Handbook for evaluating rehabilitation projects in rivers and streams

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Authors
Sharon Woolsey, Eawag
Christine Weber, Eawag
Tom Gonser, Eawag
Eduard Hoehn, Eawag
Markus Hostmann, Eawag
Berit Junker, WSL
Christian Roulier, Auenberatungsstelle
Steffen Schweizer, Eawag
Scott Tiegs, Eawag
Klement Tockner, Eawag
Armin Peter, Eawag

Additional authors of indicator method sheets
Florence Capelli, Eawag
Lukas Hunzinger, Schälchli, Abegg + Hunzinger
Lorenz Moosmann, Eawag
Achim Paetzold, University of Sheffield, UK
Sigrun Rohde, Department Bau, Verkehr und Umwelt, Kanton Aargau

Development of the Excel template 'Selection and evaluation'
Lorenz Moosmann, Eawag

www.rhone-thur.eawag.ch
www.rivermanagement.ch
eawag aquatic research
WSL
Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie
LABORATOIRE DE CONSTRUCTIONS HYDRAULIQUES
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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English translation
Sharon Woolsey (based on the German version edited by Claudia von See, Mannheim)

Layout
Norbert Novak, MEDIA-N, Vienna, www.media-n.at
Editing of the English version: Florian Spielauer, Vienna, www.dubhead.at

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Notes on the text

Glossary
A glossary is provided at the end of the handbook, which explains or defines expressions in the text, which are highlighted by colour and italics. The four keywords ‘floodplain’, ‘project evaluation’, ‘indicator’ and ‘rehabilitation’ are defined at the beginning of the glossary, but are not highlighted as glossary terms in the text due to their frequent use.

Photographs
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Internet
All internet web pages were active in November 2005.

Appendix
Appendices I to IV are currently only available in German at http://www.rivermanagement.ch/download.php.

Table of contents

1 Introduction

1.1 Aim and purpose of the handbook

Flood protection measures and other river engineering works of the past 200 years have significantly impacted Swiss rivers and streams in numerous ways. In order to counteract ecological impairments, rehabilitation projects are being carried out at increasing frequency. Rehabilitation is the term used to collectively describe all measures for re-establishing an *ecosystem's* near-natural condition. These measures focus on re-establishing a system's key elements and processes. Although rehabilitation projects primarily address ecological issues, they often have important implications for society, politics, economy and agriculture. Rehabilitation projects are conducted in various aquatic and terrestrial habitats. The present handbook, however, exclusively considers rehabilitation projects carried out in rivers and streams.

The handbook presents a tool for assessing if and to what extent the different objectives of a rehabilitation project were achieved. In the present handbook, such an assessment is defined as project evaluation. The presented evaluation method is based on a comparison of selected key elements and processes before and after rehabilitation. With the help of this tool, users can determine tendencies toward improvement and identify persisting deficits and deteriorations. Project evaluation is carried out at the level of project objectives. Indicators serve as tools for project evaluation. Indicators are parameters, which provide important information on a system's elements and processes. Their assessment can be quantitative, semi-quantitative or qualitative.

Today, flood protection projects nearly exclusively go hand in hand with rehabilitation measures. The presented evaluation method can also be applied to this type of project. However, the evaluation does not address flood safety. For this aspect, a separate evaluation is therefore essential. The second regulation of the Thur River is a fine example of a combination of flood protection measures and rehabilitation measures (Figure 1.1). In this project, economical and social aspects were considered beside environmental issues and issues of safety (Weber 2001).

Figure 1.1: Rehabilitated section of the Thur River at Schäffäuli as part of the second regulation of the Thur River (project duration: 1993–2004), TG/ZH, May 2004 (photo: C. Herrmann, BHAteam, Frauenfeld).

1.2 Target audience

This handbook for evaluating rehabilitation projects was produced for managers of rehabilitation projects at the level of cantons and local communities. It serves as a basis for planning and implementing projects and for commissioning project evaluation. For contractors, e. g. private consultancies, institutes or universities, the handbook offers practical instructions on how to select, survey and analyse suitable indicators. Indicator surveys mostly require the experience and knowledge of experts. Users may therefore have various backgrounds, such as biology, ecology, *morphology, hydraulics,* river engineering, social sciences, etc.

1.3 Overview of handbook

As illustrated in Figure 1.2, the handbook is divided into three sections. Allocation of the individual chapters to the three sections is indicated by symbols at the bottom right-hand corner of the handbook pages.

1.3.1 Basis (chapters 2 to 4)

The deficits of Swiss rivers and streams caused by river engineering activities are summarised in chapter 2. This deficit analysis elucidates the need for rehabilitation projects. The basic principles and the ideal procedure of rehabilitation projects are discussed in chapter 3. In chapter 4, the basic principles of project evaluation and the use of indicators are described. Subsequently, indicators described in this handbook are introduced and the relevance of reference systems is discussed.

1.3.2 Concept principles (chapters 5 and 6)

In this section, important concept principles are introduced. In chapter 5, the handbook's field of application is illustrated, while in chapter 6, the most important objectives of river rehabilitation projects are discussed.

1.3.3 Implementation (chapters 7 to 11)

In the section 'implementation', the procedure for project evaluation is presented. Two different approaches are possible:

1. One of the recommended indicator sets for selected rehabilitation measures is applied.
2. A user-defined indicator set is compiled.

In chapter 7, rehabilitation measures commonly applied in Switzerland are discussed and recommended indicator sets are provided. In the subsequent chapter 8, details on how to compile user-defined indicator sets and how to use the Excel template 'Selection and evaluation' (Appendix III) for automated indicator selection are given. In chapter 9, information on indicator survey is provided. Method sheets for each of the indicators are included in Appendix I. Further-reaching literature or detailed survey instructions can be found in Appendix II. In chapter 10, practical steps for project evaluation are provided. The measured indicator values form the basis of project evaluation. The evaluation can be carried out automatically using the Excel template 'Selection and evaluation'.

In chapter 11, the concept is analysed and a brief outlook on the further procedure is given. This chapter also contains a feedback sheet, with which the authors invite handbook users to communicate their results.

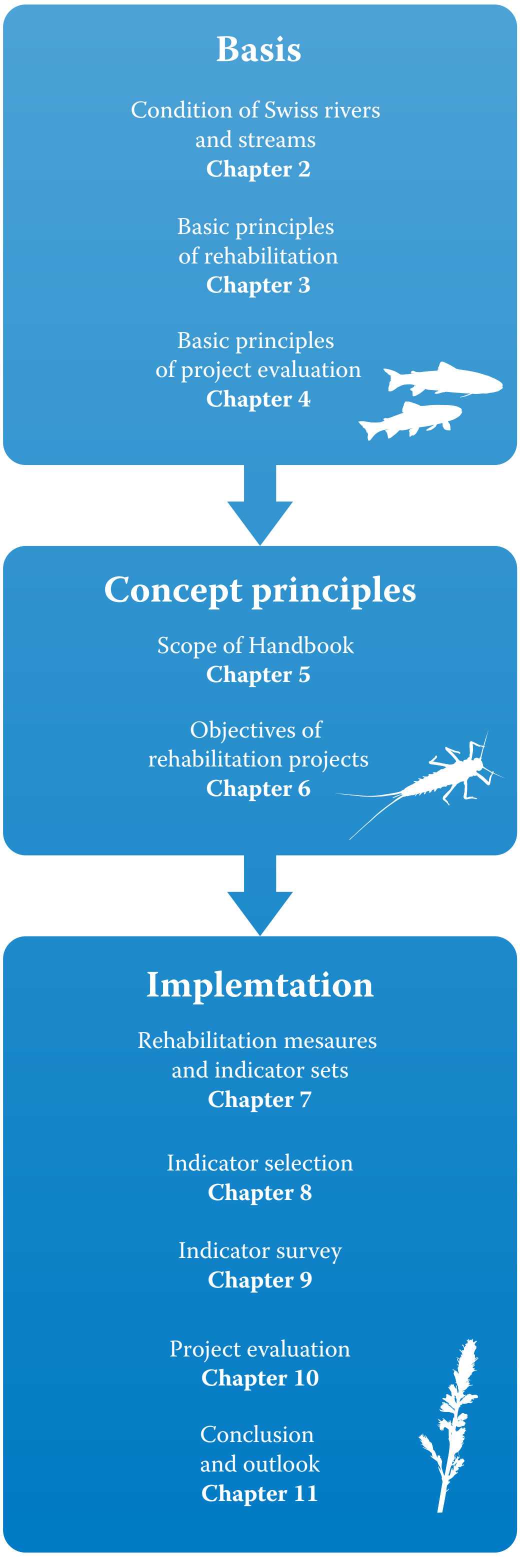


Figure 1.2: Division of the handbook into three sections.

2 Condition of Swiss rivers and streams

2.1 River canalisation in Switzerland

In Switzerland, first human interventions in rivers and streams took place already during the late Middle Ages (Vischer 2003). Between the years 1000 and 1700, the population tripled and the need for developed land increased. During this time, additional land for agricultural use was primarily gained by deforestation in mountain areas, while the larger valleys were initially left entirely to the rivers (Schnitter 1992). However, intensive use and clearing of forests led to soil erosion and resulted in greater flow peaks and in increases of *bedload* transport in rivers. As a consequence, floods occurred, particularly in the lowlands. With a further population increase in the 19th century and colonisation of the valley plains, flood risks increased dramatically (Schnitter 1992).

First attempts to prevent flood damages by river regulation were carried out already in the early 18th century. Between 1711 and 1714, an ambitious project was performed, in which the Kander River was diverted into the Lake of Thun, in order to protect the plains to the west of Thun from flooding (Schnitter 1992). However, this pioneering project did not achieve the desired effect. On the contrary: Because of the rise of the lake's water level, the danger of flooding in Thun increased. Consequently, further protection measures had to be implemented (Vischer 2003).

In the 19th century, the number of river engineering schemes increased considerably. A successful project was, for example, the diversion of the Linth River into Lake Walen, which was carried out between 1807 and 1816. This was the first flood protection project supported and realised entirely by the Swiss Confederation (Schnitter 1992, Vischer 2003). Following the Federal Constitution of 1848, the government possessed the resources to partly or wholly finance river engineering projects and subsequently supported further significant schemes (Vischer 2003). With the help of such federal subsidies, the most important Swiss rivers had become regulated and diked by the end of the 19th century (Schnitter 1992, BUWAL 1998). Some of the larger projects were, for example, the regulation of the Alpine Rhine River (1862–1900), the first regulation of the Rhone River (1863–1894) and the first regulation of the Jura rivers (1868–1891; Vischer 2003). A further intensive period of canalising and diking rivers followed after 1950 with the economic revival and the intensification of industry, agriculture and housing development. Rivers therefore became increasingly deprived of space also during the 20th century (BUWAL 1998). Figures 2.1 to 2.4 show the Alpine Rhine River and the Thur River before and after regulation.

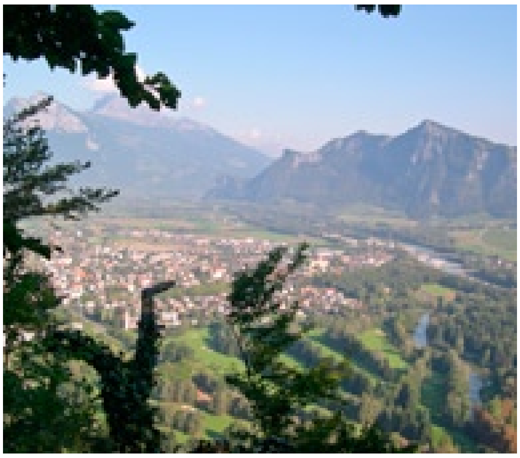


Figure 2.1 (left): The Alpine Rhine River at Bad Ragaz, SG, in the year 1826 (picture: Johann Ludwig Bleuler, reproduced with consent of the Department of the Environment Vaduz, FL).

Figure 2.2 (right): The Alpine Rhine River at Bad Ragaz, SG, in the year 2005 (photo: U. Uehlinger, Eawag).

Figure 2.3: The floodplains of the Thur River at Niederbüren around 1920 before regulation, SG (photo: Department of Civil Engineering, Canton of St. Gallen).

Figure 2.4: The canalised Thur River at Schäffäuli, TG/ZH, June 2001 (photo: C. Herrmann, BHAteam, Frauenfeld).

2.2 Problem analysis of Swiss rivers and streams

In many places, comprehensive river engineering measures of the past three centuries have transformed rivers and streams into straight, embanked systems. As a consequence, Swiss rivers and streams feature various deficits. Their natural and complex interactions with riparian zones and with the groundwater are disturbed (Ward et al. 2001). They are fragmented by innumerable longitudinal barriers, which interfere with aquatic and riparian animals and plants. Such *abiotic* deficits have significant effects on the biology of rivers and streams. In most cases, the ecological functional capability of Swiss rivers and streams is highly impaired and species richness is diminished. Floodplain systems are particularly strongly affected by these deficits. The most important *morphological*, *hydrological*, physical, chemical and biological deficits, as well as deficits in flood protection and recreational use, are discussed in more detail in the following chapters.

2.2.1 Ecomorphology

In order to fulfil their function as habitat, rivers and streams require not only good water quality, but also near-natural morphology (see chapter 6; see Figures 2.5 and 2.6 for examples of river sections rich and poor in structure). In Switzerland, standardised methods of the *Modular Stepwise Procedure* have been used since 1998 to systematically assess the ecological status – i. e. the near-naturalness – of rivers and streams (BUWAL 1998). This concept is based on the Act for the Conservation of Watercourses of 24 January 1991. It is a comprehensive approach to enable an integral assessment of rivers and streams, based on which deficits and needs for action can be identified, and countermeasures can be developed. For this purpose, methods for recording nine modules at different levels of labour intensity are being developed. The modules are: *ecomorphology,* hydrology, physical appearance, *macroinvertebrates,* fish, diatoms, macrophytes, water chemistry and ecotoxicology. With regard to labour intensity, the levels F (regional survey), S (system scale survey) and A (reach scale survey) can be distinguished. While methods for the modules 'ecomorphology' and 'fish' are already being implemented at level F, other modules only exist as a draft. The 'ecomorphology' module describes the structural and structure-forming elements of rivers and streams and their riparian zones. Already 22 cantons have assessed ecomorphology at level F (see e.g. map for the Canton of Berne www.bve.be.ch/site/bve_gsa_gwq_fliessg_berbro_gbl058.pdf). So far, results show that more than a third of the assessed rivers and streams belongs to the classes 'heavily impacted', 'unnatural/artificial' or *'in culvert'* and therefore feature considerable morphological deficits (Figure 2.7). For example, a total of

Figure 2.5: Example of a river section poor in structure: the Lichtenstein drainage canal adjacent to the Rhine River at Ruggell, April 2005 (photo: A. Peter, Eawag).

Figure 2.6: Example of a river section rich in structure: the Anterior Rhine River at Gravas, GR, September 1991 (floodplain object 34; photo: Floodplain Advisory Office SCZA).

17 % of assessed rivers and streams are *in culverts.* Ninety percent of rivers and streams of 22 cantons were examined (= 25,443 km; personal communication, Federal Office for the Environment, October 2005).

Besides assessing four *morphological* and *hydraulic* parameters (variability of wetted width, anthropogenic modification of river bed, anthropogenic modification of river bank, width and structure of riparian zone), the *ecomorphology* module additionally examines the river's continuity of flow, which serves as a measure of longitudinal *connectivity*. Intact longitudinal connectivity is a prerequisite for the upstream and downstream exchange of biological matter (see chapter 6). However, in many places, connectivity is interrupted by numerous weirs, falls and dams. In the Canton of Zurich, for example, a total of 39,024 artificial barriers were counted along a river network of 3,615 km. This is equivalent to 10.8 barriers per km of river (personal communication, P. Niederhauser, AWEL Zurich). In the Canton of Berne, 13,600 barriers were recorded along a river network of 6,800 km, which is equivalent to two barriers per km of river (Baur et al. 2004).

2.2.2 Modified flow regime

Modifications to the flow regime are mostly a result of hydropower production. In Switzerland, the use of hydropower is particularly widespread. Its production causes impounded sections and *sections of residual flow* (Figures 2.8 und 2.9), which lack natural flow dynamics and variability of flow velocity. In these sections, alterations to *bedload* transport and substrate composition occur. Water temperature is also affected. Dams additionally prevent upstream migration of fish and limit their downstream migration.

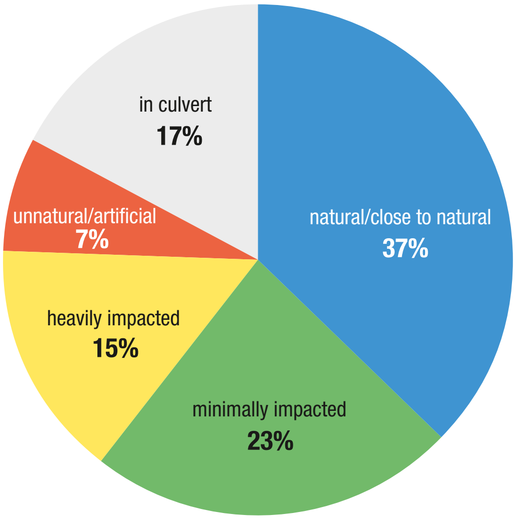


Figure 2.7: Classification of rivers and streams based on the ecomorphological assessment at level F (data: Federal Office for the Environment, situation October 2005).

Figure 2.8: Dammed section in the Alpine Rhine River at Domat-Ems, GR, September 2003 (photo: A. Peter, Eawag).

Figure 2.9: Section of residual flow in the Alpine Rhine River, October 2002 (photo: A. Peter, Eawag).

A further effect of hydropower production from storage power plants is *hydropeaking*. According to the demand, electricity is produced especially during daytime on workdays. The controlled release of water from the storage reservoir therefore causes a continuous change between high and low flow. Flow is greater during times of production than during the night and at weekends (Figure 2.10). Hydropeaking patterns modify the natural flow regime, alter the river's *bedload* transport and therefore detrimentally affect habitats for plants and animals. In Switzerland, 60 % of the entire electric power consumption comes from hydropower. Around 25 % of all hydropower stations in Switzerland (> 300 kW) cause hydropeaking in their downstream watercourses (Baumann & Klaus 2003).

2.2.3 Bedload

The bedload regime of many rivers in alpine regions and in the Swiss lowlands is significantly impaired. In some cases, bedload supply from the catchment is greatly reduced due to stream regulation measures, bedload collectors or gravel mining (Figure 2.11). Embankments additionally prevent the release of bedload from lateral erosion. At the same time, *receiving watercourses* feature an excess of transport capacity in their straightened channels. This imbalance between bedload input and transport capacity causes a tendency toward river bed erosion, which may result in the scouring of river bank protection measures, a fall in the groundwater level or complete clogging of the river bed. Cross-sectional constructions are often installed as countermeasures. Although these ensure river bed stabilisation, they inhibit longitudinal *connectivity* (Figure 2.12).

Rivers which are subject to erosion usually feature a high degree of river bed *clogging*. Fine bedload particles are transported along the top layer of the river bed and are only deposited locally in calm waters.

In wide, near-natural rivers, dynamic *morphological* structures develop. In alpine areas and in the foothills of the Alps, braided watercourses dominate as the natural channel structure. The development of structures is often linked to sedimentation processes. If bedload supply is limited, wide rivers may also

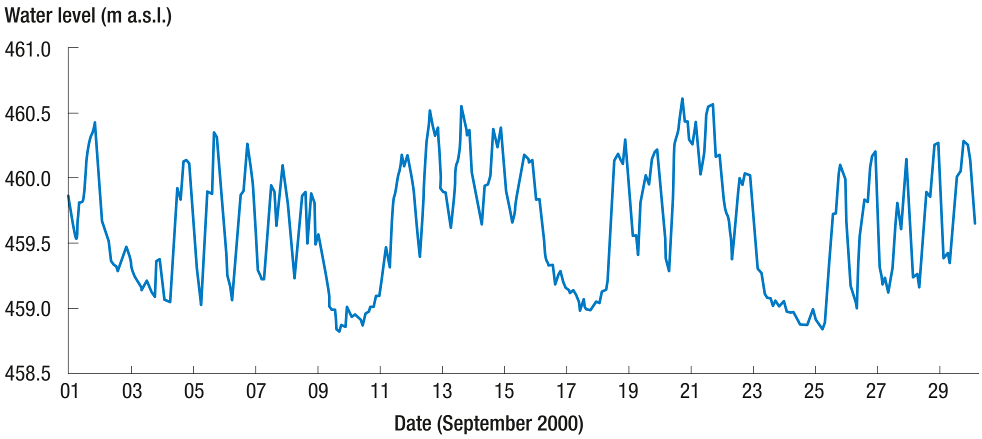


Figure 2.10: Fluctuations in the water level of the Rhone River near Branson, VS, caused by hydropeaking in September 2000 (Fette et al. 2005).

display a tendency toward river bed erosion and hence toward stable *morphological* structures (Figure 2.13).

In rare cases, the *bedload* input exceeds the river's transport capacity. This may particularly be the case during significant flood events. As a consequence, sedimentation occurs, which leads to reduced flow capacity and hence to greater danger of flooding in adjacent areas. In narrow, canalised watercourses, the capacity for bedload deposition is limited and an excess of bedload has a more immediate effect on the flow capacity than in wide watercourses.

Figure 2.11: Gravel mining in the Rhone River at Pfynwald, VS, October 2001 (photo: Eawag).

Figure 2.12: Trème: cross-sectional constructions for river bed stabilisation, September 2001 (photo: L. Hunzinger, Schälchli, Abegg + Hunzinger).

2.2.4 Water quality

Since the mid-19th century, watercourses have been increasingly polluted by synthetic compounds. As many of these compounds are not completely degradable, they can be found in the water and in the sediment, together with various other degradation products. Watercourses are therefore polluted with hundreds of compounds, of which only few have been chemically identified or toxicologically examined (Fischnetz 2004).

In the past decades, chemical inputs from industry and agriculture into the environment have declined. Problematic compounds have in part been replaced by environmentally friendly compounds. In addition, the performance of wastewater treatment plants has improved. These ameliorations in agriculture, trade and industry are opposed by the pollution resulting from the yet increasing use of chemical household products (Fischnetz 2004).

Today, substances which find their way into watercourses via wastewater treatment plants (*Abwasserreingungsanstalten ARAs*) or diffuse disposal, are of particular relevance. Inputs from diffuse sources originate principally from agriculture, but also from residential areas, industry and traffic. These inputs contribute greatly to the analytically detectable substances. ARAs are significant point sources of nitrite, ammonium and organic trace elements. Despite treatment, these can

Figure 2.13: River bed erosion in the Melezza River, TI, 1997 (photo: L. Hunzinger, Schälchli, Abegg + Hunzinger).

not be completely broken down. Many of the compounds contained in wastewater influence temperature, oxygen saturation and pH values of the *receiving watercourses*. Although chemical pollution has decreased distinctively over the last 30 years, peak concentrations of nitrogen compounds, such as nitrite and ammonium, and seasonally high concentrations of *pesticides* (particularly after heavy rainfall), pose an elevated local and short-term threat to the *ecosystem*. However, the precise effects are largely unknown due to the limited data availability on chemical pollution of rivers and streams, and long-term effects of problematic compounds (Fischnetz 2004). In the future, new challenges may be associated with hormonally active compounds contained in wastewater (Aerni et al. 2004).

2.2.5 Biodiversity

Because of its abundance of water and *diversity* of aquatic habitats, Switzerland is regarded as the ‘water kingdom’ of Europe. However, lakes and ponds only cover 3.4 % of the country’s surface, while rivers and streams make up 0.7 %. Despite these relatively small proportions, around 8 % (3,300 species) of all native animal species inhabit rivers and lakes (Küry 2002). However, high aquatic *biodiversity* is not restricted to large lakes, rivers and streams. Small watercourses, such as pools, ponds, trickles and temporary puddles, are equally rich. Springs and groundwater zones are valuable habitats for highly specialised species (Baur et al. 2004). Floodplains are important centres of species richness and contribute greatly to a river corridor’s overall diversity (Figure 2.14). Floodplains are good examples for illustrating the ecological role of watercourses: Today, floodplains of rivers and streams cover 1.2 % of Switzerland’s surface. Around 1870, they covered 3.1 %. Since 1870, they have therefore been reduced by 63 %. If only the terrestrial part of floodplains is considered, the decline is considerably greater at 87 %. For both figures, a confidence interval of 95 % applies (Müller-Wenk et al. 2003).

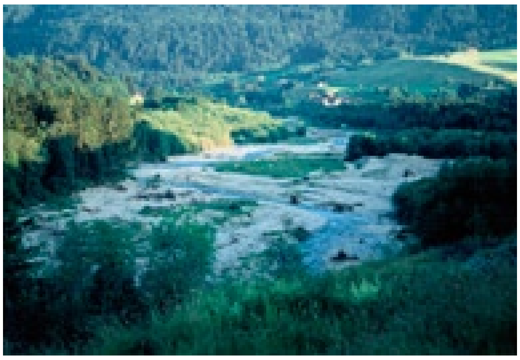


Figure 2.14: Floodplains are valuable habitats. Above: the floodplains of the Sense River, FR/BE, June 1999. Below: the Thur River at Wuer, TG, June 1995 (photos: Floodplain Advisory Office

On a global scale, the decrease in biodiversity is clearly greater in inland waters than in terrestrial habitats (Tockner & Stanford 2002). This is also the case for Switzerland. Here, 28 of 54 native fish and cyclostome species are red-listed (Duelli 1994). A further 14 species are potentially endangered. Forty-six percent of aquatic plants and 42 % of marsh plants are threatened (Landolt 1991). Nineteen of 20 native amphibian species are endangered or have already become extinct (Duelli 1994).

There are various causes for the decline in aquatic biodiversity. The main factors are quantitative and qualitative loss of habitat, modifications to the water regime, pollution by problematic chemical compounds, progressive climate change, fragmentation of rivers and streams, as well as spread and establishment of exotic species (Baur et al. 2004). However, the most important factors are river canalisation and embankments. More than 90 % of wetlands have been sacrificed for the sake of agriculture and urban settlements (Baur et al. 2004). A total of 4,500 km of rivers and streams has undergone *hydrological* modification due to the operation of around 500 power stations with a maximal performance of > 300 MW. A further approximately 1,700 small power stations add to these effects (Baur et al. 2004).

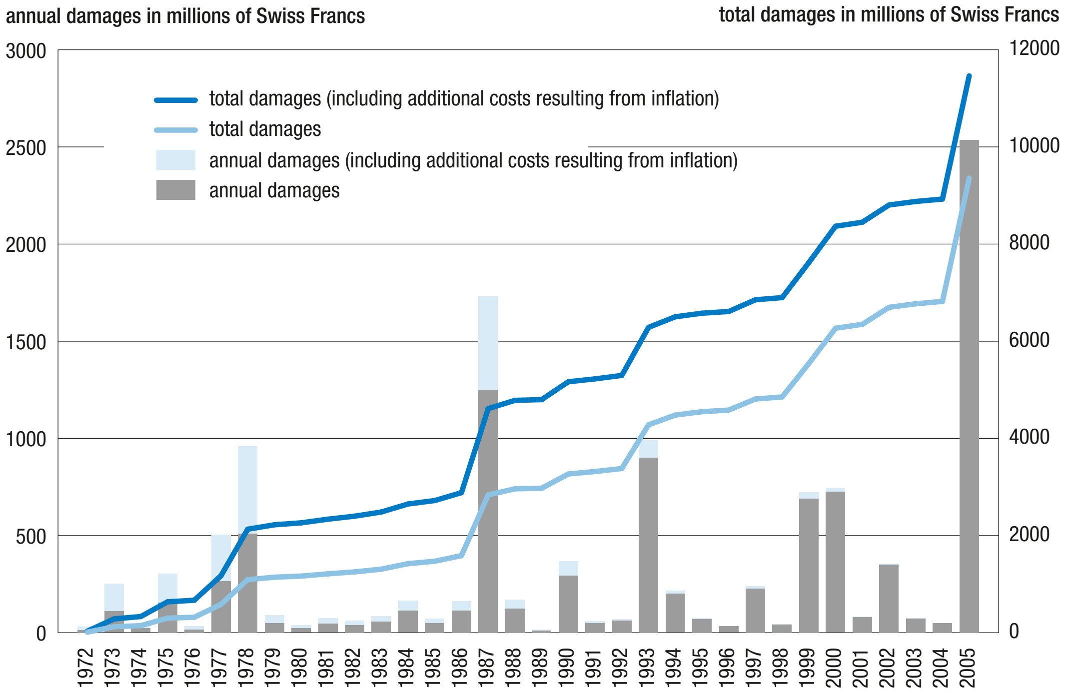


Figure 2.15: Flood damages between 1972 and 2005. Illustration of actual costs and additional costs as a result of inflation (data: Federal Office for the Environment, status in November 2005).

2.2.6 Flood protection

In Switzerland, flood protection measures of the past 200 years have proven to be insufficient. Costs caused by flood damages were particularly high after the floods of 1978, 1987, 1993,1999/2000 and 2005 (Figure 2.15). The hundred year flood in August 2005 alone, which affected wide areas of Switzerland, caused damages worth 2.5 billion Swiss Francs (personal communication, Federal Office for the Environment, October 2005). For many rivers, highest discharge on record was observed, e.g. for the rivers Aare (before entering the Lake of Biel), Lütschine, Kander, Muota, Engelberger Aa, Sarner Aa, Reuss (Figure 2.16), Kleine Emme, Linth and Sihl. Statistically, such discharges only occur every 100 to 200 years. Most lakes also reached or exceeded their highest levels. Exceptions were Lake Constance, Lake Neuchatel and Lake Murten. The size of the area affected by the floods was also unusual and exceeded that of the flood in 1999 (press releases by Federal Office for the Environment on 22 and 24 August 2005). Although extensive damages occurred in many places (see Figure 2.17), areas with sufficient flood protection were not affected (e.g. Thur River at Uesslingen, Figure 2.18).

