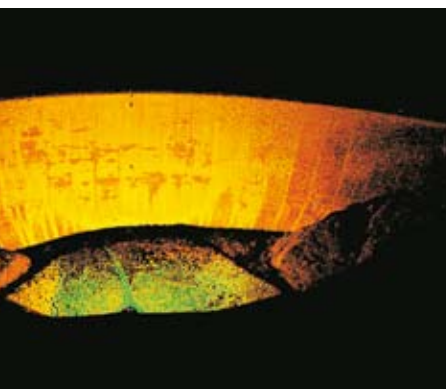


## Annual Report 2005



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# Preface

At the ETH, the year 2005 was marked by the events around the hundred-fiftieth anniversary. The president, Prof. Dr. Olaf Kübler, was succeeded by Prof. Dr. Ernst Hafen and the headship of our department was passed on from Prof. Dr. Hans Rudolf Schalcher to the undersigned.

The Department of Civil, Environmental and Geomatic Engineering (D-BAUG) was established on October 1, 1999, by merging the former departments of civil and environmental engineering (D-BAUM) and geodetic sciences (D-GEOD) as well as the former divisions II (Civil Engineering) and VIII (Rural Engineering and Surveying). Professor Schalcher, head of Division II from 1996 to 1999, was in charge of the merger and headed the new department during its first six years. Apart from the reorganisation of the department, Professor Schalcher's period of office was characterised by the implementation of the departmental autonomy, the changeover from the diploma studies to the bachelor/master programs and the retirement of eight full professors along with the proceedings to fill the vacant chairs. Professor Schalcher headed the department with great skill and gave it decisive impulses. He deserves our sincerest thanks and unreserved recognition.

I am looking forward to further advancing our department in collaboration with my colleagues and our staff and students. We want to impart the best knowledge and skills to our students and we want to promote their creativity, independence and sense of responsibility. We want to preserve and maintain sound knowledge and, through our research, contribute substantially to enlarging and deepening our knowledge and skills. Finally, we are committed to the ETH and its location and tradition and we are ready to play our part in shaping the future of Switzerland within the global community.

As in previous years, this annual report aims at providing an insight into our diverse activities both for our partners within the ETH domain and our external partners in Switzerland and abroad. We would like to sincerely thank our partners for the trust placed in us and the assistance rendered, and we are looking forward to their continued support.

Peter Marti





# Central Points

## Strategic Planning

Starting from the department's initial goals and accounting for the experiences gained in the meantime, the strategic planning for the department was advanced through a broadly supported process. This was accomplished within the context of ETH's overall planning for the period 2008-2011, resulting in a strategy paper passed by the departmental conference in April 2005. Currently, the strategy is being revised in consultation with the ETH management. Corresponding work shall be completed by the end of 2006.

The report by the evaluation committee on the evaluation of the department carried out in November 2004 gave rise to a thorough review of our strategic ideas. In general, the evaluation of our activities resulted in a lot of support and encouragement. A number of the committee's recommendations caused us to adapt or redirect some activities. In any case, the mirror held up to us necessitated a more precise definition and a better presentation of our work. The expenditure for preparing, conducting and analysing the evaluation was considerable. However, we are deeply convinced of the great value of the periodic evaluations and we consider the necessary expenditure to be justified.

The department sees itself as an internationally leading teaching and research unit in the area of civil, environmental and geomatic engineering, concentrating on the following areas and their interrelations:

- life-cycle oriented planning, realisation and management of built infrastructure (structures, infrastructure works, plants and systems)
- sustainable spatial development and management of natural resources
- high-tech measuring systems and information technologies for spatial data and processes.

The department makes nationally and internationally relevant contributions to

- developing innovative construction materials, technologies and concepts
- using space in an optimum way
- limiting the consumption of resources
- solving the global water crisis
- coping with urban traffic of people and goods
- being in control of natural hazards and technical faults
- monitoring and controlling natural and anthropogenic systems and processes.

The department has a unique potential for interdisciplinary collaboration. Its institutes and chairs are well rooted nationally, and mark a strong presence in international networks. Some of them rank at the top globally.

Scientifically, the department has been significantly strengthened by recent professorial appointments. This development shall be continued by shifting the weight towards certain identified areas and by giving corresponding incentives. In addition, the share of third-party money shall be increased and the collaboration with partners, in particular within the ETH domain, shall be expanded.

The new scientific orientation must not endanger the fulfilment of our main task, i.e. teaching. On the contrary, it shall stimulate and enrich the exchange between teachers and students. The necessary breadth in teaching and the practice-orientation required in engineering are not easily united with the struggle for the depth needed in research and the specialisation that goes with it. Yet, out of this tension, decisive impulses emerge again and again for both teaching and research. The double task of teaching and research forces one to combine breadth and depth. It prevents, if properly implemented, corresponding imbalances, and, to-





gether with the freedom of teaching and research and suitable boundary conditions in general, it provides the basis for the top performance expected from us.

The department jointly bears a great responsibility for the development of its students and it accepts the challenge. Recruitment and support of the students shall be further improved. The new bachelor and master programs shall be evaluated and, where necessary, adapted in 2009. It is envisaged that by 2009 and thereafter, 130 bachelor degrees, 150 master degrees and 30 doctoral degrees will be conferred per year by the department.

#### Faculty

In 2005, the ETH Board of Management appointed three professors assigned to the department:

- Dr. Stefanie Hellweg, associate professor of ecological system design, effective January 1, 2006, Institute of Environmental Engineering (IfU)
- Dr. Hans Jürgen Herrmann, professor of computational physics of materials, effective April 1, 2006, Institute for Building Materials (IfB)
- Dr. Bernd Scholl, professor of spatial management, effective July 1, 2006, Institute for Spatial and Landscape Planning (IRL).

