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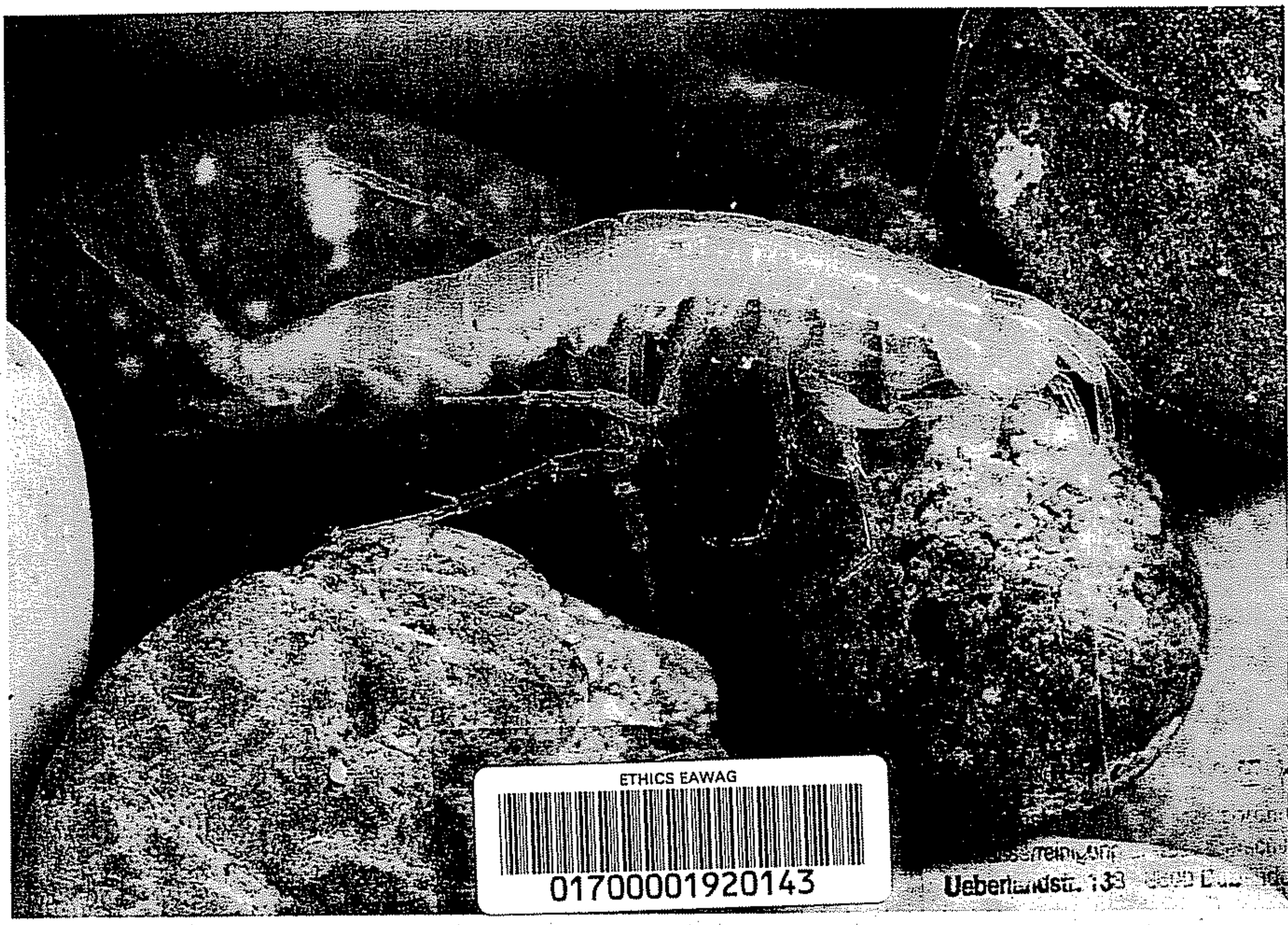

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EAWAG

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Cover
The groundwater inhabitant shown, a *Niphargus* sp. which is 8–10 mm long, does not need eyes or pigment; none of the permanent groundwater dwellers do because their environment does not receive any sunlight. Species which spend their entire life cycle in ground water have a slower metabolism, lower rate of reproduction and strategies for nutrient uptake different than their closest relatives living above ground. These adaptations render them more susceptible to disturbances, however; increased concentrations of organic material from infiltrating surface waters is just one example of such a disturbance. For more on groundwater research, see page 10. (Photo by Matthias Brunke, Ph. D. student at EAWAG)

Cheers?

Why is it that questions relating to water are so fascinating to us?

Life without oxygen has been documented for many organisms, but life (as we know it) without water is not possible. From little children to adults, everybody likes to play with water. Is it the close relationship between life and water that is the origin of our fascination?

In Switzerland, we still drink water from the tap, 80% of which originates from ground water; depending on the region, some lake water may be mixed in. Unfortunately, traces of chemicals from households, industry and agriculture still reach groundwater and springs. We know very little about possible interactions between all of the chemicals in the environment and their effect on living organisms. Are they free of harmful effects even on the long term?

The technical process of preparing drinking water is becoming ever more complicated and expensive, even here in Switzerland. Currently, 70% of our drinking water does not have to be treated at all or, at most, undergoes a one-step process. The remaining 30%, however, significantly increases the average cost of our drinking water because this water must be treated by multiple processes. It is indispensable, both for financial and ecological reasons, that all countries find new and better ways to handle this precious commodity. Only a discerning and well informed public will be capable of dealing with this task. This is why this issue of EAWAG news would like to direct your full attention to the profound importance of water.

Did you realize that there are many different life forms existing in ground water? Please refer to the cover page of this issue! Since there is exchange between ground and surface water in many places, microorganisms and small animals can make a living if they are very "frugal". Other organisms, such as insect larvae, will occasionally dare to venture into the "underground" and back to the surface.

Since missing pieces in our knowledge of groundwater systems have to be gained in an interdisciplinary effort, one contribution in this issue discusses research areas which EAWAG has made high priority topics in the work on economical use of ground water. The multiple interdependencies in the water cycle reflect the complexity of a healthy environment.

Let's drink to using water sparingly!
Cheers!

Diana Hornung
Staff of the director, Editor

Andreas Frutiger

Why Streams Need More Space

Andreas Frutiger

While the water quality in Swiss streams is now within an acceptable range of values, they are still often overused and morphologically in poor condition. Fortunately, significant improvements have become possible over the past several years due to new environmental legislation which promotes ecologically and economically balanced protection of streams.

Starting Point: the Current Status of our Streams

Switzerland is rich in water. On average, Switzerland receives approximately 1.5 m of precipitation per year. This amount of water represents an enormous energy potential, which was used only to a very small extent until the end of the last century (e.g., in flour and saw mills). Since then, over 430 large (i.e., >330 kW) and numerous smaller hydroelectric plants have been built [1]. Today, however, the economically usable potential is largely exhausted. As a consequence, there are no major streams remaining whose runoff is not affected by hydroelectric power generation. In the extreme case, water flow has ceased altogether, resulting in a complete destruction of the aquatic ecosystem.

For a long time, the abundance of water was a serious threat to human existence, and society worked hard to protect itself. A growing population demanded increasingly more area for settlement and agricultural use. In order to meet this demand and to simultaneously reduce the threat of flooding, all of Switzerland's major streams were straightened and forced into narrow channels (Fig. 1). As a consequence, almost all natural river beds and wetlands have been lost over the past 100 years. The irretrievable loss of natural beauty is painfully evident to visitors of the few remaining untouched rivers in Greenland, Alaska or New Zealand. The realization that our rivers were sacrificed solely for absolut flood control, which turned out to be an illusionary goal, should stimulate some critical thinking on the subject.

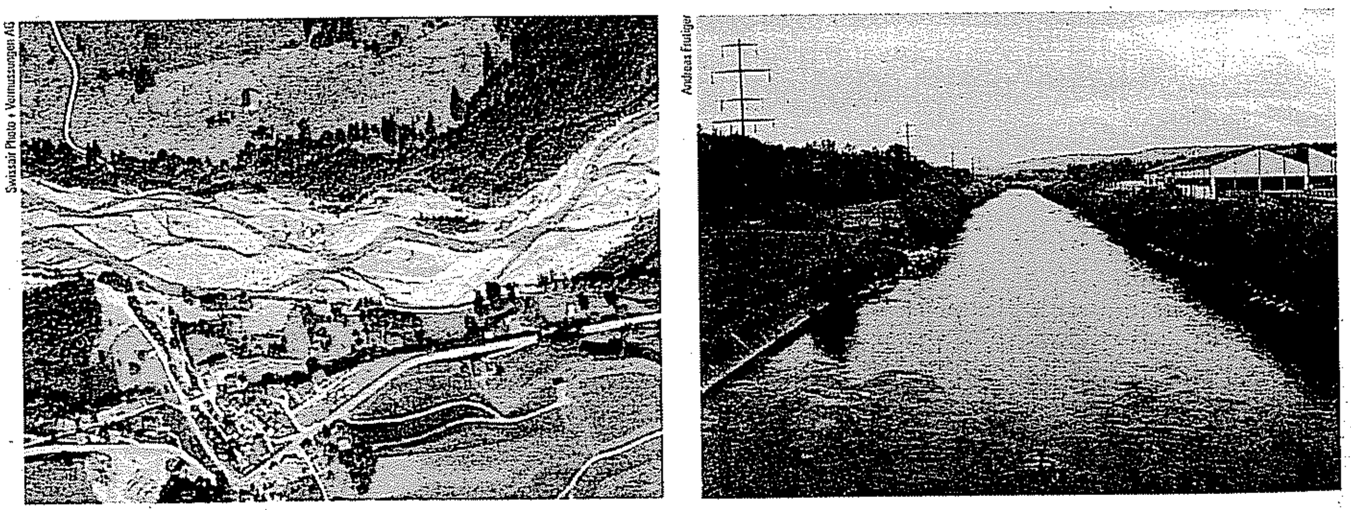


Fig. 1
Natural streams require a lot of space. In order to gain land and to reduce the danger of flooding, practically all major streams in Switzerland have been "straightened" and forced into narrow channels (left: Warme Sense near Plaffeien; right: Thur near Istighofen).

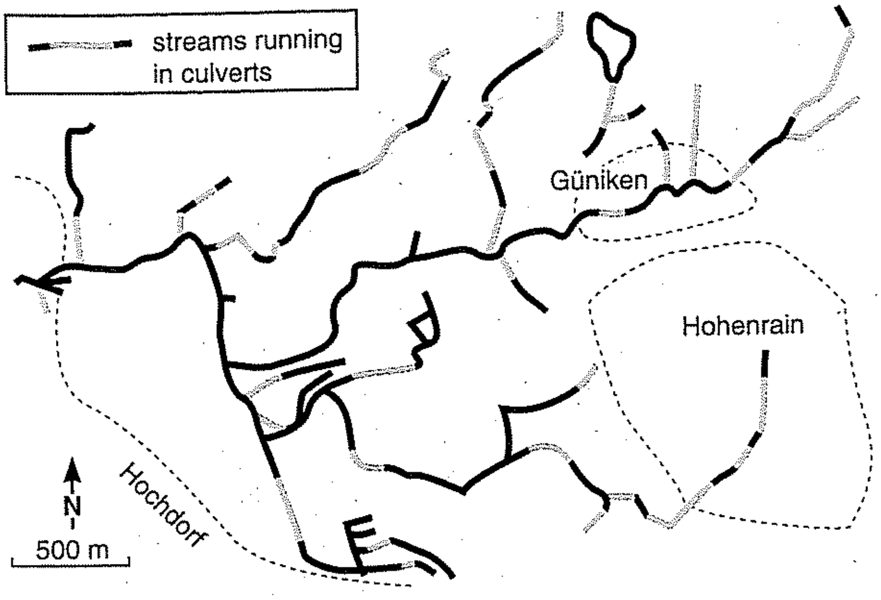


Fig. 2
For many decades, more than 100 km of stream beds "disappeared" from the landscape annually. The area shown in the map represents a situation typical for the Swiss "Mittelland", where 36% of all streams are currently running in culverts (underground sections = gray lines).

In the shadow of these dramatic river bed corrections and, for the most part, out of public view, another tragedy also took place: a large number of small streams were lost. Their natural beds were transformed into straight channels, even into culverts, since they interfered with construction projects or the use of modern farm machinery (Fig. 2). For many decades, 100 km or more of such streams died a "quiet" death each year [2, 3].

Ever increasing demands for consumption and convenience of growing population resulted in increased water pollution. The first legislative action to protect water quality was undertaken at the end of the 19th century [4], although the first water protection law was not enacted until 1 January 1957. Its success is impressive. Overall, approximately 40 billion francs have been spent nationwide on wastewater treatment so far. All major point sources of pollution (industry, small businesses and households) are connected to sewer systems and wastewater treatment plants. Oxygen and phosphate concentrations in most streams and lakes have rebounded into the "good to satisfactory" range.. Not solved, however, is the problem of non-point sources, such as nitrogen and pesticide runoff from cultivated land and atmospheric deposition of contaminants. As a consequence, for example, nitrogen concentrations have steadily increased in most streams and lakes. Until now, nitrogen limits set by law have rarely been exceeded, but the situation deserves more attention since the trend towards increasing concentrations does not appear to be abating.

This short overview should suffice to demonstrate that the ever increasing population of Switzerland and the more intensive use of streams and rivers it entails, has led to a wide variety of detrimental effects. Despite the fact that all of these consequences are interdependent, it is useful for the purpose of discussing possible solutions to group the problems into three general areas; namely, water flow conditions, river bed morphology and water quality.

Water Flow Conditions: Sustainable Flow Versus Electricity?

The revised water protection law (in effect since 24 January 1991) allows water to be withdrawn from streams only under the condition that an adequate volume of water remains. "Adequate" is defined as balance between the ecological goals of the law (e.g., preservation of natural habitats, preservation of streams, etc.) and resource use (e.g., production of electric power, irrigation). This regulation is relatively progressive and should be applauded from an ecological point of view. Its shortcoming is, however, that it does not apply to permits which were granted under the old law (before November 1991). Since use permits are typically granted for a period of 80 years and allow unrestricted use of a stream, dry mountain stream channels will be a sad reality on our alpine landscape well into the next decade (Fig. 3). Recovery of dry stream beds would be possible in the near term, of course, if power plant operators would voluntarily refrain from using all of the water to which they are entitled. Unfortunately, the likelihood of this scenario is unlikely since the national energy program "Energy 2000" aims to increase the production of renewable energy. It is very important, therefore, that any future use permits secure adequate minimal flow.

Stream Morphology: Healthy Streams Need Space!

The "100-year floods" of the last few years have taught us that engineering alone is not enough to prevent flooding. Rather, an ecologically and economically balanced approach is called for – one that considers goals for protection as well as measures to be taken in construction and planning. This philosophy is now generally accepted and has been incorporated into environmental legislation [e.g., 5, 6]. In addition, our water protection laws specifically protect streams from being culverted and allow river bed "straightening" only under clearly defined conditions. The legislative basis is, therefore, clearly established in an effort to redirect flood protection and stream maintenance and engineering practices towards a more fundamentally ecological approach. The area a stream is allowed to occupy plays a key role in flood protection. The narrower a stream bed, the more elaborate and costly the needed barriers become, with all of their negative ecological consequences. If, however, the stream is given some space which can be flooded periodically without causing major damage, the danger of destructive floods is greatly reduced. Developments in this direction have been facilitated by agricultural overproduction, which forces us to extensify a certain portion of our agricultural land. If we succeed in establishing some of these lands as buffer zones and flood plains along streams, we can achieve very progressive and ecologically valuable solutions. In order to make this possible, future projects in the vicinity of streams and rivers must be approached in an interdisciplinary manner.

Water Quality: has Wastewater Treatment Reached Economically Reasonable Limits?

Apart from a few remaining exceptions, today's wastewater treatment technologies have probably realized all measures which can be implemented in an effort commensurate with the goal of maintaining water quality. Concepts for solution of the remaining problems (especially nitrogen, heavy metals, reduction of fish diversity) should primarily target the source. It must emphasized that a broadening of stream corridors, which will have beneficial impacts on flood protection as discussed above, often also leads to improved water quality. It has been demonstrated, for example, that sufficiently wide riparian zones form buffers which efficiently reduce the input of nutrients and fine sediments from adjacent agricultural lands [7]. In addition, self-cleaning of a stream is enhanced by a structurally more diverse stream bed which develops naturally if a stream is not confined to a predefined channel.