Figure 2.16: Flood effects at the Reuss River: spilt over dam at Jonen, AG, August 2005 (photo: B. Schelbert, Department of Construction, Traffic and Environment, Canton of Aargau, Division Landscape and Water).

In order to reduce future damages and losses, improved flood protection is required. New laws for river engineering and water conservation are in place, which will facilitate the implementation of the measures needed.

2.2.7 Recreational use

Near-natural rivers and streams are valuable areas for local recreation and can be used for various activities (e. g. swimming, walking, picnicking, cycling, fishing, observing nature, relaxing). In a densely populated country, such as Switzerland, recreational areas are of particular value. However, many recreational areas have been lost over the past 200 years

Figure 2.17: Flood at the 'Chästelenbach' at Stössi (floodplain object 107) in Maderanertal, UR, September 2005 (photo: Floodplain Advisory Office SCZA).

due to the embankment and canalisation of rivers. With the help of rehabilitation projects, the value of such areas can once again be enhanced. Visitor counts at the Thur River, for example, have shown that visitor numbers were clearly higher in rehabilitated river sections (e.g. Gütighausen, Niederneunforn) than in embanked river sections (Capelli 2005).

Figure 2.18: High flow at the Thur River at Uesslingen, TG. Due to sufficient flood protection no damages occurred here, August 2005 (photo: Police, Canton of Zurich).

2.3 Need for action: preventive and sustainable

The problem analysis of Swiss rivers and streams in chapter 2.2 illustrates the scale of the need for action. For the most part, the individual deficits amplify each other, so that they can not be considered in isolation, but must be viewed as a whole. Rehabilitation offers a possibility by which habitats affected by various deficits can be returned to a near-natural state. In order to achieve a significant level of success, the catchment must be considered as a whole. Measures carried out on individual river sections will only have a limited effect. The basic principles of rehabilitation are discussed in the subsequent chapter.

Sustainability in the sectors society, environment and economy is a further important element for the success of rehabilitation projects. These three sectors must be considered as equal elements. As their interests are often in direct opposition to each other, they form an area of conflict (BWG 2001; Figure 2.19).

However, it is not sufficient to solely address impairments. It is also important to maintain and enhance existing intact habitats. Here, the Floodplain Decree on the conservation of floodplains of national importance sets a good example. The aim of the decree is to protect the most important floodplains in Switzerland. The Federal Office for the Environment designates the floodplains of national importance, while the cantons are obliged to define the precise boundaries of floodplain objects and to select ecologically adequate buffer zones. Floodplains of national importance must be preserved in an undiminished condition. Furthermore, the native animal and plant species typical for these floodplains must be conserved and actively promoted. The Floodplain Decree came into force on 15 November 1992. To date, 282 floodplain objects with a surface area of 226 km^2 have been defined. This corresponds to 0.55 % of the country's surface area (BUWAL 2005).

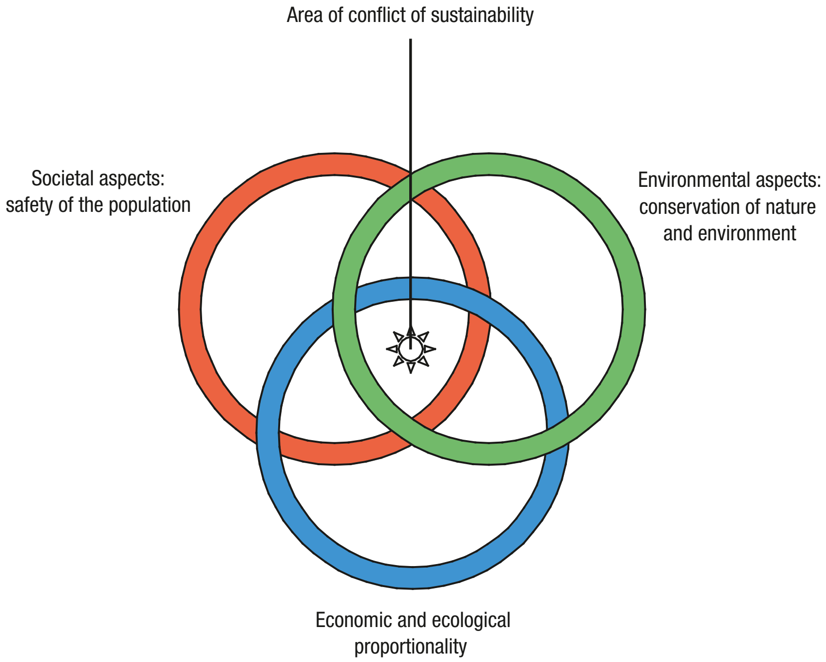


Figure 2.19: Area of conflict of sustainability (BWG 2001).

3 Basic principles of rehabilitation

3.1 Purpose of rehabilitation

Various approaches for improving ecological systems can be distinguished. The two most important approaches are restoration and rehabilitation. Restoration is defined as the collective efforts for returning *ecosystems* to their original, unimpaired condition (Bradshaw 1996, Roni 2005). In this context, active and passive measures can be distinguished (Roni 2005). In the case of active restoration, direct structural measures are carried out, in order to obtain the original ecological functional capability. By contrast, passive restoration simply excludes the *anthropogenic* activities, which are responsible for the degradation of the ecosystem, or which prevent it from regenerating (Kauffman et al. 1997).

Rehabilitation also improves important aspects of an ecosystem, but does not return it to an original condition (Bradshaw 1996, Roni 2005). Rehabilitation recreates essential key processes and elements and improves the degraded condition of a habitat. The objective of the measure is not to remedy the symptoms of an impaired system (e.g. reduced fish density), but to eliminate their causes (e. g. reduced habitat *diversity,* reduced *connectivity).* However, the terms ‘restoration’ and ‘rehabilitation’ are not used in a consistent manner, neither in practice nor in the literature. Furthermore, the English term ‘restoration’ is often mistakenly translated into the German equivalent of ‘rehabilitation.’

Both restoration and rehabilitation projects are performed in aquatic and terrestrial habitats. The present handbook for project evaluation specifically refers to rehabilitation projects in rivers and streams. The term ‘rehabilitation’ also includes measures, which have an ecological component, but do not lay a specific emphasis on it. Therefore, the handbook also refers to flood protection projects, which feature measures for ecological improvement. Due to high population density in the valleys, complete restoration of rivers and streams to their original condition is mostly – or at least in Switzerland – impossible. Ideally, rehabilitated rivers and streams will develop into natural, self-regulating systems, conforming to their landscape and their *morphological* river types. Additionally, it is desirable that the section in question will not require any further maintenance after the measures have been completed (Henry & Amoros 1995). In order for a degraded river or stream system to return to a near-natural condition, both ecological structures (i. e. species richness and complexity of the biocoenosis), as well as functions (i.e. productivity, transport and dispersal, resilience) must be re-established (Williams et al. 1997). In Figure 3.1, the approximation to this ideal condition is illustrated in a diagram.

In the following chapters, the basic principles for rehabilitating rivers and streams are discussed.

3.2 Status in science and practice

3.2.1 Legal basis

In Switzerland, the number of rehabilitation projects has increased considerably during the past decade. Unfortunately, no list of completed projects is available. The rise in projects may be associated with tightened legal regulations. The Act for the Conservation of Watercourses of 1991 laid the foundations for a better conservation and protection of watercourses and a greater emphasis on habitats and riparian zones. The subsequent Decree on the Conservation of Watercourses was accepted in 1998 and came into force in 1999. It does not only make demands with respect to water quality, but also stipulates that rivers and streams should feature near-natural

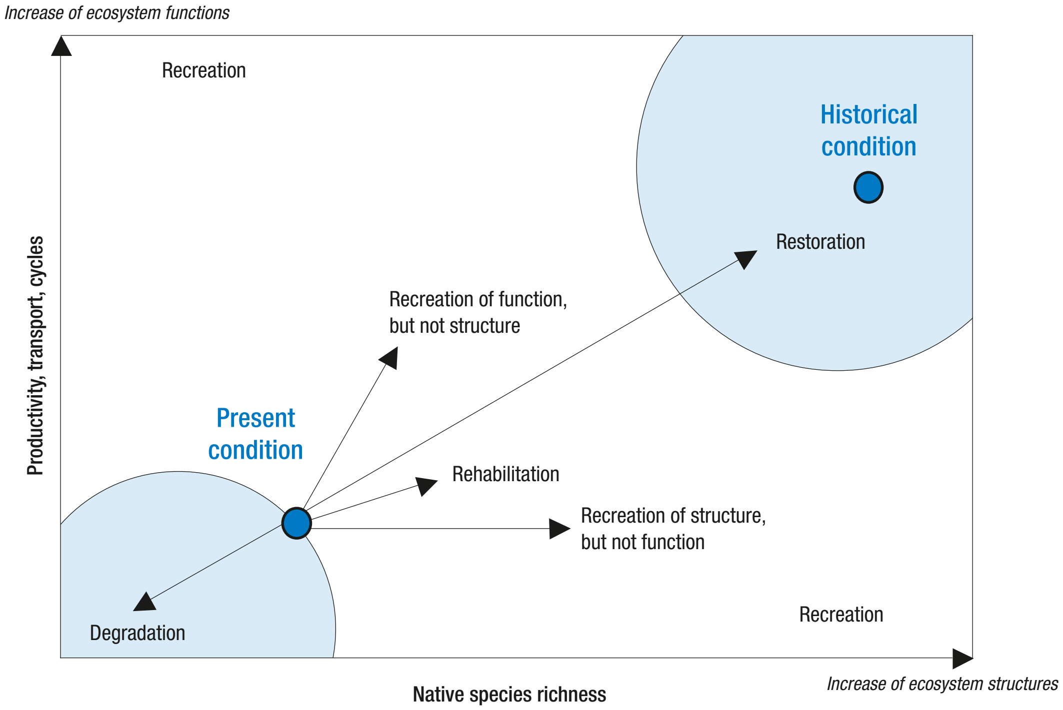


Figure 3.1: The role of ecological structures and functions in rehabilitation (Williams et al. 1997). The recreation of natural processes causes an increase of ecosystem structures (species richness, complexity of the biocoenosis) and ecosystem functions.

structures. Additionally, the Decree on River Engineering of 1994 commits the cantons to define the minimally required space for rivers and streams. In article 21, areas threatened by flooding and space requirements for watercourses are addressed:

1. The cantons designate the areas threatened by flooding.
2. They define the space required by watercourses, in order to ensure flood protection and to guarantee natural functions of watercourses.
3. When planning land use and other activities affecting land use, they take into consideration the areas threatened by flooding and the space required by watercourses.

This progressive decree is based on the experience that new approaches and tools must be developed, in order to simultaneously meet the demands of flood protection and of sustainable management of rivers and streams. Particular challenges consist in identifying synergies between flood protection and rehabilitation, and developing new, sustainable river engineering measures. This challenge can only be tackled in intense, transdisciplinary cooperation with river engineers, ecologists and social scientists.

The Floodplain Decree of 1992 on the conservation of floodplains of national importance instructs the cantons to preserve existing floodplain objects in an undiminished condition and to enhance their value. In this context, impairments to the natural water regime and to the *bedload* regime must be eliminated. Rehabilitation of degraded floodplains relies on re-establishing water dynamics. Degraded floodplains, which can not be rehabilitated, must be compensated by substitute habitats (Auenberatungsstelle 2001). By the year 2002, rehabilitation projects had been conducted or scheduled in 97 of 169 floodplain objects of national importance (Cosandey et al. 2002). Figure 3.2 contrasts the projects which were completed, ongoing and scheduled until this time. At present, up to date figures are not available. A revision of the statistic is planned for the beginning of the year 2006.

With the ‘Leitmotif for Swiss rivers and streams’ (*Leitbild Fliessgewässer Schweiz*), the Federal Office for the Environment, the Federal Office for Agriculture and the Federal Office for Spatial Development took a first step toward a holistic approach to sustainable management of rivers and streams, which would equally consider social, ecological and eco-

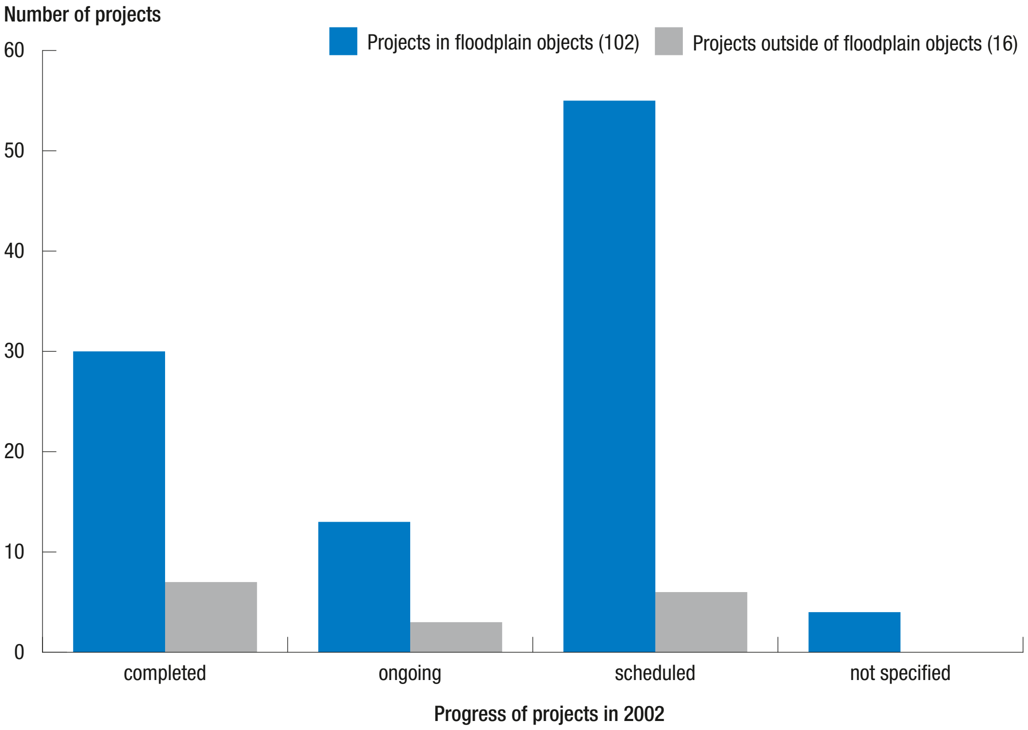


Figure 3.2: Number and progress of rehabilitation projects in floodplains within and outside of floodplain objects of national importance in Switzerland: completed, ongoing, scheduled (situation in 2002, Cosandey et al. 2002).

nomic aspects associated with watercourses. The model provides impulses for dealing with watercourses in a holistic way and demonstrates how successful solutions can be seized. The model sets vital goals: sufficient space for the watercourse, sufficient water supply and sufficient water quality (BUWAL/BWG 2003).

3.2.2 International knowledge transfer

With its 15 years of age, the practice of rehabilitating rivers and streams is still a young science. Future projects therefore rely greatly on scientific insight and practical experience (Downs & Kondolf 2002). In order to examine the hitherto involvement of science in rehabilitation ecology, a literature analysis of international scientific journals published between 1990 and 2005 was conducted using the internet search tool ‘Web of Science’. For this purpose, the following keywords were entered:

- ‚river’ and ‘restoration’ or ‘rehabilitation’
- ‘stream’ and ‘restoration’ or ‘rehabilitation’

Before 1990, there were only few publications containing these keywords. Until 2002, a continuous rise in publications in the field of rehabilitation ecology can be detected. After a stagnation between 2003 and 2004, the number of articles increased again in 2005 (Figure 3.3).

The rise in publications represents an increase in the knowledge of basic principles of rehabilitation and in knowledge transfer. These are important prerequisites for establishing a rehabilitation science. Practical experiences are, however, equally important. Both successes and failures have a high learning value and can be of great use to future projects. The willingness to communicate project results is therefore essential.

3.2.3 Potential for rehabilitation

There is a great need for rehabilitating Swiss rivers and streams: An extrapolation of the data from the *ecomorphological* survey of 25,443 km river length in 22 cantons (see chapter 2.2.1) to the overall 61,015 km river length in Switzerland shows that 23,796 km (39 %) are either heavily impacted, unnatural/artificial or *in culverts.* River sections belonging to the categories ‘natural/close to natural’ or ‘minimally impacted’ can be found particularly in headwaters and in upper reaches (BUWAL 1998). Hence, the potential for rehabilitation is highest in the lowlands. Despite the high potential, rehabilitation velocity was only 10.6 km river length per year between 1992 and 1998 (personal communication, Federal Office for the Environment, 2000).

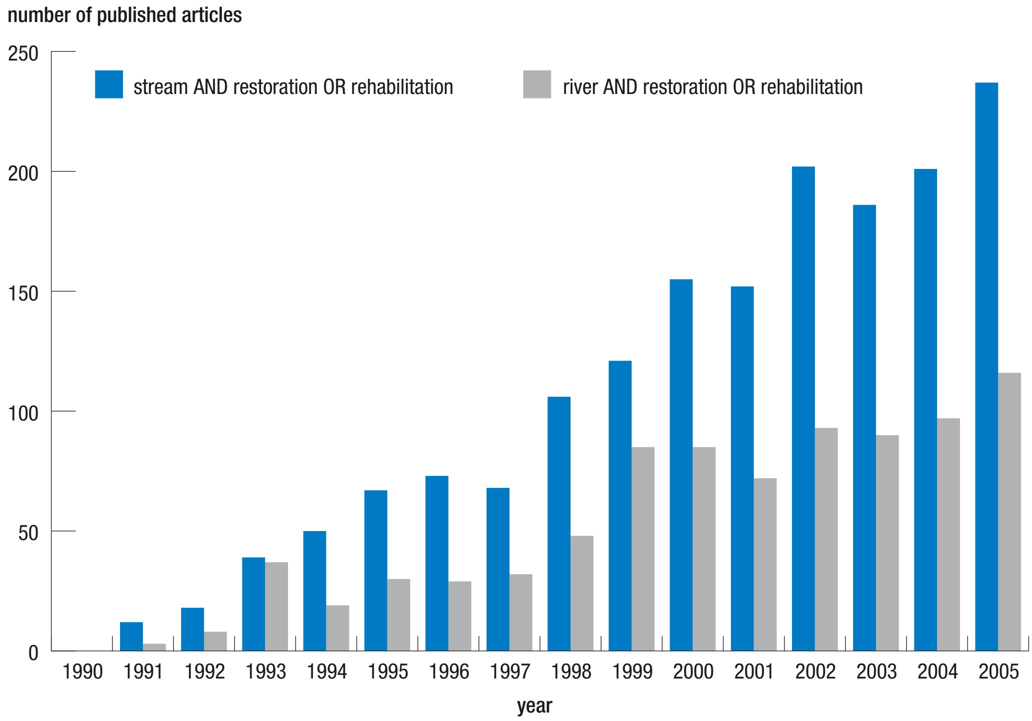


Figure 3.3: Number of annually and internationally published, scientific articles between 1990 and 2005 (situation on 1 November 2005) containing the above mentioned keywords (Web of Science, http://wok.consortium.ch/portal.cgi?DestApp=WOS&Func=Frame).

3.3 Project procedure

Rehabilitation projects benefit from careful and comprehensive planning. In Figure 3.4, the ideal procedure of rehabilitation projects is shown from the planning stage to project evaluation. The individual elements are divided into five phases, according to the 'Performance Model 95' of the Swiss Association for Engineers and Architects (Schweizerischer Ingenieur- und Architektenverein 1996).

The aim of rehabilitation projects is to recreate a condition approximating the condition prior to impairment. In order to assess the degree of such an approximation, *reference systems* are consulted, which provide information on natural variability. Reference systems are sections of rivers and streams, which represent the aspired, unimpaired condition (Chapman 1999). In Switzerland, such systems are often no longer available and a theoretical model – also called *Leitbild* or guiding image – must be developed based on historical or modelled data (Jungwirth et al. 2002; see also chapter 4.4). Defining such a guiding image is a crucial step in the planning procedure (Nienhuis & Leuven 2001). The guiding image describes the natural potential of a particular river or stream under unimpaired conditions, but taking the existing general framework conditions into consideration. In order to create a realistic guiding image, a deficit analysis of the *current condition* is required.

After a guiding image has been characterised, the project objectives are defined in consideration of the general *political and societal framework conditions.* It is vital for the acceptance of a project that representatives from different *interest groups* participate in defining project objectives. In addition, *public relations* are an important tool for presenting the rehabilitation scheme and its results. The three elements *general political and societal framework conditions, interest groups* and *public relations* are relevant to all five phases.

In phase 2, the actual *rehabilitation measure is selected* on the basis of the *defined project objectives* and by means of a *comparison of alternatives.* The phases 'Strategic planning' and 'Preliminary survey' are topics treated in the synthesis 'Collective Planning of Hydraulic Engineering Projects. Handbook for the Participation and Decision Making Process in Hydraulic Engineering Projects', which – as the present handbook – is a product of the Rhone-Thur project (Hostmann et al. 2005). In the subsequent 'Projection phase', the *detailed* *planning of the rehabilitation measure* takes place. In order to test whether the project objectives were achieved after *implementation of the rehabilitation measure,* project evaluation is required. *Project evaluation* is the core piece of the present handbook. Its basic principles are discussed in the subsequent chapter 4. Chapter 4 also contains information on the use of indicators and the importance of reference systems. Project evaluation allows for the identification of persisting deficits and – if necessary – the initiation of additional measures for their elimination. Such *adaptive management* is the most suitable planning concept, as it is difficult to predict detailed effects of the measure (Downs & Kondolf 2002). In adaptive management, every project step is considered as a collation of information, the results of which are used to modify or develop the subsequent step (Halbert & Lee 1991). Project evaluation enables the deduction of *lessons for future projects.* Because of the still little experience in rehabilitation, such lessons are of particular value. However, in order to take advantage of

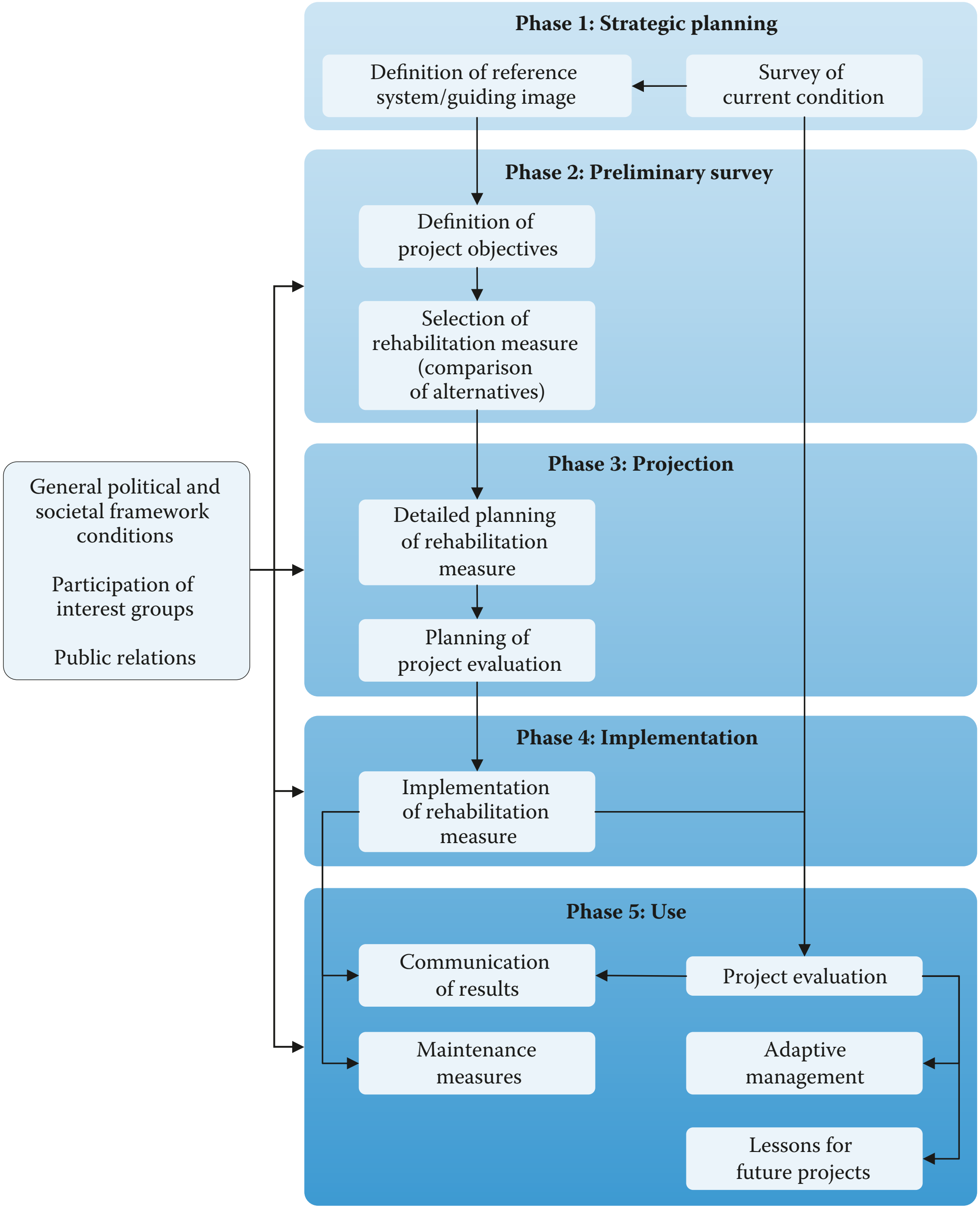


Figure 3.4: Ideal procedure of rehabilitation projects; strongly modified after Holl & Cairns (1996). Division into phases according to the 'Performance Model 95' of the Swiss Association for Engineers and Architects (Schweizerischer Ingenieur- und Architektenverein 1996).

these lessons, *communication of results* is required. Furthermore, additional *maintenance measures* are usually necessary after the rehabilitation measure has been implemented, although ideally, this should not be the case.

3.4 Consideration of abiotic and biotic heterogeneity

Rivers and streams typically show a pronounced spatial and temporal heterogeneity. Both *abiotic* and *biotic* heterogeneity arise from the interaction of time and space (Ward 1989). This heterogeneity influences *morphological* processes, disturbance effects, floods, the spatial distribution of organisms and habitats, and the *successional* stage of vegetation (Gregory et al. 1991). Hence, time and space work together to shape communities and *ecosystems* (Lewis et al. 1996). Biological interactions, such as competition for vital resources, reproduction success and the occurrence of predators, are also important. In addition, natural geographical and climatic differences can influence physical processes, species richness and species composition (Bunn & Davies 2000). A further decisive factor concerning the biological development of rivers and streams is the species pool available for colonisation (Wevers & Warren 1986).

In rehabilitation projects in rivers and streams, the catchment has a particularly strong spatial influence. This does not mean that entire catchments must be rehabilitated. However, it does mean that for measures at the local scale, the processes occurring in rivers and streams must be considered at the catchment scale (Boon 1998). Thus, the longitudinal, lateral and vertical dimensions of the catchment must be taken into account when implementing rehabilitation measures (Lorenz et al. 1997). The method for project evaluation described in the present handbook is intended for projects, which are limited to sections of rivers and streams, but take catchment processes into account.

Successful rehabilitation projects require the consideration of historical events and changes. There are two temporal levels at which changes in rivers and streams can take place: the annual scale and the historical scale. The annual scale refers to *hydrological* phases and unpredictable fluctuations within and between different years. The historical scale refers to events on the scale of decades and centuries (Amoros & Bornette 2002). For the historical scale, historical maps are frequently used, in order to reconstruct river courses which existed decades or centuries ago. However, historical data are not only needed to recreate riverine landscapes. They also provide a basis for an improved understanding of current processes and for predicting future effects of rehabilitation activities (Boon 1998).

Heterogeneity necessitates a systematic assessment of rivers and streams, which should consist of multiple surveys at various points in time (Boon 1998). This applies to surveys of the current condition, as well as to project evaluation after project completion. As different aspects of rivers and streams may be shaped and developed at different times, it must be anticipated that a conclusion on rehabilitation success may similarly vary with the timing of project evaluation. Thus, evaluation results of several years will reflect the dynamic development, while a single evaluation after project completion will provide an incomplete reflection of project success.

4 Basic principles of project evaluation

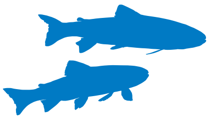
4.1 Status of project evaluation

Project evaluation is an important element of rehabilitation projects and is the core piece of the present handbook. By systematic data collection, project evaluation serves to verify whether the project objectives, which were defined during the planning phase, were achieved (Downs & Kondolf 2002). In the present handbook, project evaluation is defined as follows: With respect to rehabilitation projects conducted in rivers and streams, project evaluation is the examination to what extent the objectives defined by the project managers were achieved. For this purpose, the initial condition is compared with the condition after the rehabilitation measure has been implemented. Indicators serve as tools for project evaluation (for more details on indicators see chapter 4.3). This comparison results in a classification of the project objectives into one of five categories of change: deterioration/failure, no change, slight improvement/small success, medium improvement/medium success and strong improvement/great success. This allows for an appraisal, if and to what extent the individual project objectives were achieved. Conclusions on success therefore exclusively refer to the defined and assessed project objectives, not to the approximation of a river or stream section to a particularly near-natural reference system (for more details on reference systems see chapter 4.4.1). However, the greater the number of project objectives classed as 'successfully achieved', the more likely it is that the rehabilitation measure will also achieve an overall approximation to a reference system.

Project evaluation allows for the identification of flaws in project design, unanticipated effects of the measure and persisting deficits in the rehabilitated section. If necessary, these can be eliminated with the help of additional measures.

