as fish
- Natural and cultural landscapes
- Importance to recreation and outdoor life

Biological diversity is, broadly speaking, the variation among the organisms in an ecosystem and the ecological processes and relations that they make up and are part of. Many waters are very important for this diversity. They function as reproduction areas, food sources, growth areas, migration routes, and resting-places.

Natural resources can be renewable or non-renewable. A durable fishery is an example of how to use a renewable natural resource. It can be maintained, in principle, forever. Shallow coastal areas are among the most biologically productive areas on Earth.

The importance of conserving these values has many aspects. For instance, they are useful to study, to have as reference for scientific work and are needed to conserve biological diversity. In addition, they supply valuable production and an interesting landscape.

It is important to consider these values when making up plans. If, for example, a stream has its own trout population, which is important to conserve, extra care in the land use of the surroundings is strongly motivated. It is, for instance, desirable that unused areas are left adjacent to the shores of lakes and streams and that artificial draining or road-building projects affecting the stream are not permitted.

Legal objectives

Governmental legislation regulating management of natural resources is the basis for the protection of nature. In the Swedish Environmental Code, it is stated that water and land areas that are of general interest due to high natural values should be

[1] The chapter is based on a preliminary English translation of a booklet in the series, "Water Planning", published in 1996 by the Swedish Environmental Protection Agency and the Swedish National Board of Housing, Building and Planning. The original English text has been edited and partly expanded by Lars Rydén, who also contributed the introduction.

protected as far as possible from measures that may obviously damage the natural or cultural environment. Areas that are of national interest because of natural or cultural values shall be protected from such measures. Areas that are especially sensitive from an ecological point of view shall be protected from action that may damage the natural environment. These special protection regulations apply to many waters, including large parts of the coasts. These areas are of national interest due to the extensive natural and cultural values present.

In some countries, including Sweden, there is a general shore protection that is very important for the conservation of the natural values connected with water. The purpose of this protection is to secure the accessibility of the shores for the public as well as to preserve important habitats for plants and animals.

Some general objectives for protection of water areas in Sweden are given in the box. In summary they are:

- *Lakes and rivers.* Naturally occurring animals and plants shall be able to maintain robust populations over time.
- *Wetlands.* Sufficient areas of all wetland types and enough wetland areas shall be conserved, in order to maintain the ecological function of the wetlands.
- *Coasts and sea.* Naturally occurring animals and plants shall be able to maintain strong, balanced populations.
- *Water quality of lakes and streams.* The overall objective is to keep the waters at as high a degree of quality as possible. The objectives include: nutrient content and change; oxygen conditions and organic material; turbidity and water colour; acidification and metals in the water; and sediment and organisms. In highly agricultural areas the demand to reach a high degree of quality with regard to nutrient content may need modification with regard to influences from surrounding land and air.
- *Recreation*. Through recreation people have rich experiences of nature and come to an understanding and knowledge of the natural environment. Good land and water areas for recreation shall be secured close to cities and towns, and in areas that are visited from other parts of the country. Shores are to be kept free from buildings and other limitations in view of the right of public access.

General objectives for protection of water areas

As an example, the general objectives given by the Swedish Environmental Protection Agency in 1990 are presented. (They are essentially unchanged in the account of Environmental Goals proposed by the Agency to the Swedish government in 1999.)

Lakes and rivers

Naturally occurring animals and plants shall be able to maintain strong, balanced populations. The types of nature connected with the waters shall be conserved. All lakes and rivers shall be as unaffected as possible. Unnatural, disturbing oxygen deficiency shall not be present. Exploitation of shorelines and pollution shall not limit the recreational values, or the possible uses as drinking water, of the waters. A broad range of practically unaffected waters shall be conserved as reference areas.

Wetlands

Sufficient areas of all types of wetlands and enough wetland areas shall be conserved to maintain the ecological function of the wetlands. The natural variation in the development history, hydro-topography and plant and animal life in wetlands must be maintained. All types of wetlands must be represented as reference areas. The primary criteria and objectives for protecting mires have been stated in the Swedish Environmental Protection Agency's mire protection plan (1994). It states that the following types of mires will be protected:

- Well-developed, diverse mire complexes
- Diverse, virgin forest/mire mosaics
- Representative examples of mire types and form elements
- Rich-mires, a threatened nature type
- Spring-mires fed by groundwater
- Swamp forests with very special natural values, especially species diversity

Every mire type shall be protected in a number of places within its extension area.

Coasts, archipelago and the sea

Naturally occurring animals and plants shall be able to maintain strong, balanced populations. The goal is the natural zoning of plant and animal communities. Unnatural, disturbing oxygen deficiency shall not be present. Exploitation of shorelines and seas and pollution on and in the water shall not limit the recreational values of sea areas. The intention is to have all types of archipelagos, coastal areas and shorelines represented within protected areas.

Nesting storks require an amount of intact wetland. This nest in the Kashubian area bred two young birds (photo, Lars Rydén).

Assessing the natural values

It is often necessary to have a thorough knowledge of an entire region in order to truly appreciate the natural values of an area. The knowledge of water-related areas is often less than the knowledge of land-based natural values.

The location of the area can also be important; areas close to cities and towns are especially valuable, since many people can visit them.

When judging which areas with water-related values that are to be specially protected or managed, it is useful to consider the following characteristics:

- *Water quality* is often a decisive factor for the natural values of a water area.
- *Diversity*, including the number of species. Physical diversity - for example variation of the types of bottoms, stream conditions, water exchanges and shores - usually creates more habitats and thus high biological diversity.
- *Degree of naturalness* is usually very important to the natural values of an area. Natural, undisturbed areas usually fulfil ecological functions better than disturbed ones. Salmon spawning and the breeding of wetland fowl are examples of such functions. All water areas are, however, more or less affected by human activities. Measures can also be taken to improve or restore the natural values of an area, for instance by removing weeds in order to benefit birds that prefer an open area of water, or by creating tree-clad protection zones.
- *Character*. An area can have a special character that increases its natural values. It can be very beautiful or otherwise remarkable in appearance. Or it can be home to some special species, such as otter or river-pearl clams.
- *Size* of the area can be important, since larger areas can offer a wider range of habitats for plants and animals. In a large area it is also possible for the outer areas to function as a shield, protecting the valuable core.

Other factors to consider include the number of species present in an area, whether there are *rare species* located in the area and how *representative* the area is, for example if it is a typical forest river.

Strategies for nature protection

The landscape, including lakes, rivers and coastal areas, can be viewed as a pyramid that classifies the landscape into different value levels concerning the needs for care and general and specific protection. The objectives for conserving the natural values cannot be reached solely by protecting the high value areas. Measures must be taken for the entire landscape, including the waters.

In the everyday landscape, environmental care and good natural resource management should be applied in all areas, such as forestry and agriculture. Environmentally attuned working methods and natural consideration should achieve this. These principles apply to the entire landscape. Most waters belong to this category.

In areas with higher natural value the demands for good working methods should be even greater. General regulations and actions protect most of the natural and cultural values, for instance regulating mining and quarrying activities. Shores without buildings or other signs of exploitation, important to outdoor recreation, belong to this category and should be kept in this non-exploited state.

Areas with especially high value should be secured protection by the law, i.e. they should be nature reserves. This category includes diverse, untouched and undisturbed rivers, unregulated lakes with great bottom and shore diversity and non-exploited natural shores.

This model should be viewed as an illustration of different action and responsibility levels. It should be noted that it gives a simplified image of the actual situation. It is often so that the everyday landscape forms a web, in which areas with higher values are scattered.

The quality of these high value areas is highly dependent upon influences from their surroundings, such as ground drainage, pesticides, etc. The values, even in large areas, cannot be conserved if influences from their surroundings are not controlled. Therefore, measures of different kinds and strengths are needed throughout the landscape.

Conservation of different types of water areas

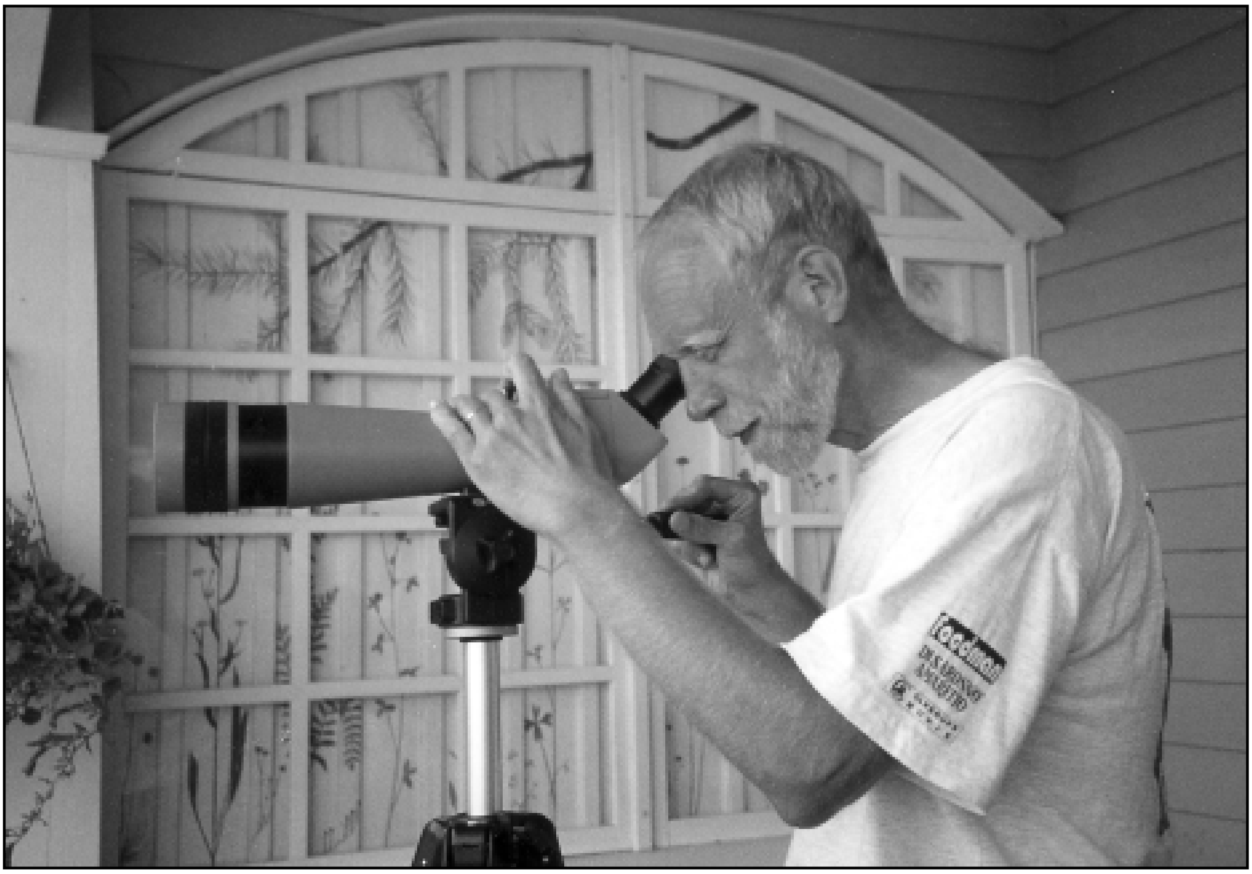
Natural values are different in different types of water areas, as are the prerequisites for conserving them. These relations depend partly on local conditions and partly on threats caused by land and water use. These threats can be direct, such as constructions in the water, exploitation of the shores or agriculture or lumbering close to the shore, or indirect, such as by supplies of nutrients or acids from contributing streams and the air.

Below are examples of conflicts of interest, and how the interests of biological diversity, natural resources and landscape qualities can be defended against other claims. Conflicts and threats should be made clearer to create arguments for or against different weighting alternatives:

- *Unaffected rivers* with falls, rapids and streams need to be protected from building hydropower and from regulation of the watercourses. If the streams have been cleared for lumber transport, boulder, cobble and gravel beds should be restored in order to benefit reproduction of fishes such as salmon and trout.
- *Meandering rivers and deltas* need protection from straightening, channelling, filling and dredging. Shores in agricultural landscapes should be armoured and shaded by trees and shrubs, to prevent erosion and lessen evaporation. This shade is also necessary for some species of fish, such as trout. Some catchments in agricultural regions are thoroughly drained, and the watercourses therefore risk drying up. Artificial drainage and irrigation would cause major disturbances in aquatic life.
- *Lakes and rivers with a low nutrient content* and with a low buffer capacity may have a characteristic, sometimes unique fauna and flora, which is decimated by acidification. They may have to be treated with lime, or otherwise buffered, to conserve biological diversity. One should, however, only counteract man-made acidification consisting mainly of sulphur compounds in the air, nutrients from settlements and humus-acids from ditches.
- *Lakes with high nutrient contents* threatened by overgrowth are overloaded, mainly by phosphorus compounds, causing the accumulation of large amounts of biomass, such as algae, and in turn a lack of oxygen, due to oxygen consumption. They may have to be restored by the removal of weeds, roots and sediment. Discharges from sewers and stormwater (from roofs and streets) may have to be treated locally in order to lessen the nutrient load and effects of toxins. The amount of fish that eat zooplankton may have to be kept down, to decrease oxygen consumption by lessening the amount of phytoplankton.
- *Lakes without fish*, found chiefly in the mountain region, had or have a very special and rich phytoplankton and evertebrate fauna, which served or serve as food for birds such as the long-tailed duck. Ponds and small lakes in southern Skåne are very important to some frogs and salamanders. They must be protected from implantation of fish or crayfish, in order to preserve the natural values.
- *Wetlands* attached to lakes and rivers are biologically very important as breeding grounds for both fish and fowl and are dependent on a natural water regime. An exception to this is so-called flooded dam meadows, which can be partly managed by regulating the water level in order to remove shrubs with the aid of rising ice. The shore wetlands need to be protected from regulation, dredging or filling.
- *Artificial wetlands*, such as flooded dam meadows, need to be maintained by regulation of the water level, and possibly mowing and grazing. In southern Sweden these wetlands are believed to be able to function as nutrient traps, and increase denitrification,

NATURE PROTECTION MEASURES ARE IMPORTANT, FOR INSTANCE, IN:

- Unaffected rivers with falls, rapids and streams
- Meandering rivers and deltas
- Lakes and rivers that are low in nutrient content
- Lakes with high nutrient contents, threatened by overgrowth
- Lakes without fish
- Wetlands attached to lakes and rivers
- Fjords and confined bays
- Archipelagos
- Lakes with a rich bird-life
- Waters, with some natural values, near towns and cities



Bird watching serves both pleasure and science. Here migrating eider ducks are counted at the Swedish Baltic Sea coast north of Kalmar (photo, Margareta Grauers Rydén).

especially if they have a long shore length and cover a large area.

- *Fjords and blocked bays* are sensitive to nutrient overload, which leads to an accumulation of biomass on the bottoms and thus to a lack of oxygen. Therefore, this load must be kept low if water quality and biological diversity are to be maintained. This is achieved by decreasing agricultural leakage by decreasing the amount of autumn ploughed land and increasing the amount of winter green farmland. Fish farming, marinas and buoy-anchorage can negatively affect water quality, flora and fauna.
- *Archipelagos* have very differing conditions regarding, among other things, water exchange and thus erosion and the transport and accumulation of sediments of different origins. There are erosion bottoms below strong streams and transport bottoms and accumulation bottoms below areas of standing water. Water passages may have to be kept open to supply oxygen. Nutrient burden from settlements and agriculture must be kept down. Fish farming should not be allowed if there is a risk of over-nutrition. New settlements in non-exploited areas should not be allowed, with regard to the importance of large non-fragmented areas for recreation and plant and animal life and to prevent infiltration of saltwater into the groundwater and further rise in the nutrition levels.

Comprehensive planning for nature protection

In comprehensive planning the local authorities can state general objectives as guidelines for later decisions and planning. These can be made into more specific geographically and qualitatively defined objectives, which can serve as support, for instance when permits are granted or denied.

The general objectives for rivers and lakes, wetlands, coastal areas and shorelines and recreation prerequisites need to be made more specific, nationally as well as regionally and locally, in both qualitative and quantitative terms. The Regional Boards are expected to adapt the objectives to local conditions. The objectives for water quality need to be developed and made clearer, taking into consideration natural conditions and influences from a regional perspective, among other things.

The following is an example of objectives that apply to the possible restoration of a lake with high nutrient contents threatened by eutrophication:

General objectives (goals):

- To recreate open water areas that enrich landscape qualities and bird-life
- To benefit recreational fishery or supply bathing opportunities

Table 6.1. Conflicts of interest and threats. The threats towards the natural values in rivers, lakes and coastal waters can come from changes in and around the water, or from the air

Activity	Immediate effects	Long term influence
Hydropower expansion, water regulation	Changes in the landscape Raised water level upstream Lowered water level downstream Changed water regime	Loss of habitats Disrupted natural processes and damaged functions
Exploitation of shores, for example port facilities	Blocking Fragmentation	Decreased recreational opportunities, less fauna and decreased natural functions
Fillings	Drainage etc.	Loss of habitat
Dredging	Increased turbidity	Loss of habitat
Clearing of shores, cultivation	Less shore stability Less shade	Erosion, lower water and habitat quality
Sewer discharges	Nutrient loads, and possibly metals and toxins	Eutrophication, Poisoning
Effluents from ditches	Supply of nutrients and humus	Lower water and habitat quality
Fish farming	Outlets of fodder and antibiotics, escapes	Eutrophication Biological disturbance
Draining enterprises	Removal of wetlands	Loss of habitat, disrupted natural processes and functions
Embankments	Forming of barriers	Loss of habitat,
Drainage	Lowered ground water table	Elimination of water plants and animals
Clear cutting or ground preparation in the drainage area	Supply of nutrients and humus	Lower water and habitat quality
Intense agriculture in the drainage area	Supply of nutrients and humus	Lower water and habitat quality
Acidic substances and nutrients brought in by precipitation	Acidification and increased nutrient content	Lower water and habitat quality

Detailed objectives:
The objectives are connected to the desired water quality and biodiversity status. The water quality should be raised from highly nutritious to moderately so; the oxygen consumption is to be limited. The water should not be too turbid and not contain too much sludge. There should not be any water diversion. Plant and animal societies should not be more than moderately disrupted. The discharges into the lake shall not have any evident influence or effect. Disturbing algal blooms should not occur.

Positions in a Comprehensive Plan

In the Comprehensive Plan the municipality can show the water-related natural values, including where they are situated, what constitutes the values, threats and problems (if there are such) and if these values have any protection by law or prescriptions. The municipality can also prioritise and give recommendations in its Comprehensive Plan. The recommendations are to be considered when applying laws connected with the Environmental Code. Indirectly, this has a great impact on natural values. How seriously these recommendations are taken depends on their motivation.

The municipality can initiate rulings according to the Environmental Code. For areas with many opposing interests a more detailed Comprehensive Plan may be needed to clarify the issues and see if the interests can be co-ordinated. The municipality may also set up guidelines for the work with detailed plans or local regulations.

Investigations may be necessary concerning, for instance, the environmental situation in certain water areas or the need for an environmental impact analysis (EIA) of a planned action. The water-related natural values may need their own assessment and management programme.

When waters influence more than one municipality the need for regional co-operation may be mentioned in the Comprehensive Plan.

Nature conservation in Höganäs and Södertälje municipalities- two cases

The Comprehensive Plan of Höganäs municipality

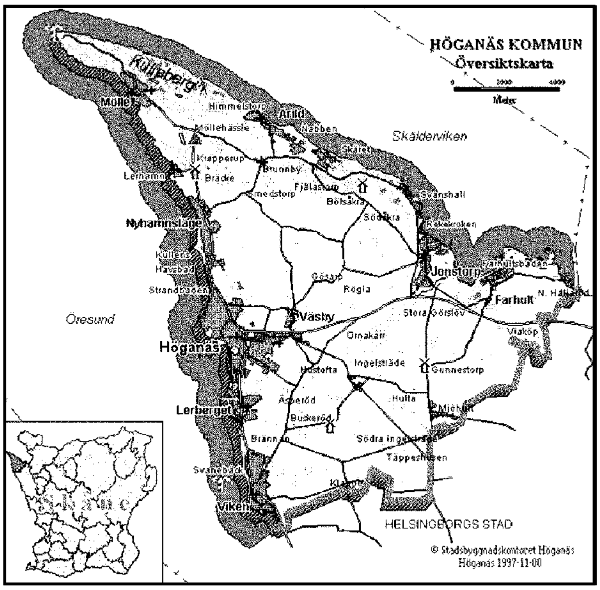


Figure 6.1. Map of Höganäs municipality.

Example: The mud graves of Danhult, Ingelsträde, Höganäs:

The following example is from the Comprehensive Plan of Höganäs municipality in southern Sweden. The municipality states that the recommendations should be transformed into regulations according to the Environmental Code.

Shifting areas consisting of water-filled clay-graves (belonging to the former brick factory of S. Danhult), thick shrubbery and open, partly grazed, moist meadows. The area is important for bird-life, with plenty of breeding birds, mainly wetland fowl. A number of rare species have bred here. There is also an important resting-place for migrating birds. The southern part is still grazed by cattle, in contrast to the northern part. Some of the graves have been filled, and the water level in the remaining ones is regulated. The water is used to irrigate nearby fields. The area is a beautiful part of the landscape. Protection here is non-existent. Motives for conservation of the area include:

- It has a rich bird-life.
- It is a beautiful part of the landscape.
- It is interesting from a cultural history point of view.

Recommendations:
The area should be declared a nature conservation area, in order to conserve the diverse environment and rich bird-life. A management plan should be made, and the need for grazing by cattle emphasised. Highly overgrown areas should be cleared and the water level regulated, so that the clay-graves do not dry up during the summer.

The Comprehensive Plan of Södertälje municipality

Example: Protection of Lake Yngern, Södertälje (area of national interest for nature conservation)

The local authorities decided to accept the following objectives:

- To achieve long-term conservation of the unique bottom fauna and water quality of Lake Yngern
- To ensure that the entire drainage area of Lake Yngern will become protected as an area of national interest for nature conservation according to the Environmental Code, and protected and managed as a nature reserve combined with a nature conservation area (protection form in the previous Nature Conservation Act)
- To formulate the intentions from the report 'Lake Yngern is Unique' in a revised comprehensive plan

They decided upon a 13-step action plan including an ecological landscape plan for the nearby forests, control of farms, concerning mainly fertiliser and chemical usage, and a detergent campaign among the locals. It was decided that: no buildings would be approved if there was not an existent municipal Comprehensive Plan; they would await the completion of a new, revised Comprehensive Plan; and that they would generally try to prevent all negative effects on Lake Yngern.

In the Comprehensive Plan the municipality can:

- Indicate water-related natural values and the threats towards these
- Weight and prioritise between different interests
- Give recommendations as to how to protect and manage these values
- State how the values shall be secured
- Enumerate future investigations, action programmes or assessment schemes
- Indicate the need for co-operation with other municipalities

A more detailed description of the natural values found in the municipality and how they should be secured may thereafter be developed. The topical areas are most conveniently shown on a map.

Types of protection

The legal protection requirements may be built stepwise, with moderate regulations first and stricter regulations last.

The first step states that everyone shall show respect in his or her interactions with nature. It states further that measures should be taken in order to limit or prevent damage to the natural environment in connection with different developments, projects or enterprises. It states finally that the municipality is responsible for nature conservation within its area.

The second step is that the Regional Board must be consulted if environmental risks are to be radically altered. It states that actions are required in order to limit or prevent damage to the environment.

The third step stresses that a permit is needed to exploit an area, e.g. to mine and remove quarry stone or soil or perform artificial drainage (ditching).

The fourth step states that shore protection is required. Its objectives are to secure recreational opportunities for the public and to maintain good conditions for plant and animal life in the water and on the shores. The shore protection regulations require that all new buildings be banned within the protected area. This ban also includes a wide range of other constructions. It is, however, possible to receive a permit (exemption) for some constructions, if there are special reasons. In general, a shore has a protection zone reaching from the shore to 100 metres inland as well as 100 metres into the sea, lake or river. The Regional Board can decide to enlarge the shore protection area up to 300 metres inland. This applies for large parts of the Swedish coast and shores of large lakes. The general shore protection regulations are also valid for areas that are within detailed plan areas.

The fifth step states that habitat protection is required for limited areas where rare species live or other natural values appear.

Nature reservations protect breeding birds (photo, Lars Rydén).

Nature reserves

The sixth step states that an area that is to be protected and managed may be declared a nature reserve. To protect a large, coherent state-owned area of a certain type of landscape with very high values in its natural state, it can be declared a national park by the Parliament.

The decisions to protect areas as nature reserves, nature conservation areas, shore protection areas or to deny/permit quarrying or ditching are taken by the Regional Boards (county) in consultation with affected municipalities. The decisions of nature reserves, nature conservation areas and exemptions from shore protection can be delegated to the municipalities.

The Environmental Code contains regulations concerning the protection of water areas against emissions of water impurities. Protected Swedish lakes are Torne Träsk in Lappland, Locknesjön in Jämtland, Lilla Ullfjärden in Uppland, Unden in Västergötland, Assjön in Småland and Ringsjöarna in Skåne.

There are other regulations that may be used for natural protection. Supported by the Environmental Code, the County Administrative Board can decide to create a protection area for a drinking water source, which also benefits nature conservation interests by ensuring good water quality.

The fishery legislation also gives opportunities to protect natural values. Here regulations can be found regarding minimum length of caught fish and protected species. The County Administrative Board can state regulations concerning the fishery. It can set up regulations concerning fresh and coastal waters. The Fishery Agency makes decisions concerning salmon, trout and eel, the County Administrative Board concerning other fishes.

In an area controlled by a fishery management association in a fishery management area, the association can decide upon regulations that can result in greater protection for and management of the fish populations than is the general case according to the fishery regulations.

7.

RIVER BASIN PROCESSES

Lars-Christer Lundin

Introduction

The concept of river basin management and the need to actually manage the whole river basin, in contrast to river management where only a part of the river stretch is managed, became an issue in the 1980s. Scientific and legal aspects of river basin management have since been developed and we can expect an increase in practical results, both in terms of legislation and in actual good management, as we enter the next century.

River basin management, or integrated catchment management (ICM), refers to the restoration of the total river environment, i.e. an integration of all sectorial interests. The issues treated differ between different countries, to some extent depending on what initially triggered the interest in river basin management. The most common triggers have been soil erosion, salinisation, floods, irrigation, navigation, hydropower, and water quality. The policies adopted and the terms used, e.g. basin-wide planning, watershed management, floodplain management, catchment management, integrated river management, etc. are thus strongly dictated by national guiding principles. The actual management strategies also differ considerably between countries. Gustafson (1989) presents a comparison of French and Swedish river basin management strategies (Table 7.1). Although the general principles and objectives are now being dictated in EU directives, the national strategies and tactics of achieving the objectives will, for a considerable length of time, be different in different countries, even among the EU Member States.

Boon (1992) lists the major anthropogenic activities affecting a river system, i.e. the basis for the need for river basin management:

Supra-catchment effects
- acid deposition
- inter-basin transfers

Catchment land-use change
- afforestation and deforestation
- urbanisation
- agricultural development
- land drainage and flood protection

Corridor engineering
- removal of riparian vegetation
- flow regulation: dams, channelisation, weirs, etc.
- dredging and mining

Instream impacts
- organic and inorganic pollution
- thermal pollution
- abstraction
- navigation
- exploration of native species
- introduction of alien species

Ward (1989) takes a four-dimensional approach to flowing-water ecosystems. The *longitudinal* dimension is along the river corridor. The earliest studies focussed on a division into discrete zones, whereas later studies use a continuum concept, the river continuum concept (RCC; Vannote et al., 1980). *Lateral* connections between the river and its valley are also important for the transport of nutrients from terrestrial ecosystems to the river that occur. The riparian zones, being the interface between the river and the surrounding land, play an important role in this lateral exchange. The *vertical* dimension includes the interaction with groundwater in the hyporheic zone. The *temporal* dimension involves the natural development of the floodplain and the channel morphology as well as man-induced changes that may perturbate with a considerable time lag along the river, downstream and upstream.

Table 7.1. Emphasised elements of water management strategies in France and Sweden (Gustafson, 1989)

France	Sweden
Economic incentive policy	Governmental regulatory policy
Decentralised decision-making	Centralised decision-making
Economic autonomy	Governmental grant financing
Actor-based decision-making	Instrumental decision-making
Preventive environmental control	Supervision
Negotiation-planning	Restriction-planning

An integrated approach to water management increases the complexity of the policy-making process considerably. A decision support system (DSS; e.g. Delft Hydraulics, 1994) is necessary for a more elaborate river basin management enterprise. It should contain:

- An information system with a relational database management system (RDBMS)
- A computational framework with mathematical models and expert systems, in order to simulate, hydrodynamics, morphology, water quality, etc.
- An analysis system to define and evaluate management strategies and measures and to perform risk assessment studies

The river continuum concept

River basin management deals with the total river environment, from the source to the sea or lake. Some basic ideas of the structure and the functioning of a river are necessary before any discussion on proper management can be started. A modern view of a river as an ecological unity is the river continuum concept, with the catchment as the logical basis. The RCC presents a view of an entire fluvial system as a continuously integrated series of physical gradients and the associated biota. The focus is on geomorphological-hydrological characteristics defining the boundary conditions for biological communities to become and remain adapted to. As these characteristics, e.g. channel width, discharge, water temperature and sediment load change from the headwaters to the mouth of a river in a predictable way, the biological community attributes become predictable as well. Stream ecosystems are thus viewed as physical templets changing along the course of the river, overlain by biological adaptations (Figure 7.1).

The concept results in open nutrient cycles, spiralling cycles (e.g. Wallace et al., 1977), because of the downstream displacement of the return phase of the cycle. Stable ecosystems have short distances between loops, i.e. high retention (see Minshall et al., 1983). Fast loops characterise systems with high biological activity. The RCC model describes the flows of organic matter as dissolved organic matter (DOM) and particulate organic matter (POM) in the river food web; in relation to the various structural and functional attributes of the lotic communities along the stream reach.

Some additional concepts have been introduced in order to refine the RCC: riparian zones, floods, community organisation in patches and hydraulic conditions.

The riparian zones can be strong discontinuous modifiers of the local river system (Pringle et al., 1988), but in most cases act to normalise the species composition (Brush et al., 1980). Floods cause inundation of parts of the floodplain and alter the longitudinal pattern (e.g., Junk et al., 1989). Disturbances, heterogeneity and patchiness along the river, e.g. high flows, are superimposed on the predictable longitudinal pattern (e.g., Minshall, 1988). Hydraulic con-

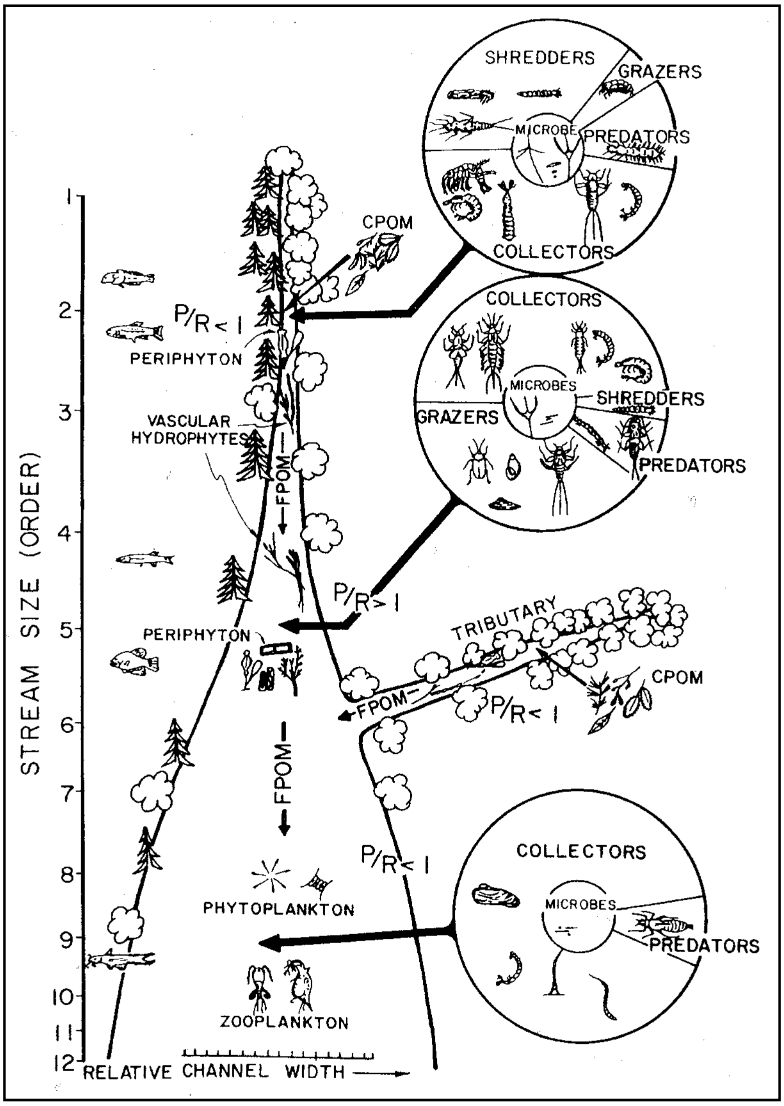


Figure 7.1. A proposed relationship between stream size and the progressive shift in structural and functional communities (from Vannote et al., 1980).

ditions, such as mean flow velocity, depth, substratum and surface slope, affect the distribution of stream organisms (Statzner et al., 1988).

Petersen, Jr. et al. (1995) have classified the rivers of the Nordic countries Denmark, Norway, Sweden, Finland and Iceland into four groups:

1. Low-gradient streams in former deciduous forests, now used for agriculture, which overlap the nemoral vegetation zone (Denmark, the plains of the counties of Scania, Östergötland, and Uppland in Sweden, and south and west coast of Norway)
2. Low-gradient streams in mixed coniferous forests, interspersed with clear and humic lakes, ponds, and wetlands, overlapping the boreo-nemoral zone (The regions of Götaland and Svealand in Sweden, the Lake District of Finland, and stretches of southern Norwegian rivers between the coast and the mountains)
3. High-gradient streams in the coniferous and deciduous forests of the boreal vegetation zone (Central and northern Finland and Sweden and central Norway, except for the Scandinavian mountain range, and the Icelandic lowlands)
4. Streams of the alpine and arctic vegetation zones (The Scandinavian mountain chains, the northern coast of Norway and the Icelandic highlands)

The rivers of the southern deciduous forest group are extensively affected by agriculture. Petersen, Jr. et al. (1987) report a 61 % conversion of forests into arable land in Denmark and Statistics Sweden (1987) an 82 % conversion in Scania. Culvert and channels are common, creating a more or less manmade system.

Spruce (*Picea abies*) and pine (*Pinus sylvestris*) forests dominate the catchments of the rivers of the southern mixed coniferous forests. English oak (*Quercus robur*) is also common and can be interspersed in the coniferous forests, together with elm (*Ulmus glabra*) and hazelnut (*Corylus avallana*). Riparian zones are dominated by European black alder (*Alnus glutinosa*). Farmland is interspersed, creating a patchy landscape.

In the boreal-forest rivers the mixed coniferous forests are totally dominant, with birch woods at higher elevations. Pasture and agriculture are insignificant except in the river valleys. Forestry (clear-cutting, ploughing, and replanting) and drainage of peat lands are common major human impacts in the region. Dams for hydropower-extraction are common, especially in Sweden and Norway, and weirs, small dams for log floatation, fishing, groundwater maintenance, and river regulation are common in Norway.

The tree line defines the boundary for the alpine and arctic rivers. The area is mainly used for grazing, which has a major impact on the landscape: In Iceland, sheep grazing dominates and in Scandinavia, reindeer grazing dominates.

All Nordic rivers have short lengths and consequently do not show all the features of a developed RCC, such as plankton populations at the river mouth. By using the RCC, changes occurring along the course of a river, such as migration barriers caused by too low a discharge or dam constructions, can be compared with developments in other rivers within the group and impacts on the various rivers can be assessed.

Fragmentation and flow regulation

Assessment of human impacts on rivers is necessary for successful environmental management. In general, it can be said that most rivers worldwide have severely deteriorated (Dynesius & Nilsson, 1994). Almost 80 % of the total water discharge of all important river systems in the larger part of the Northern Hemisphere is considerably affected by fragmentation of the river channels, by dams and by water regulation resulting from reservoir operation, inter-basin diversion and irrigation. Many types of river ecosystems have been lost by human actions. Conservation of biodiversity and the sustainable use of biological resources are urgently needed. Dynesius & Nilsson (1994) assess dam-induced fragmentation and mention the Umeälven River as one of the most fragmented rivers in the world. The highest live storage, i.e. the relative amount of water that can be stored in the river reservoirs, in Eurasia was found for the Luleälven River, with its 72 % of the mean annual discharge. Inter-basin water transfer is not very common in Sweden or Finland but the Norwegian river Suldalsvassdraget has the highest record in Eurasia, with a loss of 78 % and a gain of 68 % of its virgin mean annual discharge.

River and lake conservation

Man has used rivers more than any other type of habitat, and conservation (preservation, mitigation and restoration) of river ecosystems is nowadays an undisputed policy item. River restoration needs ecological (environmental) quality objectives as a starting point for integrated water management. The World Conservation Strategy (International Union for Conservation of Nature and Natural Resources, 1980) outlines three general aims:

1. To maintain essential ecological processes and life-support systems
2. To preserve genetic diversity

Table 7.2. Overview of some of the variables that should be taken into account as potential target variables (from Schneiders et al., 1996)

Component	Ecosystem information	Target variable
Biotic	Species: Composition Absence/presence Abundance Biomass Diseases	Plants, invertebrates, fish, amphibians, mammals Morpholocigal deformities
Abiotic	Physico-chemical characteristics Geomorphological and hydromorphological characteristics	Surface water and groundwater quality Sediment quality Water quality Slope Current velocity Substrate and sediment Structure Dimensions
Human use	Industrial uses Agricultural uses Drinking-water production Navigation Recreation	Intensity of land use Amount of groundwater pumped Number of boats passing by Amount of people allowed etc.

3. To ensure sustainable utilisation of species and ecosystems

Ecological quality objectives and environmental quality objectives (EQO) are often formulated in terms of sustainable development defining various levels of ecological quality. In order to practically use concepts of ecological quality it is necessary to translate the objectives defined into target variables. SEPA (1995), e.g. defines the EQOs for Swedish lakes and watercourses as (see also the chapter on Swedish EQOs):

- Biological diversity, such as is found in areas without significant human impact; key taxa associated with undisturbed conditions should be present
- N and P concentrations below the double background concentration (modifications are allowed in agricultural areas) with no indication of excessive development of macrophytes of algae due to human influence
- Oxygen levels that permit survival and reproduction of native biota
- Alkalinity above 75 % of natural background value, but not below 0.05 meq/l unless this is natural
- Toxic substances below known effect levels with background levels of metals not higher than at present
- Natural water regime in non-exploited watercourses

The above definition is an example of a rather abiotically oriented set of objective variables; the biotic variable, biological diversity, not being given in quantitative terms. Schneiders et al. (1996) present an overview of candidates for selection as target variables (Table 7.2).

In addition to the set of target variables, vulnerability analyses must be made. Wiederholm (1997) points to the need for tools for determining the sensitivity of specific values and for bringing this into the management process, giving Vollenweider-type models as examples of such tools for handling lake eutrophication and calculation of critical loads of sulphur and nitrogen to surface waters. Ibrekk et al. (1993) reported the results of using such an approach for Lake Mjøsa in Norway. They involve:

- Identification and weighing of user interest
- Modelling the effect of pollution loading on water quality
- Modelling the benefits to society from improvements in water quality
- Identification and ranking of abatement measures and the performance of a cost analysis for each measure

The most important user interest was nature conservation at 55 %. This was followed by drinking-water supply at 14 %, “interests downstream” at 12 %, bathing at 5 % and sport fishing, other recreational activities, boating, irrigation, and industrial water supply.

Depending on the state of the river, Boon (1992) describes five options for river conservation. Pristine rivers can be preserved in their present condition and would thus call for no change of management practises. However, diffuse pollution and the impacts of recreational interests would call for a monitoring programme to ensure that pristine conditions are kept. Rivers of high quality need limitations in the catchment development in order to be conserved. In basins where river regulation, abstraction and waste disposal are already ongoing, mitigation will play an important part of the management programme. Restoration becomes an issue for rivers that are more or less degraded. In these cases various attempts to manipulate water quality, hydrology, aquatic habitat structure and riparian zones are needed. Rivers that have become so degraded that restoration is too costly or unlikely to have success will simply be subject to dereliction.

Conservation projects often become quite costly but citizens are often willing to pay for such projects. The Royal Norwegian Council for Scientific and Industrial Research (1988) reports, that Norwegians are willing to pay an extra 500 -1 000 NOK in order to protect 50 watercourses from hydropower exploitation. In order to strengthen river conservation in general, Boon (1992) suggests a number of issues to be considered, including:

- Application of theoretical ecology concepts of stream colonisation, nutrient spiralling, resilience of stream to outside disturbances, and biological-community structure
- Increased research efforts with less distinction between pure and applied research
- Studies of habitat requirements of riverine biota in order to assess minimum ecological flows
- Scientific publication of results from conservation projects
- National and international co-operation
- Improved procedures for environmental assessment
- Adaptive management in river-modification schemes by learning from unwanted interference, treating it as an ecological experiment
- Long-term monitoring
- The importance of public education and participation

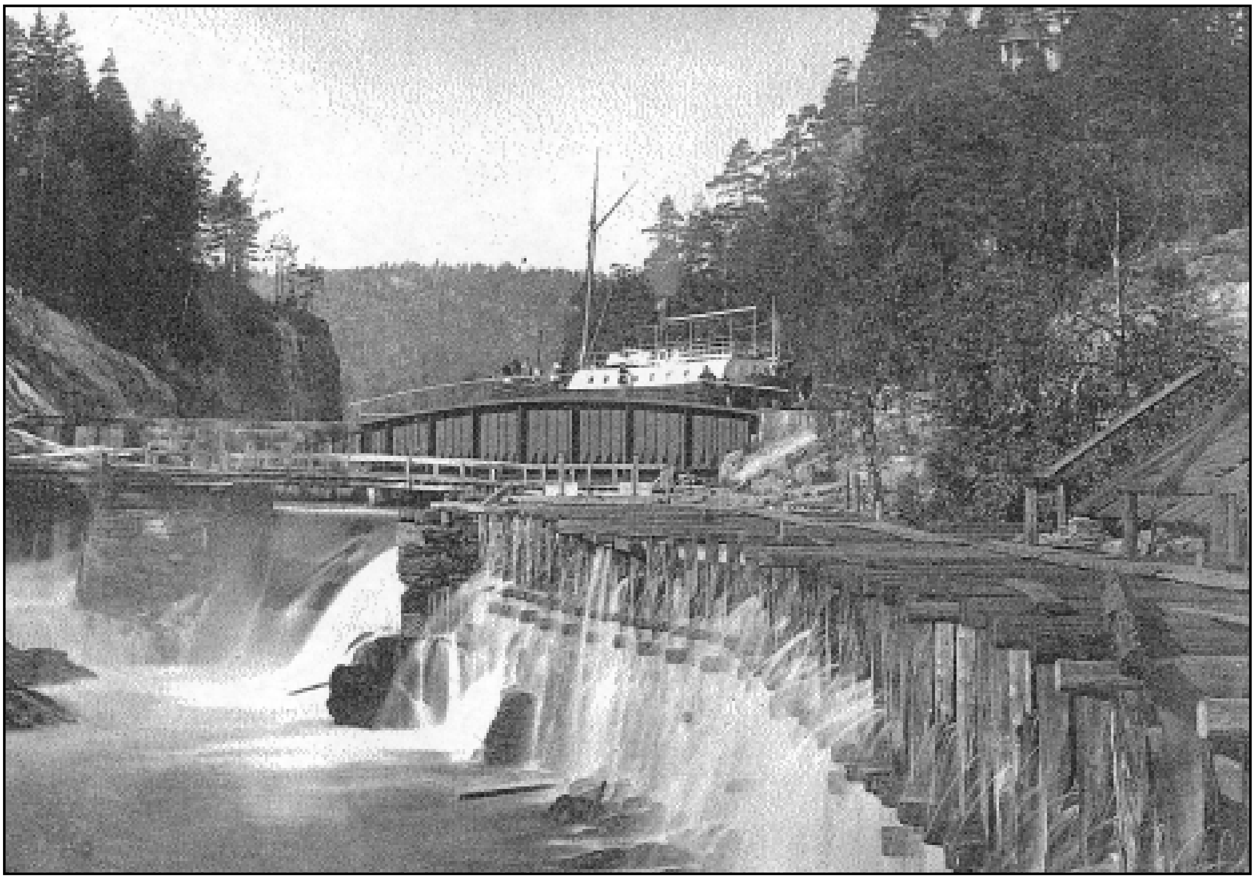


Figure 8.1. View of the aqueduct at Håverud in Dalslands Canal, Värmland, western Sweden (from a photo by Robert Dahllöf. Courtesy of Uppsala University Library).

8.

WATER REGULATION AND WATER INFRASTRUCTURE

Lars Rydén, Inger Brinkman & Yngve Malmquist[1]

Water is a carefully regulated resource

Water is probably the most regulated natural resource in the world. The flow of most of the running water in our countries is regulated, especially in the large watercourses. And there are reasons for it: Unregulated watercourses have very irregular water flow. A natural river might even be dry during late summer and flooded during spring when snow melts. In addition to this seasonal variation there is an inter-annual variation that might be considerable with large floods in wet years. In addition, water might be lacking where it is needed and too plentiful in other places. Thus the wish to control both the time and place of water supply is the background for the efforts to harness and domesticate this most basic of natural resources.

Regulation of water has a history as long as human civilisation. The first civilisations depended on regulated water to have secured access to water for agriculture and other human needs. The first canals were built about 3000 BC in the Nile River valley. The first legal texts of any kind known, from 1760 BC, dealt with the regulation of water, water rights and times to open and close the floodgates in Hamuradiji's two-river delta. The history of water regulation and hydraulic engineering is part of the Chinese civilisations, the Roman Empire and takes us to Medieval Europe, where water regulation was an integral part of the societies.

Thus, rivers have typically many ancient arrangements for the regulation of water levels. However, the large expansion of efforts to regulate water occurred during the 19th and early 20th centuries. Then, lakes were lowered all over the region, especially in Sweden, in order to create more agricultural land. In fact many lakes were completely extinguished during the 2 000-some lake drainage projects carried out in the country up to about 1950. The agricultural area of the country increased by more than one million ha, but there were also serious environmental consequences of this. A whole biotope nearly disappeared, and biodiversity of course decreased. Draining of forests and swamps has caused a massive outflow of nutrients and organic material. This may favour some species, but is a disadvantage to many others.

From the late 19th to the mid-20th century, dramatic changes were made in the rivers of northern Sweden, to ease transportation of timber. The rivers were straightened and cleansed. Slides and guidance arms were constructed to direct the timber. Today timber floating has ceased, replaced by transport on trucks. In some areas the old habitats have been restored through placing boulders, gravel, etc. back out in the rivers.

Since the beginning of this century many of the larger rivers in the northern Baltic region, especially in Norway and Sweden but also Finland, have been extensively regulated in connection with the construction of large hydroelectric power plants with dams and reservoirs. Today only a few streams and rivers flow naturally with waterfall and falls. Therefore, it is of utmost importance to preserve these waters. These few untouched rivers should also be actively protected against other kinds of influence or exploitation. In addition, the environment in regulated waters should, if possible, be improved, in order to increase biological diversity, recreation and fishing conditions.

Infrastructure of regulated river basin

The purposes of water regulation are in general fourfold, often combined:

- Agriculture very early on regulated water to irrigate fields and secure regular access of water. In other cases large areas were drained to create better conditions for the crop.

[1] The chapter is partly based on a preliminary English translation of a booklet in the series "Water Planning", published in 1996 by the Swedish Environmental Protection Agency and the Swedish National Board of Housing, Building and Planning. The original English text has been edited and expanded by Lars Rydén.

- Shipping required a minimum and constant depth of watercourses to make them suitable for sailing and boat traffic. Constructions along the shores were built for shipping purposes. Dams were used to regulate levels and locks beside the dams, allowing ships to pass.
- Water was dammed to provide increased height differences for waterpower. Upstream of the dams were ponds and reservoirs, artificial collections of water, to secure constant flow. These smaller reservoirs and ponds are today minimal compared to the very large dams and lakes, water magazines, made for electric hydropower plants.
- Dams and walls are built to protect land from flooding.

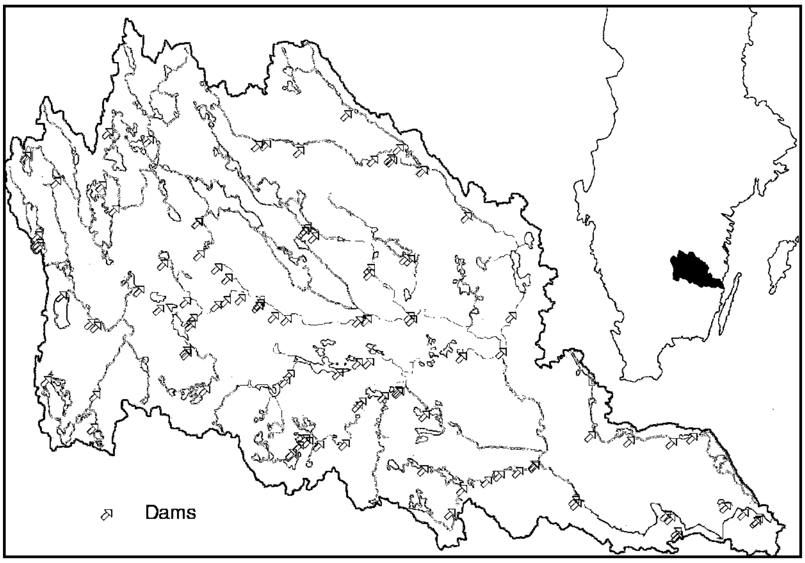


Figure 8.2. The Emån River basin in south-eastern Sweden covers an area of 4 500 km^2. The river itself extends from an altitude of 330 m to the Baltic Sea and is 220 km in length. The upper part of the basin has many lakes, most of these regulated. There are some 40 power stations and more than 100 dams (arrows) within the catchment. Still, the absence of reservoirs in the lower part causes a considerable variation of water flow, from 2 m/s to 270 m/s over the year (Gullbring et al., 1998).

Water regulation is implemented through the built water infrastructure as dams and their upstream ponds, pools or reservoirs or as canals that either are built between water courses solely on flat land, as aqueducts passing over a valley or as underground tunnels. In addition, many rivers and watercourses have been canalised to protect shores from erosion caused by boat traffic, and make them suitable for various technical purposes, harbouring of ships, etc.

When canals traverse a landscape with large differences in altitude, locks are built to move ships from one level to the next. Damming of water is carried out in areas where the water is higher than the land to protect the land from flooding, The Netherlands providing an outstanding example. This of course constitutes a risk if the water level in the rivers increases, which may happen in connection with larger than normal snow melting or dramatic precipitation.

Small scale – dams, ponds and drainage projects

Most lakes and streams are affected by regulations of some sort. It may be lowering of water levels, hydropower regulations, regulations for water supply or regulations to create reservoirs. Historically, waterpower was used to propel mills and saws and to refine iron. These early dams are now a part of our heritage, and have shaped the water landscape.

A river basin often has hundreds of smaller dams or constructions to control water. Smaller dams, once built by individual farmers or other landowners, are often quite old and have not necessarily been legalised through a court process. Existing older legally binding regulations remain, mostly from old industrial activities and drainage projects. Today they are of historical interest, as well as relevance to the waterscape, the cultural landscape and the surrounding settlements. There may also be cases where there is a valid right to perform some damming, but the facilities are not maintained.

In other cases the water regulation was conducted by clearing and cleansing a river or watercourse in order to lower the water level in a lake, and drain an agricultural area.

There are often clear conflicts of interest in many water regulation projects. The industrialist may want a high level of water for power production, mills, etc., when the farmers want a low level for keeping an area drained for agriculture. Fishermen often want high water during spring for allowing the fish to reproduce, when farmers want the areas to be drained. Shipping may also be dependent on a high water level. In old times it was not unusual that people executed their rights themselves and destroyed damming constructions, especially when it threatened their means of survival.

Water regulation has an important impact on biology in or close to the water. When the annual rhythm of water flow changes, so do the conditions for biological life. Calm-water species are others than those living in and by streaming water. Smaller or larger obstacles along the streams, such as mills and similar constructions, hinder salmon, trout and other fish that migrate, from continuing upstream. The most serious obstacles are the large hydropower dams. If the problems are too great an entire population or genetic variant of trout may disappear. On the other hand, ponds and reservoirs may become important water mirrors for ducks and other birds dependent on calm water.

The interests that can come into conflict with regulation projects are, in addition to nature conservation, fishery, recreational activities and preserving monuments of relevance to the culture and history of an area.

Canals for water supply or drainage

Canals were classically built to provide water for irrigation purposes, but this is not an important use in the Baltic region. Rather, ditches, canals and pipelines are used for the opposite purpose: to drain areas of water. Thousands of kilometres of such drainage canals or ditches exist in the region. These are often rather small (up to 2 m wide), straight and regular. As is discussed elsewhere, a major disadvantage with such drainage canals is that the water does not undergo any cleansing, such as denitrification. Such canals should thus end in a natural creek, watercourse or wetland, rather than in the Baltic Sea, to avoid eutrophication and pollution.

Water supplies are normally granted from a freshwater source in the drainage basin. However, sometimes water is taken from much further away and transported via canal to improve water supply to an urban area. Canals for water transport are also used within a drainage basin.

Supply of extra water to increase flow in a watercourse may also be done to dilute wastewater from a treatment plant. These canals are obviously smaller than those used for shipping, but still transport water from one drainage basin to another.

Large scale – canals, locks and reservoirs

Natural rivers and lakes together with canals and sometimes, canalised natural rivers constitute the inland waterways. Canals are built between rivers, lakes or even seas, most often to serve shipping. The inter-seas canals – the most famous being the Suez Canal and the Panama Canal – are the most important since they reduce travel distance so dramatically. In the Baltic region the Kiel Canal, connecting the Baltic Sea and the North Sea, belongs in this category. Other canals, which will eventually have the same role, that is connecting two large drainage basins, are the Volga Canal, connecting the Caspian Sea basin and the Baltic Sea basin and the White Sea Canal, connecting the White Sea basin and the Baltic Sea basin.

The canals normally play a small role in water transport in a drainage basin. Canals are often built to reduce water leakage by using concrete or asphalt, or in earlier times, mixtures between clay, sand and large stones were used on walls and bottoms. Of course, this also prevents groundwater from coming into the canal.

Modern canal building originated in medieval Italy and Holland. An achievement of its time was the opening in France in 1647 of the 240-km long Canal du Midi, with 62 locks. England’s industrialisation prompted an intense period of canal building. This is also the period when hydraulic engineering developed. In 1790, England had 4 800 km of canals, used mostly for transport of coal on barges. The construction of canals was at its peak just before the railways came to take over much of the transport of goods at the end of the 19th century. In the Baltic Sea the first canal, only a few hundred metres long, was constructed in 1555-58 at Drag, 20 km north of Kalmar, to avoid the dangerous waters outside the peninsula of Skäggenäs in Kalmar Sound. Most canals, however, were constructed in the 19th century.

Canals are still important today for shipping, especially for very heavy goods such as coal and grain, where time is not crucial. New canals are still being built, e.g. the canal on the Danube, on the border between Slovakia and Hungary, which was completed in 1996. In most cases canals are made to accommodate the European standard for barges, which is 80 m in length, 9.5 m in width and 2.5 m in depth, with 1 350 tonnes of cargo.

Many canals connect lakes and waterways at different levels; it is then necessary to build one or several locks where the boats change levels, as on a staircase. Thus, between the Baltic Sea and Lake Vättern in the middle of Sweden, the Göta Canal, built between 1810 and 1832, has 15 locks to handle a difference in water level of 88 metres. The classical type of canal lock is not higher than 3 metres. More recently, various types of machinery used to lift or pull ships have been constructed, allowing them to be raised up to 35 metres. In this way, a considerable amount of time, otherwise used for passing through locks, is saved.

Hydropower stations

The constructions of the large hydropower stations are the most far-reaching regulation projects carried out in river basins. Such stations have a large reservoir upstream, often many kilometres long and wide.

The sometimes hundreds of small dams in a river basin are often very old and part of our cultural heritage and landscape (photo, Lars Rydén).

The dam and reservoir serve several purposes: The water supply is constant over the year, which avoids flooding events in the downstream river; it is possible to sail the river year-round; and lastly, the dam is used for electricity production.

The consequences of hydropower plants for the large rivers in the northern part of the region are:

- The loss of great aesthetic values, such as the landscape being entirely transformed, both upstream and downstream of the plant
- The often negative consequences upstream, e.g. for groundwater levels which affect the local water supply
- The appearance of an entirely new ecology and species composition both upstream and downstream including the loss of migrating fishes, such as salmon

In the larger rivers in the south, the annual inundations of the river basins disappear and with them the very beautiful flora and fauna dependent on these annual events.

Hydropower reservoirs of the southern rivers often accumulate sediments that are transported with the rivers, which thus become increasingly shallow and eutrophied. In the water reservoirs of regulated rivers in the north, the water level changes from a maximum level when the water supply is good, to a lowest value when more hydropower is needed, mainly in winter. Both levels are normally decided on in the permit for the regulation of the river. The consequences are that a large part of the natural beach flora, bottom vegetation and bottom fauna disappears. Similar changes may also occur along the regulated parts of rivers.

There are several efforts being made to reduce the impact of water regulation caused by large-scale hydropower. Often today the Water or Environmental Court requires that a small percentage of the water be let through the old natural watercourse, to preserve the natural landscape. In the canal at the Danube, at the Hungarian-Slovakian border, one step further is taken, with flooding arranged annually, in order to preserve the original biotope as much as possible.

Licensing of water regulation

All water regulation requires a permit, which is granted by a Water or Environmental Court. The requirement includes the regulation of water for building dams, for waterpower and for the building of walls and other constructions used to protect buildings or farmland from flooding. It is also possible that existing dams and regulations may need reinforcements for safety reasons. This too requires a permit.

For operational hydropower plants, there may be some possibility of changing the conditions in order to improve the environment. Demands for expansion of hydropower may exist, and should be considered in the comprehensive planning. If these expansions are of national interest, State authorities must be involved.

In the Swedish Environmental Code, general guidelines for water projects are given. A water regulation project cannot be realised if, due to the chosen location or other reasons, it interferes with the general Comprehensive Plan for the area. The plans of the local authorities can therefore have a strong guiding effect on the court trials of different water projects.

The Environmental Code defines special rules for old facilities that are no longer in use and may need to be torn down or maintained.

Old water permits may be withdrawn or cancelled after some time. In order to avoid this, companies may choose to act for the public good by taking damage-preventing measures, such as building mirror ponds, erosion protection or compensating for damage caused, e.g. by cultivation or the introduction of fish. The Court trials may also lead to changes in existing permits, such as reduction in the fall of a river or water use.

Comprehensive planning

The local authorities should state the intended direction, protection needs and conditions for water-connected activities and environmental issues in the Comprehensive Plan. This plan is then used to make correct adjustments between different water demands, in connection with the regulation of watercourses. Comprehensive planning combined with environmental legislation should be used to minimise the damages caused by regulation of watercourses. Large projects affect areas quite some distance away, in matters such as flooding risks, settlement planning, ecosystems, water supply, landscape appearance, obstacles to migrating fish, reindeer breeding, recreation, etc. In such cases, several local authorities are affected.

In the case of smaller water companies, it is not unusual that a permit according to the Environmental Code remains long after the operation has ceased, for instance if the owner has died or neglected to cancel the verdict. It may, however, be difficult to get a permit to restore a watercourse with a regulation that is out of operation, due to effects on the cultural history, recreation or the surrounding settlements. It is often necessary for the local authorities to maintain old regulations, as society has adapted to their existence. These issues may affect more than one administrative area. In the Comprehensive Plan it is thus important to consider the consequences of new regulations, as well as the consequences of removing old ones. The need for re-evaluation of existing permits should also be considered.

Actions to improve regulated waters

Local authorities have been asked to create a list of measures that would be useful for improving the environment in their area. These measures are listed below.

Landscape preservation measures:

Introducing a minimum flow, or changing an existing one, by:

- Changing the damming and lowering limits for regulation reservoirs
- Building mirror ponds
- New designs and treatments of ponds, dumps, etc.
- Measures against erosion
- Improvements for tourism and recreation

Measures to preserve fishery:

- Minimum flow not to dry out riverbeds
- Increased minimum flow, or new distribution of water flow, over the year
- Changed regulation policy for reservoirs, e.g. no short-term regulation during spawning and no allowing the lower limit before the eggs hatch
- Building of fish ladders
- Habitat measures to give some species an advantage
- Repairing damages done to habitats by restoration and other measures
- Changed use of taxes and raised fees, according to the Environmental Code
- Change of other fishery rules, e.g. fish planting

Measures to protect cultural values:

- Documentation, inventories and measurements of ruins and other places of cultural interest that have appeared after regulation, above and below the water line
- Building of mirror ponds and minimum flow not to dry out riverbeds
- Measures to make ruins and other physical remains more visible
- Information projects, improved signs and information boards
- Development of hiking trails
- Measures to minimise erosion in areas of interest

Habitat improvement in and around the regulated river:

- Placing rocks in remaining streaming waters, or other measures to improve the environment in the river
- Measures for the animal life, such as constructing islands and placing artificial nesting places for birds
- Improving the conditions for shore meadows

Groundwater is not seen until it is reclaimed from the depths (photo, Lars Rydén).

9.

Groundwater management

Åsa Granath, Clas Magnusson & Yngve Malmquist[1]

The water framework directive

Directive 2000/60/EC of the European Parliament and of the Council on establishing a framework for Community action in the field of water policy came into force December 22, 2000. The Directive has been enforced in Swedish legislation through the Swedish Environmental Code (SFS 2003:890, SFS 2004:663) and represents a more coherent view on issues of water management. In line with the Directive, water management is carried out based on a river basin management perspective.

With support from the Directive, Sweden has been divided into five districts draining into the Bay of Bothnia, the Bothnian Sea, the North and South Baltic Seas and the Western Sea respectively. For each district the Regional Board acts as a supervising authority with responsibility to safeguard and preserve the quality (and quantity) of the aquatic environment. The authority shall in co-operation with local municipal authorities, organisations, and others involved make a water management plan for the district which consists of a general description, a summary of influences, identification of safeguarded areas, surveillance, environmental goals, an economic analysis of the use of the water resources and an outline of the action programme.

The public water authority shall establish one or more action programmes for the district, tkaing into account the results from analyses necessary to reach the environmental goals that have been decided upon. The action programmes could refer to measures that have to be taken with support of other legislation. The measures will be carried out at national, regional and local level. The regulations of the Environmental Code for Planning and Building on regional general planning are important tools for measures taken in order to safeguard and improve resources of groundwater.

The viewpoints and proposals for measures to be taken stated below are in line with the action programmes established for the different water districts in Sweden with support from the water directive.

A management perspective

The term *management* includes all measures for creating and maintaining *sustained* use of groundwater with respect to *quantity* and *quality.* The term *sustained* can be described as the *steady state extraction of groundwater of a prescribed quality*. Since the rate of extraction in theory is unlimited – the afflux area adjusts itself to the extraction rate – while groundwater quality is commonly strongly dependent on well depth, it is the prescribed quality that usually sets the limit to well depth. This is particularly evident in areas that were submerged by seawater at the end of the last glaciation, acquiring a prohibitively high salinity. Part of it was washed out as the sea receded. South and southeast of the Baltic Sea deep groundwater acquires salinity from Zechstein deposits.

In confined aquifers the extraction of groundwater is no longer a steady-state process since extracted water is released by compression of the aquifer, at least in the early stage of extraction. This source is therefore not sustainable – it does not require an afflux area in the same sense as an open aquifer. However, there are confined aquifers that are recharged at elevations above that of the aquifer. The recharge area is thus limited and sets the limit for a steady-state extraction rate.

Confined aquifers are commonly reported as leaking, permitting infiltration of water through an aquitard, a low conductivity formation. A steady state extraction is, in this case, no longer limited in the same sense as for a non-leaking aquifer.

The water quality of confined aquifers is perhaps less depth-dependent than for open aquifers.

Water resources are not always situated where municipalities have developed. Deeper knowledge and a partly changed view of society have made it necessary to give groundwater protection a stronger position in municipal planning. From an ecological point of view (among others) it is important to map the relationship between soil-, sur-

[1] The chapter is based on a preliminary English translation of a booklet in the series "Water Planning" published by the Swedish Environmental Protection Agency and the Swedish National Board of Housing, Building and Planning in 1996. The original English text has been edited and partly expanded by Lars-Christer Lundin.

face- and groundwater and the resulting effects that human influence in these systems can bring about. A sustainable use of natural resources has thus become an important issue in comprehensive planning.

As soil issues and water issues are often treated in different sectors they have not had the impact on municipal planning that is necessary. Those responsible for causing damage to groundwater resources are often not made aware of having done so, making responsibility unclear, and guilt difficult to prove. Authorities are often not aware of what groundwater problems they may have caused by, for example, allowing the building of roads at the wrong place in the landscape or through establishing industries in sensitive areas.

Resources

If we view the occurrence of groundwater from a purpose aspect we speak of a groundwater resource. Usual aspects of groundwater occurrences are:

- municipal and private water provision
- irrigation
- buildings and energy storage in soil and rock
- groundwater protection
- ecology

Groundwater quality

Water is an excellent solvent and transports many substances, including pollutants. Its chemical state and composition is usually very complex and varies in both time and space. Usually, groundwater has a low, even temperature, is free from organic pollutants and contains substances dissolved from the ground.

The natural quality of groundwater is characterised by the geological surroundings (the environment in which the water is found). Processes in the soil, the retention time in the ground and how good the protection from pollution is, influence the groundwater quality. The constitution of the precipitated water that forms the basis for groundwater formation is also essential.

Naturally high levels of iron, manganese, aluminium, fluoride, carbonate, sulphate, heavy metals and radon, as well as acid groundwater, etc. may cause problems. Approximately 10 % of all private wells have a level of radon higher than 500 Bq per litre, which is the environmental limit in Sweden. These problems can be partially solved through technical solutions on extraction. Well-drillers, the national geological survey, environmental and health departments and waterworks can offer valuable information about expected water quality.

As there are deposits of relict salt groundwater, i.e. saltwater left from the time when large parts of the country were covered by the sea and salt groundwater in areas close to the sea, great caution must be observed when extracting water in such areas.

Delimitation and impact areas

A distinction is made between surface water divides and groundwater divides. Surface water divides can be seen in the terrain more or less easily. The situation of groundwater divides can vary with time, depending, for example, on changes in groundwater level and groundwater amounts extracted. Usually, the two divides coincide. Everything that happens in a catchment is of more or less importance to the groundwater and its quality. At extraction of water, catchment areas and groundwater divides can be displaced whereupon discharge areas can become recharge areas. This can lead to spreading of pollutants and the influence of pollutants may change the water quality.

Recharge areas usually consist of light soils, sand, gravel or coarse till where the vegetation is adapted to dry circumstances. These areas are often covered with pine forest and lower vegetation of blueberry and cowberry sprigs. At a discharge area, the ground is often wet and the soil layer deep with a rich biological diversity. Common vegetation types are broad-leaved trees, shrubs and vascular plants. In certain geological conditions discharge of groundwater may form cold springs, surface watercourses and spring-lakes. Activities taking place in the recharge area often directly influence the character of the discharge area. If, for example, agriculture is practised in the recharge area, the floral composition is influenced by a nitrogen-rich groundwater.

Protecting groundwater resources

Sweden’s population of about 9 million inhabitants lives in an area of about 450 000 km^2. The population is unevenly distributed across the country. Sweden has large resources of water of good quality, but the largest resources are to be found in the northern parts of the country. Almost 8 million people are connected up to about 2 000 municipal water plants.

An estimated 2.4 million people in weekend and permanent homes get their water supply from their own private groundwater wells (about 800 000 in number), water which is mainly of a quality that can be consumed without prior treatment.

Problems occur with acidification and, in coastal areas, with salt groundwater on account of excessive or erroneous utilisation, etc. In agricultural areas nitrates occur in the groundwater. In some agricultural areas with cracks in the bedrock or with sandy soils, pesticides have been found in the groundwater.

The soil and the ground are important for their effect on our groundwater. Few scientists believed a decade ago that the ground could lose its buffer ability against acid rain to such a disastrous extent as has been discovered today. The groundwater has become so acidified in many areas that it corrodes water pipes of copper.

In order to extract water from the groundwater or surface water, permission is required from the Environmental Court except, for example, in the case of utilisation for a private household. But changes are on the way in order to make it also possible to regulate small-scale utilisation. The protection of water resources is effected in different ways:

- comprehensive planning
- environmental protection work
- water protection areas – directives regarding protective actions
- water management plans and action programmes according to EU water framework directive

Comprehensive planning

The comprehensive planning conducted in the municipalities stipulates the way in which the land and water areas of the municipalities are to be used. A clash of opposing interests can be avoided so that the threat to the interests of water resources as a result of erroneous exploitation can be minimised. In the case of opposing interests, the rule is that priority is to be given to the maximum long-term utilisation.

One of the greatest threats to the preservation of good raw-water resources is the lack of knowledge on the part of the responsible authorities regarding the need to give priority to the provision of good protection for the water resources in the regional planning. There is also a lack of awareness that the time perspective for the protection of water resources is far too short. Unfortunately, reliance is often placed on various technological solutions instead of removing the cause of pollution.

Through comprehensive planning, areas can be earmarked for water supply. Industrial localisation, roads and other environmentally hazardous operations can then be steered to areas that are less important for water supply purposes.

Unfortunately it can be noted that the interests of water resources often have to give way to the demands for exploitation. How is a balance to be struck in the conflict between the protection of water resources and the exploitation of, for instance, oil deposits?