Future Need for Integrated Water Protection Concepts and Evaluation of Success in Their Implementation

With current environmental laws in place, it is now possible to find ecologically and economically acceptable solutions to problems facing our streams and lakes; however, the existing possibilities often are only sporadically realized. The real challenge for the future is for the cantons and municipalities in Switzerland to adopt the "spirit" of our modern legislation and put forward their own initiatives. This requires that the various administrative and political barriers be dismantled in the quest for solutions. The success of conservation initiatives must also be adequately evaluated in order to correct and/or optimize the concepts used as the basis for the actions. To date, such "measures of success" are the exception not the rule [8], which is, in large part, due to Switzerland's lacking a standardized method for the ecological evaluation of a stream. In an effort to eliminate this deficiency, EAWAG is currently developing methods for evaluating various characteristics of streams (e.g., morphology, benthic biology, fish colonization). In constructive dialogue between the "water protection community" and EAWAG, these methods will hopefully be developed into useful techniques and ultimately implemented to the benefit of our streams.

[1] Schlussbericht der interdepartementalen Arbeitsgruppe Restwasser (Vorsitz: Nationalrat Dr. E. Akeret), August 1982.

[2] BRP/BUWAL (1991): Landschaft unter Druck. Zahlen und Zusammenhänge über Veränderungen in der Landschaft Schweiz (Beobachtungsperiode 1972–1983).EDMZ, Bern.

[3] BRP/BUWAL (1994): Landschaft unter Druck. Fortschreibung. Zahlen und Zusammenhänge über Veränderungen in der Landschaft Schweiz. Beobachtungsperiode 1978–1989. EDMZ, Bern.

[4] Bundesgesetz betreffend die Fischerei (vom 21. Dezember 1888).

[5] Bundesgesetz über den Wasserbau (vom 21. Juni 1991)

[6] Verordnung über den Wasserbau (vom 2. November 1994)

[7] Bach, M., Fabis J. und Frede, H.-G. (1994): Schutzfunktionen von Uferstreifen für Gewässer im Mittelgebrigsraum. Wasserwirtschaft 84 (1994), 524–527.

[8] Lehmann, R., Imhof, A. (1995): Stand der Fliessgewässerrenaturierung in der Schweiz. Eine Umfrage bei den kantonalen Wasserbauämtern. Ingenieurbiologie 4 (1995), 3–7.

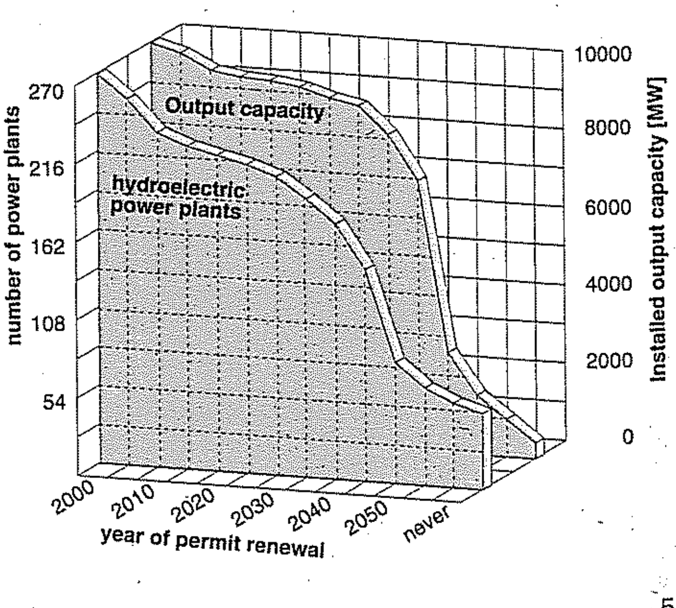


Fig. 3
Regulations governing minimum flows can only be applied to permit renewals. Since many hydroelectric plants (especially larger plants) were built after WW II and permits commonly are given for 80-year periods, they will be allowed to operate without any constraints on minimum flow well into the next century.
The graph shows the decline of the number (front) and power production (back) of plants operating under old permits over the next 60 years; 53 plants with a total production of 415 MW have unlimited permits. Only large power plants (over 300 kW), which will eventually be subject to minimum flow requirements, are included in the graph (data taken from [1]).

Jürg Bloesch

Sustainability: Empty Phrase or Close to Reality?

Jürg Bloesch

Ever since the Conference on the Environment in Rio de Janeiro in 1992, the catchword "sustainability" is on everybody's lips. But what can science contribute to sustainability so far as water is concerned? In order to address sustainability, EAWAG perhaps must leave its "ivory tower" of science.

Introduction

During the winter semester of 1994–95, EAWAG hosted a seminar series on sustainability. Presentations discussed both regional and global aspects of the issues and involved a wide range of disciplines, including physics, chemistry, biology, human ecology, municipal wasterwater engineering, cybernetics and art. One talk was entitled "Water Protection in the Watershed of Lake Lucerne" [1]. A brief description of the study can be found in the 1994 EAWAG Annual Report [2]. Models used to evaluate sustainability often are very theoretical and, therefore, heavily contested. This article will attempt to demonstrate how these disagreements are rooted in the day-to-day environmental problems in Switzerland and how they manifest themselves in the application of the above mentioned study to the real world.

Definition of Sustainability

Naturally, everybody's definition of sustainability is different. According to traditional usage, sustainability had the meaning of "continuous, intensive, strong" [3]. More recently, it is generally understood to mean "sustainable usage of resources", where renewable resources are not consumed at a rate faster than the regeneration rate. In this sense, revitalization of natural waters can certainly be characterized as sus-

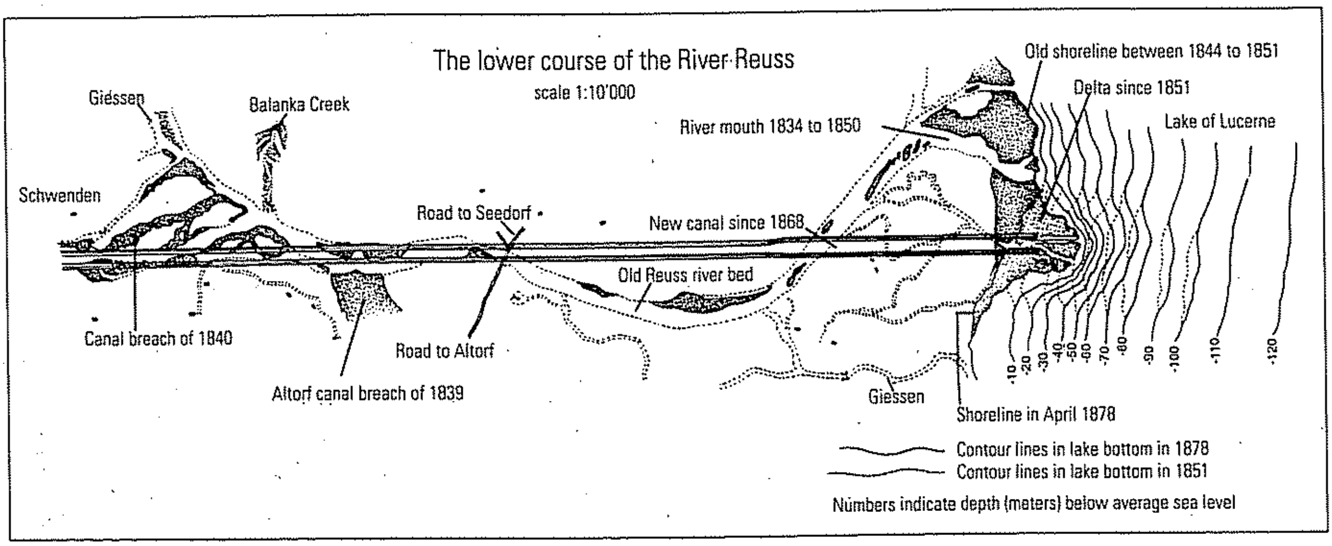


Fig. 1
Correction of the River Reuss. The lowest section of the course (canal finished in 1852, widened in 1868), after Albert Heim, from [1]. Canalization and levies have destroyed much of the fish habitat [5]. At that time, the Giessen was not yet canalized and was emptying directly into the Reuss (dotted line). Because of gravel production, the shoreline of lake Urnen had recessed to such a degree that by 1988 the canal protruded 400 m into the lake. Revitalization of the delta has dramatically improved this situation.

tainable: an aquatic ecosystem is functioning in a sustainable way, when its fauna and flora regenerate naturally. This criterion of ecological functionality is a serious challenge for the water protection law enacted on 24 January 1991 (Art.1: lit. c, d, e, h). In the following discussion, sustainability will be limited to what is achievable and currently being realized.

Permanent Destruction of Streams

Streams within the watershed of Lake Lucerne have been heavily used and altered extensively since the beginning of the last century [4, 5]. This is true for the whole region of the Alps [6], and especially for the densely settled and heavily agricultural areas of the central part of Switzerland (Mittelland). The effects of these engineering interventions on the microfauna and fish in selected streams and rivers were examined in a detailed study performed by the EAWAG [2]. Summarizing from the 1994 report on the project, it was concluded that the stream ecosystems have been "permanently destroyed" by damming and hydroelectric power production. Let us examine two representative cases from the study.

How are Things in Reality?

First Case Study: Reuss Plains (Canton Uri)

The lower course and delta of the river Reuss in Lake Urnen (southern lobe of Lake Lucerne) were massively "corrected" around 1850, as were all comparable valley floors in Switzerland in order to reduce malaria infestation, protect against floods and create agriculturally valuable land by draining the flood plain ([7, 8]; Fig. 1). In most recent times, the Reuss has become rather infamous due to the flood of 1987 which caused tremendous damage [9, 10]. Immediately, a new flood protection plan was devised. Some new levies have already been built, while others are still in the planning stage. After only a cursory examination of the situation, it becomes painfully clear that the intensive use of the corridor by trains, roads, villages, agriculture and power plants leaves virtually no room for a significant revitalization of the lower course of the Reuss. We cannot turn back time; however, an attempt has been made to revert the delta to a more natural state [11]. The company using the delta for gravel production has already spent several million francs on the project.

In addition to the "delta project" in the Reuss drainage, there is a project known as "revitalization of valley headwaters". It entails ecological improvements on smaller tributaries, the Giessen canal among others. From the point of view of water protection, the situation can be characterized as being both positive and promising (Table 1). First, money is relatively abundant: 2 million Swiss francs are available from the power plant Amsteg, as compensation for its detrimental impacts on fisheries in the Reuss which will worsen in the near future because of increased operation under flood conditions, and 5 million francs are coming from water engineering in compensation for flood protection projects. Secondly, the enormous impact of the traffic corridors of N2 and NEAT creates enough political pressure to poise the local population in favor of water protection. Despite all of the positive circumstances, the possibilities for revitalization may, in reality, be severely limited, as is dramatically demonstrated in the case of the Giessen canal. The need for land is great, and land is not freely available for political and legal reasons; therefore, neither extensive water-meadows nor a natural, meandering stream bed can be created. All that can be realized are alternating types of vegetation along the stream banks and contiguous buffer zones.

Second Case Study: Sarnen Aa (Canton Obwalden)

The situation for the lower course of the Sarnen Aa is considerably more difficult and has to be rated as rather negative (Table 1). Until very recently, revitalization efforts on this stream were completely nonexistent. A very modest experiment is currently underway above the nature preserve of Lake Wichel near Bitzighofen (Sarnen). The Sarnen Aa below Wichelsee is in a rather lamentable state (Fig. 2); it is a highly manipulated stretch of stream, running in a tight channel, and without any remaining flow for extended periods. A short distance before entering Lake Alpnach, the Aa receives effluent from the wastewater treatment plant Alpnach, which is treating both landfill leachate and municipal wastewater and, therefore, is often operating beyond its capacity [5]. Sediment transport in the Grosse Schliere, which

Topic/Problem Area	Canton Uri Revitalization of the Reuss, Reuss delta, Giessen, etc.	Canton Obwalden Revitalization Sarnen Aa – Städerried
Environmental burden	high	low to medium
Political climate	population motivated	population passive to opposed
Conflicts of interest	high, partially resolved	very serious, unresolved
Evaluation of situation	desired	urgently needed
Technical assistance	not requested by the AfU (office of environmental protection)	requested by the AfU
Revitalization	implemented, in progress or planned	only sketchy ideas, slow start
Financing	mostly secured	serious problem
Role of EAWAG	minimal help	fundamental assistance

Table 1
The differing pre-conditions for water protection in the Cantons of Uri and Obwalden.

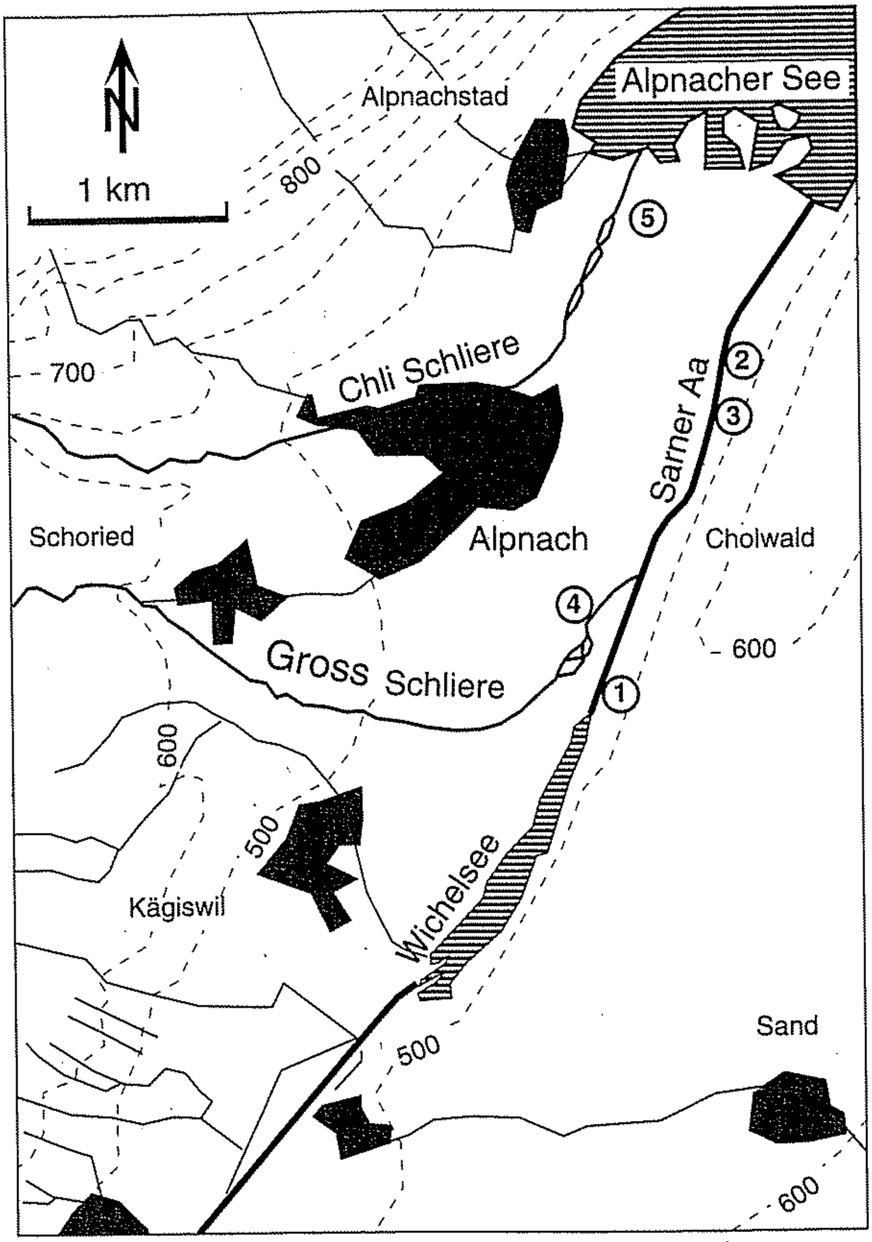


Fig. 2
Lower course of the Sarnen Aa. The stream is canalized; the banks and river bottom are lined with concrete. On the one hand, the hydroelectric power plant Sarnen Aa has created Lake Wichel, which now is a nature preserve; on the other hand, it formed a stretch of stream which is frequently dry because of "non-existent" minimum flow. The stream Grosse Schliere determines the characteristics of the Sarnen Aa up to the water return point (2). The Sarnen Aa is impacted by the wastewater treatment plant Alpnach (3), which has to treat seepage water from the landfill Cholwald. Schlierenrüti (4) is a wetland of national importance, but weirs and barriers retain sand and gravel. In the Städerried, gravel production is still ongoing. The potential for restoration is high. (Drawings by Rudolf Koblet).

flows into the Sarnen Aa just upstream of the wastewater treatment plant, is obstructed almost completely by gravel barriers at Schlierenrüti; only fine sediments are deposited in the delta of the Sarnen Aa.

