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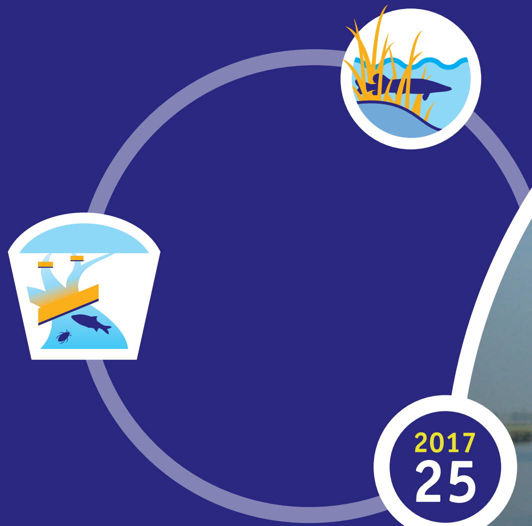
A METHOD FOR SETTING REALISTIC GOALS AND IMPLEMENTING
COST-EFFECTIVE MEASURES FOR THE IMPROVEMENT OF ECOLOGICAL WATER QUALITY

ECOLOGICAL KEY FACTORS



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P.O. Box 2180

3800 CD Amersfoort

The Netherlands

Authors Holly Mellor, Steven Verbeek, Tessa van de Wijngaart

Edited by Bas van der Wal, Guus Kruitwagen

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(photo: Ralf Verdonschot, Alterra)

CHAPTER 1 INTRODUCTION

1.1 WATER FRAMEWORK DIRECTIVE

As the natural resources of our planet are strained to unprecedented levels, the demand for sustainable water management is greater than ever. In response to this demand, the European Union has adopted the Water Framework Directive. The European Member States have an obligation to achieve a good ecological status in all waters by 2021, which may be extended to 2027.

In the Netherlands (see Box 1), regional water authorities are responsible for setting realistic goals that attain a good ecological water status. These goals should complement both the ecological status and the functions that our water systems provide (agriculture, nature conservation, recreation, drinking water). The water authorities are also responsible for identifying and implementing water quality measures to achieve the set goals. These are complex tasks, which require the collaboration of hydrologists, ecologists, policy makers, water management authorities and many other specialists.

1.2 ECOLOGICAL KEY FACTORS

The deadlines of 2021 and 2027 are fast approaching. This leaves little time for trial and error with regard to the application of water quality measures. To gain insight into potential water quality measures and their effectiveness under different conditions, STOWA (organisation for applied water research in the Netherlands) has set up a program

BOX 1: KEEPING OUR FEET DRY

Since the Early Middle Ages, the Dutch have been defending their land against flooding from the rivers and sea. They even actively reclaimed land from the sea. Over the years the nation has evolved by adapting to the challenges posed by the water. The Dutch have become internationally known for their water management approach, with windmills, dykes and levees as iconic emblems.

In the North and West of the Netherlands the water management has mostly been focused on intrusion of the land by the sea. Drainage of low-lying peaty lands for agricultural purposes has resulted in subsidence which required the need for more drainage, channelisation, the construction of dykes and installation of pumps and other infrastructure to control and balance water levels. This need was further exacerbated by the occurrence of devastating storms and catastrophic floods. The landscape in the West and the North of the Netherlands is dominated by polders and an extensive network of channels. As the influence of a changing climate becomes more profound, the need for sustainable measures for water management becomes ever more apparent.

The Eastern and Southern parts of the Netherlands are above sea-level. The soils are mostly sandy and the landscape is >>

transected by rivers and streams. The water management here focuses on flood prevention, efficient drainage of excess water and the prevention of desiccation on the higher grounds.

The intimate relationship of the Dutch with the water has made them into the forerunners of innovative international water quantity management and has resulted in high demands for their water quality management. In this booklet, a methodology for an ecological water system analysis is presented.

that uses the knowledge gained from past experience to evaluate the suitability of the chosen measures and to implement improvements accordingly. The outcomes of this program highlight the importance of understanding how the water system works by investigating the reasons for a particular state. STOWA also discovered the presence of a natural hierarchy in the processes and factors that determine the water quality. These insights have formed the basis for the development of an assessment methodology referred to as the Ecological Key Factors (EKFs).

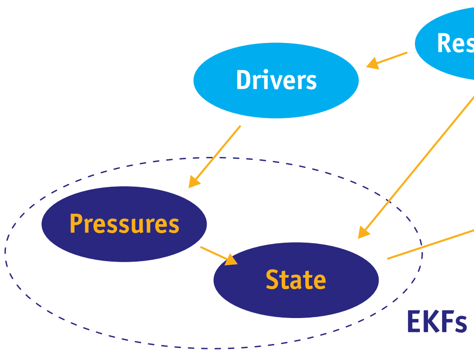
The framework consists of nine (stagnant waters) or ten (flowing

(photo: Albert Jan Perrier)

(photo: Marco Beers)

waters) ecological key factors. Each ecological key factor, abbreviated EKF, describes conditions that have to be met to achieve a good ecological water quality. Ecological quality can be characterised by parsimony of available nutrients, characteristic physical and biological structure, strong connectivity among systems and mechanisms of resilience to cope with normal, natural change (Moss, 2007). The EKFs make a structured, hierarchical and reproducible analysis of the water system possible. The EKFs are depicted with icons.