The protection of drinking water resources can often be combined with the protection of other interests such as recreational facilities and nature conservation.

Permission for and supervision of environmentally hazardous operations

Environmental protection legislation can also be used for the indirect protection of water resources. There is a ban on the establishment of certain environmentally hazardous operations without the permission of the authorities or without notification having been submitted. This permission may stipulate conditions for the running of the activities in order to minimise the latter’s effect on the environment, for example on water.

The environmental authorities must also, through surveillance measures, ensure that the conditions stipulated in any permission for industrial activities are observed and that no damage to the environment occurs. Furthermore, companies are under obligation to arrange surveillance of their own.

In collaboration with the relevant authorities, the Swedish Environmental Protection Agency has evolved environmental objectives and action programmes for various sectors including the transport, energy, agriculture and forestry sectors. The Swedish government has stated that every sector will be responsible for its measures designed to attain stipulated environmental targets. Reference is made to the action programmes prepared by the Swedish Environmental Protection Agency and implemented by the government. Mention is also made of various necessary measures.

Measures need to be taken not only against specific discharges and effluents but also against scattered sources of pollution such as leakage from sewage pipes, roads and agricultural land. Other examples of measures include the specification of routes for vehicles transporting environmentally hazardous goods, measures against the tipping of waste or dumping of litter in wetlands and similar surface water.

The government can designate land and water areas that are particularly necessary to protect as environmental protection areas for which protective action and precautionary measures can be stipulated.

Water protection areas – Directives regarding protective actions

Besides the measures mentioned above, it is important to establish a water (wellhead) protection area around the drinking water resources governed by detailed directives concerning protective measures. The water protection area can also be divided up into well zones, with varying degrees of restrictions. This is intended to gear the protection of the individual water resource still further by varying requirements in respect to the sources of pollution actually occurring in the environmental protection area, which should encompass the water resource's entire catchment area. These protected areas are marked out with signboards. The purpose of these water protection areas and the directives governing them is to:

- Acquaint landowners and users with the regulations and precautionary measures in force
- Regulate and limit certain types of operations
- Inform the general public
- Provide basic planning material

To support the work on protecting water resources, the Swedish Environmental Protection Agency has published general advice in the "Protection of Groundwater Resources", which contains guidance on how environmental protection areas and directives concerning precautionary measures can be organised.

Objectives

Central authorities release objectives and guidelines for the use and protection of groundwater. These are national objectives and are supposed to form the basis for municipalities and County Administrative Boards in their work to appoint local and regional environmental objectives. The objectives should be guiding the survey planning and other comprehensive planning and measures that have to be taken for environmental protection (see also chapter on EQOs). National objectives for the usage and protection of groundwater (from different sources):

- A sustainable use of natural resources characterises all usage of water and soil.
- Renewable resources are used within the framework of the production capacity of the ecosystem.
- A long-term protection of groundwater is necessary to ascertain the availability of high quality drinking water.
- In areas of heavily polluted groundwater, the measures taken should first be concentrated to reach drinking water quality –"fit for human consumption".
- Drinking water is one of our most important provisions/foodstuffs. Naturally, drinking water should be of high quality.
- Pollution from human activities does not limit the use of water from lakes and watercourses as sources of water supply, and does not limit the direct consumption of groundwater.
- Planning of the usage of the water resource should be developed with the aim of ascertaining the long-term supply of drinking water and high water quality.
- The objective from a perspective of military preparedness is that the water supply, for as long a time as possible, should ascertain a normal water supply and ascertains the availability of drinking water.

Basis for planning

Groundwater demands

Groundwater is often the most important part of the drinking water supply, but it is also a resource for special plant and animal communities, irrigation for farming, industrial production and energy extraction as well as cooling purposes.

In population centres in Sweden the total water consumption per individual is approximately 200 litres per day, of which almost half goes to direct consumption. The consumption has been almost the same since the early seventies. Increased prudence and with that a lower consumption is the probable future prognosis.

Large parts of the Baltic region are dependent on groundwater for municipal and private water supplies. In Sweden, the municipal water supply is based approximately half on surface water. The rest consists of groundwater, of which half is artificial groundwater, i.e. the groundwater formation has been increased through infiltration of surface water. There are approximately 1.2 million people, mostly resident in the countryside, and as many in holiday residences, dependent on private wells. The private water almost exclusively consists of groundwater that is extracted through drilled or excavated wells. These sources of water supply under regulated control of the state; the responsibility of the availability and quality of the water in reality rests almost totally on the individual. For extraction of water a permit is required, with the exception of extraction for personal needs from private property.

Influence on groundwater

The quality and constitution of groundwater is governed by both natural and human influences, which can influence the possibilities of using it as, for instance, a supply of drinking water. Besides natural pollutants in groundwater there are a number of phenomena influencing and threatening the groundwater. Extraction of groundwater, drainage, ditching and lowering of lake levels lowers the water table, while damming, irrigation and artificial infiltration has a rising effect on the water table. Building projects thus cause the most severe problems of influence on groundwater.

The groundwater is also influenced by direct or indirect discharges. Environmental influences because of human activities are diffuse and point discharges are many and mainly influence the groundwater quality, but also its quantity.

Groundwater quality is influenced by natural pollutants, the urbanising process and discharges of different kinds.

The environmental threats to groundwater quality can be regional and local. Regional threats are those where dispersal processes influence large areas, e.g. precipitation of air-transported sulphur and nitrogen compounds or other activities. Examples of regional environmental threats are acid rain and leakage of nitrogenous compounds.

Local environmental threats and risks are, for example, deposits of waste products, storage of environmentally hazardous substances, accidents during transports of oil products and chemicals by road and rail and the diffuse dispersal from farming areas and the urban environment. Examples of local environmental threats are:

- Infiltration of sewage water
- Leakage from storage tanks and pipe systems
- Spreading of fertilisers and pesticides
- Operations in ground and bedrock that may increase the mobility of environmentally dangerous substances

A recharge area is much more sensitive to pollutants than a discharge area, as water-soluble substances are easily transported with the water when the precipitation is infiltrated into the ground, thus influencing the groundwater quality. In a discharge area, the groundwater is on its way out of the soil systems, making water-soluble substances a problem for the surface water. This means that excavation and removal of the topmost layers of soil in a recharge area may have a large negative effect on groundwater quality.

Water in the wrong amounts or at the wrong place at the wrong time may also cause problems in land use. Human operations like draining, ditching, stormwater from paved surfaces, etc. or extraction of groundwater through wells can all influence the groundwater formation.

Floods can cause infiltration of polluted surface water to deeper groundwater.

Depending on the natural conditions, such as geology and hydrology, it may take decades for pollutants to spread in the ground and to reach the deep groundwater reservoirs. This should be considered in decision-making involving land use. Control and monitoring of water quality should, because of the slow processes in the ground, be extended over a long period of time.

Where can basic knowledge be found?

In Sweden, knowledge about local and municipal groundwater can be gained through the Swedish Geological Survey's hydrological maps. But there are also other maps at the Swedish Geological Survey with information that is important to use in the work of groundwater planning. Some of that information has been digitised.

The municipality has often acquired sound knowledge of the hydrological conditions through ground surveys and investigations. But the information is often spread out over many different departments and administrators. Information can be found with planners, conservationists, at the technical departments and with those responsible for the waterworks. In cases where information is missing, separate groundwater investigations have to be made. Information about the local groundwater quality and quantity can come from:

- Geological Survey archives of wells and groundwater networks
- Work on sources of water supply
- Environmental programmes and similar studies
- Investigations where water and sewage issues play a part
- Comprehensive planning
- Bridge and road building projects
- Gravel and excavation prospecting
- Test pumping
- The raw water control of the waterworks
- Ditching
- Permits according to the Environmental Code
- Well-drillers
- Hydrogeological maps
- Water analysing laboratories

Analysis and considerations

Further information can be obtained from http://www.vattenportalen.se where you also can find more links.

Conflicts of interest

Characteristic for groundwater is that it has many functions within an area. Quite often conflicts arise between water-related claims. Lately, municipalities have been forced to change sources of water supply from surface water to groundwater because of environmental damage.

Besides the aspect of water supply, groundwater is also important for the filling of surface water reservoirs and wetlands, etc.

Within municipal planning, the fact that groundwater and its infiltrating areas are site-bound resources is too seldom taken into consideration.

At different municipal and governmental decision processes it is not unusual that activities, e.g. roads, buildings and industries that are not site-bound, are allowed to be located on top of site-bound resources such as aquifers. Exploitations are hopefully meant to accommodate urgent needs but over a long period of time the individual operations lead to consequences, which are not possible to survey at the time of the decision. Because of this an overall judgement of the present and future soil and groundwater situation is an important prerequisite for strategic groundwater protection in comprehensive planning.

Usage of a natural resource can often be limiting for usage of other resources. That is the case for the weighting of the interest of extraction of gravel and the importance of these gravel deposits as sources of water supply. Extraction of gravel and removal of earth is a threat against the groundwater, mostly because the top layer of soil containing buffering substances is removed. This holds for both the levelled ground and lakes formed in gravel pits.

As an example of areas of conflict between environmental protection and the individual source of water supply, extraction for energy use, irrigation, general water supply and draining can be mentioned. From a qualitative point of view it may be difficult to accommodate both the interests of environmental protection and water supply on the one hand, with receiving water interests, e.g. stormwater, forestry and agriculture.

Application and experiences in comprehensive planning

To ascertain that the present and the future needs of groundwater for water supply can be fulfilled, there is a need for long-term planning and an increased awareness by responsible politicians and civil servants of the importance of these questions. This can partly be accomplished through increased knowledge and the guiding that comprehensive planning allows when it comes to the municipal use of soil and water.

The municipalities in their comprehensive planning can make clear what the objectives and intentions are when it comes to local use of soil and water.

To avoid short-term economical interests getting too dominating a control of soil and groundwater use, a more long-term usage can be planned in detailed Comprehensive Plans, detailed development plans and special area regulations.

Co-operation across municipal borders

Soil and groundwater use is especially difficult to manage in those cases where the catchment belongs to several countries, counties or municipalities. It might be necessary for the municipalities to put demands on each other to be able to use certain important resources. The County Administrative Boards have an important co-ordinating responsibility for the inter-municipal issues that are expressed in the comprehensive planning. A *Water Framework Directive* emphasises this way of co-operation. Groundwater aquifers that are major sources of water supply are especially worthy of protection and can be viewed as aquifers of national importance. In the case of international aquifers, transboundary agreements need to be negotiated.

A good method to provide a certain amount of groundwater protection already in the planning process is by marking the geographical locations of the important aquifers on the maps accompanying the Comprehensive Plan.

Long-term planning

Through comprehensive planning it is possible to avoid the incorporation of conflicts concerning the use of groundwater. Instead it is possible to guide activities that have an influence on the environment to sites better suited from an environmental point of view, as there is a relationship between land use and surface water and groundwater. Extraction of gravel can, for example, make it difficult or impossible to use that area as a source of water supply or for artificial groundwater formation. When a finite natural resource like sand or gravel is consumed, the interest in the site as a source of water supply cannot be met either. Decisions today concerning land use can make it difficult or impossible to use groundwater as drinking water in the future. The perspective in planning must thus be very long. The vulnerability or sensitivity of the ground should not be a starting point

Focus on groundwater

Examples of areas where the groundwater can be exposed in the municipal activities to increase knowledge about the relationships between the soil and groundwater:

- The local and regional objectives that concern groundwater can be developed and more concrete.
- Shortsighted economical interests have to stand back for a more long-term use of ground and water areas in the municipality.
- A focus on the fact that certain ground and water uses cannot be combined in the long run.
- Planners and conservationists can utilise each other's knowledge more efficiently where different kinds of knowledge and experiences can be better utilised in the comprehensive planning.
- Different values and points of view can lead to misunderstandings and difficulties in communication.
- A view of the totality and co-ordination has to govern the water issues to avoid making them only sector-bound interests.
- Possibilities of protection can be utilised more efficiently.
- Legislation can often be used in a better way.
- The time-span for planning from the perspective of natural resources should be much longer.
- The site-bound resources should govern the activities that are not site-bound.
- The often-dominating view that it is always possible to purify water should stand back for a more preventive line of thought.

Individual, small, point sources of pollution should be weighed together into a larger perspective. The total consequences of many small point sources of pollution may lead to a major environmental impact.

for choosing a site for different activities, but rather the importance of the groundwater for different uses.

The municipalities also have a general responsibility for planning for individual water supply, making it an advantage to have monitoring or control of individual sources of water supply, to get an overview of the groundwater resources in an area.

It is difficult to solve the conflicts between forestry and agriculture and other ground and water interests with planning if this land use is not included in the nature-resource legislation.

Action programmes and knowledge bases

Comprehensive Plans should be linked to concrete plans of measures to be taken and to action programmes. The measures planned can also be set in comprehensive planning but must be implemented using the acts on environmental protection and other legislation in order to prevent damage and to do something about existing environmental damage. With detailed Comprehensive Plans and special-area regulations, the use of land and water can be even more regulated to the advantage of the groundwater.

The municipality can make demands in detailed Comprehensive Plans and special-area regulations on building permits, intending to arrange or significantly alter the wells that are not included in demands of the Environmental Code. But that possibility has generally not been used to a great extent.

It is important to have access to a well-processed knowledge base for the presentation of groundwater issues in the Comprehensive Plan. The accumulation of a knowledge base is a continuing process whereupon the information and competence present in the different departments of a municipality should be used. Through early co-operation, sector thinking may be avoided and the knowledge will become deeper and more targeted. If aspects are introduced too late in the work on the Comprehensive Plan, they may be seen as uncomfortable and will thus be more difficult to pay attention to, considering different kinds of land use.

Through more detailed studies of a catchment or a system of aquifers it is often possible to accomplish more or less voluntary agreements about limitations of unsuitable uses of land and water, in co-operation between the government, municipalities, organisations and individuals with interests in those issues.

One way to produce suitable bases for planning and protection of groundwater resources is to make a so-called sensitivity analysis of the relevant parts of the municipal area. Through this it is possible to create an understanding and a connection between land use and water constitution, threats of pollution in different parts of the landscape, suitable sites for dumps and gravel extractions in relation to impor-

Checklist for work on comprehensive groundwater management

Make an inventory of the groundwater resources
- This can largely be seen from the hydrogeological maps (sometimes available from geological surveys). By reading the instructions they can be interpreted by non-experts.
- For more detailed knowledge the basic geological maps from the Geological Survey can be used together with the hydrological data that can be found mostly within the municipality. A non-expert can, to a certain extent, do this. For more detailed knowledge an expert is needed.
- The information can be complemented by data from test pumping by well drillers.
- Extraction capacity size must be considered.

Groundwater quality
- The starting point is that the quality is and should be high.
- There are often water analysis data to be found on the groundwater.
- The quality may be apparent from the municipal basic data and from Geological Survey's maps. Experts may have to complement the knowledge.
- Pollution may occur naturally. Experts may be needed in some cases to interpret the information.

Important groundwater areas
- Judge which groundwater areas are important in the municipality for water supply, now and in the future.
- What quality or quantity is wanted? Look at the established municipal objectives and other objectives or demands for use or conservation.
- Which resources and local, regional and national interests do the municipality want to protect, conserve or utilise? This should be apparent through the Comprehensive Plan and in its basic material.

Exposed groundwater areas
- The starting point is that all areas are more or less influenced by human activities.
- Certain areas have a natural level of pollution. An expert might be needed in some cases.
- Regional or local threats and influences. The municipal health and environmental authorities and the County Administrative Board can provide answers.
- Regional diffuse discharges or threats that the municipality has difficulties in taking measures against.
- Such local, diffuse discharges or point-discharges that might be possible to attend to a certain degree.

Sensitive areas
- Sensitive from the perspective that the area contains an important natural resource or is important from a usage point of view.
- Is a short- or long-term perspective being considered?
- The entire catchment is important. The catchment can be identified through a hydrological analysis based on hydrogeological or topographic maps.
- Recharge areas are especially sensitive. Recharge areas and their sensitivity can be interpreted through studies of hydrogeological or other maps and visits to the sites.
- Sensitive areas where the topsoil has been removed or is very thin, as in sites of extraction, excavation sites and road banks.
- Risk areas are those with environmentally threatening activities, such as industries and transports of toxic substances. An inventory of the pollution sources may be needed.
- The mechanisms of transportation in soil and groundwater are often slow. The influence of pollutants may take a long time to discover.
- The transport of pollutants in sand and gravel is much faster than in areas of moraine and clay. The soil conditions can be seen on geological maps.
- In areas of drought fractured clay pollutants can be transported very fast, as in fractured bedrock. This can be seen on geological and hydrogeological maps.
- Confined aquifers or reservoirs may have their recharge areas at a great distance. An expert is needed to determine this.
- Vulnerability analyses can be a tool, e.g. from soil maps or different models. An expert might be needed to a certain extent.

Standpoints/positions taken in the comprehensive plan
- Several maps with the above mentioned prerequisites are put together to form a knowledge base.
- Some areas have special requirements or importance for the water supply.
- Make a judgement of the quality and quantity of the water supply. If it is low, determine if measures should be taken to improve it or to sanitise it or decide to take no measures at all. If it is high, decide if measures need to be taken to keep it that way, or if it needs to be improved further.
- Some areas are more important and/or more exposed.
- Make suggestions of measures to be taken against pollution sources.
- Make maps with activities that may be improved.

Realisation
- The County Administrative Boards, municipalities and the public can become involved through comprehensive planning.
- Measures might be demanded for the entire catchment. Other municipalities and the County Administrative Board might become involved.
- The pollution from agriculture and forests may be difficult or impossible to do something about through present legislation, but certain measures can be taken to decrease the pollution load on a voluntary basis.
- Measures, environmental protection work and technical protection may take place through the municipal health and environmental authorities and the County Administrative Board.
- Form a protected area with regulations. The municipality is often the authority responsible for the public installations. The municipality may improve the protection through posting regulations on environmental protection, expropriation or redemption of an area or voluntary agreements and/or compensation.

tant sources of water supply, etc. Soil type analysis and other sensitivity analyses may be means of assistance. The importance of the groundwater for different uses should be the starting point for the location of different activities and not primarily the sensitivity or vulnerability of the ground. A comprehensive classification of the relative values of the different sources of groundwater can be used as a foundation for protective actions and as a basis for planning of groundwater in the long run. Different activities should not be placed together if they constitute a threat towards each other or towards the quality and quantity of the groundwater.

Experiences

As a complement to the comprehensive planning further protection of present and future sources of water supply can be announced with support from both the legislation of health protection and the water act. However, in Sweden, not even half of all the existing sources of water supply are protected. As the entire catchment is of importance to assure a good and reliable raw-water quality, present and future sources of water supply should be conformed to this and to the area of influence around the extraction points. The area of a source of water supply has often been defined too narrowly.

The lack of knowledge and the difficulties of gaining acceptance for the necessity of prioritising groundwater issues from a perspective of water supply is probably the most important cause for the fact that the water issues have not had more importance than they have so far.

Measures

Strategies of realisations

Comprehensive planning and the Comprehensive Plans should be both a means of control and a source of knowledge. A high degree of concretion increases the possibilities of comprehensive planning to provide information, to guide and to influence decisions when it comes to achieving a good result with the groundwater issue in comprehensive planning. This can only be accomplished through the accumulation of knowledge and the increase in awareness of responsible officials and politicians. Comprehensive Plans with associated documentation are a good way of illuminating complex connections for this group of people. Issues of groundwater in comprehensive planning include:

- The development of clear objectives and suggestions of measures
- Water issues taken up at an early stage of planning
- The use of long-term perspectives
- The isolation of land use questions
- Focus on mutual consultation and co-operation
- A more offensive use of legislation
- Making preventive measures of groundwater protection a high priority

Clear objectives and suggestions of measures

Clear local and regional objectives concerning land and water are needed to increase the knowledge about water, how it behaves in nature and what kind of influences it is subjected to. Unclear objectives can be a part of a conscious strategy, e.g. that the municipality does not want to commit itself to a certain land and water use, but wants to be more flexible in its land use. This does not benefit a good comprehensive planning or an efficient protection of groundwater resources.

A clear formulation of objectives should be seen as a possibility to define problems and to weigh them against each other. It should also result in good measures and clear positions for groundwater in the comprehensive planning. To be able to postulate clear objectives for an efficient protection of groundwater resources, the municipality is often dependent on the land use in neighbouring municipalities. The County Administrative Boards thus have an important role as co-ordinator for the ground and water uses within the county and on measures within regional environmental action programmes. The measures can be executed with the support of environmental legislation and other protective legislation.

A long-term perspective

The municipality decides how to use its land and water areas and defines ambitions and directions. But too often, short-term interests govern the land use. Decisions taken today can make it difficult or impossible to use groundwater resources in the future.

Through clear objectives and through planning and giving recommendations for the land use in, for example, detailed survey plans and area restrictions, serious contemplation to change the land use will be demanded. This makes it possible to get a more long-term oriented usage. If there is also a demand for descriptions of environmental consequences for every new or changed establishment of environmentally disturbing activities, establishment of such activities in sensitive areas can be avoided.

The processes taking place in the groundwater are often very slow. Long-term use should have priority. For economical reasons, a very long time period – several generations – needs to be covered during planning. Information and education should be used as a means to gaining an increased awareness of the responsibility for the water supply of future generations, which points to a perspective of 100-1 000 years.

Focus on land use

From a perspective of water supply, it is necessary to consider both the future potential water supply, and the emergency supply. The interests of individual/private sources of water supply must also be taken into account.

As certain activities cannot be co-ordinated in a long-term perspective, it is of a still greater concern to isolate the land use. As an example, the areas used as municipal waste-landfills cannot be used as sources of water supply and extraction of gravel makes it difficult or impossible to use the area for water supply and artificial groundwater formation through infiltration. With the help of comprehensive planning, it is possible to make the potential conflicts appear clearly.

Aquifers, which are especially worthy of protection as a major source of water supply, can be seen and treated as areas of national interest from the perspective of water supply and through that gain a high priority. Also small sources of groundwater supply can have a high value of protection from a local perspective. Such an area might constitute the only possible source of water supply for a housing area. The protection might also concern small systems of aquifers for the need of water supply for future generations. Here the viewpoint in a Planning and Building Act can be used where the use of land and water is regulated with area restrictions in a way to keep it open for great changes in the future or for a more permanent protection.

If forestry and agriculture are not comprised by the umbrella legislation of an environmental code, other legislation or voluntary agreements might be needed to protect the groundwater from these activities.

When it comes to the protection of individual wells there are no other rules or regulations than the general rule of carefulness in the Environmental Code. But the individual small sources of water supply must not be forgotten. The municipality has a general responsibility for planning, also for individual sources of water supply; therefore it might be an advantage to have monitoring or control of the groundwater. The different archives of Geological Surveys can be used. Local authorities can also investigate the groundwater after complaints.

Information and education

The fact that the groundwater is not normally visible in the terrain means that it demands a special degree of consideration. Both actions of information and education are thus important steps for increased comprehension. This makes it even more important to take the groundwater issues into account so that the correct balances can be made and necessary protective measures taken. Efforts of this kind should be aimed both towards politicians and officials.

Mutual consultation and co-operation

Much valuable knowledge is spread throughout the municipal administration. A part of the information efforts should be that the different sources of knowledge within the administration and the different committees are heard early in the planning process so that clear objectives and measures can be presented. That is also why sector-bound thinking should be avoided.

If conservationists, technicians and planners learn to understand each other's points of view, a well-developed basis for comprehensive planning can be presented to the decision-makers. The different sector-bound interests such as agriculture and forestry, water supply and exploitation of land need to be exposed to each other to an even higher degree so that work can be done from the same starting position.

Even if water management is mostly of municipal concern the County Administrative Boards play an important role as co-ordinators between municipalities and regions as catchments and water conducting deposits seldom coincide with municipality borders. This will be even more important when implementing the EU Water Framework Directive.

Use of legislation

As with the work within the frames of comprehensive planning, the groundwater protection can be complemented with the possibilities found via the permission and monitoring work according to other legislation, e.g. environmental protection and water acts. In some cases there may be possibilities to co-ordinate and strengthen the protection for different conservation interests within the same area at the same time with synergistic legislation.

In several cases it is not legislation that hinders the better acknowledgement and protection of the groundwater. It is rather the application of the legislation that can be changed and become more offensive from a higher ambition and political direction of will. This is clear both from the law texts and from their preliminary work. That is why it is so important with education, information and a will to dare to

Groundwater in the city of Västerås - a case

In the process of treating a so-called Water Survey, the Municipal Executive Board of the city of Västerås in mid Sweden has accepted the objective that the groundwater resources shall be protected and conserved to ascertain the possibilities of water supply and purification of water for future needs.

Regional co-operation is necessary to ascertain a continuing high quality of both surface water and groundwater in the municipality. The catchments do not follow the administrative borders that we have created. A good way to go about this might be that the parties concerned form special so-called Water Associations with the task of deciding water quality boundaries and amounts to be extracted as well as monitoring and guarding measures.

Recommendations from the "Comprehensive Plan for the Municipality of Västerås for a Conserving Use of Resources". Only those measures for use or exploitation demands should be allowed, that within:

- Areas of clay soils can maintain the present earth/dust and nutrient content
- The acidification-sensitive tills do not lower the present pH-values or the basic degree of saturation
- Glacial deposits keep the high quality of the groundwater, the possibilities of groundwater formation and groundwater extraction as well as artificial groundwater formation over an extended time-period
- Discharge areas can keep the present amount of groundwater (the extraction amount)
- Certain parts of the landscape can maintain and protect the habitats necessary for flora and fauna
- Certain parts of Lake Mälaren retain their function as spawning areas for fish
- The Västerås Bay keeps its quality as a source of raw water supply

The continued work supposes that the municipality should establish a full water management plan referring to surface water and groundwater. The water management plan accounts for:

- The catchments of all the water courses in the municipality
- The possibilities of groundwater extraction
- The movements of the groundwater
- Surface water and groundwater quality
- Pollution sources and threats
- Hydrologically relevant areas of protection for the water resources
- Wells and small sources of water supply in the municipality

An inventory of the sensitivity to load and influence on the quality of Lake Mälaren

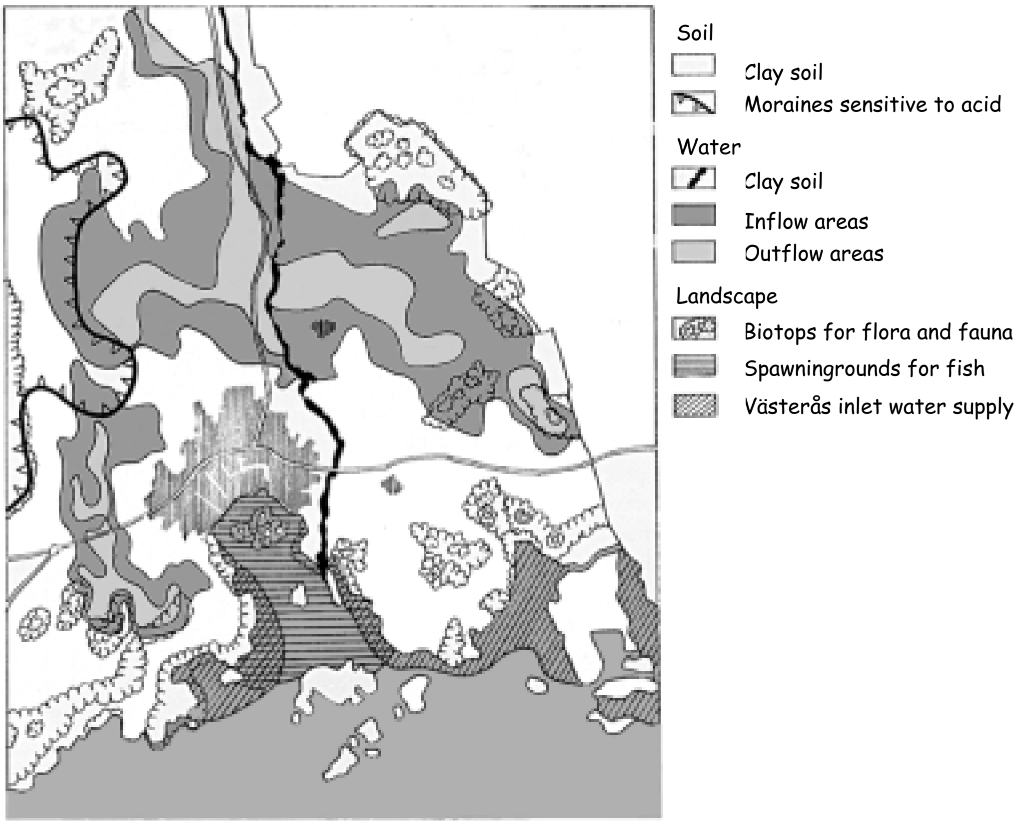


Figure 9.1. Groundwater in the comprehensive plan of Västerås.

utilise and test the legislation to make the protection work in reality. An example of this is substitution-issues in relation to the appointment of protective regulations according to the Environmental Code. No such substitutes have been processed in the Environmental Court.

Preventive groundwater protection

To prevent damage of groundwater used as a municipal water supply, protected areas are established around the sources of water supply. Through the directions for the protective areas the restrictions that are applicable for different kinds of activities can be seen. The boundaries for the protected areas are adjusted to the recharge and discharge areas. Many municipal sources of water supply lack established protected areas. Also, the control is often not perfect. This can be remedied through co-operation between the County Administrative Board, the municipal health and environmental authorities and those responsible at the waterworks, for a programme of examination and control of the protective regulations and the protected areas.

The attitude that it is always possible to purify the water through technical solutions might be a contributing factor to the environmental situation and the conflicts that exist today. Experiences show high costs of sanitation for the municipality for purification and sanitation of polluted soil and groundwater. These costs can exceed the costs of preventive measures, such as the acquisition of land, the subsidising of companies or the work on permits and supervision in comprehensive planning and environmental work.

Photo, Lars Rydén.

10.

Coastal management

Johan Persson, Per Jonsson, Markus Meili, & Mats Wallin[1]

Introduction

It was once thought that the oceans and seas, which cover 70 % of the planet's surface, had an almost infinite capacity to absorb the wastes generated by humanity. These wastes include those transported by rivers from upstream areas that deposit their polluting loads in the coastal waters. We now know that the pollution discharges on many marine ecosystems are much greater than the capacity of the systems to dilute and neutralise the polluting substances.

One example of the vulnerability of marine ecosystems is the large-scale eutrophication effects in the Baltic Sea due to excessive nutrient enrichment, mainly from nitrogen. The eutrophication effects are manifested mainly as decreased oxygen concentrations in the deeper parts. In the Adriatic Sea (a shallow subsystem of the Mediterranean Sea) and in the North Sea, the effects of eutrophication can be seen as large-scale, annoying algal blooms.

With related conflicts and competition, there is consequently a great need for scientific criteria, methods and models for water planning and assessment of the environmental consequences of pollution discharges in surface waters, etc. This chapter will try to describe different receiving water systems, methods to predict responses to different loads of pollutants and marine conventions, with a special focus on the Baltic Sea. A number of case studies are given at the end of the chapter.

The coast as a subsystem

First of all we need to define some important characteristics of the Baltic Sea, which is quite complex in many respects. Besides the fact that it consists of many more-or-less well-defined minor areas with different qualities, several different functional parts can be identified. One way of describing the Baltic Sea's system of functioning is to classify the sea into coastal and deep-sea areas, and transportation zones.

The impact of man influences mainly the *coastal areas*. Here, the local and/or regional influence can be estimated comparatively well, both in time and space.

The *transportation zone* is a transitional area, through which the different substances/contaminants that have been discharged to the sea in the coastal areas are transported to the open sea. The transportation zone is characterised by large variations, both in time and space. Therefore, it is not recommendable to study long-term time trends in sediments from this area.

The *open deep-sea zones* in the Baltic can to some extent be classified as dynamic, but the situation here is generally more characterised by long-term processes and changes than areas closer to the coast. Within all the sub-basins of the Baltic Sea there are large counter-clockwise current whirls, caused by the rotation of the earth. This contributes in time to a levelling out of local and regional differences in, e.g. the content of nutrients and contaminants. The sediments of the deep-sea zones are therefore possible environmental archives for the large-scale historical development of the Baltic Sea. A certain part of what we know about the recent history of the Baltic Sea has been obtained from offshore deep sediments.

The coastal zone under pressure

The coastal zone in Scandinavia, as well as in most coastal countries, is currently under severe and increasing pressure. The coast, forming the boundary between land and sea, is an important but also sensitive natural resource. The coastal zone is a typical zone of conflicts for many parties, for example, shipping, fishing, aquaculture, recreation and industries using the coastal zone as a receiving system for emissions of various types of pollutants. Point discharges of environmentally hazardous substances usually take

[1] Marcus Meili contributed the parts on coastal systems and sedimentation. Per Jonsson and Johan Persson contributed the introduction and the section on the Baltic Sea. Per Jonsson also contributed the case studies at the end of the chapter. The rest of the chapter was contributed by Johan Persson, Marcus Meili and Mats Wallin.

place near the shore, leading to environmental problems in the coastal zone. In this context, the water exchange between the coastal areas and the open sea is of great importance.

This section partly treats environmental consequences of pollution discharges in coastal waters. Focus is on factors affecting the environmental effect, how to predict the effects and how to classify the sensitivity of areas as regards pollution discharges. Most of the material in this section emanates from the Swedish part of the Nordic joint project, "Marine Aquaculture and Environment" (Mäkinen, 1991; Wallin et al., 1992; Persson et al., 1993b). The overall aim has been to develop criteria, methods and models for the planning of coastal waters of the Baltic Sea. Therefore, most methods and models in this section are only applicable in the Baltic Sea. However, most of the principles and theories behind this work can be applied in many other coastal environments around the globe.

In the Marine Aquaculture and Environment project, the "sensitivity" of different coastal areas to nutrient loading (nitrogen and phosphorus) has been studied in particular. This is important for the following reasons, among others:

- The coastal zone is generally considered to act as a filter and purification plant for nutrient discharges from large land-based point sources.
- The coastal zone has a high biological production and acts as a nursery and spawning area for many fish species.
- The coastal zone constitutes a large potential for different forms of aquaculture, e.g. fish-farming in cages. This implies increased release of organic matter and nutrients, which have different environmental effects in different coastal areas.

Most studies of coastal ecosystems are based on extensive fieldwork in a few individual areas where information about biological, chemical and physical properties has been collected at an increasing rate over the last years. It is still difficult to predict how different coastal areas will respond to qualitative and quantitative changes in human impact, e.g. nutrient input. An example of a comparative study in the marine environment is the work by Aure & Stigebrandt (1989) where, in a study of 30 fjords, they found that oxygen consumption in the basin water was related to the fjord topography. Boynton et al. (1982) used empirical data from 62 estuarine systems in a comparative study. Here, a positive relationship between phytoplankton production, biomass and nitrogen input was found. However, the results presented in this section show that empirical data from comparative studies in coastal ecosystems in the Baltic Sea can be used to develop predictive models. These models can be used as important components in a system for coastal water planning and for different types of environmental impact assessments.

Different coastal areas respond differently to one and the same dose of pollutants. In some areas the effect may be negligible, i.e. the areas are not sensitive to discharges of pollutants, whereas in other areas the effect may be severe due to higher sensitivity. In order to make an assessment of environmental effects of pollutants in a coastal area, it is therefore necessary to know the sensitivity of the area as regards different types of pollutants. The sensitivity of the coastal area may be expressed as a function of several factors (see Wallin & Håkanson, 1992), e.g. *water turnover, bottom dynamic conditions and morphometry*. All these factors influence the dispersal, sedimentation and recirculation of different substances (such as nutrients) in the coastal zone.

Definition of recipient ecosystem boundaries

A fundamental problem is how to define the boundaries of a so-called ecosystem. For lakes, it is obvious that the shoreline forms a natural ecosystem boundary. For some purposes a whole ocean basin may be the object of study at the ecosystem level. It may, however, be equally valid to consider a single estuary, bay or even the sediment underlying 1 m^2 of the sea floor as an ecosystem. In the contexts of eutrophication of coastal waters, one problem concerns the scale in which nutrient discharges from point sources should be considered. Is it the effects on the area in the vicinity of the point source (m^2 scale) or is it the effects on the open sea, e.g. the Baltic Sea (1 000 km^2 scale) that is of interest? The scales in focus in this work are well-defined coastal areas in the size range 1-100 km^2. This is also a suitable scale for local and regional planning and decision-making. Furthermore, it is an important scale between "site typical" information and the conditions in the open sea.

The approach adopted in this work (Pilesjö et al., 1991) assumes that the borderlines are drawn at the

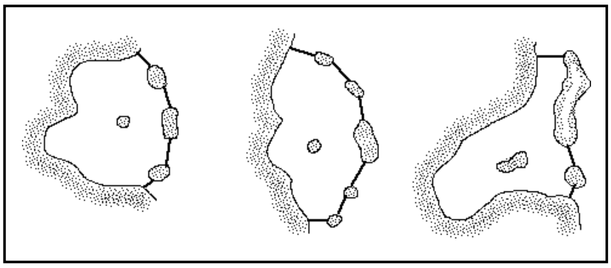


Figure 10.1. Hypothetical example showing three different coastal areas with boundary lines drawn at the topographical bottlenecks.

topographic bottlenecks so that the exposure of the coast to winds and waves from the open sea is minimised. The *exposure* (E) is defined as the ratio between the three-dimensional bottom area and the cross-sectional area, the opening area towards the sea. It is easy to use the E-value as a tool to test different borderlines and thus define the coastal ecosystem where the E-value is minimal. Different persons using such an objective method are likely to arrive at the same result. It is obvious, from a simple mass-balance consideration, that the water exchange then plays a major role as an inherent property regulating the sensitivity of a coastal area to pollution discharges. It is important to use uniform methods when defining area boundaries in order to get comparable coastal areas. Three different ecosystems with area boundaries are presented in Figure 10.1.

The energy input to the coastal areas in the Baltic Sea is controlled mainly by wind/wave impact. The coastal morphometry then determines how the energy is processed within the areas. State variables like wind/fetch and coastal morphometry influence turbidity, water exchange and bottom dynamic conditions (areas of accumulation, erosion and transportation) which in turn influence nutrient recycling, primary production and eutrophication effects (Wallin, 1991; Wallin & Håkanson, 1992). The main hypothesis in this project has been that different coastal areas have different inherent sensitivities to one and the same dose of nutrients and that the coastal morphometry, the water exchange and the bottom dynamic conditions may express this sensitivity.

It is necessary to quantify how effectively a discharge is diluted by exchange with surrounding waters, since the concentration of a certain substance is important for the environmental effect. Concentrations of pollutants or nutrients emitted from point sources cannot be determined with general mass balance models (see Håkanson et al., 1986) without knowledge of the water turnover. The dispersal and the deposition of fine matter (< 0.06 mm grain size) in coastal areas are important factors in contexts of coastal ecology since the fine matter has a great influence on the function as well as the character of aquatic ecosystems (Floderus, 1989). The environmental effect, e.g. decreased transparency or lower oxygen concentrations in the deep water, thus, depends on the nutrient load and the sensitivity of the area.

It is probably not possible to derive general environmental impact assessment models that could be used for all coast types on earth. Thus, it is only meaningful to develop models for certain coast types, like archipelago areas, estuaries or fjords. It is probably not meaningful to develop models including both small and large multibasin coasts of the same type since the conditions in each basin may vary greatly. This section only concerns archipelago coasts unaffected by tides. All the coastal areas are situated in the Baltic Sea.

Water exchange

In many contexts, it is important to know the water turnover in a coastal area. Concentrations of pollutants or nutrients emitted from point sources cannot be determined with general mass balance models (see Håkanson et al., 1986) without knowledge of the water turnover. It is necessary to quantify how effectively a discharge is diluted by exchange with surrounding waters, since the concentration of a certain substance is important for the environmental effect. Furthermore, the ecological character of coastal areas with rapid water turnover is generally different from that in areas with slow water turnover. Areas with slow water turnover are often enclosed and generally have a high biological production capacity (see Håkanson & Rosenberg, 1985). Moreover, the deep-water turnover is of great importance for the oxygen consumption/oxygen status of the deeper parts of a coastal area. The quicker the deep-water renewal is, the smaller the risk for problems with low oxygen concentrations will be.

There are several methods of determining or estimating water turnover (Håkanson et al., 1986), e.g.:

- Current meters can be used to measure direction and velocity of water currents.
- Tracers can be used to trace water movements (e.g. fluorescent dye tracers).
- The freshwater inflow to an estuary and the salinity gradient from the inflow to the sea can be used to calculate the water turnover.

Determining water turnover using those traditional field methods is both expensive and time-consuming. Therefore, different models, e.g. mathematical ones, are often used. In ecological contexts, when, for example, characteristic values rather than descriptions of the spatial and temporal variations of the water exchange are of interest, mathematical models are often difficult to use. For people dealing with coastal water planning, it is often sufficient to obtain a good estimate of the characteristic water turnover time.

Persson et al. (1993a) have presented water turnover models based on morphometric parameters. Empirical data on water turnover times (using tracers) was used to develop two models (see Table 10.1):

- A model for surface water turnover time (T_y in days; from Pilesjö et al., 1991).
- A model for deep-water turnover time (T_d in days; from Persson et al., 1993a).

Surface water is here defined as the water mass above the thermocline. Both models are based solely on

Table 10.1. Model parameters included in the most important predictive empirical models developed in the project (see Pilesjö et al., 1991: Wallin et al., 1992; Persson et al. 1993a). The statistical degree of explanation (r^2) and number of coastal areas (n) included in the models are also given.

Dependent variable	Model parameters	r^2	n
Surface water turnover time	Exposure	0.97	14
Deep water tutrnover time	Filter factor Exposure Slope	0.82	15
Proportion accumulation bottoms for open coasts	Mean depth below thermocline Slope	0.77	15
Proportion accumulation bottoms for archipelago areas	Filter factor Form factor Slope Proportion of islands	0.70	23
Secchi depth	Phosphorus load from fish farms Filter factor Proportion accumulation bottoms	0.84	22

morphometric parameters and are valid during the period of thermal stratification, i.e. approximately from the beginning of June to the end of September. Table 10.1 shows that the exposure and the filter factor generally are the most important model parameters when predicting the water turnover. This is logical, since more exposed areas are generally characterised by a rapid water turnover. The filter factor is basically a modification of the effective fetch (Håkanson et al., 1984) and it accounts for the wind/ wave impact on the entire coastal area.

Bottom dynamic conditions

The bottoms of a coastal area can be classified according to functional criteria, such as erosion, transportation and accumulation of coarse sediments (friction material) or fine sediments (cohesive material). In the contexts of coastal ecology it is important to focus on finer materials since pollutants generally show high affinity to fine materials (Förstner & Wittman, 1981). Håkanson & Jansson (1983) have defined the bottom dynamic conditions as follows: Coarse materials dominate *erosion bottoms*. *Transportation bottoms* are characterised by discontinuous deposition of fine matter. Periods of accumulation are interrupted by periods of resuspension and transportation. *Accumulation bottoms* are characterised by continuous deposition of fine matter.

The distribution of different sediment types can be mapped using an echo sounder and/or a side scanning sonar (acoustical technique). The record can identify different bottom types, since a hard bottom gives a different signal than a soft bottom. Generally, those instruments should be calibrated against sediment sampling.

Two models predicting the proportion of accumulation bottoms have been presented in Persson et al. (1993a; see Table 10.1): (1) A model for areas in direct contact with the open sea ; and (2) A model for areas inside an archipelago. The parameters in both models generally describe the sediment trapping capacity of coastal areas.

Environmental capacity

There is an on going debate on the environmental capacity (also known as assimilative or accommodative capacity) of coastal areas (e.g. GESAMP, 1986; Krom, 1986; Krom et al., 1990). A number of different definitions of the concept environmental capacity exist. According to Krom et al. (1990), the environmental capacity can be defined as the amount of material that could be “titrated” by a body of water until definable undesirable environmental effects is seen. This definition focuses on the water within a coastal area and the turnover time of this water. There are, however, a number of other factors that may affect the environmental capacity of coastal areas in contexts of pollution discharges. It is well known that toxic substances and nutrients have a high affinity for fine particles. Fine particle dynamics must, therefore, have a major impact on the so-called environmental capacity of coastal areas. Also interacting biological processes (uptake, predation, bioaccumu-lation, etc.) may affect the environmental capacity of coastal areas. Krom et al. (1990) concluded “it is premature to use the concept of environmental capacity in most situations as the basis for management decisions”. One reason for this might be that the results in Krom et al. (1990), as in many other studies in the marine environment, are based on extensive fieldwork in one single area.

To understand and predict how different coastal areas will respond to qualitative or quantitative changes in pollution input (e.g. nutrients), data on comparable effect, dose and sensitivity must be collected from different coastal areas. One reason for the lack of comparative studies on the ecosystem level in the marine environment may be that it is hard to find comparable coastal ecosystems with well-defined area boundaries. Two exceptions are empirical eutrophication models for estuaries (O´Connor, 1979) and for fjords (Aure & Stigebrandt, 1989). It appears that limnologists, in dealing with this problem, have attained greater success. Experimental and comparative studies of whole lake ecosystems have successively been used to develop nutrient loading models for lakes (Vollenweider, 1976; Schindler, 1978; OECD, 1992). To make similar predictions for marine areas, it is necessary to intensify the research on the ecosystem level (Nixon, 1990).

Why work at the ecosystem level? Studies of whole coastal ecosystems are often comparatively expensive and time consuming. To work on a large scale may also be logistically difficult. Nevertheless, this shift in scale may imply certain elements of simplification. It is, for example, easier to measure total yearly primary production on the ecosystem level than to measure the production for all included species separately. The variability is also smaller for the total primary production than for the production for single species. It is, consequently, possible to use relatively “simple” parameters on the ecosystem level and it may also be easier to find representative mean values on this level. The study of organisms and populations is important in itself, but never completely explains relationships on the ecosystem level. In coastal marine ecology, there is much more information about organisms and populations than about processes on the ecosystem level.

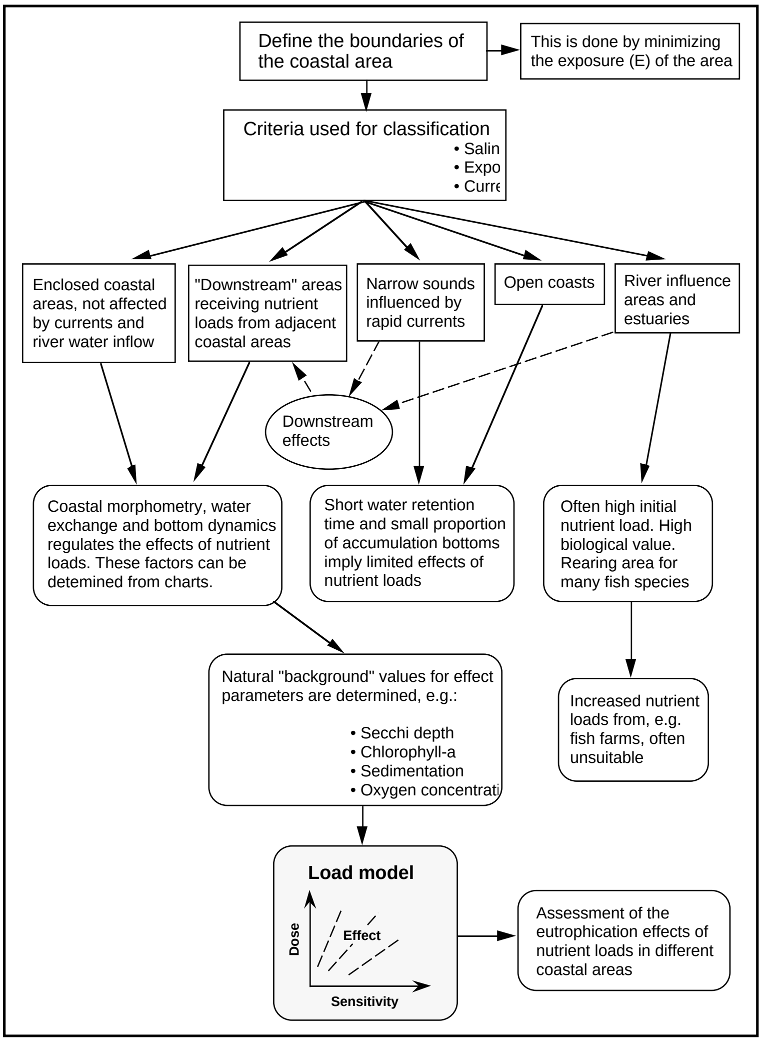


Figure 10.2. Classification-scheme for coastal areas in the Baltic Sea and for which type of areas the empirical loading models may be applied in practice.

Classification of coastal areas

Types of coastal areas

In the initial step of an environmental impact assessment of nutrient loading to coastal waters, one should first try to classify the coastal areas based on their characteristics, where the water exchange is perhaps the most important factor. Other useful criteria in this classification may include depth, salinity, stratification, flushing, tidal amplitude and river flow (see Boynton et al., 1982). The, often extensive, nutrient load and salinity gradients in estuaries make it difficult to compare these areas with other types of coastal areas in eutrophication studies.

Figure 10.2 illustrates a classification scheme for Baltic coastal areas and for which type of coastal areas the empirical loading models, developed by Wallin (1991), may be applied in practice. The following classifications are proposed:

(1) *Enclosed coastal areas not affected by coastal currents and river inflow*. In the coastal zone of the Baltic Sea, these areas may be characterised as archipelagos or embayments. The water exchange is regulated mainly by wind/wave impact. The coastal morphometry determines how much energy from the open sea reaches the coastal area and thereby influences the water exchange. The empirical loading mod-

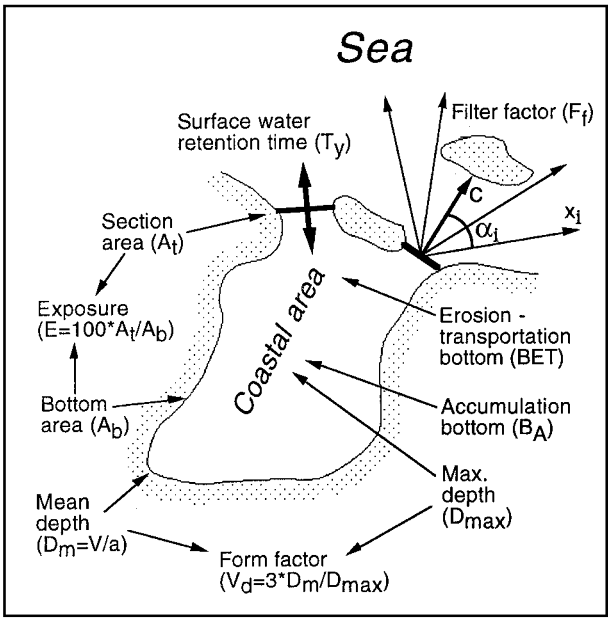


Figure 10.3. Illustration of the most important sensitivity parameters (see Wallin et al., 1992; Persson et al., 1993a). The filter factor is basically a modification of the effective fetch (see Håkanson et al., 1984). It was developed by Pilesjö et al. (1991) to be able to quantify the potential wind/wave impact on a coastal area. The filter factor (F_f) is given by: $F_f = A_t \cdot \cos \alpha_i x_i$.

els and models for predicting water exchange and bottom dynamics may be used for this type of coastal area.

(2) *River influence areas and estuaries*. The river-transported nutrient load to this type of area is generally high. The environmental conditions can be considered as very heterogeneous due to the salinity, turbidity and nutrient gradients. The water exchange is mainly controlled by the freshwater inflow. The sensitivity to nutrient loading is difficult to determine in quantitative terms, such as according to water exchange, morphometry or bottom dynamic conditions. Instead, qualitative criteria describing biological aspects might be more useful.

(3) *Narrow sounds influenced by rapid currents*. This type of area is primarily situated between larger coastal areas. Differences in water level between these larger areas generate a current in the sound connecting the areas. The characteristic surface water turnover-time in this type of area is generally very rapid, between one and three days (Pilesjö et al., 1991). The eutrophication effects of nutrient loading are limited due to the rapid transport of dissolved and particulate substances away from the area. The effects will primarily be found in the "downstream areas" receiving a large proportion of the load emitted in the sound. The load models should not be used in this type of area.

(4) *"Downstream" areas*. These areas receive nutrient loads from adjacent coastal areas such as narrow sounds and estuaries. The degree of influence of river water can be judged from the difference in salinity be-

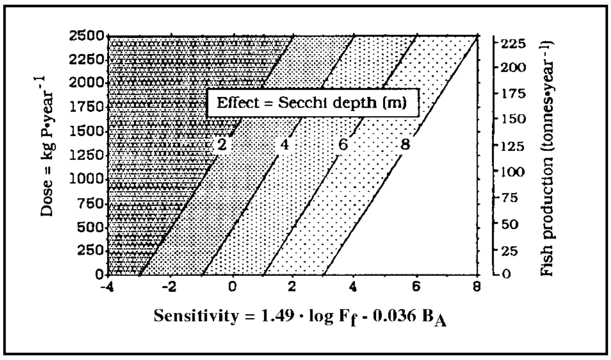


Figure 10.4. Load diagram showing the effect of nutrient loading on Secchi depth. The sensitivity is expressed as a function of F_f and B_A. The axis positioned parallel to the y-axis illustrates the corresponding fish production (x tonnes nutrient load = y tonnes fish production) for an average Swedish fish farm. From Wallin et al. (1992).

tween the area and the open sea. The empirical loading models can be used here but it may be difficult to quantify the nutrient load from adjacent coastal areas.

(5) *Open coasts*. This type of area is in direct contact with the open sea; large-scale motions of the offshore waters therefore govern the water exchange. The load models may not be used here since they require a definition of the load area, i.e. a logical way of defining the areal boundaries.

Thus, the empirical loading models presented in this section can only be applied to coastal areas in categories 1 and 4. In coastal areas in categories 3 and 5, the eutrophication effects of nutrient discharges from fish farms, etc. will generally be limited due to the efficient water exchange. However, the downstream effect in areas of category 3 must be considered.

If the model assumptions are fulfilled (see Wallin et al., 1992), we can use the Secchi depth model in order to assess the environmental impact of fish farms that emit nutrients in a coastal area. First the filter factor (F_f) and the proportion of accumulation bottoms (B_A) in the areas must be determined (Figure 10.3). B_A may be determined by surface sediment surveys, from echo sounding records (see Håkanson & Jansson, 1983) or by using a predictive empirical model (see Persson et al., 1993a). Then the limit for negative environmental effects is defined. If, for example, an environmental authority determines that the Secchi depth must not be less than three metres, then the maximum permitted load from fish farms may be calculated using the Secchi depth model or by reading directly from the load diagram (Figure 10.4).

Sensitivity classifications

This example is from the coast of Uppland, approximately 150 km north of Stockholm in the central part of Sweden. Persson et al. (1993a) have compiled all data on biology, water chemistry, water exchange and

Table 10.2. Classification of the turnover times of the surface water (Ty) and the deep water (Td) and the proportion of accumulation bottoms (BA). From Persson et al. (1993a)

Water exchange (days)	**Very slow**	**Slow**	**Moderate**	**Rapid**	**Very rapid**
Surface water	>20	10-20	5-10	2-5	<2
Deep water	>100	25-100	8-25	3-8	<3
	Proportion accumulation bottoms (%)				
	Very large	**Large**	**Moderate**	**Small**	
B_A Accumulation bottom	>50	30-50	10-30	<10	

sediment distribution from monitoring programmes, research investigations, etc. in the coastal waters. The coast was divided into six large geographical regions and approximately 40 minor sub-areas (in the size range 1-20 km^2). Empirical models for prediction of water exchange and bottom dynamics (see Pilesjö et al., 1991; Persson et al., 1993a) were applied on sub-areas where empirical data was missing. The areas were classified according to certain criteria, including rapid or slow exchange, etc. (see Table 10.2).

Generally, the sensitivity for discharge of environmentally hazardous substances increases with decreasing water turnover times. The proportion of accumulation bottoms is a measure of the sediment trapping capacity of the area. The larger the proportion of accumulation bottoms, the more sensitive the area as regards loading of organic material or nutrients. The results were also presented on maps (Figure 10.5). In that figure it can be seen that there is a large variation as regards sensitivity to discharges of environmentally hazardous substances among the areas.

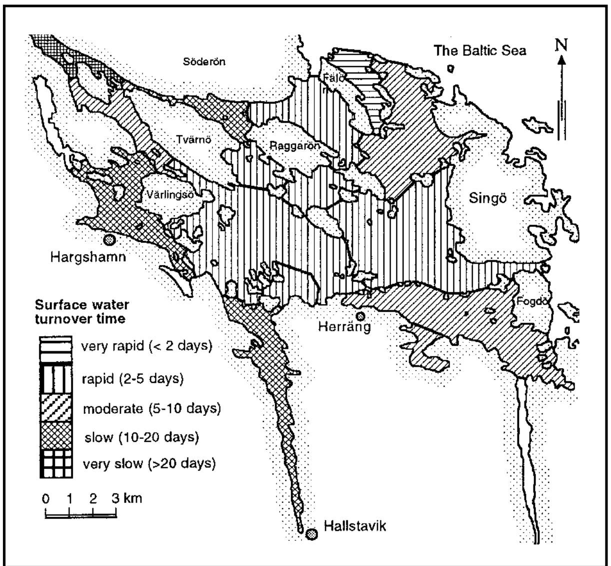


Figure 10.5. Map over the Östhammar archipelago region along the southern coast of Uppland, showing surface water turnover times in the sub-areas. From Persson et al. (1993a).

High sedimentation rates in Baltic archipelago

In deep off-shore areas of the Baltic Sea, sedimentation rates are typically in the order of one to a few millimetres, and even less in consolidated sediments, based on lamina counts and radiometric dating (Ignatius, 1958; Jonsson et al., 1990; Jonsson, 1992). In lacustrine and marine basins, the highest sedimentation rates are usually found in the deepest parts, since sediments and associated contaminants are known to be gradually "focused" from shallow to deep areas by resuspension. Accordingly, net sedimentation in coastal areas could be assumed to be low or absent due to strong erosion forces. On the other hand, coastal sediments are likely to be important in controlling the fate and turnover of contaminants that are released into coastal waters. It is therefore important to know both quantities and fluxes of coastal sediments.

Sedimentation rates can be determined in various ways. A convenient approach is the use of distinct markers with a known chronology in vertical sediment profiles. One such marker is radioactive caesium in the form of ^{137}Cs, which is an artificial radionuclide that was introduced to the environment in the early 1950s with the atmospheric testing of nuclear weapons. This testing activity increased dramatically in the early 1960s, culminated in 1963, but then practically stopped after a global agreement. A second major event was the fallout of ^{137}Cs released by the nuclear accident at the Chernobyl power plant in late April 1986. In contrast to the earlier global fallout, the Chernobyl fallout was highly unevenly distributed, with major deposition areas in the Scandinavian countries and the Baltic drainage basin.

Steep vertical concentration gradients of ^{137}Cs in sediments, extending sometimes less than 1 mm after as much as 10 years, suggest that the ^{137}Cs migration by diffusion may be minimal in Baltic sediments, despite brackish water and anoxic conditions in laminated sediments in particular. This is in contrast to many lacustrine sediments in the surrounding "shield" areas (Meili & Wörman, 1997), and contrary to expectations based on the knowledge of the biochemical behaviour of ^{137}Cs.

^{137}Cs can therefore be used in the Baltic Sea as a particle tracer, for example to study vertical sediment mixing by bioturbation, or horizontal sediment transport after resuspension. An on-going three-dimensional survey of ^{137}Cs in coastal sediments may also provide valuable information on time scales of sediment resuspension and focusing, on the origin and fate of ^{137}Cs in the Baltic Sea and on the water exchange in archipelago areas.

The use of sediment cores in environmental studies

The use of sediment cores in environmental studies can be demonstrated with data from a semi-enclosed bay (Himmerfjärden) of the coastal archipelago south of Stockholm (Figure 10.6). Chemical and physical profiles in two sediment cores are remarkably similar, although the cores were taken at some distance from each other. This indicates that both methodology is reproducible and environmental patterns are representative. The start of the discharge of treated sewage water from Stockholm coincides with the onset of a visible lamination and an increase in water content. This indicates a transition from oxic to anoxic bottom waters, and from bioturbated to undisturbed surface sediment. Despite this dramatic transition, the content of organic matter (carbon and nitrogen) is remarkably constant along the cores. This suggests a high susceptibility of the system to an even moderately increased flux of organic matter, due to an increase in either supply or production.

The observed change in the profile of water content shows that water content is not always clearly related to the abundance of organic matter, but also reflects other aspects of sediment structure and quality. The data also show that bioturbation not only results in a disturbance of vertical stratification, but also in an enhanced compaction of the sediment. Radio-caesium profiles show similar patterns for both fallout events (weapon test fallout in 1963 and Chernobyl fallout in 1986), although on a different scale. Although the Chernobyl fallout of radiocaesium in the area was negligible, the post-Chernobyl contamination of Himmerfjärden is several times higher than the pre-Chernobyl contamination. This can be explained by an intrusion of contaminated water masses from the open Baltic Sea, where a plume of radiocaesium originating from the Bothnian Sea passed several months after the fallout. The ^{137}Cs profile thus provides valuable information about the water exchange both in coastal areas and among the major

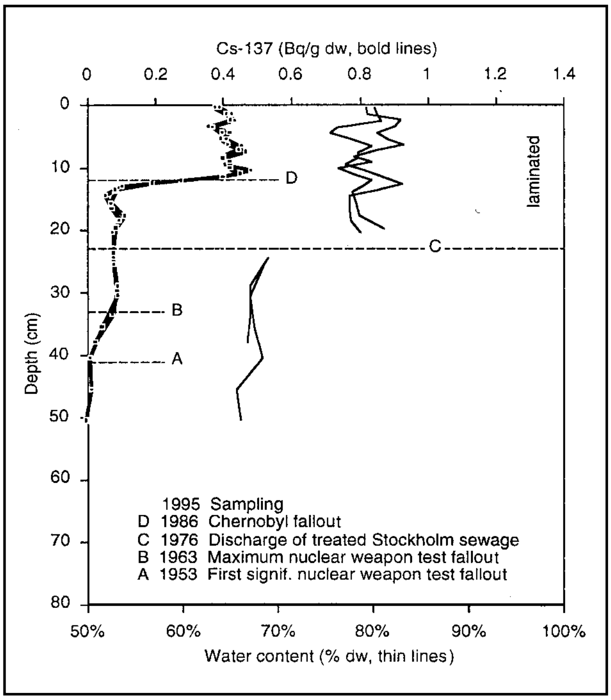


Figure 10.6. Vertical profiles of radiocaesium (^{137}Cs) and water content at two stations of Himmerfjärden, a bay in the archipelago south of Stockholm, reflecting distinct events in a coastal area of the Baltic Sea. The age of sediment is indicated by letters A(1953), B(1963), C(1976), D(1986), while the indicated 0-depth refers to 1995. The levels of radioactivity is caused by the first nuclear weapons test (1953), maximum nuclear test (1963) and Chernobyl fallout (1986). Time scale based on a constant sedi-mentation rate of 0.3 gdw/cm^{2}yrs

basins of the Baltic Sea. Another interesting aspect is that the ^{137}Cs profile suggests a very slow decline in the contamination in the overlying water, with a recovery rate of only 1-2 % per year. This indirect estimate, which can be obtained from a single sediment profile, is in agreement with much more costly long-term measurements in the water of the open Baltic Sea.

The sediment data suggest that ^{137}Cs in the Baltic Sea remains in the water column for many decades after a contamination event. The removal rate from the water of the Baltic Sea may be even slower than the radioactive decay with its half-life of 30 years. This is unlike many other contaminants, which are transferred to the sediment within a few months or years.

In conclusion, it is evident that sediment profiles can be used not only to quantify the pollution status of an ecosystem, but also to reconstruct various aspects of ecosystem dynamics.

Turnover of coastal sediments

In contrast to lakes, very little is known about the turnover of coastal sediments, in particular in heterogeneous semi-enclosed areas such as the Baltic

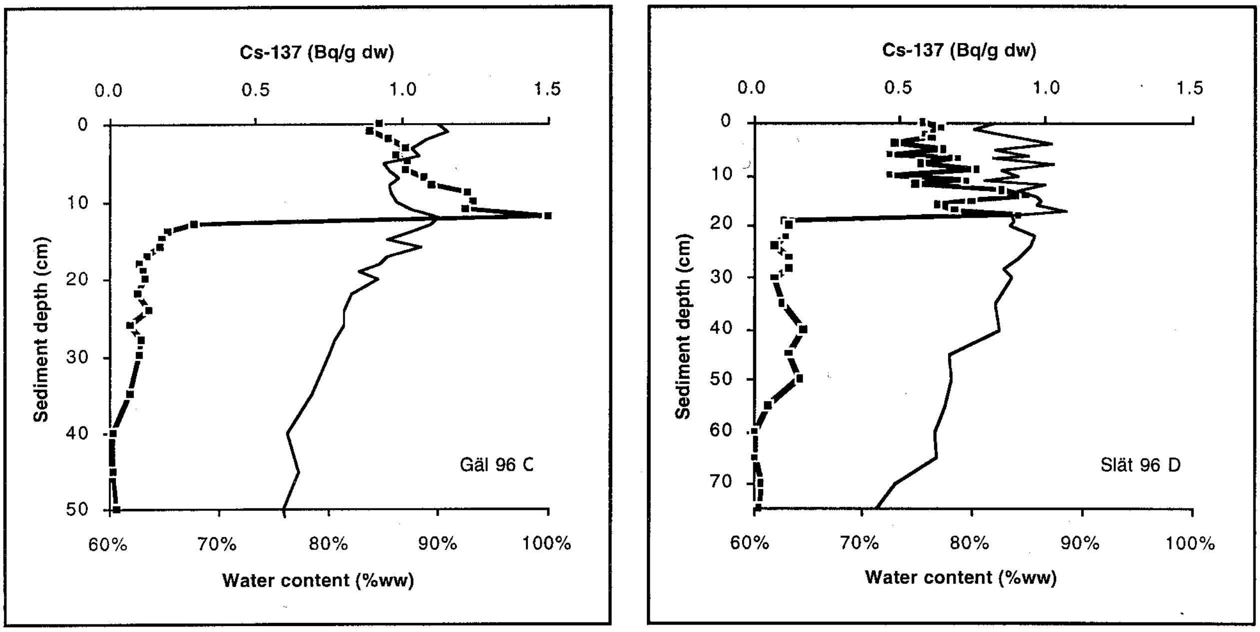


Figure 10.7. Examples of vertical profiles of ^{137}Cs (bold) and water content (thin) in coastal sediments from two Baltic archipelago areas (Gälnan and Slätbaken). In the figure to the right, seasonal changes in both variables are evident, which coincide with an annual lamination pattern that is also visible in the water content.

archipelagos. Presently, this important aspect of the Baltic Sea is being investigated as part of a project focusing on the relationship between eutrophication and contaminant cycling (EUCON). Sediment cores have been collected from suspected areas of sediment accumulation, i.e. bottoms of more or less protected bays in archipelago areas along the Swedish coast of the Baltic Sea (Meili et al., 1997). Similar studies have been conducted in Finland (Vallius et al., 1997). The sediment sampling is accompanied by a comprehensive bottom survey using a high-frequency echo sounder and a side-scan sonar.

Laminated sediments were found to be common and to cover a substantial fraction of most areas studied, even at water depths of less than 20 m. In these sediments, bioturbation can be neglected as a confounding factor for radiometric dating. Dating is further facilitated by comparatively high concentrations of ^{137}Cs (0.3-2 Bq/gdw) due to the Chernobyl fallout. Sedimentation rates can be determined here with two independent methods: from ^{137}Cs measurements at intervals of usually 1 cm and from lamina-counts in vertically sectioned cores. Distinct vertical profiles of ^{137}Cs originating from the Chernobyl fallout (1986) and to a minor extent from nuclear weapon testing (1963) allow dating with exceptional accuracy, in some cases even with seasonal resolution (Figure 10.7). Radiometric dating usually coincided with lamina counts, suggesting annual varves. Therefore, sediment ages can be determined not only for the two fallout events, but also in intermediate sediment layers. By determining the mass between markers, rates of sedimentation can be calculated.

The study shows that in many coastal areas, sedimentation rates are higher than in the deep areas of the Baltic Sea, which is contrary to common expectations. Moreover, the sedimentation rates can reach extremely high values even in a global comparison. Sedimentation rates can range over 0.5-5 cm/yr, based on the depth of the Chernobyl horizon, which usually appears at depths of no less than 5-50 cm below the sediment surface.

This implies that the sedimentation in semi-enclosed coastal areas can exceed the sedimentation in deep offshore areas of the Baltic proper by up to two orders of magnitude, if local conditions favour inflow and settling of particles. On the other hand, the sedimentation rates within areas show the expected focusing, that is, erosion from near-shore areas to deep central areas. Similar patterns and rates have recently been observed in the Gulf of Finland (Vallius et al., 1997), where this was partly attributed to river input. However, this factor is negligible in many of the studied coastal areas in Sweden. The question arises as to where all this sediment originates.

The lamination structure indicates fairly constant sedimentation conditions over adjacent years. This requires a continuous supply of sediment. Therefore, rare but extreme storm events are probably not a key factor. The main long-term contribution is most probably the “continuous” resuspension of sediment in more exposed coastal areas, and subsequent settling and accumulation in protected bays. Over long time scales, however, this would lead to a depletion of erodable sediment. Most probably, resuspension is maintained or enhanced by the gradual land uplift due to ongoing crustal rebound after deglaciation, which results in a continued supply by exposing accumulated sediments to erosion again. This is supported by the fact that the sedimentation rates along the Swedish coast are not only an order of magnitude higher than those in offshore areas, but also considerably higher than in the Gulf of Finland, where they are only 0.2-2 cm, including coastal sediments.

The high sedimentation rates in coastal archipelago areas are likely to play an important role in the turnover of contaminants entering the areas either from land or from the open water. This is of particular interest since such archipelagos are the main recipients of discharge from Stockholm and other urban areas. Moreover, these archipelagos are often important recreational areas, where contaminants may be retained for a long time. Finally, the unexpected sediment cycling may have implications for the whole Baltic Sea with respect to the effects and recovery from land-based pollution. However, the investigation of these issues has only just begun.