Efforts to protect the natural environment at Städerried and Schlierenrüti are hampered by severe conflicts of interest so progress is very slow. The implementation of the initiative to protect bogs by the BUWAL (Federal inventory of natural bogs) has not only stimulated other environmental protection measures, but soured the mood in certain circles of the population. Many people in Obwalden are no longer tolerating "foreign administrators" dictating water protection regulations. Because the area of Obwalden has not yet experienced any significant impacts on its environmental quality, there is no pressure from the public as there has been in Canton Uri. In this case, implementation of the measures recommended in the EAWAG study is very difficult and can be achieved only pragmatically and in small increments. The permit for the power plant on the Sarnen Aa expires in the year 2001 when the problem of minimum flows can be addressed according to the new water protection law of 1991. Returning the Sarnen Aa and its delta back to a more natural state (including subsurface introduction of treated wastewater directly into Lake Alpnach) borders utopia and probably lies in the distant future.

Limits of our Knowledge

Even when experts agree "on paper" about how to revitalize a small stream running through a meadow, for example, disagreement arises when they actually go and evaluate the stream in the field. A fisheries biologist will want to improve fish habitat by encouraging contiguous cover of stream banks by domestic shrubs and trees appropriate for the location, while a botanist would like to maintain established stream banks flanked by natural meadows which offer habitats for rare species of dragon flies. Not in every case will the dispute end in a "Salomonic" solution (which, in this case, would be a wooded stream bank with gaps).

The Role of EAWAG in the Sustainable Management of Streams

The Cantons of Uri and Obwalden have, based on their differing situations, have very different expectations of the EAWAG. Uri is primarily interested in obtaining help with public relations work relating to stream revitalization, since the actual problems are mostly under control. Obwalden would like to get technical assistance in solving individual water protection problems since problem solving techniques in the Canton are still in their infancy. For EAWAG, this means that there is no generally applicable formula by which research findings can be applied. Instead, the realization of abstract concepts must occur with an intuition for their limitations in the "real world" (see insert).

Conclusions

The longer we rely entirely on technical progress the more we get caught in a vicious circle (Fig. 3): Quantitative growth ultimately leads to an ever increasing degree of obstruction of streams and consequently to ever more serious impacts on ecosystems. Nature often exhibits surprising flexibility and adaptability to new circumstances, but sometimes humanity has to intervene on Nature's behalf in order to ultimately secure the basis for its own survival. The protection of streams that are still in their natural state is far more important than the revitalization of streams that have been destroyed, since the latter is expensive and much of the damage is irreparable. Extinct species cannot be brought back, even by our "highly developed" society and not for any amount of money!

With this recognition we can formulate the following hypotheses:

- Since the strongest driving force of human activity is the economy, to date ecology has been largely "reactive" since it does not offer an immediate monetary reward.
- In the politico-economic arena, one has to proceed pragmatically. It has to become commonly accepted that whoever causes a problem is responsible for its solution.
- Purely technological solutions are useful and necessary in reaching intermediate goals. In the long term, however, values will have to be reassessed, and society will have to abandon the notion of continuous growth and instead strive for sustainability. If we cannot achieve that on our own, Nature will surely reveal the boundaries.
- Nature is stronger than humankind – not only in the sense of Rousseau, but also in a very brutal way (floods, earthquakes, etc.). Destruction is a form of regeneration and is a necessary component of Nature's perpetual cycle: for example, stream bank erosion creates a diverse habitat for fish and microorganisms, gravel banks foster the growth of pioneer plants, and floods are an important part in the life cycle of wetlands.
- Readiness to compromise has to be shown by all sides since we need to resolve conflicts of interest (e.g., water use versus water protection, disagreements among experts, etc.). Solutions "with Nature" are not only more ecological, but ultimately even more economical than solutions "against Nature". Experts from water engineering and the field of ecology have to come together to find solutions which are of mutual interest.

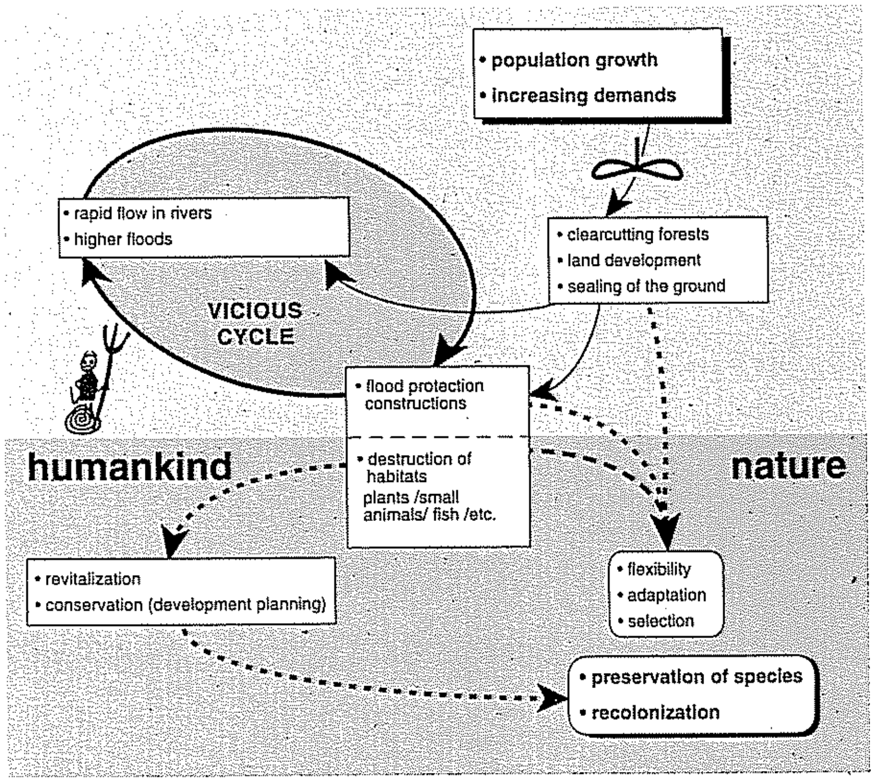


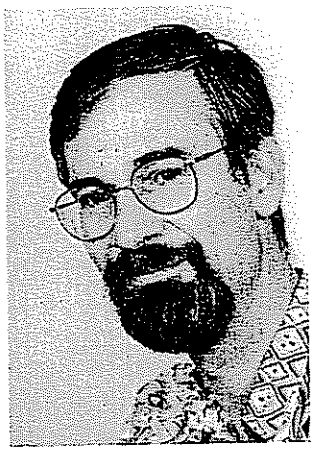
Fig. 3
Causes and effects of stream canalization – a vicious circle.
Driving forces (thin line) are population growth and increasing demands which lead to a closed circle (heavy line) of cause and effect; nature cannot completely break out of this vicious circle on its own; humankind must help with appropriate measures.

[1] EAWAG (1994): Studie Gewässerschutz im Einzugsgebiet des Vierwaldstättersees. Schlussbericht. Verfasser: J. Bloesch. Auftrag Nr. 4752, 15. September 1994.
[2] Bloesch J. (1995): Gewässerschutz im Einzugsgebiet des Vierwaldstättersees. EAWAG Jahresbericht 1994, S.12–17.
[3] Peltzer K. (1975): Das treffende Wort. Wörterbuch sinnverwandter Ausdrücke. Ott Verlag Thun, 15. Auflage.
[4] Schmid W. (1958): Wildbachverbauungen und Flusskorrekturen im Einzugsgebiet der Reuss. Wasser- und Energiewirtschaft Nr. *8/9*, 201–209.
[5] EAWAG (1994): Studie Gewässerschutz im Einzugsgebiet des Vierwaldstättersees. Auswirkungen technischer Eingriffe auf die Invertebraten- und Fischfauna der Fliessgewässer. Sachbearbeiter: J. Bloesch. Auftrag Nr. 4752, 15. Mai 1994.
[6] CIPRA (1992): Die letzten naturnahen Alpenflüsse. Heft *11*, 71 Seiten, 1992.
[7] Vischer D. (1989): Die Renaturierung von Flüssen und Bächen. Wasser, Energie, Luft 81 *(6)*: 109–110.
[8] Schnitter N. (1991): Geschichte des Schutzwasserbaus in der Schweiz. Wasser, Energie, Luft 83 *(1/2)*: 27–35.
[9] BWW/BUWAL (1991): Ursachenanalyse der Hochwasser 1987. Schlussbericht. Mittg. Bundesamt für Wasserwirtschaft Nr. 5/Mittg. Landeshydrologie Nr. 15, Bern, Mai 1991.
[10] Weber H., Huber H., Katz W., Schleiss A. & Tschopp J.W. (1992): Reuss Hochwasser 1987. Schlussfolgerungen für den Hochwasserschutz im Kanton Uri. Bauamt Uri, Abteilung Wasserbau. Altdorf, Oktober 1992.
[11] Lang O. (1983): Landschaftsentwicklungsplan Reussdelta, Kanton Uri. Band 1 und 2.

Eduard Hoehn

Importance of Ground Water at EAWAG –

with Fresh Steam into the Future



Eduard Hoehn

The public often does not realize the importance of ground water to human existence and to the environment, for not only is groundwater a vital part of the water cycle, it is also the raw material for over 80% of drinking water, our most important food staple. The use of ground water in households will receive more and more attention since it is increasingly put at risk, particularly by chemical contamination.

Goals of Sustainable Ground Water Management

Ground water is, and will remain, the primary source of drinking water. Most people are unaware of the close interdependency of drinking water and ground water. As opening a faucet to get drinking water is a very commonplace activity, and with a consumption of 400 liters per person per day (for households), frugal use of drinking water should be of foremost interest to everyone. For experts in the fields of natural and engineering sciences who are dealing with ground water management, however, it is absolutely essential to have a good knowledge of ground water flow, chemical and biological properties of aquifers and transport behavior of chemicals. EAWAG, which has a long tradition of working in these fields, will continue to contribute expertise and tools for the sustainable management of our ground water resources.

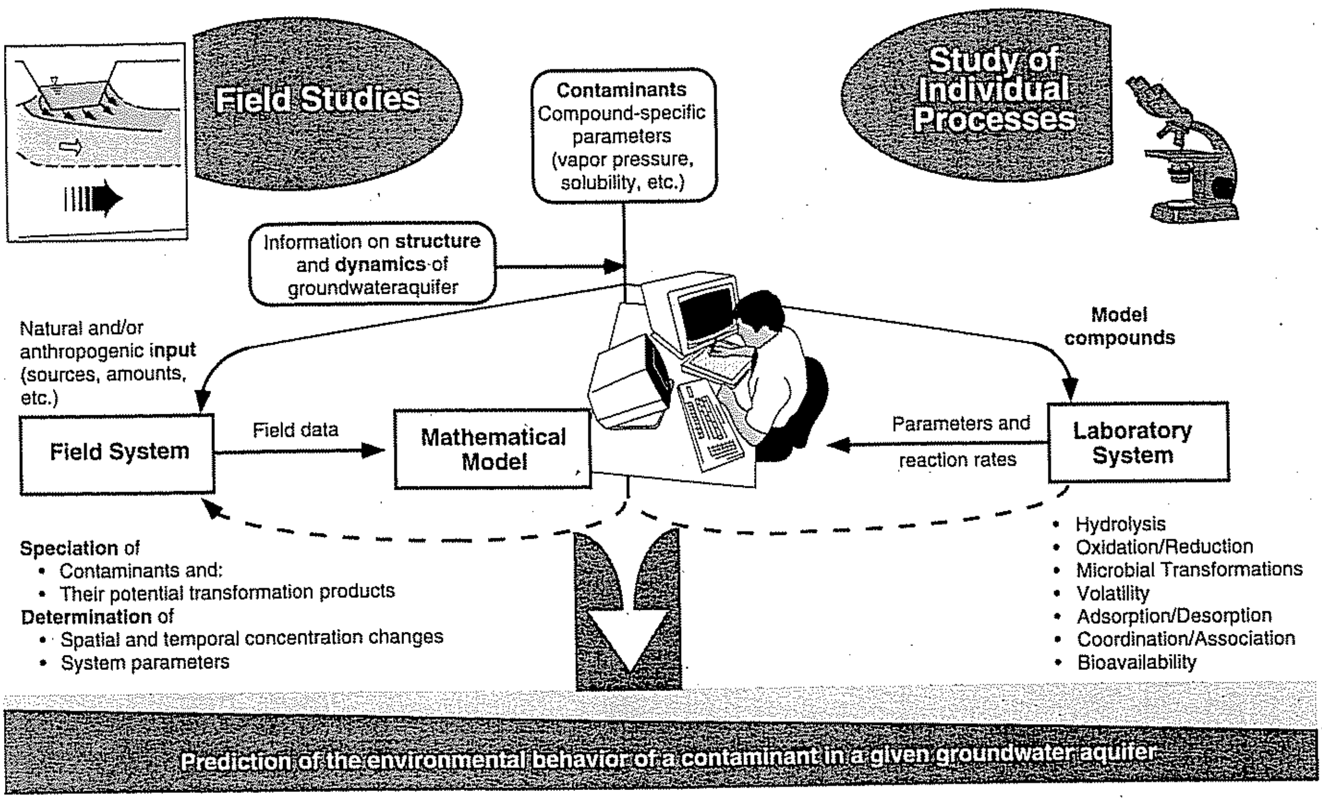


Fig. 1
Simplified schematic illustrating how the environmental fate of a contaminant in ground water can be predicted (after [4]).

Ingrid Holdenegger

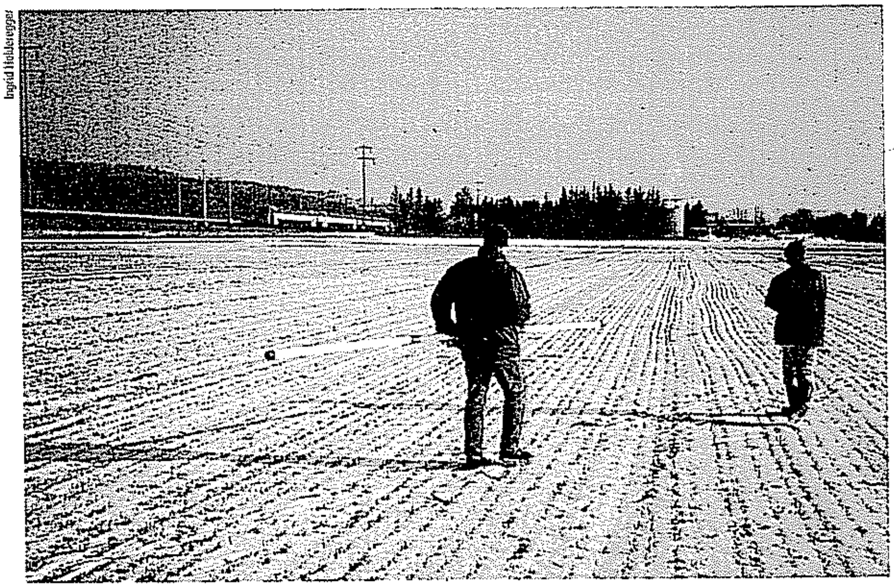


Fig. 2
Application of an electromagnetic method in a detailed study of the electrical conductivity of the ground and associated ground water (down to 4–6 m below the surface): this technique allows mapping of the location of potential contaminant plumes in the vicinity of old landfill sites. The picture shows P. Huggenberger using the measuring device in the field. Sending and receiving coils are located in both ends of the rod. A primary magnetic field created by an alternating current induces electrical currents in the ground. These currents depend on the conductivity of the ground and induce a secondary magnetic field, which is the actual parameter being measured.