The search committees for a third-party financed assistant professorship for sustainable construction as well as for an assistant professorship for process engineering passed on their recommendations to the president of ETH. Corresponding appointments by the ETH Board of Management can be expected by spring of 2006.

#### Teaching

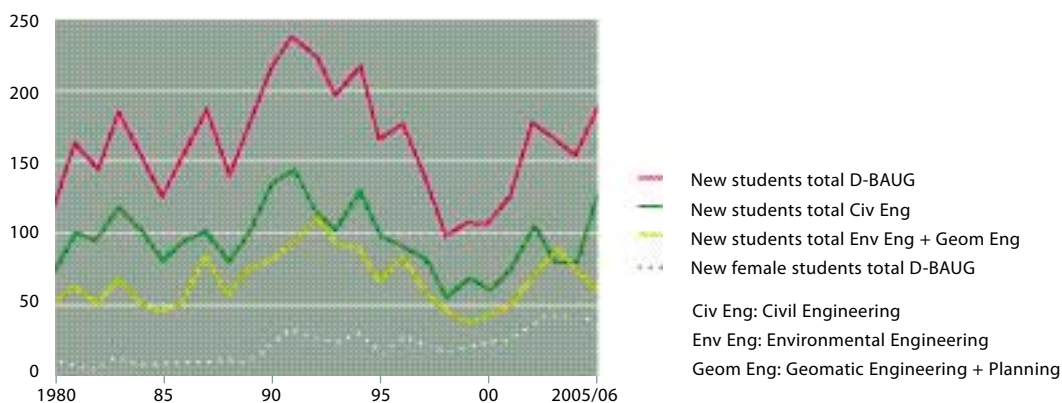
In the fall of 2003, the department started three six-semester bachelor programs in Civil Engineering, Environmental Engineering and Geomatics and Planning. The weekly contact hours were reduced and are now between 24 and 26. The first year is almost identical for all programs. During the second and third year, the specific bases for each field of study are laid. The programs are completed by a bachelor thesis in the sixth semester. In total, 180 units according to the European Credit Transfer System (ECTS) have to be acquired.

In the fall of 2006, three four-semester master programs with 120 ECTS units will begin in the areas of Civil Engineering, Environmental Engineering and Spatial Management and Infrastructure Systems; in each program, the students choose two out of several fields of specialisation and they complete their studies with a four-month master thesis. Also in

the fall of 2006, a three-semester master program will commence in the area of Geomatics and Planning (90 ECTS units).

With its different study programs, as in the past, the department tries to prepare its graduates for a wide-ranging professional activity and, in particular, for management tasks. The impartation of basic knowledge and a scientific method of working are central to the education. Creativity, independence and the ability to communicate are promoted at every opportunity, notably with seminar and project work and with the bachelor and master theses.

Peter Marti / April 2006



# Fires in Buildings

Mario Fontana / IBK

Fires in buildings may have enormous consequences for safety and economy. In recent years fire safety engineering has become a new discipline integrating all aspects of fire safety (structural, technical, organisational), into the design of buildings. Some decades ago fire safety science concentrated on performing fire tests on structural elements in furnaces. However, during the last several decades fire safety has attracted the interest of engineers and scientists from many disciplines all over the world. Fire safety science still includes fire testing, but now has a main focus on fundamental research into fire action starting from the combustion process, fire development and fire spread through the building, the mechanical and thermal behaviour of materials, their reaction to fire and the performance of the building structure as well as human behaviour in case of fire are studied.

Based on such fundamental knowledge, advanced calculation models have been developed using analytical and numerical tools. The numerical simulation of fire and smoke development and their spread through a building as well as the heating and mechanical behaviour of structural elements and complete structures have become possible during the last few years. Even models to simulate human behaviour and escape exist.

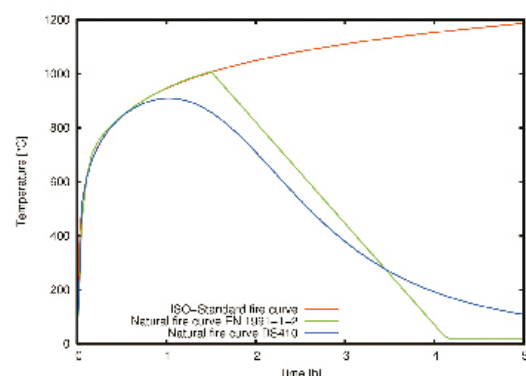
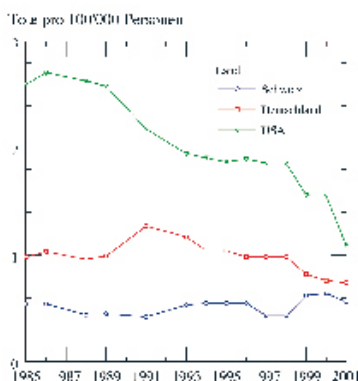
Fire is an extreme event that rarely or never occurs during the lifetime of a building. However, once it occurs it has huge consequences for the safety of the occupants and the rescue teams and damage to the building itself can lead to large financial losses. A growing understanding of the nature of fire, as well as concepts and measures to control fire has allowed the reduction of the number and consequences of disastrous fires. Statistical data shows that in developed countries the level of fire safety is steadily increasing. This can be seen from the decreasing number of fire fatalities per year and 100,000 inhabitants in most industrialised countries. About 80% of fire fatalities occur in dwellings (at home) mostly as single fatalities (Fig. 1).

In the past fire safety concepts focused on structural and some organisational measures, whereas today they include a large proportion of sophisticated technical measures like sprinkler, smoke detection and smoke evacuation systems. In Switzerland structural measures are at a very high level, while technical measures like smoke detection or even sprinklers are still very unusual in dwellings.