The EKFs unravel the complex relationships between causes (which are often related to pressures), states and impacts. This way the EKFs connect with the DPSIR system that is used by the European Union (see Box 2).



BOX 2: DPSIR

DPSIR is a causal framework for describing the relationships between anthropogenic activities and the environment (Borja et al., 2006). This framework has been adopted by the European Environment Agency. It is a useful approach for assessing the risk of failing to meet the objectives of the Water Framework Directive.

The components of the model are:

- D - Driving forces
- P - Pressures
- S - States
- I - Impacts
- R - Responses

The EKFs unravel the complex interactions between the pressures (P), states (S) and impacts (I) and provide tools for quantifying their relationships. Therefore, they give insight into the responsible driving forces (D) and help to select possible measures (R).

The methodology of the Ecological Key Factors can be used:

1 to structure a system analysis;
2 as a means to combine and integrate available information;
3 for identification of (cost-) effective water quality measures;
4 for identification of feasible water quality targets within the existing socio-economic context;
5 as a communication tool.

This booklet describes the EKFs that have been identified. In the methodology two sets of EKFs have been distinguished: one set of EKFs for stagnant waters and one set for flowing waters. In chapter 2 & 3, we describe the essence of the different key factors for stagnant and flowing water systems.

System analysis

The ecological system analysis is aimed at gaining an understanding of the processes that define the water quality. This understanding is created by providing an overview of the current situation and the factors and processes that have shaped this situation. The dialogue between the current situation and the factors and processes is the key element of the system analysis. The EKFs presented in this booklet provide a basis to structure the system analysis. Each EKF describes a requirement for good ecological water quality.

Ecological system analysis and the EKFs offer a method that improves water systems by treating the cause rather than the effect. This ethos is desperately needed to secure the continued usability of our most precious and undervalued natural resource (see Box 3: Cause and Effect).

Residence time (flow rate), soil composition, structure and the influence of the wind are examples of environmental factors that have a profound influence on the processes and functioning of the system. The way the system is manipulated, with the water levels, drainage processes and the type and frequency of maintenance (mowing and dredging), also has a profound influence on the ecological functioning of the system. It is necessary to consider all these factors and customise future management plans to maximise their effectiveness.

BOX 3: CAUSE AND EFFECT

Effective water management is complicated. Certain water quality issues or conditions can be caused by very different factors. It is therefore important to consider each water system individually and to implement measures that are system specific.

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For example:

- High turbidity (low transparency) caused by the presence of high concentrations of algae can inhibit the growth of water plants due to insufficient light penetration. In this example, the actual cause of the turbidity is the high nutrient load that initiates the bloom of phytoplankton. The lack of plants is caused by the high productivity of the water (EKF 1).

- The absence of water plants can also be caused by poor light conditions due to the presence of large concentrations of sediment particles in the water column (re-suspension), that may have been stirred up by bottom feeding fish or by passing ship traffic (EKF 2).

In both cases poor light conditions restrict plant development. These processes are very different. Measures aimed at reducing suspension of sediments will prove ineffective in the first scenario and measures aimed at reducing nutrient loading may be ineffective in the second scenario. Objective assessment of the actual causes is crucial for understanding the water quality functioning and for identification of (cost-)effective restoration measures.

Knowledge Framework

Having a framework that supports effective communication of interdisciplinary knowledge is fundamental to the effective implementation of suitable measures with achievable goals. The key factors are easy to understand so that ecologists and non-ecological professionals can refer to the factors on water quality objectives and ecology. This helps to share knowledge and understanding. Whilst establishing the ecological key factors, a framework developed for available ecological knowledge. Every key factor can be seen as a hook. Every hook provides an accessible set of rules (that strengthen our understanding), instruments and essential ecological knowledge. The EKFs make it easier to organise, unlock, share and improve our understanding of ecology and water quality.

Better ecology and water quality is cost-effective

A comprehensive system analysis offers a long-term approach to improving water quality and ecology through effective measures. This optimises funds enabling investment to focus on the central target of improving ecological water quality.

Setting realistic goals

If we understand the processes that make the system work, it becomes possible to formulate realistic goals regarding water quality and ecology. Furthermore, it gives water managers scope to improve


(photo: Liesbeth Bakker)


(photo: Connie Kolfschoten)

the system with better measures. It is vital that each system is evaluated independently.