Because of the still narrow scientific basis of rehabilitation ecology, project evaluation has an important controlling function, from which also future projects can benefit greatly. In this context, lessons from both successful and less successful projects are of great value. Additionally, results from project evaluation promote a sustainable use of natural resources (Bash & Ryan 2002). However, benefits only result if their is a willingness to admit failures and to communicate results (Kondolf 1995). Additionally, project evaluation allows for conclusions on the efficiency of invested funds. Successful projects can strongly influence and further the acceptance of future projects, while failed projects may have the opposite effect.

There is general agreement among natural scientists, social scientists, economists and politicians that the evaluation of rehabilitation projects in rivers and streams is essential. Until recently, however, project evaluation in Switzerland and abroad has been the exception. Beside the lack of necessary funds, time and labour (Bash & Ryan 2002), the lack of adequate instructions and guidelines has often been stated as a reason for omitting project evaluation. Although, in part, these arguments still apply today, the tendency toward conducting project evaluation is increasing. In Switzerland, project evaluation is particularly carried out in cantons with a high rehabilitation activity. These are, for example, the Cantons of Aargau and Berne. Great importance is also attached to evaluating rehabilitation projects conducted in floodplains of national importance.



4.2 Concepts for project evaluation

4.2.1 Project evaluation in the floodplain conservation park, Canton of Aargau

The floodplain conservation park in the Canton of Aargau came into existence as a result of an initiative by the public in 1993. The aim of the initiative was to create a floodplain conservation park within 20 years, which would cover at least 1 % of the canton's surface area and would protect the threatened riverine floodplains. The relevant law came into force in 1994. Three years later, the Council of the Canton of Aargau authorised 16 million Swiss Francs to be used for the floodplain park by 2003. For the years 2004 to 2009, 23 million Swiss Francs will be made available. Since 1995, various rehabilitation measures are underway. Evidence of their effectiveness is provided by means of project evaluation. The 'Monitoring programme Aargau' (*Kontrollprogramm Aargau*) was created to perform this task. It consists of the following subprojects:

- Long-term monitoring of species richness in the arable land of the Canton of Aargau (*Langzeitbeobachtung der Artenvielfalt in den Nutzflächen des Kantons Aargau, LANAG*). Results are summarised using the *Kessler-Index.*
- Annual spot checks for rare and protected species and habitats.
- *Connectivity* of river and shore: trend analysis and increase in extensive use of contracted fields, crop fields, fallow fields for rotation, dry late-cut fields.
- Periodic appraisals and information on the condition of nature and the effectiveness of nature conservation measures. Information of the public on success stories.

The dynamic processes of rivers and streams attract the recreational public, which, in turn, drives away species sensitive to disturbance. These kinds of species are therefore often not suitable as indicators of dynamic processes. The Floodplain Decree demands – beside other points – the reestablishment of the natural, dynamic *hydrological* regime and *bedload* regime. There is therefore a high demand for relevant indicators. Indicators must also be attractive to the target audience. Experience has shown that the floodplain conservation park can only achieve its goals with support from the public. This necessitates continuous communication. Project evaluation therefore not only serves to optimise implementation measures, but is also a tool for public relations.

4.2.2 Project evaluation for the rehabilitation fund, Canton of Berne

In 1997, the Council of the Canton of Berne passed the Act on Water Use (*Wassernutzungsgesetz, WNG*), which was based on the Federal Law on the utilisation of hydropower. This law regulates the sustainable use of public and private waters, as well as the canton's water management duties. The event prompted environmental groups of the Canton of Berne to create an earmarked fund for the rehabilitation of rivers and streams via a proposal made by the public. The generated rehabilitation fund 'RenF' (Renaturierungsfonds; article 36a of the WNG; RenF, www.be.ch/renf) receives around 3.2 million Swiss Francs annually. Since 1998, approximately 400 projects have been supported with a total of 12 million Swiss Francs. In 2000, a concept for project evaluation was developed. For the purpose of project evaluation, RenF distinguishes seven types of rehabilitation measures: channel rehabilitation, opening of culverts, structuring and widening of the river bank, bedload regime, creation of new side arms, rehabilitation of lake shores and floodplain rehabilitation. The concept is based on the principles of a type test. For each type, the effectiveness of the implemented measure is examined for selected projects. For each type, indicators are suggested based on the objectives defined. Only morphodynamic, physico-chemical and biological indicators are considered. However, the significance of socio-cultural indicators is acknowledged. The majority of the biological indicators are aquatic organisms (fish and invertebrates). For the recommended indicators for different types of measures see Table 4.1 or Kirchhofer & Breitenstein (2000).

4.2.3 Project evaluation in floodplains of national importance

The Floodplain Decree for the conservation of floodplains of national importance instructs the cantons to take adequate conservation and maintenance measures for preserving intact objects (Lachat et al. 2001). Project evaluation is carried out in floodplains, in order to examine whether the conservation goals of the Floodplain Decree have been achieved. At the same time, it serves as a tool for optimising the conservation of floodplains. The goals of project evaluation are:

- monitoring of floodplains and comparison with the target state
- early detection of development trends and threats
- examination of effectiveness and efficiency of floodplain conservation measures
- problem analysis of floodplain conservation
- identification of need for action and of possibilities for optimisation, in order to provide effective and efficient floodplain conservation
- information of stakeholders and public in a manner appropriate to the target audience
- monitoring of conservation goals of the Floodplain Decree

First and foremost, the examinations serve to evaluate efforts of floodplain conservation. In a second instance, they provide a basis for continuous monitoring in floodplain objects (Bonnard & Roulier 2004).

The focal points and concepts of project evaluation differ strongly for the floodplain conservation park (Canton of Aargau), the rehabilitation fund (Canton of Berne) and the floodplains of national importance. The present handbook offers a tool for evaluating rehabilitation projects in rivers and streams, which may contribute to standardising evaluation methods. Here, indicators similarly serve as tools for evaluating relevant processes.

4.3 Indicators

Indicators are measurable parameters, which provide valuable information on the condition of an *ecosystem* and its relevant processes (Lorenz et al. 1997). In the present handbook, indicators are defined as tools for the quantitative, semi-quantitative or qualitative assessment of project objectives. Both *biotic* and *abiotic* indicators are used. In the following, desirable indicator properties are discussed, examples of possible indicators are given and the indicators characterised in this handbook are presented.

4.3.1 Indicator properties

Often biological indicators, such as the presence of certain habitat-specific animal species, such as beaver (*Castor fiber*), otter (*Lutra lutra*), salmon (*Salmo salar*) or kingfisher (*Alcedo atthis*), are preferred to physical and chemical indicators, as they are more appealing to the public. Such *flagship species* can help to mobilise public support and motivate the parties involved. The value of such indicators should not be underestimated. However, in order to provide an adequate reflection of the dynamics of rivers and streams, additional, integrative indicators, which provide information on a number of processes, are necessary.

Project evaluation in floodplains of national importance consists of seven steps:

Administrative programme (legal norms)	**Evaluation of implementation and procedure**
Agreements with authorities, resources (execution structure)	
Action plans, intermediate outputs (execution plan)	
Outputs (final administrative products)	
Impacts, political addressees (target groups)	**Evaluation of effectiveness**
Inspection of on-site effectiveness	
Overall evaluation	**Overall evaluation**

In order for the indicators to be suitable for practice, they should fulfil as many of the following properties as possible (Cairns et al. 1993, Angermeier & Karr 1994, Lorenz et al. 1997).

- easy to measure and interpret
- continuously measurable and applicable in different areas
- biologically and socially relevant
- integrative
- cost efficient
- not destructive
- guideline values should be available
- temporal and spatial compliance with project conditions

4.3.2 Possible indicators

The number of possible indicators for project evaluation is practically infinite. Selecting suitable indicators is therefore not an easy task (Cairns et al. 1993). A careful selection is, however, essential to the effectiveness of long-term project evaluation (Cairns et al. 1993). Table 4.1 shows a collation of assessment parameters from the following sources:

- indicators for evaluating rehabilitation projects in watercourses of the Canton of Berne (RenF, see chapter 4.2.2)
- parameters used in the *Modular Stepwise Procedure* for assessing the ecological status of rivers and streams in Switzerland (see chapter 2.2.1)
- case study on the evaluation of the Skjern River rehabilitation project, Denmark (see the following paragraph)

To enable a good overview, indicators in Table 4.1 are divided into different groups. Faunal indicators are listed at the end.

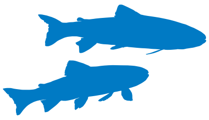
Skjern River rehabilitation project, Denmark

The Skjern River is located in south-west Jütland and is – in terms of flow – Denmark's largest river. Until 1962, the Skjern River meandered through its valley and flooded its banks several times a year, thereby producing an ecologically valuable network of lakes, floodplains and ponds. Between 1962 and 1968, however, its catchment was drained, canalised and diked for intensive cultivation. The wetlands were reduced to only 2 % of their original size. The consequences were: reduction of *biodiversity* (otter, waterfowl and salmon populations were particularly affected), reduction of the river's capacity for self-purification, subsidence and an increase in nutrient loading. In 1998, the Danish Parliament decided to rehabilitate 20 km, i.e. 2,200 ha, of the Skjern River. The aim of the rehabilitation project was to recreate a coherent nature conservation area, which would offer habitats for floodplain species and riparian species and would enable re-colonisation by displaced species. Furthermore, the new wetlands would serve as buffer zone between the river and the agricultural land, thereby reducing eutrophication in the Skjern River and its fjord. A further important goal was to develop the conservation area as a centre for recreation for the public. The rehabilitation measures were implemented between 1999 and 2002. Among other measures, the dams were removed and the original meandering river course was excavated. The project cost 34 million Euro (National Forest and Nature Agency 1999). A detailed cost-benefit analysis is presented in Dubgaard et al. (2002). Since completion of the project, comprehensive project evaluation, using the indicators listed in Table 4.1, is underway.

In all three examples, socioeconomic indicators were neglected. This is a frequent shortcoming in project evaluation. Although the present handbook focuses on the sector 'Environment and ecology', project objectives for the sectors 'Service to society', 'Economy' and 'Implementation process' are also taken into account (see chapter 6). In the presented evaluation method, the success of the individual project objectives is assessed, not that of the superior sectors to which they belong. The sector 'Environment and ecology' is an exception. Here, both the success of the individual project objectives, as well as that of the superior sector 'Environment and ecology' can be evaluated. However, this is only the case if certain conditions are met (for more details see chapter 10).

Table 4.1: Indicators and parameters used for project evaluation and for the assessment of rivers and streams: classification into different groups.

Group	Indicator		
	RenF, Canton of Berne (Kirchhofer & Breitenstein 2000)	**Modular Stepwise Procedure** (BUWAL) * = method under development	**Skjern rehabilitaiton, Denmark** (Dubgaard et al. 2002)
Physical appearance		Iron sulphide solids/refuse odour	
		Heterotrophic growth	
		Clogging	
		Plant growth	
		Foam	
		Silt	
		Turbidity	
		Discolouration	
Continuity of flow	Obstacles to migration (divided into height categories)	Mapping and description of all obstacles disrupting the continuity of flow	
Bedload	Aggradation	Solids regime*	Retention and deposition of solids
	Erosion		Suspended solids
	Amount of transported bedload, transport distance		
	Bedload dynamics and bedload resettlement		
Hydraulics	Variability of width	Variability of wetted width	Water level, water level fluctuations
	Variability of flow velocity	Flow behaviour*	Inundation dynamics
	Variability of depth		
Hydrology		Flow regime*	
		Flow dynamics*	
Morphology	Assessment of space requirements		Shape and profile of the river and its tributaries
	River course: number of side arms at different discharges, lateral connection of new watercourses to the main thalweg channel		Topography and levelling of the river system
	Watercourse: development		Physical habitats
	Ecomorphological class		
	Topography, space requirements		
	Variability of categories of fish habitat		
Organic material	Large wood		Deposition of nutrients, retention of nutrients
			Nutrient cycle
River bed	Degree of clogging	River bed width	Levelling of the river bed
	Particle size composition	Anthropogenic modification of river bed	
	Structural variability		
	Composition of river bed		
River bank	Proportion of graded and rocky river bank	Width and structure of riparian zone	River bank erosion
	Inundation areas	Anthropogenic modification of riparian zone	
	Width of riparian ecotone (space requirement BWG)		
	River bank structures: large wood, riprap, riparian vegetation		
Vegetation, aquatic	Algal growth on river bed	Diatom index	Succession of aquatic vegetation



Group	**Indicator**		
	RenF, Canton of Berne (Kirchhofer & Breitenstein 2000)	**Modular Stepwise Procedure** (BUWAL) * = method under development	**Skjern rehabilitaiton, Denmark** (Dubgaard et al. 2002)
	Aquatic vegetation		Development of *Luronium natans* and *Oenanthe fluviatilis*
Vegetation, terrestrial	Amphibians, vegetation		Succession of terrestrial vegetation
	Degree of shading and sun exposure		
	Riparian plant communities: species spectrum, extensiveness of cover		
	Spatial distribution of plant communities		
	Succession		
	Temperature		
	Indicator organisms		
Connectivity	Connectivity within channel network, connectivity gradient		
	Connectivity with landscape		
	Watercourse: lateral connection of new watercourses to the main thalweg channel		
Water quality	Organic pollution	Ammonia/ammonium	Total phosphor
	Oxygen concentration	Chloride	Total nitrogen
	Temperature	Specific conductance	Total iron
		Geochemical parameters	Soluble phosphor
		Total phosphor	Soluble iron
		Total nitrogen	Nitrate
		Nitrate	Nitrite
		Nitrite	pH-value
		Ortho-phosphate	Quality of groundwater
		pH-value	Sulphate
		Pesticides, organic micropollutants	Temperature
		Oxygen	
		Heavy metals	
		Temperature	
		Temperature regime*	
FAUNA			
Macroinvertebrates, aquatic	Abundance	Taxonomic composition of macrozoobenthos	Changes in the population over time and space
	Number of species		
	Ecotypes		
Macroinvertebrates, terrestrial	Abundance		Changes in the population over time and space
	Number of species		
	Ecotypes		
Amphibians	Presence of species		
Fish	Age classes	Species spectrum and dominance ratio	Presence of species
	Number of species	Deformities and abnormalities	
	Biomass	Fish density of indicator species	

Group	**Indicator**		
	RenF, Canton of Berne (Kirchhofer & Breitenstein 2000)	**Modular Stepwise Procedure** (BUWAL) * = method under development	**Skjern rehabilitaiton, Denmark** (Dubgaard et al. 2002)
	Species spectrum from fish catch statistics	Population structure of indicator species (age class, reproduction)	
	Reproduction of fish species, presence of juvenile fish		
	Reproduction of gravel spawning fish species: number of redds, number of brown trout fish larvae, grayling etc.		
	Fitness index		
	Redds, presence of juvenile fish		
	Larval and adult fish fauna		
Reptiles	Presence of species		
Mammals	Presence of species		Development of otter population
Birds	Presence of species		Presence of species

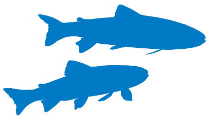
4.3.3 Characterised indicators

In the present handbook, 50 indicators for evaluating rehabilitation projects in rivers and streams are characterised (Table 4.2). The composition of the list is strongly dependent on the authors' expertise, which lies in particular in the aquatic sector. Beside the characterised indicators, many other parameters are possible, which would provide additional valuable information on the effect of rehabilitation projects. The indicator list is therefore not exhaustive and can be expanded. Such user-defined indicators can be added to the Excel template 'Selection and evaluation'. In the presented list, particularly terrestrial indicators, such as amphibians, reptiles, birds, insects and spiders, are missing. In addition, the list does not include *flagship species*, which – depending on the type of project – may facilitate public relations. In contrast to previous concepts, socioeconomic indicators are considered in addition to conventional indicators.

As in Table 4.1, the indicators in the Excel template were assigned to different indicator groups (e.g. acceptance, river bed, fish, etc.). This allocation serves to facilitate orientation. Based on the defined objectives, indicators are grouped into indicator sets. Project objectives (e.g. improved lateral connectivity) are achieved by concrete rehabilitation measures (e.g. structuring of the river bed, reconnection of backwaters, oxbows and floodplains). In order to evaluate to what extent the project objectives were achieved by a rehabilitation measure, complete indicator sets are recommended (see chapter 7). These indicator sets are based on appraisals by experts and recommendations made by the authors. Alternatively, appropriate indicator sets can be assembled based on individual project requirements and project objectives (see chapter 8).

For each of the 50 indicators, indicator method sheets are included in Appendix I, in which instructions concerning survey method and analysis are given. Indicators are surveyed before and after implementation of the measure, in order to enable a comparison and to identify changes (see chapter 10).

The indicator numbers used in Table 4.2 are given for the purpose of identification. The method sheets in Appendix I are arranged according to these numbers. The letters A, B and C in the column labelled 'Effort level' show the category of survey effort. The survey effort level refers to the number of person days which must be expected for preparation, survey and analysis of a single indicator per measurement (including the minimal number of replicates).



The minimal number of measurements which allow for natural variability, and which therefore enable a representative conclusion, is given for each indicator in its method sheet. Indicators are divided into three categories of effort level:

Effort level A	Effort level B	Effort level C
Low effort: < 2 person days	Medium effort: 2-3 person days	High effort: > 3 person days

4.4 References

4.4.1 Reference systems

Reference systems represent the condition, which river managers wish to achieve by means of rehabilitation. When planning rehabilitation projects and when later evaluating them, reference systems act as models (SER 2002). A rehabilitation project can be considered successful, when the rehabilitated river

Table 4.2: Indicators for evaluating rehabilitation projects in rivers and streams as characterised in the present handbook (arranged into groups). Effort level: A < 2, B: 2-3, C > 3 person days.

Nr.	Indicator group	Indicator	Effort level
1	**Project acceptance**	Acceptance by interest group	A
2	**Project acceptance**	Acceptance by entire public	B
3	**Project acceptance**	Acceptance by project work group	A
4	**Longitudinal connectivity**	Barrier-free migration routes for fish	A
5	**Recreational use**	Number of visitors	A
6	**Recreational use**	Variety of recreational opportunities	A
7	**Recreational use**	Public site accessibility for recreation	A
8	**Fish**	Age structure of fish population	C
9	**Fish**	Fish species abundance and dominance	C
10	**Fish**	Diversity of ecological guilds of fish	C
11	**Fish habitat**	Presence of cover and instream structures	A
12	**Bedload**	Bedload regime	C
13	**Hydrogeomorphology and hydraulics**	Inundation dynamics: duration, frequency and extent of flooding	A
14	**Hydrogeomorphology and hydraulics**	Variability of visually estimated wetted channel width	A
15	**Hydrogeomorphology and hydraulics**	Variability of measured wetted channel width	B
16	**Hydrogeomorphology and hydraulics**	Variability of flow velocity	C
17	**Hydrogeomorphology and hydraulics**	Depth variability at bankfull discharge	B
18	**Costs**	Project costs	A
19	**Landscape**	Diversity and spatial arrangement of habitat types	C
20	**Landscape**	Aesthetic landscape value	A
21	**Macroinvertebrates**	Richness and density of terrestrial riparian arthropods	B
22	**Macroinvertebrates**	Occurrence of both surface water and groundwater organisms in the hyporheic zone	A
23	**Macroinvertebrates**	Taxonomic composition of macroinvertebrate community	A
24	**Macroinvertebrates**	Presence of amphibiontic species in the groundwater	A
25	**Organic material**	Short-term leaf retention capacity	A
26	**Organic material**	Quantity of large wood	A
27	**Organic material**	Quantity and composition of floating organic matter and abundance and diversity of colonising snails	A
28	**Stakeholder participation**	Satisfaction of interest groups with the design of the participation process	A
29	**Stakeholder participation**	Satisfaction of the public with participation opportunities	A
30	**Stakeholder participation**	Satisfaction of interest groups with participation opportunities	A
31	**Refugia**	Availability of three types of refugia (hyporheic refugia, shoreline habitats, and intact tributaries)	C
32	**River bed**	Permeability of river bed	B
33	**River bed**	Temporal changes in diversity of geomorphic river bed structures	B C
34	**River bed**	Clogging of hyporheic sediments	A
35	**River bed**	Grain-size distribution of substratum	A
36	**River bed**	Diversity of geomorphic river bed structures	A B

Nr.	Indicator group	Indicator	Effort level
37	**River bed**	Degree and type of anthropogenic modification	A
38	**Temperature**	Spatial and temporal variation in water temperature	A
39	**Transition zones**	Food subsidies across land-water boundaries	C
40	**Transition zones**	Exchange of dissolved nutrients and other solutes between river and groundwater	C
41	**Transition zones**	Community composition and density of small mammals on floodplain	C
42	**River bank**	Width and degree of naturalness (vegetation, composition of ground) of riparian zone	A
43	**River bank**	Temporal changes in the quantity and spatial extent of morphological units	A
44	**River bank**	Shoreline length	A
45	**River bank**	Quantity and spatial extent of morphological units	A
46	**River bank**	Degree and type of anthropogenic modification	A
47	**Vegetation**	Presence of typical floodplain species	A
48	**Vegetation**	Succession and rejuvenation of plant species on floodplains	C
49	**Vegetation**	Temporal shift in the mosaic of floodplain vegetation categories	B
50	**Vegetation**	Composition of floodplain plant communities	A

or stream section reaches a state similar to the reference system (Chapman 1999). Spatial, historical and theoretically constructed reference systems are possible.

Ideally, unaffected or only slightly affected river or stream sections within the same geographical area serve as spatial reference systems. However, especially in the intensively used areas of the Swiss lowlands such sections are scarce. Reestablishment to the original condition of a river or stream section is therefore not a realistic objective, especially as the undisturbed condition is usually unknown. In the floodplains of national importance, for example, 18 floodplain objects serve as spatial reference systems for evaluating rehabilitation projects in floodplains. These are surveyed at time intervals of five to ten years, in order to keep track of their natural development (Bonnard & Roulier 2004). The reference objects represent the best possible approximation to the pristine condition. A certain degree of irreversible *anthropogenic* modification of the landscape, which also affects watercourses, must be accepted for a reference system – at least this is the case for Switzerland and the rest of Central Europe (Bundi et al. 2000).

Old maps or records on the presence of species can be used for creating historical reference values. Using such historical information, e.g. the original river course or the original species richness can be reconstructed. However, historical data are usually only available for certain aspects and often only for large rivers. In the case of theoretically reconstructed reference values, a reference condition is derived from concepts of aquatic ecology and general scientific insights. For this purpose, *geomorphological*, *hydrological*, zoological, botanical and other principles are taken into consideration. When deducting a theoretical reference system, however, there is much leeway for interpretation. Furthermore, the complex processes, which determine the condition of a river or stream system, have usually been poorly examined. As is the case for spatial reference conditions, a certain degree of irreversible anthropogenic modification to the watercourse must be accepted for historical and theoretically constructed reference systems. For all three approaches, it is difficult to define a reference condition, which reflects the natural variability of a watercourse (SER 2002).

Despite the addressed difficulties, the need for suitable and realistic reference systems and reference values is indisputable. Also for the *Modular Stepwise Procedure* – which is designed to assess the ecological status of rivers and streams – the issue concerning reference systems requires urgent attention. At the level

F (regional survey), the level of survey detail is relatively small. The purpose of these surveys is to provide both specialists and decision makers in politics and administration with a quick overview of the condition of a watercourse and its impairments. To facilitate such an overview, a standard classification scheme using a scoring system is used in the different modules. Total scores can be represented in the site plans by different colours. This way, water body sections with distinct deficits can be easily identified (BUWAL 1998). At the level S (system scale survey), such an approach would be insufficient. At this level, entire watercourses are analysed. Survey effort and the level of survey detail are considerably greater than at level F. A detailed analysis, which puts the different ecological deficits of the examined watercourse into a wider context, provides a basis for planning and prioritising measures (BUWAL 1998). At this level, an evaluation based on comparisons with and deviations from aquatic reference conditions is in preparation. To date, however, such reference conditions for assessing Swiss rivers and streams have not been substantiated in the *Modular Stepwise Procedure,* neither in the shape of spatial, nor historical or theoretical references.

4.4.2 Guiding image

Defining a 'guiding image' is a plausible alternative to defining a reference system. A guiding image is a case-specific vision for a watercourse section selected for rehabilitation (Muhar et al. 1995). It describes the natural, ecological potential, which the river or stream in question would have, if it was in an unimpaired state, but under consideration of the general cultural and irreversible framework conditions (Muhar et al. 1995, Jungwirth et al. 2002). Such general framework conditions include, for example, existing usage rights, land and resource uses, and legal constraints, such as they may exist for conservation areas (Jungwirth et al. 2002). When defining a guiding image, elements of spatial, historical and theoretically constructed reference conditions may be incorporated. In project evaluation, the guiding image and the achieved final condition are compared, and the degree of approximation to the guiding image is determined. Defining a realistic guiding image requires detailed knowledge of the current condition of the watercourse section selected for rehabilitation. For this reason, a comprehensive analysis of the current condition and the prevailing deficits is required.

The project-specific guiding image, which the present chapter refers to, should not be confused with the 'Leitmotif for rivers and streams in Switzerland' (*Leitbild Fliessgewässer Schweiz*) by the Federal Office for the Environment, the Federal Office for Agriculture and the Federal Office for Spatial Development (BUWAL/BWG 2003). The first serves as a concrete visionary goal of a rehabilitation project. The second outlines measures, which the cantons and local communities can take, in order to achieve sustainable management of rivers and streams. These recommendations focus on sufficient space for the watercourse, sufficient water supply and sufficient water quality.

4.4.3 Guideline values

The present handbook does not give instructions on how to define a guiding image. It does, however, discuss important objectives of rehabilitation projects. Based on these project objectives, a guiding image can be substantiated. Project evaluation relies on comparing selected objectives in their initial state and their state after rehabilitation. For such a comparison, measured values are required for the individual project objectives. These are provided by indicators. The determined indicator values are compared with indicator threshold values for the near-natural and the unnatural state. In order to standardise an indicator value, the indicator threshold value for the near-natural state is equated with the value 1, and the indicator threshold value for the unnatural state is equated with the value 0. This way, the determined indicator value can be transformed into a value between 0 and 1, according to an indicator-specific *standardisation* procedure. This standardised value therefore represents the indicator’s degree of naturalness or satisfaction. The indicator threshold values, which correspond to the values 0 and 1, are termed ‘guideline values’. Such guideline values were defined for each indicator by the respective method sheet author, based on expert knowledge and experiences from the literature. The estimations generally refer to Swiss lowland rivers of medium to large size. The 0- and 1-guideline values and the *standardisation* procedures are shown in the method sheets. If, by way of an exception, the suggested guideline values should not be suitable, they can be adapted by the handbook user. However, such adaptations must be made by relevant experts. This approach, which uses fixed guideline values, does not take differences between river types into account. The guideline values are therefore simply rough estimations to enable an initial evaluation. For some indicators, it is not possible to set indicator threshold values. For these indicators, semi-quantitative or qualitative characteristics are used as alternatives. An adaptation of the guideline values for different river types is desirable, but is beyond the scope of the present handbook.

5 Scope of handbook

5.1 Status in the project procedure

In Figure 3.4, the ideal procedure of rehabilitation projects in rivers and streams is shown. The present handbook makes contributions to the following elements of the project procedure:

5.1.1 Definition of project objectives

The present handbook specifies the most important project objectives of rehabilitation projects in rivers and streams (chapter 6). The handbook user can apply this compilation as an aid for planning. However, the handbook does not provide direct decision support for defining project objectives. For such support, consultation of Hostmann et al. (2005) is recommended.

5.1.2 Selection of rehabilitation measure

A comparison of the project objectives with the measures available for rehabilitation will facilitate planning. The measures are discussed in chapter 7. For support on selecting suitable rehabilitation measures, again, consultation of Hostmann et al. (2005) is recommended.

5.1.3 Planning of project evaluation

Project evaluation is the core piece of the present handbook. By evaluation, it is determined if and to what extent the different objectives of rehabilitation projects were achieved. When planning evaluation, indicators suitable for assessing project objectives are selected. For frequently conducted rehabilitation measures complete indicator sets for project evaluation are recommended in chapter 7. These sets are based on the project objectives relevant to the selected measure. Alternatively, the handbook user can assemble user-defined indicator sets tailored to specific project needs (see chapter 8). In this case, the project objectives also serve as a basis for selecting suitable indicators (see chapter 6). Selection can be carried out automatically using the Excel template 'Selection and evaluation' (Appendix III).

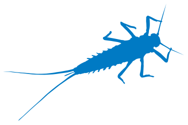
5.1.4 Project evaluation

Planning is the first step of project evaluation. Surveying the indicators is the second step. All information required for indicator surveys is provided in the indicator method sheets (chapter 9 and Appendix I). In the third and last step, indicator results are analysed. For this step, a concept is presented, the implementation of which is facilitated by the Excel template 'Selection and evaluation' (chapter 10 and Appendix III).

5.2 Suitability of concept

The present handbook provides a tool for evaluating rehabilitation projects. This includes projects, which, for example, are aimed at improving the *morphology* and dynamics of rivers and streams. However, application of the presented concept is not limited to pure rehabilitation projects. It is also suitable for projects, which focus on flood protection, as today in Switzerland, these nearly exclusively go hand in hand with rehabilitation measures. However, the presented evaluation method can not be used to assess flood safety. For such an assessment, a separate river engineering quality control carried out by experts is required. The method is primarily a tool for inspecting the extent to which project objectives have been achieved. Its purpose is not to assess the overall condition of a river or stream. However, the more project objectives are evaluated, the more accurate a conclusion on the approximation to a reference system or guiding image will be.

In order to have the potential for ecological improvement, the project should fulfil as many of the following properties as possible.



- The project features a guiding image with clearly defined rehabilitation objectives.
- The project will result in a measurable improvement of structural diversity.
- The project will result in a measurable improvement of the *hydrogeomorphological* dynamics of the river or stream.
- The project will result in a measurable improvement of the ecological condition.
- The measures will not cause any permanent damage to the river or stream ecosystem.
- The project will result in a measurable improvement of flood protection or will continue to safeguard it.
- The project will increase the *resilience* of the river or stream.