## Fire action

Fire can start if combustible material, oxygen and an ignition source are present. The combustion process releases heat energy, gases and smoke. While the gases and the smoke are the main killers in a fire (approx. 80% of fire fatalities are due to smoke), heat is the primary reason for the damage to the structure of a building. The knowledge of the time-temperature development during a fire in a building is therefore a key element when analysing the structural behaviour. To describe the fire action it must be simplified in a model. Several nominal fire curves have been proposed in codes to be used in the design process. The most frequently applied curve is the ISO 834 fire curve. Nominal fire curves provide a simple relationship between the temperature of the gases in a compartment and time. They represent a fully developed fire; the significant amount of time that sometimes elapses from the beginning of the fire to the fully developed fire is neglected. Further, the cooling down phase of the fire is not taken into account, with the nominal fire curves increasing monotonically with time.

A more realistic model of fires is given by parametrical fire curves, which take into account the most important parameters for the temperature development, namely:



By adequate structural and technical measures timber houses can be realized to be very fireproof today and such horror pictures of burning timber houses can be prevented.



- the type and amount of combustible material
- the ventilation conditions in the room
- the thermal properties of the enclosures
- the fire fighting action

Parametrical fire curves can be easily calculated with formulas developed for limited boundary conditions, as given for example in Eurocode 1 or other codes and handbooks. For a more comprehensive and more detailed analysis, numerical simulations may be used, e.g. multi-room zone models or computational fluid dynamics models (Fig. 2).

#### Human behaviour in fire

Human behaviour in fire is one of the most important factors with regard to fire fatalities. We investigated in all 33 fires in the canton of Zurich between 1990 and 1999 involving fire fatalities. The study showed that most of the fatalities had a causal relation to the behaviour of the victim (smoking, drinking, careless use of fire, etc.) the state of health (age, unconsciousness, alcohol, drugs, etc.) and only one case was related to fire spread and possibly to the unsatisfactory application of structural measures. Only in two of the 33 fires did two fatalities occur, all other fires claiming only one victim. The designer of a building can facilitate the safe escape of the occupants by providing escape

ways such as protected corridors and staircases, as well as safe access ways for the rescue teams. The evacuation itself can be supported by technical measures, e.g. providing an alarm signal and a spoken message motivating the occupants to leave the building immediately when fire breaks out. A clear layout of the building making it easy for the occupants to find their way out, as well as (illuminated) signs to direct the occupants to safe exits and measures to keep acceptable conditions in the rooms and escape ways like smoke evacuation and emergency illumination are important. Computer programs have been developed even to analyse evacuation. Human behaviour is a challenging interdisciplinary field of research.

#### Fire safety objectives and fire safety concepts

The most efficient way to control the effects of fire is to establish a comprehensive fire safety concept with adequate measures to fulfil the fire safety objectives.

- safety of occupants and fire brigade
- safety of neighbours and their goods
- limitation of financial loss (building and contents)
- protection of the environment in case of fire

These objectives can be reached with different generic fire safety concepts taking into account the type of structure and occupancy. Fire safety concepts consist of comprehensive structural, technical and organisational measures to fulfil the predefined fire safety objectives and acceptance criteria.

#### Structural fire design

The choice of building materials influences structural fire safety markedly. Combustible building materials increase the heat release rate and the development of smoke in case of fire. The strength and stiffness properties of building materials decrease at elevated temperatures. Due to their good thermal insulation properties, timber, concrete and masonry are only influenced locally in parts of the section close to the surface, while the inner parts of the cross-section still exhibit good mechanical properties (Fig. 3, 5).

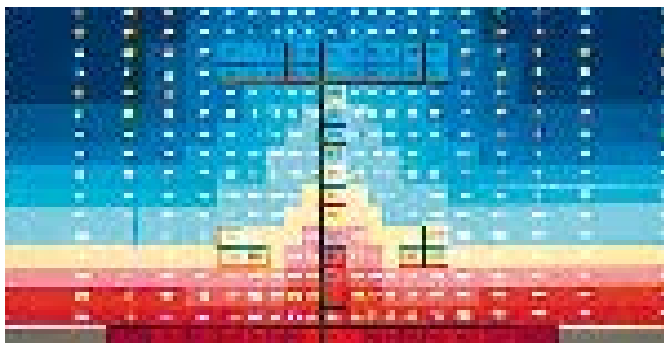


Fig. 3: Decrease of strength of concrete and steel at elevated temperatures.



Fig. 4: Spalling during fire may cause substantial damage to structural concrete elements.



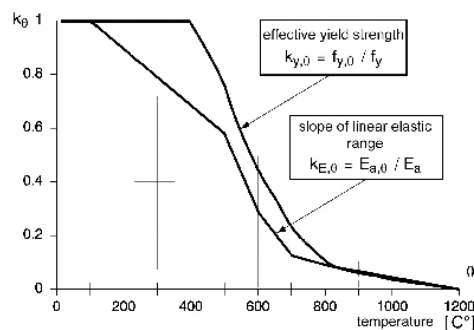
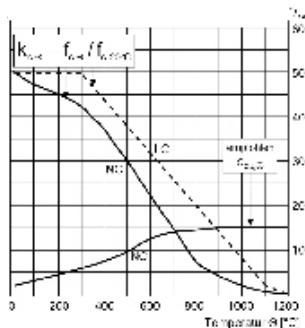


Fig. 5: Membrane action of composite floors can increase the fire resistance time considerably.

## Some special aspects related to building materials

### Wood

Wood burns at its surface, releases energy and thus contributes to fire propagation. Wood has good insulation properties and small thermal elongations. Wood changes into charcoal at a temperature of around 300°C thus losing section area. For conditions similar to the ISO fire the reduction of the section area can be described by a constant burning rate. The burning rate for soft wood has a value of around 0.7 mm/min (Fig. 4).