The open Baltic Sea, a dynamic system

Except for the long-term changes in the Baltic basin, changes that occur due to weather have great significance for the sea's ecosystem. Short variations (10-100 years) in the climate have an effect on two types of water drainage into the sea: river drainage of freshwater and salt-water inflow from Kattegat Sea (through the shallow thresholds of the Danish Sounds). Such climatic events may have significant impact on the vulnerable Baltic Sea. This enclosed sea, which is greatly dependent on the water exchange with the Kattegat Sea, is much more sensitive to these climatic changes than the oceans. The organisms that live in the Baltic Sea must therefore be very tolerant and be able to live in an environment that is highly variable in regards to temperature, salinity and oxygen.

Since the Baltic Sea can be expected to have great natural variations, it is difficult to distinguish changes that are due to contaminants. The sub-arctic climate also shows great variations between years. Rainy years are often followed by dry years. A year in which the icebreakers don't have to leave their harbour may be succeeded by a severe ice winter, where the entire Baltic Sea and parts of the Kattegat Sea are covered with ice and the icebreaker crew really have to work for their paycheque.

Obviously the ecosystem is affected by these variations. In connection with the break-up of the ice after an ice winter, the earlier so lush benthic flora can be completely scraped off in exposed areas, down to a depth of about ten metres.

Saline water is heavier than freshwater. Therefore, the saline water sinks under the brackish surface wa-

THOUSAND-YEAR-OLD SEDIMENTS STILL INFLUENCE THE SEA OF TODAY

A phenomenon caused by the elevation of the land has recently attracted the attention of Baltic Sea researchers. When the water level is lowered, the so-called wave base also goes deeper. The wave base represents the maximum water depth where waves at the sea surface lead to water turbulence. It is easy to imagine that severe storms that induce waves of more than ten metres in height, which occur regularly with a one- or two-year interval, have significant impact on the coastal ecosystem.

In exposed areas, the wave base may be as deep as 50-70 metres. Above this level there is normally no accumulation of fine-grained sediments. By the uplift of land, deeper sediments gradually become exposed to the wave turbulence and are subsequently eroded/resuspended.

Even though the seafloor of the Baltic proper only rises on average 1.5 millimetres per year, it entails several million tonnes of old glacial and postglacial clays possibly being eroded annually (Jonsson et al., 1990). Due to this, carbon, nitrogen, phosphorus, metals and mineral particles derived from these clays are mobilised into the ecosystem again, perhaps thousands of years after they settled out to the sediments in a considerably calmer environment.

Recent investigations have shown that as much as 80 % of the material that is deposited at the deep bottoms of the Baltic proper (25-30 million tonnes expressed as dry substance) is estimated to originate from old eroded sediments. Discharges to the sea via rivers, direct discharges, atmospheric fallout and bioproduction in the sea account for only 20 % of what is annually trapped in the offshore accumulation bottoms in the deeper areas. Concerning the Gulf of Bothnia, with an annual uplift of 5-10 mm, the input from erosion is even larger. In mass balances for the Baltic Sea it is necessary to take into consideration these large amounts of eroded material.

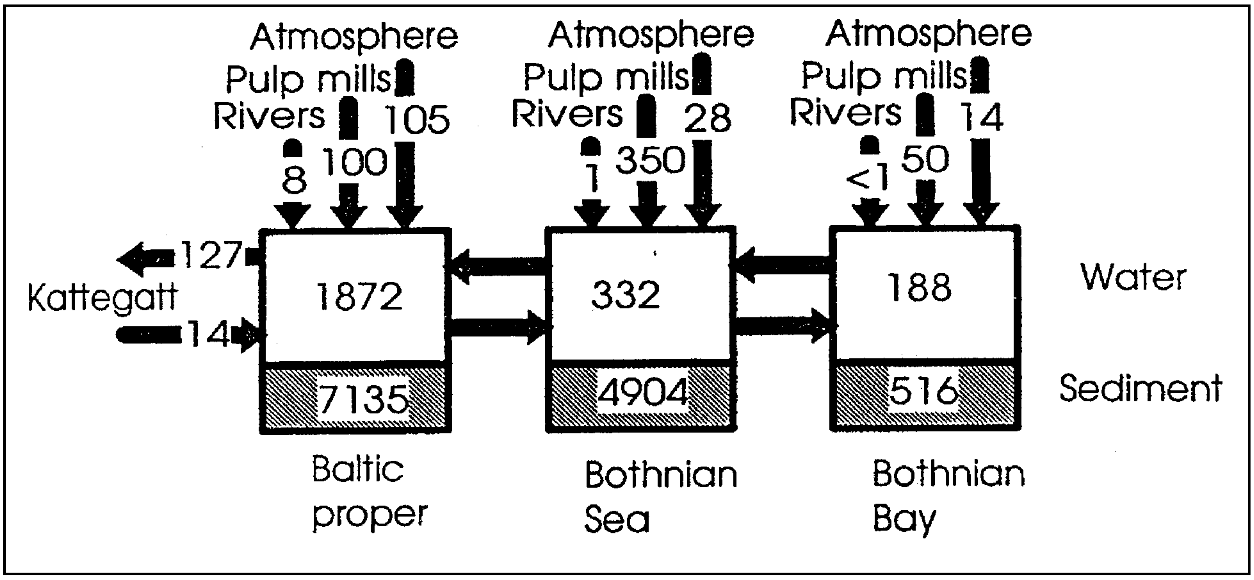


Figure 10.8. Mass balance for EOCl for the three sub-basins of the Baltic Sea based on data for 1988-1989. Input data are given in tonnes yr^{-1} and the stores of sediment and water in tonnes (Wulff et al., 1993).

ter. This phenomenon has been more or less pronounced for thousands of years. Today we know that this is of great importance for the oxygen balance of the Baltic Sea, since these two water masses are sharply held apart by a steep halocline. It works as a barrier that prevents effective mixing between the oxygenated surface and the anoxic/hypoxic bottom water.

Only during extreme weather conditions, oxygen-rich saline water flows into the Baltic Sea through the Danish Sounds and replaces the old oxygen-poor deep water in the deep basins. This happens occasionally at a few years' interval; at the turn of the century, this supply of oxygen was enough to keep the oxygen content in the deep water above 2-3 mg per litre, which is considered a critical level for the macrobenthic fauna. During recent decades this situation has changed drastically and vast areas have become devoid of many species of benthic fauna.

Interactions between the coastal zone and the open sea

For several decades there have been discussions concerning how efficiently discharges of environmental pollutants are captured in the coastal areas. Is the coastal zone, including the archipelagos, an efficient filter, prohibiting transportation of contaminants and nutrients between the coastal zone and the offshore areas?

In a mass balance study, Wulff et al. (1993) demonstrated that the discharges from pulp mills clearly dominated the input (75 %) of extractable organic chlorine (EOCl) to the Baltic Sea in the mid-1980s (Figure 10.8). The atmospheric input was estimated at 23 % of the total, while the input via rivers was negligible (< 2 %). More than 50 % of the input since the early 1940s was still stored in the Baltic Sea system, although a substantial part must have left the Baltic Sea through the Danish Sounds. The main part of the store (80 %) is found in the sediments and the rest in the water mass.

Although the main input of chlorinated compounds was to the Bothnian Sea, showing very high concentrations close to the mills, these coastal sediments contain only some 10 % of the total sediment store. About 90 % were dispersed from the discharges into the open sea areas, with the main part of the sediment store (approx. 60 %) found in the Baltic proper, indicating a large-scale transport of EOCl. Besides this mass balance indicating that a more efficient trapping in the anoxic/hypoxic sediments of the Baltic proper occurs, it also shows that the pulp mill discharges are to a major extent transported through the coastal zone, indicating a poor filter effect concerning these types of substances.

Cadmium has been the subject of interest in the co-operative works between the Baltic Sea states for several years. The total annual cadmium input to the Baltic Sea was estimated to average 140 tonnes/year during the 1980s (HELCOM, 1986). Borg & Jonsson (1996) estimated that 113 tonnes were buried annually in the Baltic Sea sediments. The main part, 90 tonnes, are trapped in the laminated sediments of the Baltic proper, especially in the northern half, where the mean sediment cadmium concentrations are more than 5 times the concentrations in the southern half. Although most of the discharges of cadmium are directed to the coastal areas, the main part of the annual input

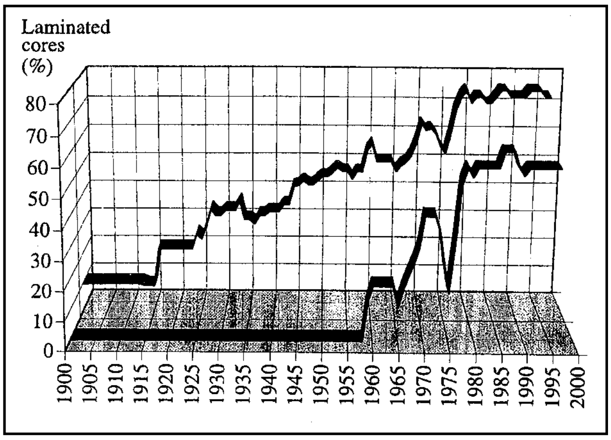


Figure 10.9. Percentage of laminated sediments in the entire Stockholm Archipelago (back curve; number of cores investigated = 47) and the central Stockholm Archipelago (front curve; number of cores investigated = 19). Unpublished data from Carman, Jonsson & Meili.

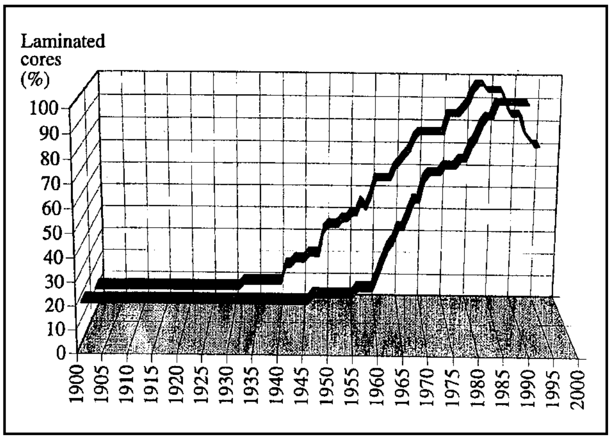


Figure 10.10. Laminated sediments in the NW Baltic proper (front curve) and Northern Baltic Proper (back curve). Unpublished data from Carman, Jonsson & Meili.

(approx. 80 %) is trapped in the offshore sediments. This mass balance for cadmium in the Baltic Sea also indicates a poor filter effect in the coastal zone.

Eutrophication in the open Baltic Sea influences coastal areas

It has been shown that the area of laminated sediments has expanded significantly during the 1950s-1980s in the open Baltic proper. In Swedish archipelagos, laminated sediments are currently found in many areas. Recent investigations in 18 bays/fjords on the Swedish Baltic proper coast with high (5-50 mmyr^{-1}) sedimentation rates show agreement between varve counting and ^{137}Cs-dating in most of the cores (Carman, Jonsson & Meili; unpubl. data). By compiling data from the cores sampled in the Stockholm Archipelago during the 1990s, the historical development of the lamination can be determined (Figure 10.9).

Obviously, laminated sediments were present in the Stockholm Archipelago as far back as the turn of the century. However, the laminated area has increased substantially from 1915 onwards, levelling out at almost 80 % of the investigated cores in the early 1980s. In the central archipelago, however, 20-40 km east of Stockholm, lamination did not occur until around 1960, thereafter substantially increasing during the 1960s and 1970s. Substantial measures were introduced concerning the municipal wastewater during the late 1960s and early 1970s and the phosphorus discharges were reduced by approximately 90 %. Despite these reductions, there are no evident signs of improvements in the soft bottoms in the archipelago.

Although great efforts have been made to reduce the nutrient discharges in the Stockholm area, the situation in the archipelagos is still getting worse. This is most likely an indication of a large-scale influence of increasing eutrophication in the open Baltic proper.

When was the situation acceptable in the Baltic Sea?

During the twentieth century, the Baltic Sea has been significantly eutrophied, which has caused great effects on the ecosystem. Is it then possible to determine, using retrospective data, when the environmental situation was acceptable in the respect that no substantial changes of the ecosystem had occurred? Unfortunately there are not many possibilities to describe the gradual change of the Baltic proper environment, except by retrospective studies of the sediments. Most other types of studies are occasional investigations, and there are only a few monitoring parameters that can be used to evaluate the long-term eutrophication trend (e.g. oxygen concentrations in the deep water).

However, the record of the expansion of laminated sediments is an excellent tool in this context (Figure 10.10). The trends detected in the sediments are not signs of subtle effects, but rather describe large and crucial changes in the Baltic Sea ecosystem. From Figure 10.10 we may conclude that we have to go back to the late 1920s or early 1930s to find a situation before the laminated sediments started to expand, indicating that no dramatic effects on the benthic fauna had yet occurred. Thus, if we consider the extinction of benthic fauna as an effect that should be avoided to achieve a sustainable situation, we may have to reduce the discharges of nutrients to the Baltic Sea to what they were in the 1920s. Certainly, other criteria may be set for what is desirable to achieve, but there's no doubt that eutrophication has become quite substantial when the benthic fauna starts to become extinct in the deep areas.

Long time to recover for the Baltic Sea

The information we presently have at hand indicates that we should not expect any fast recovery in the future after introducing measures against pollution. On the contrary, we must learn from this and use the slow recovery response as a strong argument for being very restrictive with introducing new hazards into the marine environment. There are many factors affecting the recovery time. Below we discuss some of the most important factors in this context.

Land-rise

Above we have discussed the importance of erosion/resuspension of sediments due to crustal rebound after the last glaciation of Scandinavia. How does this affect the recovery course in the Baltic Sea? For instance, we know that we have substantial quantities of contaminants in the near areas to large point sources such as pulp bleacheries and smelters. A certain amount of these contaminants will gradually be remobilised when the land, due to the crustal rebound, rises from the sea, causing the bottoms, today classified as accumulation bottoms, to turn into erosion bottoms. Thus, we can predict that the huge discharges of chlorinated compounds from the pulp industry during the 1960s-1980s will most likely continue to expose the Baltic ecosystem to bleachery-derived chlorinates for a very long time to come. We cannot be sure that the chlorinated substances are so strongly bound to sediment particles that they will sediment in deeper areas shortly after remobilisation and therefore will not cause any harmful biological effects.

From a mass balance of EOCl (Wulff et al., 1993) for the Baltic Sea it has been shown that approximately only one tenth of what has been discharged since the 1940s can still be found close to the industries. Ninety percent has already been dispersed into the vast expanses of sea. The largest impact from the discharges has already happened and the gradual remobilisation, due to land-rise, will most likely not cause any increasing problems in the future. However, the land-rise is one of the reasons why the recovery from the large discharges will be slow. Wulff et al. (1993) predicted that chlorinated compounds from pulp mills would continue to cause elevated concentrations several decades into the next millennium, although the discharges have almost dropped to zero during the 1990s.

Delay at transportation bottoms

We also know that a substantial part of the contaminants discharged to the sea is delayed at transportation bottoms in coastal and offshore areas.

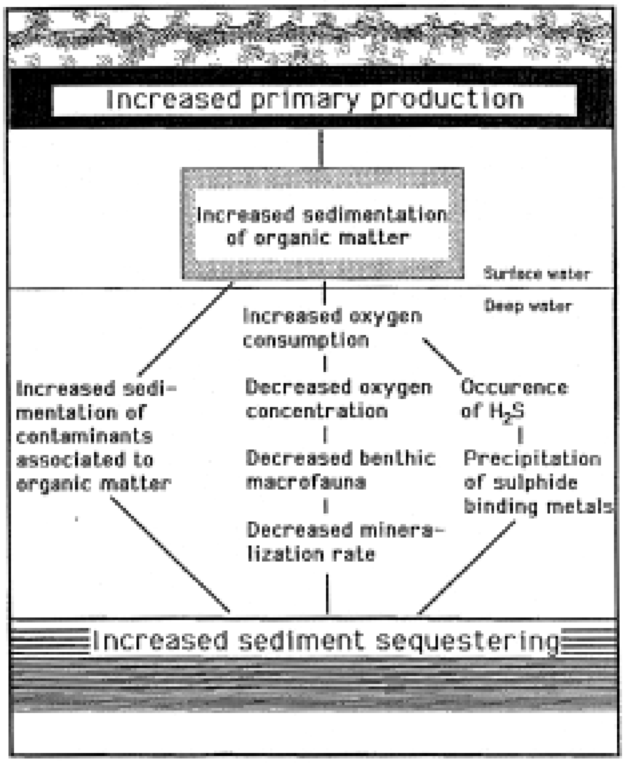


Figure 10.11. A concept of hypotheses concerning processes that may affect the burial of contaminants in Baltic proper sediments (Jonsson, 1992).

Accumulation bottoms for fine material in the Baltic Sea only constitute about one-third of the total bottom area (Ignatius et al., 1981; Jonsson et al., 1990). The accumulation bottom sediments in the open parts of the Baltic proper (Figure 10.11) are considered to be the main sinks of fine material. Let us assume that a contaminant is discharged in large quantities during just one year and thereafter no discharges occur at all. We should then expect that the year of discharge is manifested in open sea sediments in a prolonged and delayed peak mainly due to resuspension processes on the erosion and transportation bottoms. A particle, carrying the contaminant from the year of discharge, deposited on coastal transportation bottoms, may have to pass several cycles of resuspension until it is finally trapped in a laminated accumulation bottom in the open sea, far from land and the initial site of sedimentation.

This illustrates the dynamics in Baltic Sea sediments. Dividing the bottoms into either accumulation, transportation or erosion bottoms often gives a false picture of the dynamics. Of course, there is a gradual scale between the different types of bottoms. Near the shore, in the shallow energy-rich zone, wave-influenced resuspension may occur once a day or once a week, while the deep long-term transportation bottoms may be resuspended as seldom as once a decade or century, when strong bottom currents are induced by severe storms. Submarine slides may perhaps also be an important phenomenon in emptying these long-term transportation bottoms, for further transport to the deep accumu-lationbottoms. Thus, in these ways, transportation contaminants may be retained for years or decades and thereby delay the corresponding increase in sediment concentration at accumulation bottoms. This information is important for understanding how the sediments react to changed input of contaminants, and for when it comes to predictions on how fast the Baltic Sea system will react to remedial measures.

Bioturbation

Another factor that may significantly delay the recovery is bioturbation (benthic fauna mixing of the sediment). In the entire Gulf of Bothnia and in the erosion/transportation zones of the Baltic proper the macrobenthic fauna inhabits the sediment/water interface. These animals are capable of mixing the sediment, which causes seasonal differences as well as differences between years and even decades to get wiped out. Bioturbation also leads to newly highly contaminated sedi-mented matter becoming mixed with the underlying pristine pre-industrial sediment, which may lead to rapid changes in contamination being levelled out.

The opposite situation may occur if the discharges have been drastically decreased and newly sedimented uncontaminated matter is overlaying severely contaminated deeper layers. This may be illustrated by the results from a mass calculation of arsenic in the Gulf of Bothnia (Borg & Jonsson, 1996) indicating high concentrations in surficial sediments, although the discharges decreased dramatically during the 1980s. The most likely explanation is that bioturbation of the oxic sediments may cause erroneously higher values in the surficial sediments due to the influence of former substantially higher smelter emissions during the 1960s-1970s. Highly contaminated sediment particles are brought to the surface from deeper sediment layers by bioturbation.

Concerning the Baltic proper, in this respect, the anoxic/hypoxic conditions in the deep offshore accumulationbottoms may be considered a positive factor because they prevent bioturbation. Therefore, in this area decreased discharges may be manifested by more rapidly decreasing concentrations in the surficial sediments due to coverage of the contaminated layer by uncontaminated recent sediment.

Interactions between eutrophication and contaminants

A recent study of organic pollutants in fish from lakes in southern Sweden showed that the levels were negatively correlated to the trophic status and content of humic substances of the lakes (P. Larsson et al., 1992). Concentrations of PCBs and p,p|'-DDE in pike were significantly lower in eutrophic than in oligotrophic lakes, although the pollution load was similar. It was suggested that increasing productivity in the lakes decreased the pollutant levels in fish, owing to higher growth rate, higher turnover time and sedimentation of pollutants adsorbed by particles. It is also worth mentioning that the remaining otter populations in Sweden were only found in eutrophic lakes where the concentrations of PCB and DDT were low (Olsson & Jensen, 1975).

This study may also be applied to the marine environment. Below, a discussion is given on how some important processes may regulate the sequestering of contaminants in the sediments in relation to an increased eutrophication of the Baltic Sea (Figure 10.11).

Consequences of increased primary production

Besides long-term measurements indicating recent increases in primary production (HELCOM, 1990; U. Larsson & Nellbring, 1991) there are also many cases of indirect evidence clearly indicating increased primary production in the Baltic proper during recent decades (Rahm, 1987; Elmgren, 1989; Stigebrant, 1991; Jonsson et al., 1990; Jonsson & Carman, 1994).

Increased primary production subsequently leads to increased sedimentation of organic matter. This may initiate a chain of changes in large-scale processes that may be crucial for the Baltic Sea ecosystem. Wassman (1990) has shown that there is an exponential relationship between increased primary production and export production of organic carbon in the primary production interval 0-250 g C m^{-2}yr^{-1} for coastal areas in the North Atlantic. For the Baltic proper, Elmgren (1989) estimated an increase in total primary production from 73 g C m^{-2}yr^{-1} around 1900 to 160 g C m^{-2}yr^{-1} for the late 1970s. If this model is applied to these figures, it leads to a 3-fold increase in export production, sedimentating out from the photic zone. Recent investigations during 1990 (Larsson & Nellbring, 1991) have shown a recent primary production of about 200 g C m^{-2}yr^{-1}, indicating an even higher export production.

Jonsson & Carman (1994) found a two-fold increase in organic content in the sediments since 1930, corresponding to a 5-10-fold increase in sequestered autochthonous organic matter in the sediments.

Oxygen levels in deep water

It is well documented that the oxygen content in the deep water of the Baltic proper has decreased substantially in all the sub-basins since the beginning of the century (Melvasalo et al., 1981). Shaffer (1979) suggests that there must have been at least a 60 % increased supply of organic matter to the deep water of the Baltic proper to explain the decreasing oxygen concentrations up to the late 1970s.

The first reports on large-scale extinction of the benthic fauna were published in the 1950s, indicating large-scale changes from the late 1940s and onwards. In the late 1980s the macrobenthic fauna at offshore A-bottoms deeper than 70-80 m in the southern and eastern Baltic proper had become extinct or very sparse. In the 1980s, in the northern and western parts, there was a slight increase in benthos colonisation in the intermediate zone between the halocline and approx. 140 m. However, the benthic community is still very poor compared to areas above the halocline (HELCOM, 1990).

For obvious reasons, no investigations have dealt with differences in carbon mineralisation rates in the offshore laminated accumulation bottoms compared to the formerly oxic and bioturbated bottoms. However, to the naked eye, there are substantial differences in degree of mineralisation between the laminated sediments and the underlying homogeneous sediments. In offshore areas, bottoms are now devoid of many important species. The important deposit-feeders *Macoma baltica* and *Pontoporeia sp.* are lacking in the deep accumulation bottoms in the Baltic proper. Thus, the first mechanical and digestional degradation of the sedimenting material is missing. However, whether changed mineralisation is a major process for the trapping of contaminants in the sediments or not is still to be investigated.

Increased sedimentation of contaminants associated with organic matter

The increase in primary production caused by eutrophication normally occurs as increases during the algal bloom periods. The consumers are unable to utilise all the primary produced matter, and thus an increasing share of organic matter is sedimenting with increasing eutrophication (Wassman, 1990). It has been shown that marine plankton may highly enrich heavy metals (Boström et al., 1983). Increased export production would theoretically lead to shorter retention times in the phototrophic zone for contaminants associated to organic matter. Subsequently, this may result in the increased withdrawal of contaminants from the water mass.

Precipitation of sulphide binding metals

The behaviour of trace metals in the deep water of the Baltic proper is relatively well documented (HELCOM, 1987a). In general, considerable gradients are found in the interface between anoxic and oxic conditions in water as well as in surficial sediments. Anoxic conditions and subsequent presence of hydrogen sulphide in bottom water has been shown to decrease the contents of metals that are relatively insoluble or liable to precipitate as metal sulphide.

Increased sequestering of contaminants in the sediments

Sediment profiles of chlorinated compounds (e.g. EOCl, PCBs, PCDD/Fs) and metals (e.g. Cd, Cu, Hg, Zn, Pb) indicate substantially increased sequestering in the Baltic proper sediments from the 1950s and onwards, coinciding in time with the expansion of laminated sediments and clearly increasing organic content in the sediments (Jonsson, 1992). Other authors concerned with metals (Niemistö & Voipio, 1981; Tervo & Niemistö, 1989), DDTs and PCBs (Niemistö & Voipio, 1981; Perttilä & Haahti, 1986) have described similar distribution patterns.

A crucial question is whether the sequestering efficiency, due to the turnover from oxic conditions to hypoxia/anoxia close to the sediment/water interface, has increased in the sediments. One way to evaluate this is to compare the historical record in the sediments with known changes in input of contaminants to the Baltic Sea.

Increased sediment burial of pulp mill substances

A good historical record from pulp mills has been obtained for the discharges of chlorinated compounds measured as EOCl (Wulff et al., 1993). See Figure 10.12.

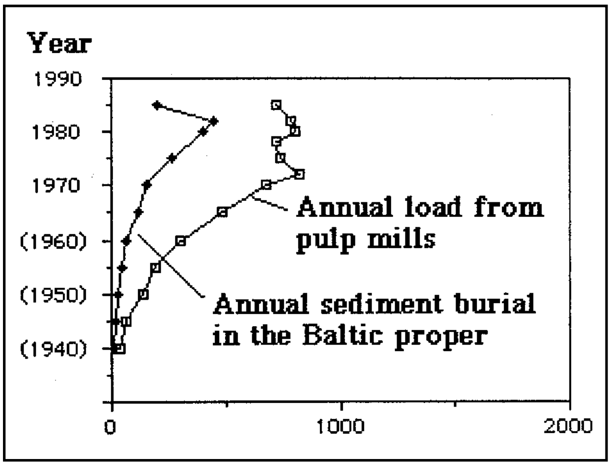


Figure 10.12. Comparison between estimated annual load of EOCl from pulp mills and estimated annual sediment burial in the Baltic proper after subtraction of the background concentration for EOCl (Jonsson, 1992).

By calculating the record of annual burial of EOCl in the offshore sediments of the Baltic proper and relating this to the annual discharges from the pulp mills, Jonsson (1992) calculated the sediment burial efficiency (Figure 10.13). Until about 1970 the curves for load and sediment sequestering were well correlated; a higher burial efficiency, however, was indicated from the mid-1970s and onwards, coinciding well in time with the large-scale expansion of laminated sediments in the Baltic proper (Jonsson et al., 1990).

One important conclusion of this is that the burial efficiency of EOCl is increased when altering the oxic and bioturbated sediments into anoxic/hypoxic and laminated sediments, which occurred over large areas in the Baltic proper during the 1960s-1980s (Jonsson et al., 1990).

To sum up, most of the contaminants studied have shown substantial increases during recent decades. In time, these enhanced levels become correlated to the recent expansion of laminated sediments in the Baltic proper. Increased sediment sequestering efficiency is indicated for EOCl in relation to estimated load from pulp mills, as well as for sulphide-binding metals in recently laminated sediments. It should, however, be noted that the results obtained should be looked upon with due reservation, as room exists for alternative explanations.

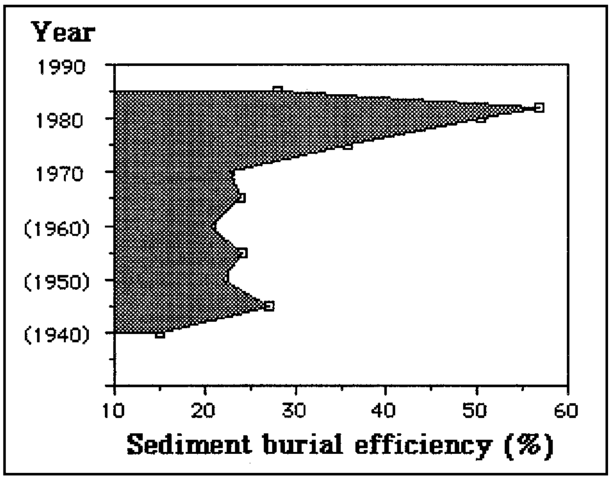


Figure 10.13. Burial efficiency in Baltic proper sediments expressed as the ratio(Jonsson, 1992): EOCl sediment burial / EOCl load to the Baltic Sea from pulp mills (EOCl = Extractable organic chlorine).

The importance of a holistic approach

There are strong indications that the status of the Baltic proper during recent decades has altered towards more eutrophic conditions. One may assume that increased eutrophication of the Baltic Sea may lead to a substantial scavenging of contaminants from the water mass down to the sediments. Results obtained in lake studies of factors controlling biological uptake of chlorinates (e.g. Larsson et al., 1992) as well as metals (e.g. Håkanson, 1984; Håkanson et al., 1988) warrant this assumption. The consequences will be lower concentrations of contaminants in pelagic biota.

During recent decades, substantially increased sequestering of many contaminants has been registered in the sediments, which may be indications of eutrophication-induced recent redistribution of contaminants within the Baltic Sea ecosystem. Substantial parts of the contaminants are presently buried and to a certain extent "pacified" in the laminated sediments of the Baltic proper. If the oxygen situation in the bottom water suddenly was to be improved, for example due to a major inflow of oxygen-rich water through The Danish Sounds, many contaminants might be mobilised back into the water mass. This could, paradoxically, also be the effect if present efforts to reduce the discharges of nutrients to the Baltic Sea are successful. The reason would be a decrease in organic matter sedimentation to the deep water.

This hypothetical problem may serve as an example of the importance of a holistic approach, considering all the different environmental problems in the Baltic Sea when remedial measures are to be defined.

11.
RIVER AND LAKE REMEDIATION

Lars Rydén, Lars Håkanson, Ryszard Kornijów & Woichiech Puchalski[1]

A multitude of water courses are damaged

Many rivers and lakes have been severely damaged by man's activities over the last 200 years. Drainage projects have dried up about 50 % of wetland areas in the Baltic Sea region, thereby diminishing or eradicating 2 000 lakes in Sweden alone. Eutrophication has affected almost all surface water in the region causing overgrowth by macrophytes along shores, massive algal blooms and dead bottoms. Acid rain, mainly caused by industrial emissions, has over a period of several decades lowered the pH values in soil and in water over large areas with insufficient buffering capacity. Forested areas in southern Poland and the northern Czech Republic have been severely affected. In western Sweden fish populations have been damaged by acidification in some 13 000 lakes. Industrial effluents have polluted soils and surface waters for more than 100 years. Many of these contain toxic and persistent compounds such as phenols, cresols or other hydrocarbons, and PCB; even if they are very old they stay in sediments and in soil and leak into water. Other sources of pollution are thousands of landfills over the region where pollution of nearby lakes and streams has not until now been detected.

Is it possible to repair and "undo" some of these damages? What happens if the sources of pollution are taken away? Are the waters and their ecology restored? It is only recently that such questions have been asked and answers formulated. Projects aimed at removing sources of pollution or repairing damaged waters have been set into action in only few instances. As a general conclusion one might say that such remediation of damaged watercourses is long-term and expensive but very often possible. This chapter will give a few Swedish examples of such remedial projects. In fact, projects have been carried out so far in countries where it has been possible to finance them. But even then it has been so expensive that oftentimes financing had to come from the national budget.

Figure 11.1. The landscape at Dalby, close to Lund in southern Sweden, is typical for industrial agriculture, which has promoted drainage of wetlands, building of subsoil water pipes and removal of vegetation close to the open water surfaces. These changes are now partly reversed in the Höje River restoration project (from the information material of the project).

Objectives and methods of remediation

The projects include watercourse damage by:
Chemical pollution such as
- Eutrophication
- Pollution by industrial pollutants, like PCB or hydrocarbons
- Pollution by radioactivity such as radioactive caesium from Chernobyl
- Acidification due to SO_x and NO_x

Physical impact such as
- Straightening of rivers, building of canals, etc.
- Drainage and changes of groundwater tables
- Overgrowth of bushes, trees or reed belts

Restoration of surface waters has several objectives:
- Increased landscape values
- Increased natural values and biological diversity

[1] Lars Rydén is the main author of the chapter, Lars Håkanson contributed the section on mercury in lakes, Ryszard Kornijów contributed the section on biomanipulation and conservation of lakes and reservoirs and Woichiech Puchalski contributed the section on ecotones.

- Improved functions such as denitrification and water treatment
- Storage of water during dry seasons

The ways in which these remediations have been carried out are multiple.

1. Taking away the source of pollution is the first important measure. In some cases this has been enough, if the self-repairing capacity of the water is able to do the rest.
2. As a second measure it might be necessary to remove polluting sediments, soil, landfill, etc., if there is an industrial pollutant remaining from, for example, industrial activities, which is too persistent for the natural processes to handle. The same thing is valid for heavy-metal pollution.
3. Finally it might be necessary to rebuild part of a watercourse to repair it. This applies to overgrowth that is taken away, changes in the wetland character of an area by dredging or damming, or removal of installations, etc. on a river or a shore.

In any single case one or several of these items need to be treated to reach desired results.

River restoration projects

In the old farming society the maintenance of rivers and watercourses was often a common responsibility of the village. River cleansing in many villages was a common undertaking of all males, and done at intervals of several years. Repair of dams, maintenance of shores and riverbanks or cutting of reed belts were other tasks managed in the same way.

During the early part of the 20th century watercourses were, especially in extreme agricultural areas, straightened to allow for more rational agriculture with large machines. Smaller wetlands and ponds were drained. The effects of this have only now become evident:

- Drainage water from agricultural fields goes straight into the Baltic Sea without any natural reduction of nutrients and causes large-scale eutrophication.
- A number of birds, fishes and other species that were part of the ecology of the former wetland areas have disappeared.
- Industrial agriculture has influenced the landscape and the variety and beauty of traditional farming land are lost.

Several river restoration projects aim at reversing this situation. These projects require more or less extensive re-channelling of rivers to recreate the natural meanders, the construction of smaller wetland areas, development of buffering zones between field and river banks and in many cases adding rocks, etc. in the watercourse itself. Many times old maps from the last century are used to study the original landscape and river course. The projects are often carried out along a river catchment by several municipalities in co-operation and require national or municipal financing to allow for construction companies with bulldozers and caterpillars, while some landowners have to sacrifice a part of their property. Large river-restoration projects take several years to carry out. Well-known projects are those of the Gelse River in southern Jutland, Denmark, and the Höje River in southern Skåne, Sweden.

River management to maintain system connectivity

Compensating properties, e.g. nutrient removal and external loading, nitrification and denitrification occur in complex, diversified floodplains with healthy channel, hyporheic and riparian zones, and when longitudinal and lateral connectivity is maintained. However, many river systems were changed by engineering works: drainage, channelisation, cutting off meanders, oxbow lakes and lateral channels, separation of floodplains from their channels by dikes, canalisation, introducing arable lands and settlements in the floodplains. The diversity of biotopes and biota, the complexity, retentive and stabilising properties of such rivers are highly limited. Other anthropogenic, but large-scale changes are eutrophication and acidification of soils, groundwater and surface waters.

Contemporary river engineering practices, supported by increasing knowledge of both technical and ecological principles of river system functioning, do consider river or floodplain restoration/rehabilitation measures. Introduction of riparian vegetated buffer strips, or channel re-meandering, has become a popular technical management practice. The processes and the importance of buffer zones have been studied and assessed in practice (e.g. Pauliukevicius et al., 1993; Haycock et al., 1997). Manuals explaining principles and procedures of such practices have been published and distributed widely (e.g. Lachat, 1994; RRC, 1999). In many cases, proper riparian management practices may be more effective and cheaper in controlling diffuse pollution than any conventional method of sewage treatment (Statzner & Sperling, 1993; Haycock & Muscutt, 1995).

River rehabilitation practices are often related to renaturalisation, i.e. return to the historical structure of the restored river floodplain. It may work properly if the historical settings are known (old maps, long-time monitoring reports on hydrology, chemistry and biota), and the landscape structure in the catchment has not changed significantly over the river regulation period. However, one should be careful if landscape changes on a larger scale (such as lowering groundwater level, eutrophication and

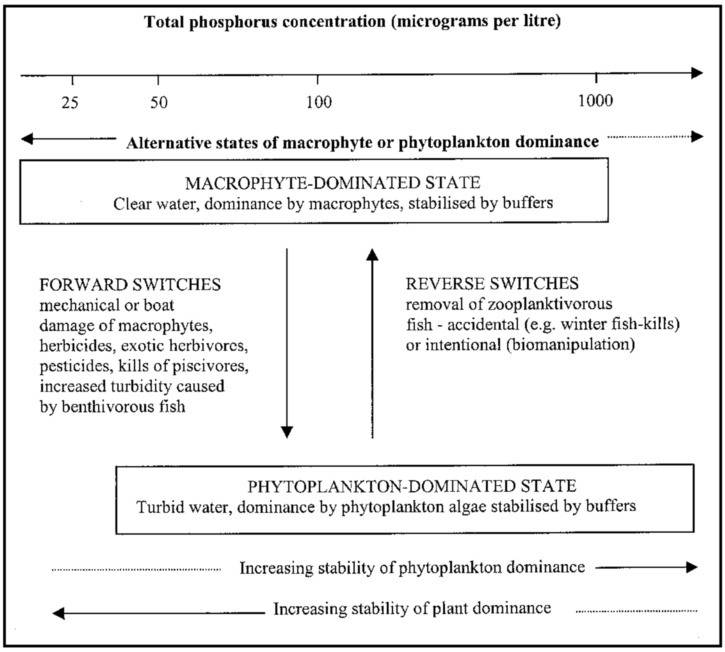


Figure 11.2. The model of alternative stable states of shallow lakes over a wide range of phosphorus concentrations. Switches needed to change one state to another are relatively independent of nutrients. Based on Moss (1998).

acidification) have occurred. In such cases we may obtain too little water in the channel to sustain meanders, or too intensive a growth of submerged plants, resulting in increased flood risks. Special attention should be paid to "natural", forested (often coniferous) riparian ecotones of streams on crystalline bedrock, susceptible to acidification. Acidified water pulses are most common in early spring, during snowmelts; they produce destruction and flushing of biotic communities. Those communities may be restored later at a rate depending on primary productivity, limited by light access (tree canopies) and nutrient availability. The restoration rate may therefore be enhanced by introducing meadow strips along such stream channels (Zalewski et al., 1994), which cannot be considered as historically natural for such sites. It is an example of a stream functional optimisation, enhancing actual system functions, which are not related directly to past ones.

The major issue in river management is to maintain system connectivity, both longitudinal and lateral, as well as diversity. Matter transport paths, as well as migration paths of riverine biota, should not be affected and maintained at their optimal intensity. Compromises are often called for in the different aspects of river and catchment use. Based on system performance characteristics and expected gains and losses, such compromises can be achieved.

As floodplain functional ecology is a young and dynamically developing branch of theoretical and applied science, not all processes and functions are sufficiently recognised. Knowledge increases rapidly and there is a need to consider the most current data when preparing a management plan. Environmental monitoring of effects of technical measures is particularly important, to assess system changes and modify them when needed. There is still a danger of making mistakes, especially when environmental conditions and constrains are not evaluated properly, or when an implemented project is nothing but a copy of another project, which has appeared to be successful in other local settings. It is necessary to establish a team of experts: geologists, geomorphologists, hydrologists, biogeochemists, biologists, engineers and social scientists, to properly recognise input data and formulate management options based on them, effective in local conditions.

According to Wissmar & Beschta (1998), restoration strategies must be derived from a concise definition of the processes to be restored and conserved, recognition of social values and commitments, quantification of ecological circumstances and the quality of background information and determination of alternatives. The basic components of an effective restoration project include: clear objectives (ecological and physical), baseline data and historical information, a project design that recognises functional attributes of biotic refugia, a comparison of plans and outcomes with reference ecosystems, a commitment to long-term planning, implementation and monitoring and a willingness to learn from both successes and failures.

Importance of food web interactions for lake restoration and management

The current understanding of food web interactions was applied to a concept aimed at the restoration of nutrient-enriched lakes (Shapiro et al., 1975). The concept is called biomanipulation and means the alteration of a fish community to favour the development of crustacean grazers and increased grazing pressure on algae. The restructuring of the fish community can be obtained by means of rough fish removal, use of fish poisons or water level withdrawal. The goal can also be achieved by enhanced stocking of predators. An increase in piscivores can cause a decrease in the population of planktivorous fish, which allows the zooplankton to develop and increases the grazing pressure on phytoplankton, reducing its density – a sequence of events called the "cascading effect" (Carpenter et al., 1985). In the improved light climate, macrophyte propagules, if still present, will

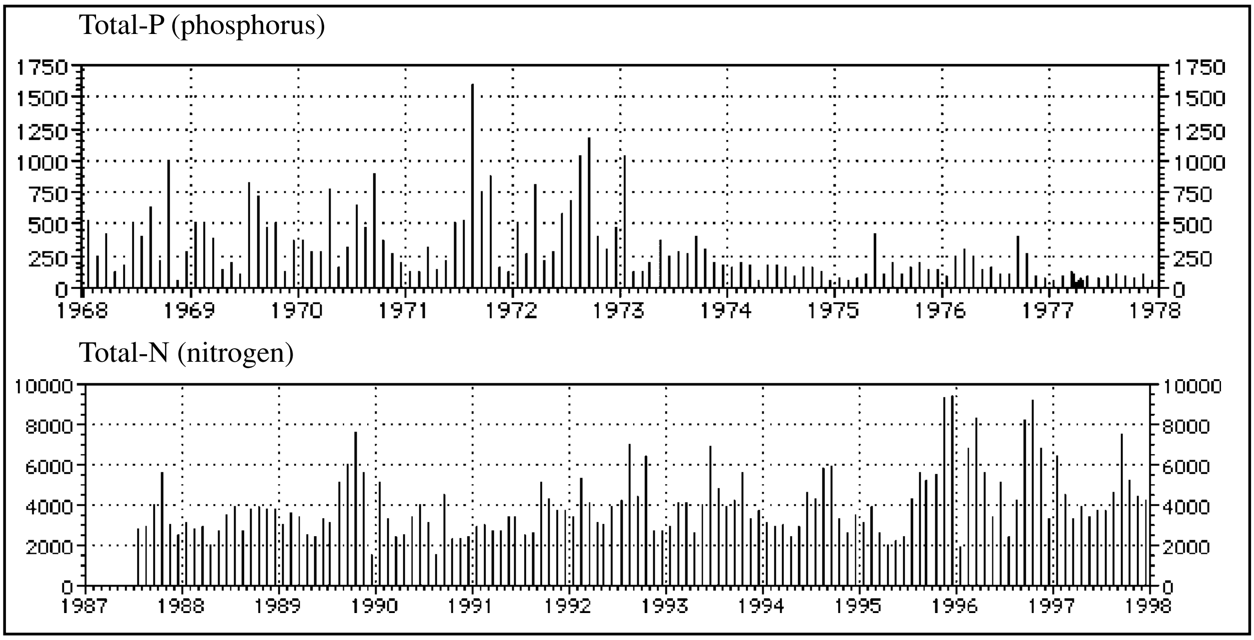


Figure 11.3. Measured values of phosphorus and nitrogen at the outflow of the Fyris River into Lake Mälaren. Notice the sharp decrease of P in 1973 when the P-removal step was introduced in the treatment plant (http://info1.ma.slu.se).

develop and re-establish buffer mechanisms, promoting a clear-water state (Figure 11.2).

Biomanipulation should only be considered as one of many other steps needed to restore a lake successfully. They should include the following sequence of measures (Moss, 1998):

1. Diagnosis of the problem and establishment of the target for restoration
2. Removal of existing or potential forward switches
3. Reduction in nutrient loading
4. Biomanipulation
5. Re-establishment of plants
6. Re-establishment of an appropriate fish community
7. Monitoring of the results

Biomanipulations, if carried out properly, are successful particularly for the first few years. Their results can be stabilised if the buffer mechanisms associated with extensive macrophyte beds are developed. Otherwise it is necessary to repeat measures leading to thinning or eliminating fish. The most effective biomanipulations have attempted to remove the whole fish community. Fishing may take several seasons on a big lake, as in Lake Vesijärvi in southern Finland (Kairesalo et al., 1998) and should be repeated for a couple of years until the plant communities have been re-established (Moss, 1998). The residual fish stock should be reduced to only 1-2 gm^{-2}, compared to a "normal" stock, usually exceeding 20 gm^{-2}.

There are many examples from all over the world of restoring lakes and reservoirs by means of biomanipulation (Gulati et al., 1990). In the Baltic basin this technique was successfully used in Finland (Kairesalo et al., 1998), Germany (Benndorf et al., 1984), Poland (Zalewski, 1990; Prejs et al., 1994) and Sweden (Faafeng & Brabrand, 1990). One of the advantages of biomanipulation is its much lower cost in comparison to chemical or technical restoration methods such as removal of anoxic sediments or precipitation of phosphorus (Kairesalo et al., 1998).

In order to overcome the food web mechanisms responsible for forward switches and, consequently, for lake degradation, it is necessary to obey some principles. First of all the protection measures should start on land, focusing on lowering the external diffuse and point-source loads of nutrients. Building wastewater treatment plants can accomplish the first; the second includes minimal cultivation of land in the vicinity of water ecosystems, contour ploughing and parsimonious fertilisation. Moreover, buffer strips or more extensive wetlands to intercept water coming from agricultural areas should be used.

The protection measures concerning the lake itself should focus on minimisation of disturbances of the bottom sediments and the aquatic vegetation. Hence, boating activities ought to be restricted or rerouted, recreation activity needs to be lowered and adjusted to the ecosystem's carrying capacity and the management of aquatic vegetation by cutting or herbicides should be stopped.

In addition, it is very important to control the density of fish, keeping the level adequate in relation to the food resources. This will avoid overexploitation of the prey population, usually composed of various invertebrates, of which *Daphnia* is crucial in order to control phytoplankton. The maximum "safe" biomass of the fish in a lake ranges from 0-15 grams per square metre, depending, among other things, on

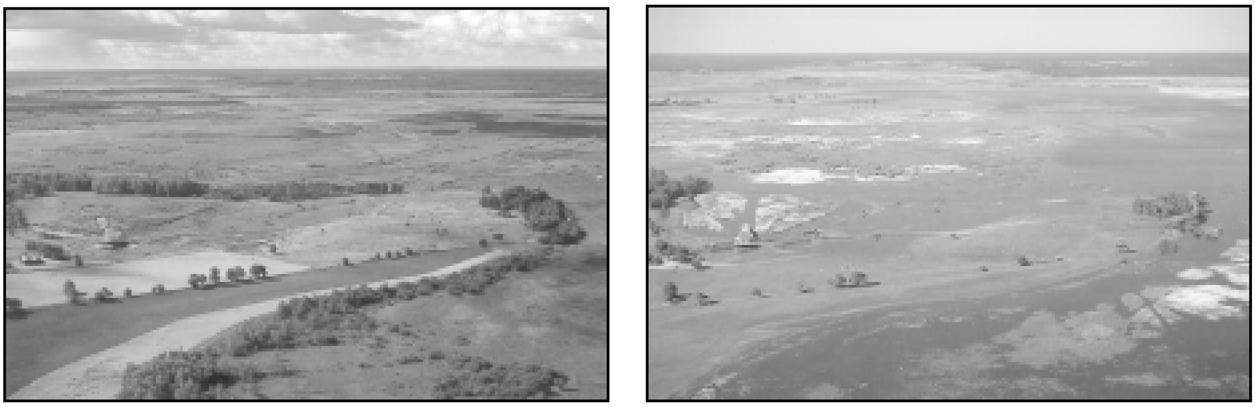


Figure 11.4. The restoration of Lake Hornborgasjön. To the left the lake in August 1987 and to the right the same view in June 1995. The open water surface has increased considerably, by a total of 7 km^2, while meadows and areas for grazing have increased by some 600 ha. Figures for improved biodiversity are very good. (Hertzman & Larsson, 1999).

the density of macrophytes and the ratio of piscivores to zooplanktivores (Moss et al., 1996).

Stocking reservoirs and lakes with exotic fish such as carp or grass carp is highly unacceptable (Moss, 1998). They can represent a real threat to the ecosystems; carp do damage in uprooting plants and disturbing the bottom sediment, while grass carp have an extremely destructive effect on macrophytes. Stocking a lake with fish species that were not present in it earlier (e.g. eel or the planktivorous European whitefish) should be forbidden as well (Kornijów, 1997). These fish can cause irreversible changes in the food web and lead to the extinction of rare species of invertebrates.

Improved wastewater treatment – Lake Mälaren

Lake Mälaren, one of the largest lakes in Sweden, drains an area with 2.5 million inhabitants or 30 % of the Swedish population. The degree of urbanisation in the catchment is 92 %. The area has a considerable agriculture and industry and a large service sector with Stockholm, the capital, as the most important centre.

In the late 1950s and 1960s large-scale eutrophication of Lake Mälaren became increasingly obvious. The formerly quite high water quality in Stockholm City, where the water from Lake Mälaren flows into the Baltic Sea, became worse. Fish, especially salmon, disappeared and the popular beaches in the city had to be closed. As a response, Project Lake Mälaren was launched as a common undertaking of all cities and towns in the drainage area of the lake, with the goal of building efficient wastewater treatment plants, especially to reduce phosphorus effluents. Researchers monitored the process continuously.

Figure 11.3 shows the long-term values of P and N in the outflow from the Fyris River, one of the main contributaries to Lake Mälaren. It is clear that in the 1980s the P values were reduced dramatically, while N reduction, although present, was considerably less. The changes, however, typical for the effect of improved wastewater treatment, were enough to make the situation in Lake Mälaren very different. In the 1990s the beaches in Stockholm were reopened. Salmon is regularly caught along the quays in the centre of Stockholm. Elsewhere in the lake the water quality is dramatically better. At present improvements of the treatment plants aim at a more efficient reduction of nitrogen effluents.

The story of Lake Mälaren teaches us that with time even very eutrophied and rather large lakes can be restored.

Overgrown and drained lakes – Lake Hornborgasjön

Lake Hornborgasjön in western Sweden is well known for its rich bird life. The lake itself was always famous for its waterfowl. Today, the most well known feature is the thousands of cranes that stop there in spring on their way north to perform their beautiful and strange mating dance.

Lake Hornborgasjön is situated in a very rich agricultural area and is thus a typical lake of the large plains and former sea bottom. During the end of the 19th century and the beginning of the 20th century the lake became the object of five consecutive drainage operations; all in all the water level dropped by more than 2 metres. Larger parts of the former lakebed were colonised by bushes and reeds and the number of waterfowl species was reduced dramatically.

As a consequence of the drainage, the surrounding, dried-up organic soil shrank dramatically, the groundwater level changed and the drainage operation had to be redone. The increased costs to maintain the surrounding new agricultural land as productive were, however, not foreseen when the

HÖJE RIVER RESTORATION PROJECT

The Höje River in the southernmost part of Sweden flows from Lakes Björkåkra and Häckeberga in the east to Öresund, between Sweden and Denmark, in the west. The catchment area is 310 km^2. Fields dominate the lower part of the catchment. The two lakes mentioned, along with forestland and an esker, are situated in the upper part of the catchment. Settlements in the area include the university city of Lund, and the smaller towns of Staffanstorp, Lomma and Dalby.

The water in the Höje River is nutrient rich. The average concentration of nitrogen in the 1980s was one of the highest-ever reported in Swedish watercourses. Each year some 700 tonnes of nitrogen and 15 tonnes of phosphorus left the Höje River to eutrophy the Baltic Sea. The nutrients originated mainly from agricultural-land leakage, and wastewater treatment plants. A smaller part came from urban stormwater and from individual households and animal facilities.

In Sweden a national goal is to cut nutrient flows to the Baltic Sea by 50 %. To achieve this, individual catchments also have to improve. In the Höje River the enlargement of the wastewater treatment plants of Staffanstorp and Lund have decreased the nitrogen content by 150 tonnes a year, and more since the farmers in the area have improved their nutrient management.

The most important thing, however, is to improve the natural capacity of the Höje River to reduce nutrient content in the water. The dominating large-scale agricultural landscape in the Höje River catchment is the result of 150 years of removal of watercourses, moving water from open ditches to large pipes and drainage of wetlands. Since 1812, open water surfaces have been reduced by 50 %, and wetlands by 90 %. Surface of open water in the Höje river catchment in 1812 was 9.5 km^2, and in 1988 0.6 km^2. Earlier, wet meadows were a normal part of the landscape but in the 1980s existed in only two places.

Today this development has been reversed. Since 1991, the Höje River Water Association has worked with water and landscape management in the drainage basin of the river. The most important project is the creation of protective buffering zones and ponds in strategic places. In the period 1992-96 a total of 38 ponds and smaller wetlands and 40 km of buffer zones were built. The project is financed by the municipalities of Lund, Staffanstorp and Lomma with a total of 1.9 MSEK (about $US 250 000) annuallyand smaller sums from the County Environmental Fund.

Today the ponds remove about 1 000 kg of N and 30 kg of P per year and ha. Denitrification is slower in winter but does not cease until the temperature is below 3 °C. The yearly reduction in 1996 was a total of 38 tonnes of N and 1.1 tonnes of P. The ponds also store water in the system. Thus, one larger facility for growing vegetables now has an even supply of water throughout the season. Several paths for recreation along the water are frequently used and several bird species have increased their numbers, especially waterfowl and wading birds.

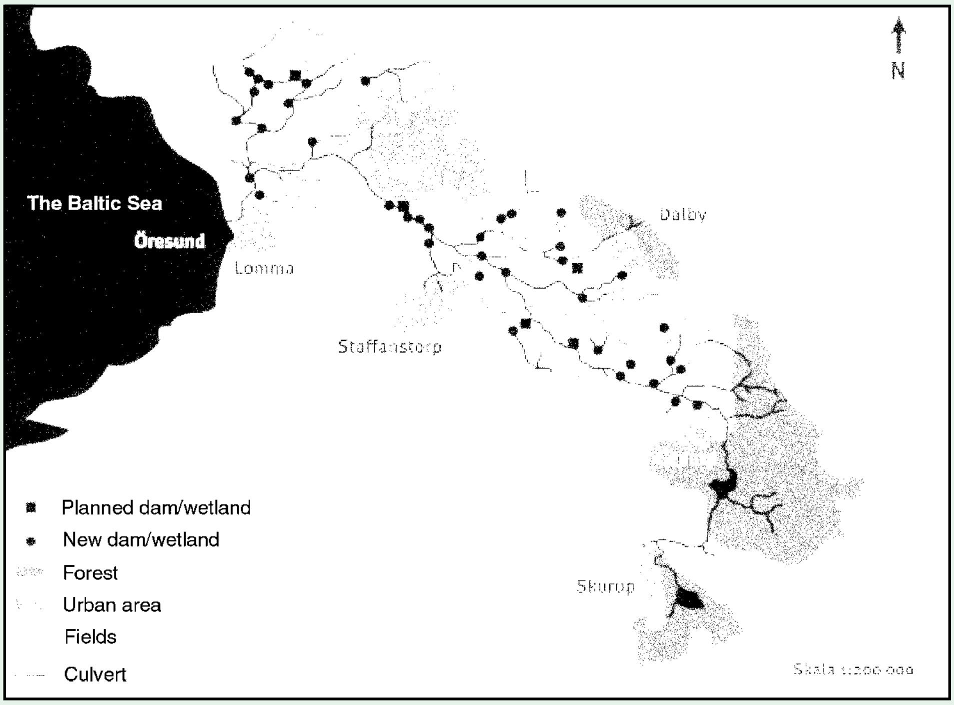


Figure 11.5. The Höje River catchment basin with the Baltic Sea to the left. Light grey shows agricultural fields, medium grey urban areas and dark grey forests. The small circles and squares are new wetlands and ponds in different stages of completion in 1997.

Lake Gårdsjön liming

Lake Gårdsjön is situated in southwest Sweden, 14 km from the Swedish west coast. The total catchment has an area of 211 ha (2.11 km^2) and a lake percentage of 23. The lake itself is 32.2 ha. Eighty percent of the land (74.3 ha) is covered by pine forest. The average precipitation in the period 1979-85 was 1 150 mm, with a standard deviation of 50 mm. The mean pH of the precipitation during the period was 4.3. The runoff from Lake Gårdsjön during the same period was 611 mm and the water had pH 4.7 (a certain neutralisation takes place in groundwater).

The data used for the calculation of liming was the following: The lake volume is 1.5 million m^3. During a three-year period a total of 4 1 million m^3 of water will flow through the lake. A total of 5 6 million m^3 then had to be treated for the three-year project. Titration of lake water showed that the Ca concentration had to increase by 5 mg/l (= 0.25 meqv/l) to reach 7 mg/l, a pH of 7.0 and alkalinity of about 0.2 meqv/l on an average over the three-year period. In practice the pH and alkalinity will be larger in the beginning and then slowly decline.

The amount of Ca needed according to the above is 28 tonnes of Ca or 70 tonnes of $CaCO_3$. In practice not all limestone is dissolved, and impurities are present. The limestone used had an expected dissolution of 80 % and a $CaCO_3$ content of 79 %. The corrected dose is thus 110 tonnes. If this dose had been used for all lakes in the catchment an average pH of 6.5 and alkalinity of 0.10-0.15 would have been reached in Lake Gårdsjön over a 5-year period.

The application of lime was made from a raft using lime suspended in lake water. Eighty percent of the lime was applied close to the shore to create the best possible conditions for fish and benthic organisms; 20 % was applied in the deep areas. The treatment was carried out between 28 April and 1 May 1982. The amount spread corresponds to 23.3 mg/l of Ca in the lake as a whole.

The acidification of the lake is shown in Figure 11.6. Microbial activity decreased immediately after treatment but after several months was back to its original rate, and even above it. Macrophytes changed dramatically as a change from one species to another took place. Fish were later introduced in the lake.

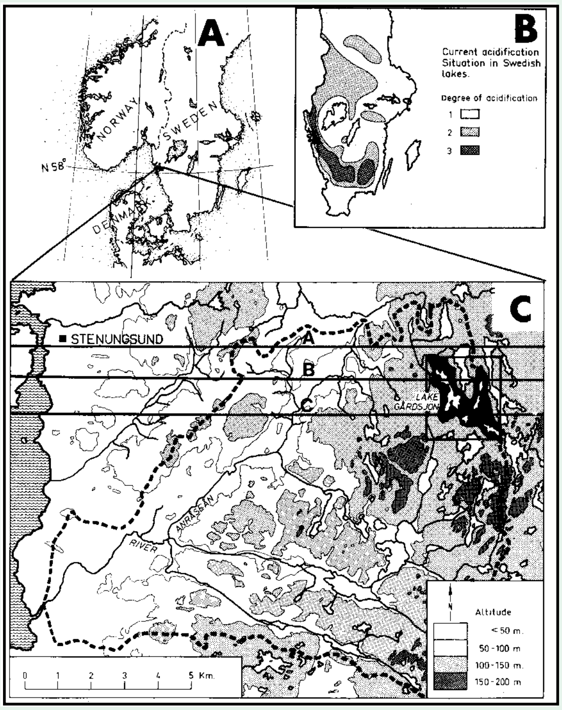


Figure 11.6. The Lake Gårdsjön catchment is situated in southwestern Sweden. The catchment belongs to the area where the acidification is most serious. Three levels of acidification are shown: (1) Less than 50 % of lakes with pH < 5.5); (2) At least 50 % of lakes with pH < 5.5 some time during the year; (3) At least 30 % of lakes with pH < 5.0 all year. The Lake Gårdsjön catchment is part of the Anråseå River catchment (dashed line).

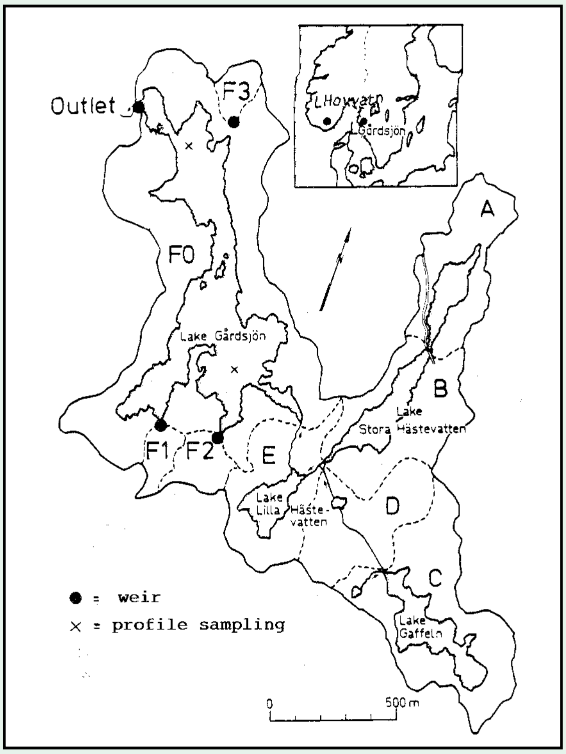


Figure 11.7. Map of the Lake Gårdsjön catchment with watershed divides marked between the lake subcatchments (A-FC) and calibrated subcatchments (P1-F3).

drainage project started. At this point the drainage project itself started to be questioned. The group that had continually argued that the lake should stay a natural reserve got the upper hand and the idea to restore the lake as a bird habitat gained support. In 1989, after a long debate, the Swedish parliament decided to finance a restoration project to restore Lake Hornborgasjön to a bird habitat. The cost of the project was calculated at 50 MSEK (about $US 6 millions).

The restoration itself consists of recreation of a large open water surface by clearing considerable areas of reeds and bushes and by dredging. New machinery for clearing the lake surface has been developed as part of the project. The total wetland area will increase from 27 to 34 km^2.

Acidified lakes

At the end of the 1960s it was observed that many Swedish lakes were severely acidified. In 1967, researcher Svante Odén identified the connection between acid lakes where the fish had died and the long-distance transport of sulphur through the atmosphere. The lakes were located in forest areas with poor soils on the Swedish west coast. The release of sulphur is connected to the use of fossil fuels (oil and coal) for transport, heating and industrial activities.

The monitoring of lakes has shown that in Sweden 15 000 lakes out of a total of 92 000 lakes with an area greater than 1 ha are assessed as acidified. The release of sulphur in Europe reached a maximum during the 70s. Reduction of the sulphur content in oil and reductions of emissions from point sources (power plants and industries) has reduced deposition of sulphur and an increased pH in the precipitation. But deposition of nitrogen is also a cause of acidification. Release of nitrogen oxides and ammonia to the atmosphere results in deposition of two forms of nitrogen; nitrate (NO_3^-) and ammonium (NH_4^+). In the ecosystems that are most sensitive to acidification, the forest ecosystems, both nitrate and ammonium are attractive nutrients. If the vegetation takes up the nitrogen, no net acidification is induced. If, however, there is a surplus of nitrogen in the soil that is transported with the groundwater to surface waters, there is an acidification effect from nitrogen.

If the pH in the forest soils is decreased to levels below approx. 5.3, aluminium will be dissolved in soil water. Free aluminium ions may damage the fine roots of trees, and disturb vegetation further down in streams and lakes. Fish and other biota are severely damaged by low pH values.

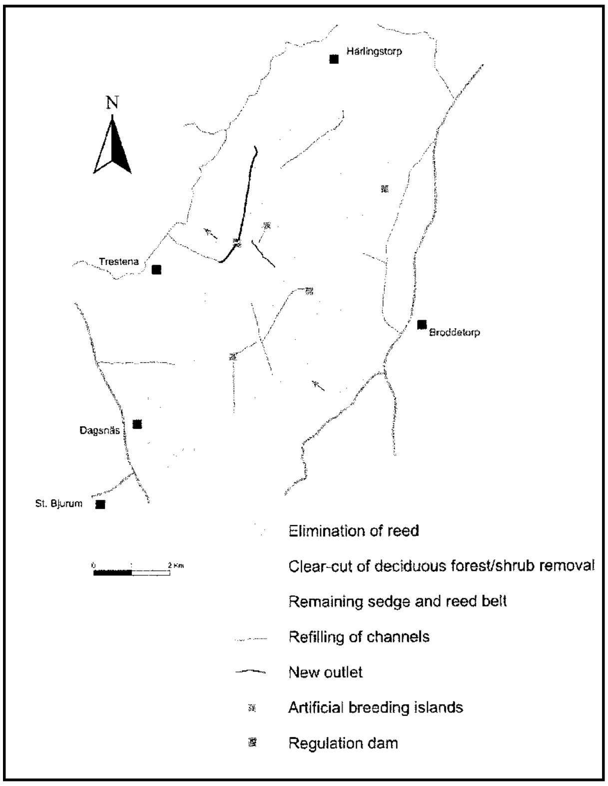


Figure 11.8. A map of the restoration measures carried out in Lake Hornborgasjön. Removal of bushes (darker grey around the entire lake), removal of reed beds (slightly lighter grey in the upper right hand area), conserved reed beds (light grey), new breeding islands for birds (small black squares) (Hertzman & Larsson, 1999).

The acidification of forest soils is worst in the south-western parts of Sweden, where the acid deposition is the highest; pH could be as low as 4-5 down to 2.5 m in depth. Most soils in the southern and middle parts of Sweden have decreased pH in the upper horizons of the mineral soil. In northern Sweden no significant soil acidification has been observed. Groundwater from the acidified land areas brings acidity to the streams and lakes.

Considerable research activity during the 1970s resulted in a series of efforts to restore the pH values in the lakes by liming. The first liming operation was carried out in the 1970s. A total of 7 500 lakes and about 11 000 km of streams have been limed since 1977 in a state-financed program under the supervision of the Swedish Environmental Protection Agency (SEPA). The annual cost of the programme is about 100 MSEK ($US 13 millions).

Lake restoration – polluted lakes

In a national survey the SEPA concluded that in the country as a whole there are some 22 000 sites with contaminants hazardous to human health and to the environment. In a long-term programme SEPA has set the goal of identifying these sites, investigating

The lake Järnsjön project

The challenge consisted in removing the contaminated sediments without causing a damaging increase of existing leakage to the river basin. Dredging was carried out with a suction device equipped with an auger designed not to spill more than 1 % of the material. A geo-textile screen was mounted in the highly contaminated areas in the eastern part of the lake to protect the river.

The sediments were further dewatered mechanically to reach 35 % dry solid content. The water returning to the lake was not allowed to contain more than 50 mg/l of suspended matter, which would give a total of 2 kg of PCB during the entire project. The dewatered material was deposited on a site west of the lake. This new landfill, requiring 5 ha, was situated well above the lake level even during high water levels. The most contaminated sediments were deposited in a specified area and secured with a mat of geo-textile screen to allow for treatment with new, unknown methods at a later date, if possible.

The entire landfill was covered with 1.2 m of uncontaminated material and then sown and restored as pastureland. Monitoring of the river during the entire project period was carried out to safeguard against toxic amounts released by accident.

In the project, 150 000 m^3 of sediments were removed, including a total of 394 kg of PCB. In the area treated, 2.9 kg of PCB was left. At a new site near the lakeside 7.4 kg of PCB was identified. No increases in PCB levels have been found in the groundwater below the landfill. After remediation, PCB levels in sediments decreased from 5 to 0.06 microgram/g dry weight. In water, the levels decreased from 8.6 ng/l in 1991 to 2.7 ng/l in 1996. PCB levels in fish decreased from 34 mg/kg fat to 16 mg/kg fat.

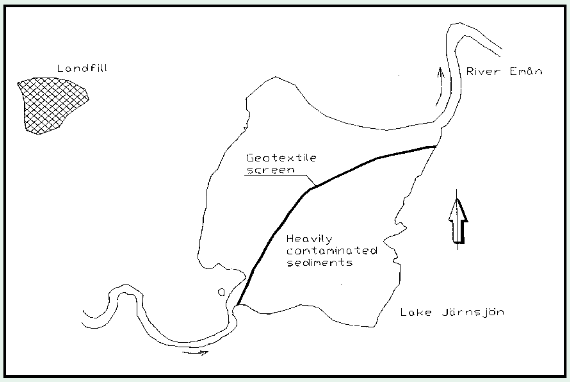


Figure 11.9. Map of Lake Järnsjön showing the position of the geo-textile screen used during dredging in 1993 and the location of the landfill (Elander & Hammar, 1998).

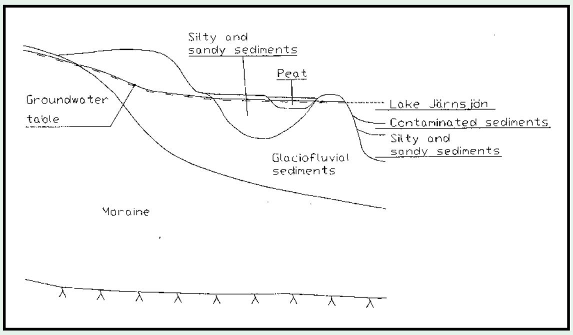


Figure 11.10.The principal geological conditions in the Lake Järnsjön area (Elander & Hammar, 1998).

and remediating them over a 40-year period. Several hundred of them involve contaminated sediments, the most serious containing sizeable amounts of methyl mercury and/or PCB. For example, downstream of a number of paper and pulp plants, wood fibre contaminated with methyl mercury has accumulated in lakes and rivers and along coasts. At other sites, where former gas factories or sites for tar treatment of wood and timber were situated, large amounts of creosote contaminate the soil. At some 3 000 landfills in the country there are a plethora of unidentified organic pollutants as well as heavy metals leaking to water. In lakes close to some of these landfills ecological disturbances and damages to fish populations have been connected with leakage from the landfill.

It has sometimes been assumed that it would be very difficult to remove contaminated sediments in an economically and environmentally sound way. To test several methodologies, a project was carried out in the PCB contaminated Lake Järnsjön in southeastern Sweden.