Once we know which measures are desirable from an ecological point of view, we can consider the socio-economic feasibility of these measures by considering the functions that the water system can provide. The ecosystem services that need to be considered include flood prevention (security), the supply and discharge of water that matches the demand of the land (nature and agriculture), transport (shipping) and recreation. Only after careful consideration can realistic and feasible goals be defined and the most cost-effective measures be selected to achieve these goals.

Communication

The EKFs provide a format to clearly communicate ecological functioning of water systems. The system of the EKFs, with its layered progressive design, allows water professionals to work together to achieve the same ecological goals (clean healthy water). Other disciplines can also access the information that is relevant for their specialism whether it be policy making, administration or other interested professionals.

The EKFs are structured in a specific order (i.e. EKF Water Productivity should be concidered before EKF Light Climate). A traffic light icon system is used to communicate the outcome of each EKF. If each EKF is ‘green’, the water system has a good ecological state. If the EKF is ‘red’, the ecological water quality fails to meet a good state. For the most cost-effective approach to water quality restoration, the highest ranking (red) EKF must be addressed first.

1.3 STATE OF AFFAIRS AND DEVELOPMENT

The EKFs have been developed for water management in the Netherlands in response to the Water Framework Directive goals. This approach works well in the Netherlands and STOWA hopes it can be equally effective in other countries. The contents (e.g. tipping point, thresholds) of the EKFs may need adjustments for use in other countries. The EKFs provide a platform to raise questions, gather information (monitoring) and to facilitate prioritisation. STOWA considers this approach to be very useful in every country.

(photo: John van Schie, Rijkswaterstaat)

CHAPTER 2
EKFs FOR STAGNANT WATERS

2.1 INTRODUCTION

STOWA first developed the ecological key factors that address slow-moving to stagnant waters. The ecological quality of these types of waters are driven by internal processes. The first eight EKFs describe the most important conditions for a healthy ecosystem. The ninth EKF is different, in that it refers to the socio-economic conditions.

The key factors are divided into four groups in order of importance.

Basic requirements for a healthy ecosystem

1 Water productivity
2 Light climate
3 Sediment productivity

Additional requirements for flora and fauna

4 Habitat suitability
5 Dispersal
6 Removal

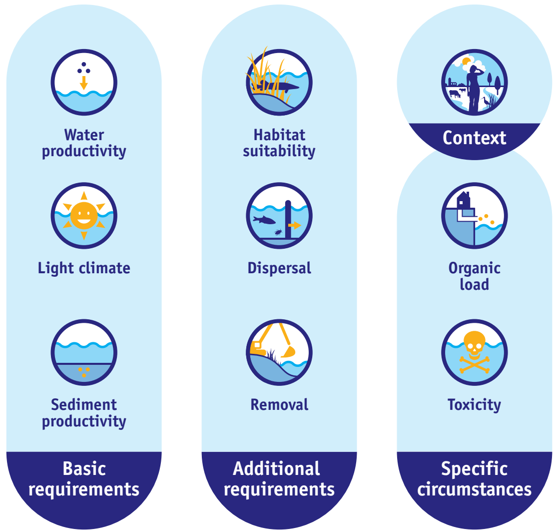
Conditions that are important in specific circumstances

7 Organic load
8 Toxicity

Conditions determined by the environment

9 Context

EKFS FOR STAGNANT WATERS



BOX 4: EUTROPHICATION; A COMMON DILEMMA

Using models to establish effective measures for shallow lakes and ditches

Eutrophication is a common problem in many shallow lakes and ponds all over the world. It is an ugly, costly and undesirable issue that affects the ecological quality of water. Eutrophication is caused by pollution from excessive nutrient input in urban areas, intensive agriculture zones, or from other direct and indirect sources. The high concentration of nutrients spark excessive growth of phytoplankton, also known as blooms, that may include toxic cyanobacteria. The blooms deplete oxygen levels, making it unavailable for aquatic organisms (anoxia).

This is often a seasonal (summer) phenomena, correlating with peak times for recreational use. Attaining a good ecological state is difficult once a system has become turbid due to eutrophication. This can be due to the amount of nutrients a system requires for a transition back to the clear state. This amount is often much lower than it was before the change to the turbid state took place. For example, lowering the nutrient input, does not automatically switch the system back to the clear water phase. The effect of a reduction of nutrient input on the water quality depends not only on the actual nutrient loading, but also on the carrying capacity or critical nutrient loads of the water system.

PC Lake/Ditch is a mathematical model, developed in the Netherlands, that enables water managers to assess the critical load of water systems and study the general behaviour of ecosystems in stagnant waters. It is used to understand the alternative stable states and hysteresis (the ability to retain a certain state from past events).

The PC Lake/Ditch model refers to the most important biotic group and it's interactions, within the general framework of bio-geochemical cycles. Water managers can use the model to evaluate the effectiveness of restoration measures with very few parameters. When used in conjunction with the system analysis and the EKFs, they provide a useful and effective tool box to recover water systems subjected to eutrophication.