### Concrete

Concrete may spall close to its surface (Fig. 4). Spalling reduces the effective cross-section and exposes the reinforcement. The extent of spalling depends on many parameters such as the moisture content, the density, the type of gravel, the mechanical stresses, etc. Adding polypropylene fibres (PP) has a positive effect as the melting of the fibres reduces the vapour pressure produced by the heating of the moisture. After reaching the highest temperatures during a fire, concrete elements may lose further resistance due to penetration of heat and chemical

changes. A concrete structure may therefore collapse even after the fire is extinguished. The penetration of chlorine gases during a fire can lead to post-fire corrosion of the reinforcement. High temperature gradients in concrete elements may lead to deformation, cracking and shear failure or anchorage failure, especially where pre-stressed tendons are used which rely on direct bonding (Fig. 6).

### Steel

Steel heats up quickly due to its high thermal conductivity and therefore loses strength across the whole sectional area. After the fire the original strength is mostly regained (exception: high strength and cold formed steel, as well as high strength bolts).

### Conceptual design for fire safety

Satisfactory behaviour of structures subjected to fire is not primarily a question of the fire resistance of the single structural members but a question of the design of the complete structure and the detailing. By taking into account the global behaviour of the structure, the objectives of fire safety can in many cases be met without providing a fire resistance rating of the single load bearing members. By providing an alternative load

path or by activating membrane action, the structures may survive a large fire even though the individual members do not have a special fire resistance rating. The beneficial effect of tensile action was demonstrated in the Cardington (UK) fire tests, where a building with unprotected steel beams and a fire resistance of the single beams of less than 30 Minutes survived a severe fire without collapse (Fig. 7).



Fig. 6: Partial loss of fire protection of steel beams in a car park.

Fig. 7: Based on the results of extensive research multi storey timber buildings reach a high level of fire safety and are accepted by the new Swiss fire regulations since 2005.



Fig. 9: The results of the research into fire safety allow today to build multi-storey timber buildings being fireproof – these buildings are approved since 2005 by the Swiss fire regulations.



### Robustness of fire safety measures

Partial damage or loss of fire protection of structural steel members may have an important impact on the fire resistance of that member. The locally missing fire protection distinctly decreases the fire resistance of the structural steel member. In a parametric study on columns we found that the consequences resulting from local loss of fire protection are most important. In practice locally missing fire protection material is not unusual. The partial loss may not only occur due to impact following an extreme event, but also due to improper application or removal in the area of connections and installations (Fig. 8).

### Conclusions

Fires in buildings can be assessed by engineering methods on a scientific basis. Fire safety engineering integrates all aspects of fire safety (fire action, structures, human behaviour, etc.) and all types of measures (structural, technical, organisational). By combining performance-based codes and fire safety engineering, a safe and efficient fire safety concept can be developed. Fire safety engineering is still a young discipline and education and dissemination of knowledge is important for its further development. A successful example for the application of research results and fire safety engineering is the approval of 6-storey timber buildings in the new Swiss fire regulations (Fig. 9).



Fig. 8: Local loss of fire protection of steel members in a parking garage. Such damages have a distinct influence on the fire resistance.

# Leaky sewers and micropollutants require innovative solutions

O. Kracht, C. Ort, J. Rieckermann, W. Gujer/EAWAG, IfU

For many generations, the population in Switzerland is living with a well-developed urban drainage system. Our ancestors mainly profited from the improved hygiene in urban areas and dry housing conditions. However, in the course of time it was recognized that discharged nutrients in urine and faeces lead to serious over-fertilisation in natural waters. The historical development (construction and extension of wastewater treatment plants, phosphate ban) shows that from time to time a reorientation is necessary to optimally adapt technical systems to changing criteria and requirements. Only an early recognition of ecological dangers or structural problems together with the development of technical solutions in due time will enable us to act proactively.

Subsequently, we present the results from three PhD theses which contribute to enhance the knowledge on crucial processes in the urban water management. On the one hand, the tools developed in these research projects will aid systematic and problem-oriented investments in future infrastructure maintenance. On the other hand, they support the evaluation of the risk potential of micropollutants.

## Micropollutants affect natural waters

In recent years, different groups of substances contained in pharmaceuticals and personal care products have gained increasing attention in environmental research and engineering. Residuals of household chemicals and pharmaceutically active compounds may have adverse effects in the smallest quantities on aquatic plants and organisms. Today, high-tech analytical chemistry makes it possible to detect these so-called micropollutants already in rivers, lakes and groundwater – our natural drinking water resources.

A part of these micropollutants, discharged via sewers, is eliminated almost completely in wastewater treatment plants. Certain substances, however, are only partly decomposed or are transformed into hazardous metabolites. For the evaluation of a wastewater treatment plant's performance, water samples need to be collected to determine the inflow and effluent loads of micropollutants. Such monitoring campaigns are not a trivial task because the chemical analysis of micropollutants is laborious and expensive. In practice, the number of samples is limited

and measuring campaigns need to be planned accurately. In order to obtain a representative sample, it is essential to know the temporal dynamics of micropollutants.

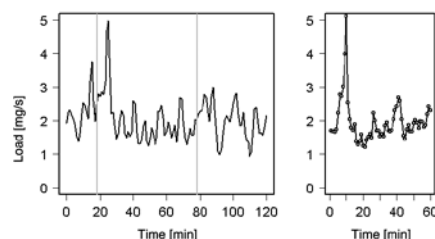
In the context of a PhD thesis we developed a model to predict short-term variations of micropollutants. Catchment specific characteristics of the sewer system and the population are being merged in a geographic information system. In combination with sales and application data of household products, this spatial information constitutes the input into a stochastic simulation model.