The Lake Järnsjön Project

Lake Järnsjön illustrates the disastrous effect that a slowly leaking source of a persistent toxic pollutant may have on an entire ecosystem. The lake is situated in the Emån River catchment, which is famous for its unusual biology and its fine fishing. The Emån River is considered a watercourse of national interest for biological, cultural and recreational reasons. Much of the original meanders of the river and its beautiful valley are intact. It has a large variety of habitats in the catchment and a considerable biodiversity both in aquatic and terrestrial environments. The river has more than 30 species of fish, among them the very unusual sheatfish, sea trout, char, several red-listed benthic organisms and otter, now rare in Sweden.

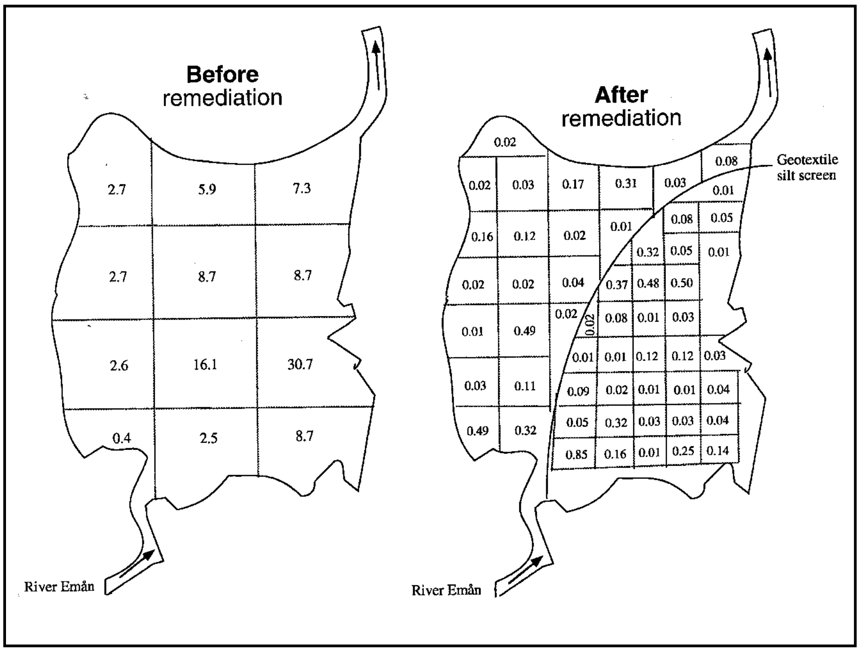


Figure 11.11. The distribution of PCB concentrations in sediment of Lake Järnsjön before and after remediation. PCB concentrations given in mg/gdw). Before remediation 12 areas were sampled; after remediation 54 areas were sampled. The line dividing the lake marks the position of a geo-textile silt screen used to hinder resuspended particles from reaching the river channel during the dredging in the eastern and most contaminated part of the lake (Bremle et al., 1998).

The Emån River is 220 km in length. Its drainage basin is 4 500 km^2, covering the whole or parts of four counties and eleven municipalities. The upper part of the catchment has many lakes while the lower has none. The lake percentage of the catchment is about 5 %. Precipitation over the year averages some 700 mm for the highlands and 500 mm at the coast. The entire catchment is characterised by coniferous forests. There is very little agricultural land, which is found mainly at the coasts and in the river valley.

A large number of industrial enterprises are or have been situated along the Emån River and its tributaries. Before adequate pollution control was adopted for these plants, large quantities of pollutants were discharged into the watercourse. In the mid-1970s a Ni/Cd battery factory discharged large amounts of metals into the river to give it about a 20-fold concentration of Cd as compared to upstream. Later, measures were taken to reduce leaking from slag deposits close to the riverbank, which much improved the situation. Still, the Emån River is one of the most Cd polluted waters in the country. In one of the tributaries an accumulator factory released large amounts of lead. Even today this part constitutes a point source of lead to the river.

Paper and sulphite pulp were manufactured at four paper mills located in the catchment for more than 100 years. Paper-pulp deposits containing, among other chemicals, mercury, PCB and PCN, have heavily contaminated parts of the river system. Mercury was used in production up to 1968. PCB was prohibited in 1972. From that year on, sewage treatment plants were built to reduce the effluents of paper and pulp to the river. In one paper mill, situated along the main stream, PCB-contaminated self-copying paper was recycled in the production process. Large quantities of PCB-containing paper fibres sedimented in Lake Järnsjön, situated downstream of the site.

Elevated levels of PCB were measured in the early 1980s in foam found at the mouth of the Emån River. High levels of PCB were also measured in fish (140 mg/kg of fat). The source of the PCB was identified as Lake Järnsjön, and the amount in the sediments was estimated to be about 400 kg of PCB in about 150 000 m^3 of sediments. Based on a yearly discharge of about 7 kg PCB it was estimated that the discharge would have caused problems at least up to year 2060 – and probably much longer – if nothing were done. Remediation was therefore considered to be an important alternative.

The Swedish EPA initiated the remedial project and was responsible for the research and detailed planning in the period 1990-92. The municipality was responsible for the project itself in 1992-94. The cost for the initial phase including research and planning was $US 0.8 millions and for the entire project $US 6.4 millions.

Lakes with elevated levels of radioactive caesium

The nuclear accident at Chernobyl resulted in large parts of Sweden being contaminated with radioactive fallout in late April to early May 1986. One result was that fish in about 14 000 lakes in Sweden had levels of radioactive caesium-137 above the acceptable level for marketing fish, that is above 1 500 Bq/kg wet weight. Forty-one lakes were treated in various ways in efforts to reduce the levels. The only method that had some effect was treatment with potash, that is potassium salt, where a reduction of 5 % per annum in perch was noted.

Mercury in lakes – a case study

There are about 60 000 publications dealing with mercury (Hg) as an environmental pollutant. But contrary to common belief, Hg does not appear to be a major threat to aquatic life. It is difficult to find environmental effects of mercury in aquatic ecosystems (although there are effects on birds), and of other heavy metals in natural waters as well. This depends, for example, on the affinity of metals to become bound to different types of carrier particles (e.g. clay minerals, humus and algae), whereupon the biological uptake of the metals is more difficult. Thus, mercury does not constitute any known threat to aquatic ecosystems. However, it is certainly a threat to the foetuses of pregnant women if the mother eats Hg-contaminated fish. The effect variable, which has been used for Hg for many years, is the Hg-concentration in 1-kg pike (*Esox lucius*). Pike is a stationary predator eaten by humans. Evidently, this is not an effect variable in the same way as reproductive disturbances in roach or mortality in crayfish due to acidification (Figure 11.12). However, it is the effect variable that is of greatest interest in the case of mercury.

The mercury load

Mercury concentrations in soil, water and lake sediments have increased by a factor of four to seven in southern Sweden and by a factor of two to three in the north of the country (Hellner et al., 1991; Lindqvist et al., 1991) due to increased emissions during the last century. The distribution pattern can partly be explained by known, historical, domestic discharge sources. The largest point sources for Hg to air (1920-1987) in Sweden were Rönnskär, Skutskär/Korsnäs and Bohus, which have caused considerable increases in the concentration of Hg in the mor layer; the discharges from Domsjö/Köpmanholmen, Östrand, Strömsbruk and Skoghall have caused a more diffuse influence.

The Hg-concentrations decrease with the distance from a major discharge source (such as Rönnskär). For the Rönnskär area, Hg-gradients in the mor layer may be observed up to about 150 km; the area of influence is up to 1 000 km, i.e. a very large impact area.

Levels in fish have increased five-fold in large parts of the country. The concentration of Hg in over 10 000 out of a total of almost 100 000 Swedish lakes is deemed to exceed the "blacklisting limit" of 1 mg Hg/kg wet weight (ww) which applies in Sweden (related to 1-kg pike). About 40 000 lakes have fish (pike) with Hg-concentrations higher than the guideline value of 0.5 (Nilsson et al., 1989). The levels are still rising in most lakes. The long-term environmental goal set by the Swedish Environmental Protection Agency is that the level of Hg in fish must not exceed 0.5 mg/kg ww. This would mean that most people would be able to eat fish from lakes without having to consider health risks.

Load-effect studies

Figure 11.13 depicts an effect-load-sensitivity (ELS) model for mercury in a 3D-diagram. The effect variable (Hgpi, the Hg-concentration in 1-kg pike) depends on how the pike has lived and what it has eaten during a long period before being caught (the half-life for Hg in 1-kg pike is about three to four years). The Hg-concentration in pike is an integrated value for the entire environment of the pike and its prey. The Hg-content in pike depends on the Hg-load supplied to the entire ecosystem, not only to the clump of reeds where the pike was caught. It also depends on the biological, chemical and physical conditions of this ecosystem over a long period, since these conditions influence the distribution of the Hg-load on different carrier particles and the bioavailability of the Hg-load. Hence, the biouptake of Hg in pike and its prey also depends

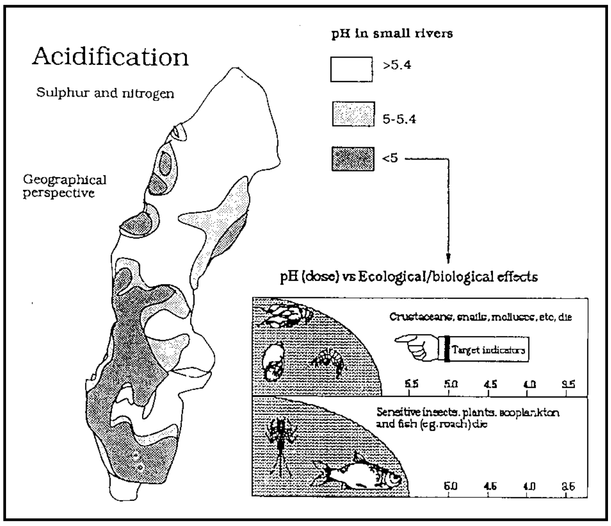
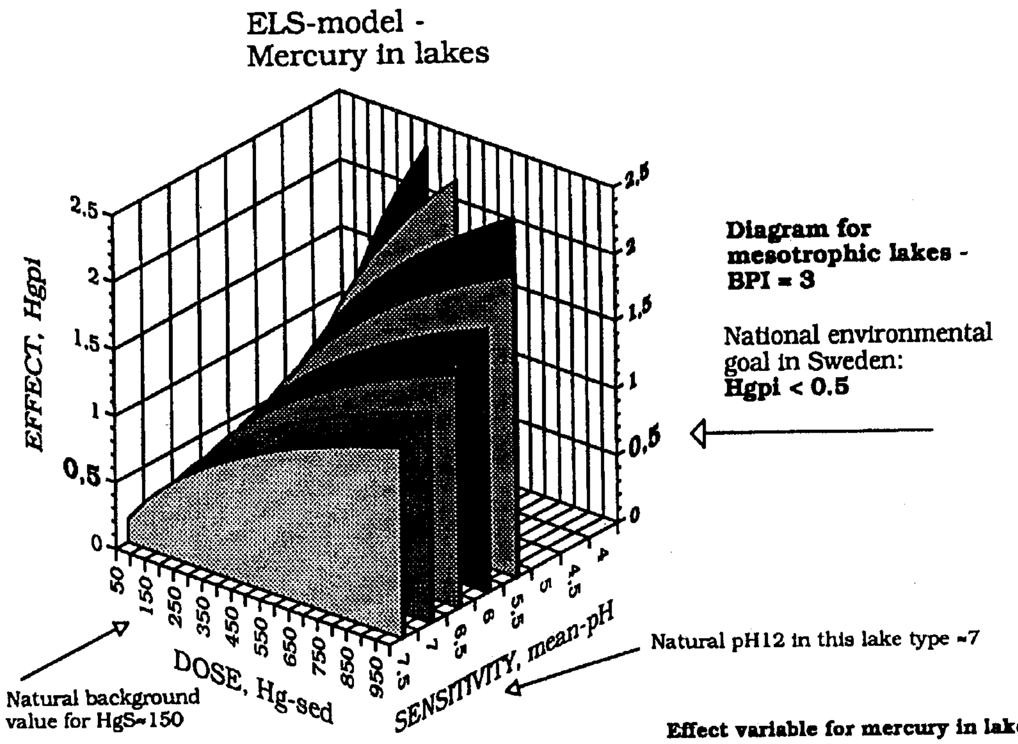


Figure 11.12. A map of Sweden illustrating the lowest measured pH in small rivers (1971-1985) and lake pH associated with different ecological effects (based on Monitor, 1986). From Håkanson & Peters (1995).



<u>Deterministic model (from Håkanson, 1980)</u>:

Hgpi=(4.8*log(1+HgS/200))/((pH12-2)*log(BPI))
(r^2=0.74; n=18)

Legend:

<u>Load variable</u>: HgS=median Hg-content in µg Hg/kg dw from surficial (0-1 cm) sediment samples
<u>Sensitivity variables</u>:
1. pH12=yearly mean lake pH
2. BPI=bioproduction index; based on surficial sediment data on nitrogen content and IG (loss on ignition in % dw)

Traffic rules and limitations:

80<HgS<2040
4.8<pH12<7.6
2.9<BPI<5.2

Model NOT applicable:

- For lakes smaller than 1 km^2
- For dystrophic lakes with IG > 25 %

Effect variable for mercury in lakes

Hgpi: Hg-content in muscle in 1 kg pike in mg Hg/kg ww (at least 5 fish in the size range from 0.5 to 1.5 kg from each lake should be analysed)

- area resolution: entire lake for lakes smaller than 25 km^2
- time resolution: ≈ 3-4 years

All load and sensitivity variables should have the same area and time resolution as the effect variable

Other effect variables:

None (except Hg-content in muscle from other species of fish for human consumption)

Figure 11.13. ELS-model for mercury in lakes. From Håkanson (1994).

on the conditions in the entire lake. The pH of the water is important for the binding of mercury to different types of carrier particles and for how Hg is distributed among different Hg-forms, such as Hg^0, Hg^+ and methyl-Hg.

In the model in Figure 11.13, pH statistically explains the greatest proportion of the variation among the lakes in the effect variable when tested against in independent set of data from 18 Swedish lakes. The next-most important factor, according to the stepwise regression, was the Hg-load to the lake (HgS, i.e. the median Hg-content of surficial sediment samples, 0-1 cm, reflecting the load to water and sediments for a period corresponding to the mean age of this sediment layer). It is interesting to note that a sensitivity factor can, in fact, be more important than a load factor in explaining the variation in an effect variable. If pH and HgS are pooled, this model can statistically explain 63 % of the variation in Hgpi among lakes. If one further sensitivity factor is added, the lake bioproduction index (BPI), the r^2-value increases to 0.74. The latter link is also interesting since it demonstrates that the Hg-concentration in fish is not only increased by *acidifica-*

tion, a case of synergistic effect, but is also associated with the third major environmental problem in aquatic systems, *eutrophication, a case of antagonistic effect*. The greater the BPI, the greater the production of algae, plankton and fish, and the greater the amount of biomass in the lake. This implies that a given Hg-load is spread over a larger biomass whereupon the Hg-content in the biomass becomes less ("biological" dilution). This is one explanation why BPI is important. Another concerns internal correlations: If the biopro-duction in a lake is increased, the entire character of the ecosystem is changed.

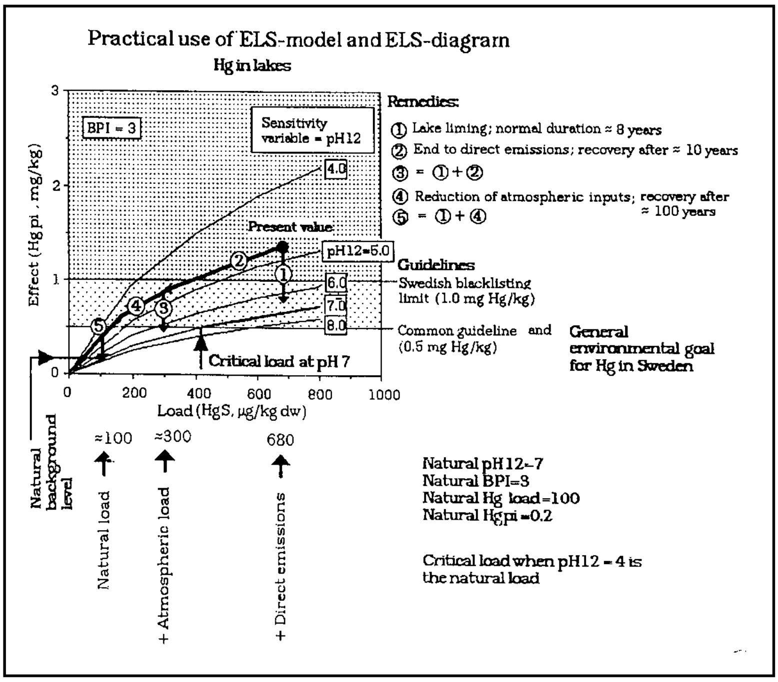


Figure 11.14. ELS-diagram based on the ELS-model for mercury in fish given in figure 11.6. The figure also indicates how practical guidelines, critical limits, natural background levels, environmental goals, etc. may be defined from the model and results of different remedial measures. From Håkanson (1994).

Application

How can load models and effect-load-sensitivity models be *used in practice*? Figure 11.14 (a 2D-version of Figure 11.13) exemplifies this for a constant bioproduction (BPI = 3, the limit between oligotrophy and mesotrophy; see Table 11.1) Hgpi increases when the Hg-load (HgS, the Hg-content of surficial sediments) increases and the mean annual pH (pH12, sensitivity) decreases. It also illustrates how this ELS-model may be used in remedial contexts in a highly polluted (HgS = 680 mg Hg/kg ww; a natural background value for HgS is about 100) and severely acidified (pH12 = 4.8) lake. On the basis of this model, one can determine which measures could be used to decrease the Hg-content in fish:

- The direct emissions of Hg to the lake could be halted (step 2 in the figure). But the Hg-content in pike will not decrease the day after direct emissions are halted. The time lag is rather long. It would take up to 10 years for the Hgpi-values to adjust to the new situation.
- The atmospheric Hg-emissions could be reduced. This would cause a reduction in the atmospheric Hg-deposition and, in due course – centuries (Håkanson & Peters, 1995) – also in the secondary Hg-load from the catchment.
- Sensitivity parameter 1, pH, could be increased (e.g. by liming; steps 1, 3 and 5 in the figure). The duration of the remedy would depend on the amount of lime added, the initial alkalinity, the size of the lake and the lake water retention time. For lakes of this type (glacial lakes), a liming would often last about four years; the retention time of Hg in pike is about three to four years.
- Sensitivity parameter 2, bioproduction, could be increased (e.g. by fertilisation, i.e. adding of phosphorus; see Håkanson et al.., 1990a). Naturally, the bioproduction, BPI, must not be increased indiscriminately to reduce the Hg-content in fish. That could lead to an eutrophication problem!

Figure 11.14 also illustrates that a *natural* pH in this lake would be about 7, a natural BPI = 3, a natural Hg-load (HgS) about 100 mg/kg dw and a natural Hgpi-value about 0.2 mg/kg ww. The different remedies, from lake liming to the halting of anthropogenic Hg-emissions, would bring Hgpi down in this lake from the very high initial value of about 1.4 to 0.2. The numerical values in the figure illustrate the different routes to achieve this natural end-point.

The *critical load* may also be defined from the ELS-model/diagram. This is the load were the effect variable reaches the level of the environmental goal. The critical load corresponds to a load of about 420 in a non-acidified lake and is equal to the natural load (100) in a lake with a mean annual pH of 4. Such environmental goals and critical loads are of great importance in water management. They get true, scientific meaning first after an ELS-model has been properly validated.

Critical loads and sewage treatment

This ELS-model may also be used to highlight an interesting, apparently paradoxical consequence of sewage treatment. Assume that a city plans to build a treatment plant. Before the treatment, the conditions in the lake are assumed to be as follows:

Loading models

How does an ecosystem respond to a certain load of pollutants? We will in this chapter, by using quantitative models, examine how a lake reacts to pollutants. The main task is then to develop a model that describes how the pollutants flow into the lake, how long they are retained in the lake, and when they leave the lake. This loading model may to some extent then be used for any aquatic ecosystem used as a recipient for polluted water.

A simple mass-balance model for an entire lake is depicted in Figure 11.17. Most dynamic mass-balance models are based on the fundamental principles illustrated in this section. Thus, if one knows these few principles, then one can construct many types of dynamic models.

A typical model envisions the lake as a "tank reactor" in the sense that the lake contents mix completely during an interval of time, dt. The flow of matter or, in this case, of a given substance, to and from such a lake may be described by the differential equation presented in the Box The loading model or "tank reactor" (See page 126). The simplest way of solving this equation is to assume steady-state conditions. That means that mass is conserved, so that outflow equals inflow:

$$Q_{in} = Q_{out}$$

How long does the water stay in the lake?

The lake water retention time (T, in days, months or years) is a crucial concept in lake management. It is defined as the ratio between the lake volume and the water discharge:

$$T = V/Q \qquad (11.1)$$

T, which is also called the residence time or turnover time, is the time it would take to fill a lake of volume V if the water discharge to the lake is given by Q.

Q could be derived from a time-series of measurements, or given as a mean monthly value, or, most often, as a mean yearly value. In the latter case, one generally refers to T as the theoretical lake water retention time.

The retention time of a chemical or of suspended particles (T_r in time units) is defined in the same way:

$$T_r = V \cdot C/(Q \cdot C_{in}) \qquad (11.2)$$

The relationship between the water retention time (T) and the substance retention time (T_r) is most important. By definition, T is equal to T_r for water and for conservative or non-reactive substances, i.e., substances which do not change (settle, evaporate or react in the lake); $T_r < T$ for most allochthonous particles and pollutants (i.e., those which are transported to the lake from the catchment).

The concentrations of most substances change in the lake because the allochthonous particles settle out. This settling results in a typical lobed pattern of contaminant levels in the sediments, decreasing with distance from the local source of pollution (e.g., the river mouth). This is illustrated in Figure 11.15 for mercury, a typical allochthonous contaminant that we will meet again later. In principle, this pattern should also be found in the water, but often those patterns are obscured by temporal variability.

The steady state situation

By setting dC/dt = 0, we can determine the steady-state solution to Equation 11.6 (See page 126) and solve for C, the equilibrium concentration of the substance of interest:

$$C = Q \cdot C_{in}/(Q + K_T \cdot V) \qquad (11.3)$$

or

$$C = C_{in}/(1 + K_T \cdot T) \qquad (11.4)$$

Equations 2.3 and 2.5 imply that:

$$T_r = T/(1 + K_T \cdot T) \qquad (11.5)$$

Substances with large K_T-values settle rapidly near the point of discharge, whereas substances with small K_T-values may be distributed over much larger areas. For contaminants that are not broken down in the lake or lost to the atmosphere, K_T is related to the settling velocity, v ($v = z \cdot K_T$, where z is the distance through which the particle sinks in the given time interval; Håkanson & Jansson, 1983). The settling velocity, v, is generally given in cm/s.

A QUANTITATIVE MODEL

Given K_T or v, one can model or predict where high and low concentrations are likely to appear in water and sediments. This is fundamental to predicting where high and low ecological effects may appear.

Settling of particles (see Equation 11.7 on page 126)

It is important to note both the similarities and difference between the settling velocity (v in cm/s) and the turnover rate (K_T in s^{-1}).

The behaviour of material that follows Stokes' law (i.e., particles with a diameter between about 0.01 and 0.0001 cm) differs from that of the coarser friction material and from that of still finer material. The sedimentological behaviour of the friction material is closely linked to the grain size of the individual particles (Hjulström, 1935; Einstein, 1950; Ippen, 1966; Allen, 1970) whereas Brownian motion governs the sedimentological behaviour of the very fine materials. These latter particles are so small that they will not settle individually, but will do so if they form larger flocs or aggregates which are dense enough to settle according to Stokes' law (Kranck, 1973; 1979; Lick, 1992). The cohesive materials that follow Stokes' law are very important, since they have a great affinity for pollutants. This group includes many types of detritus, humic substances, plankton, and bacteria. All play significant roles in aquatic ecosystems (Wetzel, 1983; Salomons & Förstner, 1984).

The settling velocity (v) of a given particle, aggregate, or particulate pollutant, and its distribution in a lake, depends on the density, size and form of the particle, and on the hydrodynamics of the flow of water in the lake. If the particle density, r_s, is close to 1, if the form factor, Ø, is large, and if the diameter, d, is small, the settling velocity, v, and the turnover rate, K_T, may be very small. If K_T is close to 0, the particle or aggregate is conservative in the sense that it may not be deposited in the lake.

Data from Lake Ekoln, Sweden (Figure 11.16) demonstrates that Cl, Ca and alkalinity are typically conservative substances, and that colour, organic matter, total-P, Si, particulate-P and suspended matter are much more reactive at least in this lake. Figure 11.16 plots the lake input concentration, C_{in}, of many different substances on the x-axis, against the lake concentration, C, on the y-axis to show that the K_T-value and the theoretical water retention time, T, regulate the difference between C_{in} and C.

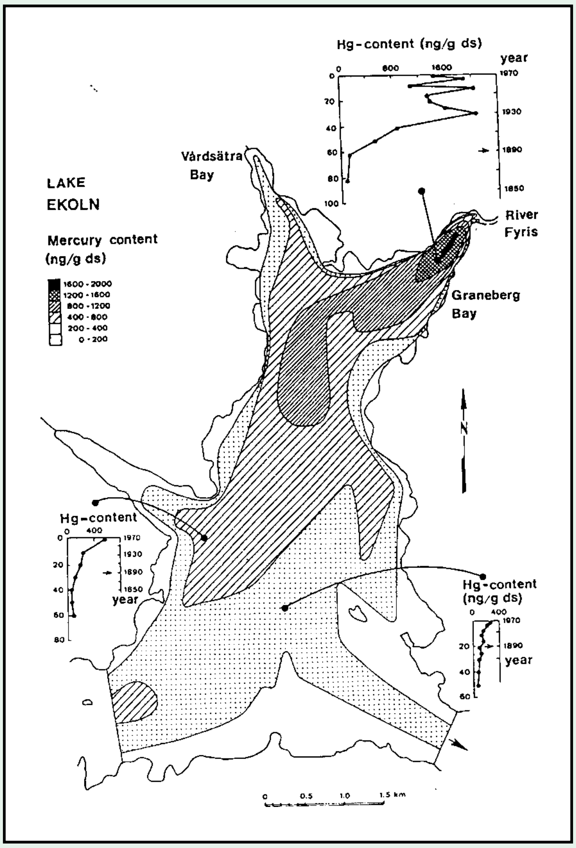


Figure 11.15. Mercury in Lake Ekoln, Sweden. A typical distribution pattern of an allochthonous pollutant (mercury) which is transported to the lake by the river (here River Fyris) and then deposited in the lake, where lobes of decreasing sediment concentrations occur with distance from the mouth of the tributary. Insets show the vertical distribution of mercury in the mud at three sites, with depth (in cm) on the left axis and sediment age on the right. Values in ng Hg per gram dry sediments (ds; same as dry weight, dw). From Håkanson & Jansson (1983).

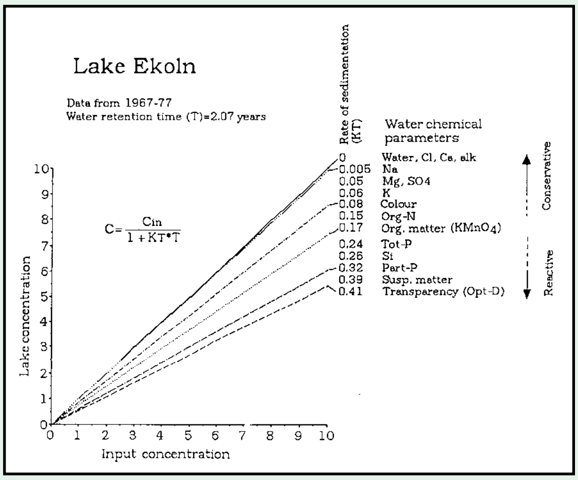


Figure 11.16. The relationship between input concentrations (C_{in}) and lake concentrations (C) for various water chemical parameters with different sedimentation rates (K_T). Redrawn from Håkanson & Jansson (1983).

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The loading model or "tank reactor"

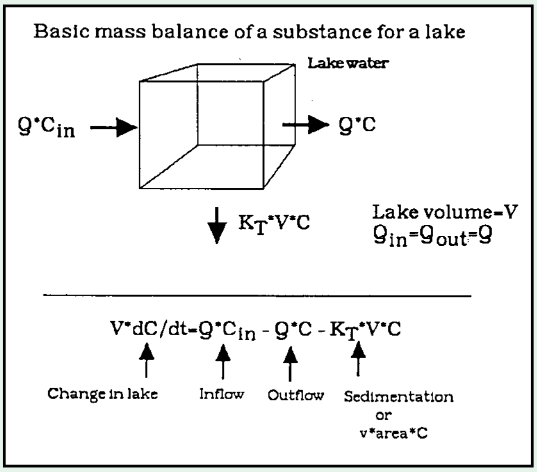

Figure 11.17. The basic components of the mass-balance equation of a substance for a lake. Q is the water discharge to the lake ($Q_{in} = Q_{out}$), C is the concentration of the substance in the inflow (C_{in}) and in the lake and its outflow (C), K_T is the rate of sedimentation (1/time), v is the settling velocity (length units/time), V is lake volume, area is lake area, dC is the change in concentration during the time, dt. From Håkanson & Peters (1995).

The flow of matter to and from a lake may be described by the differential equation

$$V \cdot dC/dt = Q \cdot (C_{in} - C) - K_T \cdot V \cdot C \quad (11.6)$$

V = lake volume; If L represents the dimension of length, the dimension of volume is L^3; its units are usually m^3 or km^3. Other relevant dimensions are T, for time, and M, for mass.

dC/dt = the change in lake concentration (dC) of the given substance per unit of time (dt). The dimensions are $M/(L^3T)$ and the units are usually g/l/day or kg/m^3/day.

C = the concentration of the substance in the lake, which is often set equal to the outflow concentration, as it is here. Its dimensions are M/L^3 and its units usually g/l or kg/m^3.

C_{in} = the concentration of the substance in the tributary; it has the same dimensions and units as C.

Q = the tributary water discharge to the lake (L^3/T, usually expressed as m^3/s).

K_T = the turnover rate (sometimes called the rate constant, but since most rates are not constants, but have values which vary temporally and areally, we will generally not use the term rate constant) of a given substance in the lake. K_T, like all rates, has the dimension 1/T and its unit is usually 1/day, 1/month or 1/year.

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- pH = 7; no acidification.
- BPI = 4.4; the lake is on the verge of eutrophication. This is the main argument for building a sewage treatment plant. The plant would reduce input of phosphorus considerably. The cost for the plant is about $US10 millions.
- HgS = 600 (mg/kg ww); the lake is contaminated by numerous diffuse emissions, e.g. from the urban area (hospitals, dentists, small industries, etc.). The plant would reduce a significant part of those urban emissions.

From empirical measurements, and from the model (Figure 11.16), the authorities would know that the test organism, a 1-kg pike, has a very high Hg-concentration in this lake (0.9), which is just below the "blacklisting" limit but much above the environmental goal. After the plant has been put into operation (and new steady-state conditions have been established), several things will have happened. Direct emissions of phosphorus and BOD (organic substances causing a biological oxygen demand) will have been reduced by 90 %. The corresponding reduction of nitrogen will be 50-60 %. Lake bioproduction will have decreased significantly, from 15 to 3 mg chlorophyll-a per m^3. The corresponding reduction in BPI will have gone from 4.4 to 3. This is anticipated and requested.

A lower production would also lead to a somewhat lower mean pH. The main reason for the re-

Settling velocity of particles

Stokes' law expresses the settling velocity as:

$$v = (r_s - r) \cdot g \cdot d^2)/(18 \cdot \mu \cdot Ø) \quad (11.7)$$

where

v = the settling velocity (L/T, usually in cm/s or m/month)

r_s = the particle density (M/L^3, usually in g dw/cm^3; g dw = grams dry weight)

r = the density of the lake water (often set to 1 g ww/cm^3; g ww = grams wet weight)

g = the acceleration due to gravity (L/T^2, 980.6 cm/s^2)

d = the particle diameter (L, in cm or mm)

µ = the coefficient of absolute viscosity (obtained from standard tables; 0.01 poise at 20 °C)

Ø = the coefficient of form resistance (set to 1 for spheres; Hutchinson, 1967).

Table 11.1. Characteristic features in lakes of different trophic levels. Note that there is a great overlap between the different categories, such that in oligotrophic lakes the concentrations of total-P may vary within a year from very low to high values (modified from Håkanson and Jansson, 1983).
B. Trophic categories in Baltic coastal areas. All variables are expressed as summer mean values (from Wallin et al., 1992). Chl-a = Chlorophyll; SedS = Net sedimentation; O_2B = oxygen conc. in bottom water; O_2Sat = oxygen saturation. From Håkanson (1994)

A.

Trophic level	**Primary[a] prod.** (g C/m²yr)	**Secchi depth** (m)	**Chl-a** (mg/m³)	**Algal[a]** vol. (g/m³)	**Total-P[b]** (mg/m³)	**Total-N[b]** (mg/m³)	**Dominant fish species**
Oligot.	<30	>5	<2.5	<0.8	<10	<350	Trout, Whitefish
Mesot.	25-60	3-6	2-8	0.5-1.9	8-25	300-500	Whitefish, Perch
Eut.	40-200	1-4	6-35	1.2-2.5	20-100	350-600	Perch, Roach
Hypert.	130-600	0-2	30-400	2.1-20	>80	>600	Roach, Bream

[a] = Mean value for the growing period (May - Oct.)
[b] = Mean value for the spring circulation

B.

Trophic level	**Secchi** (m)	**Chl-a** (mg/m³)	**Total-N** (mg/m³)	**Inorg-N** (mg/m³)	**SedS** (g/m²/d)	**O_2B** (mg/l)	**O_2Sat** (%)
Oligot.	>6	<1	<260	<10	<2	>10	>90
Mesot.	3-6	1-3	260-350	10-30	2-10	6-10	60-90
Eut.	1.5-3	3-5	350-400	30-40	10-15	4-6	40-60
Hypert.	<1.5	>5	>400	>40	>15	<4	<40

Table 11.2. Predicted effects from the installation of a new sewage treatment plant on a hypothetical lake, as given by the ELS-model in Figure 11.13. Fish are blacklisted in Sweden when the mercury burden exceeds 1.0 mg/kg ww. From Håkanson and Peters (1995)

	Before plant	**After plant**
Trophic level	mesotrophic	oligo-mesotrophic
Bioproduction index, BPI	4.4	3
Chlorophyll-a (mg/m³)	15	3
Mean pH	7	6.6
Hg-content in sediments, HgS (µg/kg dw)	600	350
Hg-content in 1-kg pike, Hgpi (mg/kg ww)	0.9	1.05
Blacklisting (in Sweden), 1.0 mg Hg/kg ww	No	Yes

duction of 0.4 pH units is that the high pH-values during the bioproductive season have decreased. The new mean pH is 6.6. The sewage treatment has also lowered the direct Hg-emissions. Measurements reveal that 50 % of the urban Hg is reduced [0.5·(600-100) = 250]. The new Hg-load is 350 (= 600-250).

On the positive side, it may also be noted that the Secchi depth has improved. Thus, the lake looks cleaner and the bioproduction has been reduced to about the normal, pre-industrial level. But what about the Hg-content in fish?

Table 11.2 summarises the results of this hypothetical but realistic example. *The data show that after the treatment, the authorities would have to blacklist the lake!* The figures given in the table indicate that it may not always be ecologically wise to build expensive treatment plants. The main reason for this result is, of course, that it would never have happened, had there been no atmospheric Hg-deposition from large-scale emissions linked to the use of fossil fuels and to industrial emissions. That part of the Hg-load is not controllable by the local authorities. Another reason for this result is that both bioproduction and pH were lowered, thereby increasing the sensitivity to Hg-contamination.

Part III

Institutions and Legal Instruments

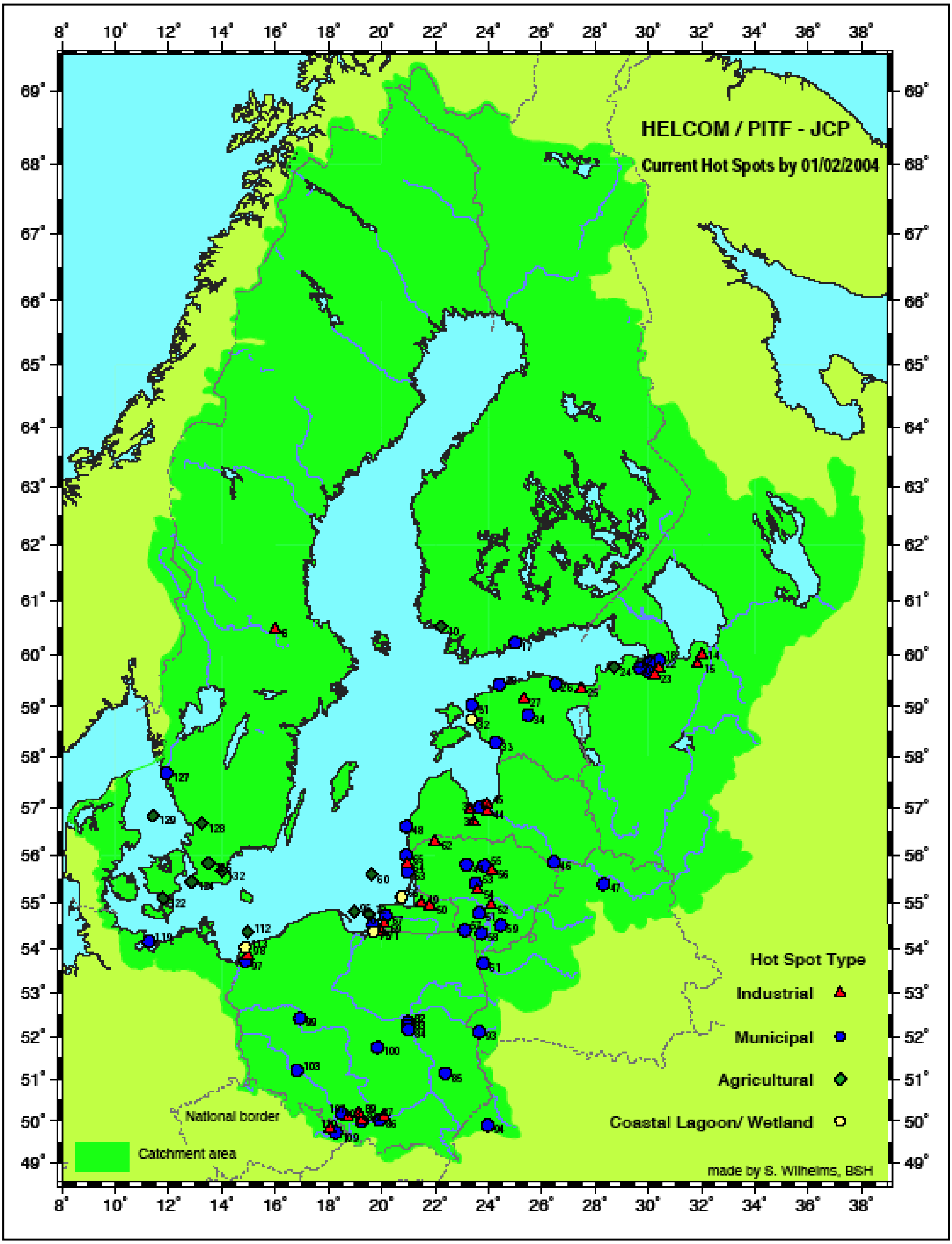

Figure 12.1. HELCOM Joint Comprehensive Environmental Action Programme Hot spots in the Baltic Sea basin. The map is also available at the HELCOM website: http://www.helcom.fi/pitf/currenthotspots2004.pdf)

12.

WATER POLICIES

Lars-Christer Lundin & Lars Rydén

Water management legislation in a state of flux

Today, local environmental problems are gradually being solved. There is a good knowledge base and, if developments are too slow, it is often a question of finding economical solutions to speed them up. The major environmental issues have shifted into diffuse-source problems, global change, pollution of international catchments and seas, continental-wide air pollution, ozone holes etc. No single administrative body, be it a ministry, can solve these problems. The developments of water policies, involving regions, countries or even taking a global perspective that started in the 70s, has accelerated, becoming an important way of dealing with large-scale environmental issues in the 90s.

The management of waters in Europe today is essentially based on national strategies, authorities and legislation. These are quite different in the different countries. Often they have a very long tradition, in fact back to medieval times, and have been developed as part of local administrative traditions. Most often, however, they do not take into account the fact that water passes over administrative borders (sometimes new) within and between countries; neither adapted them to the European integration.

It is clear that the existing legislative and administrative structures for water management are in a state of change in many countries in the region. It is thus futile to make a detailed description of the situation in each country. Instead, we devote a chapter to a short description of the present situation in Sweden as one example of the existing structures. This chapter will discuss some of the various policies, directives, conventions, protocols, agreements and co-operation projects related to water management in the Baltic region. The most important directives for the next century will probably be the EU directives.

As an introduction, we will describe the ongoing work for the European integration of water management as expressed in the *Water Framework Directive* of the European Union accepted by the Commission in 1998. This directive will, in the future give the great majority of the European states the same basic administrative structure and the same basis for decision-making on water issues. It is clear that it will break with national traditions practically everywhere, as it does not start out from the municipality, county or national authorities for administration but, on the contrary, with the water situation, that is the catchment area.

The policies will be used as a basis for national legislation, regional recommendations and local practice. In parallel with this trend is the idea that, if common people change their ways of living – their ways of managing their daily life (e.g. their consumption patterns and their waste, water, and energy management) – the sum of all these family-level management changes will make a difference. These ideas are developed in the local Agenda 21 work, trying to increase people's awareness and readiness to actively strive for a better and more sustainable environment and use of resources. There is also a Baltic 21, an agenda for the Baltic Sea region that will be briefly discussed in this chapter. The Baltic Convention, today perhaps the most well known policy in the region, specifically targeting on the Baltic Sea, will also be presented. The Convention is known by the abbreviation of its Baltic Marine Environmental Protection Commission, the Helsinki Commission (HELCOM).

New policies are developed, old ones are updated and new countries adopt the policies. Often the time between signing and being put in force is several years. It is not easy to get the latest version of all relevant policies when needed. In most cases, however, the official text, often in several languages, is available on the Internet. Comments and suggestions for application may also be found. For all EU water legisaltion, the general source is http://www.emwis.org/IFP/law_EU.htm. The Baltic Agenda 21 can be found at http://www.baltic21.org. The HELCOM documents are available from http://www.helcom.fi. Often times there are also national documents relevant to the application of the policies available on national ministry or EPA homepages.

EU directives

The number of EU directives related to environmental issues is large and increasing. The most important one in terms of water management in general and river basin management in particular is the *Water Framework Directive*. Other relevant directives address water quality. Finally, there are a number of directives that may be relevant depending on the particular water management problem to be solved. The latter category will be presented very briefly in this chapter.

The basis for the EU directives in general are stated on the web site http://europa.eu.int:

"The European Commission develops Directives with the considerable involvement and input of Member States, either via consultation or co-operation procedures with the European Parliament or discussions in the Council of Ministers or public consultation conferences. However, once adopted by Council, the Member States are solely responsible for the correct and full implementation of the requirements of the legislation. The European Commission cannot be blamed entirely therefore, for, on the one side, abuses or lack of action or, on the other side, supplementary burdens or higher taxes because of environmental protection. Nevertheless, the European Commission will ensure that Member States fulfil their obligations and, if necessary, take legal action to safeguard this."

"Unfortunately, the European Commission does not always have the resources to actively perform controls and inspections. Therefore, if you, as an individual citizen, concerned NGO or company, feel that the requirements of the legislation are not respected by industry, agriculture or competent authorities, you should always inquire with the responsible administration (Environment and/or Public Health), and at the same time inform the European Commission of your questions and findings. The European Commission will investigate your 'complaint' and take appropriate action if it is proven that the requirements are indeed not respected. The European Commission considers you therefore to be an active participant in water protection."

Rationale of the Water Framework Directive

The increasing demand by citizens and environmental organisations for cleaner rivers and lakes, groundwater and coastal beaches is evident. This demand is one of the main reasons why the European Commission has made water protection one of the priorities of its work. A thorough restructuring process concerning *European Water Policy* is on the way, and a new Water Framework Directive is the operational tool, setting the objectives for water protection well into the next century.

The Water Framework Directive aims to do three things:

Firstly, to ensure sustainable water use in the future. Both surface water and groundwater should reach good status by the year 2010. This is the first time that the connection between quality and quantity of water is taken into account. Good status is defined as the absence of damaging pollution as well as a sustainable flow and recharge. It furthermore implies both low levels of chemical contamination and the presence of a flourishing ecosystem.

Secondly, in order to stimulate a more rational and sustainable water use pattern, it will make those who pollute pay the costs of the damage they cause. This is the beginning of an integration of the full cost of water use into the price paid for the water. Costs should not be born downstream by the rest of society or by future generations.

Thirdly, Member States must co-ordinate their actions in each river basin in order to ensure that all measures on water policy work together coherently. The results of all these activities must be set out in a river basin management plan, which will be developed with full public participation.

Developing the EU Water Framework Directive

The last item is likely to be trend setting and put river basin management in focus for at least next decade. Another focal point is of citizens and citizens' groups. The envisioned new European Water Policy has to get citizens more involved.

The administrative structure that the Water Framework Directive calls for is based on the drainage basin concept. It begins with the task of defining a *River Basin District*, which can be composed of one or several river basins. Within each such River Basin District an appropriate and competent authority shall be established. This will be called the *River Basin Authority*. In case of transboundary river basins, the states should jointly establish an International River Basin District, and the corresponding authority. This corresponds to the common River Commissions of today.

A main task for the River Basin Authority is to establish and elaborate a *River Basin Management Plan*. This plan should contain the result of the work generated within the process of the Water Framework Directive. The plan should be based on the present status of the water, stated objectives for the water, and the measures needed to close the gap between the two.

The Directive contain guidelines for the work required. The environmental objectives for a River Basin District should be realistic, operational, measurable and based on regional and local conditions. Such objectives are sometimes difficult to formulate but one might use, as a starting point, the present use of water and existing and possible conflicts. The authority should establish a plan for monitoring of waters. A monitoring scheme has to be organised so that it takes into account the present environmental status of the waters. It has to, when possible; include control at the source of the pollution, both for point and non-point sources. Finally, the measures needed to reach the objectives should be cost-effective, as should the entire programme for water management in the District.

Work to implement the Water Framework Directive into national administration and legislation is ongoing in all member states. In Sweden, in 1998, a Parliament Commission published a report that proposes several steps to implement the Directives. The definition of the new River Basin Districts is discussed and it was made clear that each will include several municipalities, and constitute a considerable integration of water management in the country. There are today 286 municipalities in the country and there will be only five River Basin Districts. The River Basin Authorities will thus constitute co-operative structures between several municipalities and Country Boards. Implementing measures decided on by the new Authorities might, in the future, also be a responsibility of municipalities.

Co-operation within river basins is not new. It exists today in Sweden, in the so-called "Vattenvårdsförbund", i.e. Associations for Water Management. These have, in some cases, a very long history of more than a hundred years. They are, however, no formal authorities and are based entirely on voluntary agreements. In some countries, such as France, formal co-operative authorities within river basins have existed since long ago. They do not, however, have a strong position, when compared to the national or municipal level.

A "wave of legislation"

Early European water legislation began in 1975 with standards for rivers and lakes used for drinking water abstraction, and culminated in 1980 in setting binding quality targets for drinking water, including quality objective legislation on fish waters, shellfish waters, bathing waters and groundwater. Its main emission control element was the *Dangerous Substances Directives*.

A second "wave" of water legislation was seen in 1991, with the adoption of:

- The *Urban Waste Water Treatment Directive*, providing for secondary (biological) wastewater treatment
- The even more stringent *Nitrates Directive*, addressing water pollution by nitrates from agriculture

Later the Commission proposed further action resulting in:

- A new *Drinking Water Directive*, adopted in 1998
- A *Directive for Integrated Pollution and Prevention Control* (IPPC) adopted in 1996

The "wave of legislation" meant that the Council, the European Parliament, the Member States, regional and local authorities, water users, green groups and consumer groups, all being involved in European Community water legislation, almost "drowned" in water-related proposals.

In mid-1995 the Commission had already been considering the need for a more global approach to water policy. It thus accepted requests from the European Parliament's Environment Committee and from the Council of Environment Ministers for a new European Water Policy and invited comments from all interested parties, such as local and regional authorities, water users and non-governmental organisations (NGOs).

A single system of water management: River basin management

The first step was to find a single system of water management. The best model for this is, of course, management by river basin – the natural geographical and hydrological unit – instead of according to administrative or political boundaries. The Maas, Schelde and Rhine River basins were used as existing good examples of the approach, with their co-operation and joint objective-setting, across Member State borders, and for the Rhine River even beyond the EU territory. For each river basin district, a *River Basin Management Plan* will need to be established and updated every six years, being the context for the co-ordination requirements.

Co-ordination of objectives

There are a number of objectives for protection of the quality of water. The key ones at the European level are:

- general protection of the aquatic ecology
- specific protection of unique and valuable habitats
- protection of drinking water resources
- protection of bathing water

A general requirement for ecological protection and a general minimum chemical standard was introduced to cover all surface waters. Specific uses or objectives for the water may apply in specific areas, although not everywhere. The obvious way to incorporate these is to designate specific protection zones within the river basin, where these specific objectives must be met. The overall plan for the river basin will then require ecological and chemical protection everywhere as a minimum; for particular uses, zones will be established and higher objectives set within them.

There are uses that cause adverse effects on waters that do not fit into this picture, but which are considered essential. The key examples are flood protection and essential drinking water supply. The problem is dealt with by providing derogations from the requirement to achieve good status. However, all appropriate mitigation measures are to be taken. Other uses are less clear-cut, such as navigation and power generation, where alternative approaches (transport can be switched to land, other means of power generation can be used) may be sought. Derogations are provided here, subject to three tests: That the alternatives are technically impossible; that they are prohibitively expensive or that they produce a worse overall environmental result.

The presumption for groundwater is that it should not be polluted at all. Therefore, setting chemical quality standards may give the wrong signals. However, a few such standards have been established at the European level for particular issues (nitrates, pesticides and biocides). For general protection, a precautionary approach is taken, leaning on the principle of minimum anthropogenic impact. It comprises a prohibition on direct discharges to groundwater, and a requirement to monitor groundwater aquifers. In this way, chemical changes can be detected. Quantity is also a major issue for groundwater. For good management, only that portion of the recharge not ecologically needed can be abstracted – this is the sustainable resource.

The directive thus provides a framework for integrated management of groundwater and surface water for the first time at the European level.

In fact, the Water Framework Directive will rationalise water legislation as a whole by replacing several old directives: Those on surface water and two related directives on measurement methods, sampling frequencies and exchanges of information on freshwater quality; The fish water, shellfish water, and groundwater directives; And the directive on dangerous substances discharges.

Co-ordination of measures

A number of measures taken at the Community level tackle particular pollution problems. The Urban Wastewater Treatment Directive and the Nitrates Directive, for example, together tackle eutrophication, as well as health effects such as microbial pollution in bathing water areas and nitrates in drinking water. The application of these has to be co-ordinated to meet the objectives established. Establishing objectives for the river basin does this. An analysis of human impact determines how far from the objective each water body is. If the existing legislation solves the problem, the objective of the framework directive is attained. However, if it does not, the Member State must identify exactly why, and design additional measures needed to satisfy the objectives, such as stricter controls on polluting emissions from industry and agriculture, or urban wastewater sources.

The Water Framework Directive formalises a combined approach. On the source side, it requires that all existing technology-driven source-based controls must be implemented as a first step. It also sets out a framework for developing further such controls. A list of priority substances for action at the EU level, prioritised on the basis of risk, is to be development. Then a design of the most cost-effective measures, reducing the load of those substances, is made. On the effects side, it co-ordinates all the environmental objectives in existing legislation, and provides a new overall objective, requiring that, where the measures taken on the source side are not sufficient to achieve these objectives, additional ones be required.

The River Basin Management Plan

The River Basin Management Plan is a detailed account of how the objectives set for the river basin, i.e. ecological, quantitative, and chemical status, and protected area objectives, are to be reached within the time-scale required. The plan will include the results of an analysis showing:

- the river basin's characteristics
- a review of the impact of human activity
- an estimation of the effect of existing legislation
- the remaining "gap" to meeting the objectives set
- a set of measures designed to fill the gap

In addition, an economic analysis of water use within the river basin must be carried out to allow a rational discussion on the cost-effectiveness of the various possible measures.

Public participation

There are two main reasons for an extension of public participation. The first is that the decisions must balance the interests of various groups. The second reason concerns enforceability. The greater the transparency in the establishment of objectives, the imposition of measures, and the reporting of standards, the greater the care Member States will take to implement the legislation in good faith. This, in turn, will increase the possibilities of the citizens to influence the direction of environmental protection through consultation or through complaint procedures and courts, should consultation fail.

Full cost recovery pricing

By 2010 Member States will be required to ensure that the price charged water consumers covers the true costs. Whereas this principle has a long tradition in some countries, this is not the case in others. This is a mandatory goal, but in some cases such an approach is not possible. The main ones are derogations in order to provide a basic water service to households at an affordable price, and derogations for situations where there is both a social disadvantage and a climatic or geographic issue, making water provision more expensive than normal. This, together with the more efficient use of a resource that comes from full pricing, is to lead to a more rational approach to the exploitation of water resources.

EU directives on water quality

There are basically two different approaches to tackle water pollution:
1. The Water Quality Objective approach (WQO) defines the minimum quality requirements of water to limit the cumulative impact of emissions. The approach focuses on a certain quality level of the water where it is not harmful to the environment or to human health. This approach was mainly used in the 1970s in:

- the Surface Water Directive (1975)
- the Groundwater Directive (1976)
- the Bathing Water Quality Directive (1976)
- the Fish Water Directive (1978)
- the Shellfish Water Directive (1979)
- the Drinking Water Directive (1980)

Note that the Water Framework Directive will replace the four former directives.
2. The Emission Limits Value (ELV) approach focuses on the maximum allowed quantities of pollutants that may be discharged from a particular source into the aquatic environment. This approach considers the end product of a process, e.g. water treatment, discharges from industry, effect of agriculture on water quality, or what quantities of pollutants may go into the water. It was mainly used in the 1990s in:

- The Urban Wastewater Treatment Directive (1991)
- The Nitrates Directive (1991)
- The IPC Directive (Integrated Pollution Prevention and Control, 1996. This directive looks at all major emissions of large industries into the environment, be it air and water pollution or the dumping of waste)

More recent legislation is moving in the direction where ELVs and WQOs are used to mutually reinforce each other. In a particular situation, the more rigorous approach will apply.

Other related EU directives

Water management can seldom be treated as an isolated problem. Since water is involved in most environmental issues and also in issues of hygiene, recreation and the general well being of both man and wildlife, an open mind and broad views are often called for. Specific cases can be found when EU directives from most spheres of society need to be applied in solving water management issues. In most cases, however, the directives listed below will be a good basis for treating water management issues in a broader sense. Directives that will be superseded by the Water Framework Directive are not discussed below.

The Birds Directive (1979)

A large number of bird species are declining in number. This is a serious threat to the conservation of the natural environment and the biological balances. Various factors may affect the numbers of birds, in particular the destruction and pollution of their habitats. The preservation, maintenance and re-establishment of biotopes and habitats shall include primarily the following measures:

- The creation of protected areas
- Upkeep and management in accordance with the ecological needs of habitats inside and outside the protected zones
- Re-establishment of destroyed biotopes
- Creation of biotopes

The directive lists 181 bird species, naturally occurring within the EU. Almost half of these are waterfowl or species very much dependent on water-rich biotopes. Water management must, of course, take this directive into account when listed birds breed or feed in the catchment to be managed. In addition, changes in land use and water management practises may also change terrestrial habitats in that lowered groundwater tables may change biotopes, creating unfavourable conditions also for forest or field living birds, etc.

Deliberate disturbance of listed birds, particularly during the period of breeding and rearing, is to be made difficult by the comprehensive planning. This issue is especially relevant regarding water tourism, canoeing and boating, but also when planning for aquaculture and fishing.

The Cadmium Directive (1983) and other substances-related directives

The directive calls for limit values and quality objectives for cadmium discharges. An excerpt from the actual directive text reads:

"Whereas, since pollution due to the discharge of cadmium into water is caused by a large number of industries, it is necessary to lay down specific limit values according to the type of industry concerned and to lay down quality objectives for the aquatic environment into which cadmium is discharged by such industries."

Cadmium is also a growing concern in agriculture because of the contamination of phosphorus-containing fertilisers. The Cadmium Directive ends with giving limit values and analysis methods for various types of industry.

The Hexachlorocyclohexane Directive (1984) on limit values and quality objectives for discharges of hexachlorocyclohexane is another example of a directive directed towards limitation of a specific substance.

A specific Mercury Directive (1984) focuses on limit values and quality objectives for mercury discharges by sectors other than the chlor-alkali

BALTIC 21

Sector Actions address sector specific issues:

Agriculture Sector

- To build sustainable structures;
- To improve the viability of agriculture in the region;
- To strengthen farm management with respect to aspects of environment, biodiversity, landscape, cultural heritage, social and economic issues;
- To create demonstration watersheds with training/educational programmes;
- To improve agro-environmental legislation.

Education Sector

- Policies and strategies - includes the development of education of sustainable development guidelines and promotion of international co-operation for curricula, program and course development at all levels of education;
- Continuing education which include sustainability related knowledge and skills;
- Teaching and learning;
- Research on and development of education for sustainable development as well as stimulate the dissemination of results of research on issues concerning.

Fisheries Sector

- To secure the sustainable use and preservation of Baltic Sea and freshwater resources with an ecosystem approach, improving coastal zone management and co-operation;
- To support development of sustainable aquaculture;

Industry Sector

- Development of market-driven tools within the enterprises for sustainable development;
- Increasing market awareness of sustainability effects;
- Training/educational programmes in the region;
- Measures for monitoring environmental effects, and for promoting investments that enhance sustainable development.

Tourism Sector

- To achieve a common understanding and awareness of the requirements needed for sustainable tourism in the Baltic Sea Region, among customers and within the tourism industry alike.

Transport Sector

- To develop the necessary institutional and legal framework for a sustainable development in the transport sector;
- To establish a regular and long-term co-operation process in the region with regard to sustainable transport;
- To join together action programmes of various actors in the region (HELCOM, UBC, VASAB 2010) with regard to issues of transport and recommendations for infrastructure investments in a sustainable transport system.

Spatial Planning

- Priority to sustainable settlement and land use patterns in regional and urban planning;
- Further development of Integrated Coastal Zone Management;
- Development of a common strategic concept of maritime transport;

BALTIC 21

Some examples of action programmes are:

Restoration of habitats important to fish and fisheries in inland waters
Measures taken should prevent further degradation of inland water fisheries and should be performed on the basis of a catchment area strategy. This should aim at protecting estuaries, shallow water areas and recruitment habitats for coastal freshwater species; protecting and restoring spawning and nursery areas for commercial and endangered species in freshwaters, where appropriate; and constructing fish ladders at dams and hydroelectric power stations, where appropriate.
Actors: Coastal States, European Inland Fisheries Advisory Commission (EIFAC) and HELCOM.

Achieving sustainable aquaculture
Aquaculture production in the Baltic area is rather low because of unfavourable natural conditions. The fish produced is used for human consumption or for releases. The releases can be for enhancement, for sea ranching or for put-and-take fisheries in pounds and lakes. Aquaculture plays a particular role for stocking of salmon and trout. Action to support sustainable aquaculture is required, e.g. minimising water pollution, the spreading of diseases and interactions between wild and reared fish, including transgenic impacts on wild stocks.
Actors: Coastal States.

Development of regional strategies to support sustainable sea transport
Support sustainable sea transport and in particular short sea transport. Data on traffic flows and emissions, including those of high-speed ferries, will be collected and exchanged. Further ways of reducing emissions and use of hazardous substances will be identified, taking into account the recent adoption of MARPOL Annex VI. The measures will treat introduction of alien species in ballast water, from existing and new ships. Exploring the use of fiscal and economic instruments and the development of emission standards for the BSR will be important means. A regional strategy to support sustainable short sea shipping will be developed.
Actors: Sector, HELCOM, VASAB and shipping industry.

electrolysis industry and the Chlor-alkali Directive (1982) on limit values and quality objectives for mercury discharges by the chlor-alkali electrolysis industry.

The Habitats Directive (1992)

This directive on the conservation of natural habitats and of wild fauna and flora aims at the preservation, protection and improvement of the quality of the environment. Conservation of natural habitats and of wild fauna and flora is a main issue in this respect. The role of water in aquatic habitats is obvious but should also be considered in terrestrial habitats.

The directive has similarities and sometimes coincides with the Birds Directive, but it is more general, directed towards the habitat as such and has a more diversified approach. Habitats are distinguished as natural habitat types, natural habitat types of community interest and priority natural habitat types, calling for an increasing degree of care in planning. A *natural habitat type of community interest* means those which:

- Are in danger of disappearance in their natural range or
- Have a small natural range following their regression or by reason of their intrinsically restricted area or
- Present outstanding examples of typical characteristics of one or more of the six following biogeographical regions: Alpine, Atlantic, Boreal, Continental, Macaronesian and Mediterranean

Priority natural habitat types mean natural habitat types in danger of disappearance.

Agenda 21 for the Baltic Sea Region

The Agenda 21 for the Baltic Sea Region – Baltic 21 – was officially launched in 1996. The Agenda is set up as an action plan for sustainable development in the region. It is worked out jointly by a partnership of nations, international organisations, business, NGOs and international financial institutes. The emphasis of Baltic 21 is on regional co-operation and on the environment and it's bearing on economic and social aspects of sustainable development. Baltic 21 is sectorially oriented and focuses on agriculture, education, energy, fishing, forestry, industry, transport and spatial planning. It comprises all Nordic countries and all other countries around the Baltic Sea. For the Russian Federation only the northwestern part is included. The European Union is also a participant in the elaboration of Baltic 21.

All Baltic 21 documentation – background documents, meeting and workshop reports, and draft texts

HELCOM Structure

Monitoring & Assessment Group - HELCOM MONAS
The Monitoring and Assessment Group works to co-ordinate monitoring and assessment of the state of the marine environment. The main role of HELCOM MONAS is to assess the inputs of nutrients and hazardous substances and their effects in the marine environment.

All environmental monitoring within HELCOM and the Baltic marine environment is carried out under the COMBINE Programme. The data collected under the COMBINE programme are used for wide-ranging Periodic Assessments of the state of the Baltic marine environment.

Promoting and testing new monitoring and assessment techniques is also part of HELCOM MONAS's work.

Land-based Pollution Group - HELCOM LAND
The Land-based Pollution Group is responsible for reducing pollution from all sources on land within the Baltic Seas catchment area, by promoting investment and practical measures, such as environmentally sound practices and technologies, to limit emissions.

Maritime Group - HELCOM MARITIME
The Maritime Group of the Helsinki Commission works to prevent any pollution from ships - from operational discharges as well as accidental pollution. HELCOM MARITIME organises regular meetings involving representatives from inter-governmental and non-governmental organi-sations as well as the officials who are responsible for maritime transportation and who respond to the pollution incidents at sea.

The goal is to ensure that the international measures are properly applied and implemented in the Baltic.

Response Group - HELCOM RESPONSE
The Response Group works to ensure swift national and international response to martime pollution incidents; to ensure that in case of an accident the right equipment is available and routines are in place to respond immediately and in co-operation with the neighbouring states; to analyse the developments in maritime transportation in the Baltic and investigates possible impacts on the international response cooperation, and to coordinate the aerial surveillance of maritime shipping routes to provide a complete picture of the sea-based pollution in the area and to reveal suspected polluters.

Nature Protection and Biodiversity Group - HELCOM HABITAT
HELCOM HABITAT contributes to the conservation work of all the Contracting Parties through HELCOM's recommendations on threatened species, habitats and protected areas as well as the sustainable use of natural resources.

The goals of the group are to conserve natural biotopes and species and to protect the biological diversity and ecological processes, to manage and use coastal and marine resouces sustainably, and to promote the development of Integrated Coastal Zone Management.

Programme Implementation Task Force
The HELCOM Programme Implementation Task Force (HELCOM PITF) initiates, co-ordinates, and facilitates the implementation of the Baltic Sea Joint Comprehensive Environmental Action Programme (JCP).

HELCOM PITF consists of representatives of the Contracting parties to the Helsinki Convention; representatives of Belarus, Norway, the Slovak Republic and the Ukraine; representatives of international financial institutions and the International Baltic Sea Fishery Commission; as well as representatives of observer organisations.

The Baltic Sea Joint Comprehensive Environmental Action Programme
An international Baltic Sea Conference in 1990 called for the elaboration of a joint action programme to "assure the ecological restoration of the Baltic Sea". An *ad hoc* High Level Task Force elaborated the Joint Comprehensive Environmental Action Programme (JCP), which was approved in 1992. The key principles of the JCP are to recognise the importance of a long-term perspective for ecological restoration:

- Harmonise economic and environmental objectives
- Control pollution at the source
- Establish conditions for private sector participation

The Programme shall be implemented over 20 years (1993-2012) at an estimated total cost of 18 billion ECU.

The Programme's major focus is to reduce point and non-point sources of pollution, particularly at the initially 132 (now about 80) "hot spots" (see Figure 12.1) identified by the JCP. They are mostly of a municipal and industrial nature.

– is published on the Baltic 21 web site (http://www.baltic21.org).

One principal outcome of Baltic 21 is the Action Programme, which consists of 30 different actions addressing the transition to sustainable development in the Baltic Sea Region (BSR). It is based on selected proposals from the eight sectors that are the focus of Baltic 21 and by Visions and Strategies Around the Baltic Sea 2010 (VASAB 2010). The Programme is divided into three parts: Joint Actions, Sector Actions and Spatial Planning Actions. Issues relating specifically to sustainable water management are presented below.

Joint Actions address issues concerning several sectors:

- Use of regional fora and networks for sustainable development
- Establishment of demonstration areas and pilot projects for proving sustainable development in practice
- City co-operation and sustainable development issues in cities and communities
- Procurement of technologies for sustainable development
- Information for sustainable development
- Increasing consumers' awareness of sustainable development

The work is carried out according to the general Agenda 21 objectives. It could, however, be interesting to take a look at an excerpt from the specific visions for 2030, given for a sustainable Baltic Sea Region:

"The economic differences in the region have vanished, unemployment is reduced to a minimum, the economic dependence on non-renewable energy and material is substantially reduced, greenhouse gas emissions are significantly reduced, acidification of soils and waters is reduced to levels where the productivity and diversity of ecosystems are secured and, finally, the state of the Baltic Sea marine environment is improved and capable to sustain healthy marine ecosystems. Consumers and different actors in society are widely aware of social and environmental factors related to sustainable development."

"In the agricultural sector, crop and animal production have been closely integrated, enabling efficient recirculation of manure and decreased use of fertilisers. Organic farming principles have been further developed and applied. Wetlands have been maintained, restored or established as a measure to reduce nutrient leakage to lakes and the Baltic Sea."

The Baltic Marine Environment Protection Commission HELCOM

In 1974, the coastal states of the Baltic Sea at that time signed the first Convention on the Protection of the Marine Environment of the Baltic Sea Area. This was the first international agreement to cover all sources of pollution, both from land and from ships as well as airborne. In 1992, a new Convention was signed by all the countries bordering on the Baltic Sea and by the European Economic Community. The governing body of the Convention is the Helsinki Commission (HELCOM), or more formal, the Baltic Marine Environment Protection Commission. The parties of HELCOM are Denmark, Estonia, the European Community, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden.

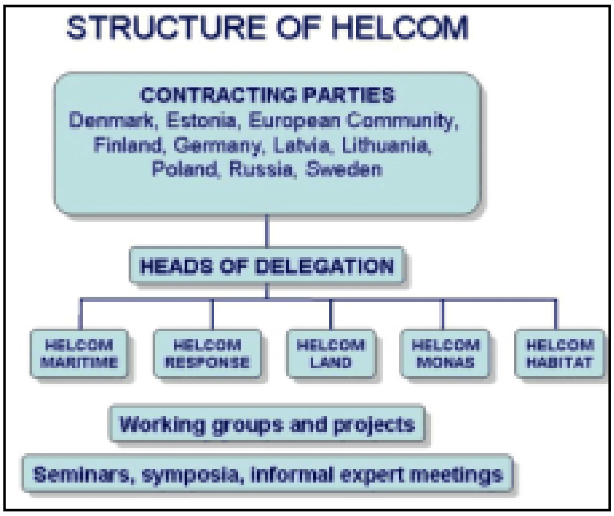

Fig. 12.2. Organisation Structure of the HELCOM secretariat.

Decisions taken by the Helsinki Commission – which are reached unanimously – are regarded as recommendations to the governments concerned. These HELCOM Recommendations are to be incorporated into the national legislation of the member countries. The Commission consists of four Committees and a Programme Implementation Task Force. Other subsidiary bodies comprise working groups and projects. A new organisation structure (see Figure 12.2) was implemented in 2001.

Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1992

The 1992 Convention was ratified by the European Community, Germany, Latvia and Sweden in 1994, by Estonia and Finland in 1995, by Denmark in 1996 and by Lithuania in 1997. The convention entered into force on 17 January 2000 as it was ratified by Poland and Russia in 1999. The convention consists of 38 articles. Article 1 defines the Baltic Sea Area, setting an outlet boundary at the parallel of the Skaw in the Skagerrak at 57° 44.43' N. It also includes internal waters within the Baltic Sea catchment.

The fundamental principles and obligations are formulated in Article 3. The Contracting parties, i.e. the members, shall individually, or in co-operation,

International conventions for the Baltic Sea

A. Convention on the Protection of the Marine Environment of the Baltic Sea Area.
Signed 1974. In force 1980. The 1992 Convention entered into force in 2000. The Baltic Sea Convention is described in the previous chapters. For treaty text, recommendations, and other information, see http://www.helcom.fi.