2.2 BASIC REQUIREMENTS FOR A HEALTHY ECOSYSTEM

In the Netherlands, submerged aquatic plants are the first consideration in the restoration of ecological water quality. The first three ecological key factors reflect the conditions necessary for submerged aquatic plants to grow. These conditions are:

- low productivity of water
- sufficient light
- low productivity of sediment

When all these conditions are met, a species-rich, non-invasive aquatic vegetation can flourish.


(photo: Ralf Verdonschot, Alterra)

EKF 1 WATER PRODUCTIVITY

The productivity of water is largely determined by the availability of nutrients which enable plants and algae (productivity) to grow. The availability of nutrients is determined by the supply from outside the water system (external load), for example, via inflowing water or nutrient-rich ground water (seepage).

This key factor determines the maximum nutrient level the water system can take before it switches to a different state. For example, from a system dominated by duckweed to a system dominated by submerged water plants. Systems with a low (yet sufficient) nutrient load have a higher variety of submerged aquatic plants than systems with high levels of nutrients.

The residence time (the time the water stays in a system) is an important factor to consider. If a water system has a low residence time (i.e. water is continuously flushed and replenished) the quality of the incoming water is responsible for determining the water quality in the system. If the productivity of the water is sufficiently low, it is likely that duckweed and algae will not disturb the development of submerged aquatic plants. If the requirements described by EKF 1 Water Productivity are met then the EKF traffic light is green.

(photo: Nico Jaarsma)

(photo: Nico Jaarsma)

EKF 2 LIGHT CLIMATE

A very important requirement for the growth of aquatic plants is light. EKF Light Climate refers to the amount of light that reaches the substrate of the water system. The amount of light is determined by several factors which include the wind (fetch), presence of fish and shipping pressures. These factors may influence the amount of light that reaches the substrate via a process called suspension which refers to particulate matter being churned up within the water column. Sources of particulate matter, excluding algae and duckweed, include the weathering of shorelines through erosion, decomposition of dead algae and sediment.

Additionally, the presence of humic acids stain the water, which has a negative influence on light availability. Aquatic plants can only grow when the requirements described by EKF Light Climate are met.

EKF 3 SEDIMENT PRODUCTIVITY

EKF 3 refers to the amount of available nutrients in the sediment and their contribution to the ecological status. If a system has previously received excessive nutrient loads (EKF Water Productivity), the sediments may be responsible for causing high nutrient fluxes to the water system.

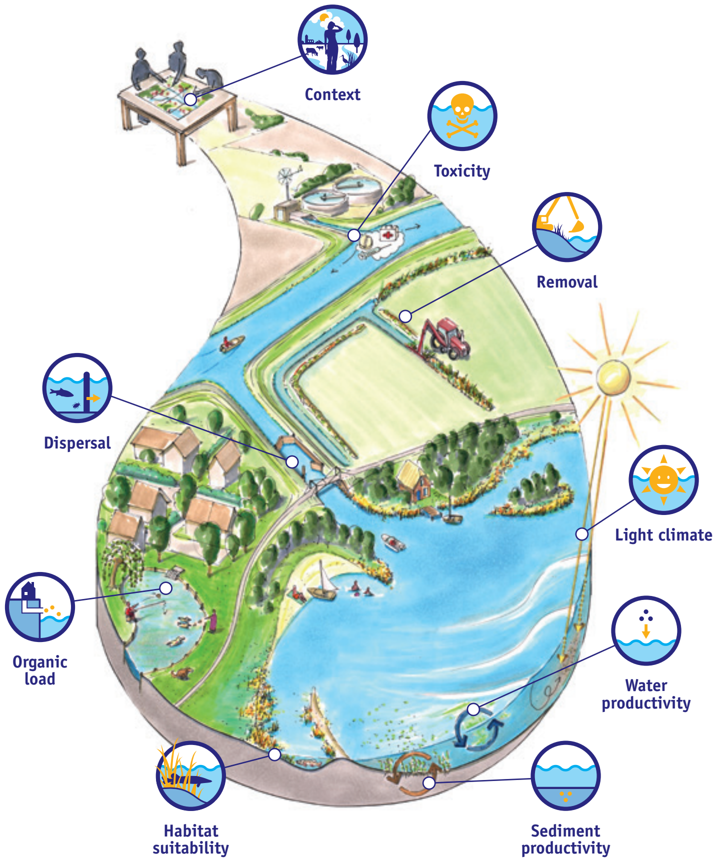
If insufficient light reaches the sediment (EKF Light Climate 'red'), the nutrients in the sediment may play a limited role in the ecological status of the water body. If there is sufficient light reaching the sediment (EKF Light Climate 'green') and the sediment is rich in nutrients (EKF Sediment Productivity 'red'), then often fast-growing submerged aquatic plants will dominate the system. This can stimulate the formation of toxic substances in the sediment, such as sulphide and ammonium, having a negative impact on the ecology. Fast-growing submerged aquatic plants often compromise the value of the system by limiting its function recreationally and reducing the flow of water. When there are few nutrients in the sediment (EKF 3 'green') a species-rich aquatic vegetation can flourish. This provides high ecological quality and requires relatively little management.