Ground water, as part of the hydrologic cycle, is an ecosystem which seems sterile, that is, it is colonized by relatively few forms of life, at least compared to streams. A large portion of Switzerland's ground water is stored in valley basins of the Lower Alps. The predominant aquifer materials in this area consist of gravel beds that are formed by glacial outwash. Important characteristics of these gravel formations are coarse-grained consistency, high hydraulic conductivity, and extreme heterogeneity [1]. It is quite common, for example, that the sand:gravel ratio varies significantly even over very short flow distances. Other significant ground water reservoirs exist in the fissured formations of the Karst areas in the Jura and the Alps. The consensus in the area of ground water management is that this resource has to be maintained in its natural condition, and future action is required to *protect* it and to effectively *monitor its quantity and quality*.

Contribution from Research is Needed

Determining transport velocities of chemicals (particularly contaminants) in ground water, as well as their behavior and fate, poses a major challenge to scientists. Studies conducted at national and international institutions, such as the Canadian Waterloo Centre for Groundwater Research at the University of Waterloo, Ontario, or the Centre d'Hydrogéologie at the University of Neuchâtel, show that ground water research requires an interdisciplinary approach. EAWAG is and has been using such an approach, especially since the enactment of the new Federal law on water protection (24 January 1991), which contains sections specifically relating to ground water (e.g.: Art. 7, Par. 2) "Percolation of non-polluted waste water"; Art. 20, "Obligation to set aside protected zones around locations of ground water production"; and Art. 43, "Preservation of ground water reservoirs"). Changes in the Environmental law of 21 December 1995, included new articles presenting information regarding regulating improvements to landfills and other locations impacted by deposits of solid waste (Chapter 4, Section 4, Art. 32c–e). Such articles as these should be used as a basis for development of concrete ordinances and instructions. EAWAG has to be able to provide the basis for this process. Simultaneous involvement in research, teaching and consulting (including work on committees) ensures efficient transfer of new scientific knowledge and its subsequent application to real problems.

What has EAWAG Accomplished to Date?

In accordance with the understanding of its mission at the time, the former Department of Geology (which EAWAG no longer has), was intensively involved in consulting activities relating to ground water into the mid-1980's. In 1976, the Swiss National Fund started to move ground water research towards the center of the "political stage" by establishing a national priority program, "Fundamental problems of water management in Switzerland", and more specifically with a sub-program entitled "Ground water reserves; quantitative and qualitative aspects". It was under this program that the EAWAG conducted the study "Behavior of organic compounds during ground water formation and in ground water flow" (e.g., [3]). The interdisciplinary approach taken at the time was exemplary and involved *process oriented laboratory and field studies as well as model calculations* (Fig. 1). Field studies were conducted primarily in the infiltration zone near Glattfelden, where the heavily polluted Glatt River contributes significantly to groundwater recharge. The transport of inorganic compounds in this system was studied in collaboration with the Paul Scherrer Institute.

Ground water research during the late 1980's focused on, among other topics, the geological characterization of ground water aquifers [5]. For the last two years, the ETH Board of Directors has finanaced a project called "Transport of organic pollutants in unsaturated soil – an integrated approach" (OPUS-IA), which involves, in addition to EAWAG, two other

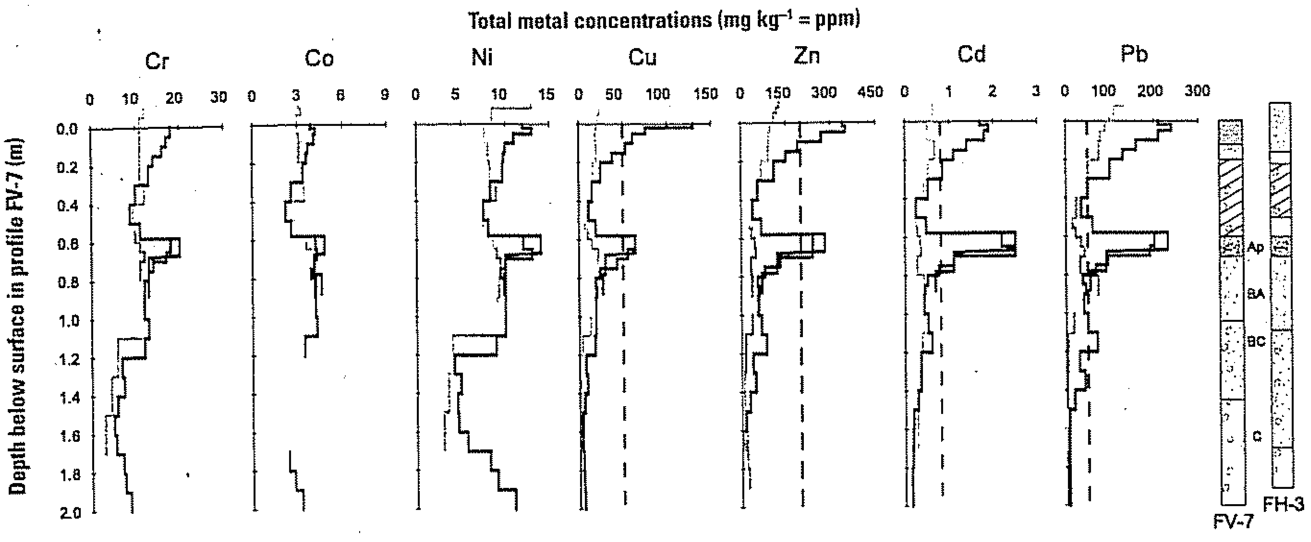


Fig. 3
Variation with depth of the concentrations of some selected heavy metal in an infiltration site for street run-off.
Horizontal axis; concentrations in mg/kg; vertical axis: depth in meters; far right: profile with soil horizons: Ap = humus, BA and BC = weathered portion of soil profile and C = gravel; solid line: profile FV-7; gray line: profile FH-3; dashed line: concentration limits according to soil protection ordinance of 1986.

ETH departments (Hydromechanics and Water Management, IHW; Terrestrial Ecology (ITÖ) and two institutes at EPFL (Institute for Agricultural and Water Management and the department for Civil Engineering at the Institute for Environmental Engineering). The main goal of this project is to describe the fundamental dynamics of chemical and microbial processes during contaminant transport in saturated flow-through porous model systems.

Formulation of New Questions Concerning Ground Water

As part of the research focus "Sustainable resource management in the example of streams, lakes and anthropogenic sediments" (FoSP), EAWAG is currently conducting process-oriented field and laboratory studies relating to ground water problems. The studies are grouped into three individual research areas and also include an integrative section [6]. A major goal of the research focus is to approach the problem in an integrated way, as illustrated in Fig. 1. This requires, of course, collaboration between various technical disciplines and a strong involvement of external partners.

Research area 1 deals with the effects of old landfill sites in the area where the City of Winterthur is now operating a repository for refractory compounds (landfill Riet). For two of the old landfill sites (they are 30–70 years old), the transport of pollutants, especially inorganic components, is being measured along the path of the ground water which is flowing into the ground water reservoir of the Eulach valley. This ground water reservoir is of particular interest because it is used for drinking water. The speciation and water-rock interactions of the pollutants are dependent upon the redox conditions. This study attempts to demonstrate in a real life situation, how a detailed scientific-technical investigation of old landfills could be conducted. In 1993, the office for Water Protection and Water Engineering (AGW) of the Canton Zürich has outlined such studies in its pamphlet called "Attention: Old Waste, New Waste".

Research area 2 is primarily focusing on the infiltration of run-off into unsaturated geological formations. Investigations at a 40-year-old infiltration site, which handles primarily street run-off, have revealed contamination of humus and underlying gravel layers (Fig. 3). In a sub-project, the transport of components in roof run-off during infiltration will be followed. In 1995, the MIGROS Co-operative (Genossenschaft) has built an infiltration pit at its new distribution center, Winterthur-Grüze. At this site, roof run-off is allowed to percolate down to the ground water reservoir through a surface layer of humus. A two-meter deep trench was excavated at the base of the trough where EAWAG is currently drilling bore holes into the sand and gravel layers in order to install instruments. This instrumentation will be used after rain events to track the fate of chemical compounds during percolation through the unsaturated zone of the aquifer. The pertinent term in the water protection law is "uncontaminated run-off"; it has to be established that infiltrating roof run-off does not contaminate the ground water aquifer or the ground water itself.

In research area 3, several working groups study the *infiltration of stream water into ground water:* The Canton Zürich is planning to revitalize the river Töss in the area of Linsental, south of Winterthur. Changes in the river bed associated with such revitalization could jeopardize ground water wells operated by the City of Winterthur. The EAWAG study has to be seen in the context of reconciliation of the conflicting interests of drinking water supplies and integrated preservation of landscape, fauna and flora. Using hydrogeological, sedimentological and geophysical methods, the extremely heterogeneous aquifer is being described and infiltration pathways and gradient fields around wells are being determined. At the same time, the ecology of the stream bottom and of the ground water is being described. It is a relatively new approach to treat ground water as an inhabited and living ecosystem. In addition, the infiltration zone near Linsental serves as a site for a tracer study in which naturally occurring isotopes of the noble gases can be monitored to determine transfer of gases from the Töss into the ground water. Under the FoSP, tracers are used to determine the age of ground water bodies and to investigate mixing processes which are important in ground water management. For deep groundwaters which are stored under pressure in poorly consolidated, quarternary rock formations and which were formed during the ice age, noble gas concentrations can reveal the temperature at the time the reservoir was formed. Because the application of tracer methods in ground water research is becoming more and more important, EAWAG is planning to establish a center of excellence in cooperation with the Institute for Physical Sciences at the University of Berne.

	Appropriate concepts for monitoring and protection against increasing over-use and pollution of ground water;
	Better understanding of below surface contaminant behavior on a field scale;
	Appropriate monitoring technology and mathematical modeling of flow paths, chemical transport and physical properties of ground water;
	Refined tools for exploration and quantification of ground water reservoirs (e. g., Geophysics);
	Evaluation of conflicts of interest by means of stream-lined studies of environmental impacts.

Fig. 4
Primary goals of the EAWAG working area "water resources and water supplies" with respect to development, production and management of ground water.

What Does the Future Hold?

The relatively new "Drinking Water Group", which has now been in existence for just about a year, works on developing, producing and managing ground water, among other things. Due to the broad application of its expertise in research, consulting, teaching and committee work, the group is expected to make major contributions to EAWAG's activities (it will be the "W" in EAWAG). The primary goals of the working area "water resources and water supply", as far as ground water is concerned, are shown in Fig. 4. These goals will be reached in cooperation with external partners, such as ETHZ, engineering companies, and the offices for water protection on the Federal, Canton and local level.

EAWAG will continue its work on old waste storage sites, since many questions relating to exploration, evaluation and remediation are still unanswered. An example of such projects is the joint effort between the experts and consultants of the "Special Waste Landfill Kölliken" (SMDK), the Section for Environmental Protection of the Building Department of the Canton · Aargau and the "working group SMDK" at EAWAG, which applies its expertise in analytical chemistry, chemical hydrogeology, microbiology, waste water treatment, risk analysis and ecotoxicology to addresss a topic at the center of public interest. Over the last eight years, an intensive monitoring program, which was a part of the effort to secure and remediate the SMDK, has documented that the exact flow path of the ground water is a very critical parameter.

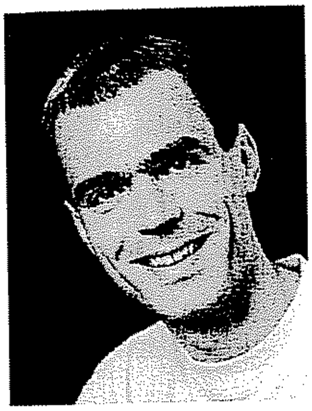
The importance that ground water will have in the future justifies a more intense effort to study underground processes. Experts at EAWAG are challenged to make useful contributions to the solution of the porblems at hand.

I would like to thank my colleagues Annette Johnson, Markus Boller, Walter Giger, Jürg Zobrist, Jürg Bloesch, Tom Bosma, Tom Gonser, Stefan Haderlein, Peter Huggenberger, Rolf Kipfer and Walter Wagner for their suggestions and additions to this article.

[1] Huggenberger, P., Ch. Siegenthaler und F. Stauffer, 1988, Grundwasserströmung in Schottern; Einfluss von Ablagerungsformen auf die Verteilung der Grundwasserfliessgeschwindigkeit, Wasserwirtsch. *78* (5), 202–212.
[2] Hoehn, E., R.V. Blau, D. Hartmann, W. Kanz, H. Leuenberger, F. Matousek, und J. Zumstein, 1994, Der Zuströmbereich als Element eines zeitgemässen Grundwasserschutzes, Gas-Wasser-Abwasser *74* (3), 187–193.
[3] Giger, W., R.P. Schwarzenbach, E. Hoehn, K. Schellenberg, J.K. Schneider, H.R. Wasmer, J. Westall, & J. Zobrist, 1983, Das Verhalten organischer Wasserinhaltsstoffe bei der Grundwasserbildung und im Grundwasser, Gas-Wasser-Abwasser *63* (9), 517–531.
[4] • Jackson, R.E., and E. Hoehn, 1987, A review of processes affecting the fate of contaminants in groundwater, Water Poll. Res. J. Canada *22* (1), 1–20.
• Stumm, W., R.P. Schwarzenbach, und L. Sigg, 1983, Von der Umweltanalytik zur Ökotoxikologie – ein Plädoyer für mehr Konzepte und weniger Routinemessungen, Angew. Chemie *95*, 345–355.
• Giger, W., 1995, Micropollutants in the Environment, EAWAG news *40E*, 3–7.
[5] Huggenberger, P., und J. Zobrist, 1990, Grundwasserforschung an der EAWAG, Mitt. EAWAG *29*, 11–16.
[6] Bundi, U., P. Baccini, M. Boller, R. Schertenleib, W. Schilling, R. Schwarzenbach und A. Zehnder, 1992, Forschungsschwerpunkt: Nachhaltige Ressourcenbewirtschaftung – am Beispiel Gewässer und anthropogene Sedimente, EAWAG Jahresbericht 1992, 10–14.
[7] Mikkelsen, P.S., M. Häfliger, and M. Boller, 1995, Pollution from two infiltration systems for road runoff in Switzerland, EAWAG-Bericht.
[8] Hoehn, E. und B. Kiefer, 1992, Ausbau der Wasserkräfte im oberen Puschlav; Untersuchungen zur Umweltverträglichkeit: Projektorganisation und hydrogeologische Ergebnisse, Mitt. Schweiz. Ges. Boden- u. Felsmech. *125*, 35–41.

Peter Krebs

Interdependencies and Dynamics within the Urban Water Management



Peter Krebs

The production of drinking water reduces groundwater levels. Sewage is mixed with rain water and reaches surface waters either directly or via waste water treatment plants. Even just a short description of the water flow through developed areas highlights the need for an integrated approach to the management of municipal water systems.

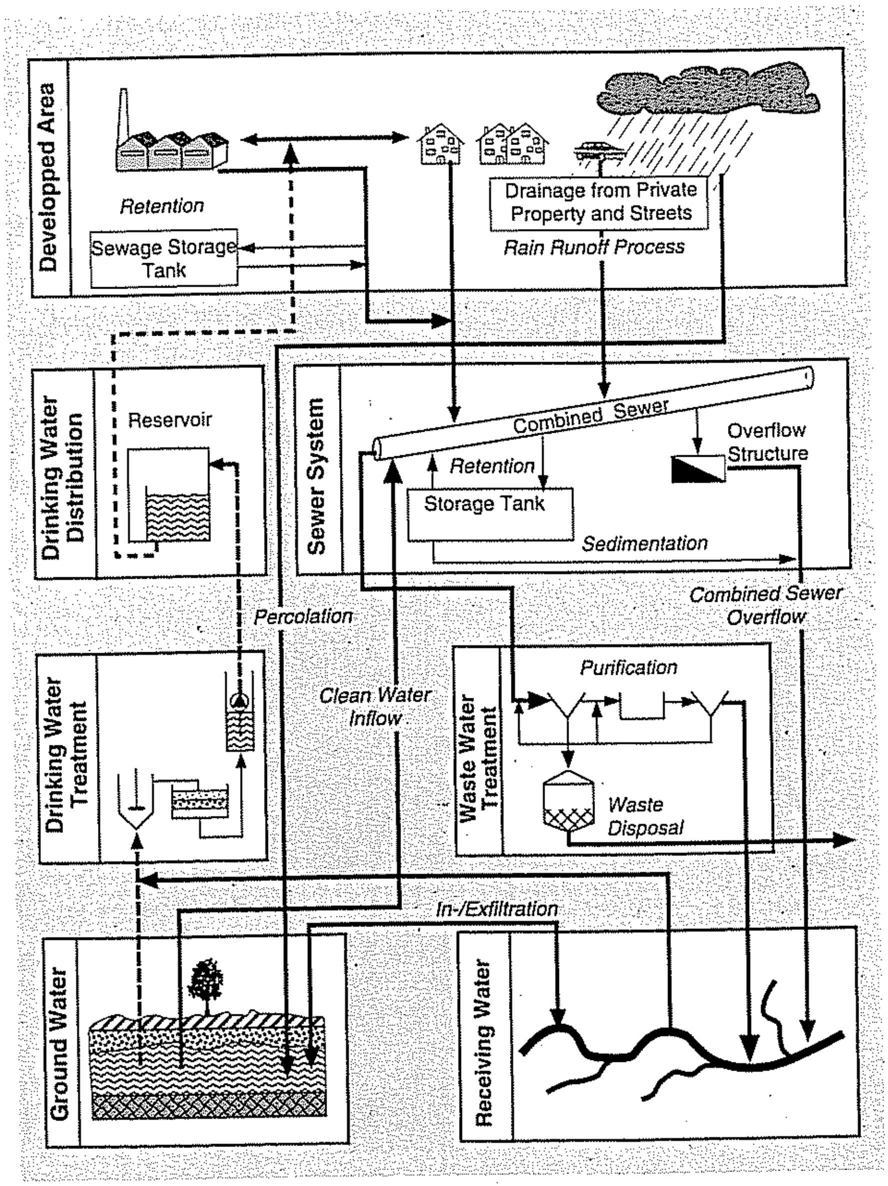


Fig. 1
The complete system of urban water management includes settlement, transport systems, and treatment processes, as well as natural water systems.