B. Convention for the Protection of the Marine Environment of the Northeast Atlantic.
Signed 1992. In force 1998. Parties: Sweden, Denmark, Germany and most states bordering the northeast Atlantic and the North Sea (Russia is not a party). The convention applies to the North Sea and the northeast Atlantic Ocean. It also applies to the water between Sweden and Denmark. As the 1992 Baltic Sea Convention, the basic principles for the control of land-based pollution sources are the principle of precautionary action, the polluter-pays principle and BAT. As regards the latter, the definition is almost identical as in the 1992 Baltic Sea Convention. As regards other activities it relies on the concept of best environmental practice, which includes various market-based instruments, permit procedures, and eco-labelling. With the entry into force of the 1992 Northeast Atlantic Convention, two conventions signed in the early 1970s were superseded. In these two conventions, the working commissions were referred to respectively as PARCOM (Paris Commission) and OSCOM (Oslo Commission). Since the two conventions merged into one, so did the commissions—hence the current commission is OSPARCOM. For treaty text, recommendations and decisions and other information, see http://www.ospar.org.

C. 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter.
Signed in 1972. In force 1975. New protocol in 1996, which will completely amend the convention when it enters into force. Parties: global convention, ratified by about 80 states (including all states bordering on the Baltic Sea). The convention is applicable all over the world, including the Baltic Sea. In contrast to the Baltic Sea Convention, which contains a total prohibition on dumping (under certain circumstances dredged spoils may be dumped), the convention does not prohibit all kinds of dumping. Substances listed on the "blacklist" (e.g. organohalogen compounds, mercury, cadmium, different kinds of oil and high-level radioactive wastes) must not be dumped at all, while substances on the "grey list" (e.g. arsenic, lead, organosilicon compounds and cyanides) may be dumped after a prior special permit by the national authority. Dumping of substances not mentioned on any of the two lists may take place after a prior general permit. With the entry into force of the 1996 Protocol, the regime will provide far stricter rules. For information about the treaty, see http://www.imo.org.

D. 1973/1978 Convention on the Prevention of Pollution by Ships ("MARPOL Convention").
Signed in 1973 and 1978. Annex I (oil) in force 1983, Annex II (noxious liquid substances) in force 1987, Annex III (harmful substances in packaged form) in force 1992, and Annex V (garbage) in force 1988. Annex IV (sewage) not yet in force. Parties to the Convention must ratify Annexes I and II, while the others are optional. Parties: global treaty, more than 100 states (including all states in the Baltic Sea Region) are parties to Annex I and II. MARPOL only deals with pollution from so-called normal operations, not with dumping. Although this treaty is global, certain areas, e.g. the Baltic Sea Area, are recognised as "special areas". For information about the treaty, see http://www.imo.org.

E. Nordic Environmental Protection Convention ("NEPC").
Signed 1974. In force 1976. Parties: Denmark, Finland, Sweden and Norway. The fundamental idea behind the NEPC is the principle of non-discrimination. When examining the permissibility of an environmentally harmful activity (based either on land or on the continental shelf), the examining authority is obliged to equate the trans-boundary nuisance or risk thereof, with any nuisance that may be entailed in the state where the activity is carried out. In case an activity may entail a nuisance of significance in a neighbouring state, the examining authority must notify and inform the supervisory authority in the other state. Persons affected by a nuisance from environmentally harmful activities in a neighbouring state have the same right to legal action (concerning permissibility, preventive measures and compensation) in the neighbouring state as an affected legal entity in that state.

The treaty text is available at http://sedac.ciesin.org/entri/texts/acroNordic.txt.html.

F. ECE Convention on Environmental Impact Assessment in a Transboundary Context ("EIA Convention").
Signed 1991. In force 1997. Parties: More than 20 states, but not all of the states in the Baltic Sea Region. An environmental impact assessment procedure must be established prior to a decision to authorise an activity that may cause significant adverse transboundary impact. This applies to certain listed activities, e.g. crude-oil refineries, thermal power stations, combustion installations, nuclear power stations and other nuclear activities, motorways, waste disposal installations, pulp and paper manufacturing, major mining, offshore hydrocarbon production and deforestation. Certain provisions apply for non-listed activities that may cause such impact. The public in the neighbouring state, which is likely to be affected by an activity, is given equal opportunity to participate in the environmental impact assessment procedure as the public in the state of the activity. For treaty text and other information, see http://www.unece.org.

G. 1979 Convention on Long-Range Transboundary Air Pollution.
Signed 1979. In force 1983. Parties: About 30 states are members of the Economic Commission for Europe (including all states bordering the Baltic Sea). Framework convention for the purpose of reducing transboundary air pollution (particularly "acid rain"). To the framework convention (which hardly contains any substantive requirements) are connected two protocols concerning limitation of emissions of sulphur and nitrogen oxides (NOx), respectively. The NOx Protocol was signed in 1988 and entered into force 1991. All states surrounding the Baltic Sea are parties to the NOx Protocol. For treaty texts and other information, see http://www.unece.org.

H. 1998 Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters ("Aarhus Convention").
Signed by 35 states, but not by all the states in the Baltic Sea Region, and the EC. Not yet in force. The parties are obliged to establish domestic procedures for public participation in decision-making related to environmental matters, and to provide a right to legal review of such decisions. Environmental information shall be available to the public. The convention recognises that environmental NGOs may act on behalf of public environmental interests. For treaty text, see http://www.unece.org.

I. 1973 Convention on Fishing and Conservation of the Living Resources in the Baltic Sea and Belts ("Gdansk Convention").

Signed 1973. In force 1974. Parties: all states bordering on the Baltic Sea, either as individual states or, for Member States, through the European Community. The parties shall co-operate to achieve optimum yield from the living resources. The Convention does not, however, lay down any particular substantive requirements. Instead an International Baltic Sea Fishery Commission is established, with the competence of giving recommendations on size limits of fish, fishing equipment, closed seasons and areas, total allowable catch etc. For treaty text, recommendations and further information, see http://www.ibsfc.org.

J. Conventions on nuclear activities.
A number of conventions deal with nuclear activities. The 1960 Convention on Third Party Liability in the Field of Nuclear Energy has not been signed by all states bordering on the Baltic Sea. The 1986 Convention on Early Notification of a Nuclear Accident or the 1986 Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency are however in force in the Baltic Sea states. Preventive instruments in the field of nuclear activities are provided by the International Atomic Energy Agency (IAEA). However, with few exceptions, the status of safety standards is recommended rather than legally binding. For treaty texts and other information, see http://www.iaea.org and http://www.nea.fr.

K. Conventions on the conservation of nature and endangered species.
Some riparian states to the Baltic Sea Area are parties to the 1979 Convention on the Conservation of European Wildlife and Natural Habitats. The contracting parties shall take appropriate measures are to ensure the conservation of the habitats of wild species of flora and fauna, especially those specified in certain lists. Measures must also be taken for ensuring the protection of species specified in lists. As some riparian states are also parties to the 1979 Convention on the Conservation of Migratory Species of Wild Animals, this is also applicable to the region. The conventions list species according to risk of extinction, and prescribe protective measures, including the protection of habitats. For treaty texts, recommendations, and other information, see http://www.coe.int and http://www.wcmc.org.uk/cms/.

Compiled by Jonas Ebbesson.

take legislative, administrative or other relevant measures to prevent and eliminate pollution in order to promote the ecological restoration of the Baltic Sea Area and the preservation of its ecological balance. Furthermore, the use of the precautionary principles best environmental practice (BET) and best available technology (BAT), and the polluter-pays principle are called for. Although the Baltic Sea Area is the focus, it is also stated that the Contracting parties shall use their best endeavours to ensure that the implementation of the Convention does not cause transboundary pollution in areas outside the Baltic Sea Area.

Principles and obligations concerning pollution from land-based sources are treated in Article 6 and prevention of pollution from ships and pleasure crafts in Articles 8 and 9, whereas Articles 10 to 12 treat prohibition of incineration, prevention of dumping, and exploration and exploitation of the seabed and its subsoil. An important issue is the agreement to notify and consult on pollution incidents that may threat a neighbouring country.

The Contracting parties shall report to the Commission on:

- The implementation measures taken
- The effectiveness of the measures taken
- Problems encountered in this implementation

On request, the Contracting parties shall also provide information on discharge permits, emission data or data on environmental quality, as far as available. In HELCOM, as in the EU Water Framework Directive, there is a focus on the citizens, the public. Article 17 describes the duties to make information available to the public on:

- Permits issued and the conditions required to be met
- Results of water and effluent sampling carried out for the purposes of monitoring and assessment, as well as results of checking compliance with water quality objectives or permit conditions
- Water quality objectives

13.
THE SWEDISH ENVIRONMENTAL CODE

Lars-Christer Lundin

Introduction

The recent development in Swedish environmental legislation has been quite dramatic in that no less than 15 environmental acts have been merged into a single Environmental Code (*Miljöbalken*). The Environmental Code has been in force since 1 January 1999. The main issue was to create a code for a co-ordinated, widened, and strengthened sustainable development. The presentation of the new code given below is by no means complete but focuses on water management issues. Some general issues involving sustainability issues are also discussed. The text builds on presentations by the Swedish Government and material from the Education in the Environmental code (*Miljöbalksutbildningen*). The full text of the Code is available in Swedish on http://www.notisum.se/rnp/sls/lag/19980808.htm. The further development of the application of the Code can be followed on, e.g., http://www.sweden.gov.se/sb/d/3704.

Superseded acts

The fifteen acts that have been merged into the Environmental Code are:

- The Natural Conservation Act (NVL)
- The Environmental Protection Act (ML)
- The Marine Dumping Prohibiting Act
- The Sulphur Content of Fuel Oil Act and Ordinance
- The Agricultural Land Management Act
- The Waste Collection and Disposal Act and Cleansing Ordinance
- The Health Protection Act
- The Water Act
- The Pesticides Act
- The Act on Chemical Products (LKP)
- The Environmental Damage Act
- The Natural Resources Act (NRL)
- The Biological Pesticides Act
- The Genetically Modified Organisms Act
- The Flora and Fauna Act

In Sweden, the most important tool for transforming environmental politics into practical management has since long ago been jurisdiction. Through the environmental acts and their application the principles of precaution, polluters-pay and substitution have got a practical meaning within Swedish legislation and been important tools in the environmental protection work.

The role of legislation

A number of new and important instruments have recently been developed in order to push environmental protection work in a favourable direction. Economical control, environmental labelling, Agenda 21 and environmental management systems are a few examples. However, the concept of sustainable development must now take the step from being a general declaration to becoming a principle that can be the foundation of concrete demands for action. This step can only be taken by introducing management through legislation and practical application of acts and codes. The earlier Swedish environmental legislation consisted of a multitude of statutes, was difficult to comprehend, and was not sufficient to solve some of the environmental problems identified in the vision of a sustainable development. Those who conducted operations that may be harmful to the environment had to comply with rules under several statutes. Several of the most environmentally destructive operations, e.g. roads and railways constructions, were considered to be inadequately regulated.

The main ideas behind the legal reform have been to modernise and update the environmental legislation. The collection of the central environmental acts in a common code and the systematic legislative changes made are, however, only a part of the reform. It is probably of more importance that the work developing the Code has created a needed broadening and sharpening of the central environmental legislation.

Objective and application

The objective of the Environmental Code, treated in its first chapter, is to promote a sustainable development that means that present and coming generations are ensured a healthy and pleasant environment. The Environmental Code forms a general legislation covering all environmental impacts. This is important since, in recent years, interest has focused on the aggregate environmental effect of many diffuse sources of pollution, such as from road traffic.

In order to reach the objectives of the Environmental Code, the set of rules should be applied in a manner so that:

- Human health and environment are protected against harm and nuisance, independently of the causes of pollution or other influence.
- Valuable natural and cultural environments are protected and managed.
- The biological diversity is preserved.
- Land, water, and physical environment in general are used in a manner that guarantees a long-term good management from ecological, social, cultural and socio-economic points of view.
- Reuse and recycling, as well as other sustainable use of materials, natural resources, and energy are promoted in order to keep resources within their eco-cycles.

The jurisdiction of the Environmental Code, defined in its second chapter, is directly coupled to the objective of sustainable development. The Code is thus applicable to all activities and enterprises that cannot be neglected from the point of view of sustainable development. All types of activities that can be of importance for the interests that are protected by the Code are concerned, whether they are a part of the individual citizen's daily life or part of some enterprise activities. The party responsible for the activity is liable to prove (the burden of proof being reversed) that the general rules of consideration of the Environmental Code are complied with. This is done through the consideration of permits and similar procedures as well as supervision.

The jurisdiction of the Code is not only of importance for the situations where the Code applies, but more important, it decides which types of issues that can be tried in an environmental case. A condition for a hazardous enterprise to be allowed, which is set based on the Code, can, for example, concern any issue that an ecologically sustainable development benefits from.

The Environmental Code pays more attention to the objective and result control than earlier environmental legislation. It calls for a trial and supervision of the activities and actions that must take the objectives of environmental politics into account. The permission and supervising work is to be governed by the national objectives specified as regional and sectorial objectives.

The governmental regulations and the authorities' directions within the field of environment are not only governed by the general aims of the Code and the rules of environmental consideration, but also by other environmental objectives that have been entered into the text of the Code.

Taken all together this means that in many cases, regulation that was part of earlier environmental acts now has a new and wider applicability. However, many provisions in the Environmental Code have a more limited scope, e.g. on protected geographical areas, water undertakings, genetic technology and handling of chemicals.

Many operations that fall within the scope of the Environmental Code are also subject to other acts, e.g. the construction of roads and railways, mining and forestry. For these cases, the Environmental Code applies in parallel with the Roads Act, the Railway Construction Act, the Minerals Act and the Forestry Conservation Act.

The general rules of consideration

The second chapter of the Environmental Code further holds a number of general rules of consideration, expressing, for example:

- The principle of precautionary measures
- The polluters-pay principle
- Application of best possible technology
- Knowledge on environmental effects
- Choice of best location
- Principles on good management and re-circulation
- The product choice principle
- Reasonable cost of requirement
- The stop rule

The product choice, or substitution, principle calls for a best environmental choice of chemical product or biotechnical organism, such as pesticides. An assessment must be made in every individual case. A general prohibition of the use or sale can never be imposed. Instead, general prohibitions of chemical products that are so hazardous that they cannot be permitted may be imposed under the provisions of the chapter of the Environmental Code dealing with chemical products.

It should be observed that the product choice principle does not only apply to commercial sale or use, but also to a private individual who takes measures. When a car owner purchases detergents to wash his/her car, he/she must choose the product that is the least hazardous to the environment, yet nevertheless cleans the car. A best choice presupposes that the goods are labelled so that the consumer gets correct information about the properties of the product. Rules concerning this are included in the chapter on chemical products and biotechnical organisms.

It cannot be excluded that an operation that satisfies all requirements still has such effects on the environment that it cannot be accepted. The stop rule should then be applied to ensure acceptable protection of human health and environment.

Only the government can grant exceptions under the stop rule, if it can be proved that the operation involves advantages that clearly outweigh the nuisance. Possible examples of such operations include installations for dealing with hazardous waste, dealing with batteries containing lead, certain transport installations of great importance to the infrastructure, and certain defence installations.

If there is a risk that a large number of people will be subject to a substantial deterioration in their living conditions or a risk of a significant deterioration of the environment, the possibilities to issue exceptions are further limited. The operation must then be of extraordinary importance from the public viewpoint. A relaxation may never be granted if the operation may cause a deterioration of public health generally.

The legislation is prohibiting by setting binding demands on enterprises, taking action to increase the knowledge on the environmental impacts of activities, and by the principle that the polluter shall carry risks for environmental impact.

The permit authorities, monitoring the environment, have the authority to directly use the rules for environmental consideration as a basis for prescriptions, prohibitions or conditions etc. The content of the general rules for environmental consideration are thus given a concrete substance through the directions given and the decisions taken in the specific cases.

Management of land and water areas

Chapters 3 and 4 of the Environmental Code concern the management of land and water areas. The main rule is that these areas must be used for the purposes they are more suited for, regarding their nature and location together with existing needs. Preference shall be given to use involving good management. Major land and water areas that are not presently affected by environment impact must be protected from measures that can influence the nature of the area.

A list is given of land and water areas that are in particular need of protection, for instance because they are ecologically sensitive, contain valuable minerals, or are especially suited for industrial installations. If the areas are of national interest, the protective principle is absolute. Such areas will be identified through the collaboration between various public authorities.

Water undertakings

Besides the Environmental Code's chapter 11 there are a large number of rules on water undertakings in the Water Undertakings (Special Provisions) Act. They do not, however, have the same environmental connection.

Water undertaking refers to a number of various measures in water and with water, such as:

- Dam undertakings
- Erection of dams
- Alteration of dams
- Storage of water in dams
- Demolition of dams
- Other installations in water
- Filling-in water areas
- Dredging in water areas
- Drainage of surface water
- Drainage of groundwater
- The introduction of water to increase groundwater quantities

A water undertaking may only be conducted if the advantages of it exceed the expense and damage caused. Especially, there is a rule concerning consideration to fishing. A water operation that may harm fishing calls for: 1) Installations that enable fish to pass by; 2) Release of as much water as required; 3) Taking other measures, such as stocking fish.

A permit is needed for a water undertaking, except if it is clear that the effects of it harm no one. Nor is a permit needed for specially listed water undertakings, such as wells for single or double family dwellings. A permit is always required for land drainage, except in the case of drainage of agricultural land by drainage pipes. In order to conserve wetlands, the government may prohibit land drainage for certain areas. There are such prohibitions today applicable to large parts of southern Sweden.

The Environmental Court considers an application for a permit for a water undertaking. The County Administrative Court considers the application for a permit for drainage.

A person who owns a water undertaking must maintain it in order to avoid serious accidents as a consequence of dam bursts, etc. In the event of a dam accident, the owner is liable to pay damages for losses, even if he was not careless.

Environmental quality norms

A novelty in the Environmental Code is the so-called environmental quality norms given in chapter 5. These are directions on minimum acceptable environmental quality for land, water, air, and other environments. While earlier environmental legislation only has been focused on minimising and dampening environmental disturbances as far as reasonably possible, the Environmental Code puts direct demands on the final result, i.e. on the properties of the environment in order to be acceptable.

Environmental impact statements

The preconditions for the environment must be taken into account in permit decisions and other decisions for protection of human health and the environment, as well as the good resource management of land, water and other resources. Decisions should therefore be based on an analysis of the impact of the decision. *Environmental impact statements* (EIS) achieve this. The rules on such statements are made more stringent in the Environmental Code.

The statement should be included as part of the basis for the decision and facilitate an overall assessment of a planned operation's effect on the environment, health and management of natural resources. In order to achieve this objective, environmental issues must be raised early and then included in the process leading to the permit decision. Those affected must also be given an opportunity to participate at an early stage, so that they have a chance to influence the work with the environmental impact statement.

The procedure for preparation of environmental impact statements and the requirements for these are dealt with in chapter 6 of the Environmental Code.

Everyone who intends to take a measure that requires a permit must consult with the County Administrative Board and private parties who may be particularly affected. The County Administrative Board must, after consultation, decide if the measure can have significant impact on the environment. The government will prescribe that particular types of measures may always be assumed to involve substantial environmental impact.

If a measure may be assumed to have a substantial environmental impact, an environmental impact assessment has to be made. The person or company conducting the operation must then also consult other government authorities, municipalities and organisations as well as the general public. The consultation will relate to the localisation, extent, design and environmental impact of the measure.

The environmental impact statements must contain a description of the measures planned to avert damage and a report concerning alternative places and alternative designs. For measures that are not assumed to create substantial environmental impact, the information only has to include statements considering the nature and extent of the measure. The party conducting the operation must pay for the environmental impact statement and the procedure with environmental impact assessment.

Public notice must be given together with the application for environmentally hazardous activities, water undertakings, or activities causing substantial environmental impact. The public can then express its opinion on the activity. The permit authority must take the content of the statement into account when it considers the application.

The chapter concludes with special provisions about plans. Every authority responsible for applying the Environmental Code must ensure that plans under the Planning and Building Act and documentary planning-bases covering issues concerning land and water management are available. The County Administrative Board has the task of compiling such planning information.

Protection of areas and species

Regulations for several forms of area protection have been merged into the Environmental Code. Examples include biotope protection, beach protection and the possibility of setting aside areas as national parks and nature reserves or proclaiming areas as being of national interest for natural conservation or recreation. Together with the regulations on species protection, the area protection is to safeguard the biological diversity.

The County Administrative Board or the municipality may declare land and water areas as nature reserves for the three-fold purpose of preserving biological diversity, conserving and protecting valuable natural environments and satisfying the needs of the area for outdoor activities. In a decision to create a nature reserve (or cultural reserve), the required limitations on the right to use the areas must be stated, e.g., prohibition against building, erection of fences, ditching, tree-felling, hunting, fishing, and use of pesticides. A limitation may also involve access to the area for the whole or part of the year. Furthermore, the landowner may have to tolerate the construction of roads or resting-huts, or the thinning-out and clearing work. Landowners are, in certain cases, entitled to compensation for damage.

The County Administrative Board or municipality may issue a relaxation from the regulations in a reserve. A relaxation may only be granted if damage to the natural or cultural value is compensated. The compensation measures need not necessarily take place within the reserve.

A special shore protection applies to the sea, inland lakes and watercourses. The purpose is to protect the preconditions for outdoor activities and to preserve good living conditions of fauna and flora. According to the main rule, shore protection comprises generally all land and water areas up to 100 metres (300 metres in some cases) from the shoreline.

Within the shoreline protection area, a prohibition applies against all measures, e.g. the construction of new buildings, fences, or piers or the building of waterline cabins for summerhouses.

A land or water area may be declared to be a water protection area in order to protect groundwater or surface water supplies that are, or may be, used as a source of water. Rules limiting the right to use the land may be issued. A prohibition may be issued against, for example, dealing with petroleum products and other chemicals, the spreading of manure or use of pesticides, infiltration of domestic wastewater and municipal drainage water, or boat traffic.

Environmental Courts

Regional Environmental Courts, described in chapters 20-23, have been formed at the District Courts in Umeå, Östersund, Stockholm, Växjö and Vänersborg. They have superseded the National Licensing Board for Environmental Protection and the Water Courts. The final appeal court is the Svea Court of Appeal.

The Environmental Court consists of a chairman who must be a legally qualified and experienced judge in the District Court, an environmental adviser and two expert lay-judges. An additional legally qualified judge and an environmental adviser may form part of the Court. The environmental adviser must have technical or scientific training and experience of environmental issues. One of the expert lay-judges must have experience in issues that fall within the operational field of SEPA. The other expert lay-judge must have experience of industrial or municipal operations.

Environmental sanction charges

A cause for the, sometimes, low environmental lawfulness could be that the risk for punishment for environmental crimes has been considered small. There has thus been a need for a rapid and efficient possibility to react to violations of the environmental rules. In connection with the enforcement of the Environmental Code, so-called environmental sanction charges were also implemented. The environmental sanction charges are charged directly by the supervisory authority when a violation is ascertained. The amount charged for a certain violation is regulated according to tariffs decided by the government. The charges are presently in the range 5 000 SEK ($US 600) to 1 MSEK ($US 120 000).

River view from Ostrava in northern Czech Republic (photo, Lars Rydén).

14.

INSTITUTIONAL FRAMEWORK AND AUTHORITIES

Henrik Lindström & Jan Gunnarson[1]

Municipal responsibilities

In Sweden, the municipalities play a key role in physical planning, through the Act of Planning and Building (PBL) and in the management of natural resources, through the Environmental Code. Since 1987, municipalities are required to have an up-to-date, Comprehensive Plan concerning land and water use, and public-authority permit-issuing activities. With the *Comprehensive Plan* (CP), municipalities exert an influence on other authorities' decisions on land and water use. The Comprehensive Plan is used in decisions on the handling of applications to the Environmental Code. In that way, Comprehensive Plans affect decisions on water use and contribute to a responsible management of natural resources on a long-term basis. Co-operation between adjacent municipalities shall be a part of the Comprehensive Plan, but is not coercive.

At the Environmental Conference in Rio, in 1992, a final document (Agenda 21) was negotiated. In this, a program for the 20th century was established. In Sweden, the Agenda work will mainly be a task for citizens and organisations in the country's municipalities. Local programs were launched in 1996 and *Local Agenda 21* documents exist today in all municipalities.

The municipalities often draw up *environmental conservation programmes* as well, which may cover both environmental protection and nature conservation aspects. The environmental conservation programme often has the character of an environmental analysis. Here it is important to strengthen the role of the Environmental Programme to summarise environmental objectives and develop action programmes.

One way to deal with the often very complex water-related issues is to gather them in a special knowledge base on water–often called *a water synopsis* or *river basin management plan*. With a thorough review of available knowledge followed by an analysis and proposal part, the document can be developed into a compilation of available knowledge on water that comprises an important platform for other planning and in the programme work. The document should be presented to the municipal council, but may not be adopted and given direct legal consequences.

The background data on which environmental conservation, and particularly environmental protection, is based has so far been dominated by numerical data. Far too little map-based information has existed. Measurement data is more interesting if it is related to the geographical relationships in the physical environment. The development of database-based *geographic information systems* (GIS) makes it possible to change this situation. This type of relational analysis is necessary in order for the water knowledge bases to be linked to the comprehensive planning.

Responsibility of the state

The state has a supervisory responsibility for national interest, health and safety as well as for inter-municipal matters. The *County Administrative Board* scrutinises the Comprehensive Plans in these three respects, at a minimum. The state also has a responsibility for the implementation of national environmental objectives on regional and local levels. This is co-ordinated in the Strategy of Regional Environment (STRAM). Through the County Administrative Board, the state has an obligation to provide Regional Background Material (RUM), which describes public interests. RUM often has shortcomings on the groundwater side, though.

The *central sectorial authorities* also have a role in planning work. In Sweden, for example, the National Road Administration, the National Board of Agriculture and the National Board of Forestry have begun to work with sectorial environmental conservation programmes. Water aspects should naturally be incorporated in these programmes. The Swedish

[1] The chapter is based on a part of the English translation of the report "A Synthesis" in the series "Water Planning", published in 1996 by the Swedish Environmental Protection Agency and the Swedish National Board of Housing, Building and Planning. The original English text has been edited by Lars-Christer Lundin.

Environmental Protection Agency works to a large extent cross-sectorially with environmental protection and nature conservation by supplying knowledge, where the water project is one part. The National Board of Housing, Building and Planning participates in method-development and knowledge dissemination regarding natural resource manage-ment, the built environment and physical planning, including water issues. Some sectorial agencies, with a special responsibility for supplying basic data on water are SMHI (the Swedish Meteorological and Hydrological Institute), the National Food Administration, SCB (Statistics Sweden) and LMV (the Central Office of the National Land Survey). Other agencies, such as SGU (the Swedish Geological Survey), are mainly supposed to represent one interest or field.

Water management in Europe

Water strategies and directives in EU

Within EU there is yet no federal or supranational assessment and apportionment of available water recourses in time or space. Instead, use is made of administrative policy instruments related to Articles 100 and 235 in the Treaty of Rome, regarding harmonisation of the Member States' legislation. The main target of the EU policy instruments is the quality of the aquatic environment. Far-reaching international co-operation for improving the aquatic environment is also embodied in the Rhine Commission and HELCOM, which lie outside the European union.

All of EU's environmental action programmes have included the aquatic environment. This is particularly true of regulation of upstream-downstream conflicts in international watersheds. In the current environmental action program, several areas of action are given high priority.

Areas of action with highest priority

- Implementation of existing water-related environmental legislation – existing EU legislation and the polluters-pay principle is only adequate if it is complied with.
- Control of all polluting substances–includes traditional environmental conservation with identification of discharges and discharge monitoring of both the source and receiving waters.
- Increasing the water-related environmental awareness of the public–intensified information on water-related environmental problems is of fundamental importance in order to strengthen protection of the aquatic environment in the future, e.g. Groundwater Directive 80/68/EEC.

In parallel with the EU water resource management, EU comprehensive planning is also being developed (also called EU cohesion planning). It resembles the Swedish national comprehensive planning program, where land and water uses are allotted among different users. EU's comprehensive planning has the disadvantage of an overemphasis on land management while the water issues are perspicuously treated.

Good water quality is considered to exist when:

- The water has retention capacity, i.e. can self-purify.
- Naturally reproducing species are present in reproducing populations.
- The sediments are of such quality and structure that natural communities are present in the ecosystems.

Tasks of the Member States according to the directive are:

- To establish operative quality objectives, in order to provide an ecologically good water quality, after which ecological status is locally or regionally adapted, based on the general premises given in the Directive
- To establish co-ordinated programmes with binding requirements to achieve the objectives
- To monitor environmental status on a regular basis and report every three years
- To update data on point and diffuse pollution sources on a regular basis
- To standardise and calibrate sampling techniques
- To create action programs to be circulated for review and comments

Based on the EU's Groundwater Directive, SEPA has issued regulations that ban the discharge of certain substances to groundwater. These regulate direct discharge to the groundwater without prior percolation through the ground or the subsoil. Excluded from this directive are discharges of domestic effluents from isolated dwellings not connected to a sewage system and situated outside areas protected for the abstraction of water for human consumption.

Substances or groups of substances that may not be discharged directly into groundwater are:

- Organohalogen compounds and substances that may form such compounds in an aquatic environment
- Organophosphorus compounds
- Organictin compounds
- Substances which possess carcinogenic, mutagenic or teratogene properties in or via the aquatic environment
- Mercury and its compounds
- Cadmium and its compounds
- Mineral oils and hydrocarbons
- Cyanides

Water in regional and municipal physical planning in Europe

The awareness of the interaction between land, water and air has, during the last decades, permeated the comprehensive planning in most northern European countries. For example, in Denmark and The Netherlands, the interest has been focused on groundwater for the obvious reason that this is the dominating source of drinking water. The connection between land use and quality of groundwater is the governing factor for land use.

In Finland the planning organisations have carried out a fundamental reconstruction in recent years. Previously, the thirteen counties comprised the basis of regional comprehensive planning. The Water Board was, until 1995, responsible for planning and decisions related to water, especially water quality issues. The legal foundation for the work is the Finnish Water Act from 1961.

In 1996, the Water Board was transformed into the Finnish Environmental Centre. The intention was that it should be an information centre for environmental issues involving not only water, but land and air as well. The reorganisation can be seen as a closer alignment with the EU and a response to the signals sent out regarding environmental matters. The role of the municipalities in Finland is very strong.
Ongoing projects of interest in Finland are:

- Water Protection programme 2005
- Restoration of polluted areas
- Protection zones for groundwater
- A national environmental monitoring program for the terrestrial environment
- Integration of groundwater protection and land use in comprehensive planning
- Solving the problem of the occurrence of the algae, *Gonyostromun semen*, which obstructs artificial recharge and clogs filters and sand beds

In Denmark, society's dependence on groundwater has shaped the process of planning that has been applied for several years. The protection of water resources and land use is co-ordinated in the plans for land and water use. Regional and municipal plans are developed in co-operation between involved authorities. Regional plans for water sources provide a framework for utilisation and protection of surface water and groundwater. The legal framework is the Danish Water Protection Act. The regional administration has a strong position with regard to the use of water and land. Municipalities are expected to comply with the regional plans.

Plans and administrative routines are, however, not enough. For this reason it is important that all those affected by land and water management issues co-ordinate their work. In Viborg, the county authorities have published a handbook on groundwater protection with the title "Think Carefully, Those of You Who Live on Top of Your Drinking Water!" The book targets municipal officers and politicians.

In the Netherlands, as in Denmark, the dependence of groundwater resources has influenced the planning work. Management and responsibility have been decentralised to a local level. Each administrative level has an environmental responsibility. The National Comprehensive Planning Agency (NPA), which is a part of the Department of Housing, has the overall responsibility. A national Comprehensive Plan has also been developed to which regional and local planning must conform. Water is an integral part of the national policy for the planning process. "The Netherlands as Waterland" is one of six areas given special attention. Both quality issues, such as drinking water, and quantitative issues, such as the risk of flooding, are considered.

The Netherlands focuses on an environmental planning of land and water issues, considering an ecosystem in which man is both a part and an influencing factor. Land and water planning is integrated in the comprehensive planning and decision-making processes.

In the U.K., it is the Department of Environment that lays down national and regional guidelines for planning. In planning of land use, the DOE works at the regional level (shire county) with comprehensive plans and at a local level with detailed development plans.

The water planning and water management, which previously have been carried out at a regional level, have gone through great changes in recent years. The previously publicly owned River Basin Authorities have been privatised and are now operated in corporate form. Each company is responsible for water supply and wastewater treatment within its own river basin. Principal responsibility for water planning lies at the regional level. Each regional water company is responsible for water planning in its river basin within the framework of legislation. The public water supply and wastewater treatment is guaranteed through legislation, imposing requirements on the companies with regard to delivery obligations, rates charged, water quality etc. There are central bodies, responsible for co-ordination and monitoring, as well as technical research and development. In the U.K., deregulation, regionalisation and privatisation of water management have been implemented consistently. The new form of planning and administration has been in use long enough to evaluate the effects of the transformation.

In France, water planning and water management have been decentralised to six regional water authorities. The most important bodies in the regional water agencies, Agence de l'Eau, are the water management committee, Comitté de Bassin, and the water district board, Conceil d'Administration. A managing director and an administration officer are available for each Conceil d'Administration.

The local water administrations work with five-year water plans. The water plans establish objectives for water quality, prioritised investments in sewage treatment, charges for polluting discharges, diversion, etc. There is also a co-ordination of the regional water administrations at a central level in the environmental ministry's Conceil Departmental d'Hygiene.

In Norway the central responsibility for water resources management is divided among several ministries and governmental agencies**.** The Ministry of Industry and Energy is responsible for power plant construction and expropriations of waterfall rights, etc. The Norwegian Water Resources and Energy Administration (NVE) is the co-ordinating agency for hydropower engineering. The Department of the Environment is responsible for the co-ordination of natural resources management and of raw-material supply. At the central agency level, The Norwegian Pollution Control Authority, The Directorate for Nature Management Norway and the Public Health Authority handle quality aspects of water planning. In recent years, the District Governor (*Fylkesmannen*) has been given greater supervisory and administrative responsibility for water pollution, waste management, conservation of nature, outdoor recreation and fishing.

There is no specific water planning; rather water planning is integrated in the county planning. The county (*fylkeskommun*) is responsible for county planning. The municipalities are mainly responsible for testing drinking water and wastewater. Through issuing building permissions, the municipalities are able to make indirect water plans. The Planning and Building Act assigns responsibilities to the municipalities to plan development so that surface water and groundwater are not polluted.

The interaction between municipalities and the state

In future water management work, an overall view will be a necessity. This means that the catchment will be the geographic region for planning and action. This requires close co-operation between region and municipality. The Comprehensive Plan is an important instrument in this work. Other important instruments are the Strategy for Regional Environment, municipal environmental protection programmes and local Agenda 21 programmes. A knowledge base can play a significant role in this context. It is also important as a basis for joint prioritisation in the work with action programmes. Since water issues are international, new forms of co-operation, not being confined within present administrative borders, must be found. Better co-ordination is also needed between activity-orientated planning, such as public works planning, environmental conservation planning and comprehensive planning. Other stakeholders are water associations that established, through decisions according to water legislation, water conservation associations, which are voluntary co-operative partners, inter-municipal co-operation organisations within a catchment, interest organisations and fishery conservation areas.

15.

Environmental quality objectives

Rob Leuven & Ad Ragas

Introduction

One of the goals of sustainable water management is to control pollution sources in order to achieve good water quality. Two basic principles can be distinguished in European water quality management: a pollution prevention principle and a carrying capacity principle (Figure 15.1).

The pollution prevention principle is based on the idea that any form of pollution may have an adverse impact on water quality, and should therefore be prevented. Within this framework, the choice of source-oriented measures depends on the technological possibilities for emission reduction and their economic and social consequences. The method of establishing source-oriented measures is often referred to as the technology-based approach.

The carrying capacity principle is based on the idea that the environment can cope with certain pollutant loads: as long as the carrying capacity of a water system is not exceeded, no adverse effects will follow. In most cases, the carrying capacity is measured in no observed effect concentrations (NOECs) or *environmental quality objectives* (EQOs). NOECs and EQOs are applied in order to predict the possible occurrence of adverse effects. Monitoring data and various water quality and exposure models are applied in order to make predictions about environmental concentrations. If the (predicted) environmental concentration (PEC) is worse than the NOEC or the EQO can be expected to be exceeded, effect- and/or source-oriented measures should be taken (Figure 15.1). Examples of effect-oriented measures are liming in acidified lakes or remediation of contaminated aquatic sediments. The procedure of predicting environmental quality concentration levels and comparing them with no effect concentrations is generally referred to as risk assessment. The method of establishing effect and/or source-oriented measures based on NOECs or EQOs is mainly referred to as the water quality-based approach (also called Environmental Quality or EQ-approach).

The goal of this chapter is to present a generalised overview of norms and legislation related to the technology- and water quality-based approaches in sustainable water management. This overview is mainly based on the following publications: Bro-Rasmussen (1994), Haans et al. (1998), Kinnersley (1994), Ragas & Leuven (1996; 1999) and Ragas et al. (1997; 1998.) The following aspects will be discussed: different types of EQOs and procedures for determining EQOs and European water pollution prevention and control in relation to emission limit values (ELVs) and EQOs.

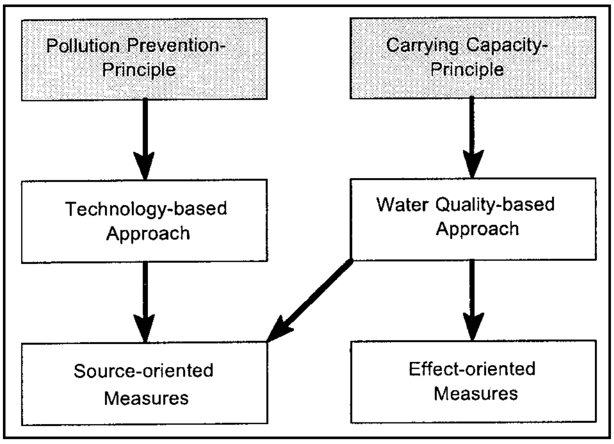

Figure 15.1. Relations between the pollution prevention and carrying capacity principles, and the related technology- and water quality-based approaches in sustainable water management (from Ragas et al., 1998).

Environmental quality objectives for water management

Different types of environmental quality objectives

EQOs can be developed to protect human health (e.g., swimming water standards), specific human interests (e.g., fishery, livestock water or irrigation water) or ecosystems. Protection can be guaranteed at several risk levels (e.g. maximum permissible or negligible risk concentrations) and each risk level can be related to specific source- and effect-oriented policy measures. In practice, three different types of consequences (from low to high protection level) of EQOs are distinguished (BKH, 1995):

- trigger intervention
- trigger further investigation
- long term quality target

In recent years, ecological quality objectives have become more important in the discussion on sustainable water management and the restoration of water systems. The focus has been on the protection of freshwater or marine aquatic life. Ecological objectives can be described for various (types of) water systems and do not only include chemical parameters like concentrations of toxic substances. Biological and physical parameters, like species indexes and temperature, may also be included, as well as limitations on water use by humans.

Procedures for setting EQOs for toxic substances to protect ecosystems

EQOs for toxic substances to protect ecosystems are primarily scientifically based (mainly on ecotoxicity, bioaccumulation and persistence) but technical, social and economic considerations may also play a key role in the final establishment of these EQOs. According to EU-terminology, EQOs set the maximum pollution levels to be reached in the environment in order to safeguard an effective protection of the aquatic environments and by taking the so-called zero-effect evaluation (EEC, 1973) into account. The term EQO is comparable to the term water quality criteria applied by the United States Environmental Protection Agency (US-EPA) and also to the concepts of environmental concern level (ECL) of the Organisation for Economic Co-operation and Development (OECD) and maximum permissible concentrations (MPC) from Dutch practice. All of these intend to define protection levels at which unacceptable, adverse (ecotoxicological) effects on ecosystems are unlikely to occur (Aldenberg & Slob, 1993; OECD, 1992; Slooff, 1992; US-EPA, 1987). Generally, the setting of EQOs rests on relatively rigid rules and procedures (Bro-Rasmussen, 1994).

The US-EPA approach to derive EQOs requires 16 acute toxicity tests, 3 chronic tests, 2 plant tests, and 1 bioaccumulation study (Stephan et al., 1985). The procedures proposed by the OECD and practised, for example in the Netherlands are very similar in design as well as in their quantitative details. They serve as a basis for identifying ECLs or MPCs, and both methodologies have introduced tiered plans for deriving preliminary, refined, and comprehensive EQOs.

Preliminary EQOs are derived when limited toxicity data is available. The use of data derived from quantitative structure activity relationships (QSAR) and a strict number of toxicity end-points for a limited number of representative species from several trophic levels are included in the practices of extrapolation. Application factors (AF) are used to derive a preliminary EQO from the data. The upper limit of this factor depends on the availability of single-species toxicity data (Chapman et al., 1998).

The distinction between preliminary EQOs and refined or comprehensive EQOs is tied directly to the amount of data that is available for the individual assessments. Four or more chronic toxicity descriptors for organisms of different taxonomic groups must be available to determine a refined EQO.

Apart from the references to different standard statistical methodologies (i.e., log-logistic or log-normal distribution curves of the effect-concentration relations), the OECD and the Dutch methods to derive refined EQOs both refer to protection levels. These are defined in relation to the single species NOECs, and in both cases, with adoption of identical 95 % protection levels for species in aquatic ecosystems (Aldenberg & Slob, 1993). This means, in principle, that the NOECs can be exceeded by, at most, 5 % of the species of an ecosystem, provided that such species are covered in a representative, underlying database.

As for the comprehensive EQOs, multiple-species experiments have to be presented but it seems that comprehensive EQOs have not yet been developed according to any of the plans (Bro-Rasmussen, 1994).

Effect-based environmental quality objectives in western countries

BKH consulting engineers made a compilation of EQOs (including their background and setting procedures) for chemical substances in (ground)water and aquatic sediment set by various countries and organisations, which are based on ecotoxicological and human toxicological effect data (BKH, 1995). Their survey involves the Netherlands, Canada, the United States, Norway, Sweden, Finland, Denmark, Germany, the United Kingdom and the European Union (EU). Apart from Norway, all countries and organisations apply effect-based EQOs for substances in surface water (Table 15.1). However, only a few countries have set EQOs for groundwater and sediments. Most effect-based EQOs are drafts, or recommendations to sub-national authorities. Relatively few EQOs have a legal status. Table 15.1 presents a rough estimate of the number of EQOs per country/organisation for different environmental areas. Because of the widely differing, scientific derivation methods and the variety of consequences associated with chosen risk levels, the comparability of the EQO values is relatively poor. Following is a more detailed overview of the sets and types of EQOs used by the respective countries in the water-quality-based approach.

In most countries/organisations, setting of EQOs is still under development. Therefore, in the near future many changes are to be expected in the number, values and status of EQOs. Environmental legislation of the European Union (EU) relevant to the different water areas is primarily controlled by issuing EU directives. These directives are aimed at harmonisation of the national legislation of member states. They have legal strength after incorporation into national legislation. Member states may not set criteria that are less stringent. Available EU-directives focus on the following specific water functions:

- bathing water
- freshwater for fish (i.e., water for cyprinids and water for salmonids)
- shellfish water
- protection of aquatic life
- surface water destined for the preparation of drinking water
- drinking water (i.e., water for human consumption)
- water affected by specific discharges

In 1995 the European Union agreed that a fundamental review and restructuring process was needed for water policy and legislation. The European commission adopted a new *Water Framework Directive* in 1997. Its purpose is to establish a framework in order to achieve the following four main objectives of a policy for sustainable water management:

1. sufficient provision of drinking water
2. sufficient provision of water for other economic requirements
3. protection of environmental quality
4. alleviation of adverse impacts of floods and droughts

The environmental objective of the directive is to achieve "good status" for all groundwater and surface waters by 2010 at the latest. To this aim, it establishes river basin management based on an assessment of the characteristics of river basins, monitoring of the status of its surface waters and groundwater, setting of EQOs and emission limit values (ELVs; see below) and measures to achieve the defined environmental objective. For a detailed overview of the subject matter of EU directives (including implementation considerations for Member States) and developments concerning the Water Framework Directive visit the Internet website concerning the approximation of European Union environmental legislation of Directorate General XI (European Commission, 1999).

Table 15.1. Rough estimation of the number of effect-based EQOs per country/organisation for various environmental compartments (based on BKH, 1995)

Country/ organisation	Water	Sediment	Groundwater
The Netherlands	85[a]	85[a]	35[a]
Canada	70	25	-
United States	50	-	-
Norway	-	-	-
Sweden	7	8	-
Finland	-	-	-
Denmark	100	-[b]	-[b]
Germany	40	1	-
United Kingdom	30	-	-
European Union	30	-	-

a: the numbers represent Maximum Permissible Concentrations (MPCs) and Negligible Concentrations (NCs);
b: criteria not yet available.

Prevention and control of pollution

Emission limit values

The technology- and water quality-based approaches may result in different limits on wastewater discharges (Kinnersley, 1994).

1. The *technology-based approach* centres on cleaning at the source level, using technological standards, which in the different European countries are known as the best practical means (BPM), the best available technology (BAT) and the best available technique not exceeding excessive cost (BATNEEC). Limits on discharges may be expressed as uniform emission limit values (ELVs). In effect it says that no effluent discharge to water must contain more than, for example, 50 parts per 1 000 of this or that substance or a maximum load per unit product.

2. The *water quality-based approach* focuses on the impact of the discharge on the quality of the receiving body of water. This approach would set ELVs in individual permits for each discharge in its specific location, taking into account the level of dilution available in the river or estuary flow and the quality of its prevailing water. The water quality-based approach comes down to predicting future water quality, comparing it with EQOs and, if they can be expected to be exceeded, deriving water quality-based ELVs. The basic ingredients in this procedure are a water quality model, input data and EQOs (Figure 15.2). In economic terms, ELVs derived from the water quality-based approach have the advantage of flexibility: if the river can dilute more pollution without ill effects, it is offering a natural opportunity that the community may reasonably decide to make use of. However, these ELVs may come under pressure when later would-be dischargers want larger shares of capacity that is

already reduced by permits granted to others. Moreover, when dischargers in high flow waters negotiate supply ELVs, a discharger in more sensitive bodies of water may feel there is little wrong in frequently breaching the rigid limits.

In practice, most countries more or less combine the technology- and water quality-based approaches in their discharge permits (Stortelder & Van de Guchte, 1995; OECD, 1996). In Germany, the Netherlands and the USA, for example, the ELVs resulting from water quality-based approach are supplementary to the discharge limits derived from the technology-based approach (LAWA, 1990; Blumen-schein, 1992). In the UK, the same goes for permits within the framework of the Environmental Protection Act (EPA), which mainly regulates the technology-based approach. Permits covered by the Water Resources Act (WRA), however, are only based on the water quality-based approach. During the 1990s, after extended discussion at EU-Member States and Community level, it became increasingly clear that an efficient protection of water needs a combined technology- and water quality-based approach (European Commission, 1999). A combined approach seems to be the best option for setting emission limits. It prevents avoidable pollution, as well as violations of environmental quality objectives (EQOs). Moreover, the combined approach also meets principles established in the European Treaty - the precautionary principle and the principle that environmental damage should, as a priority, be rectified at the source, as well as the principle that environmental conditions in the various regions shall be taken into consideration.

European legislation in the field of emission limits

European water pollution control began in the 1970s with the First Environmental Action Programme (1973) followed by a first wave of legislation (European Commission, 1999). In the field of emission-limit-values legislation the so-called *Dangerous Substances Directive* (i.e., Council directive 76/464/EEC) and several related directives for various individual substances were adopted. The *Dangerous Substances Directive* is concerned with pollution by certain dangerous substances being discharged into the aquatic environment from point sources, either direct or indirect (e.g., via sewage works). It is clearly tied to the prevention and control of pollution as it may be enforced by means of emission limit values (ELVs) and/or EQOs to be applied in relation to each specific discharge. The ELVs are to be considered as *maximum emission values* that may be established as a means to meet or nearly meet the requirements expressed by the EQOs. The directive distinguishes between two categories of chemicals or groups of chemicals.

List 1 compounds, which are selected mainly on the basis of their toxicity, persistence, and bioaccumulation. For these chemicals, discharges shall only take place when prior permission is given in compliance with harmonised emission limitations or community standards, taking into account the best technical means available or for which established community EQOs are satisfied.

List 2 compounds, which may have a deleterious effect, but that can, however; be confined to a given area. For these chemicals, a reduction of pollution shall similarly be implemented on the basis of individual permissions, but under the authority of member states, referring to nationally established ELVs and EQOs.

A second wave of EU ELV-legislation includes the *Urban Waste Water Treatment Directive* (1991), the *Nitrates Directive* (1991) and the *Plant Protection Products Directive* (1991). The IPPC, *Integrated Pollution Prevention Control Directive* (1996) covers water pollution as well. In the context of the earlier mentioned European Water Framework Directive the full implementation of existing EU ELV legislation must be provided.

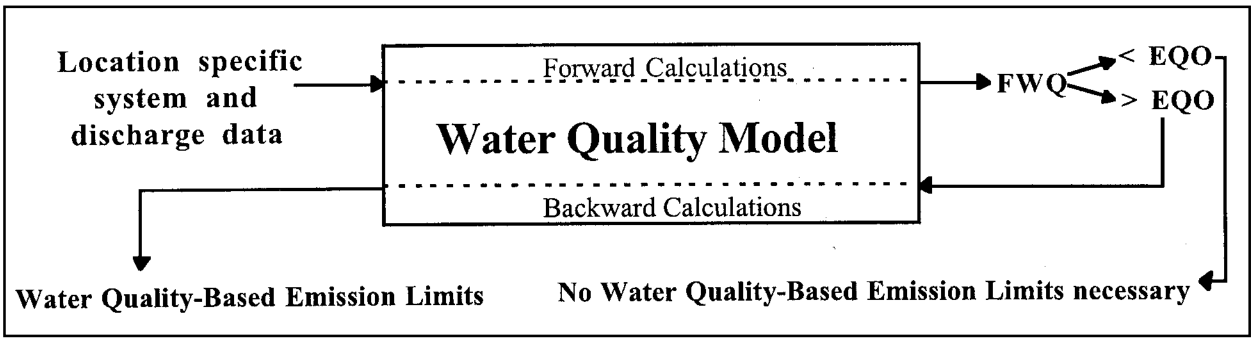

Figure 15.2. The water quality-based approach in discharge permitting (FWQ = future water quality; from Ragas et al., 1998).

Table 15.2. Sets and types of environmental quality objectives (EQOs) used in the water-quality-based approach (from Haans et al., 1998)

	European Union					Germany			NL	UK[2]		USA		
Sets of EQOs*	**D**	**B**	**F**	**Sh**	**I**	**BLAK-QZ**	**IRC**	**AGA**	**AMK**	**RQO**	**II**	**RL**	**Aq**	**Hh**
Temporal specification														
-percentile score	-	-	-	-	-	+	+	+	+	+	+	+	-	-
-duration of excursion	-	-	-	-	-	-	-	-	-	-	-	-	+	+
-frequency of excursion	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Spatial specification	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Pollution categories														
-conventional	+	+	+	+	-	-	±	+	+	+	-	-	±[1]	±[1]
-metals	+	-	±	-	+	+	+	+	+	±	+	-	+	+
-toxic agents	+	-	-	±	+	+	+	-	+	-	+	+	+	+

* D = EQOs for drinking water; B = EQOs for bathing water; F = EQOs for fish-sustaining water; Sh = EQOs for shellfish-sustaining water; I = EQOs for *List I Substances*; BLAK-QZ = federal objectives developed by the *Bund/Länder Arbeitskreis gefährliche Stoffen Qualitätsziele für oberirdische Gewässer*; IRC = objectives developed by the International Rhine Committee; AGA = *Algemeine Güteanforderungen für Fliess-gewässer* (general quality objectives of the federal state of Nordrhein-Westfalen); NL = the Netherlands; AMK = *Algemene milieukwaliteitsnormen* (general objectives for environmental quality); RQO = *River Quality Objectives*; II = national objectives for *List II Substances*; RL = national objectives for *Red List Substances*; Aq = objectives for the protection of aquatic life; Hh = objectives for the protection of human health; - = not elaborated; ± = partially elaborated; + = elaborated;

[1] = not all conventional pollutants have Aq and Hh objectives, and some are not directly the subject of a criterion; instead a related parameter is specified.

[2] = England and Waleas.

Water quality-based approach

This section provides a generalised overview of the current status of water quality-based discharge approaches in four countries: Germany, the Netherlands, the United Kingdom (UK; notably England and Wales) and the United States of America (USA). It focuses on distinguishing features of water quality-based approaches for discharge permitting, such as the types and characteristics of EQOs applied, the water quality models used, the operational aspects and the degree of elaboration.

Environmental quality objectives in the water quality-based approach

Table 15.2 gives an overview of the sets and types of EQOs used by the respective countries. The federal states of Germany use sets of function-oriented EQOs of the EU (such as those for drinking water, bathing water, fish and shellfish-sustaining waters; Höhne & Irmer, 1995) and state-specific AGA-objectives (so called *Algemeine Güteanforderungen*). The AGA-objectives are soon to be replaced by new objectives (with an ecotoxicological basis) for the protection of inland surface waters against hazardous substances, based on the so-called BLAK-QZ (BLAK-QZ, 1993). The federal government and the federal state developed this concept jointly. The resulting quality objectives are termed *Zielvorgaben* (water-quality targets) to make it clear that the derived values are guidelines rather than legally binding limit values (Irmer et al., 1997). Impairment of functional uses, such as supply of drinking water or the protection of aquatic communities, is not expected if the water-quality targets are complied with. Violation of these water-quality targets indicates the need to explore the causes, thus allowing a more appropriate fine-tuning of water pollution control and priority setting of sanitation projects and the analytical methods to be optimised (Irmer et al., 1995). A water quality classification system has been developed based on the BLAK-QZ (Irmer et al., 1997.) The water quality objectives of the International Rhine Committee (IRC) are applied in states in the River Rhine catchment area. The use of EQOs in the water quality-based approach differs in each federal state (Höhne & Irmer, 1995).

The Netherlands applies function-oriented EQOs of the EU and national AMK objectives, which are chemical-specific objectives, intended to prevent chronic effects. The IRC objectives apply for the River Rhine catchment area (VROM, 1992).

England and Wales use the function-oriented EU water quality objectives, chemical-specific EU water quality objectives for list 1 substances, national water quality objectives for list 2 and red list substances, and a set of objectives for the protection of river ecosystems (RQOs; NRA, 1994). With regard to novel substances, the various regions of the UK Environment Agency (EA) are allowed to develop and apply their own intermediary objectives, if national ones are lacking. However, where a substance

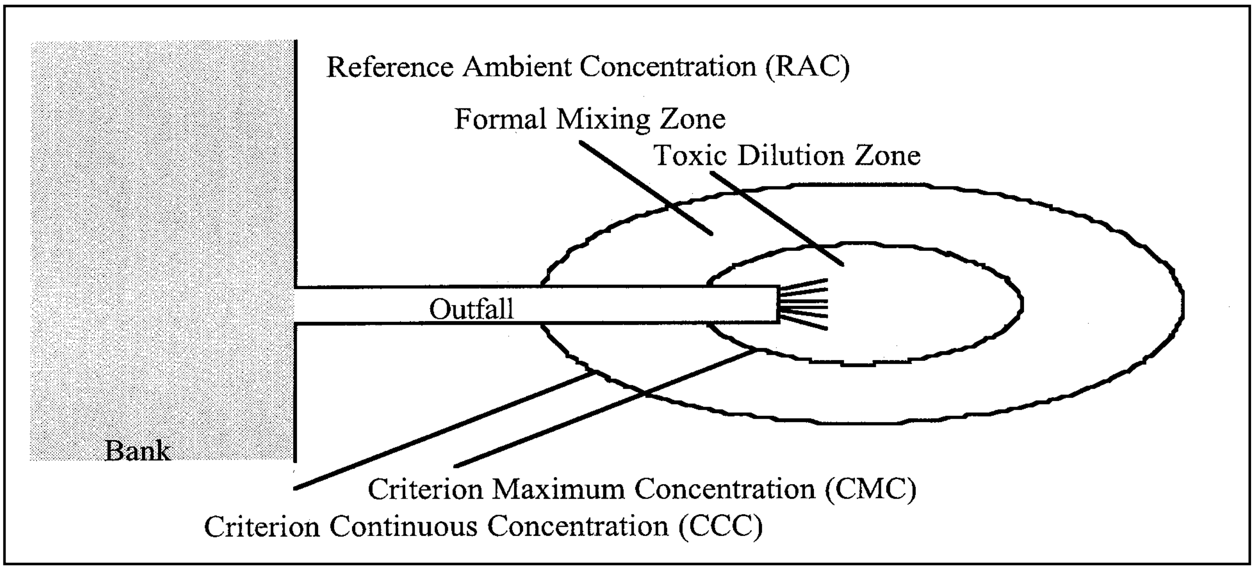

Figure 15.3. The mixing zone concept of US-EPA (1991). The criterion maximum concentration (CMC) is set to prevent acute toxicity and applies at the border of the toxic dilution zone. The criterion continuous concentration (CCC) is set to prevent chronic toxicity and applies at the border of and outside the formal mixing zone. The reference ambient concentration (RAC) is set to protect human health and applies outside the formal mixing zone (from US-EPA, 1991).

of concern is novel, toxicological data are sought so that an appropriate EQ criterion can be derived. This process is undertaken centrally by the EA and a database is maintained to ensure that the same substance is dealt with in a consistent manner by all EA-regions. The EA has recently begun consulting with industry about the introduction of toxicity-based controls. A specific National Centre has been established to take this enterprise forward.

The USA has federal water quality objectives (for which the American term is water quality *criteria*) developed by the United States Environmental Protection Agency (US-EPA), which may be adopted by the states. However, each state is allowed to develop and use its own objectives, which must be at least as stringent as the national US-EPA objectives. To this end, US-EPA has formulated guidelines, and the state EQOs and their application have to be approved by US-EPA. US-EPA recommends to use three types of EQOs: a criterion maximum concentration (CMC) to prevent acute toxic effects on aquatic life, a criterion continuous concentration (CCC) to prevent chronic toxic effects on aquatic life and a reference ambient concentration (RAC) to protect human health (Figure 15.3). The toxic dilution zone is limited by the CMC. The CCC limits the formal mixing zone. Outside the formal mixing zone the CCC and RAC apply.

In general, all countries use chemical-specific objectives to avoid chronic effects. No country actively uses sediment criteria or biological water quality parameters (in the USA also known as biological criteria) in the water quality-based approach, although the USA is working on both. The USA is the only country that uses water quality objectives based on (effluent) toxicity, as well as objectives to avoid acute effects. Germany also uses a whole effluent toxicity (WET) test, but it is applied within the framework of the BAT-approach (Höhne & Irmer, 1995). The Netherlands and the UK are considering an extensive WET-approach (Tonkes & Botterweg, 1995; Crawshaw, 1993).

Characteristics of the sets of environmental quality objectives

EQOs may actually be expressed in absolute and percentile limits (Kinnersley, 1994). If the limits are absolute - as for example, the 50-km speed limit is on roads where it applies - exceeding the limit (that is, a statistical measure beyond a limit) is readily recognisable as an offence, though no prosecution may follow. Most statutory limits are expressed in absolute terms because certainty is important for legal reasons. Percentile limits have the effect of allowing exceedences of the stated limit for a portion of a stated period or space, or, more precisely, in a portion of the sampling checks made in that period or space, respectively. Percentile limits may be useful in indicating the standard that must be achieved ‘on average’, or most of the time, which can be significant for measuring continuous discharges of effluent and their impact month after month. However, these limits have the drawback of setting no limit to peak pollution loads in x % of the time or samples outside the percentile limits. For example, peak levels of

Table 15.3. Characteristics of the sets of environmental quality objectives (EQOs) used in water quality-based approach (from Haans et al., 1998)

	Germany	The Netherlands	UK (Eng. & Wales)	USA
Sets of EQOs	**EU / AGA / BLAK-QZ / IRC**	**EU / AMK / IRC**	**EU / RQO / II / RL Environment Agency regions**	**US-EPA (federal) / states**
Sediment quality	-	-	-	-
Chemical-specific	+	+	+	+
Whole effluent toxicity	-	-	-	+
Biological water quality[1]	-	-	-	-
Acute toxicity	-	-	-	+
Chronic toxicity	+	+	+	+

[1] = parameters indicating presence or abundance of biota.
EU = function-oriented water quality objectives of the European Union; AGA = *Algemeine Güteanforderungen für Fliessgewässer* (general quality objectives of the federal state of Nordrhein-Westfalen); BLAK-QZ = *Bund/Länder Arbeitskreis (Wasser) Qualitätsziele* (federal objectives developed by the *Bund/Länder Arbeitskreis gefährliche Stoffen Qualitätsziele für oberirdische Gewässer*); IRC = objectives developed by the International Rhine Committee; AMK = *Algemene milieukwaliteitsnormen* (general objectives for environmental quality); RQO = *River Quality Objectives*; II = national objectives for *List II Substances*; RL = national objectives for *Red List Substances*; - = not applied; + = applied.

pollution can cause fish to be killed and establishing lower levels of pollution afterwards will not revive them. Thus a percentile limit applying to, say, 95 % of the samples may sound almost as tough as an absolute one applying 100 % of the time. The key difference, however, is the absence of any limit for *some* of the time. A further drawback is the increased difficulty in identifying when an offence (as distinct from an exceedence) has been committed. Say that 5 % of the samples are allowed to exceed the 95th percentile limits specified in any given period, e.g., twelve months. No single sampling result can then be said to show a breach of the permit until it is known if the other samples have failed often enough to use up the quota of allowed exceedences. This depends on the number of samples taken as well as the number failing. This uncertainty prevails much of the time: enforcement proceedings cannot begin until results are accumulated to show the full number of samples beyond the limits. Percentile scores can be very confusing for both the dischargers and the public. Furthermore, enforcement procedures such as warnings or prosecutions based on percentile scores can sometimes be complicated. Therefore, for some purposes it is helpful to set absolute and percentile standards together and to define the maximum duration and frequency for exceeding EQOs.

Table 15.3 shows characteristics of the sets of EQOs used in water quality-based approaches by several countries. The USA is the only country to use spatial specifications in its EQOs, a feature of the mixing zone approach. This approach is used by US-EPA for situations in which complete mixing does not occur near the discharge point. The European countries studied all use percentile scores as temporal specifications of their national EQOs. The time specifications of EQOs used in the USA take the form of a maximum allowable exception frequency and duration. The European function-oriented EQOs lack temporal and spatial specifications. All countries apply sets of objectives that, in combination, cover the three main groups of pollution categories. For a large number of pollutants, however, EQOs do not yet exist.

Operational aspects

Table 15.4 shows some application characteristics of the water quality-based approach at the operational level. In the UK, it is performed for each permit, while in the USA it is carried out if effluent data and calculations (or estimates) indicate that future water quality might fail to comply with water quality criteria. In Germany, the individual states have their own qualitative screening criteria to determine the need for a water quality-based approach. The Netherlands lacks detailed guidelines on when a water-quality-based approach should be performed.

The core of the water quality-based approach is a model that is used to predict future water quality and to derive ELVs that comply with EQOs. As outlined by Ragas et al. (1997; 1998) and Ragas & Leuven (1999), basically three different types of models can be applied: complete mixing models, mixing zone models and system models (including catchment-scale models).

Complete mixing models are based on the principle of mass conservation (Warn & Brew, 1980). It is assumed that complete mixing between discharge and ambient water takes place instantaneously. As a consequence, possible mixing zone effects near the outfall are neglected. EQOs used in combination with

Table 15.4. Operational aspects of the water-quality-based approach (from Haans et al., 1998)

Aspect	Germany	The Netherlands	UK (England & Wales)	USA
Application of immission assessment				
Always	-	-	+	-
Screening test[1]	±[2]	±	-	+
Types of water-quality models applied				
Mass balances	+	±	+	+
Mixing-zone models	-	±	±	+
System models	-	±	+	+
Types of models according to input definition				
Steady-state	+	±	-	+
Stochastic	-	-	+	+
Dynamic	-	±	+	+
Model selection				
Water body specific	-	±	+	+
Data-dependent	-	±	+	+
Guidelines	-	-	+	+

[1] = based on a prediction of the future water quality, effluent and/or dilution data, a decision is made regarding the necessity of immission assessment; [2] = this applies to the situation in the federal state of Nordrhein-Westfalen; - = not applied; ± = occasionally applied; + = applied.

mass balances generally lack a spatial specification: they apply to the entire water system.

Mixing zone models simulate the mixing process between discharge and ambient water. If the discharge does not meet EQOs inside the discharge pipe, violation of EQOs in the ambient water is inevitable. The area in which EQOs are exceeded is called the formal mixing zone. To ensure the integrity of the water system, the size of the formal mixing zone should be limited. EQOs used in combination with mixing zone models must include a spatial specification, e.g. the maximum length, width or surface area of the mixing zone.

Water system models are complex model frameworks simulating water quality in an entire water system, e.g. a river basin. Water system modelling makes it possible to account for the interactions between multiple dischargers. If these interactions are not accounted for, downstream dischargers depend on the performance of upstream dischargers. Application of system models does not have direct consequences for the type of EQOs used, but it necessitates permitting authorities to formulate methods to allocate waste loads efficiently and fair among dischargers.

The models can either be *steady-state* (single input values), *stochastic* (probability distributions as input values) or *dynamic* (time series as input values).

Steady-state models use single values for all input variables and, consequently, the model output is also a single value. The input values should reflect a system condition in which water quality must equal the EQO. The output of a steady-state model can be compared with both types of EQOs (a percentile score or an excursion frequency in combination with an excursion duration,) provided the incidence of the simulated system condition corresponds to the time specifications of the EQO (US-EPA, 1988). To ensure this compatibility, the development of suitable input values should include a detailed analysis of the variability in system and discharge characteristics. In practice this detailed analysis is often not done, resulting in incompatibility of model output and EQOs.

Stochastic models define some variable parameters as probability distributions. This results in an output probability distribution, which can be used to check EQOs specified as percentile scores. EQOs with a maximum allowable excursion frequency and duration cannot be checked since the output probability distribution does not differentiate between these time characteristics. A 90th percentile score may imply one excursion for 10 % of the period, as well as 10 excursions for 1 % of the period.

Dynamic or continuous models define some variable parameters as functions of time. Input data is in a time series, e.g. successive measurements of pollutant concentrations and flow. The output is a time series, which makes it possible to check the excursion frequency and duration of EQOs. Percentile scores can also be checked, provided a frequency distribution is constructed from the output time series.

Since detailed guidelines on the water quality-based approach are lacking in the Netherlands, it is difficult to draw a clear picture of model application in this country. All kinds of models are available, but in practice they are rarely applied (De Bont et al.,

Table 15.5. Degree of elaboration of the water quality-based approach for discharge permitting (from Haans et al., 1998)

Aspect	Germany	The Netherlands	UK (Eng. & Wales)	USA
Elaboration	+	±	++	+++
Documentation	+	-	++	+++
Support for users	-	+	++	+++
Scientific argumentation	-	±	++	+++
Data requirement	low	low	high	(very) high
Estimated costs	low	low	high	(very) high
Guaranteed level of protection	low	low	reasonable	high

- = not elaborated; ± = in process of development; + = limited elaboration; ++ = reasonably elaborated; +++ = extensively elaborated.

1996; Ragas et al., 1997). Germany applies a steady-state mass balance, while the UK predominantly applies stochastic mass balances and stochastic or dynamic system models. Steady-state mixing zone models are rarely applied in the UK; where the use of the receiving water body dictates, such a model may be developed to establish spatial/temporal variation in the effluent plume. This might then be used to determine necessary changes in outlet design or location, or otherwise to determine the appropriate limit value for the discharge permit. The USA uses all of the above types of models for the water quality-based approach, although the most common models used in water quality-based permitting are steady-state mass balances. The more sophisticated models usually only come into play when the cost of pollution reduction gets very high, and the permitted facility begins to question the accuracy of the simple model. The USA is the only country with well-defined recommendations in several guidance publications for the development of mixing zones and the use of mixing zone models, although these are not required. Consequently, state implementations of mixing zones vary greatly – from using sophisticated mixing zone models to just calculating a dilution factor.

Both in the UK and the USA, model selection is associated with the type of water body and available data. In both countries the opinion prevails that one general water quality model would not be compatible with the existing diversity of locations and situations.

An essential element of the water quality-based approach to discharge permitting is the comparison between predicted environmental quality and EQO (Ragas et al., 1998). It is a prerequisite for this comparison that the time specifications of model output and EQO are compatible. These time specifications depend on the way the EQO and the model account for variations in time. Most EQOs are specified as percentile scores, allowing the EQO to be exceeded during a limited period of time. It is also possible to specify the maximum allowable frequency and duration of exceptions separately.

The degree of elaboration of water quality-based approach

Table 15.5 lists a set of criteria relevant for policy decisions, such as costs, data requirement, user-support and guaranteed level of protection. The guaranteed level of protection indicates the level of certainty associated with EQO compliance. A low level does not automatically indicate insufficient protection: it is very well possible that discharge limits based on the technology-based approach offer more than enough protection. However, this cannot be guaranteed without a water-quality-based approach (Ragas & Leuven, 1996).

In Germany and the Netherlands, elaboration of the water quality-based approach is limited. This leads to low costs and low data requirement, but also to a low guaranteed level of protection.

In the UK, the approach is reasonably well defined with ample documentation, support and scientific argumentation, a high data requirement and high costs. The guaranteed level of protection is high for substances for which quality objectives apply, but it is limited in the absence of toxicity objectives and a formalised mixing zone approach.

The water quality-based approach has been developed most extensively in the USA. The procedure has been worked out for specific chemicals and for total effluent toxicity. The approach has extensive documentation and user support, and a high level of scientific support. The data requirement generally seems very high, as are the estimated costs. The result is a high guaranteed level of protection.