We found that micropollutant concentrations are subject to surprisingly large fluctuations even within short time periods (minutes). The forecasted dynamics were confirmed by means of high frequency measuring campaigns under different conditions. These results are of great importance for future monitoring practice. Even if loads have to be assessed over longer periods (days or weeks), these short-term variations have to be taken into account when planning measuring campaigns. Otherwise large sums of money are invested to laboriously analyse non-representative samples;



Residuals of dishwasher detergents can already be detected in our natural drinking water resources.

Performing a sewer monitoring campaign to investigate the occurrence of micropollutants.



Left diagram: forecasted variations of benzotriazole (silver protection contained in dishwasher detergents) in the sewer. Right diagram: effectively measured benzotriazole loads.

Wastewater treatment plants eliminate only a certain fraction of micropollutants.



the results of which are then used for further modelling purposes and decision-making.

The simulation model was successfully applied for planning different measuring campaigns. In addition, it can also be used to estimate micropollutant loads in domestic wastewater and their stochastic variations. Thus, it provides valuable information to predict quantities of pollutants directly discharged into the natural waters via combined sewer overflows, or the expected load variations in the influent of a wastewater treatment plant. However, we recommend validating the forecast with specific measuring campaigns, since it is indeed difficult to check the available information for its completeness otherwise.

The number of substances classified as micropollutants is on the one hand determined by the progress in chemical analytics and on the other hand by the knowledge of their potential risk. At present thousands rather than hundreds of different substances are considered to be problematic compounds; wastewater treatment plants were originally not designed to eliminate them. Similar to the phosphate ban in washing powders it

would make sense to take measures right at the source. Yet, an effective ban does not seem to be enforceable with regard to the multiplicity of remedies and other household chemicals beneficial for modern society. Another possibility would be to withhold such wastewater from the sewer system, collect the undiluted small volumes and treat them with special decentralised techniques.

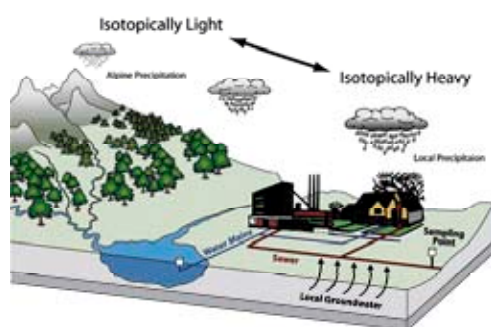
Since the current drainage system is admittedly very comfortable for the citizens, it is difficult to be open for a reorientation or redesign and, therefore, the long living but aging sewer system will probably remain in operation for quite a while. As a short or mid-term solution to effectively remove micropollutants, only extensions of existing wastewater treatment plants with additional treatment steps seem to be feasible.

The long-term maintenance and necessary adaptations of the existing wastewater collection infrastructures cause expensive investments for a community. Sewer infiltration and wastewater losses are crucial issues when evaluating the environmental impacts caused by defective sewer systems. However,

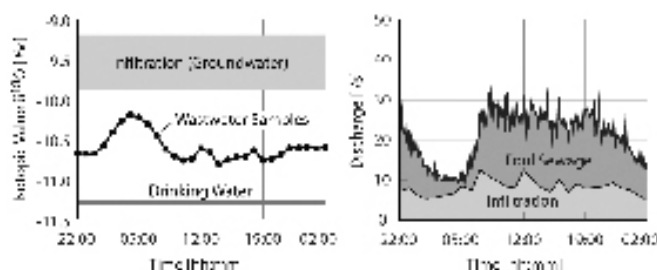
information about the water-tightness of a sewer system is often poor and investments are frequently based on uncertain information and limited data sets. The European research project APUSS (Assessing infiltration and exfiltration on the Performance of Urban Sewer Systems) has examined the potentials for a more problem oriented management of our subsurface infrastructure: can profound knowledge about the structural quality and functional efficiency of a sewer system be used as the basis for efficient planning and investment strategies?

### Sewer Infiltration – A Mass Phenomenon

The term “sewer infiltration” refers to groundwater that is unwantedly discharged into our sewer systems. Depending on the varying water tables, such non-polluted “parasitic water” enters the sewers through different kind of leaks like cracks, holes and open pipe joints. In the past, sometimes even brooks were intentionally led into the sewers for flushing purposes. Nowadays, infiltration is considered to be an unwanted interference factor that should be reduced or eliminated.



Large-scale meteorological processes are responsible for the varied isotopic signatures of natural waters in different hydrological zones. If the isotopic compositions of drinking water and local groundwater are sufficiently different, they are a suitable tracer to measure infiltration. Such usable isotopic separations can exist, where the drinking water originates from a distant hydrological regime but groundwater is recharged by local precipitation.



The stable isotopes method provides a reliable quantification of the volume of infiltrating waters in a sewer system. Left: Characterization of the different waters with respect to their isotopic composition. Right: decomposition of a diurnal wastewater hydrograph into its elementary components “foul sewage” and “infiltration”.





Fascinating research on underground infrastructures appeals to the next generation of motivated young researchers.

Under unfavourable conditions, the amount of infiltrating water can even exceed 50 % of the total wastewater volume. The rehabilitation of such defective systems has a great importance for a long-term optimisation of operational procedures and the protection of receiving waters: the additional hydraulic load transferred to the wastewater treatment plant is particularly detrimental to its pollutant removal efficiency. On top, the treatment plant's available storm event capacity is cut down and emptying times of retention tanks are extended. As a result, non-treated wastewater is discharged into the environment more frequently. Additionally, infiltration causes an increase in energy consumption and operating costs of pumping stations and treatment plant infrastructures.