The History

In the 1960's, the primary "goal of urban drainage" according to Hörler [1] was to "collect all waste waters as completely and quickly as possible and to remove them from human settlements, without damaging above- and below-surface waters". In the following two decades it was possible to expand the primary goals of urban drainage – ensuring hygiene and flood protection – to include the qualitative protection of surface waters.

The requirement of quick removal and the understanding that "waste water" includes all waters, even water flows which are now categorized as "clean water inflow" and are considered to be an unnecessary burden on waste water treatment plants, have created a set of new problems. Combined sewer overflow (CSO) after rain events have increased in sewers and overflow structures, and clean water inflow and rain water are not reaching groundwater aquifers or surface waters.

This development had to be corrected by formulating a new strategy in the Integrated Urban Drainage Masterplan (GEP, Genereller Entwässerungsplan) [2]: "Waste waters should be differentiated and only be removed if they cannot be allowed to infiltrate into soil within the area of origin without causing damage. In addition, possibilities for water retention should be utilized as much as possible in order to reduce peak flows". Thus, the goal has changed from removing as much water as quickly as possible to one of removing as little as slowly as possible. The additional demand for "integrated approaches to urban water management" requires that concrete solutions are found to many of the remaining problems.

Gaps in Existing Systems

An EAWAG case study involving Fehraltorf [3] demonstrated some of the initial steps in the realization of an integrated approach to urban drainage handling and pointed out opportunities for cooperation between technical fields which have not usually worked together. Despite the fact that the waste water system of Fehraltorf meets all the requirements of the current laws, the local stream is regularly being overloaded. One of the main reasons is due to the fact that the technical design disregarded local stream and groundwater characteristics. If Fehraltorf were situated on the River Rhine instead of the River Luppmen in the Zürich Oberland (a stream which regularly dries up in some sections during the summer months), the drainage systems would essentially be identical except for somewhat smaller combined water storage tanks.

While the main focus of the case study was on the *drainage* system of the community, major problems were found in three related systems:

- Since the 1940's, the groundwater level has dropped steadily due to the withdrawal of drinking water. The stream is no longer fed through reverse seepage from the groundwater, dries up more frequently and for longer periods of time, and is therefore more sensitive to the effects of the discharge of combined sewer overflows (CSOs).
- Water is withdrawn upstream of the community which further reduces instream flow rates.
- In addition to solute concentrations and hydrology, the morphology is an important parameter determining the quality of a stream and its ecosystem. Factors including shading by trees, river bed dynamics, and variability in geometry are all important conditions determining the diversity of habitats and the survival of small animals during flood events; such factors are completely lacking in many sections of the stream. Technical improvements become irrelevant since the ultimate goal – a near-natural state of the stream – is unachievable because of the conditions in the stream itself.

Depending on the level at which a system is being analyzed, the measures chosen to improve the conditions of a stream may vary. While increasing the retention volumes would be an appropriate measure with just the drainage system in mind, an integrated approach to the management of a municipal water system would more directly address the three problem areas mentioned above and would ultimately lead to more efficient solutions for the system as a whole.

Interdependencies in the Complete System

The complete system of urban water management includes the following subsystems (Fig. 1): the distribution and collection systems for drinking water and waste water, the process technology for drinking water and waste water treatment, as well as the natural water systems, i.e., ground water and surface waters.

Measures or changes applied to one subsystem always cause changes in others due to multiple linkage between subsystems. For example, infiltration of rain water simultaneously means recharging of the groundwater aquifer, reduction of CSOs and of the load on the waste water treatment plant, and increasing seepage of ground water back to surface waters and therefore a more stable base flow in the stream. As another example, reduced consumption of drinking water leads to the conservation of ground water as a resource and to a reduced load on waste water treatment plants, which can have a positive effect on solute concentrations in the stream, especially during dry periods.

Individual chemical components usually travel through several subsystems. The fate of heavy metals, for example, which are being washed off roofs (copper, zinc) or roadways (lead) by rain water, strongly depends on which drainage concept is chosen [4]. In a combined sewer system, heavy metals are mostly transported to waste water treatment plants, from which they are distributed diffusely by application of sludge in agriculture. In a separate system, heavy metals within the rain water are directly discharged to streams and again diffusely distributed, now in stream sediments. On the other hand, in a rain water infiltration system, heavy metals accumulate in the upper-most layers of the filter body that can periodically be removed. Including the community itself as part of the system (Fig. 1) opens new options for source control measures. For example, heavy metals could be kept out of rain water to a large extent if different materials were used for rain gutters.

Dynamic Interactions

In the case of heavy metals, total loads and accumulated concentrations over long periods of time are of interest. For other substances, acute effects and their dynamic behavior over short periods of times are crucial. A well known example is ammonium whose chemical equilibrium with fish-toxic ammonia is primarily determined by pH and temperature. The soluble ammonium comes mostly from waste water and exhibits strong diurnal variations.

Ammonium loads and concentrations for three subsystems, namely the sewage system, waste water treatment plant and stream, were simulated using a model which included dynamic interactions [5]. Calculations were based on data collected during rain events (Fig. 2), a typical diurnal sewage variation and a virtual waste water treatment plant which was modeled as a nitrifying plant using ASIM [6]. Included in the model were several effects which were due to rain events, such as the push out of ammonium

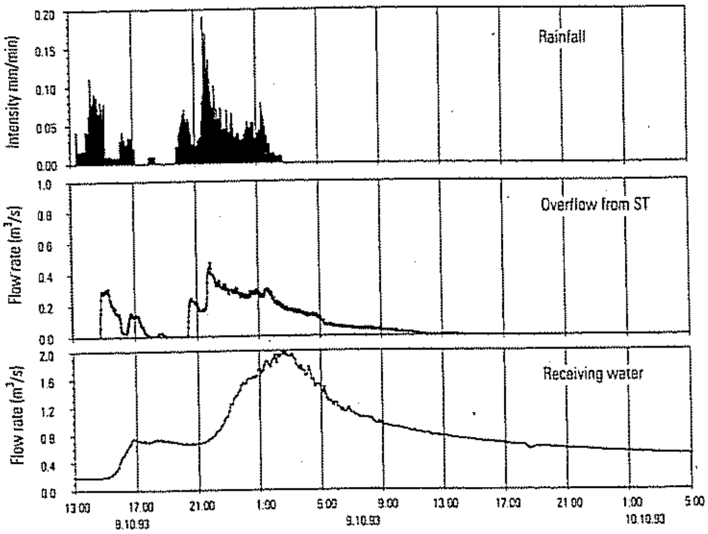


Fig. 2
Rain runoff event in Fehraltorf on 8 Oct., 1993.

from the primary clarifier to the aeration basin, the shifting of sludge from the aeration basin to the secondary clarifier, or the reduction of the specific activity of the activated sludge because of increased flocculation of particulate material into the sludge.

Figure 3a shows the ammonium loads in the CSO and in the effluent of the treatment plant. The first two peaks between hours 2 and 5 and hours 8 and 12 after the beginning of the rain event are clearly correlated to runoff volumes. Another peak is observed at the 20 hour mark despite consistently decreasing runoff volumes. This is induced by the morning peak of the diurnal sewage variation.

The ammonium load leaving the waste water treatment plant reflects the diurnal load variation, with a certain time delay. The peak values on the day after the rain event actually exceed the highest values of the day of the event itself. Due to clean water inflow, the hydraulic loading of the treatment plant remains high long after the end of the rain event, while the specific activity of the sludge still remains depressed due to the input of particulate material.

Including stream runoff in the calculation yields the concentration curves shown in Figure 3b. The second day obviously becomes less important since the flow rate in the stream begins to increase after the first overflow, goes through a maximum after approximately 20 hours, and then decreases only slowly. After 24 to 30 hours, the runoff volume still is about four times as high as the base flow at the beginning of the rain event and is therefore sufficiently high to dilute the concentrations occurring during the second day. The major ammonium concentration peak at 2 hours after the start of the event could only be significantly reduced if the rainwater runoff is decreased by infiltration and retention.

Realization

In light of the increasing knowledge of dynamic interactions, it appears appropriate to use an integrated approach to urban water management. The expansion of system boundaries allows to determine and potentially model interactions with bordering subsystems, which may uncover new management options.

New knowledge is not gained by simply expanding system boundaries, but is the result of a long-term process where experts in drinking water, waste water, ground water and limnology jointly develop concepts and methodology which simultaneously satisfy the basic needs of municipal water systems, better protect ground water as a valuable resource, and show ways to preserve or improve streams as ecosystems instead of using them as "transport systems". In order to really achieve progress, of course, science has to find receptive ears and interest in innovation within government bodies, both on the municipal and cantonal level, where officials have to actively participate in the development and the application of new concepts.

[1] Hörler A. (1966). *Kanalisation.* Ingenieur-Handbuch, Band II.

[2] VSA (1989). Genereller Entwässerungsplan (GEP). Verband Schweizerischer Abwasserfachleute, Zürich.

[3] Krejci V., Fankhauser R., Gammeter S., Grottker M., Harmuth B., Merz P. und Schilling W. (1994). *Integrierte Siedlungsentwässerung, Fallstudie Fehraltorf.* Schriftenreihe EAWAG, Nr. 8.

[4] Boller M. und Häfliger M. (1996). Verbleib von Schwermetallen bei unterschiedlicher Meteorwasserentsorgung. Gas-Wasser-Abwasser, *76* (1), 3–15.

[5] Krebs P., Krejci V., Fankhauser R. und Siegrist H. (1996). Reducing the overall impact on a small receiving water. Int. Conf. on Urban Storm Drainage, 9.–13. September 1996, Hannover.

[6] Gujer W. (1990). ASIM – activated sludge simulation program. MS DOS, public domain.

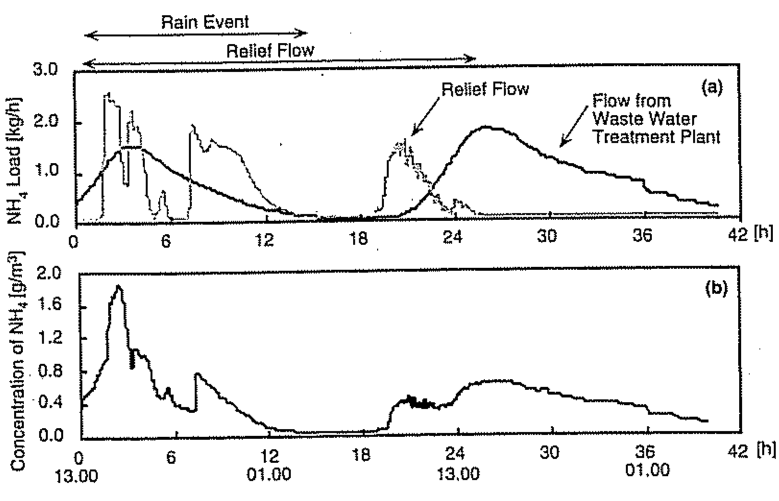
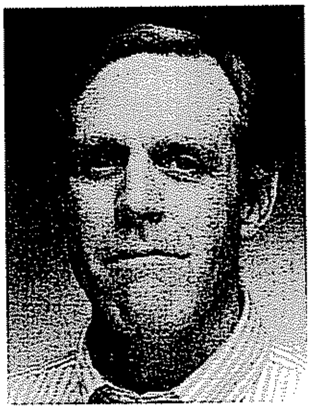


Fig. 3
a) Ammonium loads from combined sewer overflow and waste water treatment plant.
b) Ammonium concentration in the stream as a function of time.

Bruce R. James

Soil, Water and Civilizations



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The topic and ideas of this paper were developed while the author was on sabbatical leave at EAWAG in 1994 and 1995. They began while developing and teaching two undergraduate interdisciplinary courses at the University of Maryland: "Crops, Soils, and Civilization" and "Ethics in Environmental Science". Through numerous discussions and attendance at a symposium on sustainability at EAWAG, the importance of the linkages between history and science became clearer. In addition, the author is establishing an International Center for Soil and Society that will research questions of the type posed in this article by bringing together professionals from the fields of soil and water sciences, environmental history, ecological anthropology and environmental ethics.

Long-lasting human civilizations developed, persisted and possibly declined due to purposeful and drastic disturbances of soil-water relationships in agricultural systems that mimicked to some extent regional ecological communities. Coupling an examination of the patterns of such human disturbance in three civilizations (Mesopotamian, Greco-Roman, and Maya) with new theories of ecosystem stability provides insight for environmental scientists concerned about preservation and conservation of ecological systems and natural resources.

Linking concepts in ecology with the ancient history of civilizations is instructive in evaluating contemporary environmental problems related to soil and water resources. Such connections are usually missing from educational curricula, mass media reports, and public debates; but discussions of the interactions of cultural developments of civilizations and modifications of soil-water systems can inform those who formulate policies for natural resource management and environmental protection in the long-term. Also, our perceptions of land and water use and preservation can be re-examined in light of emerging principles of ecology related to the stability and dynamics of ecological communities. The goal of this article is to describe exemplary soil-water systems of ancient civilizations and new principles of ecological *sensitivity* and *resilience* in a way that encourages creative thinking and discussion in the fields of water resource management, soil science and environmental policy. Sensitivity refers to the degree to which a given ecosystem undergoes change due to natural forces or human interference, while resilience is a property that allows a system to absorb, utilize and benefit from change [1].

Models of Natural Ecological Change

When an agricultural field is left unplanted for several years, the natural process of ecological succession begins

Characteristics	Pioneer Stages	Climax stages
Yield	high	low
Food chains	linear	weblike
Biomass/Joule	low	high
Inorganic nutrients	extrabiotic	intrabiotic
Species diversity	low	high
Mineral cycles	open	closed
Symbiosis	undeveloped	developed
Nutrient conservation	poor	good
Stability	low	high
Entropy	high	low

Table 1
Comparison of the inherent characteristics of both pioneer and climax stages for an ecosystem undergoing successional change. The time needed to reach naturally the self-sustaining community is different for every region.

Years of succession*	0	1	2–20	25–100	150 +	100's
plant community	Bare field	Grasses	Shrubs	Pine forests	Oak-Hickory	??

* Years needed for the change into a higher plant community.

Typical succession of plant communities that would grow, if undisturbed, on a bare field in the humid regions of North America or Northern Europe over decades and centuries.

as weeds and other colonizing plant species establish natural plant communities. These communities change slowly over the years, and different *pioneer stages* replace one another over decades (Table 1). The disused field passes through several pioneer stages before reaching a self-sustaining, natural equilibrium plant community, known as the *climax* [2].

Pioneer stages differ from the climax community in many important ways related to the complexity of food webs, biomass supported per unit of energy flow, sources of inorganic nutrients for plant growth, the development of symbiosis, species diversity, and nutrient conservation (Table 1). This classical model of ecological succession assumes a constancy of environmental conditions and an attainment of stability in the climax community that is comparable to the dynamic equilibrium of a chemical reaction in which no net change in the concentrations of reactants or products is observed. The climax community is seen as being resistant to disturbance ("well-buffered" in the chemical sense), thereby making it long-lasting. In contrast, the pioneer stages are viewed as less stable because of their poorly developed mechanisms to resist change and perturbation.