Pollutant load allocation methods

Application of the water quality-based approach on an entire water system, e.g. a river basin, lake, reservoir or estuary, requires an allocation of pollutant loads among multiple dischargers. Several types of allocation methods are being used (Chadderton et al., 1981), such as:

- Equal percent removal (treatment)
- Equal effluent concentrations
- Equal total mass discharge per day or equal mass discharge per capita per day, per unit of raw material used or per unit of production
- Equal reduction of raw load
- Equal treatment cost per unit of production

European harmonisation of discharge permitting procedures

The relation between the technology- and water quality-based approaches is a subject of international debate in the European Union (EU), in view of the collective revision of European water quality Directives, embodied in the forthcoming *Water Framework Directive* (Kraemer, 1996). Although all EU Member States apply both approaches simultaneously, there are differences with regard to the degree of elaboration and the relation between the two (OECD, 1996). An important goal of the new EU Water Framework Directive will be the harmonisation of these different procedures to achieve greater efficiency through uniformity of regulations, and equality of law for countries and companies within the EU. The proposed EU Water Framework Directive contains a combined approach in which the source-oriented measures of the water quality-based approach are added to those of the technology-based approach. Such a combined approach has already been adopted for industrial facilities covered by the recent EU directive on *Integrated Pollution Prevention and Control* (96/61/EU) that became effective in 1999 for new discharges and will be implemented in 2007 for existing discharges.

If the EU intends to introduce a scientifically sound, practical, transparent and harmonised procedure for implementation of the water quality-based approach in discharge permitting, various options are available and the following important questions should be answered (Haans et al., 1998):

- How should the water quality-based approach be combined with the technology-based approach?
- What are the preconditions for application of the water quality-based approach?
- How is the allocation of responsibilities between authorities and dischargers regulated in the discharge permitting procedure?
- For which substances does the water quality-based approach apply?
- How should substances for which no EQOs apply be dealt with?
- How should EQOs be specified in space and time?
- Which environmental compartments should be considered during emission assessment?
- How should acute and chronic toxic effects be dealt with?
- Which models should be used to predict future water quality and derive ELVs through water quality-based approach?
- How should discharge permit requirements be formulated or specified in the actual permit?

The answers to these questions may have major consequences for the ELVs in discharge permits. To achieve harmonisation at the EU level, more research should be done on the consequences of different assessment procedures and assumptions.

To illustrate the possible consequences of differences in discharge permitting procedures, Ragas et al. (1998) and Ragas & Leuven (1999) reveal the magnitude of the differences in permitted annual pollutant loads that may arise due to the application of diverging water quality models and input data in the water quality-based approach. A comparison of their results with pollutant loads resulting from a technology-based approach reveals the overall consequences of different models and input data used and it allows conclusions concerning the possible surplus value of a combined technology- and water quality-based approach. Six water quality models used in discharge permitting in Germany, the UK, the Netherlands and the USA were selected:

- the Nordrhein-Westfalen complete mixing model (NWCM model); a simple steady-state mass balance equation that is applied in the German federal state of Nordrhein-Westfalen (LWA, 1991).
- MCARLO; a stochastic mass balance equation that is used in the UK (NRA, 1996; Warn & Brew, 1980). The only difference with the NWCM model is the stochastic nature of MCARLO.
- the Dutch mixing zone model (DMZ); a steady-state mixing zone model that was developed by the Dutch National Institute for Inland Water Management and Wastewater Treatment (RIZA) for an exploratory study on water quality-based emission limits (Voortman, 1994). The model allows excursion of EQOs in 10 % of the surface area of the physical mixing zone (the zone in which the concentration variation over the lateral direction of the water body exceeds 5 %).
- the partial stream flow model (PSF); a steady-state mixing zone model developed for use discharge permitting procedures in USA (Hutcheson, 1992). The model allows exceptions to of EQOs over 25 % of the stream width.
- the stream mixing zone model (STREAMIX); a steady-state mixing zone model developed by US-EPA Region VIII (US-EPA, 1995). STREAMIX is used to calculate a pollutant load that corresponds to a maximum mixing zone length (L) equalling ten times the stream width (L = 10W).

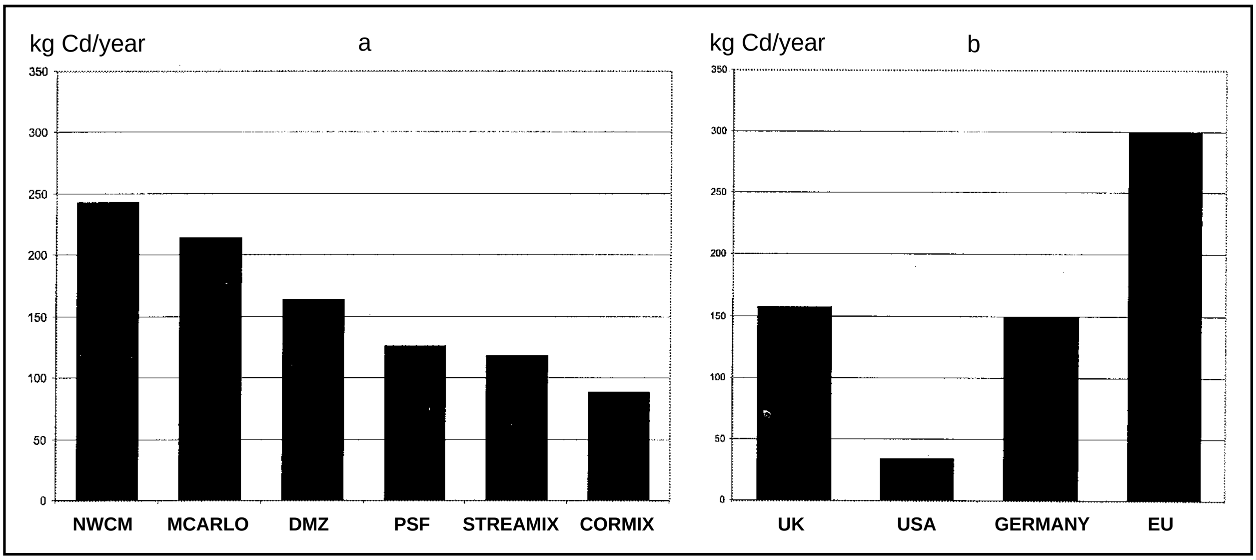

Figure 15.4. Overview of the maximum annual pollutant loads (MALs) for cadmium (in kg/year) in several states, resulting from water quality-based approaches (a) and technology-based approaches (b) for a plant processing 1 000 tonnes of cadmium per year for the production of the pigment cadmium sulphide (from Ragas & Leuven 1999). NWCM: Nordrhein-Westfalen Complete Mixing model; MCARLO: a stochastic mass balance model used in the UK; DMZ: Dutch Mixing Zone model; PSF: Partial Stream Flow model; STREAMIX: Stream Mixing Zone model; CORMIX: Cornell Mixing Zone Expert System.

- the Cornell mixing zone expert system (CORMIX); a set of steady-state mixing zone models developed in the USA (Jirka et al., 1996a; 1996b; Jones et al., 1996). CORMIX classifies a discharge, selects a proper simulation model and predicts the size of the mixing zone. It accounts for mixing processes neglected in other models like initial mixing, buoyancy and adhesion of the discharge plume. CORMIX was used in the case study to calculate pollution loads corresponding with a maximum mixing zone length of ten times the stream width.

The results of the water quality-based approach strongly vary with the type of model used and the discharge situation simulated (e.g., input data and EQOs used). So, if a water quality-based approach is to be applied within a legal context, it is important that the models, input data and EQOs used to predict future water quality and to derive emission limits, are harmonised. In this way, differences in permitted pollutant loads and unequal treatment of dischargers under comparable conditions can be avoided. Comparison of the pollutant loads of the water quality-based approach with those of the technology-based approach (see e.g. Figure 15.4) leads to the conclusion that water quality-based considerations may result in additional emission limits for several discharge situations. Therefore, a combined technology- and water quality-based approach in which the results of the latter are considered additional to those of the former is the best way to establish emission limits for discharge permits. It avoids unnecessary pollution, as well as WQO violations, which is in line with the pollution prevention and carrying capacity principles.

16.

Environmental quality objectives in Sweden - a case study

Lars-Christer Lundin

In its Government Bill of 1997/98, the Swedish Government proposed 15 environmental quality objectives (EQO) to be achieved within 20-25 years. These EQOs have been deemed necessary for the achievement of sustainable development.

The presentation in the present context will focus on the water management issues of the objectives and only give a brief idea of the other objectives. A more detailed presentation is given by the Government's website on sustainable development.[1] The list of EQOs is:

1. Clean air
2. High-quality groundwater
3. Sustainable lakes and watercourses
4. Flourishing wetlands
5. A balanced marine environment, sustainable coastal areas and archipelagos
6. No eutrophication
7. Natural acidification only
8. Sustainable forests
9. A varied agricultural landscape
10. A magnificent mountain landscape
11. A good urban environment
12. A non-toxic environment
13. A safe radiation environment
14. A protective ozone layer
15. Limited influence on climate change

A Committee on Environmental Objectives has been appointed and assigned the task of presenting proposals for targets, strategies and measures for the first 14 objectives. The last objective is to be addressed by the Government Commission for Measures against Climate Change.

The objectives specify targets, some of which are already in effect and some of which are new, as a part of the formulation of the objectives. Important elements include assessing the socio-economic effects and proposing indicators for monitoring in order to evaluate achievements. The Committee has five working groups responsible for land, water, energy, material flows and health. The Committee presents yearly updates and in-depth evaluations every four years to the Government.

The overall EQO is to hand over a society in which the main environmental problems have been solved to next generation. In the view of the Government, the EQOs, together with the Environmental Code adopted in 1999, will increase the scope for and stimulate interest in voluntary measures, not least in industry, that will improve the environment.

Within a framework of a fully developed ecocycle strategy aiming at better resource management, the Government proposes that all those concerned adjust their behaviour with respect to a specified range of products so that the declared objectives can be achieved. Vital, environmentally sound industry and ecologically sound community planning are essential conditions for sustainable management. The EQOs are thus seen as a basis for a system of management by objectives and results, while the ways and means of achieving the objectives are not defined in detail.

Since 1988, environmental goals have been formulated but, unfortunately, there have been flaws. It is thus important to formulate the EQOs within a logical framework, to define all terms used in order to make monitoring and evaluation possible. The goals must also be formulated in such a way that they can later be evaluated and followed up. A background to the proposed objectives is given in the Box

As will be seen below, a number of world-unique natural environments and habitats are identified in Sweden. Some of this unique natural heritage is reflected in the unusually large frequency of lakes and mires of different types, in the Baltic Sea and the archipelagoes, and in the unspoiled environment of the mountains of the north. The Government suggests that Sweden explicitly accept the responsibility to keep these environments functioning well for the benefit of generations to come.

[1] http://www.miljomal.nu/english/english.php

The objectives

The EQOs and the specific targets associated with them are presented briefly below. Targets that have a direct relation to water management are quoted.

Clean air

'The air must be clean enough not to represent a risk to health or to animals, plants or cultural assets'.

This target deals with decreasing airborne pollution, such as carcinogenic substances and volatile organic compounds.

High-quality groundwater

'Groundwater must assure a safe and sustainable supply of drinking water, as well as promoting viable habitats for flora and fauna in surface waters.'

Although groundwater and surface waters are in plentiful supply in Sweden, in some areas they are threatened by overexploitation. The issue of water quality is also a central one. Agricultural methods, means of transport, production processes and groundwater consumption are responsible for most of the degradation in water quality observed. The observation is made, and rightly so, that groundwater becomes surface water in time and the requirements should thus be set to meet the need to protect lakes and watercourses. Of course, in this context eutrophication and acidification are significant problems.

Objectives are stated both in terms of quality and quantity. Human activities such as land use, gravel extraction and discharge of pollutants should thus not be allowed to affect groundwater quality. Furthermore they may not lower the groundwater table in such a way that supplies or quality become jeopardized.

The following targets are suggested (the first three are already effective):

- Groundwater quality must not be impaired by land development or other activities.
- Such activities must not be allowed to affect groundwater volume.
- All landfill sites should have achieved a uniform standard and should meet stringent environmental requirements by 2008.
- The correlation between the environmental quality goal for surface water and health protection should be investigated.

Sustainable lakes and watercourses

'Lakes and watercourses must be ecologically sustainable and provide varied living environments. Natural productive capacity, biological diversity, cultural heritage assets and the ecological and water-conserving function of the landscape must be maintained.'

Sweden has almost 100 000 lakes, thereby taking a top world position, at least in terms of numbers. These lakes provide a great variety of habitats and assure biological diversity. A certain responsibility comes with this position, which is reflected in the formulation of the goals.

Loads of nutrients and pollutants must not impair the conditions for biological diversity. Non-indigenous species and genetically modified organisms (GMO) must furthermore not be introduced. This latter policy is general, and is applied on all appropriate goals stated.

A further dimension is introduced in that recreation interests, such as cultural heritage, scenic beauty, bathing and outdoors activities, are to be respected. These must be protected 'to the extent possible.' Here, the ambition is rather vague. Practice will show what extent is possible.

The following targets are aimed at:

- It must be possible to use lakes and watercourses as sources of water supply.
- Biotopes that play an important part for the biological diversity of lakes and watercourses and in the immediate surroundings should be restored wherever possible.
- Endangered species should be given a chance to spread to new locations in their natural areas of distribution so as to ensure viable populations.
- Migratory fish species must be able to migrate through watercourses in their natural area of distribution.
- The targets for the safeguarding of the cultural value of lakes and watercourses should be reviewed.

Flourishing wetlands

'The ecological and water-conserving function of wetlands in the landscape must be maintained, and valuable wetlands must be preserved for the future.'

Sweden has a very high proportion of wetlands that contribute important biotopes and a variety of species. Presently, about 3 % of the mire area is protected in natural reserves or national parks. Wetlands are to be protected as far as possible against drainage, peat extraction, road building and other development, the idea being to keep different types of well-preserved wetlands throughout the country. Peat extraction should not however be banned but restricted to appropriate sites, taking environment and biological diversity into account. Preservation of recreational assets and historical sites are also emphasised.

The main target aimed at in relation to water management is:

- The ban on ditch drainage must be extended.

There is also a general target mentioned that also applies to marine and mountain environments as well as forests:

- Endangered species should be given a chance to spread to new locations in their natural areas of distribution so as to ensure viable populations.

A balanced marine environment, sustainable coastal areas and archipelagos

'North Sea and the Baltic Sea must have a sustainable productive capacity, and biological diversity must be preserved. Coasts and archipelagos should be characterized by a high degree of biological diversity and recreational, natural and cultural heritage assets. Industry, recreation and other utilization of the seas, coasts and archipelagos must be compatible with promotion of sustainable development. Especially valuable areas must be protected against exploitation and damaging activities.'

The seas and archipelagos in Sweden are unique. The natural beauty and distinctive cultural heritage make the archipelagos important for outdoors activities. Active agriculture and fishing are also important features of the cultural environment. Sometimes interests are competing for the right of use. The most serious threats to the marine environment are eutrophication, persistent organic substances and heavy metals. Important marine habitats such as seaweed and eelgrass communities, hard bottoms and shallow-water soft bottoms are particularly susceptible to disruption. Especially bottoms that are important for breeding are important to ensure sustainable fishing.

Impact of nutrients, pollutants and physical damage must thus not be allowed to affect biological diversity and productive capacity of the marine environment. Recreation interests also call for acceptably low noise levels from boat traffic and careful planning for location of wind power stations.

The following targets are aimed at:

- Physical modification of shallow sea areas that are important for the reproduction and growth of fish and invertebrate larvae and effects due to eutrophication and pollutants should virtually cease.
- Endangered species should be given a chance to spread to new locations in their natural areas of distribution so as to ensure viable populations.
- Incidental catches of small cetaceans should be reduced in accordance with the guidelines adopted under the Agreement on Small Cetaceans in the Baltic and North Sea.
- Oil spills should cease as soon as possible.
- Shipping should operate in such a way that noise, air and water pollution, and other disruptions are minimized.
- Environmental standards for leisure boat engines will be imposed.
- SEPA (the Swedish Environmental Protection Agency) should seek to ensure that the archipelago areas listed in the National Park Plan are designated national parks wherever possible.
- The connection between eutrophication, biological diversity and other biological effects should be clarified.
- Targets should be set for the quantification of environmental effects.

No eutrophication

'Nutrient levels in soil and water must not have adverse effects on health, biological diversity or the possibility of using land and water resources.'

Unnatural increase in nutrient levels must be combated in all groundwater and surface waters. In coastal and sea areas nutrient levels should be decreased to the levels of the 1940s.

The following targets are aimed at:

- Releases of nutrients to coastal waters, lakes and watercourses and to groundwater should in the long term not exceed levels that cause an adverse impact on health, biological diversity or the possibility of versatile use.
- Discharges of nitrogen from Sweden to the Baltic Sea south of the Sea of Åland must be reduced by 40 % compared with the baseline year 1995.
- Protective areas should be established for water catchments and their most important areas of influence.

Natural acidification only

'Soil and water must not be acidified by depositions of pollutants or land use. Acidification must not increase the corrosion rate in technical materials.'

Western Götaland is the area of Sweden where the most severe effects of acidification are to be observed. Major changes in vegetation caused by acidification have been observed in 20 % of the forestland in Sweden and about 20 % of the lakes are so acidified that 10-20 % of all species have disappeared. Even if acid deposition were to cease, it would take 50-100 years for the soil to completely recover.

There is also naturally occurring acidification caused by e.g. podzolisation of soils and other natural chemical processes in the soil. For this reason it is explicitly stated that the acidification problem involves anthropogenic acidification and nothing else.

Most targets relate to decreased emission of acidifying substances but two targets are more directly of interest in a water management context (the first is already in effect):

Checklist of environmental and resource objectives

The development of environmental and resource objectives is presently, at the turn of the century strong. Any text written will rapidly be outdated in its details. The objectives-checklist presented in this box was proposed in 1996 and thus gives a background to the presently proposed Swedish environmental quality objectives (EQO). It shows that although focus may change, most items remains as objective candidates over a fairly long period of time. Note also that depending on the environmental situation and the character of climate and nature, focus will differ considerably between regions.

National objectives

Acidification of soil and water

Overall objectives:

- Limit deposition of sulphur and nitrogen oxides to levels that do not harm the natural environment or human health.

Objectives with post-1994 deadlines

- Reduce sulphur dioxide emissions by at least 65 % between 1980-1995.
- Reduce Swedish sulphur emissions by at least 80 % between 1980-2000.
- Reduce nitrogen oxide emissions by at least 30 % between 1980-1995.
- Ammonia emissions should decrease by 25 % by 1995.

Eutrophication of water and nitrogen saturation of soil

Overall objectives

- Naturally occurring species in marine and aquatic areas should be able to be preserved in viable, balanced populations.

Objectives with pre-1994 deadlines

- Nitrogen reduction by 50 % should be introduced prior to 1992 at sewage treatment plants along particularly affected coastal areas.

Objectives with post-1994 deadlines

- The ambition level should be nitrogen reduction by 50 % for other coastal sections (extension of above objective) from the border with Norway up to and including the Stockholm Archipelago prior to 1995.
- Waterborne nitrogen discharges from human activities should be halved between 1985-1995.

International treaties or conventions

- As far as phosphorus is concerned, Sweden has agreed via the 1987 North Sea Conference that discharges to the sea should be reduced by 50 % between 1985-1995 in areas where phosphorus has caused or may cause environmental problems.

Effects of metals

Overall objectives

- The input of heavy metals to soil and water may not exceed the natural concentration in the environment by more than given percentages. These percentages can vary for different metals and for different geographic areas, depending on the sensitivity of the environment to metals input. At sea, the elevation that can normally be permitted lies in the range of 50-200 %.

Objectives with post-1994 deadlines

- Discharges of mercury, cadmium and lead should be reduced by 70 % between 1985-1995. Discharges of other important metals will be halved during the same period.

International treaties or conventions

- When it comes to arsenic and chromium, Sweden has, via the 1990 North Sea Conference, agreed to a reduction of discharges to the North Sea by at least 50 % during the period 1985-1995.

Effects of persistent organic pollutants

Overall objectives

- Discharges of persistent organic pollutants (POPs) will be controlled so that by 2000 they will have reached a level that is not harmful to the environment. Environmentally harmful substances and POPs will eventually not occur in the environment.
- Discharges from industrial processes will decline to levels that are not harmful to the environment or human health. It should be possible to achieve such an environment by 2000.
- Flows and use of chemicals hazardous to health and the environment should decrease. The flows that nevertheless contain harmful chemicals should be closed wherever possible. Use of the most harmful substances should be phased out.

Objectives with pre-1994 deadlines

- Discharges of organically bound chlorine from sulphate mills should be reduced to 1.5 kg per tonne of chlorine-bleached pulp. The measures should be initiated at all pulp mills prior to the end of 1992.

Exploitation of land and water resources in production and supply

Overall objectives

- Natural resources will be used in a long-term sustainable fashion.
- Renewable resources will be utilised within the limits of the ecosystem's production capacity.
- Pollutants will not limit the use of water from lakes and watercourses, or of groundwater as a water source.
- Biodiversity and genetic variation in the forest will be ensured. The forest will be managed so that plant and animal species that belong in the forest are given a chance to survive under natural conditions and in viable populations. Endangered species and habitats will be protected. The cultural heritage value of the forest, as well as its aesthetic and social values, will be defended.
- In the choice of land use and tillage methods in agriculture, consideration must be given to the requirements for a good environment and long-term management of the natural resources. The objective is to safeguard a rich and varied cultivated landscape and to minimise the environmental load of agriculture.

RELEVANT FOR WATER MANAGEMENT PLANNING[1]

Exploitation of land and water for housing, industry and infrastructure

Overall objectives

- Land and water areas with particularly high natural values, as well as ecologically particularly sensitive areas, will be exempted from development as far as possible.
- In the 1990s, the main tasks of comprehensive planning was to secure long-term good management of land and water resources and to give consideration to natural cycles ("ecocycles") in social planning.
- In the future, urban areas should be planned more clearly on the basis of established environmental requirements. Adequate areas for outdoor recreation and leisure activities should be set aside.
- The Swedish Environmental Protection Agency has formulated quality objectives for lakes and watercourses in "Fresh Water '90". To achieve and sustain good water quality in Sweden, the quality objectives should be taken into consideration by the County Administrative Boards in their decision-making work.
- Gravel management plans should be established for areas with land-use conflicts. In such areas, material supply should concentrate primarily on crushed rock and other alternative materials to natural gravel.

Non-cyclic material flows, wastes and environmentally hazardous residues

Overall objectives

- Measures within agriculture and forestry will be oriented towards a resource-efficient closed-loop ("ecocycle") society.
- The principle that flows and use of chemicals hazardous to human health and the environment should decrease will serve as a guideline for chemicals control. The flows that nevertheless contain harmful chemicals should be closed, wherever possible. Systematic risk management of chemicals needs to be further developed. Use of the most harmful substances should be phased out.
- A programme should be established to eliminate the most dangerous substances in the sludge from municipal sewage treatment plants by no later than 1995. The goal is that sludge can be utilised on a continuous basis within, e.g. agriculture, without risks to health and the environment.

Regional environmental and planning objectives

Forestry

Quality objectives for logged areas with normal environmental consideration

- Unlogged buffer zones at least 5 metres in width should be provided along watercourses, small ponds and other wetlands.
- No final felling should occur within 15 metres of these waters and wetlands.

Quality objectives for logged areas with strong environmental consideration

- No clear felling should occur in swampy forests and forests in middle and inner archipelagos.

Areas completely exempted from forestry should be

- Wetland forests and forests in outer archipelagos.

As far as the environmental impact of forestry is concerned, the quality objective entails that water resources in the forest landscape may not be degraded by forestry practices in such a manner that the habitats of aquatic organisms are jeopardised or human health problems are created.

Action objectives in forestry with normal environmental consideration

- Adaptation of felling site layout to topography and soil conditions.
- Restrictive soil scarification.
- Better site adaptation in tree selection.
- Increased protection of watercourses and wetlands in connection with felling.
- Ban under the Forestry Act on forestry measures on non-productive forestland.

Agriculture

Quality objectives for biodiversity

- Wetlands should exist on at least the same scale as at the beginning of the 20th century.
- Natural hay meadows and grazing lands should exist and be tended so that the region's flora and fauna survive.
- New wetlands should be created within certain specially designated areas.
- Vegetation-covered zones at least 5 metres wide should be provided along watercourses and lakes on arable land in open cultivation in the plains districts of Götaland (southern Sweden) and Svealand (central Sweden).

Quality objective for groundwater in the cultivated landscape

- It can be drunk without previous treatment without posing health risks to animals or humans.

Quality objective for runoff water from agricultural land

- It should be of such quality that watercourses, lakes and seas offer a good environment for the organisms that live there naturally and permit multiple use of the water resources.

Quality objective for land drainage, irrigation and watercourse clearing

- It should be done in such a way that the natural environment of the watercourses and the biological status of the water are not damaged unnecessarily.

Action objectives to reduce the input of nutrients

- Manure handling throughout the country should be regulated by the Environmental Code.
- Voluntary buffer or edge zones along lakes and watercourses.
- Watercourse-specific planning for conflict description, interest co-ordination and proposals for solutions within the framework of water management in municipal and regional comprehensive planning should be carried out.
- Utilisation of irrigation reservoirs should be carried out.

Sand and gravel extraction near or below the groundwater table

Quality objectives for handling of sand and gravel extraction

- The number of extraction operations open simultaneously should not be greater than necessary to meet the needs of the community.
- Sites of sand and gravel extraction operations should be rehabilitated after the conclusion of extraction operations so that they do not disrupt the surrounding landscape or pollute the environment and so that appropriate future land use is possible.
- Preference should be given to using materials that offer fully acceptable alternatives to natural gravel and that entail less damage in extraction.
- The permit requirement for natural gravel extraction is broadened to include so-called “extraction for household needs”. A site restoration plan can cover small bodies of water.

Urban development

Quality objectives in urban planning

- Greater attention should be given to wetlands and green spaces.
- Appropriate technology should be used for closed-loop water recirculation.

Eutrophication

Quality objective for lakes and watercourses

- The perturbation caused by nitrogen and phosphorus should not exceed a DAP (degree of anthropogenic perturbation) of unity according to the Swedish Environmental Protection Agency’s quality criteria. A modification is made in typical agricultural areas.

Quality objective for groundwater

- The nitrate concentration in drinking water in wells should be less than 5 mg N per litre. The same standards apply to nitrogen and phosphorus load on groundwater as for lakes and watercourses.

Quality objective for coastal waters

- A desirable reduction of the nitrogen and phosphorus inputs, which is, however, dependent on local conditions, should be achieved. There is an impact from the open sea, where the anthropogenic load of nitrogen and phosphorus should be reduced by at least 50 % as soon as possible.

Water supply and sewerage

Action objectives for drinking water supply

- There should be more and better protection zones for water-supply sources.
- Greater attention should be given to drinking water supply in comprehensive planning.
- There should be improved co-ordination between comprehensive planning and local traffic regulations to protect water supplies.
- There should be a regulation of private water supply.
- No discharge of sludge from sewage treatment plants to recipient, and recycling of treatment chemicals and use of the sludge. Further, important recharge areas and groundwater reservoirs should be protected.

Action objectives for municipal sewage treatment

- Installation of nitrogen removal capacity in sewage treatment plants should be carried out according to earlier plans and additional measures should be adopted after remedial action analyses for individual drainage basins.
- Inventory of water supply and sewage systems and overflow monitoring should be carried out and retention basins or ponds should be built.
- Local stormwater disposal should be arranged for new housing developments.

Action plan for private sewage systems

- For improved treatment in systems that serve permanent households, action plans should be drawn up based on the water planning provided for in the Act of Planning and Building. Private arrangements should only be allowed in sparsely populated areas.

Acidification

Quality objective for acidification of forestland and lakes and watercourses

- Deposition of sulphur and nitrogen should be less than the critical load, i.e. the level that, as far as we know today, does not damage the ecosystems in the long run. The levels for sulphur, measured in kg per km^2, are 300 in Götaland (southern Sweden) and 250 in Svealand (central Sweden) and Norrland (northern Sweden). The levels for nitrogen are 500 for Götaland, 400 for Svealand and 300 for Norrland.

Action objectives for liming

- Liming of agricultural land needs to increase.
- Liming and revitalisation fertilisation may be necessary on acidified forestland in southern Sweden, and the proportion of broad-leaved trees may need to increase in forest management.

Metals

Quality objective for lakes and watercourses

- The background concentration of metals in water, living organisms and sediments in non-acidified lakes may, as a short-term objective, not increase from today’s regional levels.

Quality objective for groundwater

- The concentration may not exceed today’s level.

Quality objective for coastal waters

- The concentration may not increase from today’s levels.

Persistent organic pollutants

The long-term quality objective for POPs

- Those compounds that derive from human activities may not occur in the environment.

Henrik Lindström & Jan Gunnarsson

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[1] The box is based on a part of the English translation of the report “A Synthesis” in the series “Water Planning” published in 1996 by the Swedish Environmental Protection Agency and the Swedish National Board of Housing, Building and Planning. The original English text has been updated by Lars-Christer Lundin.

- The community acidification strategy will apply: the number of ecosystems where the critical load is exceeded must be reduced by 50 % in Europe by 2010 compared with the baseline year 1990.
- Emissions of ammonia must continue to be reduced.

Sustainable forests

'The natural productive capacity of forests and forest land must be protected and biological diversity and cultural heritage and recreational assets preserved.'

The targets deals with protecting endangered species and biotopes in order to maintain biological diversity. A new target involving environmental certification of forests is also introduced.

A varied agricultural landscape

'The value of agricultural land for biological production and food production must be protected, and biological diversity and cultural heritage assets must be preserved.'

Environmental quality for farming land as a whole is the overall target. The food policy goal adopted by Parliament will remain. A continuing evaluation is to be carried out by the Swedish Board of Agriculture, the National Heritage Board and SEPA and will provide data for possible future revision. There is also an ongoing discussion on common agricultural policy (CAP).

The central theme of the targets is a balance of the nutrient status and maintaining good structure, humus content and pollution levels, so that functioning ecosystems and good human health are guaranteed. In one of the targets preservation of the open landscape is particularly mentioned.

There is only one target, already effective, explicitly dealing with water management:

- The ecological and hydrological functions must be restored by the gradual establishment of wetlands and ponds to agricultural land that was drained in conjunction with extensive structural rationalization.

A magnificent mountain landscape

'The traditional biological diversity and the recreational and natural and cultural assets of the mountain region must be preserved as far as possible. All human activity in the mountain region must take these assets in to account in order to promote sustainable development. Especially valuable areas must be protected against exploitation and damaging activities.'

Among the – sometimes conflicting – interests of the mountain region are reindeer husbandry, tourism, hunting and fishing. In this context it is stated that the specific mountain heritage, the heritage of the indigenous Sami, must be preserved and developed. An interesting and somewhat unusual target deals specifically with protection of the lichen cover, which is important as reindeer fodder and also protects the soil from erosion.

One new target relating to fishing is given:

- Fishing in mountain lakes and watercourses should be sufficiently extensive to allow the reproduction and regrowth of local fish stocks.

A good urban environment

'Urban areas must provide a good, healthy living environment and contribute to improvement of the regional and global environment. Natural and cultural assets must be protected and developed. Buildings and amenities must be located and designed in accordance with sound environmental principles and in such a way as to promote prudent long-term management of land, water, energy and other natural resources.'

The focus here is on the efficient and economical use of energy, water and other natural resources. There is also a concern for gravel deposits, being of great value for water supply.

It is stated that open areas are important as they help to clean polluted surface water and should thus be protected. It is also acknowledged that towns depend on their surrounding countryside for water supply, as a depot for waste products etc. Other issues are traffic, noise and the handling of wastes.

One new target relates to water areas:

- Elaboration of regional and local programmes for the rehabilitation by 2020 of land and water areas where toxic substances and other pollutants have been stored.

A non-toxic environment

'Eventually, the environment must be free from manmade substances and metals that represent a threat to health or biological diversity.'

This means that the concentration of naturally occurring substances must be close to the background levels and anthropogenic substances should not occur whatsoever in nature. The goal is based on the Esbjerg Declaration, calling for a cease in discharges of hazardous substances into the North Sea by 2020.

The only target, already effective, is:

- The pollution of the Baltic Sea, and its catchment area, and the North Sea must be terminated by a gradual process during which discharges and leakage of hazardous substances must be reduced to zero by 2020.

A safe radiation environment

'Health and biological diversity must be protected against the harmful effects of radiation in the external environment.'

People, animals and the environment are protected against harmful radiation under the Radiation Protection Act. Maximum exposure is regulated by limits issued by the Swedish Radiation Protection Institute. Separate targets can be specified for various activities. The Nuclear Technology Act regulates the safety requirements in nuclear installations and the Nuclear Power Inspectorate is responsible for ensuring that appropriate measures are taken.

No explicit further targets are specified. The ALARA (as low as reasonably achievable) principle however is to be applied for the radiation dose. An annual limit of effective dose of 1 millisievert per year is thus prescribed for the general public.

A protective ozone layer

'The ozone layer must be replenished so as to provide long-term protection against harmful UV radiation.'

Sweden should urge that levels of chlorine, bromine and ozone-depleting substances in the stratosphere must not exceed natural levels. There is also a target relating to further studies of effects of air traffic.

Limited influence on climate change

'The UN Framework Convention on Climate Change provides for stabilization of the content of greenhouse gases in the atmosphere at levels that ensure that anthropogenic activities do not make harmful impact on the global climate system. This goal must be achieved in such a way and at such a pace that biological diversity is preserved, food production assured and other goals of sustainable development are not jeopardized. Sweden, together with other countries, must assume responsibility for achieving this overall objective.'

A climate change would of course cause totally new challenges for water management. The primary gases involved and possibly playing a part in the greenhouse effect are carbon dioxide, methane, nitrous dioxide and persistent hydrocarbons and sulphur hexafluoride. Emissions of methane derive from e.g. dumping of organic wastes and from animal management (ruminants and manure). The main sources in Sweden are municipal landfill sites and agriculture.

The measures specified are to stabilize the level of carbon dioxide in the atmosphere at less than 550 ppm and to ensure that the levels of other greenhouse gases in the atmosphere do not increase.
The effective target is:

- A Climate Committee is to be set up. On the basis of the Kyoto Climate Conference and the climate objectives adopted by Parliament, the Committee will propose targets and a programme of action.

Implementation and monitoring

The Government presents annual reports on progress, prepared by the Committee on Environmental Objectives, to Parliament. The Committee has the task to make a comprehensive review of targets, strategies and measures that are necessary to ensure that proposed environmental goals are be achieved in a sustainable and effective manner within a generation. The work will be performed in co-operation with competent authorities.

SEPA is responsible for continuous monitoring of goal achievement. Furthermore, it will, together with sectorial and other authorities, be responsible for proposing measures to develop and define quality goals in greater detail in each sector. County Administrative Boards and certain other regional bodies will have corresponding responsibilities in their own regions. Municipalities, along with residents, associations and other local bodies, are to be responsible for developing and monitoring achievements of the national environmental quality goals in their planning and they are also expected to set their own local goals and programmes of action.

The task of the Government is to establish clear-cut rules in relation to the market. The Environmental Code lays the foundation for this work. It would be good if consumers and households influenced production by demanding environmentally sound products and services. We foresee that the consumer's interest in a company's environmental reputation will increase, thereby encouraging enterprises to intensify their pro-environment efforts. Purchase personnel who make demands could also be a significant driving force in technological development. Producers choose materials, chemicals, manufacturing processes, transport systems and energy utilization and are thereby in the best position to exert influence, being able to request designs and products of low environmental impact. As environmental issues are being incorporated into business strategy, there is a corresponding increase in economic motives to take environmental aspects into account in credit rating and investment.

17.

WATER MANAGEMENT IN THE HARD COAL SECTOR IN POLAND - A CASE STUDY

Magnus Andersson

General trends

Poland faces two major challenges with respect to water management and water protection: (1) the country is endowed with scarce water resources and (2) the surface water is extensively polluted.

Poland's river water is divided into four classes: Class I - drinking water quality; Class II - water suitable for agricultural purposes; Class III - water suitable for industrial purposes and Class IV - water not suitable for any purpose. Poland has no larger rivers in the water-purity class I and the criteria for water-purity class III are not met by almost 70 % of the length of the main rivers.

Still, the situation is somewhat better today than in the 1980s. Between 1989 and 1995 there was a 12 % decline in the amount of wastewater discharged to surface waters, including a decline of more than 30 % in untreated discharges.

Poland has a relatively long tradition in the field of water management. The first legal framework for this activity was set out in the Water Law Act of 1922. Currently the Water Law Act of 1974 is in force. It has been amended several times in the 1990s.

Poland's system for water management and water protection relies on a combination of regulatory and economic instruments. The environmental protection departments at the provincial level license water use for economic purposes. Permits for particular use of water determine permissible quantities of water intake, set quality parameters for wastewater discharged into surface water or the ground, and introduce limitations on water use envisaged by the law. Fees are used for both water use and wastewater discharges. The fees are collected by the environmental authorities and constitute a major source of income for the environmental funds: the National Fund for Environmental Protection and Water Management, the provincial Funds for Environmental Protection and Water Management (16) and the municipal environmental funds (2,460). These funds finance, via soft-loans or grants, almost 50 % of the annual environmental protection investments in Poland. In the early 1990s, the fee levels were raised by more than 1,000 %. This provided a drastic increase in the incomes of the environmental funds. Thanks to this, the environmental funds could devote much more money to water management and water protection investments than they had in the 1980s. In 1996 more than 400 wastewater-treatment plants were completed. This could be compared with 1980 when 56 such plants were put into operation. A large number of new plants are currently under construction in the country.

Economic entities that do not meet their environmental obligations as defined in the permits must pay fines. The fines are up to ten times higher than the fees. The fines are imposed by the State Inspectorate for Environmental Protection (SIEP) and accrue in the environmental funds. The SIEP has the right to inspect industrial plants and to measure or test the quality of wastewater discharged into the surface water. Plants that do not comply with their environmental obligations can be temporarily shut down by the SIEP.

The state hydrological and meteorological services carry out systematic monitoring and measurements of precipitation, water stages and flows in rivers and lakes. The services also monitor the state of the groundwater. Collected data are used in the preparation of annual water balances for surface water for the whole country and particularly for river basins.

In 1991, seven Regional Water Management Boards were established with the task to undertake preparations for the introduction of river basin management of water resources. In 1997, this system was endorsed by the parliament in an amendment to the Water Law. The seven river management boards – subordinated to the Ministry of Environmental Protection, Natural Resources and Forestry – will be the key actors with respect to water management and water quality issues. An important role will also played by the Ministry of Agriculture and Food Economy, whose areas of supervision will include rural water supply and sewerage systems, flood embankments, regulation of smaller rivers and fisheries in freshwaters.

The case study

The topic of this case study is a major implementation failure in Poland's environmental policy in the 1990s: the discharges of saline water to the Wisła and Odra Rivers. Since systemic change in 1989, Poland has substantially improved its environmental performance. The mechanisms for the financing of environmental protection measures (notably the National Fund for Environmental Protection and Water Management) and the enforcement of environmental law have eliminated much of the notorious implementation deficit of the 1980s. However, with respect to the discharge of saline wastewater from the hard-coal mining sector in the Katowice region, these two mechanisms have not worked properly and hence very little progress can be seen.

The hard-coal sector

Poland has large reserves of hard coal and is one of the most coal-dependent countries in the world. Without access to coal, it is unlikely that Poland's early industrialisation in the nineteenth century could have taken place – not the shock of socialist industrialisation after the Second World War. In the three decades of the post-war period coal production, mainly located in Poland's industrial heartland in Upper Silesia, more than doubled. Before the annual production peaked at 201 million tonnes in 1979, Poland had already become the most important coal producer in Europe (the former Soviet Union excluded.) Since its transformation to a market-based democracy, Poland has continued to rely on coal. In 1992 approximately two thirds of Poland's total primary energy supply was covered by domestic coal. In 1993, coal contributed to more than 80 % of the heat that was produced in Poland. By comparison: in 1993, coal's share of the primary energy market within the European Union was 13 %. The importance of hard coal for the Polish economy is also underscored by the fact that it has traditionally been an important export product. Poland is likely to remain heavily dependent on coal in the coming years for two reasons. First, there are no nuclear power plants in operation and second, as a flat land with little water, Poland's potential for waterpower is almost negligible.

Since the systemic change in 1989, output of hard coal has declined sharply (Table 17.1). This decline is due to several factors. The most important ones have been the economic slump during the first years of the transition, increased prices for coal, and a loss of the export market to former CMEA countries. Other driving forces behind the reduction in coal production have been industrial restructuring, competition from other fuels, energy conservation and environmental policy.

Table 17.1. Polish hard-coal production (in million tonnes saleable) (Source: Ing BH Consultants et al., 1994)

Year	Production
1988	192.2
1989	177.4
1990	147.5
1991	140.0
1992	131.3
1993	130.2

The first steps towards a reorganisation of the hard-coal sector were taken in 1990 when the centralised management system was abolished and the 70 or so mines were transformed into independent enterprises, albeit still owned by the state. The same year the government began to free prices and started to reduce subsidies for mines that did not cover their costs. Coal subsidies declined from $US 2,294 in 1989 to $US 134 million in 1993. In 1992, only 1.1 % of the coal sales were subsidised.

For each year in the 1990s the hard-coal sector has grown deeper in debt. There are a number of factors that had a negative impact on the economic performance of the sector in the 1990s. First, the contracting coal demand in Poland resulted in unfavourable selling prices for the coal. The coalmines tried to compensate for the losses in the domestic market by increasing exports. However, the export price was lower than the selling price on the domestic market and far below the costs of production. Second, the wages increased more than expected. Third, the coal price increased slower than inflation. Finally, energy prices have been raised much more than coal prices. This has favoured the power sector over the cost of the hard-coal sector.

The mining activities in the Upper Silesian coalfield in the Katowice region have a detrimental impact on the environment in four major ways:

1. *Disposal of waste rock*. Each tonne of hard coal produced is accompanied by the production of almost half a tonne of waste rock and material. Large amounts of waste also arise in connection with coal preparation. In 1989, most of the waste was disposed of in land levelling and reclamation (43 %) and in surface dumps (38 %). Some 12 % were stowed underground. The hard coal sector has problems finding additional dumping space (World Bank, 1992).

2. *Surface subsidence*. The surface in Upper Silesia is seriously damaged because of various forms of underground movements in the coalmines. The effects of these movements are manifested in the form of cracks in buildings and damaged infrastructure such as roads, pipelines, electricity cables and rail-

way tracks. In the mid-1980s 34,000 flats had been damaged (Surkiewicz & Matiakowska, 1984). Between 1980 and 1986 more than 700 shakes were registered in Upper Silesia (Ciesielski, 1988).

3. *Air pollution* During the 1980s some 150 million tonnes of coal were annually burned in Poland, causing substantial emissions of sulphur dioxide, particulate matter, and carbon dioxide. Minor parts (approximately 1 %) of these emissions were caused by energy production for the coalmines' own needs.

4. *Saline wastewater discharges* (see below). An additional problem is the enhanced levels of radium, which appear in the coal beds. Radium is pumped out together with the wastewater. The concentration of radium in the wastewater from certain mines reaches 17,000 Bq per cubic metre water. This should be compared with the Polish norm for radium in drinking water, which is 110 Bq. A complicating factor is that the halftime for radium is several thousand years. The issue of radium in the hard-coal mines was highlighted in the popular weekly magazine *Wprost* in 1994. In an article entitled "Silesian Chernobyl," the journalist Bartosz Dabrowski wrote that the level of radium was above the permissible level in 26 mines.

The salination problem

In extracting coal, many mines in the Katowice region discharge wastewater containing high concentrations of saline minerals. The salinity of the water is measured by the concentrations of Cl^- and SO_4^{2}. When salt is dissolved in water, negatively and positively charged ions are created. The most common way of expressing salinity equivalents in water is to indicate the content of chloride ions (Cl^-) and sulphate ions (SO_4^{2-}). All hard-coalmines in the Katowice Voivodship discharge groundwater into the rivers. In 32 coalmines, the water is pumped out to the River Wisła basin, 36 mines discharge water to the River Odra basin. Half of the mines in the former group discharge saline water (1.8-42 g/l), 31 mines of the latter group. Of the 400 million cubic metres of water that was pumped out of the coal mines in Poland 1989, about two thirds were considered to be usable, the remaining third was excessively saline.

The reason this problem appears in this region is that the seams of the coalfield lie in predominantly sandstone strata aquifers in which water gradually increases in salinity with increasing depth. In some of the deeper mines the water is three times more saline than seawater. In the 1980s the daily discharges of salt was close to 7,000 tonnes. In 1992, the discharges had declined to the level of 4,800 tonnes. The major part of the saline water (approximately three-quarters) is pumped out to the Wisła River; the rest ends up in the Odra River. The salinity of the water in the southern parts of these two rivers is, in certain locations, higher than in the Baltic Sea.[1]

The highest permissible level of concentration of sulphates in river water is 0.4g/l. In the Wisła River, the water contains more sulphate than this down to the town of Kazimierz, situated more than 300 kilometres from the polluting coalmines. In dry years the permissible level is sometimes transgressed in the Wisła River's water in the Warszawa region. In Kraków, a city situated some hundred kilometres east of the Katowice region, the concentration of sulphate reaches up to 2.2 g/l. Some 280 kilometres of the Odra River have increased salinity.

The concentration of chloride ions in the Wisła River near Piast, Ziemowit and Czeczott, the mines discharging most of the saline water, amount to 5.55 g/l. In Bierń Nowy, a small town near these mines, the average concentration is 7.3 g/l.

The negative environmental impact of the salination can be divided into three categories: first, harm to ecosystems and river life, second, increased costs for drinking water treatment downstream. The increased salinity in the rivers should be seen in the light of the fact that Poland is poorly endowed with freshwater resources, and the ratios for available water resources is one of the lowest in Europe. For many urban residents, surface water is the main source of drinking water, a fact that makes Poland vulnerable to pollution of the surface water. Third, material costs. According to one estimate, the annual economic losses due to corrosion caused by saline water may be as high as $US 100 million. The productivity costs of these discharges probably account for the largest component of total losses due to water pollution in Poland (0.5-0.8 % of GDP.) In Kraków, saline river-water causes considerable problems for certain types of industrial activity. A large number of companies in Kraków that are dependent on water from the River Wisła claim that they have to change pipes with increasing frequency due to

[1] As a rule, raw water concentrations are measured as total dissolved solids content (TDS) in g/l of water. Based on the degree of salinity, raw water can be classified in the following way: Saline water of low concentration: 0.5-3 g/l TDS; brackish water: 3-20 g/l TDS; seawater: 20-50 g/l TDS and brine: more than 50 g/l TDS. Oceans have an average concentration of 35 mg/l TDS (Ribeiro, 1996). On an average, the salinity of the water in the Baltic Sea is somewhat below 10 g/l. Some of the water, which is discharged by the mines Czeczott, Piast, and Ziemowit, contains more than 42 g salt per litre.

salination damage.[2] The cost for replacing the pipes has continued to increase. The saline water in the River Wisła has also been recognised as a problem by the heating sector in Warszawa.

Estimates have been made of future discharges of saline water. According to one estimate the situation by the year 2005 will be the following: water pumped out by the mines will decrease by 14 % but the concentration of chloride and sulphate ions will rise by 67 %, due to the increased average depth of excavation. Hence, in the absence of a radical solution the salination of the Polish rivers is likely to become an increasingly serious problem.

Table 17.2. Amount of saline wastewater discharges from the coal companies in 1993 ($Cl^- + SO_4^{2-}$ tonnes/day) (Source: Chaber, 1994)

Coal Company	Discharges
Bytomska	159
Gliwicka	456
Jastrzębska	270
Katowicki Holding	366
Nadwiślańska	3,348
Rybnicka	390
Other mines	54
Total	5,232

The main polluter: NSW

The hard-coal mines belonging to Nadwiślańska Coal Company (*Nadwiślańska Spółka Węglowa* or NSW) contribute 93.5 % of the salt discharges to the Wisła River (Table 17.2). NSW is seated in Tychy near Katowice and was created as a joint stock company on 1 March 1993. There are eight hard-coalmines that belong to NSW. NSW is the largest of the coal companies in terms of production. The main discharges of NSW originate from Czeczott, Piast, and Ziemowit. These three mines are responsible for 87 % of NSW's saline discharges which, in 1994, totalled 3 520 tonnes per day of ($Cl^- + SO_4^{2-}$) salts. In other words, three NSW mines provide nearly 80 % of the total chloride discharge.

Towards a solution?

The hard-coal sector's salination problems were recognised as early as the 1960s and 1970s. First and foremost, the problem was signalled by various voivodships situated along the Odra and Wisła Rivers, who had become increasingly aware that the salination of the rivers not only was a threat to their main source of drinking water, but it also constituted a problem for industry. A number of voivodships demanded that the central government and the authorities in Katowice take action. The problem was also recognised by the German Democratic Republic (GDR), which asked Poland for economic compensation for the economic losses that the East German industry had incurred due to the salinated water in the River Odra region.

In the 1980s, the non-governmental organisation (NGO) community also highlighted the problem. Its most important statement was made by the PKE (the Polish Ecological Club) at its second general congress in February 1987. The club adopted a resolution that stated that the main Polish rivers were likely to be biologically dead by the year 2000 if no measures against the saline discharges would be taken. The club demanded a number of measures to be taken: it advocated coal excavation in layers containing less salty water; it proposed the construction of desalination plants for heavily salinated waters (containing more than 42 g/l) and it sharply rejected the idea of diluting saline waste in other regions.

In 1988, the national environmental programme to the year 2010 identified saline wastewater discharges as one of the most urgent environmental problems that needed to be addressed (MOSiZN, 1988). It made clear that in order to bring all water of the Wisła and Odra Rivers to class III quality (i.e. suitable for industrial use) it was necessary not only to build a large number of municipal and industrial wastewater treatment plants but also to address the salination problem. The programme warned that discharges were likely to double by the year 2005 due to increased production depths and the start of coal production at new mines with wastewater of high salinity. It was the policy-makers' intention to solve the problem by constructing small desalination plants and creating a pipeline system for dosing the most saline wastewater from retarding reservoirs to the Odra River in the Kozla region and to the upper and central parts of the Wisła River. Financing was to be achieved via the saline account, a special fund set

[2] A World Bank mission that visited a combined heat and power plant in Kraków reported the following: "They had installed desalination equipment, but this was inadequate to meet the full water requirement. As a result, they estimated that the life of pipework and other equipment that came into contact with water from the Vistula was halved due to corrosion. This caused great inconvenience and substantial losses of energy during the winter because it was difficult to schedule the replacement of pipework during the non-heating period of the year."

up within the Environmental Protection Fund fed by fees for discharges of saline wastewater, introduced in 1987. The programme estimated that it would take 10-15 years to accumulate the appropriate financial resources necessary for solving the salination problem.

In the 1990s, the salination problem seems to have lost the prominent position on the environmental agenda that it enjoyed before systemic change. This trend was apparent at the environmental table of the round-table discussions between the socialist government and Solidarity in early 1989 – the problem was not mentioned at all. Furthermore, in the national environmental policy of 1991, the Ministry of Environment did not put salination among those problems that were considered urgent. In addition, the environmental movement has attached less priority to the issue in the 1990s. Or, to put it bluntly: it has not indicated any interest all.

A perusal of the main environmental magazines reveals that the NGO interest in the environmental problems of the coal-mining sector has been minimal. For example, in the Green Brigades (*Zielone Brygady*), a national magazine that publishes articles by representatives from a large segment of Polish environmental organisations, there was not a single article about the coal sector between 1989 and 1995. Likewise, the PKE branch in Katowice has not written a single article about the topic in its bulletin during the past few years. Furthermore, in the 1990s, no environmental organisation has officially presented any view on how to solve the problem. This leads to the conclusion that there were more debates and more concern about the problem in the 1980s than in the 1990s. The minimal interest in the salination issue shown by the environmental organisations in the 1990s implies a change in the agenda-building process. The policy process has become more closed and there is little interaction between the actors within the environmental policy subsystem. There were clearly more interactions between the actors in the 1980s than in the 1990s. Since systemic change virtually all policy initiatives related to the problem have originated from the government and the hard coal sector itself.

Standards and permits. Standards for permissible level of chlorides and sulphates in receiving water were introduced in 1975. These standards have

Table 17.3. Maximum permissible concentrations of pollutants in surface water (Source: Karaczun & Indeka, 1996)

Substance	Unit	Water quality classes		
Chlorides	mg Cl/l	250	300	400
Sulphates	mg SO_4/l	150	200	250

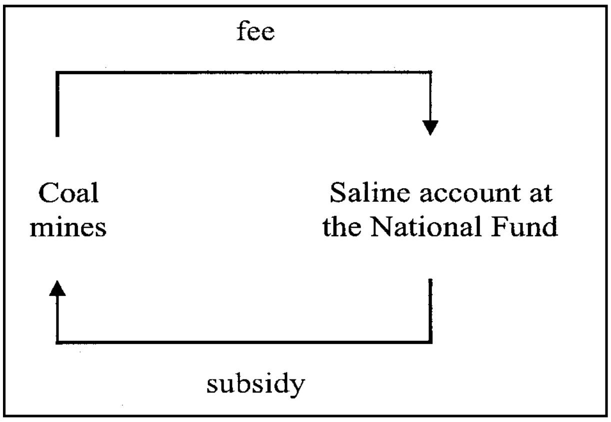


Figure 17.1. Main strategy for addressing the salination problem.

remained the same since then (Table 17.3). Effluent standards for these substances were introduced in 1991. Czeczott and Piast have never operated with valid permits for their discharges of saline wastewater. Hence, in a strict sense their activities have been illegal from the very outset. In 1974 Ziemowit was granted a permit that expired in 1984.

Enforcement. Fines for discharges causing impermissible concentration of salinity in the receiving waters were introduced in 1975.

The three main polluters of saline water, Czeczott, Piast and Ziemowit, were all included in SIEP' list of the 80 largest polluters in 1990. Two of these mines were obliged to minimise their harmful impacts on the environment before 31 December 1994, another mine was obliged to do so before 31 December 1996.

Fees and financing. Environmental fees for discharges of saline wastewater from the coalmines were introduced in 1987.

The fees have been earmarked for a so-called "salt account" first located within the Environmental Protection Fund (1987-89) and then moved to the National Fund for Environmental Protection and Water Management. Money that accrued in the account has been reimbursed to the hard-coal sector in the form of subsidies for various measures to reduce the discharges of saline wastewater (Figure 17.1). Hence, the rationale for setting up this account was to force the coal-mining sector to save money for future investments. In other words, the account has functioned as a piggy bank. Before systemic change, the fees for saline wastewater were kept at a symbolic level. In 1989, the pollution fees for chlorate and sulphate ions content were $US 0.53/tonne. In 1990, the Ministry of Environment, Natural Resources and Forestry increased the rate more than tenfold, and the fee reached $US 7.89/tonne. Interestingly, there are no indications that the coal sector made any objections to this dramatic increase. Since then the fee level has been periodically adjusted for inflation. In the beginning of 1996, the fee reached a level of $US 55.15/tonne (Table 17.4).

There is no doubt that the fee makes a real difference to the financial performance of the coalmines. For example, a representative of NSW claims that in 1996, 13.6 % of the coal price was made up of environmental fees.

Technology. Two major solutions came forward during the 1970s and 1980s, desalination and dilution of the saline water in other regions.

I. *Desalination*.[3] A small-scale pilot plant for desalination by thermal evaporation was put into operation in 1975 at the Dębieńsko mine. The construction of large-scale desalination plants was not considered to be technically and financially feasible. Instead, attention was focused on leading away the wastewater from the Katowice region.

II. *Dilution*. For many years, policy-makers argued that the proper solution was to send the saline water all the way to the Baltic Sea via a large pipeline. This concept was dropped in the mid-1980s. A more realistic idea was to divert the polluted water to places a few hundred kilometres downstream the River Wisła where the saline water was to be diluted with river water from tributaries to the River Wisła. In dry years the saline water was to be retained in large reservoirs and to be released when the amount of water in the river were considered to be sufficiently high. The technical preparations for this project involved such institutions as the Central Mining Institute in Katowice, the Department for Mining Projects in Kraków and others. The idea was seriously considered until the beginning of the 1990s. There were three reasons why the concept was not realised: dilution ceased to be perceived as an effective solution in environmental terms; the concept was thought to be too expensive; and it was discovered that construction of a long pipeline system would entail complicated negotiations with municipalities about land-use permits.

After 1989, Poland was offered foreign assistance to address the problem. The Japanese company Kawasaki H.I. initiated co-operation with Ziemowit to achieve reduced discharges by way of reversed osmosis and thermal methods for recycling of saline wastewater. Simultaneously PHARE, the European Union’s aid programme for central and eastern Europe, offered support to a few small projects at the Piast and Czeczott mines.

Table 17.4. Pollution fees for saline water. Chloride and sulphate ions content, rates (USD/tonne) (Source: Śleszyński, 1996.)

Year	Rate	Year	Rate
1989	0.53	1993	30.31
1990	7.89	1994	39.61
1991	23.62	1995	45.37
1992	40.35	1996	55.15

In 1995, a second desalination plant, Dębieńsko II, was put in operation to treat saline water from two hard-coal mines, Dębieńsko and Budryk. The plant, whose technology is based on reversed osmosis and evaporation, has a capacity to treat some 14 200 m^3 saline wastewater per day, which corresponds to a few percent of the total saline discharges in the Katowice region.

In the 1990s, various low cost measures at the coalmines were investigated and partly implemented. One of the measures realised is the limitation of the supply of saline water to the headings of the mines. This method has been most successfully applied at the Silesia mine where closed mining headings have been sealed and where water has been slowed behind the dams. Similar methods have been tested and used at another 13 coalmines, including Czeczott, Piast, and Ziemowit.[4]

In the early the 1990s the Ministry of Environment and NSW agreed on a plan for the construction of a large-scale desalination plant for the treatment of saline wastewater originating from Czeczott, Piast, and Ziemowit. In connection with this decision NSW established Ekosol, a limited liability company, which was given the following tasks with respect to saline water management:

- to co-ordinate engineering in the domain of management of saline water by means of utilisation, geologic-engineering, and hydrotechnical methods;
- to optimise the saline water utilisation processes in the domain of energetic and chemical technologies and quality guarantees of the products; and
- to act as a substitute investor in designing and realisation of technological installations on behalf of the mines in NSW.

The large-scale thermal desalination plant that was agreed to be built should be able to treat 32 680 m^3 per day of the most saline waters. According to the

[3] By the end of 1991, there were 8 886 desalination installations in operation over the world. Most of the desalination occurs in Saudi Arabia (24.4 %), the USA (15.2 %), the Arab Emirate (10.6 %) and Kuwait (9.1 %). In commercial desalination, two main types of technologies have been used extensively throughout the world: thermal processes and membrane processes. The former is based on distillation, where water is evaporated from a saline solution and condensed as fresh water, while the latter makes use of semi-permeable membranes to separate water from the saline water. For treatment of mine water with high salinity, desalination by thermal evaporation is considered to be the most effective approach.

Table 17.5. Collection rate of environmental fees in % (Source: Śleszyński, 1996)

Year	Environmental fees					
	Saline water	Sulphur dioxide	Nitrogen dioxide	Ind. and mun. wastewater	Waste disposal	Groundwater withdrawal
1990	119	99	94	108	107	105
1991	62	86	85	69	63	77
1992	6	86	80	50	86	83
1993	5	150	84	55	68	75
1994	12	97	96	45	78	96

concept, saline water will be carried away via pipelines and treated at a desalination plant that will be built on unoccupied land area belonging to the "Oświęcim" Chemical Plant.

The total cost of the desalination plant, pipelines and additional steam and power is estimated to approximately $US 500 million. Some 60 % of the saline wastewater discharge from Nadwiślańska Coal Company will be eliminated thanks to the new investment. The salinity of the Wisła River is expected to be reduced by at least 40 %, perhaps even 50 %.

The desalination plant is expected to be a profitable endeavour for NSW. The financial viability of the investment is an effect of the avoided fees and fines. Without these instruments the internal rate of return ends up at 8 %. If the avoided costs of fees and fines are included, the financial viability of the plant increases dramatically and the internal rate of return reaches 23.1 %. The desalination plant thus has the potential of becoming a so-called win-win investment.

Implementation

Since 1992 the National Fund has received approximately 5-10 % of the fees that the hard-coal mines were obliged to pay for their discharges of saline water. The collection rate of the fees for saline wastewater discharges has been considerably lower than for other pollution charges (Table 17.5). This implied that small amounts of money have accrued in the saline account. In 1996, the debt of the unpaid fees had accumulated to PLN 700 million, corresponding to some $US 300 million. Table 17.6 shows that the unpaid fees to the National Fund constituted the largest part of NSW's total liabilities in 1994. There is some evidence that the government led by Hanna Suchocka in 1992-93 secretly exempted the hard-coal sector from the obligation to pay its pollution fees.

In July 1996, the Ministry of Environment, Natural Resources and Forestry and the Ministry of Industry and Trade began negotiations on the conditions for repayment of the unpaid environmental fees. The position of the Ministry of Environment was that the coalmines should be allowed to postpone payment of the fees for a few years and to repay the debt, including interest rate, when the financial

Table 17.6. Liabilities of NSW in mid-1994 (million US$) (Source: Ing BH Consultants et al., 1994)

Type of debt	Amount
Suppliers	34.7
State	42.5
Taxes	22.7
Social security	49.3
Credit and loans	74.0
National Environmental Fund	
Fees	154.0
Fines	31.0

[4] A number of other small-scale measures have been proposed and partly realized. The most important ones are (1) Reduction of wastewater discharges through actions at the mine. The amount of water varies with the exposed coal seam areas. Concentration of production onto fewer and more productive faces may reduce wastewater by 10-15 %; (2) Production at deep levels with the most saline water may be reduced (Ing BH Consultants et al., 1994). The coalmines have tried to focus mining activity above the 500-metre level, where the salt concentration of the water is lower than in strata situated below the 500-metre level (Ing BH Consultants et al., 1994); (3) The deposition of saline water in headings together with fly ash and post-flotation waste. This method is used by 13 mines to treat some 3,000 m3 saline water per day; (4) The management of medium saline wastewater at the mechanical processing of the coal. This method, relying on filling up silt-water circulation at the plants for mechanical processing of the coal, has made possible the management of some 5,400 m^3 saline wastewater per day at 14 coalmines (e.g. Czeczott); (5) Reinjection of saline wastewater into underground strata. The idea is simple and cheap but technically unproven (Ing BH Consultants et al., 1994); and (6) Geological methods for limiting the discharge of wastewater after it is pumped out of the coalmine. The following technologies have been considered: recirculation, deep and shallow compression and draining of the coalmine without discharge of wastewater. All of these solutions have been investigated in the 1990s.

situation had improved. Under the condition that the coalmines undertake investments in desalination measures, the Ministry of Environment is open to investigate the possibility to fully or partly forgive the interest rate. Also, the Ministry of Industry was in favour of exempting the mines from the debt but it also wanted to exempt the mines from paying fees during the next 3-5 years. In December 1996, the parties reached a compromise, which was that the fee for saline wastewater discharges was to be reduced by 50 %.

It is obvious that SIEP has been a toothless tiger *vis-à-vis* the largest polluters of saline wastewater. SIEP has been less influential in the hard-coal sector than in other sectors. This is due, in part, to the fact that the environmental inspectorate is only responsible for enforcement of environmental protection measures above the surface, not inside the coalmines. There is a special mining law that states that inside the coal mines the Highest Mining Authority (*Wyzszy Urzad Górniczy* or WUG) is responsible for *all* kinds of inspections, including those which concern protection of the environment. WUG issues operational permits for the coalmines and is the main body for supervision of the coalmines. Basically, all decisions that concern the operation of a coal mine have to be agreed on by a Regional Mining Authority (*Okręgowy Urzad Górniczy* or OUG). A coalmine may only become closed on agreement with an OUG. As a consequence, saline water only becomes a concern for SIEP when the saline water has been pumped out of the coalmines. Additionally, the influence of the voivodship authorities is limited regarding activities taking place underground; the environmental authorities cannot intervene to demand changes in the technology. This restriction is defined in the mining law. The enforcement failure should also be seen in the light of certain features that make the hard-coalmines unique compared to other major polluters.

- Water must be pumped out of the coalmines continuously or floods will occur underground.
- A coalmine is a dangerous work place. When conflicts between environmental protection and working security arise, the latter always has priority.
- Many coalmines are hydrologically interconnected. If one mine is closed and another one in the immediate vicinity is not, water from the closed mine is likely to flow into the one that is still in operation. Every decision to change the drainage system of one coalmine requires a careful analysis of the potential hazard for neighbouring coalmines.

These three examples show that environmental protection is more complicated in the hard coal sector than in many other industrial sectors.

Another factor impeding closures of Piast and Ziemowit is that these mines are assumed to be competitive in the future and have a long economic life. Ziemowit is the largest hard-coalmine in Europe (with a capacity of 30,000 t/d) and Piast is the second largest coalmine in Poland. Their reserves are large, the geological conditions are good, and they are modern in terms of infrastructure. They also belong to the lowest cost per tonne coal producers in Poland.

18.

WATER IN COMPREHENSIVE PLANNING

Henrik Lindström, Jan Gunnarson & Yngve Malmquist[1]

Background

Town and urban planning to date has not paid sufficient attention to the natural characteristics of different water areas, or how the aquatic environment is affected by various demands. There are many questions that are often not dealt with, for example how a municipality should best manage its waters, what impact on water the expansion of communities has, what targets we should set when it comes to water quality, and how vulnerable the soil and the water are.

Water-related questions have had low priority in some municipalities. Few municipalities have taken a firm grip on water management in their comprehensive planning. Questions relating to groundwater and coastal waters have in particular not been given adequate attention. This is also true in some cases of watercourses and lakes. In those cases where water-related issues have been focused on, they have often been the more visible and conspicuous ones.

To improve the prevailing situation and avoid problems, as well as to solve conflicts at an early stage, management of water resources should be given a greater emphasis in community planning.

Water conservation integrated with comprehensive planning offers a means of achieving more cost-effective water conservation and water supply in a long-range perspective. Comprehensive planning also provides opportunities for weighing different water-oriented interests against each other. Political standpoints on environmental objectives in comprehensive plans offer opportunities for preventive environmental protection. Consideration should be given to the nature of the water area in question when judging suitable land and water uses. Buildings, for example, should be located with a view towards opportunities for arranging water supply and sewerage, and so that water pollution is prevented.

Water-related issues that have been given priority in comprehensive planning are ones that are conspicuous to the public, are necessary for a functioning community, can be remedied with quick results, have a tradition in planning, or are the subject of environmental debate. This limited approach should be expanded to a more holistic view of the planning work, which will pay in the long run. When water conservation is coupled with comprehensive planning it is cost-effective, ensures long-term water supply, enables different interests to be weighed against each other and provides opportunities for preventive environmental conservation.

Step 1 – Establish a basic document, the water knowledge base

Future water management work will demand a holistic approach. This means that the drainage basin will often define the geographic range of the need for planning and remedial action. This requires close co-operation between region and municipality. The Comprehensive Plan is an important instrument for this. Other important instruments are municipal environmental protection programmes and local Agenda 21 programmes.

A *water knowledge base* plays a central role in this context. It is also important as a basis for a joint prioritisation of the work with action programmes. Since water is a transboundary resource, other co-operation forms must be sought than those that follow traditional administrative boundaries. Better co-ordination is also urgently needed between activity-oriented planning (such as public works planning), environmental conservation planning and comprehensive planning. Other stakeholders are water associations established by decisions under the Environmental Code, water conservation associations (voluntary co-operative bodies), inter-municipal co-operation organisations within a drainage basin, interest organisations (NGOs) and fishery conservation areas.

As a rule, there are a large number of background-reports on file with the municipalities in the form of inventories, analyses etc. regarding water. It is urgent that these reports be compiled. This then gives us a knowledge base that gives us information about

[1] The chapter is based on a part of the English translation of the report "A Synthesis" in the series "Water Planning", published in 1996 by the Swedish Environmental Protection Agency and the Swedish National Board of Housing, Building and Planning. The original English text has been edited by Lars Rydén.

Steps in water management strategies

Step 1 - Establish a basic document, the water knowledge base.
Step 2 - Make a demand analysis.
Step 3 - Establish overall environmental and resource objectives.
Step 4 - Make potential use analyses.
Step 5 - Establish local environmental and resource objectives.
Step 6 – Propose remedial or development actions and make cost analyses

the municipality's water resources, the water-needs and water-impacts of different sectors, a description of conflicts and problems, and analyses of the need for remedial action. This knowledge base is an important part of the municipality's environmental conservation and natural-resource management work, and it serves as a basis for the Comprehensive Plan and sectoral planning in the environmental field. Some municipalities call the water knowledge base a *water synopsis* or *river basin management plan*.

The surface water and groundwater resources that exist in the municipality are reported as a basis for the knowledge base. Recharge and discharge areas as well as infiltration-prone soils should also be noted – at least in problem areas.

Waters of differing quality are merged in areas near the coast. Some of the water comes from the Baltic Sea or the Kattegat/Skagerrak, some from local watercourses, and some from effluents. The proportions from the different sources, the mixing conditions and the effects are determined by, among other things, the shape of the coast (morphometry). Morphometric data can be used to describe areas with different water exchange. These areas can comprise geographic reporting units in the knowledge base.

To enable surface water and groundwater resources to be reported, the municipality is first divided into drainage basins (also known as river basins, watersheds, or catchment areas) delimited by water divides. The land areas within a drainage basin are drained through its watercourses (rivers, streams). *Hydrological data* such as area, flow conditions, turnover times, depth and groundwater discharge is reported. If a more detailed account is needed, the drainage basins are in turn divided into sub-basins.

To give an indication of the status and degree of perturbation of the water, scientific data is obtained based on different measurement parameters. The degree of perturbation is obtained by comparison between current and original status. Status and degree of anthropogenic perturbation (DAP) can be determined to obtain a uniform classification of water areas with regard to water chemistry and metals in sediments and organisms. Colour and/or symbol coding can be used on maps.