Limitations or difficulties in the application of the handbook may occur in the following instances:

Evaluation of water quality

As water quality has improved over the past 30 years due to the introduction of wastewater treatment plants (Fischnetz 2004), measures for enhancing water quality are not a high priority in Switzerland. For this reason, no specific indicators for evaluating water quality are discussed in the present handbook. If necessary, these can be added by competent users and incorporated into project evaluation.

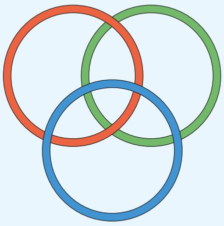
Modifications to flow regime

In many places, river and stream sections are subjected to hydropower use or water abstraction. Such activities modify the flow regime and lead to river segments with *hydropeaking* or *residual flow.* Here, it is extremely difficult to achieve ecological improvement and to reach a near-natural condition, as the modified flow regime may antagonise rehabilitation measures. However, even in this case, a certain degree of improvement can be expected. Most of the indicators recommended in the present handbook can also be used in river segments with hydropeaking or residual flow. Only few indicators are unsuitable for such segments. These are indicators N° 14 'Variability of visually estimated wetted channel width, N° 15 'Variability of measured wetted channel width', N° 16 'variability of flow velocity', N° 17 'Depth variability at bankfull discharge', N° 34 'Clogging of hyporheic sediments' and N° 41 'Community composition and density of small mammals on floodplain'. Indicators for evaluating the effects of hydropeaking are presented in Meile et al. (2005).

6 Objectives of rehabilitation projects

The present handbook exclusively addresses rehabilitation projects in rivers and streams. The concept for the recommended evaluation method is based on the guideline 'Flood protection in rivers and streams' (*Hochwasserschutz an Fliessgewässern;* BWG 2001). In this guideline, the three sectors society, environment and economy are defined as equal elements of sustainability (see also Figure 2.19). This is a universally valid principle, which is also recommended for planning and evaluating rehabilitation projects. For the three sectors, important project objectives are defined (according to phase 2 in Figure 3.4), which should be considered when rehabilitating rivers and streams (Table 6.1). Further important project objectives are political acceptance and stakeholder participation, which characterise the implementation procedure of a project. However, 'Implementation' is not an element of sustainability and is therefore not included in Table 6.1. Project evaluation takes place at the level of project objectives. Indicators are used to assess if and to what extent the project objectives were achieved. The more project objectives register a measurable improvement, the more successful a project is. The four sectors primarily serve to allocate project objectives into groups.

The project objectives listed in Table 6.1 are based on the authors' expertise. Beside these, additional project objectives may be



Society: service and protection	Environment and ecology	Economy
Project objectives:		
Sustainable flood protection	Near-natural flow regime	**Keeping the budget**
Sustainable supply of drinking water	**Morphological and hydraulic variability**	Increase in jobs
Provision of high recreational value	**Near-natural bedload regime**	Rise in real estate prices
	Near-natural temperature regime	
	Longitudinal connectivity	
	Lateral connectivity	
	Vertical connectivity	
	Near-natural water quality	
	Near-natural abundance and diversity of floodplain vegetation	
	Near-natural abundance and diversity of fauna	
	Cycling of organic matter	

Table 6.1: Possible project objectives of successful rehabilitation projects in rivers and streams. Project objectives are allocated to the three elements of sustainability according to the Federal Office for the Environment (Weber 2001). Project objectives, which are included in the evaluation method recommended in the present handbook, are shown in bold.

of interest. For the sector 'Environment and ecology' the list is comprehensive. A summary of success is therefore carried out for this sector, in addition to the evaluation of the individual project objectives. For the sectors 'Society', 'Economy' and 'Implementation', however, only few project objectives are discussed. Therefore, in the present handbook, no guidelines for summarising success in these three sectors are given (see chapter 10). The evaluation ends with the assessment of the individual project objectives. The significance of the project objectives is discussed in the following paragraphs.

6.1 Society: service and protection

Rivers and streams and their floodplains offer numerous possibilities for use, such as supply of drinking water, shipping transport, breakdown of pollutants, hydropower production and fishing. They are also appreciated as areas for recreation and leisure (Sparks et al. 1990). With such different demands for use, there is a high potential for conflict (Ehrenfeld 2000).

Beside the services provided by a river system and the possibilities for use, rivers and streams also hold dangers for local residents. Flood security is therefore an important objective when rehabilitating rivers and streams. Safeguarding and re-establishing aspects of service and protection of riverine systems are important objectives, which are often also of economic interest.

The following project objectives are of relevance to society: sustainable flood protection, sustainable supply of drinking water and provision of high recreational value.

6.1.1 Sustainable flood protection

Fortification measures for flood protection can not be reconciled with the ecological goals of rehabilitation projects. In contrast to these, ecological flood protection measures are based on providing more space to the river. Floodplains and retention areas serve as natural flood protection structures, as they can absorb peak flows and buffer short-term water level fluctuations (Pinay et al. 1990, Bayley 1991). Widening the river bed and removing man-made embankments help to improve lateral *connectivity* and can increase water retention in floodplains. If the space requirements of a river are taken into account, floods can become predictable events with limited spatial dimensions (Nienhuis & Leuven 2001).

In the present handbook, no indicators for the project objective 'sustainable flood protection' are suggested. In order to evaluate flood protection, a separate river engineering quality control is required.

6.1.2 Sustainable supply of drinking water

Natural floodplains, with their postglacial, permeable soils, are reservoirs for groundwater, which is suitable for supplying drinking water. Alluvial groundwater is mainly regenerated by the *infiltration* of river water and hill slope groundwater. Engineers took advantage of the natural infiltration process, by building the wells for pumping groundwater close to rivers. The proportion of freshly infiltrated, i. e. *hyporheic*, groundwater in the extracted mixed groundwater depends on the permeability of the river bed and river bank (specific infiltration rate). In the event of floods, this proportion is greater and varies depending on the *morphology* of the river course and of the riparian zone.

Reservoirs of drinking water have a life span of many decades. If such reservoirs are located in sections with widened river beds, the proportion of freshly infiltrated water increases and the residence time of the extracted mixed groundwater may be reduced to an unwanted degree. The same applies when an *adjacent parallel canal* is constructed or widened. In groundwater protection areas, rehabilitation projects in rivers and streams are subject to special regulations. These ensure that rehabilitation projects have exclusively positive effects on the supply of drinking water.

6.1.3 Provision of high recreational value

Beside ecological and river engineering functions, rivers and their floodplains play an important role as living space and recreation area for the local population. Some rivers even serve as national destinations for recreation and leisure (e.g. Aare River in Berne). The goal of providing high recreational value should therefore be taken into consideration when planning and evaluating rehabilitation projects.

Rivers and streams and their floodplains do not only offer space for leisure activities, such as walking, cycling, bathing, fishing, jogging and Nordic walking, but are also important areas for nature observation, relaxation and social interaction (Gloor & Meier 2001). Studies have shown that the local population favours natural, multipurpose, accessible river landscapes (House & Sangster 1991, Junker et al. 2003). It is therefore recommended to evaluate the recreational value of a river landscape – for example, using indicators, such as number of visitors, public site accessibility for recreation, Variety of recreational opportunities and the aesthetic landscape value.

6.2 Environment and ecology

The ecological functional capability of a river or stream is maintained by natural, system-specific processes and by the species richness and habitat *diversity* relying on these processes (Angermeier & Karr 1994, Bradshaw 1996). It is also dependent on the degree of the ability of the river or stream to regenerate and restructure (Muhar & Jungwirth 1998). The ecological functional capability therefore refers to the *resilience* of a watercourse, rather than its present condition (Angermeier 1997). Dynamic processes and continuous reorganisation, which drive *rejuvenation*, are important characteristics of ecological functional capability. These also include seasonal fluctuations in flow, temperature and turbidity (Jungwirth et al. 2002). Chronic changes, such as *hydropeaking*, however, can damage a system's resilience and hence its ecological functional capability (Frissell & Bayles 1996).

The main project objectives, which contribute to re-establishing the ecological functional capability of a river or stream, are discussed in the following paragraphs.

Figure 6.4: Leisure activities at the Thur River widening at Gütighausen, ZH, 2005 (photo: A. Peter, Eawag).

6.2.1 Near-natural flow regime

A near-natural flow regime determines important habitat qualities of rivers and streams, such as water depth, flow velocity and the supply of nutrients, large wood and *bedload* (Angermeier 1997, Stromberg 2001). Rivers and streams with a near-natural flow regime feature natural inundation patterns and natural flow dynamics. A strongly modified flow regime has a detrimental effect on river organisms, such as water plants, invertebrates, fish and *decomposers*. This impairment must be taken into consideration when evaluating measures, which have been implemented in sections with strongly modified flow regimes. In Switzerland, measures for improving the flow regime have – so far – only rarely been

Figure 6.2: Bird observation at Broc, FR, as a form of recreational use, 2003 (photo: Floodplain Advisory Office SCZA).

Figure 6.3: Camping at the Thur River at Lütisburg, SG, July 1999 (photo: Floodplain Advisory Office SCZA).

Figure 6.5: Morphological and hydraulic variability at the Thur River widening at Schäffäuli, TG/ZH, 2003 (photo: A. Peter, Eawag).

conducted. They only take place when the operation system of a run-of-river power station is ecologically adapted, when the *residual flow* is increased or when water abstraction is abandoned.

The project objective 'near-natural flow regime' is listed in Table 6.1 because of its essential role. However, in the recommended evaluation scheme, it is not included as project objective, as measures for rehabilitating it are rarely conducted.

6.2.2 Morphological and hydraulic variability

Beside a near-natural flow regime, additional physical processes are essential to the development of habitats and for providing *refugia* for flora and fauna. At the level of a river section, gradient, discharge depth, river width and sediments are particularly crucial parameters, which are responsible for *morphological* conditions (Jungwirth et al. 2003). The morphological development of habitats is especially dependent on dynamic processes of erosion and sedimentation (Muhar & Jungwirth 1998).

The *hydraulic* conditions are determined by flow regime, geometry, gradient and flow resistance. Flow resistance is dependent on particle friction, i.e. particle size distribution, and structural changes caused, for example, by gravel banks and groynes (Zarn 1997). These parameters influence flow velocity, discharge depth, shear stress on the river bed, sediment transport and river bed stability. In rivers and streams rich in structure, the flow pattern is additionally dependent on large wood, vegetation and other instream structures on the river bed. Compared to watercourses poor in structure, they feature greater current variability, and hence a greater number of available habitats. Areas of still water, which may serve as refugia and niches to benthos and fish, are a further result of structural variability (Jungwirth et al. 2003).

6.2.3 Near-natural bedload regime

Flow regime and the transport of solids are important factors, which influence the morphological dynamics of the river bed. Transported solids include *bedload*, suspended solids and floating matter. Bedload is transported at the stream bed surface and is reduced to small pieces in the process. It originates from lateral and vertical erosion and from tributaries. Suspended solids consist of sand, silt and fine organic particles. Floating material consists of organic particles, such as leaves, fruits, and wood which are transported at the water surface (Jungwirth et al. 2003).

Figure 6.6: Bedload sediments in the Rhone River at Pfynwald, VS, August 2001 (photo: Eawag).

Important factors, which shape the river bed, are the available *bedload* and the transport capacity of a watercourse. If transport capacity is greater than bedload input, river bed incision occurs. This is particularly the case when the bedload input is reduced due to upstream retention or direct removal of bedload. Rivers and streams with artificially narrowed cross sections have a particular tendency toward river bed incision. If the bedload input is greater than that which can be moved by the water's friction force, the river bed is raised (Jungwirth et al. 2003).

In dynamic rivers and streams, floods cause the solids to be stirred up and resettled and reshape the river bed (Jungwirth et al. 2003). If the solids are not stirred up, *clogging* will occur. Clogging inhibits the exchange between river water and groundwater, which jeopardises the generation of groundwater (Boschi et al. 2003). In addition, e.g. the pore space – which is of ecological significance for *macrozoobenthos* or fish spawn – is reduced.

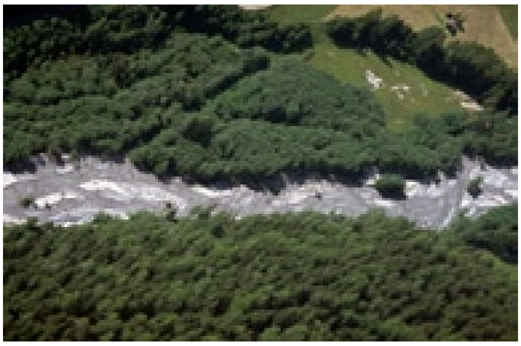


Figure 6.7: The Dranse de Ferret River at Praz de Fort, VS, with near-natural bedload regime, 2001 (photo: Floodplain Advisory Office SCZA).

6.2.4 Near-natural temperature regime

Water temperature and heat balance are primarily dependent on irradiation, climate and *hydrology* (Ward 1985). Canalised rivers and streams mostly feature homogenously temperate bodies of water. Very deep rivers and streams with only little turbulence are the exception. In structured channels, however, large temperature differences often exist between the main channel and stagnated, shallow waters (Jungwirth et al. 2003; see Figure 6.8). In these floodplain habitats, temperature is a particular determinant of species richness and *ecosystem* processes.

Large temperature differences may also occur in the vertical direction, i.e. in the adjacent groundwater, and can lead to the development of thermal *refugia* (Tockner et al. 2000). The temperature regime on and in the river bed is of particular significance, as it influences, for example, decomposition rates of organic ma-

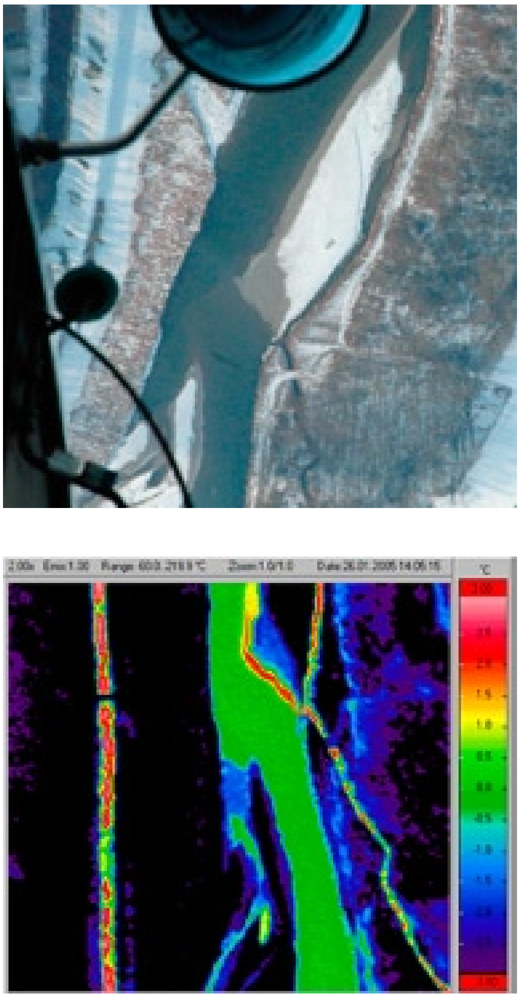


Figure 6.8: Temperature variability in the Thur River widening at Schäffäuli, TG/ZH. Above: true image, below: infrared image (resolution 1 m^2, accuracy 0.1 °C), January 2005 (photos: C. Tanner, EMPA; U. Uehlinger, Eawag).

terial, life cycles of *macroinvertebrates*, and development of fish eggs and larvae (Petts 2000). Natural temperature variability is a requirement for high species richness. Because of their species-specific temperature preferences, this is particularly the case for fish. On the other hand, extreme temperatures can be *lethal* for individual species or can have indirect effects, such as altered metabolic rates.

6.2.5 Connectivity

In large floodplain systems, ecological functional capability is primarily dependent on intact *connectivity* (Petts 1996). Spatial connectivity of rivers and streams with their surroundings takes place in three directions: longitudinal, lateral and vertical.

Longitudinal

Continuous connection between a river's upstream and downstream sections ensures the exchange of organisms and material. Fish and *macroinvertebrates* are particularly dependent on such connectivity. This connectivity is, however, often interrupted by insurmountable obstacles in the shape of cross-sectional constructions. Cross-sectional constructions can inhibit fish migration, and can hence eliminate natural reproduction. Furthermore, they can increase a river's cross section, increase the deposition of fine sediments and cause the loss of aquatic habitats (Muhar & Jungwirth 1998). Additionally, they interrupt transport of large wood and floating organic matter. Longitudinal constructions can also hinder longitudinal connectivity.

Lateral

Lateral connectivity ensures the connection and exchange between aquatic, semi-terrestrial and terrestrial habitats. Conditions for lateral connectivity are a natural flow regime and natural inundation dynamics. Lateral connectivity influences composition, productivity and *successional* stage of the riparian vegetation and hence also water temperature, aquatic light conditions, and quality and quantity of organic material fed into rivers and streams (Ward 1989). In many instances, lateral connectivity is no longer ensured, due to canalised river courses, steep banks and embankments. The river and its floodplain are often seamlessly separated.

Vertical

Hydrological exchange between river water and groundwater, i.e. *infiltration* of river water into the *aquifer* or *exfiltration* of groundwater into the river water, requires an intact vertical connectivity. Intact vertical exchange processes are crucial for organisms, which spend part of their life cycle in the *hyporheic* habitat (Amoros & Bornette 2002). This exchange is dependent on flow, water quality (in particular organic matter pollution) and water temperature.

6.2.6 Near-natural water quality

The water quality of a river or stream affects the *abundance* and *diversity* of flora and fauna in its habitats. In the case of *infiltration,* it also

Figure 6.9: Laterally connected oxbow of the Aare River at Lyss-Dotzigen, BE, 2003 (photo: Floodplain Advisory Office SCZA).

influences groundwater quality. Water quality of Swiss rivers and streams is currently good (Bundi et al. 2000).

The rehabilitation measures discussed in the present handbook have a minimal effect on water quality. For this reason, this project objective is not evaluated. It is listed in Table 6.1 for the sake of completeness.

6.2.7 Near-natural abundance and diversity of floodplain vegetation

Abundance and diversity of floodplain vegetation are strongly dependent on the intensity and frequency of inundation events and the nutrients supplied through these events. Vegetation is therefore an indicator of habitat availability and river dynamics (Paar 1997). It also offers information on changes occurring over time: The herb communities reflect a habitat's current ecological condition, while trees are reminders of past environmental conditions and also allow a glance into the future development of forests (Roulier 1998). In the presented evaluation method, the aquatic flora is not taken into consideration.

In Switzerland, numerous plant communities typical for floodplains have become rare, as a direct consequence of canalisation (Delarze et al. 1998). Rehabilitation projects stimulate the development of, for example, pioneer formations of softwood species (Ellenberg 1996). They can also support the reestablishment of a natural *vegetation zonation* or of a *mosaic* of herb, shrub or tree associations. Pioneering herb species colonise the gravel bars, which develop as a result of river widenings. Shrub and tree formations can then follow. When re-establishing near-natural floodplain landscapes, natural river courses, as described by historical documents and data, serve as guiding image.

Figure 6.10: White willow (*Salix alba*) and ribbon grass (*Phalaris arundinacea*), 2004 (photo: Floodplain Advisory Office SCZA).

Figure 6.11: Left: false tamarisk (*Myricaria germanica*), 1987, right: dwarf cattail (*Typha minima*), 2001 (photos: Floodplain Advisory Office SCZA).

6.2.8 Near-natural abundance and diversity of fauna

The strong dependence of abundance and diversity of fauna on suitable habitats has already been emphasised. Habitats for fish, small mammals, *macroinvertebrates,* amphibians, birds and other aquatic and semi-aquatic animals are shaped in particular by *morphological* and *hydraulic* variability, a near-natural temperature regime and intact longitudinal, lateral and vertical *connectivity.*

Figure 6.12: The habitat specific nase (*Chondrostoma nasus*) has only been recorded in the Thur River since rehabilitation measures were implemented, 2003 (photo: A. Peter, Eawag).

High abundance and diversity of flora, and particularly of fauna, are often not only ecological objectives of rehabilitation projects, but are also of great significance to the public. These project objectives can only be achieved in combination with other objectives aimed at improving ecological and environmental conditions (see Table 6.1).

Figure 6.13: Eggs of the common sandpiper (*Actitis hypoleucos*), Aergera at Plasselb - Marly, FR, 1992 (photo: Floodplain Advisory Office SCZA).

Figure 6.14: Eggs of the grey wagtail (*Motacilla cinerea*) in the floodplains of the Sense River, FR/BE, 1997 (photo: Floodplain Advisory Office SCZA).

Figure 6.15: Deposits of large wood and organic material in the floodplains of the Sense River, FR/BE, June 1999 (photo: Floodplain Advisory Office SCZA).

6.2.9 Cycling of organic matter

Colonisation by flora and fauna are strongly dependent on supply and input of organic matter, which, in turn, are influenced by numerous *abiotic* factors. In riverine *ecosystems,* organic matter is supplied, retained and transformed in a cycle. The intensity of these processes and the origin and size of organic matter vary along the river course. In the upper reaches, primary production is low and the organic matter fed into the watercourse originates mainly from riparian vegetation (allochthonous organic matter). In the middle reaches, the allochthonous fraction of organic material decreases and inputs originating from riverine primary production dominate (autochthonous organic matter). In the lower reaches, inputs originate particularly from the exchange of nutrients, minerals and organic material between the river and its floodplains (Lorenz et al. 1997). The supply of organic matter into rivers and streams is therefore greatly dependent on inundation cycles, vegetation cover, vegetation growth, as well as longitudinal and lateral *connectivity* (Lorenz et al. 1997).

6.3 Economy

An important economic goal is cost efficiency, i. e. the ratio between resource input and achieved effect. An evaluation of this goal is extremely complex and can usually only be conducted a few years after a project has been implemented. For these reasons, cost efficiency is not assessed in the present handbook. Alternatively, the closely related project objective ‘keeping the budget’ is evaluated.

6.3.1 Keeping the budget

This project objective provides information on how the available financial resources are handled. Along with the ecological effect of a rehabilitation project and its acceptance among the population, efficient handling of time and finances have a strong influence on project success (Bratrich 2004). If a project is not within its budget, this often has consequences for future rehabilitation projects. In some cases, it may mean that the project can not be completed as planned. Keeping the project budget is therefore an important economic objective.

Additional possible project objectives are ‘increase in jobs’ and ‘rise in real estate prices’.

These objectives are not included in the evaluation scheme recommended in the present handbook, as they are only significant in very large rehabilitation projects. For further information on the economic effect of rehabilitation projects see Spörri et al. (2005).

6.4 Implementation

Beside the three elements of sustainability shown in Table 6.1, a further group of project objectives is of great significance to evaluating rehabilitation projects: the quality and procedure of project implementation. This sector includes political acceptance of a project and stakeholder participation. In the past decades, society's sensitivity to ecological problems has increased continuously. A particular increase can be observed for projects, in which persons are directly or indirectly affected by the consequences of such ecological problems (Selin & Chavez 1995, Zaugg 2002).

6.4.1 Political acceptance

Political acceptance is an important prerequisite for the success of a rehabilitation project (Bratrich 2004). It describes how a project and its entire procedure are received by the population. The greater the acceptance is, the easier it will be to implement future rehabilitation projects in the same area.

Enhancing the value of an area as a leisure destination, ensuring flood protection and improving the ecological condition are important factors for the acceptance of a project. However, involving affected persons in the decision-making process (stakeholder participation) and keeping within the budget are factors which also influence project acceptance. Acceptance is therefore an integrative indicator, which provides a comprehensive conclusion on implementation success.

Figure 6.16: Participation of representatives from different interest groups during definition of project objectives, May 2005 (photo: M. Buchecker, WSL).

6.4.2 Stakeholder participation

Societal, ecological and economic demands on a river or stream can often result in conflict (Jungwirth et al. 2002). It is therefore important to involve persons directly or indirectly affected by a project at an early stage, in order to identify conflicts and develop compromise solutions. Involving interest groups and the local population is particularly important in comprehensive rehabilitation projects. Here, goals and tasks are to:

- promote a wide acceptance of rehabilitation projects
- avoid costly conflicts – which may arise in later project phases – early on (Susskind & Cruickshank 1987)
- legitimise decisions publically
- improve the atmosphere for decision-making in future projects with the aid of social learning processes (Beierle & Konisky 2000) .
- promote environmental education and interest in river engineering measures and ecological measures in river courses (House 1996).

The demand for public participation in managing natural resources has increased greatly since the 1970ies. Despite this increase, however, there is a lack of *standardised* guidelines for evaluating participation processes (Farrell et al. 1976, Hampton 1977, Homenuck 1977, Vindasius 1977, Sewell & Phillips 1979, Beierle & Konisky 2000, Rowe & Frewer 2000, Jackson 2002). This can be partly attributed to the difficulty of quantifying socioeconomic indicators. For this reason, they are often assessed qualitatively.

7 Rehabilitation measures and indicator sets

In Switzerland, various measures for rehabilitating rivers and streams are currently being implemented (Table 7.1). The most frequent measures are those, which promote the structural *diversity* of a river system. Measures for improving the *bedload* regime are less common. Measures for re-establishing *connectivity* are currently already in use, but will become even more significant in the future, due to the strong fragmentation of Swiss rivers and streams (see chapter 2). Which rehabilitation measure is selected, is dependent on a project's objectives.

In the present handbook, indicator sets for evaluating selected rehabilitation measures are introduced. Only active rehabilitation measures are considered. As in the presented evaluation scheme, the project objectives form the basis for project evaluation. Table 7.2 relates the different project objectives discussed in chapter 6 to the selected measures. This provides an overview of which measures are suitable for achieving which project objectives. However, the handbook does not provide decision-making guidelines for selecting a measure. Information on deciding for or against a measure can be found in Hostmann et al. (2005). The choice of indicators is dependent on the project objectives. Assembling indicator sets, however, is also dependent on the measure to be implemented. Suitability of the indicators for the different measures is therefore characterised in Table 7.3. Here, three levels of relevance are distinguished. Assigning indicators to levels of relevance is based on expert opinion.

In the following chapters, the selected rehabilitation measures are briefly discussed, individual case studies are provided and recommended indicator sets are presented. Both Swiss and international projects were chosen as case studies. The size of the indicator sets is related to the measure and its relevant project objectives. For measures with complex effects, larger indicator sets are required, in order to be able to consider all aspects of the rehabilitation project. The recommended sets contain between 11 and 26 indicators. The individual indicator sets cover all project objectives relevant to the measure in question. They are gen-

Improving the flow regime
Re-establishing a natural, dynamic flow regime
Increasing residual flow
Reducing hydropeaking
Increasing structural diversity/lateral connectivity
Widening the river bed*
Opening culverts*
Structuring the river bed*
Structuring the river bank*
Creating and reconnecting side channels*
Reconnecting backwaters, oxbows and floodplains*
Creating inundation areas
Re-establishing continuity of flow
Longitudinal connectivity*
Improving bedload regime
Bedload rehabilitation*

Table 7.1: Rehabilitation measures frequently applied in Switzerland, divided according to their scope of effect. Measures marked by asterisks (*) are addressed in the present handbook.

erally designed for medium-sized to large rivers of the Swiss lowlands. The indicator set for the rehabilitation measure ‘opening culverts’ is an exception, as it is designed for small streams. The authors urgently recommend applying an indicator set in its entirety. If the user, however, decides against applying the recommended set, he has the option of assembling his own, user-defined set, according to the Excel template ‘Selection and evaluation’ presented in chapter 8. In this case, the recommended set may be useful as a basis for decision.

Table 7.2: Suitability of rehabilitation measures frequently implemented in Swiss rivers and streams for achieving important project objectives (marked ‘•’).

	Service to society		Environment and ecology									Economy	Implementation	
	Project objectives													
Measures (in parentheses: handbook chapter, in which measure is discussed)	Sustainable supply of drinking water	Provision of high recreational value	Morphological and hydraulic variability	Near-natural bedload regime	Near-natural temperature regime	Longitudinal connectivity	Lateral connectivity	Vertical connectivity	Near-natural abundance and diversity of floodplain vegetation	Near-natural abundance and diversity of fauna	Cycling of organic matter	Keeping the budget	Political acceptance	Stakeholder participation
Widening the river bed (7.1)	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Opening culverts (7.2)	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Structuring the river bed (7.3)		•	•					•		•	•	•	•	•
Structuring the river bank (7.4)	•	•	•		•	•	•		•	•	•	•	•	•
Creating and reconnecting side channels (7.5)	•	•	•		•	•	•	•	•	•	•	•	•	•
Creating and reconnecting backwaters, oxbows and floodplains (7.6)	•	•	•		•	•	•	•	•	•	•	•	•	•
Longitudinal connectivity (7.7)		•	•	•		•		•	•	•	•	•	•	•
Bedload rehabilitation (7.8)	•		•	•		•	•	•		•		•	•	•

Table 7.3: Relevance of indicators recommended in the present handbook for selected rehabilitation measures: 3=very relevant, 2=moderately relevant, 1=not relevant. Level of survey effort: A: <2, B: 2–3, C: >3 person days.