Larger punctual sewer leaks can be located relatively easy. However, sewer infiltration typically occurs through a vast amount of smaller defects, which are rather „diffusively“ distributed over widespread ranges of the sewer system. Sound information about the extent, expansion and nature of such infiltration sources is an important basis for the evaluation of the structural quality of a sewer system. Conventional measuring practices provide only limited information about this problem. For instance, the common practice of interpreting the nocturnal discharge minimum cannot be considered at all unambiguous when applied in the context of today's growing agglomerations.

Two innovative methods for the quantification of parasitic discharges into sewers with natural tracers have been proposed as routine applications within the scope of the APUSS project. Based on natural tracer signals, these measurement procedures provide a reliable quantification and better quality knowledge than traditional approaches. The first method is based on combined analyses of continuous in situ flow and pollutant concentration time series. The second method utilises measurements of the oxygen and hydrogen isotopic ratios of the water. In the following, some details of this stable isotopes method will be discussed.

The applicability of the stable isotopes method requires a sufficient isotopic separation between local drinking water and infiltrating groundwater. An example are towns and villages from the Swiss Plateau that are obtaining their drinking water from lakes or bank filtrate of rivers whose natural hydrological catchments are partly situated in an alpine altitude. This drinking water and, consequently, the communal wastewater as well are isotopically lighter than the regional groundwater, which is recharged by local precipitation. In this way, the actual foul sewage can be differentiated from the infiltrating groundwater by means of mass spectrometry.

This new approach excludes many conventional sources of error. However, it has to be considered that the accuracy of the quantification depends fundamentally on the natural variability of isotopic compositions in the possible sources of infiltration (e.g. groundwater, brooks). Therefore it is mandatory to undertake a thorough hydrologic investigation in the catchment area. The simultaneous investigation of oxygen and hydrogen isotopes can be essential in order to detect and discriminate possible interferences (evaporation effects, unknown sources of infiltrating water). Beyond this, practical difficulties may also result from regional cross-linking of individual drinking water systems. In the case when parts of a catchment area receive water from different drinking water supplies in the course of a day, this can cause a disturbed tracer signal. To optimise the boundary conditions for one of our reference experiments, it was necessary to substitute all local groundwater production of a village by additionally supplied lake water for a period of several weeks.

The cooperation in an international research project enabled us to test our methods in several European cities and under variable local conditions of our research partners. We received valuable feedback about the practical applicability as well as about the restrictions that have to be considered in individual cases of operation. Based on our experience, we are confident that under suitable condi-

tions a careful experimenter can estimate infiltration ratios with an accuracy of better than 10 % (double standard deviation, related to the total infiltration).

APUSS had the objective to explore the potential of using quantitative knowledge about infiltration as a benchmark criterion for a problem-oriented rehabilitation management. Actually, this is expedient where sewer pipes are situated below the groundwater table. However, potential losses of wastewater can occur in areas with low groundwater tables. In order to provide a sound benchmarking instrument, a suitable monitoring tool for sewer exfiltration is required, too.

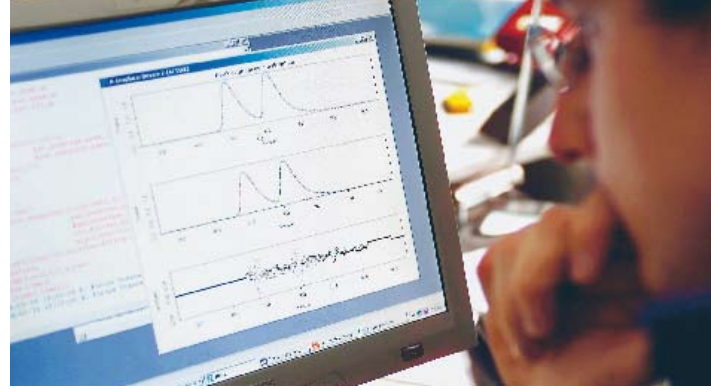
### Tracing wastewater losses with marker substances

The pollution of groundwater by leaky sewers is, among other things, problematic regarding the above-mentioned micro-pollutants. However, almost nothing is actually known about the absolute magnitude of sewer leakage since suitable measuring methods are lacking. Traditional sewer investigation methods (e.g. CCTV) show holes, cracks and fissures but do not allow for reliable statements about the amount of sewer leakage.





The analysis of measured tracer signals of an exfiltration experiment requires computational modelling. In addition, advanced statistical procedures are required to reliably assess the remaining uncertainty of the computed results.



The amount of sewer leakage is generally measured with special pressure tests of individual damages or by means of groundwater modelling. Both methods are relatively complex and not necessarily informative: pressure tests are too time-consuming to assess the many defects in a sewer network at reasonable costs. Groundwater modelling delivers only integrated results over a large area, from which no concrete measures of rehabilitation concerning individual sewer reaches can be derived. In contrast to this, our method allows for direct measurements of sewer leakage over defined sewer reaches.

The fundamental idea underlying our method is simple: at the beginning of the investigation reach, the wastewater is marked with an accurately defined quantity of tracer substance, whose concentration is measured downstream at the end of the investigation reach. A mass balance over the investigation reach (comparing tracer input to output) makes it possible to determine precisely how much of the dosed tracer was lost. The practical implementation, however, requires increased know-how regarding the experimental design and statistical data analysis. On the one hand, an appropriate dosing strategy avoids systematic errors. On the other hand, advanced statistical methods (e.g. bootstrap parameter estimation) are used to assess the remaining uncertainty in the measured results.

Exfiltration experiments with salt tracers (in connection with conductivity measurements), as well as lithium and bromide (measured with ion chromatography) were performed under various real-world conditions in the region of Zurich, London, Berlin, Dresden, Lyon and Rom. At present, the tracer method is used in Haifa and Bologna.

First results suggest that in badly maintained sewers larger losses of wastewater arise locally. Since the measurements contain a certain inaccuracy, fractions of exfiltration of less than 1 to 2 % of the marked wastewater cannot be reliably detected yet.