Step 2 – Demand analysis

A systematic review should be made of current use interests. Demands that make use of the same property of the water – for example flow, quality or surface – can be compiled to provide an overall picture of resource utilisation and warn of possible areas of conflict. Alternative use-options can be distinguished and the foundation can be laid for impact assessments. Preservation is also to be regarded as a kind of use in the demand analysis.

Since the knowledge base on water is an important tool for taking water-related activities into account in the Comprehensive Plan, it is valuable if the demand analysis can be structured in accordance with the Environmental Code's treatment of public interests. The way in which public interests are dealt with is crucial for the usefulness of the Comprehensive Plan. It must be comprehensible and manageable for planners who do not normally have specialised knowledge of water and environmental conservation. The checklist for sectoral reporting is therefore oriented towards providing a summarising picture of how the scope of the sectoral interest and its impact on the water can be described in the simplest and clearest fashion. Clear map presentations illustrating the physical cause-and-effect relationships in the discharge areas are necessary in order for the knowledge base to be useful in the comprehensive planning work.

Step 3 – Overall environmental and resource objectives

The objectives relevant to water management planning, especially environmental and resource objectives, are formulated and established by legislative and political bodies on all three levels: State, county and municipality. In order for the national environmental objectives to be of use in the practical environmental work, they must be translated into regional and local terms. It is urgent that the regional objectives be measurable and linked to a geographic area. This requires knowledge of the conditions that determine the objectives regionally, for example the natural range of plant and animal species in the region and their proportions of the total population, and of course the current load on the environment.

The measurable objectives should, if possible, be translated into parameters that can be followed up and that serve as indicators of prevailing conditions. One example on how this might be done is given in the case of the Mälar Committee's report "The water of Lake Mälaren–Goals and Measures".

In its action programme "Strategy for Sustainable Development – Enviro '93", the Swedish Environmental Protection Agency defined national objectives based on thirteen overall threats. The majority of these threats concerns the aquatic environment and is included in the Box on objectives. Overall environmental objectives include preservation of biodiversity, management of natural resources and protection of the natural and cultural landscape.

The overall objectives should be translated into operational quality objectives, which for surface water means that no more than a DAP (degree of anthropogenic perturbation) of unity should be tolerated in the long term, according to the Swedish Environmental Protection Agency's quality criteria. These objectives should in turn be broken down into action objectives.

At present work is ongoing in many places to establish operational indicators for sustainable development. If such indicators are established it is important that the issue of targets for defined points in time are included. Regrettably, no such indicators are included in the list in the box.

Step 4 – Potential use analyses

Each water area may have several possible uses. These need to be weighed against each other and judged as to their suitability. An analysis of the potential for utilisation of a water area may be presented in the form of maps, while the ranking of each potential use can be shown in a matrix. Here each possible use is given a value from 1-4, where 1 is very suitable and 4 is not at all suitable for the proposed use. Very often it is obvious how to judge the potential for different uses, e.g. fishing and swimming, while in other cases, such as water resource or recipient, an investigation might be required. The map and matrix are also used when water conflicts are analysed.

Step 5 – Local environmental and resource objectives

If the purpose of the knowledge base is clearly formulated and the strategic procedure is established, objectives – alternatives for actions – can be set. An objective can be defined as an expression of a desire for a future status at which we should have arrived by a given point in time, in the near or far future. A numerical objective is often called a target.

Since the knowledge base has the character of a supporting document, there is no political underpinning of the proposals for objectives arrived at by the civil servant or consultant. The proposals are considered in the work with the Comprehensive Plan. To make the regional objectives operational and verifiable in the local environmental work and in the management of natural resources, they must be formulated so that they fit the tools of the municipal departments, for example a liming plan or a permit application review. This definition process is also important for identification of conflicts in the Comprehensive Plan work.

The objectives (targets) should be:

- Relevant – appropriate to the threat or need to be addressed
- Communicable – clearly and simply formulated so that they can be understood by the general public and can be related to the relevant activity
- Measurable – capable of being expressed in numerical values as far as possible
- Geographically specified – reported on maps to clarify relationships
- Chronologically specified – with short- and long-term horizons
- Realistic – capable of being achieved by those involved in their realisation with respect to both time and resources
- Actively formulated – so that it is clearly evident what is to be done

Local, regional and national objectives can be divided into:

- *Overall objectives*, which indicate the strategic direction and draw up guidelines for the work
- *Quality objectives*, which express the environmental quality, resource quality or resource capacity that should be striven toward
- *Action objectives*, which clearly stipulate what is to be done during a given time period

Status, objectives and remedial measures

Original status: The lake, located near an urban area, is eutrophic. Blooming of blue-green algae (cyanobacteria) poses a threat to the local drinking water supply, bathing and canoeing. The cause of eutrophication is excessive phosphorus loading from various sources.

Question: What measures are appropriate to improve the water quality in the eutrophic lake?

Work sequence: What has to be done here is to find out which sources are major and which are minor, and to see what options are available for tackling the problem.

We start with the drainage basin. See Figure 18.1, which shows the lakes and watercourses in question, land and water uses, and the demands on water use. At the outlet of the lake is a drinking water intake, and in the lake is a bathing site and areas for recreation, e.g. canoeing.

- Data on the volume of the lake, the area of the drainage basin and its water yield are obtained as a basis for budget calculations. The lake's volume is 8 Mm^3. The drainage basin area is 10 km^2. The mean water yield for the basin is 6 litres per km^2.
- Data are collected on concentrations of phosphorus and nitrogen in watercourses and lakes. An analysis is made of trends and natural status. By comparing the current situation with the natural status and consulting SEPAs "Quality Criteria for Lakes and Watercourses", a value for DAP (degree of anthropogenic perturbation) is obtained for phosphorus (P) and nitrogen (N). If the lake is deep, leaching of accumulated phosphorus from the sediments can be of great importance for the effectiveness of attempts to improve the water quality.
- Our calculations show that the lake has status class 4 = 50 micrograms of P per litre. The DAP is then 2, i.e. strong perturbation.
- The contributions to the load are calculated for the different activities for both point sources and non-point (diffuse) sources (agriculture and forestry). Here the source distribution programme in "Water Planning–Plant Nutrient, Calculation Model" can be used. The contributions from the different activities are shown in Figure 18.2.
- The objective (target) for the lake is a DAP of 1. We need to lower the phosphorus concentration in the lake from 50 to 25 micrograms of P per litre. With the aid of water yield data, we can calculate that the rate of transport of phosphorus out of the lake is about 100 kg P per year and will be reduced to 50 kg/y.r
- The source distribution showed that the load on the lake is about 200 kg per year. Since the lake acts as a phosphorus trap, we can assume that it should immobilise (retain) 5-100 kg per year. The lake has a turnover time of about 4 years and is therefore more sensitive to loading than a lake with a turnover time of a few months. We therefore assume the lower value for retention. We then see that the discharges should be reduced by around 100 kg per year in order to meet the established objective in the long term. See Figure 18.3.
- After analysis of how much the various contributions can be reduced, the possible reduction is indicated in the chart.
- A review is made of the practical remedial measures that can be adopted and the relative environmental effects within the different activities.
- The measures can be divided into three types: measures at the point sources, measures against soil leaching, and measures to reduce transport in the watercourses.
- The first two types attack the problems at or near the sources. This is the primary way to attack environmental problems. For various reasons, this is not always possible or sufficient. Then different forms of wetland solutions can give further reduction. Different options have different costs, and it is important to find cost-effective solutions.
- In our case, possible measures include setting aside or leasing edge zones along the fields, improving water supply and sewage systems in rural areas, (re)creation of wetlands and/or relocation of the fish farm to another lake. The industry has improved its wastewater treatment to a high level. Which measures are legislated? Manure management facilities or private sewage systems that do not meet the basic requirements must be brought up to standard. In general, the closer to the lake the activities are located, the more urgent the measures are, since the risk is greater there that leached nutrients can reach the water without being immobilised in soil, vegetation and sediments (retention).
- If possible, a cost assessment is made. What is the cheapest measure? How cost-effective are the measures in a total assessment?

FOR NUTRIENTS IN A LAKE CLOSE TO A CITY

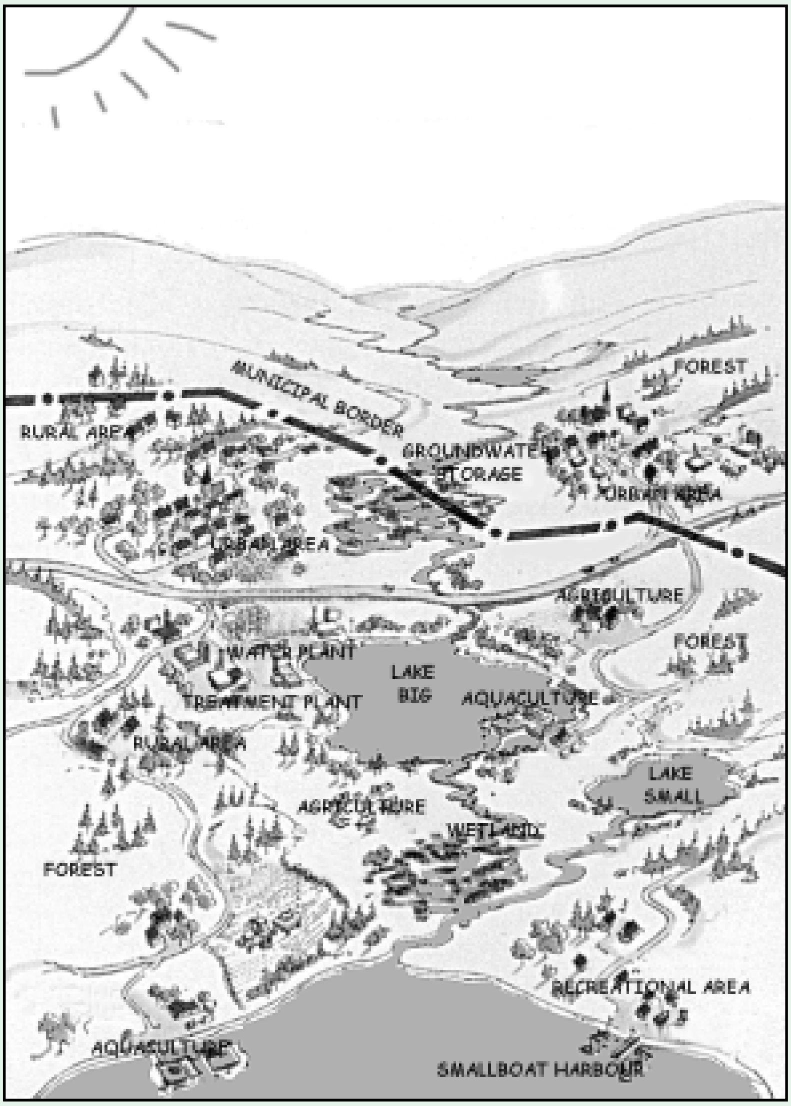


Figure 18.1. Example of a drainage area. Compiled from a drawing by Nils Peterson.

How is the same question answered for a coastal area? The same work sequence can also be used to calculate a reduction of the nutrient input to the sea. One difficulty is assessing how great a reduction is required to reduce the concentration of, for example, nitrogen in a bay if the bay is open. Here, expert knowledge is required to calculate the water turnover. A bay with a narrow mouth towards the sea can be treated in the same way as a lake. Otherwise the work sequence is the same as for the lake above.

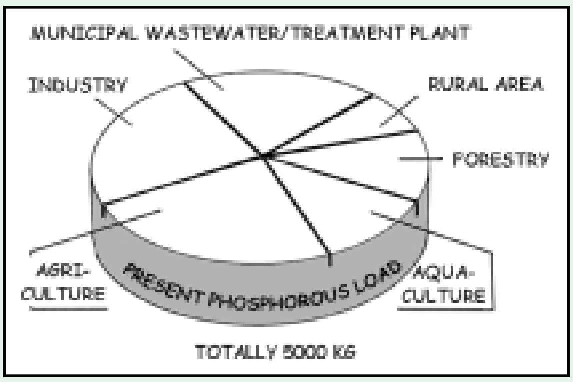


Figure 18.2. Present load of phosphorous from different sources. Compiled from a drawing by Nils Peterson.

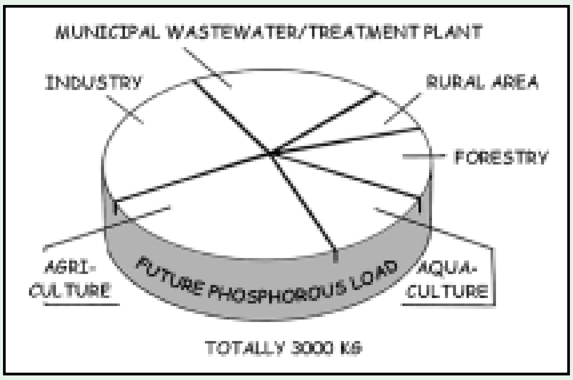


Figure 18.3. Objective for the load of phosphorous from different sources in the future.Compiled from a drawing by Nils Peterson.

Checklist for sectoral reporting

Agriculture

According to the Environmental Code, "agricultural land" is such arable land and cultivated grazing land that is included in property that is tax-assessed as agriculture property. By "cultivable agricultural land" is meant land that, by virtue of its location, nature and other aspects, is suitable for agricultural production.

- Report the land class distribution in percentages for load calculations.
- Make map presentations of the arable land and the number of head of livestock on the farms. The number of head of livestock is classified as follows: < 20, 20-50, 50-100 and > 100.
- Report manure management facilities, milk sheds.
- Calculate the nutrient load.
- Assess the impact on the groundwater of pesticides.
- Report land reclamation, land drainage and irrigation schemes, as well as aquatic biotopes worthy of protection in the cultivated landscape.
- Report energy forest–regarded as crop and dealt with in the Environmental Code.

Forestry

According to the Forestry Act, "forest land" is land that is suitable for timber production and that is not used to a significant extent for other purposes, as well as land that should be forested to protect against sand or soil erosion or against a lowering of the tree line.

- Calculate the nutrient load.
- Make map presentations of data on fertilisation, drainage, protective drainage, large felling-sites and soil scarification if it is deemed to have an impact on water.
- Assess the status of wetlands and the potential for restoration.
- Estimate leaching of organic acids and humic substances from felled sites.

Commercial fishing

By "commercial fishing" is meant fishing that is pursued full-time or as a sideline with all types of tackle and which represents a sizeable portion of the individual's livelihood.

- Assess an area's biological potential for the survival of a species (chemical, physical, geographic and economic factors should also be weighed in).
- Determine whether the oxygen content of the water is sufficient.
- Determine whether water and bottom sediments are free of toxins and other pollutants.
- Report unperturbed spawning, nursery and migration areas as well as fishing grounds on shallow bottoms, in the mouths of watercourses and in the sea.
- Report the accessibility of fishing grounds, navigation channels, harbours and service facilities.

Aquaculture

By "aquaculture" is meant the raising of fish and shellfish etc. for consumption.

- Assess the potential for aquaculture on the basis of the following criteria: good water turnover, water quality, water depth, sheltered location, good bottom conditions (not accumulation bottoms), and accessible location.
- Assess the impact of fish farming based on the following criteria: water quality – excrement and feed residues, eutrophication, changes in bottom conditions, obstacles to shipping, odour, landscape, spread of bacteria, diseases and genetic contamination to wild fish strains.

Nature conservation

Nature conservation includes protection of valuable features in the natural and cultural landscapes by means of preservation, consideration, tending and restoration.

- Report areas subject to rulings under the Environmental Code. The purpose of the protection is described with reference to documented natural values. Note that as from 1 July 1994, shore protection provisions also apply to protection of plants and animals.
- Specify the natural value class of areas reported in nature inventories, along with a summarising assessment based on documented values. Note that since there are strong biological links between water and surrounding land, the report should also describe the importance of the water area for the surrounding land and wetland and its flora and fauna, and vice versa.
- Determine the shortcomings that generally exist in the description of the vulnerability of the water in nature inventories based on other long-range use interests and of what factors should be considered in connection with development in an ecologically particularly sensitive area, e.g. shallow bottoms with fish reproduction.
- Distinguish and report wetlands on the basis of their close link to the aquatic environment and their importance for biodiversity and the nitrogen reduction process.
- Report bird and seal sanctuaries that are off-limits during certain times of the year.
- Report existing water and green-areas in the cities. Greater attention should be given to the cities' green structure from an ecological viewpoint. A contiguous belt of water and green areas is needed for ecological "balance" in built-up areas.

Cultural heritage preservation

Demands from cultural heritage preservation lie in the preservation value of older valuable buildings and/or in the character of a cultivated landscape with its combination of farming and forestry practices, the structure of the built-up areas, ancient monuments and other remains of older settlements. Preservation values are often the same for nature conservation, cultural heritage preservation and outdoor recreation.

- Report near-coast and maritime cultural values such as wrecks, ship cemeteries, old fishing-harbours, lighthouse stations, pilot stations and shipbuilding sites.
- Report preserved old ponds in watercourses – also of importance from nutrient viewpoint – as well as blast furnaces, mills, log floating trails and river locks.

Outdoor recreation

Areas of importance for outdoor recreation have an attractive natural and cultural setting, a suitable location (including in conurbations), a beautiful landscape, interesting phenomena, variation, and capacity for leisure utilisation, e.g. recreational fishing. Areas of value for recreational fishing are included in the term "outdoor recreation". This means that the provisions of Environmental Code cover reproduction, spawning and fishing grounds.

- Report areas for recreational fishing.
- Report fish species, accessibility and responsible authority. Locally, there is competition with commercial fishing for fishing spots.

- Report harbour facilities – they may disturb the natural environment by dredging, filling, oil and petrol spills, noise and littering.
- Report streambeds on canoe trails. Clearing of streambeds can affect fish species. Crayfish plague can spread, vegetation and animal life can be disturbed and in some areas wear and damage occur.
- Report bathing areas – they require special bottom and water qualities and no currents.
- Report suitable ice-skating areas – they can cause direct disturbances of bird life, mainly for early breeding birds.
- Report shore protection regulations.
- Report near-shore development that constitutes an impediment to the accessibility of the shore zone.

Water supply and wastewater management
Areas of importance for water supply include ridges, infiltration areas, and surface water and groundwater sources with catchment areas. Areas with facilities of importance include waterlines, wells and waterworks.

- Report protection zones, both inner and outer, for water supplies according to the Environmental Code, plus reserve water supplies.
- Determine in which areas water shortages may occur.
- Make surveys of:
  - urban sewage systems – report the number of population equivalents served, the type of treatment system, estimated nutrient load, discharge points, and location and impact of overflows
  - urban drinking water networks – also specify surface water and groundwater sources, including protection zones, and report important reserve water supplies
  - urban stormwater networks – specify where water is discharged and estimate its composition
  - rural sewage systems, both public and private systems – report number of population equivalents served, type of treatment system, estimated nutrient load, discharge points, and location and impact of overflows
  - rural drinking water supplies in both drilled and dug wells – specify number and location
  - water supply and sewage systems for holiday homes, including hotels – specify number of houses, type of system, discharge points and estimated nutrient load.

Waste management
This includes sites for disposal and treatment of nuclear waste, other environmentally hazardous waste, industrial waste, construction and demolition waste, household waste, excavation materials, sludge, slag and ashes, along with landfills, incineration plants and recycling facilities, as well as contaminated land and water areas with old abandoned waste dumps and snow tips.

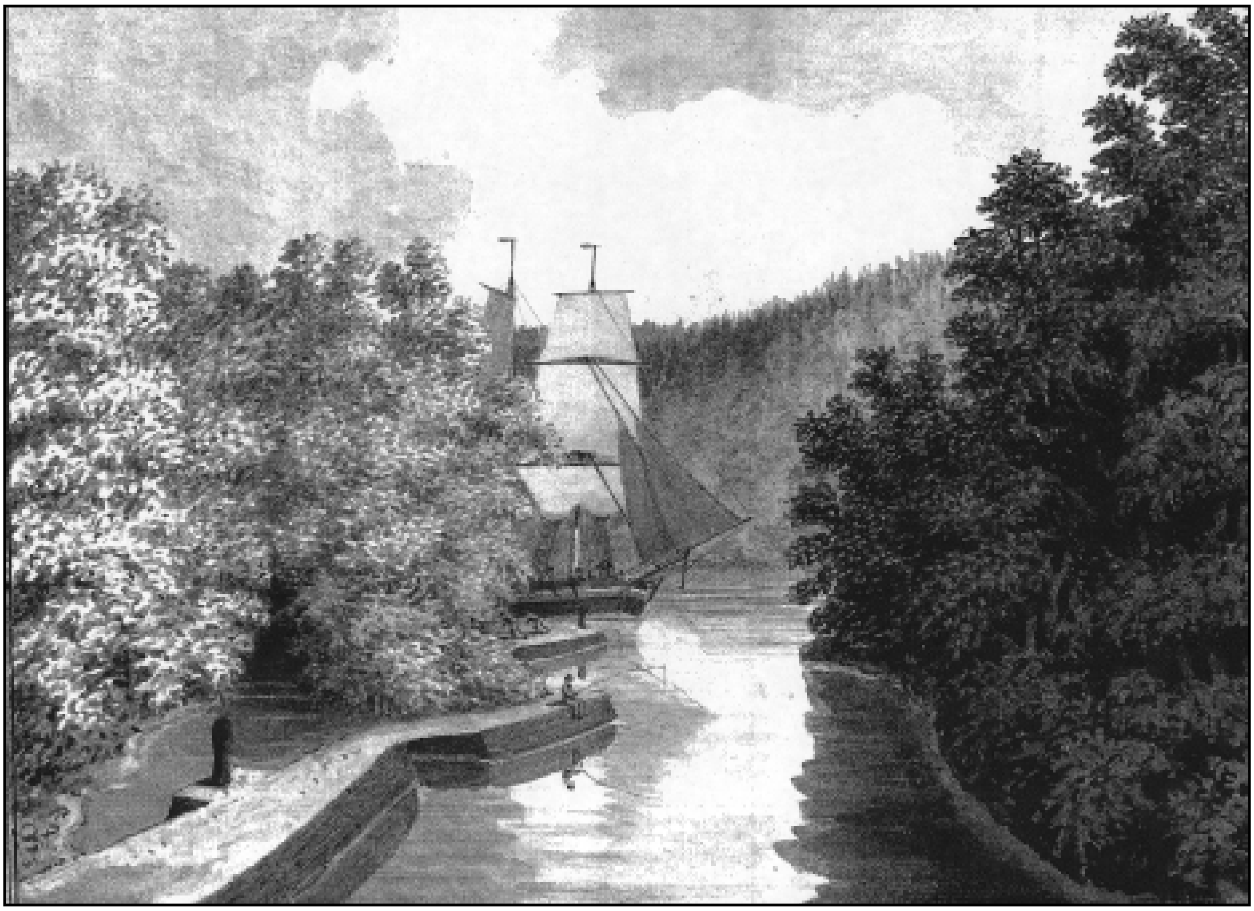
- Report the above facilities.
- Conduct a survey of where relatively flat ground is available, preferably consisting of impervious soil types.
- Conduct a survey of where local collection and treatment of leachate can be done. Road choice should be considered in the localisation decision.
- Conduct a survey of leaching of dangerous substances to surface waters and groundwater. The pollution load on the environment may persist for many decades after landfilling has ceased.
- Assess possible risk of degradation of organic matter under anoxic conditions. This can give rise to chemical compounds which, when they come into contact with oxygen, precipitate metals as oxides: rust-red sludge. These in turn can cause clogging, which can lead to moisture damages to basements and foundation slabs.
- Conduct a survey of contaminated sites, since they pose a risk in themselves and in connection with future development, e.g. excavation and earth moving. Such work may expose and spread pollutants.

Total defence
Sites of importance for total defence facilities include exercise grounds and shooting ranges, airfields, fortifications, stores and radar stations. Sites that are of national interest for the national defence should be protected against measures that can significantly impede access to or utilisation of the facilities. National interests for defence have priority over other national interests.

- Conduct a survey of above facilities and sites.
- Determine the leaching of nitrogen that can result from anti-skid treatment of landing runways.
- Determine wastewater-borne discharges of nutrients from military establishments. The sewers are usually connected to municipal sewage treatment plants. Some secret facilities have their own wastewater treatment plants.
- Determine the discharges of metals consisting of lead from shooting ranges, older types of motor vehicles and buildings, and copper from large-calibre ammunition.
- Determine discharges of persistent organic pollutants, such as pesticides for vermin control and previously used anti-fouling additives in paints.
- Conduct a survey of risk areas in conjunction with shooting ranges, shooting sites and shooting targets. They may extend up to 20 km over water areas. This entails complications for commercial and recreational fishing and outdoor recreational-activities.
- Conduct a survey of the feasibility of access to exercise grounds and shooting ranges by the public – restricted at certain times by safety considerations. Some sites are not accessible at all. Try to assess the feasibility of co-utilisation.
- Determine where driving with motor vehicles can cause soil erosion, which can lead to water pollution in the form of suspended solids.

Tourism and outdoor recreation
The sectoral interest is connected with the Environmental Code: “The interests of tourism and outdoor recreation, especially active outdoor recreation, shall be given particular consideration when the permissibility of development or other interference with the environment is assessed”. The section covers whole or parts of all so-called “primary recreational areas”. They are divided into coast and archipelago, the islands of Öland and Gotland, major lakes, major forest and wilderness areas, river valleys and mountains. It is of great importance that the country’s most valuable recreational areas not be exploited for purposes that exclude large groups of the population from visiting and using the areas. However, simple holiday homes near urban areas should be able to be allowed under certain conditions (form of tenure), even in heavily developed coastal areas.

- Report the impact of fisheries management on biodiversity.
- Report also building-development that occupies large unaffected areas and ecologically particularly sensitive areas.



Göta Canal is the longest canal in Sweden with a length of 190 km. It runs through southern Sweden from Gothenburg by the North Sea via Lake Vänern and Lake Vättern to Mem by the Baltic Sea. It was constructed during the years 1810-1832. This view is from Forsvik. (Engraving by J. Way. Courtesy of Uppsala University Library).

Step 6 – Remedial or development action and cost analysis

The environmental and resource problems that have been defined for the different drainage sub-basins can be addressed in different ways. To prioritise measures and optimise effects, from both an environmental and a cost viewpoint, a systematic analysis should be made of how the local environmental and resource objectives can be met. Alternative suggestions are compared.

The analysis should offer proposals for remedial environmental measures, such as load reduction and/or restoration. Which measures are to be implemented will be a question for the Comprehensive-Plan work, where the various demands on land and water uses are weighed together. It also serves as a reference for the remedial-action work in municipal environmental programmes, local Agenda 21 work, etc.

Below is a run-through of a possible procedure, where the purpose of the analysis has been limited to surface water conservation and reduction of nutrient transport. The run-through is done with the aid of two fictitious examples, one for freshwater and the other for coastal water or seawater.

Follow-up and monitoring

The knowledge on which the work of water management is based comes from regional and sometimes national environmental monitoring. Local environmental monitoring in particular is designed to monitor the environmental threats that existed when the programme for national environmental monitoring was devised. Now as the work with water-related issues continues, new needs arise to follow up new objectives. Or perhaps knowledge gaps are discovered in important areas. It is therefore important to re-evaluate the local environmental monitoring programmes in particular. It is also important to see whether different programmes can be co-ordinated in order to obtain better coverage, as well as to reduce costs. In re-evaluating the programmes, it is also important to avoid disrupting time series that are necessary to follow trends in different water areas. It is also important to try to reflect biological changes and not, as is often the case, merely hydrochemical changes.

Remember that the quality and scope of environmental monitoring is the foundation of the quality of the future work with water-related issues.

How to develop a river basin management plan

1. A suitable way to begin the document is with a general overview of the physical conditions in the municipality where the most important environmental and natural resource issues are summarised. The geology in the municipality, i.e. bedrock, topography and soil, is also described, along with land class distribution, precipitation, evaporation and runoff.

2. This may be followed by a review of the surface water and groundwater resources. A status description of water quantity and quality identifies the fundamental physical, chemical and biological conditions in the drainage basin in question. Known knowledge gaps should also be identified here.

3. The next step is a review of what demands exist on land and water use. This demand-analysis should also assess how the different demands impact the water resources. Different demands on use and preservation of land and water areas should be assessed with reference to the potentials for use defined by the flow and quality of the water, and in observance of the environmental and resource objectives that have been set in the region. It is appropriate to structure the analysis according to the treatment of public interests in the Environmental Code.

4. In order to ascertain what planning-needs exist after the initial inventory and documentation, the water resources and claims are analysed in relation to one another, and in observance of overall environmental and resource objectives.

5. Local environmental objectives for a particular drainage basin are determined after contact with the County Administrative Board, as well as in consideration of existing municipal environmental objectives. If the drainage basin extends into one or more adjacent municipalities, close contact should be maintained with them and with the County Administrative Board so that important inter-municipal water issues can be considered jointly.

6. The knowledge base includes recommendations for remedial action, where proposals for environment-improving measures are, wherever possible, co-ordinated and integrated in comprehensive planning and the municipal environmental conservation programmes.

Checklist of water-related information

There are usually plenty of certain types of knowledge on water. The information that is common has been marked with a (C). The degree of detail of the information naturally varies. Municipalities with lots of lakes may only have knowledge regarding the large lakes, while lake-poor municipalities may have detailed information on relatively small lakes and watercourses. Co-ordinated recipient monitoring is often available from coasts. Material that can be dealt with using SEPAs "Quality Criteria for Lakes and Watercourses" has been marked with a (Q). Quality criteria for coastal waters and groundwater are lacking, but are currently in production. Under the various points it is appropriate to describe the current situation, trends, degree of anthropogenic perturbation (DAP) and lack of knowledge. DAP is the ratio between an unperturbed state and the current state. DAP is a value that can be used to set targets.

Lakes, watercourses and coastal waters

- Hydrology (C): Information on precipitation, runoff, discharge, etc. Input data for various calculations.
- Hydrology (coast): The shape of the coast and depth conditions are crucial for water turnover, which in turn determines the effects of various substances brought to the coast. Expert help is often needed to calculate water turnover in coastal areas.
- Geology (C): Is important for an understanding of groundwater resources and groundwater quality, risk of saltwater intrusion, acidification-sensitivity, etc.
- Land use (land class distribution etc.) (C): Input data for calculation of source distribution of plant nutrients, among other things. Areas of arable land, forest, conurbations and water.
- Nutrient status or trophic level (C): Concentrations of phosphorus and nitrogen in lakes, watercourses and coastal waters.
- Oxygen status and oxygen-demanding substances (C): Input data for determination of water quality. Oxygen conditions are often described in conjunction with various samplings in lakes, watercourses and coastal waters.
- Light conditions (C): Secchi depth (a measure of transparency) gives a good picture of our perception of water quality. A paradox is the acidified lake, which has crystal-clear water with great Secchi depth. Secchi depth is a common parameter in most measurement programmes.
- Acidity status or acidification (C): Gives a picture of the acidification situation and sensitivity to acidification.
- Metals: Measurement values for metals are often restricted to mercury in fish. Values may be available from special studies.
- Persistent organic pollutants (Q): Here there is often a dearth of information. Values may be available from special investigations.
- Hygienic status (C): Levels of bacteria in water. Data from, e.g. bathing water sampling and recipient monitoring. Good hygiene is a prerequisite for leisure and outdoor recreational activities at or in water.
- Biodiversity: These assessments contain structural polymorphism, naturalness, rarity, species diversity, characters of special interest, and representativeness.

Groundwater

- Geohydrology(C): Geology and conditions for groundwater recharge, flows and sensitivity of different groundwater reservoirs. Expert assistance is often required to make these analyses.
- Land use (land class distribution) (C): Basis for making risk assessments. Areas occupied by, e.g. arable land, forest, conurbations, landfills and roads. Basis for risk analysis. Locations of oil tanks, petrol stations, industrial plants, transport of dangerous goods, etc.
- Acidity status or acidification (C): Acidified well-water is a problem mainly in dug wells. SGUs (Geological Survey of Sweden) well archives have information on pH and sulphate concentrations in wells.
- Metals: Acidification gives rise to the threat of elevated metal concentrations in groundwater. The availability of measurement values here is poor.
- Persistent organic pollutants: Here pesticide residues and leachates from landfills and contaminated sites pose the main risks. The availability of measurement values is often poor.
- Nitrate (C): The nitrate concentration in groundwater may be elevated in agriculture-intensive areas. Information is available in SGUs well archives.
- Chlorides (c): Elevated chloride concentrations indicate saltwater intrusion.
- Hygienic status (C): A risk of poor hygienic status is posed by inappropriately located sewerage systems or manure management facilities.

Case: Reduction of the nutrient load to Lake Mälaren

Objectives

The overall, nationally established environmental objectives for lakes and watercourses in Sweden is an anthropogenic influence DAP of zero, equivalent to an increase in the background concentration by no more than 1.5 times. In catchment areas with a high proportion of arable land, a high animal density, and heavy urbanisation this is difficult to achieve. In addition, many lakes have been lowered or have regulated water levels, which also affects nutrient cycling. These conditions prevail in Lake Mälaren and its catchment area. The long-term target has therefore been set, in accordance with the national action programme "Fresh Water '90", to a DAP of unity. For plant nutrients, this corresponds to a maximum of 2 times the background concentration, which corresponds, on average, to 40 % lower concentrations than today.

The short-term (within 10 years) quality objectives have been formulated on the basis of what is realistic to implement under present-day conditions. Then phosphorus concentrations in Lake Mälaren should decrease by 10-25 %, depending on the particular sub-basin. For the lake as a whole this corresponds to a 20 % reduction, or 80 tonnes less phosphorus per year.

Planning

Existing planning needs are analysed in 4 steps:

1. An initial inventory of resources and demands is made. Certain use conflicts may then come to light.
2. An analysis of the environmental situation and resources is made to identify the threat picture, such as weighing the pollution load against the current status of the water, or identifying if a dominant source of pollution for the water area is located inside or outside the municipal borders.
3. Next environmental or resource problems are defined, as decided by the sensitivity of the ecosystem, and the capacity and vulnerability of the resource, and by the relevant objectives established by society.
4. An analysis of the potentials for the utilisation of a water area provides a good basis for standpoints in the Comprehensive Plan. The assessment leads to standpoints on use of land and water, where the planning needs, set up in the municipality's Comprehensive Plan work, are clear.

Remedial actions

This then leads to a remedial action plan and cost analysis, which shows how remedial measures, can be prioritised and effects optimised from both the environmental and cost viewpoints. In many cases the remedial measures cannot be formulated until during the Comprehensive Plan work, where all land and water use demands are weighed together.

Table 18.1. Quality objectives for phosphorus concentrations (micrograms per litre) for the sub-basins of Lake Mälaren.

	Sub-basin				
	A	**B**	**C**	**D**	**E**
Quality objective, long-term	30	20	12	30	12
Quality objective, short-term	35	25	20	40	15
Present-day concentration	41	32	23	53	19
Natural background concentration	15	10	6	15	6

Table 18.2. The measures for phosphorus and nitrogen are projected to give the following input reductions (tonnes/year)

	Reduction	
Measure	***Phosphorus***	***Nitrogen***
Changeover to phosphate-free dishwashing and laundry detergents in rural areas	25	
Rehabilitation of private sewage systems	10	
Tougher phosphorus limits for municipal wastewater	10	
Measures to reduce in-leakage and overflow in sewer systems	10	200
Measures in agriculture	25	700
Nitrogen reduction at certain sewage treatment plants		500
Deposition reduction, atmospheric		120

Coastal meadows near Kalmar, southern Sweden (photo, Margareta Grauers Rydén).

19.

Monitoring and Control

Anders Berntell, Britta Hedlund, Ylva Rönning & Bengt Larsén[1]

The meaning of monitoring

Ideally, environmental monitoring is conducted on the total environment including the atmosphere, the sea, lakes and watercourses, the terrestrial environment, as well as the urban environment and individual protected sites. The purpose of monitoring is to follow developments in the environment over a long period of time and record trends and changes. Monitoring is supplemented with a variety of special programmes that follow specific, directed actions and their effects on the environment.

Natural, unperturbed, conditions can hardly be found today. The water environment as a whole is more or less affected by man, through diffuse impact from land use, point-source discharges, deposition of different chemicals from the atmosphere, the development of water reservoirs and introduction of species alien to the region. It is hard to define what is a natural condition. Moreover, if the results are to be compared to pre-industrial conditions, we need to decide on which pre-industrial conditions should be used as reference points.

The objectives of environmental monitoring are: to track different pollutants and disturbances and their impact on the environment; to establish a reference for the determination and follow up of environmental quality development of criteria and methods; to form a base for planning, implementation and evaluation of protective measures; and to be a resource in comprehensive planning and survey possible impacts of new developments in urban areas, industry, agriculture etc.

Basics of environmental monitoring

A program for environmental monitoring should be long-term and relatively inflexible. Some development and changes may occur over the years but they should be gradual since the environmental data should be collected and compared over long periods of time.

Co-ordinated environmental monitoring programmes are performed by the state (National environmental monitoring), county authorities (Regional environmental monitoring), and the municipality. In special programmes receiving waters are monitored and controlled.

Using statistics, environmental monitoring answers questions on the status of the environment and follows changes over time. The information should be precise enough to determine the size and location of the problems that are detected.

National environmental monitoring has the task of describing the conditions in the country. The Swedish lake survey, for example, provides information on the acidification status and estimates the need for liming. On a regional level, environmental monitoring provides clear information on environmental conditions in the county. It also acts as a reference for investigations performed on, for example, the conditions in receiving waters.

In Sweden, environmental monitoring has old traditions. In some instances monitoring has been continuous since the late 1800s. The most extensive type of environmental monitoring programme is the co-ordinated control of receiving waters of lakes and watercourses that is often described by Water Associations. Many of these associations started their activities in the 1850s and 1860s and have established a sound base of knowledge of conditions in the environment.

Environmental monitoring is to be viewed as a link in a long chain of activities within overall environmental protection. The principles for such work are the same independent of the level on which it is performed - national, regional or local.

When compiling information on an environmental issue, is it common to find basic material is limited. The available information is often not sufficient to answer the questions asked about the environment. The insight given by such an evaluation generates valuable information that can be used in a revision of the existing environmental monitoring. This is true whether or not it is performed within the framework

[1] The chapter is based on a preliminary English translation of a booklet in the series “Water Planning” published by the Swedish Environmental Protection Agency and the Swedish National Board of Housing, Building and Planning in 1996. The original English text has been edited by Lars Rydén.

Environmental monitoring may be performed on a:

- National level through a national compilation of knowledge, decisions on national environmental objectives and through work with national measures
- Regional level through regional environmental analysis, decisions on regional environmental objectives and regional action programs
- Water district level, within the regions defined by the EU water framework directive
- Local level through municipal environmental programs, decisions on local environmental objectives, local Agenda 21, municipal Comprehensive Plans and local action programs
- Watercourse, a coastal area, for example the Öresund or a larger lake

of the control of receiving waters or within environmental monitoring financed by other sources.

Environmental inspection and control

Environmental inspection is performed to be certain that environmentally hazardous activities are carried out according to the existing rules. This is done to limit as much as possible its impact on the environment. The inspections should be carried out within existing legal frameworks and should be based on well-functioning control programs run by the companies in question. Inspection means that the authority responsible for the inspection ensures that those responsible for an environmentally hazardous activity are in control of the discharges and their impact on the environment.

Environmental monitoring establishes the natural conditions in the environment and gives reference values on background concentrations. In order to achieve this, a special strategy is needed for sampling and selection of sampling sites for the factor studied. Control of receiving waters is using this strategy for its environmental monitoring.

Authorities responsible for monitoring

The government appoints the authorities responsible for environmental monitoring. The Swedish Environmental Protection Agency, SWEPA, is responsible for national environmental monitoring, the County Administrative Boards and the water district authorities for regional environmental monitoring and the municipalities for local environmental monitoring. The extent of the monitoring will, for natural reasons, vary depending on ambitions, economy, interest, competence and the persons involved.

Authorities performing environmental monitoring are responsible for:

- looking for new emerging threats to the environment
- ensuring that changes in conditions in the environment are followed over time
- ensuring that the results are continuously evaluated and form a basis for measures, for example to limit the sources of disturbance
- the production of basic material for planning
- the production of a picture covering the situation in the whole country, district, county or municipality
- ensuring that the effects of different sources of pollution in the surroundings are investigated and followed
- a sufficient quality of the different types of national and international reports
- ensuring that the data is quality controlled and stored in such a way that it is available, for example for compilations and evaluations

An environmental monitoring program should be strong and designed to follow long-term changes. It has to be flexible enough to incorporate new emerging environmental threats. This can be done through, for example, screening studies or using information from research projects. This means that a regular evaluation of the activities should be done in case of changes in the environment and the emergence of threats, and to make it possible to modify the monitoring activities.

Data quality and interpretation

When information on the water environment of an area is compiled, data of different origins and quality is used. It is thus of great importance that the methods are comparable. The quality of older data in particular may be variable since the rules, systems and standardisation methods for collecting data are more developed today.

Also the quality of biological surveys performed in the past may be questioned due to the lower degree of standardisation of sampling methods, sample treatment and the determination of species in the past.

The current system, with accredited laboratories and sampling, contributes, together with standardized methods a guarantee that the data are of a high quality. Even today, however, results have to be critically evaluated and related to what is known of biological and chemical processes in water.

The Swedish Environmental Protection Agency is responsible for a handbook of environmental monitoring. The main purpose is to match the different environmental monitoring programs strategies, statistical design and methods for environmental monitoring independently whether they are performed on a national, regional or local level. Standardisation and harmonisation are important parts of a more continuous strategy to secure the quality of environmental information.

When compiling and evaluating the conditions in the environment a few questions arise: What is the natural condition? What is the natural variation? Is the situation described by monitoring harmful for the naturally occuring organisms?

The situation is exemplified by the chemical water quality criteria. These criteria are used when relating values from lakes and watercourses to the natural or the expected background and to concentration levels that are considered to have ecological effects. Chemical water quality criteria consist of two parts, status and degree of perturbation. The status of conditions is a more objective classification and is related to different ecological effect levels. For example, a total phosphorus concentration between 25 and 50 µg per litre is always considered to be a eutrophic condition independent of its natural condition. The degree of perturbation is a way of relating the classified condition to what can be considered natural in the environment in question. Different types of calculations can be used to establish the degree of perturbation.

Similar well-developed and accepted water quality criteria are not available for the classification of biological conditions in lakes and watercourses. In many cases, however, different biological indices are valuable tools to summarise conditions in the environment and their changes over time.

Most index systems have been developed to describe either the impact of acidification or nutrients with the use of benthic fauna. Systems exist where phytoplankton and algal epiphytes are used in a similar way.

Biological water quality criteria for lakes can be used to monitor environmental qualities in the water. They will fit well into a system for water planning where different measures are used in relation to the value of protection of different water environments.

Monitoring data as a basis for planning

A rough classification of results, for example through using water quality criteria, gives an idea on the size and order of different environmental problems. In the planning it is also advantageous if the results are presented in a map in order to facilitate the evaluation of environmental problems. The graphical presentation of other types of data is also helpful in the comprehensive planning. In many cases this is done when environmental monitoring data is compiled. The use of a geographical information system (GIS) is also of great value when data is presented.

Access to information in environmental monitoring programs

Information on investigations performed within the environmental monitoring can be obtained from different sources on national, regional and local levels. Data are often published as reports from the Environmental Protection Agency, the County Administrative Boards, the municipalities and from the persons who performed the environmental monitoring assignment.

Information on environmental monitoring can be obtained from:

- A national register collecting information on investigations performed
- Data hosts which have results from national and some regional investigations
- Data hosts at the County Administrative Boards that have data on regional investigations
- The municipality or, in some cases, organizations that have data from municipal or local investigations

Examples of information from environmental monitoring:

- Average values of different types of airborne pollution in urban areas - SO_2, NO_2, soot, PM_{10}, volatile organic hydrocarbons
- Mapping of concentrations of heavy metal in moss
- Measurements of metals in lakes and sediments
- Measurements of metals harmful to health and to the environment and organic environmental toxins in fish - for example PCB, DDT, HCH, HCB, Hg

Monitoring lakes and running waters in Sweden

The monitoring of lakes and running waters in Sweden is principally divided into three different types of partial programs. In one type, chemical and biological qualities in lakes and running waters, as well as a mapping of specific freshwater habitats, are ex-

ENVIRONMENTAL MONITORING OF

One of the ten program areas of the environmental monitoring concerns the monitoring of the conditions of our lakes and running waters. Below is an exposition of the surveys conducted nationally, regionally and locally with the objective to follow changes in Swedish lakes and running waters. The national monitoring objectives present an overall picture of the environmental conditions but do not contain as many details as regional monitoring.

Sweden is rich in lakes and running waters when compared to many other countries. Due to the climate and soil conditions, however, many of the lakes and running waters are sensitive to disturbances. This has resulted in acidification of a large number of water areas through airborne deposition and metal problems for example mercury in fish. In more fertile areas, the waters often are more resistant to this type of impact. In these areas the land use is more intense and the population density is higher. As a consequence, the impact on water resources is high – for example the discharge of nutrients from urban areas. Land use, in the form of hydrological interference in agriculture and forestry and the regulation of watercourses, has a large impact on water resources in many areas. This particularly affects the biodiversity of many smaller watercourses. The effects of environmental toxins also constitute a serious future environmental problem. The environmental toxins that have received most of the attention can be assumed to be only the tip of a large iceberg. To summarise, pollutants and other interference more or less seriously affect a large portion of the waters in the country.

Monitoring of transport in river mouths

The monitoring of transport in the river mouths enables a quantification of the transport from Sweden to the surrounding coastal areas. Statistics on land use, discharges and deposition, in combination with budget-model calculations, enable the performance of a source analysis. The high frequency of the sampling allows the program to record approximately 80 % of the river transport to the sea.

Use of models, scenarios and predictions can be established and used to describe the sum of effects of different environmental protection measures or future development of the environment regarding point sources, deposition and land use.

The partial program has also proved useful when tracking long-term changes in large-scale leakage and transport from many types of soils in Sweden and to calculate area-specific leakage coefficients.

Intense and integrated monitoring of lakes and running waters

An integrated and intense monitoring of biological conditions and occasional variations is performed in approximately 10 lakes and 10 running waters. In this partial program changes in indicators and the interplay between different trophic levels are studied. Among other things, the partial program shall form a basis for modelling of physical-chemical and biological connections. The modelling work should eventually enable use of the results in this partial program to make statements on questions not being covered by the national monitoring program. The use of models should also enable the establishment of scenarios and prediction. These models may later be used in environmental monitoring – for example within the area-covering monitoring network and within the control of receiving waters. This type of work demands accurate documentation of background information such as climate, land use, deposition and geochemistry.

Inventory of lakes

The partial program describes how conditions in and how the degree of impact on Swedish lakes are developing both quantitatively and on an area basis. This information enables a description of environmental conditions and a quantitative description of the number of lakes in a region that has a certain environmental condition. On a national level, samples are taken every 5-7 years in about 3000 randomly chosen lakes. Regional enlargements of the sampling scheme may be done when decided by the counties. Scenarios for the entire Swedish lake and running water population can be established using models. The models can, among other things, clarify the results of future environmental development and measure alternatives.

Reference lakes and reference watercourses

The national time-series monitoring is made up of about 85 + 10 reference lakes and about 35 + 10 reference watercourses. This is done to follow the variation between years, the long-term development, to obtain references in time and space for regional and local investigations and to describe the effects of the human impact and thereby enable the interpretation of the area-covering picture of the lakes and watercourses in Sweden. The selected objects are typical for their natural geographical region so that together they represent a normal distribution of water chemistry, type of lake or watercourse and size class, excluding the larger size classes due to difficulties in interpreting these results.

Regionally reference lakes and watercourses may exist that are financed either within the framework of the Co-ordinated control of receiving waters or by other environmental monitoring funds. The purpose and design of the partial plan is otherwise identical.

In addition to the pure time-series monitoring, both water chemistry and some biology are followed since the monitoring in this partial program is focused on cause and effect relations. It also demands documentation of background information like climate, land use, deposition and geochemistry.

Measurements of metals and organic environmental toxins in fish

Measurements and compilations of the concentrations of metals and organic environmental toxins in fish are often performed on a regular basis. An example is the long existing time series of measurements of PCB, DDT and mercury in fish. Data from this type of investigation are available at the municipality, the County Administrative Board or at the national data hosts. The Swedish Environmental Protection Agency has taken over this “blacklisting register” from the Swedish National Food Administration and transferred it to one of their data hosts.

Monitoring of species diversity

The objective of this program is to follow the development of stocks or populations of some specific freshwater species worth protecting. The monitoring of species is an important complement to regional or local environmental monitoring. The species of interest usually have a local distribution. The monitoring of species thus fits well into the regional or local environmental monitoring. A list of the species in question, however, has not yet been established. A preliminary judgement is that the species would be found within the threat categories 3 and 4 according to the threat categories of the species data bank. The construction of this partial program varies among different counties.

The follow up of liming effects

Regional or local follow up of liming measures is financed and administered within the framework of regional or local liming programs. Great importance is attached to the co-ordination of this follow up with the regional monitoring of lakes and running waters performed within other partial programs. Examples of such co-ordination include a mutual need of reference lakes and reference watercourses, sharing of sampling stations between the Co-ordinated control of receiving waters and the follow up of liming effects and finally the choice of variables and investigation types in common for the different partial programs.

During recent years a considerable amount of information regarding, among other things, biological conditions in lakes, has been collected within the frameworks of regional liming programs. This information shall naturally be used in designing future regional monitoring of lakes and running waters.

Monitoring of limnological national interests

Interest in nature conservation allows us to select some waters for their limnological values. The objective of this partial program is to check the limnological values that were the basis of the national interest. The construction of this partial program varies greatly between the different counties.

Habitat mapping

The objective of this partial program is to monitor the existence of specific freshwater habitats using extensive and comprehensive methods. Some habitats are very important for the biodiversity of untouched patches of running water, lakes with a specific flora or fauna, transition forms between wetlands and open waters, etc. The construction of this partial program varies largely between the different counties.

tensively monitored over large areas. Other programs involve reference monitoring of the water quality of lakes, running waters and selected freshwater habitats. Finally, the water quality of lakes and running waters is monitored with respect to effects of different forms of impact within control of receiving waters programs and the contribution of the Environmental Code and within the follow-up of liming effects. Additionally, specific species especially worthy of protection associated with lakes and running waters are monitored.

A general problem within most of the partial programs in the monitoring of freshwater is the large amount of background information necessary for interpretations of cause and effect connections. This includes, for example, conditions like climate, land use, discharges, deposition and geochemistry.

The partial programs within the target areas of lakes and running waters exist on both a national and regional level. They consist partly of an area-wide monitoring of lakes and running waters every sixth years, and partly of monitoring time-series in reference to lakes and watercourses. The national program includes an intense monitoring of a small number of lakes and watercourses and monitoring the supply of different substances to the surrounding coasts through measurements in river mouths. Surface waters are also extensively monitored within the national program for leakage from soils within the two partial programs of forest and agriculture.

On a regional level, the monitoring of lakes and running waters can be performed within a number of partial programs other than the two mentioned. An overview mapping of the occurrence of limnological habitats that need protection should be done on an extensive level. Some of these habitats, however, should be selected for monitoring regarding the qualities they can be expected to contain. On a regional level, results from local monitoring of the quality of surface water reservoirs and waters for swimming can also be used in regional compilations. In addition there is already a well-developed and co-ordinated control of receiving waters.

Co-ordinated control of receiving waters

Whoever performs an activity that can be assumed to be hazardous to the environment is, in Sweden according to the Environmental Code, also obliged to investigate the impact of the activity on the environment. The impact on surface waters shall if they occur be surveyed. The survey shall provide facts and basic material to the permitting authorities for the judgement of the impact on the environment.

The permitting authority makes decisions on control of receiving waters either in connection with the establishment of a control program for the activity or for a larger geographical area, like a watercourse. The inspecting authority decides on co-ordinated control of receiving waters. It may, for example, appoint a water association to perform the surveys. Co-ordinated control of receiving waters is today the dominant form of surrounding control of watercourses and comprises approximately 75 % of the Swedish land area. It is often preferred from both the perspectives of the inspection authority, since it enables a co-ordinated evaluation of the environment, and from the perspective of whoever performs the activity, since it is cost efficient.

Non co-ordinated control of receiving waters may occur if a single point source constitutes the only form of impact in a larger, receiving water, such as a large lake or watercourse in a sparsely populated area. The permitting authority should, to the greatest possible extent, strive for a coordinated control.

The control of receiving waters should:

- Clarify the transport and loading of substances from single pollution sources in a water area
- Relate conditions and development tendencies regarding pollutants emitted in the water area and other disturbances in the water environment to the expected background and/or the water quality criteria for environmental quality
- Bring to light the effects of pollution discharges and other interference in nature
- Provide basic information for evaluations, planning and the performance of measures of environmental protection

Sampling for monitoring receiving waters

Environmental monitoring and control of receiving waters are closely related and in many cases the methods are the same. Co-ordination in the selection of sampling sites, design of the investigations and the choice of methods can therefore give rational advantages and enable an improved analysis of the results.

The sampling sites for control of receiving waters are selected based on the environmental impact of the activity. Sampling sites selected for environmental monitoring must represent the natural conditions of, for example, a lake.

In order to form an opinion on the past or future impact of an activity, information on background values and the natural condition are required. This information should be obtained from environmental monitoring and it is important that the results are comparable.

Examples of control of receiving waters performed in a control program:

- Regular measurements in a watercourse in order to calculate the impact of a specific activity. The company responsible for the activity normally performs the measurements.
- Regular measurements in the air close to the activity in order to calculate the impact. The company responsible for the activity normally performs the measurements.

Examples of environmental monitoring activities:

- Annual measurements of acidification parameters, metal concentrations etc. in a number of lakes evenly distributed over the country or county in order to show the general condition in the lake.
- Measurements of soot, SO_2, NO_2, particles and volatile organic substances at representative sites in a number of urban areas in order to give a picture of the general air quality.

Compilation of data from surface water reservoirs

The objective is to make judgements on the long-term development of prerequisites for municipal water supply using surface water reservoirs. The status should be based on the available investigations of water quality in surface water reservoirs. It is important that this monitoring is co-ordinated with other regional monitoring of lakes and running waters in respect to the choice of variables and sampling.

In the future, data from this partial program may be reported to the EU. The development of this partial program varies largely between the different counties.

Monitoring water from beaches

Many municipalities regularly collect water samples from beaches for swimming and compile the results. Municipal data from 1995/96 forward are reported to the EU through the Swedish Environmental Protection Agency. The objective of the compilations is to inform the public of the conditions at the beaches of the municipality and to form a basis for local measures to correct possible problems.

Other organizations performing environmental monitoring

Important information regarding conditions in lakes and running waters can, in some cases, also be obtained from non-profit organisations. This information may relate to nature surveys of birds, plants and fishes.

When compiling relevant background information as a basis for the planning work, it is important to consider all the information that can be obtained from different types of continuous and temporary monitoring programs and surveys. This demands close co-operation between conservationists and municipal planners.

It is also desirable that the forms are developed for “translation” of environmental data into relevant planning material. The Swedish Environmental Protection Agency and the National Housing, Building and Planning Board are presently conducting a co-operative project, on the development of environmental indicators with a coupling to environmental objectives that are meant to be used as a foundation in the comprehensive planning. The work concerns the presenting of information on certain especially important factors with an obvious relevance to planning.

Photo, Peter Ocskay.

20.

Water conflicts in comprehensive planning

Henrik Lindström, Jan Gunnarson & Yngve Malmquist[1]

Water conflicts and comprehensive plan work

Numerous demands are aimed at water and can often lead to conflicts between interests. Land and water uses are interrelated. In many cases, the different interests manage to share a water area amicably, but in some cases a certain use may be hampered by the co-utilisation of a natural resource.

Use conflicts arise when several different sectoral interests want to use the same water. Their interest may centre on the flow, quality, natural value or the surface of the water. The conflict may only exist during a certain season, with use and availability varying over the year. For instance, a low stream discharge often causes a shortage of water.

Identifying conflicts of use in water areas generally requires more complex analyses, including not only the land areas. Assessing consequences, geographic relationships and chronological relationships may necessitate inclusion of a whole drainage sub-basin in the analysis.

To make it easier to identify various conflicts of use, a number of different conflicts are listed (see Box overleaf). The identified conflicts can also be visualised on a map. An example of conflict mapping is shown in Figure 20.1.

Water-related issues in municipal planning have long been treated as a special sector. A more satisfactory result could be achieved if water-related issues were dealt with across the sectoral boundaries in comprehensive planning. The comprehensive plan plays an important role in this as an integrating inter-sectoral document.

In the Comprehensive Plan, an analysis can be made of how and to which extent different demands can be matched with different potentials, such as natural conditions, existing environmental loads and environmental objectives. Possible consequential effects are also analysed. Comprehensive planning is a way to think ahead.

Comprehensive planning is important for environmental conservation, since it:

- provides a geographical picture of environmental qualities,
- identifies different demands that can pose a threat to the environment,
- facilitates an appropriate and resource-conserving infrastructure and settlement pattern, and
- prevents conflicts and offers alternative solutions regarding urgent development projects.

Using the Comprehensive Plan, different modes of use and relationships can be examined, conflicts can be clarified and different interests can be weighed against each other, when necessary. The Comprehensive Plan interacts in different ways with other documents having a co-ordinating role, with a focus on land and water uses. Due to the mobile nature of water, water planning is not solely a municipal concern, but to a high degree an inter-municipal and regional question.

Responsibility for different water-related matters is somewhat fragmented at the local, regional and central levels. In some cases, several different laws or acts deal with water-related matters. The municipality can bridge over this fragmentation by clarifying its viewpoint regarding the need for inter-municipal co-ordination in the Comprehensive Plan. The County Administrative Board can in turn promote inter-municipal co-ordination through its work with e.g. the Comprehensive Plan (CP) and the so-called “Strategy for Regional Environment”.

Democracy in the planning process

Experience from the Comprehensive Plans that have thus been adopted reveals that reporting, analysis and standpoints regarding surface water and groundwater areas and water use are often incomplete and that there is good reason to improve them. One means for the municipal authority to do this is to develop an up-to-date CP covering the whole

[1] The chapter is based on a part of the English translation of the report “A Synthesis” in the series “Water Planning”, published in 1996 by the Swedish Environmental Protection Agency and the Swedish National Board of Housing, Building and Planning. The original English text has been edited by Lars Rydén.

Example of a conflicts map

A Sävarån River: Valuable area for fishing and outdoor recreation vs. hydropower scheme.
B Lower part of Sävarån River: Important area for scientific nature conservation vs. regulation of stream discharge.
C The esker Sävaråsen: Water source vs. gravel source.
D The aquifer in the Kulla-Forslunda area: Water source vs. gravel source.
E The aquifer in the Frängstorp: Water source vs. gravel source.
F Lower part of River Umeälven: Ornithologically valuable area vs. pressure for reed control, dredging and road construction.
G The Innertavlefjärden bay: Ornithological interests vs. pressure for reed control. Threatened navigability due to silting-up.
H The mire Storåmyran: Mire worthy of protection (national interest) vs. crossed by road (E4).
I Umeälven River: Raw water intake vs. discharges from sewage treatment plant located upstream.
J The rapids of Hörnefors, at the mouth of Hörneån River: Remains of industrial era (fibre banks prevent development of fishery in river).
K Millpond in Rödån River: Obstacle to fish migration.
L Lakes and watercourses threatened by acidification

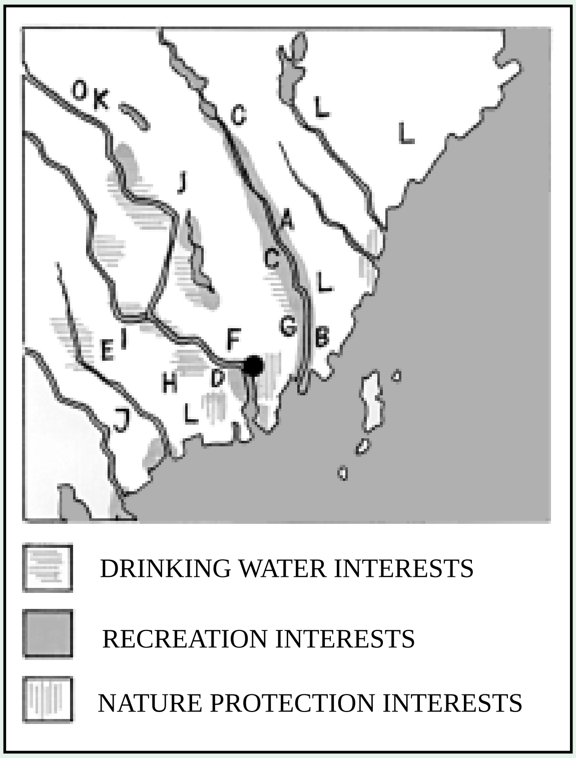


Figure 20.1. Example of conflict mapping. The map shows where the problems are and which resources should be defended. Such an overview can be a first step in integrating water management aspects into the Comprehensive Plan. It can also be a way of describing where the planning need is greatest.

municipality. In Sweden the Planning and Building Act (PBL) require this. It is important that the CP shed light on the relationships between the values of different resources so that the effects of changes can be understood. Concrete and adequate descriptions of the public interests give the municipality high readiness to act and facilitate the weighing of different interests that are embodied in most permit rulings.

The Comprehensive Plan must describe:

- the public interests in the municipality, as well as relevant environmental and risk factors,
- the basic outline of the intended use of the land and water areas – the crucial parameters for water being surface area, volume and bottom properties,
- the municipality's view of how the built environment is to be developed and preserved, and
- how the municipality intends to satisfy national interests.

In the Comprehensive Plan, the municipalities describe how they intend to satisfy *national interests*. In this way different actors can find out what the concrete consequences would be if they planned to suggest changes in the use of the areas of national interest.

Municipal intentions regarding *land and water uses* are expressed and explained in the Comprehensive Plan, which in turn guides decisions pursuant to the acts associated with the national natural resources. As far as water is concerned, the Comprehensive Plan shows how the municipality has planned to use water and shore areas, and discusses environmental issues such as water quality and water management.

In this way, the Comprehensive Plan serves as an instrument for presenting and balancing different *public interests* and for promoting a sustainable and multiple usage of the water and land in the municipality. The work with the Comprehensive Plan also provides good opportunities for citizen dialogue.

PBL sets forth requirements on the planning process. The requirements are intended to ensure that the planning work takes place with transparency and insight. Their purpose is to guarantee that the plan adopted by the municipal council has been arrived at under legal and democratic forms. PBL regulates

- how consultation is to take place and what it must deal with,
- how a broader public is to be informed,
- how proffered viewpoints are to be dealt with,
- who makes decisions,
- how the decision gains legal force and is disseminated, and
- that the Comprehensive Plan must be regularly updated.

The Comprehensive Plan makes recommendations to decision-makers regarding land and water use after taking into account the *prioritised interests*. The plan stipulates where ongoing land and water uses can continue, areas where a change in utilisation is proposed, and conservation areas. The Comprehensive Plan is not legally binding, but should be viewed as an expression of the municipality's intentions – its overall policy for land and water uses.

Information and how to present it

In most cases there is a broad set of data concerning various water-related issues. This normally consists of many different inventories and analysis reports commissioned by various municipal and state agencies, water conservation associations, etc. This material might provide a more coherent and manageable dataset for comprehensive and sectoral planning in the environmental field than is often the case today.

A well-processed and *compiled knowledge base on water-related matters* facilitates the treatment of water in the municipality's Comprehensive Plan process. The planner obtains a good picture of important water-planning questions and can more easily weigh different interests against each other. The municipal leadership has a firmer basis for its standpoint on aims, premises and overall objectives of the comprehensive planning.

In the Comprehensive Plan, the municipality must take a stand regarding various relationships in a geographic context. This includes the fact that an activity on land affects the aquatic environment, sometimes quite far downstream in the catchment. The factual basis for the standpoint should be so simple and comprehensible that the relationships can be interpreted without access to scientific expertise within for example limnology or hydrology.

A good starting point for work on the Comprehensive Plan is to conduct an inventory of current water planning issues in the municipality and make a list of them. Then it is time to assemble *map material* that illustrates the problems and visualises the strategic issues. If possible the different sources should also be depicted and the map material should be augmented with a written account. The account should not be overloaded with background data, but focus on an understanding of the scope of the problems. Issues that require inter-municipal and countywide co-ordination are to be indicated and chronological trends to be described.

Finally, weighing or *rating the problems* that have been brought to light in the inventory should be attempted. This can be done, for example, with the aid of DAP (degree of anthropogenic perturbation). Surface water quality can be assessed according to the following:

- very good situation – insignificant impact by surroundings,

A CONFLICT MATRIX

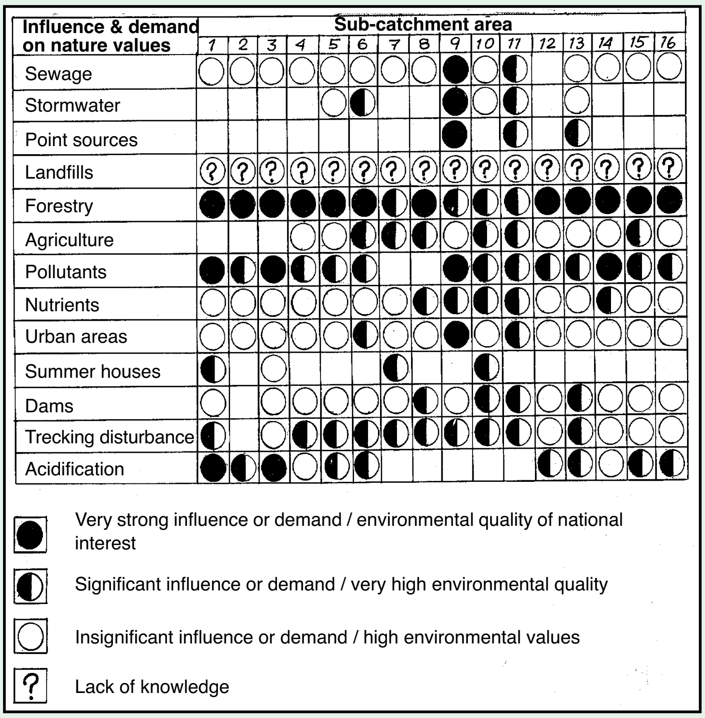


Figure 20.2. A matrix can be a useful tool in analysing and describing problems of conflict.

- acceptable situation – the ecosystem works, but is in the risk zone if discharges increase,
- unacceptable situation – very severe impact, or
- assessment cannot be made due to lack of knowledge.

In Comprehensive Plan issues that are related to water, it is often necessary to maintain contacts with *other concerned municipalities*, e.g. those located in the same drainage basin or sharing a groundwater resource. The water flowing out through the municipal border is to be used by municipalities located downstream.

Important questions for work on the Plan are:

- What is the cultural, social and economic importance of lakes, watercourses, seas and shores for the municipality, its inhabitants and visitors?
- What values exist in and alongside the municipality's watercourses and in its water and shore areas, as well as in its groundwater resources? What protection is required in the short and long term?
- How does the municipality view future development of these areas? What interests must be satisfied or prioritised? Are there potentials that have not yet been realised?
- Does degraded water quality or other environmental impact pose a threat to the future development of these areas?
- What water quality objectives does the municipality have? Have national and regional objectives been translated into municipal objectives?

A CHECKLIST OF WATER CONFLICTS

Flow conflicts:

- irrigation vs. infiltration for water supply
- irrigation vs. dilution of wastewater
- hydropower vs. dilution of wastewater
- aquaculture vs. dilution of wastewater
- industrial water withdrawal vs. dilution of wastewater
- drainage in agriculture and forestry vs. alternate flooding or drought (flooding can however be positive for nature conservation)
- building on land, paving of surfaces, road construction vs. groundwater source
- drainage pumping of mines, sand and gravel pits, tunnels etc. vs. groundwater source
- gravel source vs. water source
- groundwater source for drinking water and irrigation vs. saltwater intrusion
- groundwater source vs. decreased nitrogen reduction process in wetlands

Quality conflicts:

- wastewater and industrial effluents vs. water source
- wastewater and industrial effluents vs. aquaculture
- wastewater and industrial effluents vs. bathing
- stormwater vs. water source
- aquaculture vs. water source
- aquaculture vs. swimming
- eutrophication vs. water source, both surface water and groundwater
- eutrophication vs. swimming
- acidification vs. water source, both surface water and groundwater
- pesticides vs. water supply source
- even-aged forest management vs. leaching of organic acids and humic substances
- transport of dangerous goods vs. water source
- discharges from boats vs. water source
- refuse tip vs. water source, both surface water and groundwater
- snow tipping vs. water source

Conflicts with nature conservation:

- hydropower vs. fishery conservation vs. oligotrophication and migration obstacle or damages to spawning grounds
- aquaculture vs. bird life
- acidification vs. fishery conservation
- eutrophication vs. fishery conservation
- industrial effluents vs. fishery conservation
- boating and canoeing vs. bird life
- oil spills from boats vs. bird life
- harbour facilities vs. fishery conservation
- canoeing vs. crayfish plague
- dumping of solid wastes and tipping vs. nature conservation
- dredging vs. nature conservation
- groundwater source vs. bird life
- fishery conservation vs. biodiversity

Conflicts concerning use of surface water:

- hydropower vs. near-shore development
- hydropower vs. outdoor recreation
- aquaculture vs. boating
- near-shore development vs. outdoor recreation
- boating vs. shipping
- boating vs. bird life
- boating vs. near-shore development
- recreational fishing and boating vs. commercial fishing
- coast-based industry vs. outdoor recreation, tourism, cultural heritage and nature conservation.

Demands on land and water use

As a rule, many demands are made on water areas and shores. In recent years, the development pressure has in some cases increased and environmental problems have thereby increased.

It is important to define the scope and importance of the demands in the Comprehensive Plan. In this way it is possible to prioritise between types of use and to draw up guidelines for land and water uses.

The report of demands is best structured in accordance with the natural resources framework legislation showing how public interests should be dealt with.

Demands to be reported in the Comprehensive Plan (text and map) include current use and preservation interests, existing new demands and expected future demands.