				Relevance of indicator for different measures							
Nº	Indicator group	Indicator	Effort level	Widening the river bed	Opening culverts	Structuring the river bed	Structuring the river bank	Side channels	Backwaters, oxbows and floodplains	Longitudinal connectivity	Bedload rehabilitation
1	**Project acceptance**	Acceptance by interest group	A	3	3	2	3	3	3	2	1
2	**Project acceptance**	Acceptance by entire public	B	3	3	2	3	3	3	2	1
3	**Project acceptance**	Acceptance by project work group	A	3	3	2	3	3	3	2	1
4	**Longitudinal connectivity**	Barrier-free migration routes for fish	A	2	3	2	2	2	2	3	1
5	**Recreational use**	Number of visitors	A	3	3	2	3	3	3	2	1
6	**Recreational use**	Variety of recreational opportunities	A	3	3	2	3	3	3	2	1
7	**Recreational use**	Public site accessibility for recreation	A	3	3	1	3	3	3	2	1
8	**Fish**	Age structure of fish population	C	3	3	2	3	3	3	3	2
9	**Fish**	Fish species abundance and dominance	C	3	3	2	3	3	3	3	2
10	**Fish**	Diversity of ecological guilds of fish	C	3	3	2	3	3	3	3	2
11	**Fish habitat**	Presence of cover and instream structures	A	3	3	3	3	2	3	1	2
12	**Bedload**	Bedload regime	C	3	1	3	1	1	1	3	3
13	**Hydrogeomorphology and hydraulics**	Inundation dynamics: duration, frequency and extent of flooding	A	3	3	1	2	3	3	1	1
14	**Hydrogeomorphology and hydraulics**	Variability of visually estimated wetted channel width	A	3	3	3	2	1	1	2	2
15	**Hydrogeomorphology and hydraulics**	Variability of measured wetted channel width	B	3	3	3	2	1	1	2	2
16	**Hydrogeomorphology and hydraulics**	Variability of flow velocity	C	3	3	3	2	2	1	2	2
17	**Hydrogeomorphology and hydraulics**	Depth variability at bankfull discharge	B	3	3	3	2	1	1	2	2
18	**Costs**	Project costs	A	3	3	3	3	3	3	3	1
19	**Landscape**	Diversity and spatial arrangement of habitat types	C	3	3	1	3	3	3	3	2
20	**Landscape**	Aesthetic landscape value	A	3	3	2	3	3	3	2	1
21	**Macroinvertebrates**	Richness and density of terrestrial riparian arthropods	B	3	3	1	3	3	3	2	1
22	**Macroinvertebrates**	Occurrence of both surface water and groundwater organisms in the hyporheic zone	A	3	3	1	1	1	2	1	2
23	**Macroinvertebrates**	Taxonomic composition of macroinvertebrate community	A	2	3	3	2	2	3	2	3
24	**Macroinvertebrates**	Presence of amphibiontic species in the groundwater	A	3	3	1	1	1	2	1	2
25	**Organic material**	Short-term leaf retention capacity	A	3	3	3	2	1	2	2	1
26	**Organic material**	Quantity of large wood	A	3	3	3	2	1	2	3	1
27	**Organic material**	Quantity and composition of floating organic matter and abundance and diversity of colonising snails	A	2	1	1	2	2	2	3	1

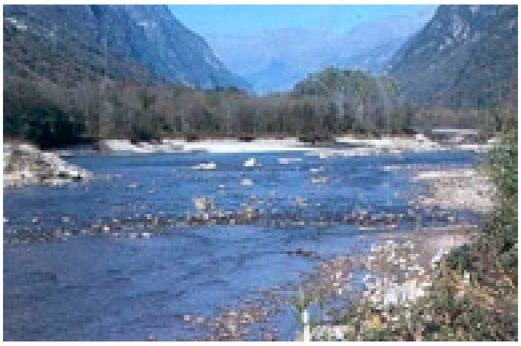
				Relevance of indicator for different measures							
N°	Indicator group	Indicator	Effort level	Widening the river bed	Opening culverts	Structuring the river bed	Structuring the river bank	Side channels	Backwaters, oxbows and floodplains	Longitudinal connectivity	Bedload rehabilitation
28	**Stakeholder participation**	Satisfaction of interest groups with the design of the participation process	A	3	2	2	2	3	3	2	1
29	**Stakeholder participation**	Satisfaction of the public with participation opportunities	A	3	2	2	2	3	3	2	1
30	**Stakeholder participation**	Satisfaction of interest groups with participation opportunities	A	3	2	2	2	3	3	2	1
31	**Refugia**	Availability of three types of refugia (hyporheic refugia, shoreline habitats, and intact tributaries)	C	3	3	2	3	3	3	2	2
32	**River bed**	Clogging of hyporheic sediments	B	2	3	1	1	2	2	2	2
33	**River bed**	Temporal changes in diversity of geomorphic river bed structures	B C	3	2	3	1	1	1	2	3
34	**River bed**	Clogging of hyporheic sediments	A	2	3	1	1	1	1	2	2
35	**River bed**	Grain-size distribution of substratum	A	3	2	3	1	1	1	1	3
36	**River bed**	Diversity of geomorphic river bed structures	A B	3	2	3	1	1	1	2	3
37	**River bed**	Degree and type of anthropogenic modification	A	3	3	3	1	1	2	2	1
38	**Temperature**	Spatial and temporal variation in water temperature	A	3	3	2	3	2	3	1	1
39	**Transition zones**	Food subsidies across land-water boundaries	C	3	2	1	3	3	3	1	1
40	**Transition zones**	Exchange of dissolved nutrients and other solutes between river and groundwater	C	2	3	1	1	2	3	2	2
41	**Transition zones**	Community composition and density of small mammals on floodplain	C	3	2	1	2	2	3	1	1
42	**River bank**	Width and degree of naturalness (vegetation, composition of ground) of riparian zone	A	3	3	1	3	2	2	1	1
43	**River bank**	Temporal changes in the quantity and spatial extent of morphological units	A	3	2	1	3	2	2	2	1
44	**River bank**	Shoreline length	A	3	3	1	3	3	3	2	2
45	**River bank**	Quantity and spatial extent of morphological units	A	3	2	1	3	2	2	2	1
46	**River bank**	Degree and type of anthropogenic modification	A	3	3	2	3	2	3	2	1
47	**Vegetation**	Presence of typical floodplain species	A	3	3	1	2	2	2	1	1
48	**Vegetation**	Succession and rejuvenation of plant species on floodplains	C	3	3	1	2	2	2	1	1
49	**Vegetation**	Temporal shift in the mosaic of floodplain vegetation categories	B	3	3	1	2	3	3	1	1
50	**Vegetation**	Composition of floodplain plant communities	A	3	3	1	2	3	3	1	1

7.1 Widening the river bed

7.1.1 Explanation of measure

This measure consists of removing river bank constructions on one or both banks of a canalised river and, if need be, widening its channel (Figures 7.4–7.6). These actions provide the river with more freedom of movement. For the most part, they are carried out along a limited length of a few hundred metres. To date, river widenings with a length of 1–2 km have been the exception. If dimensions are sufficient, river widenings may cause an increase in *bedload* deposition, which will result in stabilisation of the river bed and the development of gravel bars and sand banks. Depending on the river type, the additional width will result in channel braiding and island formation. Further consequences are a greater variability of depth and current, an increase in habitats typical for floodplains and an associated surge in species richness.

River widenings can be carried out in medium-sized and large rivers, but are especially suitable for formerly braided systems. Further information and recommendations with regard to the dimensions (length and width) of river widenings can be found at www.rivermanagement.ch, the homepage of the Rhone-Thur project.



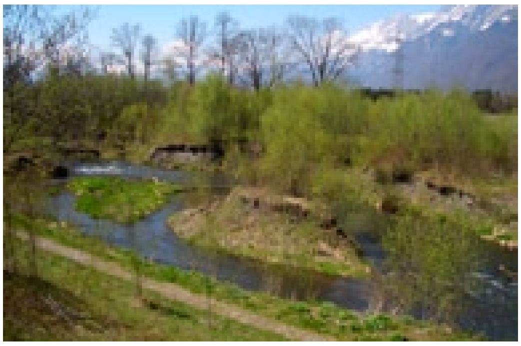


Figure 7.4: River widening at the Pascoletto River at Grono, GR, 2002 (photo: M. Hostmann, Eawag).

Figure 7.5: River widening at the Thur River at Gütighausen, ZH, 2002 (photo: M. Hostmann, Eawag).

Figure 7.6. Small river widening in the Lichtenstein drainage canal adjacent to the Rhine River at Ruggell, 2005 (photo: A. Peter, Eawag).

7.1.2 Case studies

Thur River widening at Schäffäuli, Switzerland

The 127 km long river – with mountain stream character in its headwaters – originates at Mount Säntis, Canton of St. Gallen and flows into the Rhine River downstream of Andelfin-

Figure 7.7: The Thur River at Schäffäuli, TG/ZH. Left: June 2001, before the river was widened, right: May 2004, after the river was widened (photos: C. Herrmann, BHAteam, Frauenfeld).

gen. After heavy rainfall in its 1,750 km^2 large catchment and combined with water saturated grounds and simultaneous snowmelt, the Thur River's flow can increase dramatically within only few hours. When this is the case, there are neither lakes nor reservoirs along the Thur River, which could retain the resulting large body of water. Already in the 19th century, devastating floods led to comprehensive river regulation. But even after the implementation of flood protection measures, further floods followed in the 20th century (Weber 2001). After the floods of 1978, during which the flow increased to thirty times its annual average, plans were made in the Cantons of Thurgau and Zurich for a second Thur River amelioration. In the Canton of Zurich, construction works have been underway since 1987, while in the Canton of Thurgau, work began in 1993. The aims of the amelioration project are to improve flood protection and enhance the ecological value of the river landscape. The most important ecological deficits are disturbed *bedload* regime, lack of river dynamics, insufficient longitudinal and lateral *connectivity* and fluctuating water quality. Additionally, the river landscape is used intensely for recreation by the local population (Weber 2001). It is anticipated that, by the year 2015, a combination of rehabilitation projects and flood protection measures will have eliminated the Thur's main deficits. Widening the river bed is one of the main measures selected for improving river dynamics.

Figure 7.8: Pioneer communities typical for floodplains on gravel bars near Schäffäuli, TG/ZH, July 2003 (photo: C. Roulier, Floodplain Advisory Office SCZA).

Figure 7.9: The original headwaters of the Isar River at Vorderriss, Bavaria, 1999 (photo: Bavarian State Office for the Environment (LfU), Munich).

The Thur River widening, which was constructed at Schäffäuli between 2001 and 2002, is exemplary (Figure 7.7): Here, the river bed was widened from 50 to 100 m on both banks and along a river length of 1,500 m. On the side belonging to the Canton of Thurgau, the river bank was secured using tree trunks and bundles of sticks. The beginning, middle and end of the widening were additionally fitted with gabions. On the side belonging to the Canton of Zurich, the bank was secured using flat groynes, groynes, guide beams and bundles of sticks (www.rivermanagement.ch/aufweitungen). The widenings have improved river dynamcis significantly. A number of new habitats, such as graded banks, gravel bars, backwaters, *pools* and *riffles* have developed. Pioneer communities typical for floodplains grow on the gravel bars (Figure 7.8) and are washed away in the event of floods. The *diversity* of *macroinvertebrates* has increased in the widening, although *abundance* and biomass have remained the same. The newly developed habitats have caused an increase in fish species. The nase (*Chondrostoma nasus*), for example, has been recorded for the first time. Birds also benefit from the new habitats. A particular success has been the return of the little ringed plover (*Charadrius dubius*).

Isar River widening at Munich, Germany

Around 1850, the Isar River at Munich still had its original river style: A wild, braided river without fixed banks, split into innumerable channels, which were relocated with every flood. After 1850, river regulation measures forced the Isar River into a rigid course. Between 1900 and 1912, the Isar at Munich was tamed by the construction of a channel. As a measure against floods, the river was narrowed by longitudinal constructions, groyne fields and dikes. Its original characteristic as a typical alpine and prealpine river is only apparent in some of its headwater regions (Figure 7.9).

Since the year 2000, the Isar River at Munich has been restored and its ecological value enhanced over the course of several construction phases and along a total length of 9.3 km. The measures have cost 26 million EUR. As a principal measure, the river bed was widened to more than twice its width in many places. This ensures additional space for flood waters and enables the river to shape its banks with every flood. The hereby created graded gravel bars are easily accessible and are therefore intensely used by the recreational public. Beside river widenings, gravel islands were constructed and vertical falls and banks were levelled. This way, habitats for animals and plants were created and lateral and longitudinal *connectivity* were improved. In order to increase flood protection, dikes were restored. The rehabilitation was a joint project of the Office for Water Management, Munich (WWA München) and the Provincial Capital Munich (reference and further information: www.wasserwirtschafts-amt-muenchen.de/app/neues_leben_isar).

Further examples:
Widening of the Kander River Augand, Switzerland, rehabilitation fund RenF, Canton of Berne.

Further river widening examples can also be found at www.rivermanagement.ch/aufweitungen/aufw_b1.php

7.1.3 Indicator set

For evaluating the measure 'widening the river bed', the indicator set in Table 7.10 is recommended.

Table 7.10: Recommended indicator set with 26 indicators for evaluating the rehabilitation measure 'widening the river bed'.

				Service to society		Environment and ecology									Economy	Implementation	
				Suitability of indicator for evaluating important project objectives (♦ = direct parameter; • = indirect parameter)													
Nº	Indicator group	Indicator	Effort level	Sustainable supply of drinking water	Provision of high recreational value	Morphological and hydraulic variability	Near-natural bedload regime	Near-natural temperature regime	Longitudinal connectivity	Lateral connectivity	Vertical connectivity	Near-natural abundance and diversity of floodplain vegetation	Near-natural abundance and diversity of fauna	Cycling of organic matter	Keeping the budget	Political acceptance	Stakeholder participation
1	**Project acceptance**	Acceptance by interest group*	A													♦	
5	**Recreational use**	Number of visitors	A		♦												
8	**Fish**	Age structure of fish population**	C			•	•		•	•			♦				
9	**Fish**	Fish species abundance and dominance**	C			•	•	•	•				♦				
10	**Fish**	Diversity of ecological guilds of fish**	C			•	•	•	•				♦				
12	**Bedload**	bedload regime	C			•	♦		•				•				
17	**Hydrogeomorphology and hydraulics**	Depth variability at bankfull discharge	B			♦	•					•	•				
18	**Costs**	Project costs	A												♦		
20	**Landscape**	Aesthetic landscape value	A		♦												
21	**Macroinvertebrates**	Richness and density of terrestrial riparian arthropods	B							•			♦				

				Service to society		Environment and ecology									Economy	Implementation	
				Suitability of indicator for evaluating important project objectives (♦ = direct parameter; • = indirect parameter)													
N°	**Indicator group**	**Indicator**	**Effort level**	Sustainable supply of drinking water	Provision of high recreational value	Morphological and hydraulic variability	Near-natural bedload regime	Near-natural temperature regime	Longitudinal connectivity	Lateral connectivity	Vertical connectivity	Near-natural abundance and diversity of floodplain vegetation	Near-natural abundance and diversity of fauna	Cycling of organic matter	Keeping the budget	Political acceptance	Stakeholder participation
22	**Macroinvertebrates**	Occurrence of both surface water and groundwater organisms in the hyporheic zone	A				•				•		♦				
23	**Macroinvertebrates**	Taxonomic composition of macroinvertebrate community	A			•	•		•	•	•		♦				
25	**Organic material**	Short-term leaf retention capacity	A			•				•				♦			
26	**Organic material**	Quantity of large wood	A	•						•				♦			
28	**Stakeholder participation**	Satisfaction of interest groups with the design of the participation process	A														♦
30	**Stakeholder participation**	Satisfaction of interest groups with participation opportunities*	A														♦
33	**River bed**	Temporal changes in diversity of geomorphic river bed structures	B C			♦	•		•	•	•	•	•	•			
34	**River bed**	Clogging of hyporheic sediments	A	•		•	•				♦						
35	**River bed**	Grain-size distribution of substratum	A			♦	•				•		•				

*/** The survey takes place at the same time as an identically marked indicator. The survey effort level corresponds to a single survey.

♦ = direct parameter: indicators, which assess the project objective directly.

• = indirect parameter: indicators, which assess a situation, which is secondarily influenced by the project objective.

7.2 Opening culverts

7.2.1 Explanation of measure

The *culverting* of streams, i.e. laying them through pipes, is a measure, which used to serve the purpose of flood protection, agricultural cultivation or wastewater drainage (Figure 7.11). Since the Act for the Conservation of Watercourses of 1991, culverting is prohibited, although few exceptions remain (Art. 38). In culverted sections, *hydrology,* water chemistry and habitat characteristics are strongly impaired. In addition, such sections are barriers to fish migration (Gallagher 1999).

Ecomorphological data from 22 cantons show that 17 % of surveyed watercourses are culverted (chapter 2). The smallest streams (stream order 1 or 2) in the agricultural zone are mainly affected by culverting. As the problem is so widespread, opening these streams is a particular challenge for future rehabilitation.

In article 6 of the Decree on River Engineering of 1994, the opening of culverts is mentioned as a rehabilitation measure of special priority. The measure is not particularly time-consuming or complex, yet has a very high ecological potential. It enables the reestablishment of longitudinal, lateral and vertical *connectivity*. Additionally, it creates *morphological* and *hydraulic* variability, which increases *abundance* and *diversity* of flora and fauna. The indicators in the present handbook are suitable for evaluating the opening of culverted streams, but not culverted springs. Here, more complex interactions must be taken into account.

7.2.2 Case studies

Stream concept of the City of Zurich, Switzerland

Around 1850, approximately 160 km of open streams flowed through the municipality of Zurich. Around 1980, only approximately 60 km remained, the majority of which were in forests. During urban development, streams were culverted for wastewater drainage and gradually degraded to sewers. The unwelcome effects were flooding at times of peak flow and an unnecessary burden to sewage works, due to river water being mixed with wastewater. Additionally, habitats for animals and plants were lost, and rivers became fragmented and disconnected along all three dimensions. In order to counteract these consequences, a stream concept was developed, with the aim of achieving sustainable urban wastewater drainage combined with comprehensive conservation of streams. In 1988, the stream concept was approved by the City Council. It defines which culverted streams and stream sections are designated for being opened, newly created or rehabilitated, and defines procedural guidelines for these projects. Among other points, the guidelines stipulate that unpolluted waters and rainwater should be connected to streams, that space should be created for recreation and that streams should be structured in a near-natural way, in order to provide habitats for native plants and animals. Until the year 2002, around 16 km of streams and stream sections were opened, newly created or rehabilitated in the City of Zurich based on the stream concept. The concept is well accepted among the public. In May 2003, the City of Zurich was awarded the Water Price of Switzerland (*Gewässerpreis Schweiz*) for its successful stream concept (Entsorgung und Recycling Zürich (ERZ) 2003).

Figure 7.11: Culverted tributary to the Thur River (close to confluence with the Rhine River), 2005 (photo: A. Peter, Eawag).

The culverted Albisrieder Dorfbach, for example, was opened over a length of 2.5 km between 1989 and 1991 (Figure 7.12). Today, the stream flows through public parks and private properties at the periphery of the City of Zurich with an average flow of 12 l/s. A rainwater retention pond was transformed into a biotope. The stream banks were partly vegetated and a gravel bed with different particle sizes was created in the stream bed. A biological survey carried out in the year 2000 showed that the new stream section had been well colonised. A total of 36 animal species had been found, more than twice the number found in the catchment. Mayflies and caddis flies dominated in *abundance* and *diversity.* Further species of worms, eels and water lice had immigrated. The stream is well accepted by the population and is used intensely for recreation (Entsorgung und Recycling Zürich (ERZ) 2003). For further examples of opened culverts in the City of Zurich, see the last-mentioned reference which can be found at www3.stzh.ch/internet/erz/home/medien/broschueren.ParagraphContainerList.ParagraphContainer1.ParagraphList.0028.File.pdf/b_baeche_in_der_stadt.pdf.

Opening of the Litzibuch Stream, Switzerland

Since 1877, over 60 % of small streams have been culverted in the Canton of Aargau. In the south-east of the community Oberwil-Lieli, at the border to the Canton of Zurich, streams of the cultivated landscape disappeared completely. Between 1943 and 1944, the area around the hamlet Litzibuch was drained by a dense drainage network. These comprehensive amelioration measures produced productive agricultural land. At the same time, however, they destroyed a diverse, ecological network and landscape-shaping structures. Numerous species disappeared from the area. Today, many of these species are very rare in the Canton of Aargau.

Figure 7.12: The opened Albisrieder Dorfbach at Saumackerstrasse, ZH, (photo: Waste Disposal and Recycling Zurich ERZ).

In Oberwil-Lieli, part of the stream system, which was culverted during amelioration, was opened in 2003, requiring low effort and low cost, but resulting in high impact. The stream section concerned is approximately 200 m long and was particularly suited for being opened and rehabilitated due to its ecological potential and the low technical effort required. Because of the low average flow of only few litres per second, a small cross section around 40 cm wide and 35 cm deep was sufficient. Today, the opened stream fulfils an important *connectivity* function in the water system and greatly adds to the landscape aesthetics. In the future, colonisation by species, such as demoiselles, dragonflies, various amphibians and river bank shrubs is expected.

The opened stream flows into the Geissweid Stream, a tributary to the Reppisch Stream, which – according to the Zurich Nature Conservation Concept – belongs to the ecologically most valuable river systems of the Canton of Zurich. In the eyes of the canton, rehabilitating these watercourses and their tributaries is a priority. *Culverted* streams are to be opened and small networks of near-natural field streams are to be developed. The described project makes an important contribution to this goal. (Reference: www.litzibuch.ch/Landwirtschaftsbetrieb/Bachausdolung.htm)

7.2.3 Indicator set

For evaluating the measure 'opening culverts', the indicator set in Table 7.13 is recommended.

Measure: Opening culverts

Table 7.13: Recommended indicator set with 16 indicators for evaluating the rehabilitation measure 'opening culverts'.

N°	Indicator group	Indicator	Effort level	Service to society		Environ-ment and ecology									Economy	Implemen-tation	
				Suitability of indicator for evaluating important project objectives (♦ = direct parameter; • = indirect parameter)													
				Sustainable supply of drinking water	Provision of high recreational value	Morphological and hydraulic variability	Near-natural bedload regime	Near-natural temperature regime	Longitudinal connectivity	Lateral connectivity	Vertical connectivity	Near-natural abundance and diversity of floodplain vegetation	Near-natural abundance and diversity of fauna	Cycling of organic matter	Keeping the budget	Political acceptance	Stakeholder participation
1	**Project acceptance**	Acceptance by interest group*	A													♦	
8	**Fish**	Age structure of fish population**	C			•	•		•	•			♦				
9	**Fish**	Fish species abundance and dominance**	C			•	•	•	•				♦				
10	**Fish**	Diversity of ecological guilds of fish**	C			•	•	•	•				♦				
18	**Costs**	Project costs	A												♦		
20	**Landscape**	Aesthetic landscape value	A		♦												
22	**Macroinvertebrates**	Occurrence of both surface water and groundwater organisms in the hyporheic zone	A				•				•		♦				
23	**Macroinvertebrates**	Taxonomic composition of macroinvertebrate community	A			•	•		•	•	•		♦				
25	**Organic material**	Short-term leaf retention capacity	A			•				•				♦			
28	**Stakeholder participation**	Satisfaction of interest groups with the design of the participation process	A														♦
30	**Stakeholder participation**	Satisfaction of interest groups with participation opportunities*	A														♦
36	**River bed**	Diversity of geomorphic river bed structures	A B			♦	•		•	•	•	•	•	•			
38	**Temperature**	Spatial and temporal variation in water temperature	A	•				♦		•	•						
40	**Transition zones**	Exchange of dissolved nutrients and other solutes between river and groundwater	C	•		•	•	•			♦						
44	**River bank**	Shoreline length	A				•			♦				•			
47	**Vegetation**	Presence of typical floodplain species	A						•			♦					

*/** The survey takes place at the same time as an identically marked indicator. The survey effort level corresponds to a single survey.

♦ = direct parameter: indicators, which assess the project objective directly.

• = indirect parameter: indicators, which assess a situation, which is secondarily influenced by the project objective.

7.3 Structuring the river bed

7.3.1 Explanation of measure

The presence of different structures in the river bed determines habitat *diversity* in rivers and streams, and hence habitat quality for aquatic flora and fauna. Here, structures, such as *pools, riffles,* large wood and rocks, have a significant influence on the distribution of both flow velocity and substrate. Additionally, these structures serve as shelters and *refugia* for various organisms (Jungwirth et al. 2003). Structuring the river bed is a rehabilitation measure, which requires only little time and labour. However, the river bed should be structured as naturally as possible (Figures 7.14 and 7.15). If only structural diversity is enhanced, but water dynamics is not, then the natural functional capability will generally barely improve.

7.3.2 Case study

Skerne River, England

The Skerne River has a catchment area of 250 km^2 and flows into the Tees River south of Darlington, County Durham. In the past, the Skerne River was straightened, in order to facilitate waste disposal from the iron industry into the river's floodplains. The regulation measures led to distinct river incision and to poor water quality. Furthermore, flood measures were installed, in order to protect densely populated residential areas and infrastructure. Today, sewers, gas pipes and industrial waste sites are additionally located close to the river (Vivash 1999).

Between 1995 and 1996, rehabilitation measures for enhancing the river's ecological value were carried out along a 2 km long section. In the lower section, meanders were created. In the upper section, there was not sufficient space for meanders, as here a gas pipe runs along one side of the river bank, while on the other side a waste disposal site is located close-by. In this section, the 9 m wide monotonous, trapeze-shaped river bed was restructured with the help of various measures. Along the river banks, tree trunks with a diameter of approximately 30 cm were placed as current deflectors, were fixed with poles and wire and were filled with stones and clay, in order to initiate the development of gravel bars. These measures enabled the development of small meanders and of greater structural diversity. The constructions, however, had to be repaired after winter floods. Furthermore, ledges of vegetated mats were installed, with the purpose of retaining silt and mud, in order to enable the natural establishment of vegetation. The ledges protruded into the river up to 2 m and served to inhibit scouring of the river bank and to create additional habitat diversity. As a third measure for structuring the river bed, riffles were created on opposite banks by accumulating stones and gravel. This led to variability of depth, flow velocity and flow direction (Vivash 1999). (More information on the project can be found at www.therrc.co.uk/projects/skerne.htm).

Figure 7.14 (left): River bed of the Thur River at Eggrank, Thurspitz, ZH, enhanced by structures, 2003 (photo: Floodplain Advisory Office SCZA).

Figure 7.15 (right): River bed of the Lichtenstein drainage canal adjacent to the Rhine River, 2005 (photo: A. Peter, Eawag).

Structures were also created in the river bed of the new bypass at the power station Ruppoldingen, Canton of Solothurn (see chapter 7.7.2).

7.3.3 Indicator set

For evaluating the measure 'structuring the river bed', the indicator set in Table 7.16 is recommended.

Measure: Structuring the river bed

Table 7.16: Recommended indicator set with 11 indicators for evaluating the rehabilitation measure 'structuring the river bed'.

				Environment and ecology				Economy	Implementation	
				Suitability of indicator for evaluating important project objectives (♦ = direct parameter; • = indirect parameter)						
Nº	Indicator group	Indicator	Effort level	Morphological and hydraulic variability	Vertical connectivity	Near-natural abundance and diversity of fauna	Cycling of organic matter	Keeping the budget	Political acceptance	Stakeholder participation
1	**Project acceptance**	Acceptance by interest group*	A						♦	
8	**Fish**	Age structure of fish population**	C	•		♦				
9	**Fish**	Fish species abundance and dominance**	C	•		♦				
10	**Fish**	Diversity of ecological guilds of fish**	C	•		♦				
11	**Fish habitat**	Presence of cover and instream structures	A	•		•	•			
16	**Hydrogeomorphology and hydraulics**	Variability of flow velocity	C	♦		•				
18	**Costs**	Project costs	A					♦		
23	**Macroinvertebrates**	Taxonomic composition of macroinvertebrate community	A	•	•	♦				
25	**Organic material**	Short-term leaf retention capacity	A	•			♦			
30	**Stakeholder participation**	Satisfaction of interest groups with participation opportunities*	A							♦
36	**River bed**	Diversity of geomorphic river bed structures	A B	♦	•	•	•			

*/** The survey takes place at the same time as an identically marked indicator. The survey effort level corresponds to a single survey.

♦ = direct parameter: indicators, which assess the project objective directly.

• = indirect parameter: indicators, which assess a situation, which is secondarily influenced by the project objective.

7.4 Structuring the river bank

7.4.1 Explanation of measure

Along the river bank, structures are influenced particularly by the river course, the substrate and the vegetation. These shape the habitat in the transition zone between water and land, and are therefore of great significance to the presence of aquatic and terrestrial organisms (Jungwirth et al. 2003). Due to passed river regulation activities, however, river banks are often strongly modified or have been designed too steeply, so that the river is cut off from its riparian zone. Structuring the river bank can involve, for example, removal of man-made embankments and vegetation, and levelling of the bank. On the one hand, these measures can help to re-establish lateral *connectivity,* while on the other hand, they can promote the development of structures along the river bank (Figure 7.17).

7.4.2 Case study

Skerne River, England

As part of the Skerne River rehabilitation project described under 7.3.2, various measures for vegetating and stabilising the river bank were carried out. These were particularly applied in the river section, in which meanders were created. As a first measure, posts were driven vertically into the edge of the bank and willow branches were woven through them. This method is particularly suitable for steep banks, which require support and protection from erosion. In the new, levelled banks, willow mats were installed. These consisted of willow branches, which were covered with nets for fixation. Additionally, stones were deposited at the transition between water and land. In order to stabilise the newly created banks, tree trunks were fixed along their edges. At places with minor threat of erosion, stones, which were held together by nylon nets, were installed, in order to prevent scouring of the bank. These were subsequently covered with similarly designed, seeded plant rolls. With the help of these measures, new structures were created along the formerly often vertical or steep river banks of the Skerne River. These not only prevent erosion, but also provide new habitats for flora and fauna (Vivash et al. 1998).

River bank structuring has also been applied as a rehabilitation measure in the confluence area of the rivers Aare, Reuss and Limmat at Vogelsang (see chapter 7.5.2) and in the floodplain Foort at Eggenwil (see chapter 7.8.2).

7.4.3 Indicator set

For evaluating the measure 'structuring the river bank', the indicator set in Table 7.18 is recommended.