SUMMARY

A species-rich underwater vegetation is a sign of a healthy ecosystem. EKF 1 (productivity of the water), EKF 2 (light climate) and EKF 3 (productivity of the sediment) describe the basic conditions required for a healthy ecosystem.

2.3 ADDITIONAL REQUIREMENTS FOR FLORA AND FAUNA

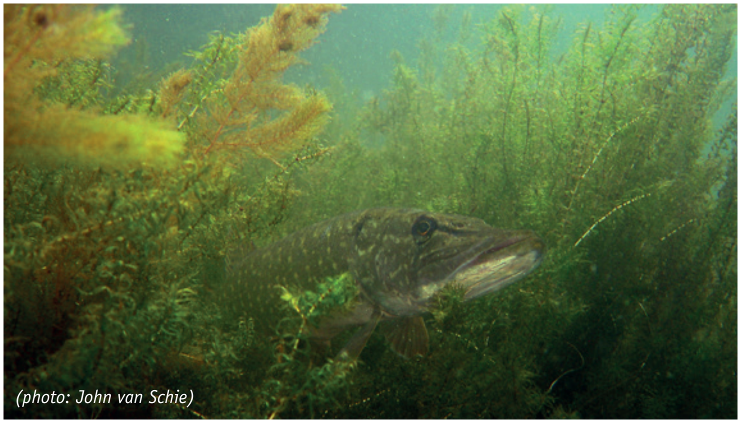
If the first three EKFs are 'green', the basic requirements are met for a system rich in flora and fauna with a high biological value. Additional preconditions determine which specific species are present in the water system. These are addressed below.



EKF 4 HABITAT SUITABILITY

EKF 4 indicates the most important habitat requirements of organisms in their environment. This includes the chemical composition of water (such as the presence of carbon dioxide), hydrological conditions (such as water level fluctuation and movement), and morphological characteristics (such as depth, distribution and type of substrate).

When this ecological key factor is 'green', the habitat is suitable for plants, fish and macro-invertebrates to thrive.



(photo: John van Schie)

EKF 5 DISPERSAL

This ecological key factor refers to the potential for organisms to move between water bodies and systems. EKF Dispersal refers to fish, plants, seeds, and macro-invertebrates. The success of these organisms depends not only on the availability of suitable habitats, but also on their ability to move, reach these habitats and migrate beyond. For example, fish migration routes being obstructed by dikes and dams.

EKF 6 REMOVAL

The sixth ecological key factor, referring to flora and fauna, focuses on active removal of plants and animals from the water system. This can either be caused by human activities, such as mowing and dredging, or by animals (whether it be grazing by flocks of geese, or the invasive American crayfish).

If the requirements described by EKF 4 (habitat suitability) and 5 (dispersal) are met, there is potential for settlement and presence of different species of flora and fauna. Whether these species continue to be present in the future also depends on the extent to which they are subjected to removal (EKF 6).

The removal method, the degree of removal, and the frequency of

(photo: Waterschap Hunze en Aa's)

removal all have a large impact on the survival and persistence of species in a habitat. Excessive impacts may cause the requirements for EKF 6 to not be met.

SUMMARY

For the restoration or recovery of specific types of systems, the habitat must meet the requirements of the species (EKF 4 Habitat Suitability), the species should have the opportunity to migrate between suitable habitats (EKF 5 Dispersal), and they should not be exhausted by removal (EKF 6 Removal). These factors play an important role in the presence or absence of specific organisms.

2.4 SPECIFIC SITUATIONS

The first two groups of ecological key factors address the requirements that define the potential for good water quality in the most common situations in Dutch surface waters. Under specific circumstances, the ecological water quality may be dominated by loading with organic substances or the presence of toxic conditions. The EKFs organic load and toxicity are important for water quality and ecology in specific situations. The influence of the EKF organic load often occurs in urban areas. The effects of the EKF toxicity predominantly occur in areas of intensive horticulture and bulb production and in industrial areas that have been subjected to high levels of pollution.

EKF 7 ORGANIC LOAD

Run-off, untreated discharges, dog faeces, feeding of bread to ducks, or leaf litter are all sources of organic load in a water system. Oxygen is required for the degradation of the organic substances that are introduced in the water system. A high organic load can lead to lack of oxygen. This can result in the death of organisms that rely on oxygen in the water, such as fish, but also in the growth of toxin-producing bacteria. The effect of organic load is usually temporary and local, and occurs often in urban areas. When the EKF 7 is 'red', it is frequently the most important problem to solve locally for an improvement of the water quality.