This model of ecological succession has also dominated thinking about human relationships to natural systems, but it has been challenged recently as an unrealistic and inaccurate description of real ecosystems [3]. New thinking and research in ecology are showing that ecosystem stability is a function of constant recovery from disturbance, and recovery dynamics are the key to understanding the processes involved. Fires, floods, stream erosion, soil erosion, drought, and extremes in temperature are examples of natural and human-induced disturbances that may increase spatial and temporal heterogeneity in ecosystems, create opportunities for colonization by organisms, and thereby promote biodiversity and greater stability of whole ecosystems. Such nonequilibrium models of ecosystem function are instructive in understanding how the growth of lasting human civilizations has been dependent on drastic and purposeful disturbance of soil-water systems associated with agricultural production and the development of the city.

Anasazi Culture

The Anasazi people (whose descendents are the Pueblo Native Americans) created a "micro-civilization" in the semi-arid mesa country of the southwestern United States for a thousand years beginning around the time of Christ. They actually "created" agricultural soil SYSTEMS behind small, stone dams at the tops of steep ravines just below the tops of the mesas where soil was eroded into the ravines by thunderstorms [11]. They lived in stone cliff dwellings along and within canyon walls where drinking water was probably available after draining from the mesa tops above. There is no written record of these people and their accomplishments, but the archaeological record provides a detailed picture of the relationships of these people with soil and water resources and how they used them creatively to establish small, self-sustaining communities. As with the Maya, no clear reason for their decline is evident, but a 30-year drought may have forced them to disband and migrate from the region. As in the other three civilizations, purposeful and creative responses to limitations of water supply and quality enabled these people to develop persistent, stable societies, but under severe enough stresses, these civilizations disbanded, declined, or were overrun by outsiders.

The Rise and Fall of Civilizations: The Role of Ecosystem Disturbance

How have soils, water supplies, and ecosystems been changed intentionally by humans to allow the growth of civilizations? Can answers to this question help us assess current and future human relationships to natural systems?

A "civilization" is a complex socio-political form defined by the institutions of the state and the existence of a "distinctive great tradition" (sets of elite values and behaviors that emerge from folk traditions and that are expressed in distinctive rituals, art, writing, and other symbolic forms) [4].

Three civilizations that rose and developed within disturbed soil-water systems exemplify different ways that geographic location, soil resource, water supply, climate, and climax community shaped human cultural development. These include those that arose on the floodplains of the Tigris and Euphrates Rivers (Mesopotamia), surrounding the Mediterranean Sea (Greco-Roman), and in the lowlands and tropical rain forest of Central America (Maya).

Mesopotamia

This arid, drought-prone region known as "the land between the two great rivers" is the site of the first agriculture ten millennia ago and is the genetic center of the origin of barley *(Hordeum vulgare* L.), wheat *(Triticum aestivum* L.) and the date palm *(Phoenix dactylifera* L.). Extensive flood control and water delivery systems were needed to raise these crops and allow the rise of the famous civilizations of the Fertile Crescent [5]. Water control systems of dikes and canals were built between the rivers on the barren plain of swamps and other soil environments that were either too wet or too dry for consistent crop production.

In Assyria and Babylonia, approximately 40'000 km^2 of irrigated land supported 15–20 million people in and around the first cities of Nineveh and Babylon. Many first and great traditions were developed in Mesopotamia, including fabric (8000 BC), pottery (first artificial human material requiring "know-how"), and cuneiform writing (first repeated use of the same symbols in different words). As a result of trade associated with the products of irrigated agriculture, the concepts of the "man-day", apprenticeships, business accounting, and private property developed. Child support for aging parents and many women's rights (e.g., owning land and allowing widows to remarry) were instituted in these societies.

Intensive and extensive water and soil management were critical to successful crop production, and slaves were used to remove the constantly accumulating silt carried in the waters of the Tigris and Euphrates Rivers to the irrigation canals and ditches. Due to the regular and long-term additions of water to the land in this arid climate, soil salinity increased and caused a shift from wheat to the more salt-tolerant barley as the main crop. Barley became a staple food and was used in diverse products from bread to beer. In addition, the salt-tolerant date palm provided many important foods.

A gradually rising water table accompanied the salinity buildup due to lack of soil drainage, and as a result, barley yields gradually declined over decades and centuries. Barley is intolerant of poorly-drained soils and anaerobic conditions in its root zone. In response to the declining yields, the area of land under irrigation was expanded; but there is no evidence of a migration in response to these conditions.

During the third millennium BC, this civilization declined in part due to the accumulating effects of siltation of rivers and irrigation works, salinization of soils, and the rise of the groundwater level to within one meter of the soil surface [5]. The successful use and purposeful disturbance of soil and water resources in this first agriculturally-based civilization also were the invisible seeds for its decline millennia later.

Mediterranean Sea

In the Mediterranean region (meaning "sea between the lands"), the ancient civilizations of Greece and Rome responded differently than did that of Mesopotamia to soil and water resource constraints [6]. In contrast to the arid climate and saline soils unaffected by erosion in Mesopotamia, the xeric climate of the Mediterranean (dry summers and wet winters) and hilly topography of the Greek and Roman peninsulas resulted in erosion of the shallow, relatively infertile soils. The massive deforestation which took place for thousands of years throughout the Mediterrenean basin (as a source of wood for ship building, construction, and firewood) accelerated the development of these soil-climatic conditions. These conditions created a climax plant community dominated by widely-spaced, relatively small trees. Domesticated grapes *(Vitis* spp.) and olives *(Olea europaea)* simulated this type of climax community and were grown successfully in the Mediterranean region. Trade on the Mediterranean Sea was possible, and a commercial agriculture developed, partly in response to the limited and degraded soil resource of the Greek and Roman peninsulas [7]. The production of wine and olive oil was a prerequisite for transport and solved the problem of storage for fresh grapes and olives.

One of the results of extensive trading and travel on the Mediterranean Sea was exposure to and rapid dissemination of new languages and ideas. New forms of government evolved that began to recognize the importance of the individual in society, especially in Greece. Some of the earliest books written in Latin gave advice on soil and crop management on *latifundia,* large farms where olives and grapes were produced commercially. Military conquests were necessary to control land used for grain production in North Africa, and the conquered people were forced to sell grain in exchange for olive oil and wine.

In the ancient civilizations of the Mediterranean basin, the shallow infertile soils, combined with erosive rainfall patterns, fostered an agriculture

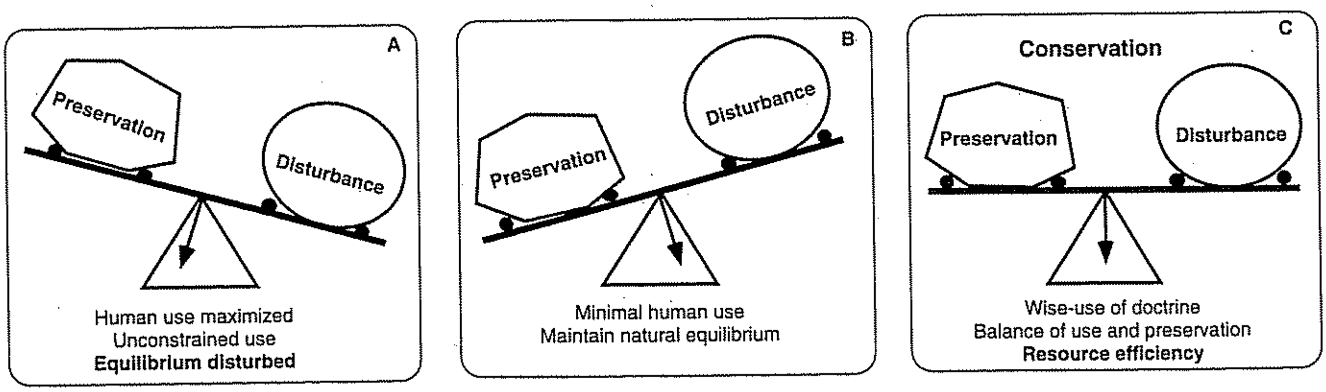


Fig. 1
Seesaw models to illustrate the balance between preservation and disturbance of ecosystems and natural resources. On the ends of this seesaw are "preservation" and "disturbance" as possible ways that humans may use and change ecosystems.
If tipped toward disturbance (a), natural equilibria are disrupted, and human use is maximized.
If tipped toward preservation (b), there is minimal human use, natural equilibria are supported, and effects of natural changes are tolerated.
When preservation and disturbance are brought into balance (c), resources are both preserved and used; and the concept of "conservation" is applicable. Conservation embodies a wise use doctrine and blends human use and protection of nature in ways that are long-lasting.

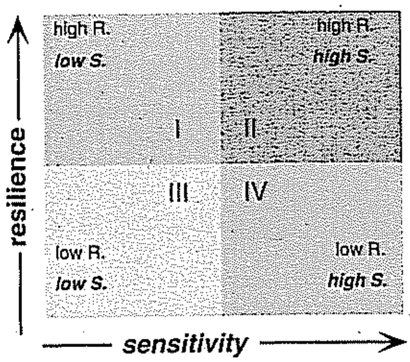


Table 2
A sensitivity-Resilience Matrix.

that forced people off the land and into maritime trade, was based on products for trade and, therefore, was mercantile or commercial rather than subsistence-based. In this way, soil-water relationships were an important determinant of the growth of these cultures, their interactions with others, and possibly with the decline of the resource base of the Greek and Roman peninsulas. In this case, intensified water management was not the key response to a degraded soil-water resource base; instead, engaging in the trade of agricultural products grown in simulation of the ecological climax allowed the growth of these civilizations.

The reasons for the decline of these civilizations are myriad and subject to much debate among historians, but the role of natural resource mismanagement deserves more careful consideration, especially as related to complex soil-water interactions in these cultures.

Lowlands of Central America

The Maya people of lowland, tropical rainforest areas of Central America (now parts of Guatemala, Belize, Mexico, and Honduras) developed an intensive "hydraulic agriculture" using raised soil beds, a system that could be described as "irrigation with air". In these areas of poorly drained soils and wetlands, large-scale, sustained crop production was not possible under natural soil conditions [8,9]. In that region, 80% of the annual rainfall (up to three meters) falls between May and November, the growing season for maize *(Zea mays* L.), the staple crop. The construction of the raised beds was labor-intensive. No special machinery or imported fertilizers were needed, and these food production and soil-water management systems were immune to the buildup of salinity. The loss of soil fertility through washout (heavy rainfall), nitrogen depletion via harvest of the maize crop (maize requires a lot of N), and weed effects could be compensated for by the repeated addition of a mulch consisting of water lilies *(Nymphaceae)* and other material from the drainage canals.

Although the rainforest vegetation was cleared for cities and crop production, maize was native to Central America and was grown successfully using this system for approximately three millennia from 2500 BC to 800 AD. In this case, excess water was a continuing limitation for food production and indirectly for the growth of cities. The crop production and soil-water management schemes apparently were efficient and could have supported the large, urban, non-agricultural population for a long period, perhaps indefinitely. Why the Maya civilization declined rapidly after 800 AD is unclear, but it is evident that the autocratic societal structure and sophisticated cultural developments were related to the intensive management of poorly-drained soils in a tropical climate. A comprehensive system of soil and water management was developed that apparently was sustainable; no evidence exists for its decline or mismanagement by the Maya people. Today, these soil-water management structures lie abandoned, but could be a rehabilitated water and soil resource in this region [10].

Heuristic Lessons and Concepts

How can the emerging theories of ecosystem change and stability be joined with these historic examples of human disturbance of soil-water systems to direct our thinking as we address contemporary issues of soil and water management and use? Do these ecological and historical examples justify unchecked consumption of soil and water resources without concern for the future? Can we assume that disturbed ecosystems will recover and be stable and that our modern civilizations may proceed without change as resources are consumed?

A schematic metaphor of a seesaw is useful in stimulating thought on these questions (Fig. 1). Since there are many positions of this seesaw, and since there is continuous variation from disturbance to preservation, how can decisions be made about its "correct" or "desirable" position? Should a given position be established rigidly, or should there be flexibility in time and for different human cultures supported by particular soil-water-plant systems?

Combining these concepts from the seesaw with a decision-making matrix may be helpful. A two-by-two matrix (Table 2) that uses the concepts of "sensitivity" and "resilience" at high and low levels is germane to this thinking [1]. Soil-water systems that have low sensitivity and high resilience are ones that humans may disturb, while ones that have high sensitivity and low resilience should be preserved from human disturbance. The high sensitivity-high resilience and low sensitivity-low resilience combinations are intermediate cases between the two extremes.

How sensitivity and resilience of soil and water resources are perceived, defined, and quantified is a challenge for environmental scientists, natural resource managers, government officials, and the general public. The historical examples teach us that human uses and management of water resources, in accordance with soils of particular regions, play a central role in the development, persistence and decline of complex, urban-centered civilizations. We must define sensitivity of our own soil and water resources and understand how resilient they are when used, preserved, and conserved in industrialized and developing nations. Because water is often considered a "renewable resource" within the hydrological cycle, and soil development and renewal are poorly understood by most people in modern societies, we often assume that they are not principal determinants or supports of our lifestyles. History teaches us that we disregard soil and water resource conservation at our peril and that we heed their constraints to our benefit.

Perceptions and knowledge from the natural sciences, humanities, and social sciences must be combined to generate new ideas pertinent to our cultural values and ethics associated with soil and water resources. The task may be made easier if the new principles of ecology (described above) are studied, combined with knowledge from soil and water sciences and applied in the context of facts and principles from human history.

[1] P. Blaikie, and H. Brookfield (1987) *Land Degradation and Society,* Methuen, London.
[2] E.P. Odum (1969), The strategy of ecosystem development, Science, *164,* 262–270
[3] S.R. Reice (1994), Nonequilibrium determinants of biological community structure, Am. Scientist, *82,* 424–435.
[4] Council of Biology Editors (1994), *Scientific Style and Format,* 6th Edn., Cambridge Univ. Press.
[5] D. Hillel (1994), *Rivers of Eden,* Oxford University Press, New York; and W.C. Lowdermilk (1953), *Conquest of the Land through 7000 Years,* Agric. Bull. No. 99, U.S. Dept. Agric., Soil Conservation Service, Washington, DC.
[6] M.J. Cary and T.J. Haarhoff (1961). *Life and thought in the Greek and Roman World,* University Paperbacks, Methuen, London.
[7] Hyams, E. (1976), *Soil and Civilization,* Harper and Colophon Books, New York.
[8] Peter A. Furley, Ed. (1989) Advances in Environmental and Biogeographical Research in Belize, Chapter 5, Biogeographical Monographs No.3, Univ. of Edinburgh.
[9] K.V. Flannery (ed.) (1982), *Maya Subsistence,* Academic Press, New York.
[10] D.J. Hillel (1991), *Out of the Earth,* The Free Press, New York.
[11] A.H. Rohn (1963), Prehistoric soil and water conservation on Chapin Mesa, Southwestern Colorado, Am. Antiquity, *82,* 441–455.

An Interview with the Biochemist Joan Davis

Water Protection: New Problems Demand New Solutions

Much of your work deals with rivers. What are your current research activities in this field?

The main work focuses on factors which affect the quality of river water. There are two main categories of influences we look at: the anthropogenic loading and natural factors. Both affect physical parameters (such as electrical conductivity) and fluctuations in substance concentrations. Understanding natural influences helps to interpret appropriately the fluctuations of the parameters examined. In particular it helps recognize whether an observed increase or decrease is a sign of a significant change (e.g., temperature increase, see Fig. 1), or perhaps only due to particular characteristics of the current hydrological year such as seasonal distribution of discharge.

• Most of the rivers examined are part of the ongoing research program "National long-term studies of Swiss Rivers", abbreviated as NADUF (an acronym of its German name). This program has existed for 20 years as a joint project with the Swiss Federal Department of the Environment and the National Hydrological and Geological Survey. Other EAWAG scientists involved in this project are Prof. Laura Sigg, Dr. Jürg Zobrist, Dr. Adrian Ammann and their coworkers, who are responsible for the chemical analyses and data control. The multisiciplinary team working on the project has contributed to a fruitful cooperation with regard to conceptual planning and technical aspects of the sampling. This serves both routine measurements and special, usually short-term, studies.