Figure 7.17: River bank of the Thur River at Wuer, TG, enhanced by structures, 1998 (photo: Floodplain Advisory Office SCZA).

Measure: Structuring the river bank

Table 7.18: Recommended indicator set with 17 indicators for evaluating the rehabilitation measure 'structuring the river bank'.

Suitability of indicator for evaluating important project objectives
(♦ = direct parameter; • = indirect parameter)

N°	Indicator group	Indicator	Effort level	Service to society		Environment and ecology						Economy	Implementation	
				Sustainable supply of drinking water	Provision of high recreational value	Morphological and hydraulic variability	Near-natural temperature regime	Lateral connectivity	Near-natural abundance and diversity of floodplain vegetation	Near-natural abundance and diversity of fauna	Cycling of organic matter	Keeping the budget	Political acceptance	Stakeholder participation
1	**Project acceptance**	Acceptance by interest group*	A										♦	
5	**Recreational use**	Number of visitors	A		♦									
8	**Fish**	Age structure of fish population**	C			•		•		♦				
9	**Fish**	Fish species abundance and dominance**	C			•	•			♦				
10	**Fish**	Diversity of ecological guilds of fish**	C			•	•			♦				
15	**Hydrogeomorphology and hydraulics**	Variability of measured wetted channel width	B			♦		♦						
18	**Costs**	Project costs	A									♦		
21	**Macroinvertebrates**	Richness and density of terrestrial riparian arthropods	B					•		♦				
25	**Organic material**	Short-term leaf retention capacity	A			•		•			♦			
30	**Stakeholder participation**	Satisfaction of interest groups with participation opportunities*	A											♦
38	**Temperature**	Spatial and temporal variation in water temperature	A	•			♦	•						
40	**Transition zones**	Exchange of dissolved nutrients and other solutes between river and groundwater	C	•		•	•							
42	**River bank**	Width and degree of naturalness (vegetation, composition of ground) of riparian zone	A			♦	•	•	•	•	•			
43	**River bank**	Temporal changes in the quantity and spatial extent of morphological units	A	•		♦		♦		•				
44	**River bank**	Shoreline length	A					♦			•			
45	**River bank**	Quantity and spatial extent of morphological units	A	•		♦		♦		•				
47	**Vegetation**	Presence of typical floodplain species	A						♦					

*/** The survey takes place at the same time as an identically marked indicator. The survey effort level corresponds to a single survey.
♦ = direct parameter: indicators, which assess the project objective directly.
• = indirect parameter: indicators, which assess a situation, which is secondarily influenced by the project objective.

7.5 Creating and reconnecting side channels

7.5.1 Explanation of measure

Side channels are secondary branches of the main channel. They are permanent and carry water during periods of both high and low flow. Side channels differ from chutes and gullies, which lie close to the main channel, but are cut off from it during periods of low water. Side channels contribute significantly to the habitat *diversity* of rivers and streams, and therefore often feature high *abundance* and diversity of flora and fauna. They can differ considerably from the main channel, for example, in temperature, substrate, depth, riparian vegetation, food supply and flow velocity, and may therefore have an important role as *refugia* (Habersack & Nachtnebel 1995). By dredging, former side channels can be reconnected to the main channel or new, artificial channels can be created.

7.5.2 Case studies

Confluence area of the rivers Aare, Reuss and Limmat, Switzerland

In Vogelsang, Canton of Aargau, the rivers Aare, Reuss and Limmat – which drain nearly half of Switzerland – join together. For decades, the Vogelsang floodplain area was subject to advancing civilisation and intensive agriculture. Because of stone blocks installed along the banks of the rivers Aare and Limmat, lateral *connectivity* was nonexistent, so that the foreland was completely isolated from the river, except during flood events.

Within the context of the Floodplain Decree of 1992 and the floodplain conservation park of the Canton of Aargau, several rehabilitation projects were implemented in the confluence area at Vogelsang, in order to reestablish floodplain dynamics. On the left bank of the Aare River, the following measures were implemented: A 950 m long side channel was recreated (Figure 7.19), ponds and pools were created, small, shallow bays were formed on the bank of the inside river bend, and flow channels were created to enhance lateral flow (Lachat et al. 2001). Between the Aare island and the area 'Schachenacher', bank constructions were removed and the side channel was widened (Figure 7.20). A new side channel was also created on the left bank of the Limmat River, in order to create new habitat. The channel of the small power station at Vogelsang, which divides the peninsula into two parts, was widened and levelled on the left side. In order to increase structural diversity, gravel bars and sand banks were created here. The near-natural river landscape has led to the return of species typical for this habitat, such as kingfisher (*Alcedo atthis*), golden oriole (*Oriolus oriolus*), beaver (*Castor fiber*), grayling (*Thymallus thymallus*), black poplar (*Populus nigra*) and white willow (*Salix alba*) (Jenny 2003). Further information can be found at www.ag.ch/natur2001/auenschutzpark/.

Figure 7.19 (left): Side channel of the Aare River at Vogelsang, AG, 2004 (photo: S. Woolsey, Eawag).

Figure 7.20 (right): Aare island at Limmatspitz, AG, 2005 (photo: S. Woolsey, Eawag).

Waal, Netherlands

In the Netherlands, the Rhine River divides into three rivers. With 70 % of the Rhine River's discharge, the Waal River is the largest of the three. It forms an important, intensely used waterway for transport between Rotterdam and Germany (160,000 freight ships annually). During regulation works in the 19th and 20th centuries, groynes were installed, in order to ensure a deep channel for shipping and to prevent river bank erosion. As the groynes prevent the river from meandering, *rejuvenation* of the floodplain is no longer possible. The resulting continuous sedimentation causes the level of the floodplain to rise steadily.

The strong economic interest in shipping traffic rendered any rehabilitation measures in the main channel impossible. Instead, in 1994, the first two side channels with permanent flow were constructed in Opijnen and Beneden-Leeuwen with flow capacities of 1.2 and 0.5 % of the main channel. These side channels feature shallow, flowing water and strong *connectivity* to the main channel (Figures 7.21 and 7.22). Intense biological monitoring has shown that species of *macroinvertebrates,* fish, macrophytes and wading birds characteristic for rivers and streams benefited almost immediately from the newly created habitats in the side channels, with both their *abundance* and *diversity* having increased (Simons et al. 2001).

Further example:

Wildibach, Switzerland: new side channel at the Aare River: development of fish fauna in the Wildibach (www.ag.ch/umwelt-aargau/pages/index.htm?/umwelt-aargau/pages/suchergebnis.asp?ID_Artikel=460). (See also Diploma thesis Boller & Würmli 2004.)

7.5.3 Indicator set

For evaluating the measure 'creating and reconnecting side channels', the indicator set in Table 7.23 is recommended.

Figure 7.21 (left): Newly created side channel at the Waal River at Opijnen, Netherlands, June 1997 (photo: T. Buijse, RIZA, Netherlands).

Figure 7.22 (right): Newly created side channel at the Waal River at Beneden-Leeuwen,Netherlands, 2003 (photo: Bert Boekhoven, Netherlands).

Table 7.23: Recommended indicator set with 20 indicators for evaluating the rehabilitation measure ‘creating and reconnecting side channels’.

Measure: Creating and reconnecting side channels

Suitability of indicator for evaluating important project objectives
(♦ = direct parameter; • = indirect parameter)

				Service to society		Environment and ecology								Economy	Implementation	
N°	**Indicator group**	**Indicator**	**Effort level**	Sustainable supply of drinking water	Provision of high recreational value	Morphological and hydraulic variability	Near-natural temperature regime	Longitudinal connectivity	Lateral connectivity	Vertical connectivity	Near-natural abundance and diversity of floodplain vegetation	Near-natural abundance and diversity of fauna	Cycling of organic matter	Keeping the budget	Political acceptance	Stakeholder participation
1	**Project acceptance**	Acceptance by interest group*	A												♦	
4	**Longitudinal connectivity**	Barrier-free migration routes for fish	A					♦								
8	**Fish**	Age structure of fish population**	C			•		•	•			♦				
9	**Fish**	Fish species abundance and dominance**	C			•	•	•				♦				
10	**Fish**	Diversity of ecological guilds of fish**	C			•	•	•				♦				
16	**Hydrogeomorphology and hydraulics**	Variability of flow velocity	C			♦					•	•				
17	**Hydrogeomorphology and hydraulics**	Depth variability at bankfull discharge	B			♦					•	•				
18	**Costs**	Project costs	A											♦		
20	**Landscape**	Aesthetic landscape value	A		♦											
22	**Macroinvertebrates**	Occurrence of both surface water and groundwater organisms in the hyporheic zone	A							•		♦				
25	**Organic material**	Short-term leaf retention capacity	A			•			•				♦			
28	**Stakeholder participation**	Satisfaction of interest groups with the design of the participation process	A													♦
30	**Stakeholder participation**	Satisfaction of interest groups with participation opportunities*	A													♦
35	**River bed**	Grain-size distribution of substratum	A			♦				•		•				
36	**River bed**	Diversity of geomorphic river bed structures	A			♦		•	•	•	•	•	•			
38	**Temperature**	Spatial and temporal variation in water temperature	A	•			♦		•	•						
40	**Transition zones**	Exchange of dissolved nutrients and other solutes between river and groundwater	C	•		•	•			♦						
44	**River bank**	Shoreline length	A						♦				•			
45	**River bank**	Quantity and spatial extent of morphological units	A	•		♦		•	♦			•				
47	**Vegetation**	Presence of typical floodplain species	A					•			♦					

*/** The survey takes place at the same time as an identically marked indicator. The survey effort level corresponds to a single survey.
♦ = direct parameter: indicators, which assess the project objective directly.
• = indirect parameter: indicators, which assess a situation, which is secondarily influenced by the project objective.

7.6 Reconnecting backwaters, oxbows and floodplains

7.6.1 Explanation of measure

In dynamic rivers and streams, aquatic elements often develop, which only feature periodical or episodical flow (Jungwirth et al. 2003). These include oxbows, floodplain ponds and floodplain pools, which are mainly formed when meanders are cut off during flood events. Oxbows are connected to the main channel, while floodplain ponds and pools are completely isolated. The input of biogenic material and fine sediment causes a gradual aggradation of these water bodies and consequently leads to a loss of structural variability and species richness (Jungwirth et al. 2003). With a small amount of effort, isolated, stagnant water bodies can be reconnected to the main channel and their natural dynamics can be reestablished. However, isolated aquatic elements created by natural processes may provide valuable habitats. In such cases, the authors generally advise against reconnection to the main channel. For specific cases, experts must decide on site, whether reconnection is desirable or not.

Former floodplains, in which regular flooding has been rendered impossible by river engineering measures, can also be reconnected to the main channel via man-made connections. This way, floodplain dynamics and a *succession* typical for floodplains can be reestablished.

7.6.2 Case studies

Machme oxbow of the Aare River, Switzerland

In the course of the Aare River regulation carried out between 1887 and 1906, the Aare River at Klingnau (Canton of Aargau) was straightened and diked. The river's side channels, which were cut off, gradually filled with silt. The water surface of the Machme oxbow – formerly connected to the Aare River – was steadily reduced, until only individual water holes and gullies lined by reed remained. In the winter of 1995/1996, the Machme oxbow was rehabilitated, with the aim of re-establishing the former *mosaic* of habitats typical for wetlands. In addition, the populations of dragonflies, amphibians and reed-breeding birds were to be preserved and promoted. A particular focus was placed on increasing the kingfisher population (*Alcedo atthis*) and reintroducing beavers (*Castor fiber*) (Laimberger & Zumsteg 1998).

During construction works, 13,000 m^3 of silt and sediment were removed and 8,000 m^2 of open water surfaces were recreated. A 500 m long coherent water network was created with an average maximal depth of 1.5 m and a width of 10–20 m. Furthermore, a fish ladder with four steps was installed, which connects the Machme oxbow to the canal adjacent to the Aare River. By switching to extensive agriculture, the nutrient input to the Machme oxbow was reduced. Project evaluation in the rehabilitated habitats showed positive results: reed warbler (*Acrocephalus scirpaceus*), reed bunting (*Emberiza schoeniclus*), water rail (*Rallus aquaticus*) and little grebe (*Podiceps ruficollis*) have already been recorded. A pair of kingfishers (Alcedo atthis) has moved into the breeding tunnel, which was built in the spring of 1996. Beavers (*Castor fiber*) also utilise the new habitat. Today, the Machme oxbow of the Aare River forms a large nature conservation area at the reservoir lake of Klingnau and is one of the most important river oxbows in the whole canton (Laimberger & Zumsteg 1998).

Brede, Denmark

The Brede River system lies in the south of Jütland (Denmark). It consists of more than 1,000km of rivers and streams and has a catchment size of 473 km^2. The main rivers are the Brede River and the Lobaek Brook. The Brede River flows through agriculturally used lowland close to towns, until it enters the Wadden Sea via a sluice at Ballum. In the 1950ies, both rivers underwent regulation as a part of agricultural intensification. Meanders were eliminated and both river courses were straightened. The river beds were lowered, in order to increase flow capacity during floods. Numerous weirs were constructed, with the purpose of reducing the rivers' energy for forming meanders. These measures resulted in drainage or isolation of the surrounding floodplain elements and fragmentation of the water system. Consequently, valuable habitats and structures were lost. Also, the once lucrative trout fishery was practically eliminated. Before the regulations, the floodplain systems served as filters for nutrients originating from agriculture. Now, these drained straight into the rivers, causing increased algal growth in the shallow Wadden Sea.

In 1991, comprehensive rehabilitation works began at the Brede River and its tributaries. Not only ecological improvements, but also enhancements for recreational use were at the centre of the rehabilitation project. Between 1991 and 1997, 13.6 km of the canalised river were transformed into 20 km of meandering watercourse. At the same time, the river bed was raised, so that the floodplain elements of the river valley would be inundated more frequently. In addition, new ponds were constructed in some of the original meander loops. Also, an ecologically valuable marsh area at Draved – the flora and fauna of which had been threatened by desiccation and overgrowth – could be restored. In 1993, several channels, which drained the centre of the marsh, were sealed. Consequently, a 25 ha large lake was formed. Developments in the new habitats are being closely and intensely monitored. *Macroinvertebrates,* birds, plant communities, development of fish populations, nutrients, sediments, *hydrological* regime and stability of the river bed are being surveyed. In addition, project acceptance, public perception, recreational value and cost-benefit ratio are being analysed (County of Sonderjylland 1996). (More information on the project can be found at www.therrc.co.uk/projects/brede.htm.)

Planning of the rehabilitation project took several years. During this time, the catchment of the Brede River was considered as an entity. In Europe, this project is regarded as an example of its kind (Nielsen 1996). Further projects for the ecological improvement of the Brede River system will follow in the coming years, although in the future, the Lobaek Brook will be at the centre of rehabilitation (County of Sonderjylland 1996).

7.6.3 Indicator set

For evaluating the measure 'reconnecting backwaters, oxbows and floodplains', the indicator set in Table 7.24 is recommended.

Measure: Reconnecting backwaters, oxbows and floodplains

				Service to society		Environ-ment and ecology								Economy	Implemen-tation	
				Suitability of indicator for evaluating important project objectives (♦ = direct parameter; • = indirect parameter)												
Nº	Indicator group	Indicator	Effort level	Sustainable supply of drinking water	Provision of high recreational value	Morphological and hydraulic variability	Near-natural temperature regime	Longitudinal connectivity	Lateral connectivity	Vertical connectivity	Near-natural abundance and diversity of floodplain vegetation	Near-natural abundance and diversity of fauna	Cycling of organic matter	Keeping the budget	Political acceptance	Stakeholder participation
1	**Project acceptance**	Acceptance by interest group*	A												♦	
8	**Fish**	Age structure of fish population**	C			•		•	•			♦				
9	**Fish**	Fish species abundance and dominance**	C			•	•	•				♦				
10	**Fish**	Diversity of ecological guilds of fish**	C			•	•	•				♦				
16	**Hydrogeomorphology and hydraulics**	Variability of flow velocity	C			♦					•	•				
17	**Hydrogeomorphology and hydraulics**	Depth variability at bankfull discharge	B			♦					•	•				
18	**Costs**	Project costs	A											♦		
20	**Landscape**	Aesthetic landscape value	A		♦											
22	**Macroinvertebrates**	Occurrence of both surface water and groundwater organisms in the hyporheic zone	A							•		♦				
25	**Organic material**	Short-term leaf retention capacity	A			•			•				♦			
28	**Stakeholder participation**	Satisfaction of interest groups with the design of the participation process	A													♦
30	**Stakeholder participation**	Satisfaction of interest groups with participation opportunities*	A													♦
31	**Refugia**	Availability of three types of refugia (hyporheic refugia, shoreline habitats, and intact tributaries)***	C					•	•	•	•	•				
35	**River bed**	Grain-size distribution of substratum	A			♦				•		•				
38	**Temperature**	Spatial and temporal variation in water temperature	A	•			♦		•	•						
40	**Transition zones**	Exchange of dissolved nutrients and other solutes between river and groundwater	C	•		•	•			♦						
44	**River bank**	Shoreline length***	A						♦				•			
50	**Vegetation**	Composition of floodplain plant communities	A						•		♦					

Table 7.24: Recommended indicator set with 18 indicators for evaluating the rehabilitation measure 'reconnecting backwaters, oxbows and floodplains'.

*/**/*** The survey takes place at the same time as an identically marked indicator. For * and ** the survey effort corresponds to a single survey. For *** the greater survey effort level C applies.

♦ = direct parameter: indicators, which assess the project objective directly.

• = indirect parameter: indicators, which assess a situation, which is secondarily influenced by the project objective.

7.7 Longitudinal connectivity

7.7.1 Explanation of measure

Swiss rivers and streams are strongly fragmented by various types of cross-sectional constructions. Removing such cross-sectional constructions helps to recreate *connectivity.* In Switzerland (in contrast to the USA), such rehabilitation measures are not realistic at this stage. For this reason, the present handbook does not discuss indicators for measures involving the removal of dams and large weirs. Removing small weirs and falls, however, is currently an important rehabilitation measure. The main purpose of these barriers is to stabilise the river bed. Weirs are obstacles to the upstream and downstream migration of fish, while falls prevent or hamper downstream migration. Additionally, weirs limit the downstream transport of organic material, such as floating organic matter and large wood. Removing barriers therefore has positive effects particularly on longitudinal connectivity, but also on vertical connectivity and natural *abundance* and *diversity* of fauna (particularly with respect to fish) and organic cycles. Depending on the type of barrier, an improvement to *morphological* and *hydraulic* variability may also occur. When barriers are removed, an alternative solution for river bed stabilisation must be sought.

Some barriers can be made passable for upstream migration with the help of fish passage facilities and bypass channels (Figure 7.25). Downstream migration, however, is more problematic, as fish may injure themselves on turbines or rakes. To date, this issue has not been satisfactorily solved. Fish passage facilities and bypass channels can increase longitudinal connectivity and contribute to natural abundance and diversity of fauna, i.e. of fish. If fish become more abundant, the watercourse will become more attractive to sport fishers and its recreational value will therefore increase.

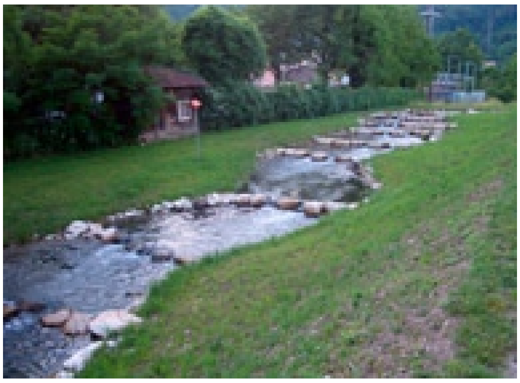


Figure 7.25: Bypass channel at the Aare River at Winznau, SO, 2005 (photo: A. Peter, Eawag, 2004).

7.7.2 Case studies

Bypass channel Ruppoldingen, Switzerland

The hydropower station Ruppoldingen (Canton of Solothurn), which dates back to 1896, was replaced by a new plant between 1996 and 2000. During construction of the new plant, comprehensive rehabilitation measures were implemented as compensation measures. These included, for example, a bypass channel between the upstream and downstream sections of the power station. The bypass channel was to enable upstream migration, including that of species which are less powerful swimmers (www.poweron.ch/de/umwelt/content---1--1126.html). It has a total length of 1.2 km, a width of 10–20 m and an average slope of 0.4 % (Figure 7.26). Its flow is 2–5 m^3/s. In total, the bypass negotiates 5.6 m of altitude. In order to provide suitable habitats for different gravel spawning fish species, different river bed structures and instream structures were installed. The bypass consists of a sequence of gravel chutes with shallow flow and a deeper channel flowing parallel to it. The subsequent areas are characterised by slow current, greater water depths and level gravel bars. As an additional measure, a 5.2 ha large floodplain downstream of the power station was connected to the flow dynamics of the Aare River, which provided the conditions required for a natural zonation of softwood and hardwood floodplain forest (www.biodiversity.ch/downloads/hotspot_6_2002_D.pdf).

The new bypass channel has developed into a valuable habitat for fish. Today, it is populated by a dense and manifold fish fauna. Species diversity is greater than in the Aare River (www.atel.ch/atel_gesellschaften/atel_hydro/Ruppoldingen_Umwelt_gewinnt.jsp).

Beside the bypass channel, shallow water zones, islands and areas for natural development were created by additional rehabilitation measures along a river stretch of 8.4 km. As a result of the new habitats, the number of bird species increased from 35 to 47. Furthermore, the number of breeding stations increased. Kingfishers (*Alcedo atthis*) continue to breed at Ruppoldingen, while the little ringed plover (*Charadrius dubius*) has settled as a new species. The rehabilitation measures also promoted various plant species typical for floodplains. The number of species of flora rose from 213 to 306. Not only nature, but also the population benefits from the rehabilitated floodplain landscape: Ruppoldingen has developed into a popular recreational area (www.atel.ch/atel_gesellschaften/atel_hydro/Ruppoldingen_Umwelt_gewinnt.jsp).

Removal of barriers at the Brede River, Denmark

In the rehabilitation project of the Brede River system described under 7.6.2, not only former floodplains were reactivated and meanders created. Longitudinal *connectivity* was also restored. Particularly comprehensive measures were carried out in 1990: In the Landeby River four concrete weirs were replaced by several *riffles,* while in the Brede River at Bredebrao, one large weir was replaced by three riffles, which had a total length of 110 m. In Lobaek Brook, a large, four-level weir was replaced by riffles. Additionally, several small concrete weirs were removed from the Brede River, from Lobaek Brook and from Ny Havnebaek Brook. By eliminating these migration obstacles, upstream and downstream migration of fish and *macroinvertebrates* were made possible. Today, sea trout (*Salmo trutta trutta*) and salmon (*Salmo salar*) are frequently found in the Brede River. In addition, the population of a whitefish (*Coregonus oxyrinchus*), which had nearly become extinct in the early 1980ies, has been re-established (County of Sonderjylland 1996).

Figure 7.26: Bypass channel at Ruppoldingen, SO, 2004 (photo: A. Peter, Eawag).

Further example:

Bypass channel at the run-of-river power station Unzmarkt at the Mur River, Austria (Jungwirth et al. 1994).

7.7.3 Indicator set

For evaluating the measure 'longitudinal connectivity', the indicator set in Table 7.27 is recommended.

Table 7.27: Recommended indicator set with 13 indicators for evaluating the rehabilitation measure 'longitudinal connectivity'.

Measure: Longitudinal connectivity

				Service to society	Environment and ecology						Economy	Implementation	
				Suitability of indicator for evaluating important project objectives (♦ = direct parameter; • = indirect parameter)									
Nº	Indicator group	Indicator	Effort level	Provision of high recreational value	Morphological and hydraulic variability	Near-natural bedload regime	Longitudinal connectivity	Near-natural abundance and diversity of floodplain vegetation	Near-natural abundance and diversity of fauna	Cycling of organic matter	Keeping the budget	Political acceptance	Stakeholder participation
1	**Project acceptance**	Acceptance by interest group*	A									♦	
4	**Longitudinal connectivity**	Barrier-free migration routes for fish	A				♦						
5	**Recreational use**	Number of visitors	A	♦									
8	**Fish**	Age structure of fish population**	C		•	•	•		♦				
9	**Fish**	Fish species abundance and dominance**	C		•	•	•		♦				
10	**Fish**	Diversity of ecological guilds of fish**	C		•	•	•		♦				
12	**Bedload**	Bedload regime	C		•	♦	•		•				
16	**Hydrogeomorphology and hydraulics**	Variability of flow velocity°	C		♦	•		•	•				
17	**Hydrogeomorphology and hydraulics**	Depth variability at bankfull discharge°	B		♦	•		•	•				
18	**Costs**	Project costs	A								♦		
27	**Organic material**	Quantity and composition of floating organic matter and abundance and diversity of colonising snails	A				♦	•	•	•			
30	**Stakeholder participation**	Satisfaction of interest groups with participation opportunities*	A										♦
47	**Vegetation**	Presence of typical floodplain species	A				•	♦					

*/** The survey takes place at the same time as an identically marked indicator. The survey effort level corresponds to a single survey.

° These indicators are not suitable, if the rehabilitation measure for longitudinal connectivity is a fish ladder, as the hydraulics in the main channel are not influenced.

♦ = direct parameter: indicators, which assess the project objective directly.

• = indirect parameter: indicators, which assess a situation, which is secondarily influenced by the project objective.

7.8 Bedload rehabilitation

7.8.1 Explanation of measure

From an ecological point of view, a *bedload* regime, which complies with the *geomorphological* characteristics of the watercourse, is desirable. Most rehabilitation projects are conducted in rivers and streams of the *alluvial* lowland and in sections of bedload movement, which – in their natural condition – would have a tendency toward aggradation. However, because of reduced input from the catchment and/or excess transport capacity, they have a tendency toward erosion. The aim of bedload rehabilitation is generally to increase bedload input from the catchment. This can involve one or several of the following measures:

- remove bedload collectors or cease their clearance
- manage bedload collectors in favour of the *receiving watercourses* (clear collectors and return material into receiving watercourses)
- renovate weirs and reservoirs, in order to improve bedload transport
- temporarily lower reservoir water level in run-of-river power stations during flood, in order to promote bedload transport
- abandon gravel mining in rivers
- add bedload to watercourse
- remove river bank protections, in order to initiate bedload supply from lateral erosion
- allow natural bedload movements
- reduce transport capacity through channel widening

7.8.2 Case studies

Creation of gravel bars in the Aare River, Switzerland

In its natural state and downstream of its confluence with the Emme River, the Aare River used to transport an average of 20,000 m^3/a bedload. In 1970, however, the large run-of-river power stations Flumenthal and Bannwil were constructed at the confluence points with the rivers Emme and Sigger and bedload collectors were installed. Consequently, bedload transport and its input into the Aare River were completely eliminated. Because of the large storage reservoirs, bedload could not be transported across the weir during high water flow. The bedload deficit led to channel erosion and river bed *clogging* downstream of the power stations, detrimentally affecting the aquatic habitat. In order to reactivate the bedload regime, two large gravel bars – each with a volume of approximately 12,000 m^3 – were deposited in the Aare River at suitable downstream positions. During spate, the gravel deposits are gradually eroded and sufficient bedload is supplied downstream of the power plants. Once the gravel bars have been eroded, they should be renewed. The gravel bar at Deitingen (Canton of Solothurn) was created in January 2005 (Figure 7.28). The second gravel bar at Aarwangen (Canton of Berne) was deposited in November 2005. The project is financed by the Cantons of Solothurn and Berne and is subject to project evaluation.

Floodplain Foort at Eggenwil, Switzerland

For the floodplain Foort at Eggenwil, which lies in a large bend of the Reuss River, plans for a comprehensive rehabilitation project were developed in 2001 and were implemented in the winters of 2002/2003 and 2003/2004. At this point in time, the river banks were lined by concrete elements and stone blocks. Bedload movement was practically nonexistent. In the adjoining floodplain forest, there was a lack of softwood trees. Measures for floodplain rehabilitation included the removal of the concrete elements and stone blocks along a stretch of approximately 1,500 m. Furthermore, six ponds were created and two approximately 500 m long side channels were excavated. In the floodplain forest, the fir trees atypical for this habitat were felled and the forest was partly cleared. These measures ensured that the periodically flooded surfaces could expand and improved *connectivity* between the river and its floodplain. In order to activate the bedload regime and to increase structural variability of the river bed, several gravel bars and sand banks of 2,000 to 3,000 m^3 were created on the inside of the river bend (Figure 7.29),

Figure 7.28: Deposited gravel bar in the Aare River at Deitingen, SO, 2005 (photo: U. Schälchli, Schälchli, Abegg + Hunzinger).

which are subject to erosion during times of flood (references: www.pronatura-aargau.ch and www.ag.ch/natur2001/auenschutzpark).

Floodplain of the Bünz River at Möriken, Switzerland

Between 1920 and 1940, the Bünz River was canalised and deepened between Muri and Othmarsingen, in order to contain the danger of flooding. Downstream of Othmarsingen, the stream was not affected by the regulation measures. Therefore, in the Möriken area (Canton of Aargau), it still meanders freely. The topography and possibilities for use of this section were completely transformed by the hundred year flood of 1999. During a peak flow of 70 m^3/s between May 12th and 13th, 15,000 m^3 *bedload* were moved and numerous pipelines for sewage, electricity and gas were uncovered. During the flood, the stream bed was widened to such an extent that today, the Bünz River uses a width of 100 m to meander. Practically overnight, these bedload movements created a new floodplain in the middle of cultivated land. The newly developed gravel bars were rapidly colonised by pioneer species. In August 2000, the 60 ha large floodplain of the Bünz River at Möriken was accepted as a floodplain of national importance and was included in the floodplain inventory (Schlupp & Schelbert 2001). No further constructional measures followed after the flood. The Bünz River is allowed to continue to meander freely and to move its

Figure 7.29: Gravel deposit in the Reuss River at Foort, Eggenwil, AG. **Left:** the gravel deposit behind the natural gravel bar. **Right:** the deposited gravel bar was eroded during the flood of August 2005 (photos: Oekovision GmbH, 8967 Widen).