Further results of the APUSS project suggest that wastewater losses from defective house connections can contribute significantly to the total situation. For optimal sewer rehabilitation this is particularly critical since house connections are private property and thus usually not professionally maintained. Obviously, a target-oriented approach does not only require new measuring methods but also a reorientation regarding innovative forms of organization and sewer operation concepts.

### Great challenges for the future

The extensive future challenges arising in the field of urban water management require a steady advancement of available tools and methodologies. On the one hand, we must assimilate state-of-the-art knowl-

edge from different environmental disciplines in order to assess and minimise the hazard potential of an immense multiplicity of chemical substances. On the other hand, the large financial investments for the maintenance of our sewer systems require an optimal, problem-oriented rehabilitation and investment strategy. Against this background, we developed detection methods, which make it possible to substantially improve the knowledge about important sewer processes (such as micropollutants, groundwater infiltration or sewer leakage).

Regarding the education in environmental engineering, this means that we must be prepared to increasingly deal with challenging interdisciplinary concepts. Our graduates are entitled to expect a diversified and exciting field of work. The historical development shows that from time to time a reorientation is necessary so that technical systems can be adapted optimally to the respective needs and objectives. Our research will continue to make contributions to this end, supplying the necessary knowledge and methods.

A tracer experiment is performed to quantify wastewater losses from leaky sewers. An exactly defined quantity of tracer substance is dosed to the wastewater and measured at the end of the investigation reach. Since tracer is lost together with seeping wastewater, a mass balance over the system makes it possible to quantify sewer leakage.

# Terrestrial Laser Scanning – A New Measurement Technology in Geomatics

Hilmar Ingensand, Ralph Glaus, Thorsten Schulz, Hans Martin Zogg / IGP

For the three-dimensional geometrical reconstruction of objects, a novel technique has become widely accepted. By means of laser scanners, objects in the distance range of a few centimetres up to several hundred metres can be surveyed within a few minutes with centimetre accuracy. Similarly to the emergence of GPS navigation in the nineteen eighties, laser scanning asks for a rethinking of working methods used by geomatics engineers. Laser scanning partly overlaps with application areas of photogrammetry. For the three-dimensional reconstruction of objects classical photogrammetry requires at least two images. Light rays are registered by passive sensors. In contrast, laser scanning allows for the representation of objects by just one shot. Instead of ray bundles, vectors are registered; active sensor laser scanners take the place of passive sensors.

Laser scanners are designed as polar measuring systems. A laser scanner provides vectors represented by polar coordinates. The radial component bases on electro-optical distance measurement (EDM). Both, time of flight and phase difference measuring EDM techniques are used in the various commercial systems. A scan of the environment is carried out by the deflection of a laser beam with a rotating or oscillating mirror. The in-

stantaneous deflection of these fast rotating mirrors is determined by high-resolution angular encoders.

A result of a laser scan can be understood as a three-dimensional point cloud. Each point has three-dimensional coordinates with accuracies up to a few millimetres. Apart from this geometrical information, the intensities of the received signals give valuable indicators for post-processing. In contrast to classical EDM with appropriate reflectors, laser scanning accuracy is highly correlated with the angle of incidence of the laser beam at the surface and the distance itself. Furthermore, the surface texture is another accuracy-affecting parameter. Laser scanners can be used statically or on moved platforms.

For static, terrestrial applications, not only one survey is carried out. In order to cover obstructed, not visible sectors, survey positions are dislocated. Then, the particular scans are connected by control points. A drawback of today's laser scanners is that only point clouds and not structure elements are obtained. Structure elements like corners of buildings, curbs or catenary masts (still) have to be extracted from the point cloud by a post-processing step. This is interactively done in a CAD-system. Automating techniques are developed and are advanced for

specific tasks. Corresponding research work is carried out at the Institute of Geodesy and Photogrammetry (IGP).

The Geodetic Metrology Group (geomETH) of the Institute of Geodesy and Photogrammetry (IGP) intensively deals with questions concerning the laser scanning application area. Apart from definitions of new applications, laser scanners are integrated in kinematic surveying systems. The three subsequent topics are current research projects of the geomETH group.

## Example 1: Deformation monitoring of a concrete dam with terrestrial laser scanning

The concrete dam of Nalps is located south of Sedrun (operating company "Kraftwerke Vorderrhein", volume of 44.5 million m<sup>3</sup> water). Its height is around 100 m and the length of its capstone is 478 m. Due to construction works of the Gotthard base tunnel (AlpTransit), concrete dams in this region are monitored very attentively. The concrete dam of Nalps is just situated above the Gotthard base tunnel. Settlements and deformations of the dam due to excavation work in the tunnel can not be excluded. Consequences can be cracks and disruptions in the dam. That is the reason why dam monitoring is indispensable. A permanent moni-