• The Alptal project, based at the WSL (Swiss Federal Research Institute for Forest, Snow and Landscape) is a second long-term project with which important insight was gained into the behavior of biogeochemical substances and physical parameters in rivers. Since work first started on NADUF, a continuous exchange of ideas and data with Hans Keller, former head of the Alptal project, was maintained. After his untimely death by an accident in the mountains three years ago, we (i.e.,

After completing a Bachelor of Science in Chemistry, Joan Davis studied biochemistry at Ohio State University, where she received her Ph.D. in 1965. Her postdoctoral studies first brought her to England and then to Switzerland. In 1975, she was awarded, together with Samuel Mauch, the first international Mitchell-Prize for the paper on "The Basis for a Blueprint for Progress in Switzerland" which deals with sustainable use of resources.
She has been working at EAWAG since 1970 and teaching at the Swiss Federal Institute of Technology Zurich (Department of Electrical Engineering, and later in Chemistry and Environmental Sciences Departments) since 1975. She was a visiting professor at the Technical University of Berlin from 1985 to 1986, a guest lecturer at the Gesamthochschule Kassel from 1987 to 1988, has been teaching at the University of Zurich since 1989 and, since 1996, also at the University of Basel.
She is a member of the following commissions:
- *Early Warning Systems in Science Policy (Swiss Academy of Science)*
- *Working Group for Operational Hydrology (in conjunction with the National Hydrological and Geological Survey)*
- *Swiss Commission for Environmental Observations*
- *Scientific Advisory Board for the project "Sustainable Germany", of Wuppertal Institute, Wuppertal, Germany*
- *Committee of experts of the research foundation "Man-Society-Environment" of the University of Basel*
- *International Network of Resource Information Centers (INRIC, better known as the Balaton Group), New Hampshire (USA)*

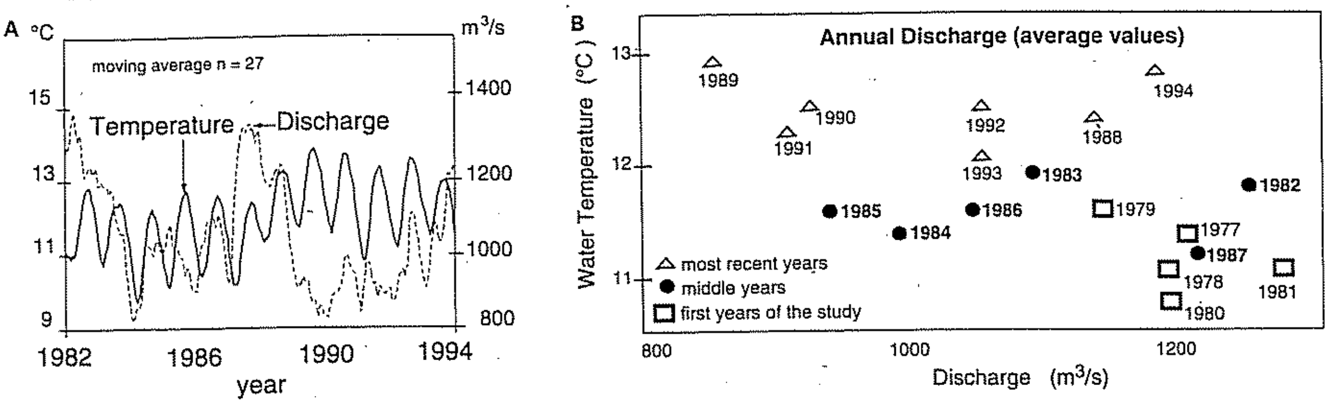


Fig. 1
The water temperature, in addition to nutrients and other substances, has an important influence on aquatic systems.
As illustrated by the graph on the left (A) a noticeable increase in temperature is visible, in spite of the strong annual fluctuations. The graph on the right (B) shows this more clearly: it compares the water temperature of years with equal water flow. The increase is significant: almost 2 °C, of which only a very small part can be attributed to direct anthropogenic influences [Rhine: Village-Neuf, downstream from Basel]. Such a rapid warming raises the question of the effects on the biotic communities of water systems.

several of his colleagues and me) were determined to continue his work. A research project was formulated which compares small streams that are anthropogenically less loaded, with larger partly heavily loaded rivers. A better understanding of anthropogenic and natural influences, affecting concentrations and physical parameters was the objective of the project.

⊚ The work on river water quality prompted me to become involved in another level of water protection – a level which deals less with measuring the problem but more with ways to avoid the pollution which causes the problems. Such a "beginning-of-pipe" approach is essential to prolonging the reserves of natural resources and reducing environmental pollution in general. In this connection, my participation in the Scientific Advisory Board of the project "Sustainable Germany" at the Wuppertal Institute for Climate, Environment and Energy was very fruitful. There are currently two other projects on water and sustainable resource use with which I am working. Both of these aim at providing decision-makers with essential information from scientific studies on environmental problems. One of these is a project for the Scientific Council of the German Federal Governement's Studies on Global Environmental Changes. The other deals with environmental indicators to be compiled for decision-makers within the EU.

Which is the central theme of your work on water systems?

Actually three key elements come to mind. Two deal with data interpretation, i.e., determining the water quality and interpreting the changes in

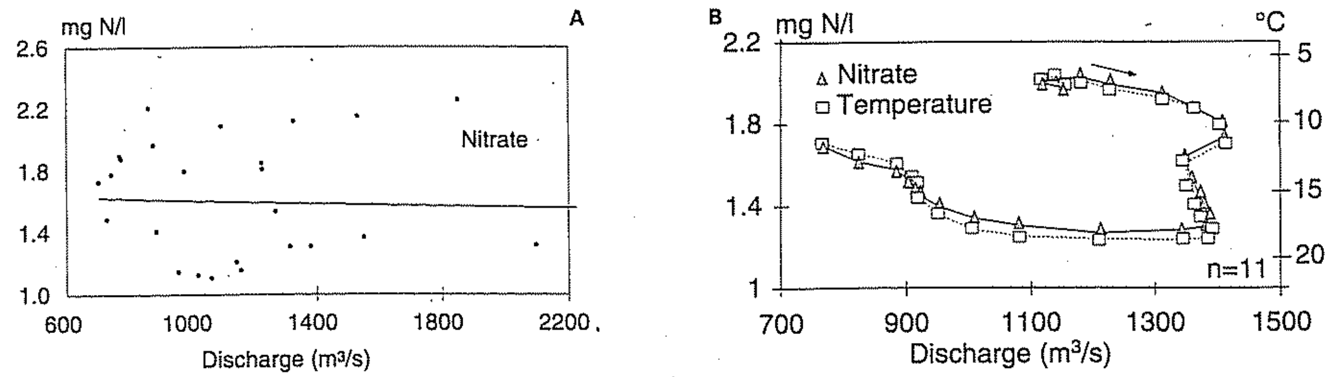
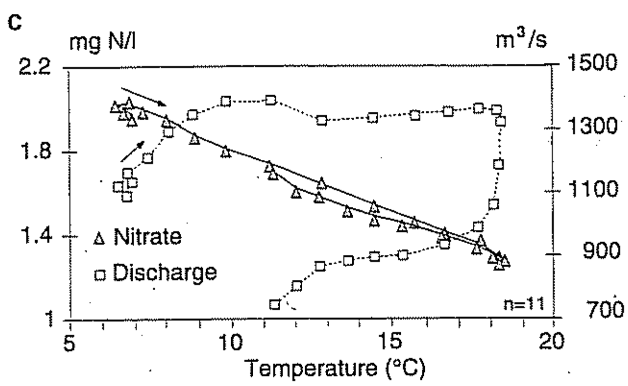


Fig. 2
The concentrations of substances in river water were formerly considered mainly dependent on water flow; however, the marked deviation from the regression curve in graph A indicates a strong influence of other factors.
If the data are plotted differently (B) – e.g., by using a moving average, here over 11 values and the points interconnected – it becomes clear that it is mainly the temperature (C) and not the discharge which is responsible for the concentration. Its influence on the concentration of nutrients (particularly those containing nitrogen and phosphorus) is readily seen. This dependency is quite comprehensible as water temperature is known to influence the metabolism of organisms. In summer, nutrients (here nitrate) are therfore consumed faster by the organisms, be it in wastewater treatment plants, in soil (agricultural areas), or in water systems [all data from the Rhine at Village-Neuf, downstream from Basel, 1994].



quality. The third element aims at making the first two possible. It centers on developing graphical methods of data representation – to enhance recognition of the behavioral patterns of the parameters, and thus make them more understandable. Such attemps to "transform data into information" have a historical background. Formerly, statistics was the main tool of numerical evaluation; however, it contributed relatively little to revealing the reasons for the marked deviations observed. It provided too little insight into the behavior patterns of rivers to allow a differentiation between short-term fluctuations and long-term changes. Although simple graphical methods, such as regression curves, have been used to present an easily understood correlation, understanding the assumptions used to simplify the graphical representations have sometimes led to misinterpretation. To avoid this problem, new graphical approaches were necessary (see example in Fig. 2).

The improved graphical methods helped to refine data interpretation, but also revealed the necessity of data from several years of observation if the development of water quality, and not only its momentary condition, is to be examined. The marked hydrological differences usually observed from one year to the next make it almost impossible to draw significant conclusions from data obtained only over a few consecutive years, unless changes are particularly pronounced.

Have you noticed any major changes associated with water protection problems over the last 25 years?

Several changes are quite apparent: the problems of the past were more visible – e.g., eutrophication – and were attributed to substances which could generally be removed within a functional period of time either via natural reactions or technical methods. In contrast, the more recent problems are often caused by invisible micropollutants of nondegradable synthetic substances that can remain in the environment for a very long time.

These micropollutants add yet another dimension to the new problems: even in very low concentrations (in many cases hardly measurable) they often have unexpected effects on biological systems. We are only just beginning to grasp the significance of these impact on organisms and ecosystems. This new aspect calls to mind the warnings of Rachel Carson, who, three decades ago, reported in her book "Silent Spring" that DDT can cause problems in very low concentrations and in a quite unexpected manner. We are faced with an uncomfortable situation if substances already have negative effects in concentrations which are barely above the prevailing quality standards, or if supposedly harmless chemicals yield degradation products which are themselves a source of danger.

What conclusions do you draw from these observations and concerns?

If certain chemicals are really so persistent, and if even traces of them constitute a potential risk for the biological systems, the consequences for our actions then seem clear to me: Water protection must change its goals from placing emphasis on reliable measurements of those substances, which should not be in water at all, to preventing such substances from getting into water in the first place.

In any case, the chemicals which are the cause of major problems can technically not be removed efficiently on a routine basis. Even if they could, the use of resources would be too high and come into conflict with other environmental goals, such as sustainable resource management.

Based on the aforementionned considerations, it becomes readily apparent that these new problems do indeed demand new solutions. But more than that, they also demand new approaches – approaches that reach beyond science and technology and involve cooperation at other levels in society, including everyday consumer habits, politics, business and education.

[1] Zukunftsfähiges Deutschland, ein Beitrag zu einer global nachhaltigen Entwicklung. Birkhäuser Verlag, Basel.

[2] Wiss. Beirat der Bundesregierung (Deutschland): globale Umweltveränderungen (Wasserbereich). Jährliche Forschungsberichte im Economica-Verlag, Bonn.

[3] Presentations from the Infoday in September 1995, EAWAG news *40E*.

[4] Theo Colborn et al. «Our stolen Futures», Dutton, New York, 1996

[5] Joan S. Davis: Ist Wasser mehr als H_2O? *Das Lebenselement zwischen Mythos und Molekül*, Vortragsreihe «pantha rhei» der Hans Erni Stiftung, Luzern (1995).

[6] Jakob, J., Liechti, P., Schädler, B. «Temperatur in Schweizer Gewässern – Quo vadis», GWA, *4*, 1996.

The EAWAG "Algae Group"

Since the beginning of 1993, an interdepartmental and interdisciplinary EAWAG "Algae Group" has been meeting monthly to discuss current projects, research ideas, theses and dissertations in which algae play a prominent role. Talks are given by EAWAG scientists and postgraduate students from all departments as well as by invited guests. Further information about the "Algae Group" can be obtained from: Tati Behra (Limnology), Nina Schweigert (Microbiology), or Bettina Rinne (Environmental Physics).

Can be ordered separately from the EAWAG library (use last page)

Publications

Publications

2005 **Bloesch, J., Hohmann, D., Leemann, A.:** Die Limnologie des Oeschinensees, mit besonderer Berücksichtigung des Planktons, der Sedimentation und der Schwemetallbelastung. Mitt. Naturforsch. Ges. Bern, NF *52*, 121–145 (1995).

2006 **Beer, J., Joos, F., Lukasczyk, C., Mende, W., Rodriguez, J., Siegenthaler, U., Stellmacher, R.:** ^{10}Be as an Indicator of Solar Variability and Climate. In: «The Solar Engine and Its Influence on Terrestrial Atmosphere and Climate», E. Nesme-Ribes (Ed.). NATO ASI Ser., Vol. I/25. Springer-Verlag Berlin & Heidelberg 1994, pp. 221–233.

2007 **Brüschweiler, B.J., Würgler, F.E., Fent, K.:** Cytotoxicity in Vitro of Organotin Compounds to Fish Hepatoma Cells PLHC-1 (*Poeciliopsis lucida*). Aquatic Toxicology *32*, 143–160 (1995).

2008 **Bucheli, T.D., Fent, K.:** Induction of Cytochrome P450 as a Biomarker for Environmental Contamination in Aquatic Ecosystems. Critical Reviews in Environ. Sci. & Technol. *25* (3), 201–268 (1995).

2009 **Beer, J., Sturm, M.:** Dating of Lake and Loess Sediments. Radiocarbon *37*, 1, 81–86 (1995).

2010 **Bloesch, J.:** Mechanisms, Measurement and Importance of Sediment Resuspension in Lakes. Marine Freshwater Res. *46*, 295–304 (1995).

2011 **Hupfer, M., Gächter, R., Rüegger, H.:** Polyphosphate in Lake Sediments: ^{31}P NMR Spectroscopy as a Tool for its Identification. Limnol. Oceanogr. *40* (3), 610–617 (1995).

2012 **Fent, K., Hunn, J.:** Organotins in Freshwater Harbors and Rivers: Temporal Distribution, Annual Trends and Fate. Environ. Toxicol. & Chem. *14* (7), 1123–1132 (1995).

2013 **Harms, H., Wilkes, H., Wittich, R.-M., Fortnagel, P.:** Metabolism of Hydroxydibenzofurans, Methoxydibenzofurans, Acetoxydibenzofurans, and Nitrodibenzofurans by *Sphingomonas* sp. Strain HH69. Appl. Environ. Microbiol. *61* (7), 2499–2505 (1995).

2014 **Lupi, C.G., Colangelo, T., Mason, C.A.:** Two-Dimensional Gel Electrophoresis Analysis of the Response of *Pseudomonas putida* KT2442 to 2-Chlorophenol. Appl. Environ. Microbiol. *61* (8), 2863–2872 (1995).

2015 **Hajdas, I., Zolitschka, B., Ivy-Ochs, S.D., Beer, J., Bonani, G., Leroy, S.A.G., Negendank, J.W., Ramrath, M., Suter, M.:** AMS Radiocarbon Dating of Annually Laminated Sediments From Lake Holzmaar, Germany. Quaternary Sci. Rev. *14*, 137–143 (1995).

2016 **Ivy-Ochs, S., Schlüchter, C., Kubik, P., Beer, J.:** Das Alter der Egesen-Moräne am Julierpass. Geowiss. *13* (8/9), 313–315 (1995).

2017 **Baccini, P., Oswald, F.:** «Achtung: die Schweiz» ein Aufruf 1955 – eine Replik 1995. Neue Zürcher Ztg. Nr. 189, 17.8.1995.

2018 **Boller, M.:** Abwasserentsorgung im ländlichen Raum. Gas, Wasser, Abwasser *75* (7), 522–532 (1995).

2019 **Baumer, P., Volkart, P., Bretscher, U., Krebs, P.:** Untersuchungen zur Verbesserung der Strömung in den Nachklärbecken der Kläranlage Einsiedeln. Korrespondenz Abwasser *42* (4), 598–612 (1995).

2020 **Krebs, P., Vischer, D., Gujer, W.:** Inlet-Structure for Final Clarifiers. J. Environ. Engineering *121* (8), 558–564 (1995).