Figure 7.30: Floodplain of the Bünz River at Möriken, AG, June 2000 (photo: Oekovision GmbH, 8967 Widen).

bedload (Figures 7.30 and 7.31). In the future, the dynamic processes of sedimentation and erosion will be tolerated. For this purpose, two thirds of the floodplain have become public property (Ringgenberg et al. 2004).

7.8.3 Indicator set

For evaluating the measure 'bedload rehabilitation', the indicator set in Table 7.32 is recommended.

Figure 7.31: Floodplain of the Bünz River at Möriken, AG, September 2005 (photos: S. Woolsey, Eawag).

Table 7.32: Recommended indicator set with 11 indicators for evaluating the rehabilitation measure ‘bedload rehabilitation’.

Measure: Bedload rehabilitation

N°	Indicator group	Indicator	Effort level	Servicet to society	Environment and ecology						Economy
				Suitability of indicator for evaluating important project objectives (♦ = direct parameter; • = indirect parameter)							
				Sustainable supply of drinking water	Morphological and hydraulic variability	Near-natural bedload regime	Longitudinal connectivity	Lateral connectivity	Vertical connectivity	Near-natural abundance and diversity of fauna	Keeping the budget
8	**Fish**	Age structure of fish population*	C		•	•	•	•		♦	
9	**Fish**	Fish species abundance and dominance*	C		•	•	•			♦	
10	**Fish**	Diversity of ecological guilds of fish*	C		•	•	•			♦	
12	**Bedload**	Bedload regime	C		•	♦	•			•	
18	**Costs**	Project costs	A								♦
23	**Macroinvertebrates**	Taxonomic composition of macroinvertebrate community	A		•	•	•	•	•	♦	
32	**River bed**	Permeability of river bed	B	•	•	•			♦		
33	**River bed**	Temporal changes in diversity of geomorphic river bed structures	B C		♦	•	•	•	•	•	
34	**River bed**	Clogging of hyporheic sediments	A	•	•	•			♦		
35	**River bed**	Grain-size distribution of substratum	A		♦	•			•	•	
40	**Transition zones**	Community composition and density of small mammals on floodplain	C	•	•	•			♦		

*The survey takes place at the same time as an identically marked indicator. The survey effort level corresponds to a single survey.

♦ = direct parameter: indicators, which assess the project objective directly.

• = indirect parameter: indicators, which assess a situation, which is secondarily influenced by the project objective.

8 Indicator selection

The presented scheme for evaluating rehabilitation projects in rivers and streams is used to assess to what extent the objectives defined by the project management were achieved. The method uses indicators to compare if and to what extent a measure has caused changes in a rehabilitated section. For frequently implemented measures, indicator sets are recommended in chapter 7. Composition of the indicator sets is dependent on the project objectives, which are to be achieved. In the present chapter, the procedure for selecting indicators for a user-defined indicator set, with regard to specific project objectives, is described. In the first part of the chapter, the concept and procedure of indicator selection is presented. The Excel template 'Selection and evaluation' facilitates the process of selecting indicators. The template can be found in Appendix III. Its operation is described in the second part of this chapter.

8.1 Concept and procedure of indicator selection

Project evaluation draws conclusions on the extent to which project objectives were achieved. Selecting indicators suitable for project evaluation is therefore based on the project objectives defined during the planning process. Hence, the first step consists of determining project objectives using the list provided in the Excel template 'Selection and evaluation'. The most important project objectives, for which the present handbook provides indicators, are discussed in chapter 6. Usually, several indicators are available for evaluating a project objective. Table 8.1 shows a list of all indicators recommended and discussed in this handbook. Parameters for assessing project objectives directly are marked with the symbol ♦, parameters for assessing project objectives indirectly are marked with the symbol •. A blank field indicates that the indicator is not suitable for evaluating the project objective. Parameters for direct assessment are indicators which directly assess a project objective, as they are directly influenced by the project objective. Parameters for indirect assessment are indicators which indirectly assess a project objective, as they are only indirectly or secondarily influenced by the project objective. When selecting indicators for measuring project objectives, direct parameters are particularly recommended. Indicators are assigned to the categories for survey effort level A, B and C, which are discussed in chapter 4.3.3.

The Excel template 'Selection and evaluation' additionally provides information on temporal relevance of the indicators and their suitability for sections with *hydropeaking* and *residual flow.* Temporal relevance indicates when indicators should be surveyed: 1st to 2nd year, 3rd to 5th year or 6th to 15th year after implementation of the measure.

Table 8.1: Suitability of indicators for evaluating important project objectives: ♦ = direct parameters; • = indirect parameters. Indicators are numbered and are divided into indicator groups and categories of survey effort: A < 2 person days, B: 2–3 person days, C > 3 person days.

				Service to society		Environment and ecology									Economy	Implementation	
Nº	**Indicator group**	**Indicator**	**Effort level**	Sustainable supply of drinking water	Provision of high recreational value	Morphological and hydraulic variability	Near-natural bedload regime	Near-natural temperature regime	Longitudinal connectivity	Lateral connectivity	Vertical connectivity	Near-natural abundance and diversity of floodplain vegetation	Near-natural abundance and diversity of fauna	Cycling of organic matter	Keeping the budget	Political acceptance	Stakeholder participation
1	**Project acceptance**	Acceptance by interest group	A													♦	
2	**Project acceptance**	Acceptance by entire public	B													♦	
3	**Project acceptance**	Acceptance by project work group	A													♦	
4	**Longitudinal connectivity**	Barrier-free migration routes for fish	A						♦								
5	**Recreational use**	Number of visitors	A		♦												
6	**Recreational use**	Variety of recreational opportunities	A		♦												
7	**Recreational use**	Public site accessibility for recreation	A		♦												
8	**Fish**	Age structure of fish population	C			•	•		•	•			♦				
9	**Fish**	Fish species abundance and dominance	C			•	•	•	•				♦				
10	**Fish**	Diversity of ecological guilds of fish	C			•	•	•	•				♦				
11	**Fish habitat**	Presence of cover and instream structures	A			•	•			•			•	•			
12	**Bedload**	Bedload regime	C			•	♦		•				•				
13	**Hydrogeomorphology and hydraulics**	Inundation dynamics: duration, frequency and extent of flooding	A							•				•			
14	**Hydrogeomorphology and hydraulics**	Variability of visually estimated wetted channel width	A			♦	•			♦							
15	**Hydrogeomorphology and hydraulics**	Variability of measured wetted channel width	B			♦	•			♦							
16	**Hydrogeomorphology and hydraulics**	Variability of flow velocity	C			♦	•					•	•				
17	**Hydrogeomorphology and hydraulics**	Depth variability at bankfull discharge	B			♦	•					•	•				
18	**Costs**	Project costs	A												♦		
19	**Landscape**	Diversity and spatial arrangement of habitat types	C		•	•			•	•	•	•	•	•			
20	**Landscape**	Aesthetic landscape value	A		♦												
21	**Macroinvertebrates**	Richness and density of terrestrial riparian arthropods	B							•			♦				
22	**Macroinvertebrates**	Occurrence of both surface water and groundwater organisms in the hyporheic zone	A				•				•		♦				
23	**Macroinvertebrates**	Taxonomic composition of macroinvertebrate community	A			•	•		•	•	•		♦				
24	**Macroinvertebrates**	Presence of amphibiontic species in the groundwater	A				•				•		♦				
25	**Organic material**	Short-term leaf retention capacity	A			•				•				♦			
26	**Organic material**	Quantity of large wood	A	•						•				♦			

				Service to society		Environment and ecology									Economy	Implementation	
Nº	**Indicator group**	**Indicator**	**Effort level**	Sustainable supply of drinking water	Provision of high recreational value	Morphological and hydraulic variability	Near-natural bedload regime	Near-natural temperature regime	Longitudinal connectivity	Lateral connectivity	Vertical connectivity	Near-natural abundance and diversity of floodplain vegetation	Near-natural abundance and diversity of fauna	Cycling of organic matter	Keeping the budget	Political acceptance	Stakeholder participation
27	**Organic material**	Quantity and composition of floating organic matter and abundance and diversity of colonising snails	A						♦	●		●	●	●			
28	**Stakeholder participation**	Satisfaction of interest groups with the design of the participation process	A														♦
29	**Stakeholder participation**	Satisfaction of the public with participation opportunities	A														♦
30	**Stakeholder participation**	Satisfaction of interest groups with participation opportunities	A														♦
31	**Refugia**	Availability of three types of refugia (hyporheic refugia, shoreline habitats, and intact tributaries)	C				●		●	●	●	●	●				
32	**River bed**	Permeability of river bed	B	●		●	●				♦						
33	**River bed**	Temporal changes in diversity of geomorphic river bed structures	B C			♦	●		●	●	●	●	●	●			
34	**River bed**	Clogging of hyporheic sediments	A	●		●	●				♦						
35	**River bed**	Grain-size distribution of substratum	A			♦	●				●		●				
36	**River bed**	Diversity of geomorphic river bed structures	A B			♦	●		●	●	●	●	●	●			
37	**River bed**	Degree and type of anthropogenic modification	A			♦							●				
38	**Temperature**	Spatial and temporal variation in water temperature	A	●				♦		●	●						
39	**Transition zones**	Food subsidies across land-water boundaries	C							●							
40	**Transition zones**	Exchange of dissolved nutrients and other solutes between river and groundwater	C	●		●	●	●			♦						
41	**Transition zones**	Community composition and density of small mammals on floodplain	C							●			♦				
42	**River bank**	Width and degree of naturalness (vegetation, composition of ground) of riparian zone	A			♦		●		●		●	●	●			
43	**River bank**	Temporal changes in the quantity and spatial extent of morphological units	A	●		♦			●	♦			●				
44	**River bank**	Shoreline length	A				●			♦				●			
45	**River bank**	Quantity and spatial extent of morphological units	A	●		♦			●	♦			●				
46	**River bank**	Degree and type of anthropogenic modification	A			♦				●	♦	●	●	●			
47	**Vegetation**	Presence of typical floodplain species	A						●			♦					
48	**Vegetation**	Succession and rejuvenation of plant species on floodplains	C							●		♦					
49	**Vegetation**	Temporal shift in the mosaic of floodplain vegetation categories	B						●			♦					
50	**Vegetation**	Composition of floodplain plant communities	A							●		♦					

♦ = direct parameter: indicators, which assess the project objective directly.
● = indirect parameter: indicators, which assess a situation, which is secondarily influenced by the project objective.

Each defined project objective should be assessed by at least one indicator, although the use of several indicators would be better. Indicators which assess several project objectives simultaneously are therefore particularly recommended. Also, indicators which enable a direct assessment of a project objective are to be given preference over indirect parameters. Conclusions from project evaluation refer exclusively to the extent to which the selected, individual project objectives were achieved, not to the approximation of a river or stream section to a reference system or guiding image. However, the more project objectives are included in the evaluation, the more likely it is that any achieved success will also correspond to an approximation to a guiding image. Project evaluation therefore only takes place at the level of project objectives. No assumptions on the overall project success are made. However, under the conditions discussed in chapter 10, a conclusion with regard to a project's ecological success can be drawn.

It is recommended that indicator selection is performed within an interdisciplinary group. Such a group should consist of project managers, biologists (experts for fish, *macroinvertebrates,* vegetation), ecologists, *hydrologists, geomorphologists,* social scientists and river engineers.

8.2 Instructions for using the Excel template

8.2.1 Recommended indicator sets

If one of the indicator sets recommended for the measures discussed in chapter 7 is applied, the user can click on the button 'Recommended indicator sets' in the work sheet 'Start' of the Excel template 'Selection and evaluation'. On the subsequent work sheet labelled 'Recommended', the desired measure can be selected. After clicking on 'Next', the recommended indicator set is presented, which can be printed out by clicking on the button 'Print preview'. By clicking on the button 'Back', the user can go back one step at any point in the procedure.

8.2.2 Compiling a user-defined indicator set

Before compiling a user-defined indicator set, the objectives, which are to be achieved by the rehabilitation project, must be defined. The handbook does not offer direct instructions for this step. It does, however, discuss 14 important project objectives, which provide the user with a basis for defining his project-specific objectives (see chapter 6). In a next step, indicators for evaluating these project objectives can be selected using the Excel template 'Selection and evaluation'. The template guides the user through the required steps.

If the option 'User-defined indicator set' is selected on the 'Start' sheet, the programme compiles a work sheet, which shows all indicators divided into their groups. In the column 'Temporal relevance', grey boxes indicate when and within which time frame after implementing the measure survey of the individual indicators is appropriate. The survey effort for each indicator is given in person days. Indicators, which are suitable for sections affected by *hydropeaking* or *residual flow,* are also marked. The suitability of an indicator for evaluating a particular project objective is indicated by the following symbols: ♦ = direct parameter, • = indirect parameter, no symbol = not suitable.

As a first step, the boxes of those project objectives must be ticked, which the user wishes to evaluate. The boxes are located in row 6 of the work sheet, right above the project objectives. Now click on 'Next'. The programme deletes all project objectives and their respective indicators, which are not part of the user-specific evaluation.

In the next sheet, only the selected project objectives and their respective indicators are displayed. A user-specific indicator set is now compiled using this reduced list of indicators. This is achieved by ticking the indicator boxes. The boxes are located in column B, to the left of the indicator names. Each project objective must be represented by at least one indicator. Integrative indicators, i.e. indicators which assess more than one project objective, are particularly recommended. Also, direct parameters should be given preference over indirect parameters. Further, only indicators with an appropriate temporal relevance should be considered for selection. If the indicator survey should only require low effort, the choice is limited to type A indicators (< 2 person days). If the effort level is irrelevant, type B (2–3 person days) and type C indicators (>3 person days) should also be included in the selection.

At the end of the table, up to three additional, user-defined indicators can be added. These indicators can be selected by ticking the boxes in column B. In column E, names can be added for these indicators. In a subsequent step, all project objectives, which the new indicators will assess, must be identified. This is achieved by ticking the boxes in columns N to AA.

By clicking on ‘Next’ all indicators, which were not selected, will be deleted. If a project objective is not represented by at least one indicator, an error message will appear. Otherwise, an individual indicator table is compiled, which can by printed by clicking on the box ‘Print preview’. At any time, the selection can be saved as an ‘Excel file’ (*.xls). The template itself is an ‘Excel template’ (*.xlt), and is therefore write-protected, if it was copied from the CD.

8.2.3 Further procedure

Now, before rehabilitation works begin, the user is ready to survey his indicators within the project perimeter. At this point, the relevant indicator method sheets in Appendix I must be consulted and the survey instructions must be followed. In order to take natural variability into account, indicator surveys must be repeated several times (depending on the indicator), before construction works begin. Subsequently, the obtained indicator values must be averaged. Further details are given in the indicator method sheets. After the measure has been completed, indicators are surveyed again, and their new mean values are determined. Indicator values from before and after implementation of the measure are then compared. For this step, it is important to consider details on time of survey provided in the method sheets. Once surveys have been completed, project evaluation can be carried out using the second part of the Excel template ‘Selection and evaluation’ (see chapter 10). If, at a later point, indicators are surveyed a second or third time etc., the new values are compared with the values from before rehabilitation. This way, temporal changes can be monitored.

9 Indicator survey

For each indicator recommended in the present handbook, a method sheet is provided in Appendix I, which contains information on indicator survey and analysis. For some indicators, further-reaching literature or detailed survey instructions have been compiled. These can be found in Appendix II. Reference to these additional documents is made in the relevant indicator method sheets.

All indicator method sheets have an identical structure. Their content is divided into six subheadings, which are identified by six different icons. In the following, the method sheet template is shown and details on the contents of each subheading are given.

Indicator group: Indicator name

Author: name surname, institute/agency

Background

Short description of indicator: What does the indicator assess? For which project objectives is the indicator relevant (see Table 1)? Why is the use of this indicator appropriate for assessing these project objectives?

Table 1: Suitability of indicator for assessing project objectives (fictitious example).

Service for society		Environment and ecology		Economy		Implementation process	
	Sustainable supply of drinking water	•	Morphological and hydraulic variability		Keeping the budget		Political acceptance
	Provision of high recreational value	•	Near-natural bedload regime				Stakeholder participation
			Near-natural temperature regime				
		•	Longitudinal connectivity				
		•	Lateral connectivity				
			Vertical connectivity				
		♦	Near-natural abundance and diversity of floodplain vegetation				
			Near-natural abundance and diversity of fauna				
			Cycling of organic matter				

♦ = direct parameter: indicators, which assess the project objective directly.
• = indirect parameter: indicators, which assess a situation, which is secondarily influenced by the project objective.

Survey

Assessment unit: What kind of parameter is assessed for this indicator?

Survey procedure: How is the parameter assessed?

Secondary surveys: e. g. GPS survey or aerial survey of sampling sites

Effort in terms of time and personnel: Specification of survey effort level. What is the minimum number of persons and person hours required for one survey (preparation, assessment, analysis)? -> to be specified in Table 2.

Table 2: Estimated survey effort in terms of time and personnel.

Required step	**Specialists**		**Assistants**	
	Number of persons	Duration per person (h)	Number of persons	Duration per person (h)
Total number of person hours (p-h):				
Comments: e. g. additional effort (package and posting, laboratory order etc.)				

Material requirement: What kind of instruments and equipment are needed?

Frequency and time frame of survey: Appropriate time (e.g. perhaps weeks, months or years after the rehabilitation measure has been completed), appropriate season (consideration of flood events or life cycles of biological indicators). How often should the indicator be surveyed (e.g. monthly, every six months, annually)?

Special features: E. g. only suitable for particular river types or seasons. How are recorded data filed? Are they stored on a data base? Which programmes are used to store data?

Alternative data source: Can the data be obtained from any other source, so that measurements are not required?

Analysis of results

Interpretation: methods, computer programmes. *Standardisation* of measured values to a non-dimensional value: definition and explanation of 0- and 1-guideline values (near-natural and unnatural indicator threshold values) and of standardisation procedure (standardisation equation or standardisation classes). Chart for standardising indicator values.

Relation to other indicators

Is the indicator in any way related to other indicators described in the handbook? Do any of these complement the information of the present indicator?

Examples of application

Where has the indicator already been successfully applied? Literature references, briefly commented.

Literature

Complete reference details of literature mentioned in the text.

10 Project evaluation

In this chapter, we explain how to interpret the results from the indicator survey and how to use them for evaluating rehabilitation projects in rivers and streams. Subsequently, instructions are given for using the Excel template 'Selection and evaluation', which can be used for automated project evaluation. The procedure is identical for both recommended and user-defined indicator sets. The Excel template can be found in Appendix III.

10.1 Concept and procedure of project evaluation

The evaluation procedure consists of multiple stages. The various steps are outlined in the following paragraphs. Their practical implementation using the Excel template is described in the subsequent chapter 10.2.

10.1.1 Establishing mean values

The values from the indicator survey form the basis of project evaluation. Each indicator has its individual unit. Using the information provided in the method sheets, two mean values are established for each indicator: one from the values obtained before the rehabilitation measure was implemented and one from the values obtained after the measure was completed.

10.1.2 Standardisation of indicator values

The determined values have different indicator-specific units, such as 'number of individuals', 'surface area', etc. In order to draw meaningful conclusions, it is necessary to transform them into *standardised*, non-dimensional values. These values lie between 0 and 1 and represent the degree of naturalness of or the degree of satisfaction with the examined indicator. Indicator threshold values are defined for the unnatural condition 0 and the near-natural condition 1 (0- and 1-guideline values). The standardised value shows how close the measured indicator value is to its best possible value. Values from before and after project implementation are therefore standardised separately.

Indicator values are transformed into non-dimensional values (i. e. are standardised) by following the transformation procedures provided in the indicator method sheets. These describe the relationship between the measured indicator values and the degree of naturalness or satisfaction. For many of the indicators, this comparison is based on a quantitative standardisation equation. This equation can be linear, but may also be of a more complex nature. For other indicators, a quantitative comparison is not possible. In this case, the degree of naturalness or satisfaction is determined semi-quantitatively or qualitatively based on criteria or classes (standardisation classes). The allocated scores are averaged and a value between 0 and 1 is obtained.

For each indicator, 0- and 1-guideline values are provided in the method sheets. These are values recommended by the handbook authors. They are based on reference conditions and expert judgement. In the Excel template 'Selection and evaluation', standardisation of the indicator values is performed automatically. Indicator values can also be standardised manually by a competent user, if reasons exist for altering the recommended 0- and 1-guideline values, standardisation equations or standardisation classes.

10.1.3 Evaluation: indicators, project objectives, ecological success

Indicators

The averaged and standardised indicator values are now compared in a matrix, in order to identify changes, which have occurred as a result of rehabilitation (Table 10.1). Depending on how the values have changed, the matrix

gives five possible categories, which indicate improvement or deterioration (Table 10.2). The categories of change are highlighted in different colours. Using this procedure, not only the degree and the type of change are taken into account, but also the initial situation is considered. An increase of an initial value by 0.3 can therefore be classed either as small success (e. g. from 0.1 to 0.4) or as medium success (e. g. from 0.5 to 0.8).

Project objectives

In a next step, the individual project objectives are evaluated. For this purpose, the *standardised* values from before and after the measure are summarised for all indicators characterising the same project objective, by establishing their mean value. For each project objective, two values result: one for the situation before rehabilitation and one for the situation after rehabilitation. These two values are then once again compared in the matrix, in order to determine the category of change for each individual project objective.

Ecological success

As the three sectors 'Service to society', 'Economy' and 'Implementation' are represented by one, or at the most by two project objectives (see also chapter 6), the project objectives are not further summarised. For these three sectors project evaluation ends at the level of the individual project objectives. The list of project objectives is based on the authors' expertise. Beside these, further project objectives may also be of interest. The list is therefore not exhaustive. A conclusion on project success, with regard to the three individual sectors, would indeed be useful, but would only be meaningful, if it was based on a comprehensive list of project objectives.

The sector 'Environment and ecology', however, is comprehensively characterised by the project objectives recommended for evaluation. This focus of the handbook is due to the authors' expertise. The nine project objectives cover various structural and functional aspects of rivers and streams. Therefore, a conclusion on the project's ecological success is deemed

Table 10.1: Matrix for comparing standardised indicator values (before and after measure was implemented).

Value after rehabilitation \ Value before rehabilitation	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0	–	–	–	–	–	–	–	–	–	–
0.1	+	0	–	–	–	–	–	–	–	–	–
0.2	+	+	0	–	–	–	–	–	–	–	–
0.3	+	+	+	0	–	–	–	–	–	–	–
0.4	+	+	+	+	0	–	–	–	–	–	–
0.5	++	++	+	+	+	0	–	–	–	–	–
0.6	++	++	++	+	+	+	0	–	–	–	–
0.7	++	++	++	++	++	+	+	0	–	–	–
0.8	+++	+++	++	++	++	++	+	+	0	–	–
0.9	+++	+++	+++	+++	+++	++	++	++	++	0	–
1.0	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	0

Table 10.2: Categories of change.

Symbol	Change	Explanation
–	Deterioration, failure	The difference between the condition after the measure and the initial situation is negative.
0	No change	The difference between the condition after the measure and the initial situation is 0.
+	Small improvement, small success	The difference between the condition after the measure and the initial situation is positive. Classification depends on the initial situation.
++	Medium improvement, medium success	The difference between the condition after the measure and the initial situation is positive. Classification depends on the initial situation.
+++	Great improvement, great success	The difference between the condition after the measure and the initial situation is positive. Classification depends on the initial situation.

appropriate. In order for such a conclusion to be supported by the provided data, an evaluation of at least five of the nine project objectives is required (recommendation by the authors). (Note: This limitation entails that no conclusion on ecological success can be drawn for the measure ‘structuring the river bed’. Here, only four project objectives are evaluated.) Five categories of success are formed. The names of these categories correspond with those of the five categories of change:

- deterioration, failure
- no change
- small improvement, small success
- medium improvement, medium success
- great improvement, great success

Allocation to the categories of success is dependent on the categories of change of the individual project objectives. Depending on the number of evaluated project objectives, the criteria for qualifying for a particular category of success vary slightly. These criteria are identical for five and six project objectives, and for seven and eight project objectives. If all nine project objectives were evaluated, again slightly different criteria for allocating a category apply (Table 10.3). The categories of success were generated based on appraisals made by the authors.

A conclusion on a project’s overall success would be particularly useful when comparing different projects. Such a comparison, however, is difficult, as the initial conditions and the project objectives often vary greatly. To be meaningful, an overall conclusion would also have to be based on a large variety of project objectives. As discussed at the beginning of this chapter, this is only the case for the sector ‘Environment and ecology’. It is not the case for the sectors ‘Service to society’, ‘Economy’ and ‘Implementation’. In the present handbook, we therefore refrain from summarising the results further.

	5 or 6 project objectives evaluated	7 or 8 project objectives evaluated	9 project objectives evaluated
Failure	3 or more project objectives are rated as a failure.	4 or more project objectives are rated as a failure.	4 or more project objectives are rated as a failure.
	The number of objectives rated as successful (small, medium or great success) is smaller than the number of objectives rated as a failure.	The number of objectives rated as successful (small, medium or great success) is smaller than the number of objectives rated as a failure.	The number of objectives rated as successful (small, medium or great success) is smaller than the number of objectives rated as a failure.
No change	At least 3 project objectives are rated as ‘no change’ or higher.	At least 4 project objectives are rated as ‘no change’ or higher.	At least 5 project objectives are rated as ‘no change’ or higher.
	No more than 2 project objectives are rated as a failure.	No more than 3 project objectives are rated as a failure.	No more than 3 project objectives are rated as a failure.
	The number of objectives rated as successful (small, medium or great success) is the same or greater than the number of objectives rated as a failure.	The number of objectives rated as successful (small, medium or great success) is the same or greater than the number of objectives rated as a failure.	The number of objectives rated as successful (small, medium or great success) is the same or greater than the number of objectives rated as a failure.
Small success	At least 3 project objectives are rated as ‘small success’ or higher.	At least 4 project objectives are rated as ‘small success’ or higher.	At least 5 project objectives are rated as ‘small success’ or higher.
	No more than 1 project objective is rated as a failure.	No more than 1 project objective is rated as a failure.	No more than 2 project objectives are rated as a failure.
Medium success	At least 3 project objectives are rated as ‘medium success’ or higher.	At least 4 project objectives are rated as ‘medium success’ or higher.	At least 5 project objectives are rated as ‘medium success’ or higher.
	No more than 1 project objective belongs to the class ‘no change’.	No more than 1 project objective belongs to the class ‘no change’.	No more than 1 project objectives belong to the class ‘no change’.
	No project objective is rated as a failure.	No project objective is rated as a failure.	No more than 1 project objective is rated as a failure.
Great success	At least 3 project objectives are rated as ‘great success’.	At least 4 project objectives are rated as ‘great success’.	At least 5 project objectives are rated as ‘great success’.
	No more than 1 project objective belongs to the class ‘small success’ or ‘no change’.	No more than 1 project objective belongs to the class ‘small success’ or ‘no change’.	No more than 2 project objectives belong to the class ‘small success’ or ‘no change’.
	No project objective is rated as a failure.	No project objective is rated as a failure.	No project objective is rated as a failure.

Table 10.3: Criteria for five categories of success when evaluating ecological success. Criteria vary slightly, depending on the number of evaluated project objectives.

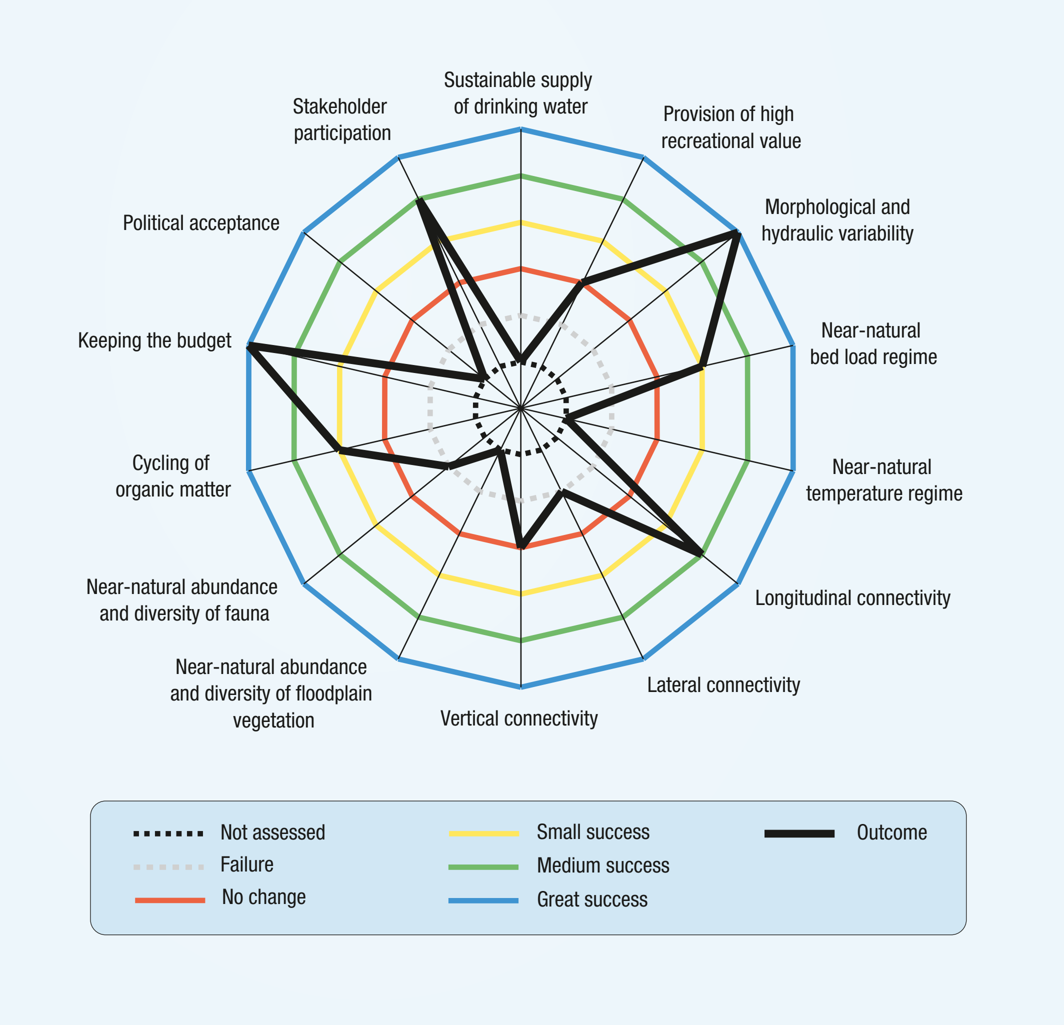


Figure 10.4: Evaluation outcome displayed in a radar diagram. The fictitious example shows to what extent project objectives were achieved. With respect to the project objectives 'morphological and hydraulic variability', 'longitudinal connectivity' and 'keeping the budget', the project was particularly successful, while the project objectives 'lateral connectivity' and 'near-natural abundance and diversity of fauna' were rated as failures.