(photo: Marco Beers)

EKF 8 TOXICITY

Certain substances in the water system may have a toxic effect on flora and fauna. These include heavy metals, pesticides, drug residues and other micropollutants, such as plastic. The effect of these impurities depends on the location and the form the substances take within the system.

The level of contamination can vary. Often the problem has a local impact and is species specific. Effects are generally difficult to pinpoint on a system level, unless they are very profound.

(photo: Waterschap Peel en Maasvallei)

2.5 BALANCING PURPOSES AND FUNCTIONS

The first eight key factors provide insight into the ecological functioning of the water system and set the conditions for a healthy ecosystem. This makes them well suited to define realistic goals and effective measures to improve the water quality and ecology.

However, the final consideration for setting goals and defining action takes place in the broader context of water management. The ninth key factor defines the context which connects the requirements of healthy water systems with the broader context of water management.

(photo: Arnold Osté)

KF 9 CONTEXT

Water systems in the Netherlands perform many different functions including the supply and discharge of water for agriculture, aesthetic appreciation, recreation, security and nature conservation. They are an important link in the Nature Network of the Netherlands. Many are protected by European regulations such as Natura 2000.

The EKFs prioritise the importance of the conditions to achieve the desired ecological quality. They also provide a starting point for determining effective restoration measures. However, the political decision on the (environmental) goals that are ultimately pursued and the measures that are taken, often depends on these assessments whilst considering the other functions of the water system like water safety, agriculture and recreation.

The ninth key factor brings synergies, contradictions and highlights the necessity of making choices in the broader context that includes all the functions of a water catchment. The key factor Context provides a platform to share knowledge gained through an ecological system analysis within the water management field and beyond. It connects many interested specialists, raises the standard of knowledge, creates an integrated assessment of goals and facilitates the effective use of resources.

(photo: Steven Verbeek)

CHAPTER 3 EKFs FOR FLOWING WATERS

3.1 INTRODUCTION

The main factors controlling ecological water quality in flowing water systems are different to those of stagnant waters. The dominant processes that define ecological water quality, in water systems with flowing waters, are discharge dynamics and sediment transport.

Some elements present in the EKFs are relevant for other EKFs (e.g. the amount of groundwater is also part of discharge dynamics) and feedback mechanisms may play an important role between the EKFs. By combining some EKFs, it is possible to create a realistic ecological picture of the system. The key factors are divided into four groups in order of importance.

Basic requirements for a healthy ecosystem

- Discharge dynamics, which include:
  - Groundwater
  - Stagnation
- Wet cross section

Additional requirements for flora and fauna

- Continuity
- Flood plain
- Macrophytes

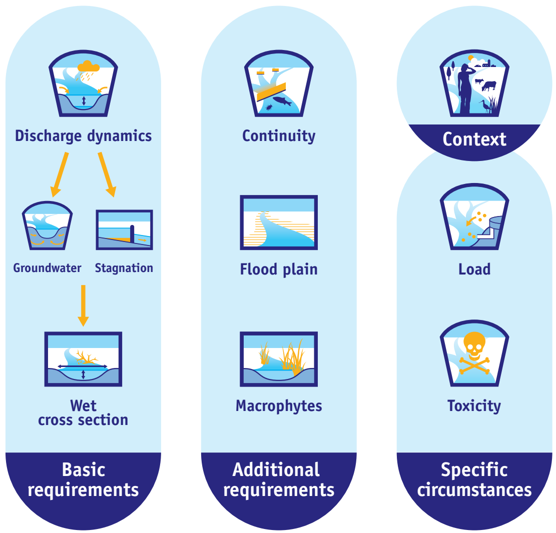
Conditions that are important in specific circumstances

- Load
- Toxicity

Balancing goals and functions

- Context

EKFS FOR FLOWING WATERS



(photo: Steven Verbeek)

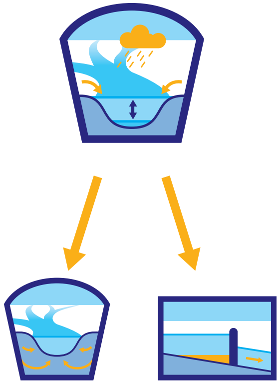
(photo: Steven Verbeek)

3.2 BASIC REQUIREMENTS FOR A HEALTHY ECOSYSTEM

This group of EKFs are fundamental for the functioning of all flowing water systems. The EKFs refer to hydrology, transport of sediment and the effects of stagnation. The primary focus in this group is on how flow rate and the type of substrate determine the ecological state.

EKF DISCHARGE DYNAMICS

(including EKF groundwater and EKF stagnation)



The soil types present in the catchment have a profound influence on the discharge dynamics of the system. If the surface has a high presence of man-made paved surfaces (urban areas), and hard infrastructures such as canals (including dams) and upstream barriers (weirs and pumping stations, etc.) then the discharge dynamics will be relatively high due to the increased rate of run-off and there will be low discharge during dryer periods.

