The Swiss Modular Concept

A Basis for the Assessment of Streams

The Swiss Modular Concept creates a framework for the examination and evaluation of streams and includes hydrological, morphological, biological, chemical and ecotoxicological modules. It will become an important tool in integrated assessment and management of streams.

In Switzerland over the 20th Century, the various ways in which streams have been intensively utilized for a variety of purposes have led to extensive physical degradation of the streams. Expansion of hydroelectric installations has resulted in significantly different discharge patterns. Extensive development of towns and villages, the related expansion of roads, as well as the more intensive agricultural use of the land have continuously reduced the space left for streams. In addition, water quality has been severely impacted. With the rapid increase in chemical contamination during the 1950s, it became clear that the public sector had to get involved. The Water Protection Law of 1955 ("Gewässerschutzgesetz"; first revised in 1971) provided a legal basis for problems relating to water pollution. Due to complete coverage by wastewater treatment plants, water quality continuously improved. In addition, the Recommendations for the Examination of Switzerland's Streams ("Empfehlungen über die Untersuchung der schweizerischen Oberflächengewässer") issued in 1982 provided a set of tools for the assessment of water quality for the first time.
With the second revision of the Water Protection Law in 1991, the protection, preservation and restoration of streams as integral ecosystems became a central issue. This required improved methods for the assessment of stream health [1]. In order to gain a holistic assessment of streams, chemical parameters have to be examined along with various aspects of hydrology, ecomorphology, biology and ecotoxicology.

A nearly natural stream: the Brenno in the flood plain near Loderio. Morphologically, this section of the stream may be classified as natural/close to natural (class I, see Table 4). It is characterized by a particularly high biodiversity. Eleven of the 12 fish species occurring in the entire Brenno system are found in this section of the stream.

Requirements for Evaluation Procedures

Depending on the specific questions asked in a particular case, the assessment of stream quality must allow for different approaches. The need ranges from fast survey methods for rapidly assessing the condition of a large catchment to methods for the detailed analysis of individual streams, even sections of streams. Streams should be evaluated from different perspectives, employing biological as well as non-biological assessment methods.
The evaluation procedure should include two steps: the analysis of the current stream condition using a range of criteria and evaluation methods and a comparison of the current condition to the desired near-natural condition. The challenge lies in combining factual and analytical information with more subjective values into one relatively objective assessment [2]. Ideally, the assessment criteria should be designed so that different evaluators come to the same conclusion. The assessment can be either in the form of a narrative or based on a point system in which the scores for individual parameters are added to obtain an overall score. In order to maximize the comparability, we need to develop methods that are applicable to any stream in Switzerland and which are consistent with methods used in other European countries.

Ecological Basis for Stream Assessment

An assessment scheme that considers all aspects of stream quality may only be realized by using a modular approach. We chose the modules hydrology/morphology, chemistry/ecotoxicology, and biology. Each of the modules incorporates the current state-of-the-art findings of the respective scientific disciplines. The biology module,

	Level I	Level II	Level III
Scale	Region/canton	Stream system	Medium to short stream section
Effort	Small	Medium	Large
Goal	Rough overview, analysis of ecological deficiencies	Detailed overview, analysis of deficiencies, development of remedial action	Detailed analysis of specific questions
Assessment	Point scores	Verbal	Verbal

Table 1: The three levels of the Swiss Modular Concept.

in particular, was shaped by the following ecological considerations (see article of U. Uehlinger, p. 16):

The **River Continuum Concept** is an attempt to identify and rationalize longitudinal changes in stream ecosystems [3]. Relationships among the catchment, the flood plains associated with the stream, and the stream system itself are demonstrated; changes in community composition between the headwaters and the mouth of the river are analyzed. In using this concept, it is clear that a particular stretch of river can never be considered an isolated entity but has to be examined in the context of the entire river system, including the surrounding land. This has a particular impact on the formulation of remedies for the ecological deficiencies.

The **Flood-Pulse Concept** suggests that the dynamic interaction between the water and the surrounding terrestrial habitats influences the inhabitants of both the stream and the flood plain [4]. Flood plains must be considered as very special habitats for plants and animals. As areas that are periodically flooded, they harbor special fauna and flora. The "flood-pulse" concept clearly demonstrates that the stream, the riparian vegetation and the surrounding flood plain should be treated as a single entity.

Hierarchical Structure of Streams: Frissel et al. [5] describe the hierarchical organization of streams (whole river systems to microhabitats), on both spatial and temporal scales. Investigations of larger portions of a river system clearly need to use approaches based on this concept and consider "scale" as an important factor both during the investigation and in the final evaluation.

The **Four-dimensional Stream Concept** describes a stream in its four dimensions; namely longitudinally, laterally, vertically and temporally [6, 7]. The strength of this concept lies in its revealing the importance of spatial exchange processes for water, material, energy and organisms along a stream corridor. The temporal dimension deserves special attention since it illustrates the dynamic behavior of a stream corridor.