10.1.4 Radar diagram

Displaying the evaluation results in a radar diagram provides an overview of what has been achieved by the rehabilitation project. In this diagram, all project objectives are arranged in a circle. The five coloured rings correspond to the five categories of change. The further a project objective reaches into the outer periphery of the circle, the better. Figure 10.4 shows a fictitious example of project outcome.

10.2 Instructions for using the Excel template

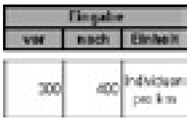
Now project evaluation can be carried out using the Excel template 'Selection and evaluation'. For this step, all measured indicator values from before and after the measure was implemented are needed. Beginning at the 'Start' sheet, the indicator set can be reproduced (see chapter 8.2), or a saved copy of the originally selected indicator set can be used. If one of the recommended indicator sets was chosen, this set should also be reproduced. Now click on 'Next' to display the evaluation table. In this table, the selected indicators are grouped into the four sectors 'Service to society', 'Environment and ecology', 'Economy' and 'Implementation'. Indicators, which are relevant for more than one project objective, are listed repeatedly. Now the template guides the user through the subsequent steps, which are described in the following paragraphs.

10.2.1 Entering mean values

Mean values of indicators measured before rehabilitation are entered in column D. Mean values of indicators measured after rehabilitation are entered in column E. For those indicators which appear under different project objectives, values are completed automatically. It is therefore not necessary to enter any values in the grey boxes.

As described in the individual indicator method sheets, indicator values are physical parameters, non-dimensional parameters or parameters, for which assessment results are divided into classes. In the following sections, the procedure for entering these values is illustrated by some examples (As the Excel template 'Selection and evaluation' is currently only available in German, the screen shots in the following examples are in German.):

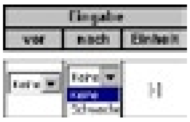
(a) Parameters with a unit (example: indicator N° 47 'presence of typical floodplain species'): Enter measured values in columns D and E.



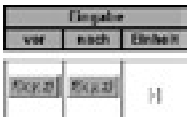
(b) Scores or non-dimensional parameters (example: indicator N° 7 'public site accessibility for recreation'): Enter scores in columns D and E.

Note: In some indicator method sheets, scores already represent *standardised* values (i.e. the values lie between 0 and 1). In this case, boxes in columns D and E are coloured grey and values can be entered in the columns for standardised values (columns G and H).

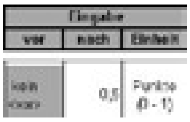
(c) Categories (example: indicator N° 34 'clogging of hyporheic sediments'): The respective categories can be selected from a menu.



(d) Parameters, which incorporate more than one category (example: indicator N° 8 'age structure of fish population'): Click on the button 'f(x,y,z)'. A window will appear, from which the appropriate category can be selected. Click on 'calculate' and close the window.



(e) Indicators, which do not require a 'before-value' (example: indicator N° 29 'satisfaction of the public with participation opportunities'): Enter only one measured value in column E.



(f) User-defined indicators: The user determines the standardised values (i.e. values between 1 and 0) and enters them in columns G and H.

10.2.2 Standardising indicator values

By clicking on the button 'Standardisation/ evaluation', the values are standardised. Note: If the programme does not react to the click, check whether the box, into which you entered the last figure, is still active (i. e. has a black frame). If this is the case, press the enter key and then click on the button 'Standardisation/evaluation'.

The standardised values are given to one decimal place. Values of 0.05 are rounded up. Standardisation is carried out individually for each indicator and according to indicator-specific standardisation equations (quantitative standardisation) or standardisation classes (semi-quantitative or qualitative standardisation). Brief information on the applied equation or classification appears when clicking on the question mark next to the relevant indicator name.

Note concerning the internal operation of the programme: The Excel template does not calculate the standardised values using the respective standardisation equations or classes, but accesses a matrix, in which indicator values are compared with the standardisation categories 0–0.1, 0.1–0.2, ... 0.9–1. These are listed in auxiliary table 4, which can be made visible by clicking on 'Sheet' and 'Unhide' in the menu 'Format'. If the 0- and 1-gudeline values, standardisation equations or standardisation classes recommended in the indicator method sheets have been altered by the user, the relevant standardised values must be entered manually in columns G and H in the work sheet 'Evaluation'.

10.2.3 Evaluation: indicators, project objectives, ecological success

After standardisation, the evaluation results appear and are presented as follows: In column I, categories of change are shown for the individual indicators, while in column N, categories of change are shown for the individual project objectives. If at least five ecological project objectives were evaluated, the category of ecological success is displayed in column T. The programme determines the categories of change for the individual project objectives by calculating the mean values of the relevant standardised indicator values. The five categories are identified using the colours and symbols shown in Table 10.2. On the one hand, allocation to the categories depends on how the value after rehabilitation has changed compared to the value before rehabilitation. On the other hand, the initial condition is also taken into account (see Table 10.1). Categories of ecological success are established based on the criteria given in Table 10.3. A table summarising all evaluation results can be printed by clicking on the button ‘Print preview’.

10.2.4 Radar diagram

In addition to the evaluation summary, results can also be graphically displayed by clicking on the button ‘Radar diagram’. The diagram can be printed by clicking on the button ‘Print preview’.

In order to change the measured values in the evaluation table, the user can click on the button ‘Back’ in the work sheet ‘Evaluation’. If the user wishes to alter the evaluation table, i.e. to select different indicators, he can select the work sheet ‘Indicator list’ and click on the button ‘Back’.

10.2.5 Further procedure

Using the results from project evaluation, persisting deficits of the rehabilitated river or stream section can be identified and decisions can be made, on whether further measures are required to eliminate these deficits. Furthermore, rehabilitation measures with positive outcome can be identified.

Comprehensive project evaluation necessitates several survey repetitions. Further surveys using identical indicators should therefore be carried out after increasingly greater time intervals. This way, river managers can keep track of the developments and changes taking place in the rehabilitated section.

11 Conclusion and outlook

11.1 Summary

The handbook presents a scheme for evaluating rehabilitation projects in rivers and streams. This project evaluation examines to what extent the objectives, which were defined by the project managers during the planning phase, were achieved. For this purpose, the initial condition of the project objective under consideration is compared with its condition after the rehabilitation measure has been implemented. Indicators act as parameters for assessing project objectives. While some indicators can be surveyed quantitatively, others must be surveyed semi-quantitatively or qualitatively. Project evaluation takes place at the level of the project objectives. No conclusions are drawn on overall project success.

The handbook offers two approaches to project evaluation, both of which rely on the same principle: In the first approach, indicator sets are recommended for eight frequently implemented rehabilitation measures (see chapter 7, Table 7.1). Their composition is based on expert judgement and recommendations made by the authors. In this first approach, all project objectives relevant to the respective measures are taken into account. Overall, 14 project objectives are considered, which are allocated to the four sectors 'Service to society', 'Environment and ecology', 'Economy' and 'Implementation'. The main purpose of this allocation is to provide a clearer overview. Project objectives are discussed in chapter 6. In an alternative second approach, indicator sets tailored to specific project requirements can be compiled by the user. For this approach, the same 14 project objectives are used as a basis. Mostly, more than one indicator is available for assessing a project objective. The recommended indicator sets, as well as a scheme for compiling user-defined indicator sets, can be found in the Excel template 'Selection and evaluation' in Appendix III. The necessary information for surveying and analysing the individual indicators is compiled in the indicator method sheets in Appendix I.

In both approaches, project objectives are allocated to one of five categories of change. Allocation is based on a comparison of the initial condition and the condition after rehabilitation (see chapter 10). The categories of change indicate the degree, to which the individual project objectives were achieved. Conclusions on project success refer exclusively to the extent to which the selected, individual project objectives were achieved, not to the approximation of a river or stream section to a reference system or guiding image. However, the more project objectives are included in the evaluation, the more likely it is that any achieved success will also correspond to an approximation to a reference system. If at least five of the nine project objectives from the sector 'Environment and ecology' are evaluated, the project's ecological success can be determined based on the criteria listed in Table 10.3. These criteria enable the classification of a project into one of five categories. The names of these categories of success correspond to those of the five categories of change. If at least five project objectives from the sector 'Environment and ecology' were evaluated, the Excel template 'Selection and evaluation' automatically determines the category of success.

11.2 Analysis of concept

The main strength of the presented evaluation scheme is that it considers a large variety of project objectives. Previous concepts have often exclusively focused on ecological aspects. The presented concept, however, additionally evaluates project objectives from the sectors

'Society' and 'Economy'. Furthermore, it provides the option for evaluating political acceptance and stakeholder participation. To date, these important aspects have often been neglected.

A number of indicators recommended in the present handbook are suitable for assessing more than one project objective. Such integrative indicators are particularly helpful if the user wishes to apply a small indicator set. Especially the innovative, less traditional indicators (e. g. indicator N° 25 'short-term leaf retention capacity' or indicator N° 27 'quantity and composition of floating organic matter and abundance and diversity of colonising snails') are promising with respect to their integrative character. Methods for surveying and analysing these indicators are based on cutting-edge research results. Often, only semi-quantitative or qualitative analysis is possible for these indicators, as mostly, only a small amount of data is available. The more frequently these indicators are put to the test, the more accurately reliable guideline values can be defined.

The 0- and 1-guideline values recommended for the indicators in their method sheets are based on expert knowledge and experiences from the literature. The recommendations generally refer to medium-sized to large rivers of the Swiss lowlands. However, ideally, guideline values should be defined for different river types. Such an adaptation is an immense challenge for future schemes.

The list of indicators recommended in the present handbook is not exhaustive. Further indicators are possible. Especially terrestrial indicators, such as amphibians, reptiles, birds, insects and spiders, are missing from the presented list. In addition, the list does not include *flagship species,* which – depending on the type of project – may facilitate public relations.

At this point in time, the presented evaluation method can not be used – or only with difficulty – for comparing evaluation results from different projects. With regard to future research needs, this issue requires particular attention.

11.3 Further procedure

The present handbook is a first step toward *standardising* project evaluation in Switzerland. Although a finished product is at hand, certain amendments will be necessary after an initial implementation phase. Results and experiences from completed projects are therefore of great value to future users. In a second phase, these field reports can be incorporated into the handbook as case studies. In addition, they will provide a basis for critical revision of the handbook. The duration of the test phase, after which the handbook should be revised, is estimated at two to three years.

Indicators and their method sheets, as well as the evaluation procedure, will be at the centre of this revision. The following questions will need to be addressed:

- Which of the described indicators have proven to be particularly useful? Which are less useful?
- Which indicators are particularly meaningful, yet inexpensive?
- Which method sheets require alterations or amendments?
- Should additional indicators be included in the handbook?
- Are the indicator sets recommended by the authors useful? Do the recommended indicator sets require amendments?
- Is the evaluation procedure user-friendly?
- Is the condition of the rehabilitated section adequately reflected?
- Which further aspects can be improved?
- How can projects be compared?

In the summer of 2006, a training course for handbook users was held at Eawag. The course consisted of a unit on 'project evaluation' and a unit on 'decision-making'. Further courses may follow (www.rivermanagement.ch).

11.4 Communication

In order to ensure a successful second phase, collaboration with the users is essential. For this purpose, users are asked to communicate project details and results of project evaluation to the authors. Required information includes:

1. work group responsible for project
2. brief description of project perimeter (name of river or stream, location, size, special characteristics etc.)
3. overview of evaluated project objectives
4. type of measure implemented
5. survey results of individual indicators (to be included as Excel file)
6. qualitative description of effects of measure
7. time frame of project evaluation
8. feedback on suitability of the evaluation method for practical use
9. contact person for queries

The subsequent form can be used for communication (e-mail: rhone-thur@eawag.ch). An electronic version of the form can also be found in Appendix IV.

Please send the completed form and the Excel file containing survey results of the individual indicators to: rhone-thur@eawag.ch.

11.5 Queries and contact

For queries concerning the concept or individual indicators please contact:

Armin Peter
Eawag
Seestrasse 79
CH-6047 Kastanienbaum
E-mail: rhone-thur@eawag.ch

Feedback form for 'Handbook for evaluating rehabilitation projects in rivers and streams'

1. Work group responsible for project:

2. Brief description of project perimeter (name of river or stream, location, size, special characteristics etc.):

3. Overview of evaluated project objectives:

Service to society	Environment and ecology	Economy	Implementation
☐ Sustainable supply of drinking water	☐ Morphological and hydraulic variability	☐ Keeping the budget	☐ Political acceptance
☐ Provision of high recreational value	☐ Near-natural bedload regime		☐ Stakeholder participation
	☐ Near-natural temperature regime		
	☐ Longitudinal connectivity		
	☐ Lateral connectivity		
	☐ Vertical connectivity		
	☐ Near-natural abundance and diversity of floodplain vegetation		
	☐ Near-natural abundance and diversity of fauna		
	☐ Cycling of organic matter		

4. Type of measure implemented:

5. Survey results of individual indicators:

Please include an Excel file using the Excel template 'Selection and evaluation'.

6. Qualitative description of effects of measure:

7. Time and time frame of project evaluation:

8. Feedback on suitability of the evaluation method for practical use:

Questions:

1. Which indicators have proven to be particularly useful for practical application?
2. Which indicators have proven to be less useful for practical application?
3. Which indicator method sheets require alterations or amendments?
4. Which additional indicators should be included in the handbook?
5. Are the recommended indicator sets useful?
6. Which modifications would you make to the recommended indicator set which you applied?
7. Is the evaluation procedure user-friendly and practical?
8. Do you have further suggestions or feedback?

Answers:

9. Contact person for queries:

Name:

Institute/agency:

Address:

Telephone number:

E-mail:

Please send the completed form and the Excel file containing survey results of the individual indicators to: rhone-thur@eawag.ch.

Glossary

Keywords
Due to their frequent use, keywords are not highlighted in the text.

floodplain
A floodplain is defined as the valley bottom area that is capable of flooding. This includes the channel network. Floodplains are shaped by their rivers (Jungwirth et al. 2003). They are inundated by floods at more or less regular intervals and feature high groundwater levels (Rossol & Werth 1992). Floodplains are exceptional areas of unspoiled nature, in which water dynamics create habitats for an incomparably great diversity of animals and plants (Auenberatungsstelle 2001). Floodplains often act as natural retention areas for organic matter and nutrients.

project evaluation
Evaluating rehabilitation projects in rivers and streams serves to examine, to what extent the objectives, which were defined by the project managers during the planning phase, were achieved. For this purpose, the initial condition of the project objective under consideration is compared with its condition after the rehabilitation measure has been implemented. Indicators act as parameters for assessing project objectives. Based on this comparison, each project objective is allocated to one of five categories of change:

- deterioration/failure,
- no change,
- small improvement/small success,
- medium improvement/medium success,
- great improvement/great success.

Conclusions on project success refer exclusively to the extent to which the selected, individual project objectives were achieved, not to the approximation of a river or stream section to a reference system or guiding image. However, the more project objectives are included in the evaluation, the more likely it is that any achieved success will also correspond to an approximation to a reference system.

indicators
Indicators are measurable parameters, which provide valuable information on the condition of an ecosystem and its relevant processes (Lorenz et al. 1997). In the present handbook, indicators are defined as tools for the quantitative, semi-quantitative or qualitative assessment of project objectives. Both biotic and abiotic indicators are used.

rehabilitation
The aim of rehabilitation projects is to restore the essential processes and elements of degraded ecosystems. It is not their aim to return ecosystems to their original condition (Bradshaw 1996, Roni 2005). In the present handbook, the term ‘rehabilitation’ always refers to rehabilitation projects in rivers and streams. This also includes projects, which consider ecological aspects, but do not set them as a main focus. Therefore, the handbook and its recommendations also apply to flood protection projects, which include measures for ecological improvement.

Alphabetic glossary
In the handbook text, the following terms are highlighted as ‘glossary terms’.

abiotic
Abiotic factors are the non-living components of an ecosystem (e.g. rock, water, air, climate).

abundance
In ecology, abundance signifies density or frequency, e.g. the density of individuals of a species (individual density, population density) with respect to a particular surface area

or volume. Abundance can also refer to the absolute number of individuals living there (http://de.wikipedia.org/wiki/Abundanz_(%C3%96kologie)).

adjacent parallel canal

A man-made drainage canal, which was created during river regulation and often contains groundwater.

alluvial basins

Natural sedimentation areas in valley plains. Channels with a wide river bed, in which bedload input exceeds transport capacity. The channel is braided and has a tendency toward aggradation.

anthropogenic

Influenced, caused or created by humans (www.hlug.de/medien/wasser/gewaesserguete/bericht/alt/glossar.htm).

aquifer

In hydrogeology, an aquifer (from the Latin aqua= water and ferre= to carry) is a water-bearing stratum. An aquifer is geologically limited by layers (so-called aquifuges), which can not be penetrated by water (e.g. clays). This results in the development of groundwater horizons (http://de.wikipedia.org/wiki/Aquifer).

bedload

Bedload is a term for rounded rock material or rubble, which is transported by a glacier, river or stream. In geology, the use of the term 'bedload' is often limited to the bedload transported by glaciers. In river engineering and limnology, solids transported along the river bed by currents in a gliding, rolling or bouncing movement are also included in the term 'bedload' (http://de.wikipedia.org/wiki/Geschiebe).

benthos

The term benthos describes the entirety of all animals and plants living on the sea bed or on the bed of inland waters, i.e. the biocoenosis found in this biotope. Benthos includes sessile, as well as crawling, walking or temporarily swimming organisms.
Depending on their size, the following groups can be distinguished:

- macrobenthos (> approx. 1 mm)
- meiobenthos (1 mm to 0.063 mm)
- microbenthos (< 0.063 mm) (http://de.wikipedia.org/wiki/Benthos).

biodiversity

Biodiversity stands for 'biological variety' and includes species richness, genetic variety and abundance of different habitats (www.biodiversitymonitoring.ch/deutsch/service/glossar.php).

biotic

Biotic factors are the living components of an ecosystem.

clogging, to clog

Deposition of fine particles, such as clay or silt, at the surface and in the pores of a permeable porous medium, which results in reduced permeability (International Hydrological Glossary, www.cig.ensmp.fr/~hubert/glu/HINDDE.HTM).

connectivity (lateral, longitudinal, vertical)

Connectivity is the term used for exchange processes and interactions between different aquatic habitats, and between aquatic and terrestrial habitats. Such processes include the transport of water, bedload, energy, nutrients, detritus and the active transport of organisms (Muhar & Jungwirth 1998).
lateral connectivity:
Sideways connection of a river or stream with its floodplain habitats and terrestrial habitats.
longitudinal connectivity:
Lengthwise connection of a river or stream between its upstream and downstream habitats.
vertical connectivity:
Vertical connection between river water and groundwater.

culvert, to culvert

The watercourses of culverted streams are led underground through pipes or channels.

decomposers

Decomposers are organisms, which use the oxygen (O_2) produced by plants during photosynthesis for the oxidative decomposition of dead biomass, and release carbon dioxide (CO_2) into the atmosphere. As minerals are released too, decomposers are also called 'mineralisers'. These microorganisms occur in every ecosystem and are important for its natural equilibrium (http://de.wikipedia.org/wiki/Mineral).

detritus

In biology, the term detritus is used for ubiquitous products of cellular decomposition. In geology, the term refers in particular to ground residues of organisms (http://de.wikipedia.org/wiki/Mineral).

diversity

Diversity is a term used for species richness, species spectrum, species variety, species number, etc. Diversity considers the range of species in a biocoenocis, but also the density of individuals (www.guidobauersachs.de/oeko/glossar.html).

ecomorphology, ecomorphological

Ecomorphology describes the structural and structure-forming elements of a watercourse and its riparian zone.

ecosystem

An ecosystem is a functional unit of organisms and their habitat. The organisms interact with their living and non-living surroundings and exchange energy, substances and information (www.biodiversitymonitoring.ch/deutsch/service/glossar.php).

exfiltration

Flow of water from the aquifer across porous material.

flagship species

Flagship species are species, which can gain support from a wide audience, due to their size or conspicuousness. This includes species, such as panda bear or lynx (www.biodiversity-monitoring.ch/deutsch/service/glossar.php).

geomorphology, geomorphological

Geomorphology is a branch of physical geography, which examines shapes and shape-forming processes on the surface of the earth and other planets. Geomorphology examines the interrelations and interactions between lithosphere, atmosphere, hydrosphere and biosphere. Knowledge of the current climate and its characteristics in past geological eras are crucial factors for understanding geomorphology (http://de.wikipedia.org/wiki/Geomorphologie).

hydraulics, hydraulic

Hydraulics is the study of the flow behaviour of liquids. In particular, this includes flow processes in open channels (canals, rivers) and lakes, as well as in pipelines, pumps and in the groundwater (http://de.wikipedia.org/wiki/Hydraulik).

hydrology, hydrological

Hydrology is the study of water, its spatial and temporal distribution in the atmosphere and on the earth's surface, as well as its associated biological, chemical and physical characteristics. It examines the interrelations and interactions of the different physical conditions of water, its cycle, its distribution at the surface and its changes caused by anthropogenic influences (http://de.wikipedia.org/wiki/Hydrologie).

hydropeaking

Frequent, but rapid fluctuations in the flow of rivers or streams caused by the release of storage water to the turbines of hydropower stations for power production during times of peak demand (www.mdc.missouri.gov/fish/watershed/fabius/glossary/110gltxt.htm). Hydropeaking sections are sections of rivers or streams affected by such fluctuations in flow.

hyporheos, hyporheic

The hyporheos or hyporheic zone is the transition zone between groundwater and surface water. It consists of a coherent network of underground habitats and interstitial spaces. Here, different faunal species and microorganisms live. The hyporheos is the preferred habitat of early larval stages of different mac-

Calculation of the Kessler index:

$$\textbf{KI (ut)} = \frac{\text{MSRbir. (ut)}}{\text{MSRbir. (basic)}} + \frac{\text{MSRsna. (ut)}}{\text{MSRsna. (basic)}} + \frac{\text{MSRpla. (ut)}}{\text{MSRpla. (basic)}} + \frac{\text{MSRbut. (ut)}}{\text{MSRbut. (basic)}} \times \frac{100}{4}$$

KI (ut)	Kessler index of the utilisation type 'Ut' (forest, residential area or agriculture) in the year 't'
MSR (ut)	mean species richness (e.g. average number of plants / sampling area) in the utilisation type 'Nt' (forest, residential area or agriculture) in the year 't'
MSR (basic)	basic value of mean species richness (= mean value of the years 1996 and 1997) of the respective utilisation type and species group
bir.	birds
sna.	snails
pla.	plants
but.	butterflies

(www.ag.ch/natur2001/alg/pages/natur/programme/mehrjahresprogramm/kontrollprogramm/LANAG/Kessler.htm)

robenthic species (www.fish.washington.edu/classes/fish547/lectures_2003/01April2003_A_Basin_Per%23618.pdf).

infiltration
Movement of water through the ground into a porous medium (International Hydrological Glossary, www.cig.ensmp.fr/~hubert/glu/HINDDE.HTM).

Kessler index
The Kessler index summarises all information gained from the project 'Long-term monitoring of species richness in the arable land of the Canton of Aargau' (*Langzeitbeobachtung der Artenvielfalt in den Nutzflächen des Kantons Aargau LANAG*). The index value 100 refers to the average species richness in all habitats of the Canton of Aargau between the years 1996 and 1997. If the index for a site in the Canton of Aargau is higher, the site features more animal and plant species. If the index is lower, it features fewer species. The index is designed to be particularly sensitive to fluctuations of frequent species. Similarly to an early-warning system, it demonstrates where action is needed. The Kessler index is named after Erich Kessler, a nature conservation pioneer of the Canton of Aargau.

lethal
Deadly, leading to death.

macroinvertebrates
Invertebrate animals, which can be recognised by the naked eye due to their size (> approx. 1 mm).

macrozoobenthos
Invertebrate animals, which live on the sea bed or on the bed of inland waters and which can be recognised by the naked eye due to their size (> approx. 1 mm), e.g. snails, mussels, worms, crabs, insect larvae (www.hlug.de/medien/wasser/gewaesserguete/bericht/alt/glossar.htm).

Modular Stepwise Procedure
The Modular Stepwise Procedure is a new concept for assessing rivers and streams in Switzerland. It is a joint project of the Federal Office for the Environment, the Eawag and cantonal departments for aquatic conservation. The goal of the project is to develop standardised methods for assessing the ecological status of Swiss rivers and streams. At different levels of labour intensity the methods measure structural, hydrological, biological, chemical and ecotoxicological aspects of a watercourse. The developed methods provide the cantonal departments with a tool for execution support. The concept and the first method (ecomorphology, level F) were issued in the BUWAL publication series 'Execution of environmental policy, communications on water conservation' (*Vollzug Umwelt, Mitteilungen*

zum Gewässerschutz). In the future, further modules will appear in the same publication series (www.modul-stufen-konzept.ch).

In the Modular Stepwise Procedure, the ecological status of rivers and streams is surveyed with respect to habitat function. In a first phase, assessments are carried out at the regional level. At this level, sections of watercourses are assessed using various ecomorphological criteria and – depending on the achieved score – are subsequently assigned to four quality classes. Ecomorphological criteria include: river bed width, variability of wetted width, degree and type of anthropogenic modification of the river bed, degree and type of anthropogenic modification of the river bank and width and nature of riparian zone. The four quality classes of ecomorphology are: natural/close to natural, minimally impacted, heavily impacted and unnatural/artificial. Culverted stream sections form a separate class. Results from the ecomorphological survey may provide an important basis for planning river engineering schemes and rehabilitation projects as they enable an immediate identification of structural deficits (BUWAL 1998).

morphology, morphological

Morphology is the study of the structure and shape of organisms and habitats.

mosaic

Plant community distributions determined by fluctuating environmental factors (Gillet et al. 1991).

pool

A morphological unit along streams which is formed by erosion and is characteristically deep and has a low-gradient and slow flow. During erosion, material is removed from the river bed or from the river bank and transported downstream (International Hydrological Glossary, www.cig.ensmp.fr/~hubert/glu/HINDDE.HTM).

pesticides

Collective term for man-made toxins with specific effects on selected organisms or organism groups, e.g. herbicides affect plants, insecticides affect insects, fungicides affect fungi (www.hlug.de/medien/wasser/gewaesserguete/bericht/alt/glossar.htm).

receiving watercourse

A receiving watercourse is a body of water, into which an (authorised) input of water (wastewater, drainage water) occurs. Natural receiving watercourses are open rivers or streams, which receive water from other watercourses, bodies of groundwater or drainage systems (http://de.wikipedia.org/wiki/Vorfluter).

refugia

Refugia are areas from which re-colonisation takes place after disturbance (flood, drought, anthropogenic impacts). The availability of refugia is essential to the ecological elasticity ('resilience') of an ecosystem.

rejuvenation

Cycle of destruction and regeneration of the vegetation community.

resilience

Resilience is the term for the range, within which an ecosystem will return to pre-disturbance condition after a natural or anthropogenic perturbation (FISRWG 1998). Resilience therefore expresses, to what extent an ecosystem is capable of maintaining its structure and function under the influence of stress. If the resilience range is exceeded, a new condition is created (Rapport et al. 1998).

riffle

A shallow area of a stream in which water flows rapidly over a rocky or gravelly stream bed (Rossol & Werth 1992).

sections of residual flow, residual flow

Sections of rivers or streams which feature reduced flow after one or more water extractions. The Decree on the Conservation of Watercourses regulates an adequate quantity of residual flow.

standardisation, to standardise

Standardisation is the harmonisation of units, types, procedure types, etc. The objective is to create mutual standards. In statistics, standardisation is the term used for transforming numerical values with different scales into a uniform range, in order to enable a comparison of differently distributed values (http://de.wikipedia.org/wiki/Standardisierung).

succession

In ecology and biology, succession is known as the sequence of merging stages of plant and animal communities at a particular location over time. With changing species richness and a decreasing rate of change, this successive development leads from the initial stage via various stages to a climax community. During this process, the entire system adapts to an optimal use of resources (ecological optimum). Successional stages usually begin at an arbitrary phase and occur simultaneously in different spaces. If an ecosystem is strongly disturbed, e.g. by flood, drought, fire or human impact, distinct changes in structure and in species composition occur. If the disturbance is so intense that the previous biocoenosis can no longer exist, an initial stage is established (http://de.wikipedia.org/wiki/Sukzession).

vegetation zonation

Spatial sequence of typical vegetation communities.

zonation

Local succession of plant or animal communities along an ecological gradient (e.g. humidity, light, mechanical influence). Zonations can be found, for example, in aggradation areas on the shores of lakes, floodplains, dumping sites or below glaciers (BUWAL 1997).

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