If the surface is dominated by soil types where precipitation can easily infiltrate, the discharge dynamics are lower. The system stores water as groundwater, reducing the seasonal peaks and troughs. The EKF groundwater requires special consideration as it is essential for the 'base flow' in the Netherlands. It also influences the transportation of substances between water catchments on a large and local scale. As the focus in this group is on flow and sediment, the substances are part of EKF Load. Changes in land-use, whether it be channelisation or the building of dykes, restrict seepage and reduce the natural processes that stabilise the groundwater. Increased water levels, due to barrages in large rivers, may sometimes lead to seepage from river water to the surrounding areas.

Stagnation (absence of flow) is also an EKF that has a significant contribution to flowing water systems, especially in the Netherlands. Man-made barriers and weirs in the upper catchment of flowing water systems, accumulate organic matter and form sludge. This can lead to the excessive growth of phytoplankton, which consume and deplete oxygen levels (anoxia) which, in turn, can lead to eutrophication.

EKF WET CROSS SECTION

In natural circumstances the wet cross section of a stream is formed by a combination of processes involving sediment and hydrodynamic energy. In many systems, the cross section has been broad-

BOX 5: SCALE

Scale is an important factor in flowing water systems. Some EKFs play a role on the entire catchment, while others only have local effects. When you perform a system analysis, it is important to ascertain the appropriate scale for the recovery of degenerated systems.

Catchment

The catchment scale includes the relationship between the entire catchment and the factors that determine the ecological status of the entire watershed. On the river basin scale six EKFs are important to address. Two refer to the hydrology (drainage dynamics and groundwater), one to the degree of connection within the water system (continuity) and two address the water quality (load and toxicity). The balance between objects and functions is included as a separate key factor (context) which refers to the entire catchment.

Reach

This scale includes factors that relate to the river itself and the flood plain. A reach is a uniform proportion of the catchment area which can be either several hundred square meters or even several square kilometers. At this scale, there are four ecological key factors that require consideration; cross-section, buffer zone, macrophytes and stagnation.

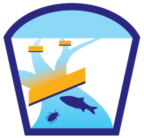
ened and deepened reducing the flow rate and altering the sedimentation processes of fine material. In these heavily altered systems, the EKF traffic light is often red. This EKF has a strong relationship with the growth of macrophytes (aquatic plants) as they alter the flow rate by increasing the amount of resistance. When the flow is low, excessive growth of macrophytes can occur.

3.3 ADDITIONAL REQUIREMENTS FOR FLORA AND FAUNA

If the traffic lights of the first group of EKFs are all green, the basic requirements are met for a healthy flowing water system. The EKFs in the following group determine which specific species are present in the water system. The primary focus of the next group is connectivity and the types of structures vegetation engineer on the flood plain and the banks of the water system, whether it be a river or stream. Vegetation structures are important for temperature, light availability, organic matter and as substrates for other organisms.

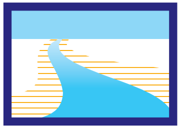
(photo: Steven Verbeek)

EKF CONTINUITY



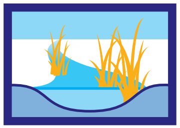
The EKF continuity reflects the ability of the sediment, organic material and organisms to move freely and migrate throughout the watercourse. It focuses on longitudinal connectivity. Continuity is primarily influenced by the presence of dams, locks, and pumping stations (barriers) and the alteration of the flood plain which can limit the ability of fish to spawn and seeds to be dispersed. Barriers also influence the transportation of sediment and organic matter in the water catchment which also affects the presence and distribution of organisms as their natural food source becomes depleted.

EKF FLOOD PLAIN



EKF flood plain addresses the role of buffer zones and riparian zones on the ecological functioning of the water system. The buffer zone can be several, to tens of, meters wide (streams) or wider (flood plains along rivers) and consists mostly in a natural state of forest or swamp. This key factor is related to the so-called "lateral connectivity" that describes the connection between the water and the bank. Along many water courses, the buffer zone is important for shading and for the distribution of macro-invertebrates. The buffer zone has a direct impact on the temperature and light regime, the supply of organic matter (leaves) and the growth of macrophytes in the watercourse.

EKF MACROPHYTES



This EKF addresses the important role of macrophytes on the ecological functioning of the water system. Macrophytes need sufficient light, nutrients, suitable substrate and flow conditions to establish and grow. Macrophytes themselves form a substrate for other aquatic organisms, alter flow rates (locally), vary the quality and quantity of sediment, regulate the amount of light and influence the presence of organic matter and oxygen.