The **Stream Corridor Concept** includes the stream bed, the flood plain and the transitional zone in between [8]. These three components form a dynamic entity within the landscape. Within this space, water, solid materials, energy and organisms are linked in a tight, dynamic relationship. The consideration of the stream corridor as a whole allows us to see ecological deficits and required mitigation measures in a wider context.

Restoration and Rehabilitation Concepts are supposed to assist us in bringing degraded streams back to a condition that is closer to their original state [9, 10]. The main goals are improvements to the structure of the ecosystem (e.g. habitats and species diversity) and to its ecological functioning, even though the original condition of the stream cannot usually be restored. These concepts are particularly useful once the stream assessment is complete and mitigation measures need to be developed.

Structure of the Swiss Modular Concept

The Swiss Modular Concept was developed under the guidance of the project group "Stream Assessment"[1] in collaboration with representatives from the SAEFL (Swiss Agency for the Environment, Forests and Landscape), FOWG (Swiss Federal Office for Water and Geology), EAWAG and the Canton of Zurich [11]. Each of the modules contains a three-level structure (Table 1). At the regional level (level I, regional scale survey), the goal is a rapid, cost-effective analysis. In more detailed evaluations of an entire stream system or catchment (level II, catchment scale survey), or of selected stream sections with lengths between 0.1 and 1 km (level III, extensive reach scale survey), the cost per analyzed area is significantly higher. For levels I and II, new assessment methods are currently being developed while existing ones are being continuously expanded. This is not true for level III, where specific aspects of a stream system need to be evaluated (e.g., microhabitats, structural composition, species inventory, populations). It usually is more efficient to rely on established methods.

Table 2 provides an overview of the nine modules of the Swiss Modular Concept and the specific methods used in analysis levels I and II. Each module examines a particular aspect of a stream. The modules are independent units and can be used in any combination. However, it is reasonable to combine a biological module with a non-biological module at the same time.

Temporal and Spatial Dimensions of the Modules

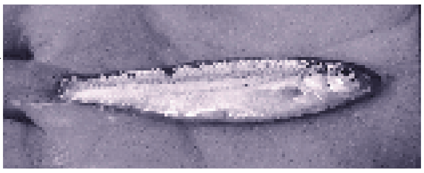
Each module has specific advantages in evaluating a stream, but at the same time also has some temporal or spatial limitations. This also holds for the biological

	Module	Level I	Level II
Hydrology and Morphology	Hydrology	General characterization of the discharge	Systematic observation
	Ecomorphology	Major ecomorphological impacts, longitudinal connectivity	Analysis of deficiencies, catalog of remedial action with indication of priority
Biology	Algae	Examination of diatoms	Not examined
	Macrophytes	Estimation of abundance	Mapping of all species
	Riparian vegetation	Simple mapping	Detailed mapping, action plan
	Macroinvertebrates	Coarse species overview	Detailed mapping
	Fish	Overview of fish species	Detailed studies, examination of populations
Chemistry and Ecotoxicology	Chemistry	Rough screening of water quality	Detailed investigations of water quality
	Ecotoxicology	Random checks, 2–3 simple analyses	Seasonal or more frequent analysis of chemical impacts

Table 2: The nine modules of the Swiss Modular Concept for assessment levels I and II.

[1] Members of the project group are: Paul Liechti, Ueli Sieber (SAEFL), Ulrich von Blücher, Hans Peter Willi (FOWG), Christian Göldi, Urs Kupper, Walo Meier, Pius Niederhauser (Canton Zurich), Ueli Bundi, Andreas Frutiger, Michael Hütte, Armin Peter (EAWAG)

Armin Peter, EAWAG



Fish are particularly well suited for the assessment of stream quality. The extremely sensitive Blageon (Leuciscus souffia) is found almost exclusively in stream sections that are very close to their original, natural state.

moduls (Table 3). Algae have very short reproductive and life cycles and can be sensitive to certain pollutants that may not cause observable effects in higher organisms. Algae, therefore, are good indicators of short-term processes that are limited to relatively small areas. Members of the macroinvertebrates on the other hand, are present in practically all streams, even if fish populations have already been eliminated. This group of organisms is, therefore, a good indicator of long-term environmental impacts on areas of several 100 m^2. Since environmental requirements of fish are well understood, the ecological interpretation of the condition of a fish population can yield a very precise assessment of a stream. Fish, thus, reflect environmental conditions of a longer period spanning several years. Because of their high level of mobility, environmental impacts to the catchment as a whole may be assessed. Prevailing conditions over time periods on the order of decades are reflected in the composition of the riparian vegetation.