Examples of scope and importance of different demands are:

- information on how many people are affected,
- which investments have already been made and which ones are planned,
- how do the different uses rank in importance to the municipality, and
- what are the rights of different users.

Water and shore areas within a municipality have different potentials for meeting the different demands that are made on their use. This is analysed by evaluating relevant landscape information and other background data on water areas and water resources as well as shore areas.

Questions of the following type are asked for the continued planning: Is the water area suitable for e.g. outdoor recreation interests with respect to attractiveness, accessibility and capacity? This question leads automatically to the next one: What potentials does the area have for different kinds of use? To be able to answer these questions, a systematic analysis should be made of the suitability of the area for different purposes. At the same time, the possibilities of co-utilisation for two or more water use interests should be particularly considered. The potentials for different purposes are to be reported on a map and in text. If necessary, the values and resources should be divided into classes.

Furthermore, the need for remedial measures should be reported. These include e.g. physical alterations and restorations in the relevant water or shore area that may be required if one or more demands on the area are to be satisfied.

Example of co-utilisation of an old pond

- compensation basin
- power source
- nitrogen trap for reduction of the nitrogen concentration in the water
- cultural-historical preservation value
- leisure and recreation
- sedimentation of humus

Analysis of conflicts of interest and possibilities for co-operation

Conflicts of interest can arise in a situation of different demands. These conflicts are brought to light by relating the demands to the potentials and values of the different water and shore areas, current use and preservation interests, and existing and expected future demands on them.

Different demands can often share a water or shore resource amicably. The possibilities for *co-utilisation* of water and shore resources should therefore be explored. This may require an adjustment of certain demands. The results of the analysis should be reported clearly in the Comprehensive Plan, along with the effects on the resources, the conse-

Examples of important water-related planning issues

- present and future needs of public and private water supply
- handling of issues pertaining to utilisation of water and shore areas, as well as water quality issues in relation to demands such as development, outdoor recreational activities, fishing, etc.
- recipient issues
- protection of natural areas, cultural heritage, special habitats and biodiversity
- treatment of demands from transport and communication interests
- impact caused by water pollutants from agriculture and forestry
- acidification and eutrophication

Ronnebyån river drainage basin

demands, problems and resources

- Extensive liming has been performed both within and upstream of Ronneby Municipality.
- Unsatisfactory water quality.
- The main channel is blacklisted.
- The main channel transports very large quantities of plant nutrients and pollutants.
- River is recipient for municipal wastewater and for industrial effluents and fish farms.
- Several old, disused refuse landfills.
- Hydropower potential is harnessed to a great extent – eight major hydropower plants.
- Several ecologically sensitive areas.
- Stationary population of trout lives in a minor tributary.
- Public swimming sites.
- The main channel is of interest for canoeing.
- Strategic long-term reservoirs in Lakes Läen and Rottnen upstream of Ronneby Municipality.
- The main channel is of interest for diversion of infiltration water to the municipal water supply.

quences of various conflicts and the possibilities for co-utilisation.

In areas where strong interests compete with each other, *zones of conflict* arise. It is useful to depict such zones of conflict on a map in the Comprehensive Plan with clear comments in the text of the Plan. Such zones of conflict may in some cases require further consideration in the planning process in the form of an *elaboration of the Comprehensive Plan* (ECP).

Examples of possible considerations in an ECP are:

- specification of surface areas of water detention basins, new or restored wetlands and other closed-loop solutions,
- recommendations for environmentally sound technology and requirement levels for housing, industry and other installations, e.g. wastewater and waste, and
- information and consultation on how land- and water-using activities such as agriculture, forestry, fishing and aquaculture can reduce nutrient leaching and resort instead to closed-loop solutions that return nutrients to the cultivated landscape, for example in integration with future water supply and sewage systems.

Based on the analysis of the possibilities for co-operation between different demands and in the conflict analyses, *different plan alternatives* and their effects on water quality and water areas can be specified and considered. Thereafter it is possible to make a comparison between the plan alternatives with regard to their total consequences and compare them with the aggregate demands included in the alternative. This is then related to the objectives set up by the municipality. Ultimately, it is up to the municipal politicians to take a stand on the outcome of this process.

Weighing different interests against each other

One of the main tasks of the Comprehensive Plan is to weigh different public interests against each other. This should be done integrally for land and water aspects. This weighing of different interests isn't usually necessary throughout the whole municipality, but can be limited to areas where the construction or development pressure is great or where there are

Example of what different plan alternatives should show

- how great a demand the different alternatives make on water and shore resources
- possible changes in future potentials for utilisation of resources
- the cost of the resource utilisation
- the consequences for land use and the environment

other forces of change. In the weighing process, the municipality makes various priorities among land and water uses. An important ingredient is contacts with concerned members of the public, landowners, neighbouring municipalities and other interests.

These interests are weighed with reference to the provisions of the legal framework. In Sweden, PBL states that land and water areas shall be used for the purpose or purposes for which they are most suited.

Precedence should be given to uses that entail good management from a general viewpoint. This has not been done clearly in some existing Comprehensive Plans. If co-utilisation between several land and water use interests is possible, there is usually no reason for ranking these interests in order of priority. It is important that the *reasons* why the municipality prioritises one demand over another should be given in the Comprehensive Plan.

As mentioned above, in some areas it may not be possible to make the final prioritisation in the Comprehensive Plan. Such areas should be reported as zones of conflict in the Comprehensive Plan. If continued investigations or other measures are called for, this, too, should be noted in the plan.

Assessment of ecological impact is one of several important steps when decisions on the land and water use strategy are to be taken.

Tool analysis

In order for the municipality's decision to achieve the greatest practical impact, a selection should be made of suitable tools for implementation. In this context it is important to think about how the citizens of the municipality and other authorities can be induced to work with these tools.

The overview below shows how the municipality's standpoints on land and water uses in the Comprehensive Plan can be linked to different tools for implementation. Higher-level documents, however, such as environmental conservation programmes, are not shown here.

Consensus-building among citizens and policy-makers regarding the municipality's intentions requires appropriate forms of consultation. Comprehensive planning provides opportunities for influence in the early phases. Joint consultation is provided for in PBL. Consultation provides a channel for the viewpoints of citizens, landowners and interest groups to reach the policy-makers, giving them information on how affected groups view their proposals.

Water-related issues that the County Administrative Board should consider in joint consultation:

- national interests, for example shipping and nature conservation,
- inter-municipal issues, for example water supply, and

Table 21.1.Tools for regulating various uses of water

Land and water use	Tool
Development for:	
- housing, plant	elaboration of CP, detailed development plan, building permit, land permit, EIA, shore protection dispensation
- hydropower	water ruling
- material extraction (gravel, sand, peat)	permit
- animal husbandry > x head	permit
- recipient	objective for environmental quality for e.g. recreational fishing, phosphorus level and transparency
Strategic areas for:	
- industry, water supply, urban expansion, transport and communications	readiness to act through restrictions against certain use
Current land use:	
- agriculture, forestry with character of "everyday landscape"	general consideration
- nature conservation area with agriculture and forestry	regulations as decreed, possible management plan
Co-utilisation for:	
- outdoor recreation, landscape conservation, tourism, ecologically particularly sensitive areas	consultation, supervision, special consideration, voluntary measures, recommendations for use
Active protection of natural and cultural values as well as natural resources:	
- very strong nature conservation interests	safeguard through nature reserve decree
- municipal water source	protected area, area regulations
- heavily polluted areas with e.g. algal blooms or acidification	need for pollution control, restoration, liming, recommendations for use

Example of National Action Programme

A number of measures should be taken to reduce groundwater withdrawal where necessary. The measures that are most urgent at present are listed below:

- individual water metering in both single-family houses and multiple-family buildings,
- information/advertising campaigns aimed at a long-term change in attitudes,
- user influence in the water supply organisation,
- installation of new water-saving technology in older buildings,
- continued development of water-saving technology,
- development of storage technique for urine and solid toilet waste,
- development of organisational forms for transport and spreading of urine and solid toilet waste, and
- evaluation of existing areas with technical systems.

- health and safety, for example recipients of industrial effluents.

Evaluations of the consultation activities involving comprehensive planning suggest that there are important items for the municipality to consider obtaining maximum benefit from the consultation process.

In consultation in comprehensive planning, the municipality should especially bear the following in mind:

- consultation must be given sufficient time,
- information material used in consultation should clearly set forth the reasons, implications and consequences of the proposed plan, and
- it is in the consultation phase that the greatest work of a more ambitious and illustrative presentation of the proposed plan is done.

Presentation of the Comprehensive Plan

The municipality's adoption of the Comprehensive Plan should be based on and make reference to documents that provide clear information on how land and water areas are planned to be used, how public interests will be safeguarded, what the planning assumptions have been and the County Administrative Board's statement of opinion.

The following documents should be referred to in the municipality's Comprehensive Plan:

- maps showing the basic features of the intended use of land and water areas and the location of development,
- a listing of public interests, including national ones, should be taken into account in connection with the planning and review of permit applications in areas with different development potentials,
- a plan description including the planning assumptions, the reasons behind the plan and the measures which the municipality intends to adopt to implement the plan, or which the municipality wants other authorities to adopt, and
- the County Administrative Board's statement of opinion.

It is important that the Comprehensive Plan have high *readability*, for the sake of the public as well as for municipal politicians and officials, the County Administrative Board, and others. To increase the readability of the Comprehensive Plan with regard to water resources and water-related resources, it is important that the basic map that is used also show the boundaries of the drainage basins in the municipality, groundwater reservoirs and infiltration-prone land areas.

Better readability is obtained by:

- reporting the physical situation before and after an implementation,
- using illustrations to visualise general issues,
- presenting figures and charts of good technical quality,
- being attentive to layout, for example making sure that text and figures that belong together are positioned together,
- limiting the information content of the figures so that they are clear,
- using aerial photos instead of maps when appropriate, since they are often more illustrative, and
- using a sufficiently large scale for illustrations and map material.

Normally, in most parts of a municipality's drainage basin, different activities can be co-ordinated without giving rise to conflicts that have to be settled in comprehensive planning. These areas can be designated as water areas where current use may continue.

As a rule, it is a good idea to treat water and land uses together so that the water areas are included in a larger reporting area for e.g. forestry purposes. If any of these water areas have particular environmental or resource problems, recommendations may be required. The recommendation map then indicates this.

In the case of certain water areas, it may be necessary to report land and water uses separately, de-

FROM EMÅN RIVER INCLUDING NÄVELSJÖN LAKE

REGIONAL COMPREHENSIVE PLAN

Description:
The area includes the main channel of the Emån River from Lake Målsjön to the county line after Kvillsfors, including the gravel deposits in Tälläng. This stretch is of varying nature with alternating lakes, rapids and more quiet-running sections. The freshwater pearl mussel is found along this stretch of river, as is the otter, which has been observed at several places along the river. Lake Nävelsjön is considered to be a good otter habitat. The lake is also one of the county's finest bird lakes with many important resting bird species, and is one of the country's most important resting areas for the whooper swan. The river system is one of the most fish-rich in the country, containing asp as well as wels in the lower parts.

Proposal for safeguarding:
Regarding Lake Nävelsjön and part of Tjurken Lake, an inquiry is in progress where the municipality, together with the County Administrative Board and the Swedish Environmental Protection Agency, will work out the necessary measures to safeguard the high natural values. A decree under the Environmental Code is deemed necessary. However, this decree will not adversely affect current land use. Active agriculture is a prerequisite for natural values.

Irrigation may not, however, be practised in such forms that it jeopardises natural values. Annual flooding to satisfy the needs of the resting birds must be safeguarded. For the rest of the Emån River, all activities that are presumed to affect the natural values in the river must be preceded by environmental impact assessments. Activities that increase concentrations of toxic metals, plant nutrients and persistent organic pollutants in the Emån River must be avoided.

pending on their particular nature. In areas with conflicts of interest, high vulnerability, sensitivity, or with special values for a particular group or individual, the municipality may wish to give priority to some use, current or proposed. These areas are designated, for example, water supply area, sewage treatment area and bathing beach area.

Recommendations

In the Comprehensive Plan, it may be appropriate to divide the municipality into sub-areas with different development potentials. Each area should be described in concise and concrete terms. The description serves as a basis for the municipality's judgements and standpoints in the form of *area-specific recommendations*. These provide guidance for decisions under PBL or related acts.

General recommendations can be issued for certain types of areas or sites. In the case of roads and utility lines, for example, recommendations can be issued that are related to roads and lines of a certain class. General recommendations can also be used for e.g. lakes or watercourses of a certain kind or class.

The recommendations in the Comprehensive Plan should stipulate how the situation in various areas can be followed up in the wake of different decisions and measures. In the case of preservation areas and ecologically sensitive areas, the plan should set forth restrictions or rules of consideration for buildings and plants, as well as for e.g. the impact of agriculture and forestry on water.

Objectives for water quality can be specified as target values for the environmental requirements of the prioritised interest. Active preservation may require special decrees under a specific legal condition. A need of consultation regarding voluntary measures within forestry, for example, may have to be reported with geographic delineation. In the case of areas of changed use, this may for example involve stipulating requirements on a detailed development plan and impact assessments, or stipulating restrictions on for example building, in order to maintain a readiness to act.

Measures for implementation

To meet the plan's objectives it is urgent that an *action programme* be formulated in which measures are specified. The programme serves as a platform for further specification of details and responsibilities. The point of departure for such a strategy can be national, regional or municipal surveys, which should be stipulated in the knowledge base.

The *forms* for implementation are established in a second stage. This can best be done in collaboration with the executive bodies, for example

Watershed conflict resolution

Cornell University has, within the Cornell Co-operative Extension and its Local Government Programme at the Centre for the Environment, worked on the issues of watershed conflicts. One result is a manual of Watershed Conflict Resolution, from which eight principles are cited below. The method is based on a wide range of experience of watershed conflict resolutions. It uses participatory principles and is thus in line with Agenda 21 work. It provides an illustration of how democratic methods contribute constructively to managing water issues.

Introduction

Watersheds are fertile arenas for public policy conflicts. These conflicts arise from perceived threats to health and safety, recreational uses, water supply needs, aquatic habitats and plant/animal species, navigational needs, power generation, and aesthetic qualities, for example. Common causes for these perceived threats include the effects of land uses such as agriculture or urban development, which includes point and non-point water pollution, waste disposal, and changes in runoff and groundwater replenishment, for example.

The perception of winners and losers often quickly arises as policy conflicts escalate. Goals of different interests may be incompatible. Benefits and costs may be perceived as falling unevenly on watershed residents, non-resident users, farmers, business and local governments that share the watershed. If a city located outside the watershed uses it for its water supply it will demand a voice in management decisions, and may advocate changes seen by some watershed residents and local governments as inimical to their interests.

Watershed policy-making within these contexts must begin with dialogue among the various interests and stakeholders. Education, mediation, negotiation or litigation may be employed at various stages in the process. How and when such tactics are employed depends upon the type and intensity of the policy issues raised.

The character of each watershed differs from other watersheds. This includes natural, social, demographic and economic characteristics as well as historical experiences that have shaped local attitudes. These differences will emerge in watershed policy conflicts and influence how they are dealt with. A precise pathway for resolving such policy disputes is not possible due to these differences.

Below follows a shortened outline of a set of principles to better understand what is involved in watershed policy disputes. Their application must be tailored to mix the social, political, economic, and land use and physical characteristics of each unique watershed.

Principle 1. Watershed conflicts are normal

Watershed conflicts are generated by differences in values, stakes, interests, availability of information, and perceived roles among affected parties. The outcome need not be negative. Attempting to avoid it may be counterproductive. The issues often re-emerge later with greater vehement and more sharply defined positions.

Interest groups or municipalities may react to conflict in several ways: Compete for dominance; Attempt to avoid the issue; Give in to the demand of others; Seek a compromise; Collaborate to find a common solution.

Advocates and opponents often design strategies to influence decision-makers rather than each other. This results in public posturing that locks the protagonists into positions that only escalate the conflict.

The nature of a policy dispute can often be established by asking these questions: Who benefits and who pays? What differences exist in perception and values? What factual watershed data exist? Who has power and who has not? What is the socio-economic and environmental context? Who feels threatened and who does not? What roles are being played by private groups and public agencies? Is there receptivity to co-operation in seeking solutions?

Principle 2. Seeking a constructive outcome

Conflicts increases public awareness to bring issues into focus, mobilise constituencies, and develop leadership. Misunderstanding of the role of conflict in public policy-making makes it difficult for many to understand or consider methods for settling such disputes. The challenge is to find a suitable arena where social priorities and power centres that drive a policy conflict can interact to yield a constructive outcome rather than resisting change.

Critical steps in fostering constructive outcomes are: 1) Focusing on process rather than positions. Positions promote one way of resolving an issue, while excluding other ways. Process is a co-operative effort to find common goals and examine the options for achieving them. 2) Developing a general consensus that something must be done even if there is no agreement on what that may be. This encourages openness to a range of ideas, including the bad ones that will eventually be dropped, as the process continues. 3) Creating a non-confrontational arena for dialogue to take place. This is a principle role for ”third” parties such as educators and mediators. 4) Building a sense of trust among those involved in a dispute and responsibility for a constructive outcome.

Principle 3. Power, perception and values

An essential part of the conflict resolution process is to identify how power is used by those involved in a dispute, both by legal and extralegal means, and the perception and values held by different interest groups. These include e.g. stakeholders such as property owners, municipalities, interest groups, and business.

Non-technical factors often govern the reactions of public interests groups such as perceived fairness of proposed solutions and trustworthiness of information sources.

Critical questions are: How are decision actually made by each group involved in a dispute? What perceptions are driving local policies in a watershed that is likely to be affecting these decisions? What state of national political developments may be affecting the perceptions and stances for protagonists? Understanding how these factors are influencing the groups involved is often essential to finding constructive solutions.

Principle 4. Conflict context

Watershed policy conflicts usually pass through identifiable stages. Each stage establishes a specific context for conflict resolution techniques. These public policy stages are: Awareness and growing concern; Discovery and analysis of the situation and its alternative solutions and their consequences; Choices for implementation.

The steps in a dispute resolution are: 1) Setting the stage (establishing report), 2) Identifying concerns (listening), 3) Framing the issues (negotiating agenda), 4) Generating alternatives (options) 5) Selecting alternatives (feasibility) and 6) Written agreement (frames specifics).

Complexity, fragmentation and uncertainty among agencies, local governments and interest groups may have to be resolved to find common watershed goals and public support for them. This usually increases with the size of the watershed. Those affected by an issue seldom work in the context of the whole watershed. A united effort to seek solutions to watershed-wide problems often occurs only when a critical area-wide consensus is created and sustained.

Principle 5. Can this conflict be saved?

The goal of conflict management is to guide the protagonists into more productive channels by diverting them from an endless cycle of unresolved conflicts that does not generate positive solutions. Examine the groups involved, their interests, their power base, and how they are organised. Look for both ”open” and ”hidden” agendas and how the issue arose.

Perceived threats can stimulate recognition that co-operation is needed to prevent them from happening. Other complicating factors in conflict resolution: One or more parties feel they can ”win” without having to compromise through litigation or political or economic influence. Those who benefit may not be, or are not perceived to be, the same as those who pay the costs. People tend to blame others for causing the problem. Some will want changes, results, more quickly than others. Prevention vs. remediation: it is often more difficult to get agreement and support for prevention than remediation.

Principle 6. Conflict management strategies

1) Break issues into component parts, beginning with the simpler ones first. 2) Translate issues into easily recognised terms, how a public health-related beach closing can be avoided, for example. 3) Be aware that scientific ”facts” may not be perceived as neutral. They affect various parties differently. Be prepared to respond to those who feel threatened by such ”facts”. 4) Do not assume the parties involved already have defined a problem. Seek a variety of perspectives. Integrate these into a new understanding of the problem. 5) Seek to help parties with a defensive posture to honestly assess whether or not confrontation, and their power base to support it, is a desirable alternative compared to a negotiated agreement.

All major stakeholders should be involved with a reasonably level playing field. This reduces perceived threats and inequities to a tolerable level. Devising a conflict management strategy is extremely difficult if some groups persist in being ”martyrs” who would rather go down with the ship than to consider any deviation from a specific position.

Principle 7. Watershed alliances

Watershed alliances provide an agreed-upon structure for working out policy disputes. They require 1) Recognition that co-operation is needed to achieve watershed protection goals. 2) Clearly defined benefits that outweigh the perceived costs of participating and 3) An agency/group/individual with recognised standing to promote an alliance.

Acceptance of an alliance is enhanced if a common threat is perceived to exist. Recognition of the specific role of an alliance is necessary in determining their role in conflict resolution.

Educational and consensus-seeking alliances are usually best able to provide a non-confrontational setting for resolving watershed management disputes. Critical factors in successful alliances are: Commitment of leaders; Clearly understood missions; Measurable results; Trust among parties; Clear identification of who’s responsible; Representation of all interests; An experienced facilitator; and Willingness to compromise, flexibility.

Creating an alliance should not be an end in itself. It is only a means to a desired end. Formal alliances may not always be needed. The spirit of one may be sufficient. It is tempting, but a grave mistake, to include only like-minded members in a watershed alliance. This risks non-acceptance by those not included who can block a policy agreement later.

Principle 8. Public issues education

Public issues education provides a non-confrontational forum to clarify issues underlying conflicts. It can stimulate recognition that it may be more advantageous to search for common grounds for agreement rather than not doing so. An educational approach to conflict is itself an advocacy position with its own set of values. It typically includes these concepts: 1) Broadening the range of viewpoints and knowledge is beneficial; 2) Public experience and concerns should be given equal credence with scientific information; 3) Education is important in resolving conflicts 4) The educational purposes is to assist and facilitate, not take over, the decision-maker’s job or promote outcomes.

An honest educator will form opinions about possible solutions to a problem. Audiences have a right to know that opinion given in a low-key non-confrontational mode will be seriously discussed and examined. It must be clear that the views of others will also be given a full, credible examination in the educational process.

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The full text ”Watershed Conflict Resolution: Some Guiding Principles” can be obtained from Cornell University Media Services Resource Center. 7 Cornell Business and Technology Park. Ithaca NY 14850 USA. Fax +1-607-255 20 80, distcenter@cce.cornell.edu

the public works department, the environmental department or the physical planners. The means of implementation, i.e. policy instruments and resources, should be described. It is also important to schedule the measures, preferably divided into long and short term.

The continued work of implementing the intentions of the plan can be summarised as *programme items*. The point of departure can be the knowledge base on water in the municipality, where proposals for measures have been put forth.

21.

Transboundary waters

Lars Rydén, Nina Munthe & Andris Spricis

Transboundary waters are common

River basin management quite often becomes an international undertaking. River basins that cover more than one nation state constitute some 50 % of the total land area of the world. The local history is decisive for how much transboundary water there is. "Unnatural" borders, such as many borders between states of the United States, do not take rivers into consideration and thus often cut across them. Older borders, on the other hand, follow such natural obstacles as high mountains, and then very often coincide with water divides. This is the case for the borders between Norway and Sweden and between Poland and Slovakia.

There are three clear categories of international rivers: Firstly, many large rivers belonging to several states. Of the 31 major rivers in Europe (Magnuszewski, 2000) more than half are transboundary, the largest one being the Danube with a basin shared by 17 countries. Secondly, there are the rivers that constitute borders between states. In the world at large there are some 200 important border rivers, according to the research database on border rivers at the Department of Peace and Conflict Research at Uppsala University. In the Baltic region, we have e.g. the Odra and Neisse Rivers forming the border between Germany and Poland, the Narva River between Russia and Estonia, and the Torne Älv River between Sweden and Finland. Finally, there are many small rivers and watercourses that cross back and forth between two countries.

A second category of transboundary waters consists of the large lakes belonging to several nation states. Of course we may include the Baltic Sea itself in this category. Other important such waters include Lake Peipsi/Chudskoe, which belongs to both Estonia and Russia.

International water co-operation and conflict

One of the most challenging issues for the 21st century will be to guarantee sustainable access to water for present and future generations. Today water consumption is increasing rapidly, and an increasing part of the world's population will experience severe water constraint, affecting human health, food security and regional political stability. Management of our shared waters becomes increasingly important and co-operation and co-ordination are needed to protect and restore the transboundary river basins.

Existing legally binding international instruments date back more than 100 years; at present some 150 international agreements are still in force. Europe has a long experience of managing transboundary rivers. Many lessons can be learnt by studying the experiences of the European river commissions. One

River Dvina at Politsk, Belarus on its way from Russia to Latvia and the Baltic Sea (photo, Lars Rydén.

example is the Rhine Commission, which is almost 50 years old. For many centuries the Rhine has been a major shipping lane but also a source of food and a place where vast industrial complexes have been constructed. It has in addition been used for agricultural purposes, for energy generation, for disposal of wastewater and for recreation.

With so many different claims on water it is not difficult to foresee that conflicts on the use of water may occur. The experience of the international river commissions is nonetheless generally positive (Wallensteen & Rydén, 1991). Co-operation around a common river seems to be easier than many other tasks in difficult times, e.g. the Mekong Commission was one of the few channels whereby the warring parties could meet during the Vietnam war, and the Rhine Commission provides another example.

A very serious case of pollution in upstream Switzerland badly damaged downstream Germany and the Netherlands, when in November 1986 a fire broke out in a chemical warehouse near Basel where 1 300 tonnes of hazardous chemicals were stored (Hultman & Levlin, 2000). Some 30 tonnes of chemicals, including mercury and organo-phosphorous pesticides, were washed out in the river during the fire-fighting operation. The water intakes to downstream German towns were closed and water had to be brought in to them by truck. Just a few days later 1 100 tonnes of the herbicide dichlorophenoxyacetic acid leaked into the Rhine River from an industry in Ludwigshafen in Germany and again, all water intakes downstream were closed. Instead of large demands for compensation these events led to strengthened co-operation for safeguarding the water in River Rhine against future pollution.

In contrast, when claims on water access are in conflict, serious international disputes may result (Wallensteen & Rydén, 1991). This was the case e.g. between India and Bangladesh when India unilaterally diverted the flow of the Ganges River for its own purposes. In the Middle East the water resources on the Golan Heights are one reason for the conflict between Syria and Israel. The building of large hydropower stations and the reservoirs that serve them, also resulting in large scale changes in water access, is a typical source of conflict both within and between states. In the Baltic region international conflicts concerning water flows have not occurred, although construction of reservoirs has caused internal conflicts, in northern Norway, Finland and Sweden.

International agreements and conventions

Today policies and measures associated with the management and use of water resources in the Baltic region receive increased attention. New international and national legal instruments, including the United Nations Economic Commission for Europe (UN-ECE) Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki, 1992) and the draft Water Framework Directive drawn up by the European Commission, promote an ecologically sound management of transboundary waters based on the river basin as the management unit.

The above-mentioned UN-ECE convention is intended to strengthen national measures for the protection and ecologically sound management of transboundary surface waters and groundwater. It obliges its parties to prevent, control and reduce water pollution from point and non-point sources. It also includes provisions for monitoring, research and development, consultations, warning and alarm systems, mutual assistance, institutional arrangements, and the exchange and protection of information, as well as public access to information. This convention has up to now been signed and ratified by 24 countries as well as by the European Commission.

Other related conventions and protocols addressing the co-operation in transboundary waters are:

- Protocol on Water and Health to the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes, written in London, on 17 June 1999
- 1998 UN-ECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters
- United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses
- 1992 UN-ECE Convention on the Transboundary Effects of Industrial Accidents
- 1991 UN-ECE Convention on Environmental Impact Assessment in a Transboundary Context

On the European level much progress has been made in water protection in individual states but there is still a need of increased efforts to get the European waters clean or to keep them clean. Major attention is currently directed towards the proposed European Council Water Framework Directive. If and when this directive comes into force it will drastically affect the management of water basins, as well as the involvement of stakeholders. This proposed directive aims to do three things:

- attain a good status in all waters by the year of 2010
- make those who pollute pay
- co-ordinate actions in each river basin, by development of river basin management plans

Some of the lessons learned from the drawing up and implementation of transboundary water agreements can be summarised as:

- There should be *a common will* to resolve the existing problems.
- There should be *confidence among the parties*.
- The principle of *acting in partnership* becomes increasingly important.
- The parties should *set challenging medium-term and long-term objectives.*

Transboundary water management means participating in a process that is based on mutual trust, understanding and commitment from the riparian countries.

Guidelines for river management

Under the umbrella of the convention guidelines on water quality, monitoring and assessment of transboundary rivers have been elaborated. These guidelines are intended to assist ECE governments and joint bodies, e.g. river basin commissions, to develop and implement procedures for monitoring and assessing transboundary waters. The character of the guidelines is strategic rather than technical.

In the guidelines there is a list of issues that riparian countries, individually and collectively, need to agree upon:

- specific human uses and ecological functions of a river basin
- the issues that have an impact on human uses and the ecological functioning of the river
- existing and future pressures that are part of these issues
- the relation between the state of the river basin and the functioning of receiving water bodies (seas, lakes, reservoirs, estuaries)
- quantified management targets

The guidelines constitute the common ground needed as a basis for future actions. One of these activities is monitoring. It is important to keep in mind that the ultimate goal of monitoring is to provide information, not just data. The information should furthermore be part of the decision-making process.

The Odra Commission

A good example of a functioning river commission in the Baltic Sea Basin is the Odra Commission. This commission, which co-ordinates international co-operation between the countries of the Odra River basin, was established through participation from Germany, Poland and the Czech Republic. The commission has several difficult problems to deal with. One is the management of the floods from the Odra River, which were very severe in 1998. Another is the large-scale pollution of the river from all three countries.

Although the Czech Republic does not contribute much to the Odra River drainage basin, what is coming to the river from the area around the city of Ostrava is polluted by the heavy steel industry in the district. This is different from the other major Polish river, Wisła, where the small contribution from the Slovak republic is not polluted at all, and the contribution from western Ukraine is not of a detrimental sort, either. Management of the Wisła River is thus mainly a Polish national concern.

The Swedish programme on transboundary waters

The Swedish Environment Protection Agency, SEPA, is one of several Swedish actors supplying assistance in the environmental field to central and eastern Europe. In co-operation with the Swedish government and Sida, a programme on transboundary waters initiated in 1997. This programme focuses on the co-operation in three transboundary waters east of the Baltic Sea: Peipsi/Narva, Daugava River and Nemunas River. The overall aim of the programme is to support the co-operation between the countries sharing a water basin, with the objective of promoting sustainable use of the joint water basin. This will hopefully contribute to a better environment in the river basins and also in the Baltic Sea as a whole. The more specific goals are to contribute to:

- the development of bilateral/trilateral agreements related to each river basin
- the development of river basin management plans
- the establishment of river/lakes commissions
- the co-ordination of environmental information and monitoring
- a joint and integrated view on water management

Activities within the programme in the Peipsi region have focused on support to regional authorities in Russia and Estonia in the field of environmental monitoring and information exchange. The Russian-Estonian Transboundary Water Commission has also received support to promote the accessibility of information and development of shared visions with focus on groundwater and nutrients. Much attention was paid to calculating the nutrient loads. SEPA-supported projects in the Daugava basin include the elaboration of a trilateral assessment report as well as the elaboration of a draft co-operation agreement with assistance from international law expertise. More recent activities include preparations for establishment of international commissions in the basins of Daugava and Nemunas as well as training in water management for top levels of the environmental administration in Russia and Belarus.

The Latvian situation

Latvia has sufficient resources of surface and groundwater to fully provide the necessary water volume to its population. The total annual discharge of Latvian rivers is estimated to be about 33-35 km^3 per year. There are 777 rivers in Latvia with a length exceeding 10 km; the total length of waterways is approximately 12 000 km. There are also more than 3 000 lakes, 802 of them with an area exceeding 0.1 km^2. The renewal rate of groundwater is 4.7 km^3 per year.

Surface water and groundwater are used in equal amounts in Latvia. Due to the economic recession and restructuring, and also as a positive result of the Law of Natural Resources Tax, water consumption has fallen since 1990. Latvian rivers have moderate levels of organic pollution and nutrients, quite high concentrations of oxygen, and rich flora and fauna. Water quality is considered to be quite good in 80 of Latvia's rivers.

The transboundary watercourses as well as the transboundary groundwater are of particular significance for Latvia. All of Latvia's largest rivers have their origins in neighbouring countries, and 53 % of the discharge of Latvian rivers into the Baltic Sea comes from beyond its borders, thus carrying also the pollution produced in neighbouring countries and posing a direct threat to the health of Latvia's residents in the event of large industrial accidents. Most important are the Daugava River (29 % of its catchment is located in Latvia), Lielupe River (50 %) and Venta River (50 %).

The largest river, the Daugava, also called West Dvina, has a river basin that runs through in Latvia, Belarus and Russia. Its total area is 87 900 km^2, of which 24 700 km^2 is Latvian territory. In Latvia it flows though 367 km and is then discharged into the Gulf of Riga. Daugava originates in Russia but it is when flowing through Belarus that it receives most of its pollution load. There are large production facilities, including chemical industries, in Vitebsk, Polock and Novopolock in Belarus that discharge their wastewaters and other hazardous chemicals into the Daugava. The downstream water is used as a drinking water supply in Latvia.

Likewise significant amounts of wastewater from the Mazeikiai oil refinery and other industrial enterprises, small towns and runoff from intensive agriculture in Lithuania leak into the watercourses of the Venta and Lielupe catchment areas.

Not surprisingly Latvia as a downstream country signed and ratified the UN-ECE 1992 Convention on Transboundary Watercourses before the neighbouring countries promised to take an active part in activities aimed at the common goal: a better state of inland waters, which is reflected in the state of the Baltic Sea.

The Gulf of Riga is especially hard hit. The almost enclosed nature of the gulf and the very large discharge from rivers have led to a continuously increasing phosphorous and nitrogen pollution over the last 20 years. This eutrophication causes a gradual decrease in the dissolved oxygen content of water during the summer months, although over the last few years it was not observed. This is due to favourable hydrological processes, as well as a drastic fall in nitrate pollution, that can be explained by decrease of nitrates from rivers due to a fall in agricultural production. Still phosphorus and chlorophyll measurements over the years show that eutrophication of the gulf continues.

Coastal pollution from Lithuania (Klaipeda and Palanga) and the southern part of the Baltic Sea enters Latvia's territorial waters with dominant currents and winds and negatively influences the biotopes of the Kurzeme coast. The open sea oil terminal now being built near the Lithuanian village of Butinge on the border to Latvia will significantly increase the risk to the coastal ecosystems.

The Ministry of Environmental Protection and Regional Development of Latvia has proposed the following measures for transboundary water problems in Latvia:

- to reduce transmission of pollution from other countries into the territory of Latvia, thus protecting internal waters of the country and the Baltic Sea,
- to increase the safety of the population of Latvia in case of accidents in neighbouring countries that substantially increase pollution in Latvian waters,
- to reduce pollution leakage from the territory of Latvia into the Baltic Sea.

Several steps have been taken in this direction. To ensure the safety of surface water and with the help of the Dutch government and RIZA, Latvia opened the Piedruja Early Warning Station of the Daugava River, at the border with Belarus, in December 1996. Other undertakings include the project "Clean Venta" that is now carried out in co-operation between Latvian and Lithuanian local authorities with support from the European Commission. Finally, within the framework of a project supported by Sweden, a formal agreement on the protection and use of the Lielupe River was signed by Latvia and Lithuania.

Lake Peipsi

Lake Peipsi is the fourth largest lake system in Europe. Its surface area is 3 550 m^2; its average depth is 7.1 meters, and the maximum depth is 15 meters. Approximately 240 rivers and streams flow into Lake Peipsi. The 77 km-long Narva River connects the lake with the Gulf of Finland.

The water body is divided into three parts with distinctive limnological features: Lake Peipsi (2 613 km^2, average depth 8.3 m), Lake Pskov (709 km^2, 3.8 m) and Lake Lämmi (236 km^2, 2.5 m). The latter lake serves as a strait connecting the two other lakes. Thus, in an international comparison, the lake is very shallow. This, in combination with the well-mixed water masses and the relatively high water temperature in summer, leads to intensive biological processes and a high trophic level in the lake. However, the morphological and morphometric difference between the parts of the lake is a significant reason for its ecological heterogeneity. The lake as a whole is eutrophic, with a clear south-north gradient.

Lake Peipsi discharges into the Narva River, which has an annual flow of 380 m^3/s and is the second largest river flowing into the Gulf of Finland. There are approximately 20 main rivers and streams discharging into Lake Peipsi. The largest rivers are the Velikaja (in Russia) and the Estonian river, the Emajogi, together responsible for more than 60 % of the total freshwater input to Lake Peipsi (Stålnacke et al., Nutrient loads to lake Peipsi. 2000. Jordforsk Report No. 4/01).

The total load of nutrients on the lake is mainly caused by diffuse nutrient loadings from agriculture and forest and to some extent (i.e. phosphorus) from e.g. the cities of Pskov and Gdov in Russia and Tartu in Estonia. Despite this, agricultural emissions seem to be low or moderate in comparison to Nordic conditions, and the area-specific loads of nutrients from the largest Russian and Estonian rivers seem to be low in an international perspective (Stålnacke et al., in prep). Notable is also that the retention of nutrients in lake-rich basins of Lake Peipsi (e.g. Emajogi River basin) is substantial, as is the retention of both nitrogen and phosphorus in Lake Peipsi (Stålnacke et al., in prep). These low-to-moderate nutrient load estimates from the mid- and late 1990s may be explained by the economical recession after the collapse of the Soviet Union in the beginning of the 1990s, resulting in a dramatic decline in agricultural and industrial production, and a plausible reduction in nutrient loads to the lake. Improved municipal sewage treatment may also have affected the nutrient loads.

River water quality is presently monitored in eight of the largest rivers on the Estonian side (totally 30 sampling sites) and in four river basins on the Russian side, besides the sampling sites in the Narva River.

Water quality monitoring in Lake Peipsi has a long tradition; studies began as early as 1851. More systematic hydrobiological studies were started in 1962, in affiliation with the Institute of Zoology and Botany. The Hydrometeorological Service started hydrobiological monitoring in 1950. Today the monitoring is performed separately by Estonia and Russia. Nutrient concentrations and other eutrophication-related parameters are presently monitored at five sites on the Estonian side and ten sites on the Russian side. Previously there were 14 sampling sites on the Estonian side.

The lake is of great importance to the local population. It is one of the most productive large lakes in Europe with an annual fish catch of some 9 000-12 000 tonnes with pike-perch as the dominant species, and figures indicating that a hundred years ago the catch even exceeded 25 000 tonnes, of which smelt was by far most important. As in other international lakes there is a need to agree on fishing regulation, environmental protection actions and in general on co-operative measures regarding the lake.

After Estonia and Russia adopted their respective declarations of state independence in 1991, relations between the two countries became tense, and only recently have contacts between Estonia and Russia at the intergovernmental level improved. The first step was thus not taken until 1996, when an intergovernmental agreement on border activities was signed. It was followed in 1997 by the UN-ECE convention and an agreement on the protection and sustainable use of transboundary waters. As a consequence, a joint Estonian-Russian Commission on Transboundary Waters was established in 1998 and, under the control of the commission, working groups for monitoring and research, water protection and water economy were established. In addition some agreements have been made regarding the *oblast* and county levels. Still there is no border agreement between the two countries, which hampers development.

The role of non-governmental organisations (NGOs): the Lake Peipsi Project

Created in 1993, the NGO Lake Peipsi Project (LPP) works to promote communication and information exchange across the border. The LPP collected information from both Estonian and Russian sources on the environmental situation in the Lake Peipsi basin, and it organised conferences and projects to establish contacts between authorities, scientists, education experts, businesses and NGOs working in the watershed. It also prepared publications and informed the media in order to reach out to the local and general audience regarding the pollution in Lake Peipsi and it worked to establish international contacts.

The legal basis for the co-operation was in the process of formation and LPP organised meetings that gave Estonian and Russian environmental experts an opportunity to meet informally and discuss future co-operation. As a result of the meetings, Estonian and Russian environmental officials wrote a first draft of an agreement on protection and sustainable use of natural resources in the Lake Peipsi water basin. LPP submitted its proposals to the text of an Estonian-Russian draft agreement on management of the shared transboundary waters, aimed at promoting more participation by the public, NGOs and local authorities in protection of Estonian-Russian transboundary waters. Most of the proposals were incorporated into the text of the agreement signed by Estonian and Russian governments in 1997.

The agreement established a Joint Commission on Transboundary Waters. Both Estonian and Russian state officials emphasised the importance of developing the co-operation between the two countries on the intergovernmental as well as on the local level. The Commission established a working group in co-operation with NGOs, local governments and international organisations, that also incorporated NGOs and local governments representatives.

As a part of an environmental monitoring project supported by the Swedish Environmental Protection Agency, LPP has set up an Internet server, developed a Lake Peipsi regional website and established an e-mail network that joined officials and NGOs involved in water protection of Lake Peipsi.

In 1998, the Center for Transboundary Co-operation was established as an NGO umbrella organisation. In accordance with the working plan of the Estonian-Russian Transboundary Water Commission, the Center works to implement the transboundary water agreement in the Lake Peipsi Basin through involving public and local stakeholders in the implementation of the international environmental agreement

22.

Implementing sustainable water regimes

Henrik Lindström, Jan Gunnarson, Tord Wennerblom & Hans Kvarnäs[1]

The Agenda 21 framework

The concept of sustainable development, which was first formulated by the UN, entails a development of society, which abandons today's linear resource management, in which natural resources are converted to garbage and the natural environment is polluted. Instead, it adopts a philosophy of closed-loop cyclical resource-management within nature's own "ecocycles."

Agenda 21 contains a number of overall objectives related to social and economic dimensions, conservation and management of resources for development, strengthening the roles of major groups, and means of implementation.

Chapter 28 of Agenda 21 reads: "Because so many of the problems and solutions being addressed by Agenda 21 have their roots in local activities, the participation and cooperation of local authorities will be a determining factor in fulfilling its objectives." This means that it is people and organisations at the local level that must do the work.

The Local Agenda 21 should express an overall strategy and be characterised by a holistic perspective, while being cross-sectoral and based on long-term objectives. The work should be characterised by great openness towards different local actors.

The role of the municipality ("local authority" in Agenda 21) is to act as a catalyst and to collect and co-ordinate the energy and initiative of all individuals. The Agenda emphasises the importance of getting citizens involved. Mobilising the general public is crucial if the Agenda is to have a true impact.

The following quote from Agenda 21 illustrates how the process of consultation is emphasised: "Through consultation and consensus-building, local authorities would learn from citizens and from local, civic, community, business and industrial organizations and acquire the information needed for formulating the best strategies."

The task set for the Agenda 21 work is to translate global and national objectives to local objectives, so that they are meaningful to the local community. It is a question of seeing the proper proportions of one's own municipality, workplace or home in a larger environmental perspective, and taking advantage of the local environmental commitment of private citizens and organisations in pursuing the municipality's environmental objectives.

The option of setting up interim goals and check stations to provide an opportunity for correction of actions should be considered. Direction analysis is an instrument for assessing various future-oriented strategies. A project is moving "in a sustainable direction" as long as the question of whether an action leads to desirable development of the environment is always answered in the affirmative.

At present, development work is being pursued in a number of municipalities with sights set on increased integration between physical comprehensive planning and working with the local Agenda 21. In some municipalities, sustainable economic issues are also dealt with in this context. The social aspects of comprehensive planning are under further development.

Sustainable economics

It is not always meaningful to put a price tag on, for example, a good environment and human health and reduce everything to dollars and cents (or the equivalent in other currencies.) An alternative is to select and spotlight a number of indicators and systematise "soft data," i.e. data that normally falls outside of financial accounts.

[1] The chapter is based on a part of the English translation of the report "A synthesis" in the series "Water Planning" published by the Swedish Environmental Protection Agency and the Swedish National Board of Housing, Building and Planning in 1996. The original English text has been edited and partly expanded by Lars Rydén. The section on decision support systems for river basin management was provided by the Delft Hydraulics, Delft, the Netherlands, 1994; the example of calculation of nutrient leakage that has been prepared by Tord Wennerblom from the County Board of Älvsborg County in Sweden and Hans Kvarnäs from the Swedish University of Agricultural Sciences.

It is possible to measure and describe sustainable development by using a sustainable economics model. This model describes an activity's resources, their movement, transformation, consumption and reproduction, and the values thereby created by the activity. The model can be viewed as a way to illustrate management-by-objectives and focuses on results. The values one wishes to create, while putting as little a burden on the resource base as possible, govern the design of the activity and its impact on resources.

The result – from which the citizens of the municipality derive benefit and which is the relationship between resource base, activity and values – is measured by means of three key ratios. What the key ratios are meant to reflect is the fact that an activity is economic when something valued by people is created with as little effort as possible.

The three key ratios are margin, thrift and efficiency, and they answer different questions by describing ratios in the sustainable economics model.

Margin describes the ratio between resource flow to and from the resource base and the actual size of the resource base. Will the resources on which the activity is dependent exist for a long time, or are they being depleted? Are they being replenished at the same rate they are being consumed?

Thrift describes the ratio between the activity being pursued and the flow of resources on which this activity is dependent. Is the activity being conducted with a large or small turnover of resources? Is the activity thrifty or wasteful with resources?

Efficiency describes the ratio between the values that are created and the activity that creates them. Does the activity lead to the intended purpose? Is there any point in trying as hard as we do?

The key ratios can be sorted in "swarms" based on objective and presented graphically in such a way that a rising curve signifies a positive trend. This provides an easily comprehensible information tool that even a layman can use. A description of the key ratios should accompany the graphical presentation.

The need for an accounting system that, unlike traditional national accounts, includes environmental factors such as pollution and resource depletion has emerged on a national and international level as well. This system must take into account the accumulated environmental debt (i.e. the cost of repairing environmental damages that are technically and economically feasible to repair) plus the amount of capital required to pay for recurrent repairs. Such a tool is called a green GDP (gross domestic product).

Overall objectives in Agenda 21

Social and economic dimensions, for example
- changing consumption patterns, protecting and promoting human health conditions
- promoting sustainable human settlement development
- integrating environment and development in decision-making

Conservation and management of resources for development, for example
- protection of the atmosphere
- promoting sustainable agriculture and rural development
- conservation of biological diversity
- environmentally sound management of solid wastes and sewage-related issues

Strengthening the role of major groups, for example
- global action for women towards sustainable and equitable development
- children and youth in sustainable development
- local authorities' initiatives in support of Agenda 21

Means of implementation, for example
- financial resources and mechanisms
- transfer of environmentally sound technology, co-operation and capacity building
- promoting education, public awareness and training
- national mechanisms and international co-operation for capacity building

Examples of questions in a direction analysis:
- Will energy use decrease?
- Will the biodiversity or resource-building capacity of nature increase or be sustained?
- Are we closing natural cycles?
- Are we staying within the limits of nature?
- Are we solving several problems at the same time?
- Are we applying the precautionary principle?

Agenda 21 differs from traditional environmental action programmes in that:
- the emphasis is on sustainability,
- the bottom-up perspective is strongly stressed the time horizon extends well into the next century

Cases - Implementing sustainable regimes in Västervik Municipality

In 1993, officials in Västervik Municipality drew up a model for a sustainability plan that contains an overview of the most important local environmental issues, e.g. eutrophication of the coast and acidification of soil and water. This working model, which is used for the Sustainability Plan and Agenda 21, entails studies conducted in working groups with representatives from different areas. The working groups have produced an "Idea catalogue for sustainable development of Västervik Municipality" containing an implementation-oriented project description of practical solutions (see examples below).

The working groups contained members of:

- municipal departments including schools and Västervik Consumer
- County Administrative Board – agriculture and environmental units
- non-profit associations: SNF, Q2000, Association for the Promotion of Outdoor Life
- interest organisations: Federation of Swedish Farmers, Swedish Tenants Association, National Association of Water Users, Resource Management Society
- companies and entrepreneurs
- County Council and general practitioners
- County Forestry Board

The studies of the working groups contained the following water-related issues:

- waste
- energy
- flora and fauna
- health and housing
- chemicals
- water – agricultural, forestry, aquaculture and water-treatment works, local disposal of stormwater, acidification of lakes and watercourses, private sewage groups
- policy instruments, information, etc.
- measurement, evaluation, green accounts

Computer based decision support systems (DSS) for river basin management

The management of river basins deals with a variety of user functions and environmental aspects. In the past, water resources and water quality used to be carried out separately. Increasingly however, the approach to both water resources and water quality management are integrated to enable the assessment of impacts of managerial actions on the quality of surface water, sediment and biota in rivers, estuaries and coastal zones.

This integrated approach of water management dramatically increases the complexity of policy making. A decision support system (DSS) can be used to support such a complex and integrated approach. The model system that has been used for most river basins includes systems to structure the required data, to calculate the impact of intended measures and strategies and to present the results of the model calculations in a clear way.

The approach includes the quantification of the input of organic and bacterial pollution, nutrients, heavy metals and organic micropollutants into the water system as a function of human activities and natural processes. Both point and non-point sources are distinguished. The transport of pollutants through rivers and estuaries as well as the water quality process in the water bodies are analysed, evaluated and predicted using a computational framework of mathematical models.

The DSS analysis

The computational framework has been used to analyse the present and future water resource management in terms of water quantity, water quality and waste loads. The basic steps in such an integrated analysis, of which some are of limited importance for the situation in the river basin, are:

- effects of demand-increase and identification of quantity problems
- identification and screening of water quantity measures
- effect of waste load increase, identification of water quality problems
- identification and screening of water quality measures
- analysis and evaluation of integrated measures and strategies

The preparation of an integrated analysis involves the specification of analysis conditions, hydrological scenarios and the definition of cases. A case is defined as a combination of a project year, a hydrological scenario and a measure of strategy.

After calibration of the available data, the computational framework can be and has been used to analyse different measures and strategies. In many river basins the loads mainly originate from domestic and industrial (point) sources. In different strategies, the domestic and industrial loads can be adapted to the projected loads for the future wastewater discharges.

The water quality model calculates the water quality situation that results from the adapted wastewater discharges. By analysing the violation of water quality standards at a number of characteristic locations in the river basin, the differences between the various cases are judged in relation to the costs that are involved with that measure.

Analysis of the oxygen budget, nutrient budget and coliform related water quality problems is only a first step in controlling water quality problems. After fulfilment of the intended water quality measures, such as the construction of a sewage treatment plants for the domestic or industrial

Agenda 21 examples from Västervik municipality

1. Wetland upstream of Lake Kvännaren

Purpose: The purpose of the project is to reduce the nitrogen load on Lake Kvännaren and water-courses situated downstream. Natural purification in a wetland harmonises well with the concept of natural ecocycles and is also an inexpensive method, with good effect, at least during the growing season.

Measure: To create wetlands upstream of Lake Kvännaren.

Implementation: The nitrogen load on Lake Kvännaren comes partly from the cropland upstream (3–4 tonnes per annum), and partly from landfill leachate (1.5–2 tonnes per annum.) Run-off from the cropland peaks when the snow melts, at which time the purification effect of the wetlands is unfortunately at it's lowest. Leachate runoff, on the other hand, is fairly even throughout the year.

Owing to the varying nature of the runoff, the wetlands should be designed differently for each case to achieve optimum effect. The best solution is to treat the landfill leachate and the cropland runoff separately.

For leachate treatment a study is currently under way. We suggest waiting for experience from the leachate wetland before deciding on the best design for the wetland for cropland runoff.

A calculation of the surface areas required shows that the area south of the entrance to Västervik is required for the leachate wetland. The cropland wetland must then be located north of the entrance.

A possible obstacle to wetland establishment could be that ditches are being deepened to drain waterlogged areas. The municipality leases out these areas today. The rider club also uses the land up to the ditch.

Cost: The cost of establishing the wetlands is estimated at around SEK 500 000 each.

Office in charge: Public works department.

2. Alternative toilet systems

Purpose: To reduce the load of nitrogen in particular to municipal sewage treatment plants and ultimately to the recipients by separating urine and faecal matter.

To convert waste into a resource and close the ecocycle loop by using the urine as a fertilising agent and the faecal matter for soil improvement.

Measure: To install separation toilets in different projects.

Implementation:

1. At schools. Pupils in the vocational programmes build and install separation toilets at one or more of the municipality's schools. The toilets are developed and installed as school projects.

Intensive environmental instruction is given in the schools today. Using the function of the separation toilet as a practical example, ecocycles can be demonstrated, explained and used.

Cost: SEK 3 000 per toilet.

Office in charge: Child and education committee.

2. In the Ängholmen neighbourhood. Discussions are being held in the Ängholmen block of Västervik regarding installation of a type of separation toilet where the urine is separated and collected in a separate tank in the building. The faeces are flushed away to the treatment plant as usual.

The point of this is to reduce the quantity of wastewater entering the treatment plant at the same time as the nitrogen load is greatly reduced.

In addition, a concentrated nutrient solution is obtained which is attractive for several users in the community. Wastewater management is more ecocyclical.

Cost: Reduced revenues, since the urine is not discharged to the wastewater system, which at the same time entails reduced costs for treatment.

Office in charge: Local building board.

3. On East and West Eknö Islands. East and West Eknö Islands have difficult conditions for solving their water and sewage problems today. If separation toilets were installed, it might even be possible to accept new development, which is in principle impossible today.

An inventory of current housing development on the island will be conducted. The next step is to try simpler and new solutions for the sewerage situation on the island. A simple solution may be separation toilets in combination with a simpler type of sewage system. To make it possible to try this solution, some form of common water supply is necessary.

Cost: SEK 45 000 for 3 months of inventory work.

3. Emptying of night soil tanks

Purpose: To obtain a sustainable, closed-loop method for disposing of the nutrients from sealed tanks.

Measure: Emptying of tanks into liquid manure containers for storage and subsequent use as fertiliser.

Implementation: The contents of sealed tanks from bathing and camping grounds in the northern part of the municipality are emptied into liquid manure containers on Ottingen Manor instead of being driven to the sludge reception station at the Lucerna Works in Västervik. This can be done

since there is little livestock on the Manor now and therefore available capacity. Altogether, it is estimated that between 500 m^3 and 700 m^3 will be transported there. The sludge is covered with 20 cm of chopped straw. Sampling takes place according to a special programme. The costs of analyses and SLU's part in the project are funded by grants from VAV (Swedish Water and Wastewater Organisation).
Cost: No special costs will arise for the municipality. The water and sewage works will, however, be deprived of revenues of about SEK 70 000 due to less sludge being taken to the sludge reception station.
Office in charge. The parties involved are Ottinge Manor, the Sewage Treatment Works, Anders Tankservice, the environmental and health protection office and research leader Staffan Steineck with doctoral students Barbro Beck-Friis and Eva Salomon.

4. Modification of the regulation amplitude of Lake Yxern

Purpose: To reduce the regulation amplitude of Lake Yxern, which is the county's largest lake with large wetland areas, a rich bird life and a valuable fish fauna. Lake Yxern is suffering from accelerated plant growth, which is choking the lake and threatens its very existence in the long run. A Water Court ruling in the late 1930s allowed the lake to be used as a reservoir for several power stations located downstream. The amplitude of the lake's regulation is about 3 metres.The consequence is that the surface area of the lake shrinks by about 40 % at low water. A reduction of the regulation amplitude is required to save Lake Yxern for the future. The Water Court ruling must therefore be reviewed. The project involves drawing up a plan for restoration of the lake with reed cutting etc., plus payment of compensation to the regulation companies.
Strategy: For several years, a working group consisting of representatives of the fishery conservation association, the municipalities of Västervik and Vimmerby, the Swedish Society for Nature Conservation and others have tried to reach agreements with the regulation companies. Among other things, a changed drainage schedule has been proposed. Unfortunately, it has proved difficult to reach an agreement without a change in the water court ruling. Since 1 January 1994, the National Judicial Board for Public Lands and Funds can apply to the Water Court (from 1999, the Environmental Court) for a review of rulings older than 30 years. Therefore, the Board has now been contacted to pursue the case further.
Cost: Compensation to the concerned water regulation companies is difficult to estimate today. It is entirely dependent on what settlement can be reached.

5. Ecological stormwater management.

Purpose: To develop a working model with methodology for engineered closed-loop solutions and ecological storm water management.
Measure: In conjunction with the comprehensive planning for a housing area (the property Grantorpet 1:1), to introduce regulations regarding ecological stormwater management, and closed-loop solutions for sewage management.
Implementation: The Plan covers 12 detached-home plots of about 500 m^2 each. The plots are surrounded by undeveloped land. The area consists of rock outcroppings and its own catchment area that drains to a natural wetland area and ditch system. Existing water supply and sewage lines do not have capacity for the housing.

In order to be realised, the project requires collaboration between property-owners and special contracts in connection with the sale of the land.
Cost: Investigation, plan and contract costs have been estimated at around SEK 100 000.
Office in charge: Town architect's office.

6. Ecocyclical and resource-compatible planning on Gränsö Island

Purpose: To demonstrate that planning and implementation based on sustainable ecocycles and resource management can be carried out in both existing and additional buildings. Design the buildings in a nature reserve on the basis of ecocyclical and sustainable resource management principles.
Measure: Plan for ecocyclical and resource-compatible construction in holiday home area on Gränsö Island.
Implementation: The holiday home area, which is called the "intermediate area", includes 65 leasehold plots. The municipality intends to densify this holiday home area with 27 new plots. A Comprehensive Plan will be drawn up for this area. The Plan will incorporate provisions regarding the construction of alternative toilet and sewage systems, energy use, ecological stormwater handling, and refuse separation and composting. There will be collaboration with owners of existing properties so that they are also included in the closed-loop solutions.
Cost: Extra costs for the Plan procedure due to ecocyclical adaptation. The Plan procedure is estimated to be about 25 % more expensive than normal due to necessity of collaboration with property-owners to be able to modify existing water supply and sewage systems. Extra cost: SEK 70 000. Evaluation: SEK 50 000.
Office in charge: Local building board.

waste loads and a reduction of industrial waste loads obtained by a shift to more efficient production processes, some water quality standards may still be violated. It has to be stressed that this, or any other computational framework, always analyses a specific subset of all water quality substances, in most cases due to the absence of relevant data.

Water quality and water quantity cannot be separated. Integrated strategies have to be considered to achieve the desired objective at minimum costs. Often, sanitation measures are the only feasible solution to achieve major improvements with regard to surface water quality.

The general structure of a DSS

Generally a DSS consists of three subsystems
- An information system containing databases, data files and a database management system
- A computational framework containing mathematical and expert models to simulate i.e. hydrodynamics, morphology and water quality, including phytoplankton growth, bioaccumulation
- An analysis system to define and evaluate management strategies and measures and to perform risk assessment studies

In the information system all relevant data for analysis, calibration and validation of the mathematical models are stored. The information is generally aligned as a two layered data structure: one layer contains the data itself, while the second layer contains information related to the stored data in the first layer (e.g. executive institute, location, reference, sampling and analysis methods, etc.). A data quality control procedure may be included in the data entry part of the system to verify the accuracy of the entered data.

The computational framework consists of a set of coupled mathematical models that enable a quantitative analysis of the relationship between the input of pollutants and the assimilation capacity of the water system. In this set of mathematical models, the following aspects are included: hydrodynamics, waste load calculation, pollutant transport, water quality processes.

In the analysis framework, strategies can be defined and evaluated in order to support the development activities for the river basin.

Although a general outline for a decision support system is easy to draw, a general DSS for a river basin does not exist. A DSS has to be tailor made for each specific river basin depending on the main water management problems in the basin. In this chapter the general outline of the DSS for a specific river basin is described in more detail.

The components of a DSS

The information system. Data storage is the part of the DSS in which all data concerning the river basin are stored. The content of the database is not limited to water related data; it will also contain meteorological data, data on land use, data on industrial activities, population density, etc. Meteorological data are used to determine process rates of biological and chemical reactions and to determine the importance of surface runoff and the diffusive waste loads. Data on industrial activities and population density are used to estimate industrial and domestic waste loads if no direct measurements of the effluents are available. Relevant data are stored in the database and in accompanying data files.

Mathematical models. All sorts of mathematical models can be part of a DSS: Hydrodynamic models, surface water quality models, morphological models, waste production models, groundwater quality models, sediment models, etc. The management questions that have to be answered by using the DSS and the availability of data determine the set of models that will make up the computational framework in the DSS. The most important task of the DSS is to manage and control the data transfer between all models. When all models are linked to each other and the output results of one model serve as input for the next model, the resulting set of models is often referred to as a computational framework. Input data will be retrieved from the database in the information system, while all (model) output results will be accessible for the user.

The analysis system. A specific DSS for a river basin may become very complicated if the management problems are very complex and the DSS contains a lot of data, and quite a number of mathematical models are involved. In such cases it will be very hard for the water manager to combine all available data and model results, and define the ultimate strategy or measure. Therefore, an interactive user interface is an integral part of every DSS. The user interface leads the user step by step through the analysis taking care of the administration of model calculations (which specific input data has to be used, how to store the model results, etc.) and the presentations of model results. Furthermore, the DSS is equipped with a case definition tool (CDT) to simplify the formulation of scenarios or cases including the preparation of model input. It is also equipped with a case analysis tool (CAT) to enable the manager to compare different scenario calculations, to aggregate the vast amount of (calculated) information to simple scorecards and effect-matrices, and to produce summarised statistical information.

The computational framework. The models of the computational framework are strongly related. The output of a model serves as input for one or more other models. The river basin oriented computational framework for a specific river basin might include the following main models:

- The hydrological model (HYDSIM) to simulate the surface or water balances and to allocate surface water flows in the network representation of the river basin
- The waste load model (WLM) to calculate waste loads from domestic, industrial, non-point (agricultural), and livestock sources
- The water quality model (DELWAQ) to calculate the time variable transport of pollutants including all relevant water quality processes to which they are subdued
- The cost model (COIN) to evaluate and assess the overall yearly cost of water quality measures, in particular the measures to reduce the wastewater discharges from point sources of pollution in the river basin
- The risk assessment module (QRIUS) to evaluate the ecotoxicological effects of the deterioration of surface water quality

To serve the user of the computational framework (CF) the system is supplied with some cases including a case management tool (CMT).

An example - a nutrient calculation model

A series of different computer tools are available for water management work. These might be part of a DSS or be used separately. Here we will describe a model that allows calculation of nutrient fluxes to surface waters. The calculations are quite simple and carried out using an Excel type of spreadsheet program.

Calculations according to this report will produce the total loading as results – that is, both the natural part and the part caused by different kinds of human influence. To get a better view of "the pollution situation" the model is designed to show natural and human caused loading separately. The part caused by human activities is the most interesting since it is the only part that can be improved by measures.

The model is to be viewed as an attempt to make a rough estimate of the most important sources of pollution. The objective has been an attempt to quantify the gross loading of nitrogen and phosphorus from different sources as reliably as possible, using the knowledge available at the moment according to Swedish Water Quality Criteria. The model is to a large extent based upon data from a Swedish Environment Protection Agency action programme from 1990

DESCRIPTION OF THE ÄLVSBORG MODEL

Tord Wennerblom from the county of Älvsborg in Sweden constructed the so-called Älvsborg-model. Later additions include the possibility of calculating nutrient status and effect degree of perturbation according to Swedish water quality criteria.

The model demands Excel 3.0 or later, PC or Macintosh, to be run. Only elementary knowledge of Excel is needed.

Forest:

The calculations are based on five forest-dominated rivers in Northern Svealand and Norrland (central and north Sweden.) The leakage from the ground in forests has been calculated as follows:

NH_4-N (kg N/ha year) = 0.03945
NO_3-N (kg N/ha year) = 0.000445 · Q + 0.00551
Org-N (kg N/ha year) = 0.00279 · Q + 0.00893
Tot-N (kg N/ha year) = NH_4-N + NO_3-N + Org-N
Tot-P (kg P/ha year) = 0.00014 · Q - 0.00383
Q = runoff (mm)

To this "base leakage" an extra contribution of nitrate has been added for fertile forests, partly because this type of forest has a higher natural leakage and partly because of the higher atmospheric deposition. There is really no scientific ground for using areas with high fertility as parameter in the calculation model, but these areas to a large extent coincide with nitrogen-saturated areas, which have a high leakage. Forests with fertility classes I and II are considered to leak 10 and 5 times more than an ordinary forest, respectively.

15 kg Tot-N/km^2 is considered to be the anthropogenic contribution for all types of forest, due to air pollution and, to a small part, fertilisation. In 1990 it was estimated that forests leak 0.15 kg more nitrogen per hectare than they did 25 years ago. To forests with fertility classes I and II, extra contributions due to air pollution of 8 and 3 times, respectively, that of ordinary forests have been added. It was also assumed that the background leakage of fertile forests is twice that of ordinary forests. All remaining leakage from forests is considered natural.

Forestry

As an additional contribution to forests, described above, effects from forestry, felling, ground preparation, draining and fertilisation, are added. It is calculated as a contribution per hectare of treated forest and year.

Felling is considered to increase the leakage of nitrogen with 800 % during the 8 years following the felling and that of phosphorus with 200 % during 3 years.

For draining activities (ditching), the assumption is an increase of the leakage of both nitrogen and phosphorus 3 times, during 5 years for nitrogen and 1 year for phosphorus.

Fertilisation is expected to cause nitrogen leakage to increase 3 times during 3 years.

All this leakage from forestry is considered anthropogenic.

Marshes

Marshes are considered to leak as much as forests, except for organic nitrogen and phosphorus, which are supposed to leak twice as much.

In the model all leakage from marshes is considered natural, which can be discussed.

Other areas

In this category all areas that are not forest, fields or lakes are collected. It contains, e.g. mountains, rocky terrain, impediments, roads and towns. These areas are considered to leak as much as ordinary forests. Stormwater and the like are dealt with under Wastewater treatment plants, flooding and stormwater.

Leakage from these areas is considered natural, which could be discussed.

Fields

Leakage from fields is calculated as follows:
Tot-N (kg N/ha year) = 0.1257 · Q + 6.52
(southern Sweden)

Tot-N (kg N/ha year) = 0.13(0.06121 · Q + 0.7947)
(mid Sweden)

Tot-P (kg P/ha year) = 0.001005 · Q + 0.04593
(entire Sweden)

Q = runoff (mm) from the test fields of the national monitoring programme

The County of Älvsborg is considered to be in mid Sweden. When making calculations one can, however, use values for southern Sweden, which includes Bohuslän and Halland, or whichever area loss seems fit.

The formulas above are collected from 17 test-fields run by SLU (Swedish University of Agricultural Sciences) in the national monitoring programme. The median runoff from these fields differs significantly from the total average runoff. In order to allow the above formulas to be used in real life, Q has been adjusted (multiplied with 0.55) to make the result match national data.

The area loss of phosphorus can be underestimated with the above equation, as erosion is probably underestimated. Therefore, the possibility of increasing the area loss by any factor, due to erosion, has been incorporated in the model.

The leakage of nitrogen from areas that are green during the winter is considered to be 25 % of the area loss of other fields and fallow land. These areas consist of the following areas: fields for green fodder or silage and hay, and unused fields. (There has been no reduction of the phosphorus leakage however, and this can be discussed).

The equations above give the gross leakage from fields, including the contribution from air pollution. A leakage corresponding to that of fertile forests is considered as natural contribution, this is the same as ordinary forests, but with twice as high loss of nitrogen. Man-made contribution in form of air pollution is, as it were for forests, assumed to be 15 kg N per km^2 and year and 8 times the nitrate leakage of ordinary forest. The rest is considered to be man-made (anthropogenic), agricultural, contribution.

Deposition on lakes

Dry deposition of nitrogen on lakes is quite small, about 10 % of the total. It thus follows that total deposition can be approximated with wet deposition. The nitrogen deposition is well known due to the rainfall measurements done.

For phosphorus the standard value 8 kg P/km^2 lake area and year is used, but it can be varied.

120 kg nitrogen per km^2 and year and 33 % of the phosphorus is considered natural (the nitrogen leakage of the 1950s, usually about 45 % of those today, can be an alternative to 120 kg nitrogen per km^2 and year.) Everything else is considered anthropogenic.

Water treatment plants, flooding and storm water

In the model measured effluents and/or standard values are used when calculating direct discharges. The standard values for contributions from people are 12 g N/person and day and 2.5 g P/person and day. Purification effect can be varied as wished.

To estimate the overflow and storm water contribution the effluents from sewage treatment plants are increased with 15 % for phosphorus and 3 % for nitrogen (can be varied due to local conditions.) Monitoring programmes for the sewage treatment plants give yearly effluents of nitrogen and phosphorus (to be found at the technical department of the municipality).
All is considered anthropogenic.

Sewage treatment systems for private houses

The same standard values as for water treatment plants are used. If phosphate-free detergents are used the amount of phosphorus is decrease with 40 %.

The fraction of the households that have the different facilities can be varied. If it is unknown use the following: sludge separation only, 50 %, sludge separation and sand filter and sludge separation and infiltration 25 % each.

Everything is considered anthropogenic.

Rooms for milk storage in barns with cows

Production is assumed to be 0.1 g N/cow and day and 1.11 g P/cow and day, if regular dishwashing agents are used, if the agents are phosphate free the value is 0.11 g P/cow and day.

Purification effect as for private sewers above. For milk rooms there are also the possibilities of urine or dung pools, with 100 % purification or direct discharge, with 0 % purification.

If the fractions are unknown the following is used: sludge separation only 39 %, sludge separation and infiltration 18 %, urine or dung yard 21 % and direct outlet 21 %. If the number of milk cows is unknown it is said to be 34 % of the number of cattle, which was the average in Sweden in the 1980s (probably lower today).

This contribution is all anthropogenic.

Manure facilities

Production of nutrients in manure is assumed to be 75 kg N/animal unit and year. The leakage from fertiliser facilities can be calculated as a percentage of the nutrient content. This percentage can be varied in the model. 0.5 % is considered normal or, in other words, half of the facilities leak 1 %.

Again it is all anthropogenic contribution.

Aquaculture

According to “measurements” of phosphorus or the standard values: 6-7 kg P and 75 kg N per metric ton fish produced.

Categorised as anthropogenic.

Industries

According to measurement. These are often incomplete concerning nutrients.

This is also considered anthropogenic.

Degree of treatment of sewage treatment facilities of private houses

	N-reduction (%)	P-reduction (%)
Sludge separation only	15	15
Sludge separation and & filter	30	40
Sludge separation & infiltration	30	70

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