3.4 CONDITIONS THAT ARE IMPORTANT IN SPECIFIC CIRCUMSTANCES

The first two groups of ecological key factors define the most common requirements for good water quality in flowing water systems in the Netherlands. Under specific circumstances the ecological water quality may be determined by other factors. This group focuses on


(photo: Steven Verbeek)


(photo: Istockphoto)

the effects of substances (load) whether they are caused by nutrients, organic substances or toxic compounds. The nutrient load is also addressed in this third group highlighting its role and significance in many Dutch water systems.

EKF LOAD

This EKF refers to the impact of naturally occurring substances including organic matter, nutrients and salt. There are non-point and point sources, which change the substrate composition, the concentrations of nutrients and oxygen regime. This directly influences the functioning of aquatic organisms. Excessive amounts of nutrients can lead to rapid growth of duckweed or blue-green algae, known as blooms, which leads to deterioration of the natural oxygen regime (eutrophication) and stagnation.

An example of a non-point source is groundwater. Groundwater carries substances including macro-nutrients of iron, manganese and silica that are essential for the growth of aquatic organisms. The groundwater can also be responsible for the input of other substances that can have a negative effect on the system in excessive amounts. These nutrients include nitrogen, phosphorus and sulphur. Seepage from the groundwater is often responsible for introducing these substances into the catchment and can be hard to identify.

Problems may also arise from other sources that include thermal stress of cooling water discharges. This occurs predominantly in major rivers.

EKF TOXICITY

Certain substances in the water system may have a toxic effect on flora and fauna. These include heavy metals, pesticides, drug residues and other micro-pollutants, such as plastic. The effect of these impurities depends on the location and the form the substances take within the system. The level of contamination can vary. Problems resulting from toxicity are generally confined to small localised areas and are commonly species specific. Effects are difficult to identify on a system level.

3.5 BALANCING PURPOSES AND FUNCTIONS

KF CONTEXT

The key factor Context is an important key factor that requires consideration when undertaking a system analysis. Its focus is not about ecology.

For a full description refer to the EKFs for stagnant waters, as described on page 21.

(photo: Steven Verbeek)

(photo: Jeroen van Herk, LINKit consult)

(photo: Roelof Veeningen, Wetterskip Fryslân)

FINALLY

This booklet describes our approach to water system analysis using the Ecological Key Factors. We encourage other member states to apply the methodology to their own systems. We would like to hear about your experiences using the EKFs so we can make additional improvements.

Take a look at our website for more information:
www.stowa.nl.

REFERENCES

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Moss, B. (2007). Shallow lakes, the water framework directive and life. What should it all be about?. Hydrobiologia, 584 inst(1), 381-394.

WEBSITES

STOWA
www.stowa.nl

Ecological Key Factors
www.watermozaiek.nl

STOWA's library
www.hydrotheek.nl

ABOUT STOWA

STOWA (Acronym for Foundation for Applied Water Research) is the knowledge centre of the regional water managers (mostly the Dutch Water Authorities) in the Netherlands. Its mission is to develop, collect, distribute and implement applied knowledge, which the water managers need in order to adequately carry out the tasks that their work supports. This expertise can cover applied technical, scientific, administrative-legal or social science fields.

STOWA is a highly demand-driven operation. We carefully take stock of the knowledge requirements of the Water Authorities and ensure that these are placed with the correct knowledge providers. The initiative for this mainly lies with the users of this knowledge, the water managers, but sometimes also with knowledge institutes, business and industry. This two-way flow of knowledge promotes modernisation and innovation.

Demand-driven operation also means that we are constantly looking for the 'knowledge requirements of tomorrow' - requirements that we dearly want to put on the agenda before they become an issue - in order to ensure that we are optimally prepared for the future.

We ease the burden of the water managers by assuming the tasks of placing the invitation to tender and supervising the joint knowledge projects. STOWA ensures that water managers remain linked to these projects and also retain 'ownership' of them. In this way, we make sure that the correct knowledge requirements are met. The projects are supervised by committees, which also comprise regional water managers. The broad research lines are spread out per field of practice and accounted for by special programme committees. The water managers also have representatives on these committees.

STOWA is not only a link between the users of knowledge and knowledge providers, but also between the regional water managers. The collaboration of the water managers within STOWA ensures they are jointly responsible for the programming, that they set the course, that several Water Authorities are involved with one and the same project and that the results quickly benefit all Water Boards.

MISSION STATEMENT

STOWA's fundamental principles are set out in our mission: Defining the knowledge needs in the field of water management and developing, collecting, making available, sharing, strengthening and implementing the required knowledge or arranging for this together with regional water managers.

STOWA

P.O. Box 2180 | 3800 CD Amersfoort | The Netherlands
033 460 32 00 | stowa@stowa.nl | www.stowa.nl

STICHTING
TOEGEPAST ONDERZOEK WATERBEHEER

stowa@stowa.nl www.stowa.nl
TEL 033 460 32 00 FAX 033 460 32 01
Stationsplein 89 3818 LE AMERSFOORT
POSTBUS 2180 3800 CD AMERSFOORT