Example: Module Ecomorphology Level I

The main purpose of the level I assessment within the ecomorphology module is to provide an area-wide representation of the ecomorphological condition of a stream system, together with a rough analysis of the main deficiencies [12]. Data is gathered by inspection in the field, covering the length of the stream and recording the following characteristics:

- variability of stream width (submersed area at average water level),
- width of streambed and degree of obstruction by corrective structures,
- erosion control structures along the bottom of the stream bank,
- width and condition of the area adjacent to the stream bank.

Each of these characteristics receives a separate score for each of the survey sections. The assigned score is proportional to the deviation from the ideal, natural condition. Distinct stream sections are then classified according to their overall score. A graphical representation of conditions within the entire stream system can be produced by assigning different colors to different classes of stream condition (Table 4).

Current Status of the Modules

The federation (SAEFL/FOWG/EAWAG) and representatives of the cantons have taken on the responsibility for planning and quality assurance. Over the next 2–3 years, the development of the modules should be complete. Procedures for level I of the ecomorphology module were finalized in 1998 [12]. The level I procedures for the macroinvertebrate and fish modules will be made available to users in 2001. A concentrated effort is underway to assure rapid delivery of the remaining modules.

Stream Assessment as the Basis for Sustainable Stream Management

Switzerland ratified the agreement on biodiversity in Rio de Janeiro in 1992 and has thereby made a commitment to restore damaged ecosystems. There is significant potential for revitalization along approximately 12,600 km of Switzerland's streams, which corresponds to roughly 20–25% of the total length of all stream systems in Switzerland (see article of H.P. Willi, p. 26); stream sections running in culverts are not included in these numbers.

Stream sections amenable to revitalization will be easily identified using the evaluation methods of the Swiss Modular Concept. The success of revitalization efforts can be assessed using a different set of modules. Ongoing monitoring of the revitalization results assures sustainable improvement of stream quality.

Armin Peter, fisheries and stream ecologist, project leader of the department "Applied aquatic ecology" (APEC). Current research interests: rehabilitation of streams, hydroelectric utilization of streams, population dynamics and migratory behavior of fish.

Module	Temporal scale	Spatial scale
Algae	Days – weeks	m^2
Macrophytes	Years	Several 100 m^2
Riparian vegetation	Decades	km^2
Macroinvertebrates	Month – 1 year	Several 100 m^2
Fish	Years	km^2 (whole watershed)

Table 3: Temporal and spatial scales of the modules.

Class	Condition	Color code
I	Natural/close to natural	Blue
II	Minimally impacted	Green
III	Heavily impacted	Yellow
IV	Unnatural/artificial	Red

Table 4: Classification of stream condition and color code for mapping.

[1] Bundi U., Peter A., Frutiger A., Hütte M., Liechti P., Sieber U. (2000): Scientific base and modular concept for comprehensive assessment of streams in Switzerland. Hydrobiologia *422/423,* 477–487.
[2] Bastian O., Schreiber K.-F. (1999): Analyse und ökologische Bewertung der Landschaft. Spektrum, Akademischer Verlag, Heidelberg, 564 p.
[3] Vannote R.L., Minshall G.W., Cummins K.W., Sedell J.R., Cushing C.E. (1980): The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences *37,* 130–137.
[4] Junk W.J., Bailey P.B., Sparks R.E. (1989): The flood pulse concept in river-floodplain systems. In: Dodge D.P. (ed.) Proceedings of the International Large River Symposium. Canadian Special Publication of Fisheries and Aquatic Sciences *106,* 110–127.
[5] Frissell C.A., Liss W.L., Warren C.E., Hurley M.D. (1986): A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management *10,* 199–214.
[6] Amoros C., Roux A.L., Reygrobellet J.L., Bravard J.P., Pautou G. (1987): A method for applied ecological studies of fluvial hydrosystems. Regulated Rivers: Research & Management *1,* 17–36.
[7] Ward J.V. (1989): The four-dimensional nature of lotic ecosystems. Journal of the North American Benthological Society *8,* 2–8.
[8] Haltiner J.P., Kondolf G.M., Williams P.B. (1996): Restoration approaches in California. In: Brooks A., Shields Jr. F.D. (eds.) River channel restoration: Guiding principles for sustainable projects. Wiley & Sons, Chichester, p. 291–329.
[9] Bradshaw A.D. (1997): What do we mean by restoration? In: Urbanska K.M., Webb N.R., Edwards P.J. (eds.) Restoration ecology and sustainable development. Cambridge University Press, Cambridge, p. 8–14.
[10] Cooke G.D., Jordan III, W.R. (1995): Ecosystem rehabilitation. In: Using ecological restoration to meet clean water act goals. U.S. Environmental Protection Agency, Chicago, Illinois, p. 1–4.
[11] SAEFL (1998): Modul-Stufen-Konzept. Mitteilungen zum Gewässerschutz Nr. 26, 43 p.
[12] SAEFL (1998): Ökomorphologie Stufe F. Mitteilungen zum Gewässerschutz Nr. 27, 49 p.