2021 **Albrecht, A., Reichert, P., Beer, J., Lück, A.:** Evaluation of the Importance of Reservoir Sediments as Sinks for Reactor-derived Radionuclides in Riverine Systems. J. Environ. Radioactivity *28* (3), 239–269 (1995).

2022 **Sulzberger, B., Laubscher, H.:** Reactivity of Various Types of Iron(III) (Hydr)oxides Towards Light-induced Dissolution. Marine Chemistry *50* 103–115 (1995).

2023 **Klausen J., Tröber, S.P., Haderlein, S.B., Schwarzenbach, R.P.:** Reduction of Substituted Nitrobenzenes by Fe(II) on Aqueous Mineral Suspensions. Environ. Sci. & Technol. *29* (9), 2396–2404 (1995).

2024 **Cini Castagnoli, G., Albrecht, A., Beer, J., Bonino, G., Shen, C., Callegari, E., Taricco, C., Dittrich-Hannen, B., Kubik, P., Suter, M., Zhu, G.M.:** Evidence for Enhanced ^{10}Be Deposition in Mediterranean Sediments 35 Kyr BP. Geophys. Res. Lett. *22* (6), 707–710 (1995).

2025 **Ammann, A.A., Rüttimann, T.B.:** Simultaneous Determination of Small Organic and Inorganic Anions in Environmental Water Samples by Ion-exchange Chromatography. J. Chromatogr. A *706*, 259–269 (1995).

2026 **Hug, S.J., Dietliker, K.:** Conference Report. Solar Energy & Solar Cells *38*, 3–8 (1995).

2027 **Ulrich, M.M., Imboden, D.M., Schwarzenbach, R.P.:** MASAS – A User-friendly Simulation Tool for Modelling the Fate of Anthropogenic Substances in Lakes. Environ. Software *10*, 177–198 (1995).

2028 **Tengberg, A., De Bovee, F., Hall, P., Berelson, W., Chadwick, D., Ciceri, G., Crassous, P., Devol, A., Emerson, S., Gage, J., Glud, R., Graziottini, F., Gundersen, J., Hammond, D., Helder, W., Hinga, K., Holby, O., Jahnke, R., Khripounoff, A., Liebermann, S., Nuppenau, V., Pfannkuche, O., Reimers, C., Rowe, G., Sahami, A., Sayles, F., Schurter, M., Smallman, D., Wehrli, B., De Wilde, P.:** Benthic Chamber and Profiling Landers in Oceanography – A Review of Design, Technical Solutions and Functioning. Prog. Oceanogr. *35*, 253–294 (1995).

2029 **Wehrli, B., Wüest, A., Imboden, D.M.:** Sind biogen meromiktische Seen intern sanierbar? Fallbeispiel Zugersee. Limnologie aktuell *8*, 29–37 (1995).

2030 **Reichert, P.:** Design Techniques of a Computer Program for the Identification of Processes and the Simulation of Water Quality in Aquatic Systems. Environ. Software *10*, 199–210 (1995).

2031 **Maurer, M., Gujer, W.:** Monitoring of Microbial Phosphorus Release in Batch Experiments Using Electric Conductivity. Rapid Communication. Water Res. *29* (11), 2613–2617 (1995).

2032 **Wild, D., Kisliakova, A., Siegrist, H.:** Die Ausfaulung von Schlämmen aus der erhöhten biologischen P-Elimination: Ziele und gegenwärtiger Stand der Forschung an der EAWAG. In: «Auswirkungen der Phosphorelimination auf die Schlammbehandlung; Theoretische Erkenntnisse und praktische Erfahrungen», Workshop Inst. WAR, Darmstadt 24./25. Nov. 1994. Schrr. WAR 84, 45–60 (1995).

2033 **Jaeger, C.C., Davies, H.C., Imboden, D., Zehnder, A.J.B.:** Neuorientierung in der Klimapolitik. «Energieschranke» als Anstoss zu Neuentwicklungen. Neue Zürcher Ztg., «Inland», Nr. 242, 18.10.1995.

2034 **Hauser, P.C., Liang, C.L.C., Müller, B.:** A Solid-state Instrument for Fluorescence Chemical Sensors Using a Blue Light-emit-

ting Diode of High Intensity. Meas. Sci. Technol. 6, 1081–1085 (1995).

2035 **Hoigné, J.:** Réactions de l'ozone et des radicaux OH' en traitement de l'eau, dans la troposphère et dans les nuages. Journée d'étude de CEBEDEAU. Tribune de l'eau No. 575/3, 31–37 (1995).

2036 **Fent, K.:** Endokrin wirksame Stoffe in der Umwelt: Erkenntnisstand und Probleme. Fachgespräch «Umweltchemikalien mit endokriner Wirkung», Berlin 9.–10.3.1995. Texte 65/95 des Umweltbundesamtes, S. 45–56.

2037 **Egli, T.:** Microbial Ecophysiology and Growth Kinetics During Mixed-substrate/ Multiple-nutrient-limited Growth: Implications for Pollutant Degradation in the Environment. OECD Documents Bioremediation: the Tokyo '94 Workshop, OECD 1995, pp. 419–426.

2038 **Imhof, A.:** Ufergehölze und die Lebensgemeinschaft des Baches. GAIA *4*, 150–158 (1995).

2039 **Uehlinger, U., Naegeli, M.W., Meyer, E.I.:** Schlüsselprozesse im Energiehaushalt von Fliessgewässern: Primärproduktion und Respiration. GAIA *4*, 166–173 (1995).

2040 **Wanner, O., Cunningham, A.B., Lundman, R.:** Modeling Biofilm Accumulation and Mass Transport in a Porous Medium Under High Substrate Loading. Biotechnol. Bioengng. *47*, 703–712 (1995).

2041 **Lendenmann, U., Egli, T.:** Is *Escherichia coli* Growing in Glucose-limited Chemostat Culture Able to Utilize Other Sugars Without Lag? Microbiology *141*, 71–78 (1995).

2042 **Xue, H., Kistler, D., Sigg, L.:** Competition of Copper and Zinc for Strong Ligands in a Eutrophic Lake. Limnol. Oceanogr. *40* (6), 1142–1152 (1995).

2043 **Kari, F.G., Giger, W.:** Modeling the Photochemical Degradation of Ethylenediaminetetraacetate in the River Glatt. Environ. Sci. & Technol. *29*, 2814–2827 (1995).

2044 **Semlitsch, R.D., Foglia, M., Mueller, A., Steiner, I., Fioramonti, E., Fent, K.:** Short-term Exposure to Triphenyltin Affects the Swimming and Feeding Behavior of Tadpoles. Environ. Toxicol. & Chem. *14*, 1419–1423 (1995).

2045 **Gloor, E.U.:** Methode der Temperaturmikrostruktur und deren Anwendung auf die Bodengrenzschicht in geschichteten Wasserkörpern. Diss. ETHZ Nr. 11'336, Zürich 1995.

2046 **Mottier, V., Bucheli, T., Kobler, D., Ochs, M., Zobrist, J., Ammann, A., Eugster, J., Müller, S., Schönberger, R., Sigg, L., Boller, M.:** Qualitative Aspects of Roof Runoff. 8th Junior Eur. Workshop «Urban Rainwater: Resourcefully Used», Deventer NL, 22–25.9.1995, 13 pp.

2047 **Caprioli, R.M., Suter, M.J.-F.:** Mass Spectrometry. In: «Introduction to Biophysical Methods for Protein and Nucleic Acid Research», J.A. Glasel, M.P. Deutscher (Eds.). Academic Press, San Diego 1995, pp. 147–204.

2048 **Peter, A.:** Lebensraumänderungen in Fliessgewässern – eine fischbiologische Perspektive. GAIA *4*, 159–165 (1995).

2049 **Voorhorst, W.G.B., Eggen, R.I.L., Luesink, E.J., de Vos, W.M.:** Characterization of the celB Gene Coding for β-Glucosidase from the Hyperthermophilic Archaeon *Pyrococcus furiosus* and Its Expression and Site-directed Mutation in *Escherichia coli*. J. Bacteriol. *177*, 7105–7111 (1995).

2050 **Von Gunten, U., Hoigné, J.:** Ozonation of Bromide-containing Waters: Bromate Formation Through Ozone and Hydroxyl Radicals. In: «Disinfection By-Products in Water Treatment», R.A. Minear, G.L. Amy (Eds.). CRC Press Inc., Boca Raton 1996, pp. 187–206.

2051 **Zehnder, A.J.B.:** Altlasten: Lösungsansätze aus Sicht der Umweltwissenschaften und des Risk Management. VSA-Verbandsber. Nr. 493, 194. VSA-Mitgl.-Versamml. vom 18.11.1994 in Bern, S. 3–9.

2052 **Gloor, M., Kocsis, O., Omlin, M., Schurter, M., Wüest, A.:** Temperaturmikrostrukturen. Eine Methode zur Bestimmung der Mischungsintensität in geschichteten Gewässern. Gas, Wasser, Abwasser *75*, 1087–1096 (1995).

2053 EAWAG-Projekt Integrierte Siedlungsentwässerung Fallstudie Fehraltorf. VSA-Verbandsber. Nr. 490, 193. Mitgl.-Versamml. vom 2.9.1994 in Zürich. [Gas, Wasser, Abwasser *74*, 114–122 (1994); *75*, 34–46, 243–259, 315–328, 394–407, 470–490 (1995).]

2054 **Baulch, D.L., Cobos, C.J., Cox, R.A., Frank, P., Hayman, G., Just, T., Kerr, J.A., Murrells, T., Pilling, M.J., Troe, J., Walker, R.W., Warnatz, J.:** Evaluated Kinetic Data for Combustion Modeling, Supplement I. J. Phys. Chem. Ref. Data *23*, 847–1033 (1994).

2055 **Karametaxas, G., Hug, S.J., Sulzberger, B.:** Photodegradation of EDTA in the Presence of Lepidocrocite. Environ. Sci. & Technol. *29*, 2992–3000 (1995).

2056 **Escher, B.I., Schwarzenbach, R.P.:** Partitioning of Substituted Phenols in Liposome-Water, Bioimembrane-Water, and Octanol-Water Systems. Environ. Sci. & Technol. *30*, 260–270 (1996)

2057 **Boller, M., Häfliger, M.:** Verbleib von Schwermetallen bei unterschiedlicher Meteorwasserentsorgung. Gas, Wasser, Abwasser *76*, 3–15 (1996).

2058 **Nowack, B., Sigg, L.:** Adsorption of EDTA and Metal-EDTA Complexes onto Goethite. J. Colloid & Interface Sci. *177*, 106–121 (1996).

2059 **Von Schulthess, R., Gujer, W.:** Release of Nitrous Oxide (N_2O) from Denitrifying Activated Sludge: Verification and Application of a Mathematical Model. Water Res. *30*, No. 3, 521–530 (1996).

2060 **Hupfer, M., Gächter, R., Giovanoli, R.:** Transformation of Phosphorus Species in Settling Seston and During Early Sediment Diagenesis. Aquatic Sci. *57*, No. 4, 305–324 (1995).

2061 **Akeret, B.:** Specific Density of Resting Eggs and Adult Morphology of *Leptodora kindtii* (Focke, 1844) (Cladocera). Crustaceana *68*, No. 6, 751–758 (1995).

2062 **Hofmann, M.:** Umweltrisiken und -schäden in der Haftpflichtversicherung. Hintergründe – Schadenanalysen – Kostenkalkulationsmodell. Schrr. Verbraucherschutz, Produktionssicherheit, Umweltschutz 3, Verlag Versicherungswirtschaft VVW, Karlsruhe 1995, 200 Seiten. ISBN 3-88487-518-3.

2063 **Klausen, J.:** Abiotic Redox Transformations of Aromatic Nitro and Amino Compounds in Suspensions of Soil Minerals. Laboratory Studies in Batch and Flow-Through Systems. Diss. ETHZ No. 11'206, Zürich 1995.

2064 **Baumgartner, S.M.M.:** Kosmogene Radioisotope im Pleistozän des Summit-

Publications

Publications

GRIP-Eiskerns. Diss. ETHZ Nr. 11'264, Zürich 1995.

2065 **Escher, B.**: The Relationship Between Membrane-Water Partitioning, Uncoupling, and Inhibitory Activity of Substituted Phenols in Chromatophores of *Rhodobacter Sphaeroides*. Diss. ETHZ No. 11'283, Zürich 1995.

2066 **Brüschweiler, B.J.**: Cytotoxicity and Interactions of Organotoins and Heavy Metals with Cytochrome P4501A in Fisch Hepatoma Cells. Diss. ETHZ No. 11'413, Zürich 1996.

2067 **Egli, T.**: The Ecological and Physiological Significance of the Growth of Heterotrophic Microorganisms with Mixtures of Substrates. In: «Advances in Microbial Ecology», Vol. 14, J. G. Jones (Ed.). Plenum Press, New York 1995, pp. 3 05–386.

2068 **Wüest, A., Van Senden, D.C., Imberger, J., Piepke, G., Gloor, M.**: Comparison od Diapycnal Diffusivity Measured by Tracer and Microstructure Techniques. Dynamics of Atmospheres and Oceans *24*, 27–39 (1996).

2069 **Kari, F.G., Giger, W.**: Speciation and Fate of Ethylenediaminetetraacetate (EDTA) in Municipal Wastewater Treatment. Water Res. *30*, No. 1, 122–134 (1996).

2070 **Beres, M., Green, A., Huggenberger, P., Horstmeyer, H.**: Mapping the Architecture of Glaciofluvial Sediments with Three-dimensional Georadar. Geology *23*, 1087–1090 (1995).

2071 **Wellnitz, T.A., Sheldon, S.P.**: The Effects of Iron and Manganese on Diatom Colonization in a Vermont Stream. Freshwater Biology *34*, 465–470 (1995).

2072 **Stemmler, K., Kinnison, D.J., Kerr, J.A.**: Room Temperature Rate Coefficients for the Reactions of OH Radicals with Some Monoethylene Glycol Monoalkyl Ethers. of Phys. Chemistry *100*, 2114–2116 (1996).

2073 **Bally, M., Egli, T.**: Dynamics of Substrate Consumption and Enzyme Synthesis in *Chelatobacter heintzii* During Growth in Carbon-lmited Continuous Culture with Different Mixtures of Glucose and Nitrilotriacetate. Appl. Environ. Microbiol. *62*, 133–140 (1996).

2074 **Tros, M.E., Schraa, G., Zehnder, A.J.B.**: Transformation of Low Concentrations of 3-Chlorobenzoate by Pseudomonas sp. Strain B13: Kinetics and Residual Concentrations. Appl. Environ. Microbiol. *62*, 437–442 (1996).

2075 **Wanner, O., Reichert, P.**: Mathematical Modelling of Mixed-Culture Biofilms. Biotechnol. Bioengng. *49*, 172–184 (1996).

2076 **Nowack, B., Kari, F.G., Hilger, S.U., Sigg, L.**: Determination of Dissolved and Adsorbed EDTA Species in Water and Sediments by HPLC. Anal. Chem. *68*, 561–566 (1996).

2077 **Kinnison, D.J., Mengon, W., Kerr, J.A.**: Rate Coefficients for the Room Temperature Reaction of Cl Atoms with Dimethyl Sulfide and Related Alkyl Sulfides. J. Chem. Soc. Faraday Trans. *92*, No. 3, 369–372 (1996).

2078 **Aeschbach-Hertig, A., Kipfer, R., Hofer, M., Imboden, D.M., Wieler, R., Signer, P.**: Quantification of Gas Fluxes From the Subcontinental Mantle: The Example of the Laacher See, a Maar Lake in Germany. Geochim. Cosmochim Acta *60*, No. 1, 31–41 (1996).

2079 **Werlen, C., Kohler, H.-P.E., Roelof van der Meer, J.**: The Broad Substrate Chlorobenzene Dioxygenase and cis-Chlorobenzene Dihydrodiol Dehydrogenase of *Pseudomonas* sp. Strain P51 Are Linked Evolutionarily to the Enzymes for Benzene and Toluene Degradation. J. Biol. Chem. *271*, No. 8, 4009–4016 (1996).

Books

Zehnder, A.J.B. (Ed.): Soil and Groundwater Pollution. Fundamentals, Risk Assessment and Legislation. Proc. of the SCOPE Workshop Český Krumlov, Czech Republic, June 6–7, 1994. Kluwer Academic Publ. Dordrecht, Boston & London 1995, 164 pp. ISBN 0-7923-3743-3.

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