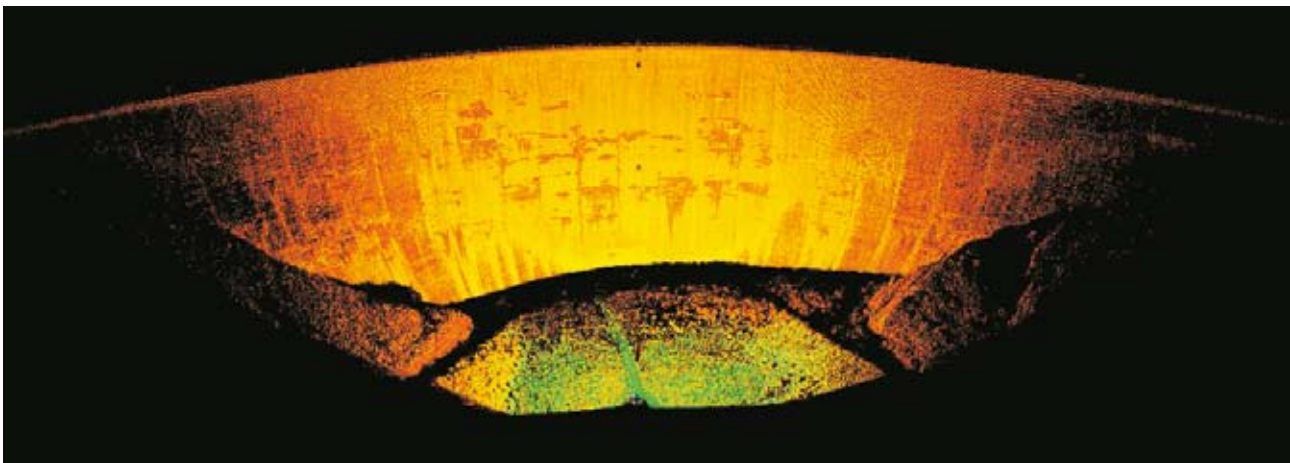


Fig. 1a: 3D-Point cloud of concrete dam Nalps (Sedrun). Millions of points describe the geometry of the dam. The colours correspond to the intensities of the returned laser lights.

Fig. 2a (right) : Measurement setup along the road area to be investigated. The laser scanner and some tie points are mounted on tripods.

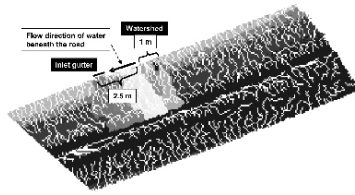


Fig. 2c (left): Calculated streams based on the geometrical surface model. In addition, flow direction due to preferential flow beneath the road is also indicated. Locations of an inlet gutter as well as a watershed are shown.



toring system has been additionally installed at Nalps to monitor movements of the valley of Nalps. Conventional measurement methods as tacheometry or levelling are used for this deformation monitoring. Compared to laser scanning, discrete points on the concrete dam are observed by tacheometry and levelling. It is important for these measurement techniques to choose and set representative object points in advance. In contrast, deformation monitoring by laser scanning technology does not need any discrete object points. Laser scanning has this big advantage to detect area-wide deformations.

First test measurements with terrestrial laser scanning for deformation monitoring of the concrete dam of Nalps have been performed in the geodetic project course 2005 organized by geomETH. The laser scanning system acquires the surface of the concrete dam in a non-contact approach within a couple of minutes.

A first step in post-processing the point cloud is the reduction of mismeasurements by filter algorithms. Then a mesh is calculated with all points of the point cloud. This means that each point is connected with its neighbours. The result out of the point cloud is a geometric model, which has been re-

duced to surfaces. Digital pictures are used for texture mapping. For deformation analysis the geometry of the first scan is set as the reference geometry. All the following scans are compared with the reference geometry of the first scan. Differences between the scans and the reference model indicate deformations of the concrete dam.

### Example 2: Terrestrial laser scanning for road surface analysis

Nowadays, there are ongoing discussions in Switzerland about how to treat polluted road runoff of roads with a high traffic density. One possible treatment is the infiltration of road runoff in vegetated road shoulders. In order to determine their loading and removal effectiveness for heavy metals such as lead, zinc, cadmium and copper as well as organic substances, a pilot plant was installed in a road shoulder of a road with a traffic density of more than 17'000 vehicles per day. The purpose of the pilot plant was, among others, to collect the road runoff from a road section in order to calculate the percentage of runoff draining directly into the vegetated swale and not being dispersed diffusely with spray. Based on this information, mass balances can be calculated in order to access the accumulation rates of pollutants in the vegetated road shoulder and to calculate the removal efficiency of the vegetated swale.

The classical approach to estimate the size of a catchment area is to conduct large scale experiments using coloured tracers sprayed over the whole road surface area near the pilot plant. For the present situation, this is hardly possible because due to the heavy traffic density, the road cannot be blocked for hours. As another possibility, a mathematical surface model based on topological data can be used in order to calculate the catchment area. Therefore, the geometrical data (3D-coordinates) have to be acquired by surveying.

In general, 3D-coordinates can be derived using different methods, such as tacheometry, levelling, GPS, and (terrestrial) laser scanning. These four methods have to be compared regarding accuracy, point density (sampling interval) and measurement time (sampling rate). Because the road can only be blocked for several minutes, the performance becomes a crucial parameter. In a preliminary trial, the different methods were evaluated. The conclusion is that laser scanning has a significant advantage because of the high sampling rate with several thousand points per second and high sampling interval with a point density from some centimetres up to several millimetres. Further, the desired accuracy for this project of one centimetre (single point) can be met with

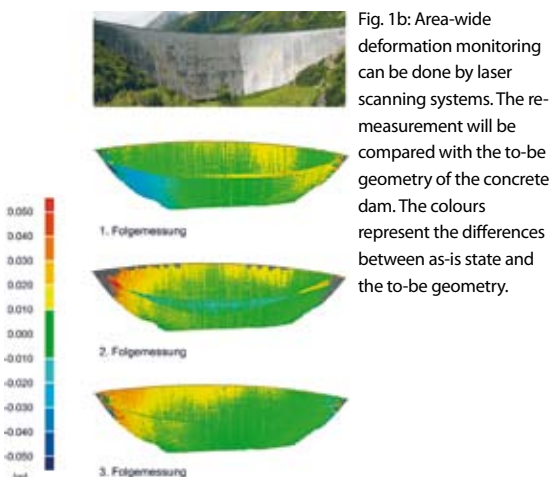


Fig. 1b: Area-wide deformation monitoring can be done by laser scanning systems. The re-measurement will be compared with the to-be geometry of the concrete dam. The colours represent the differences between as-is state and the to-be geometry.

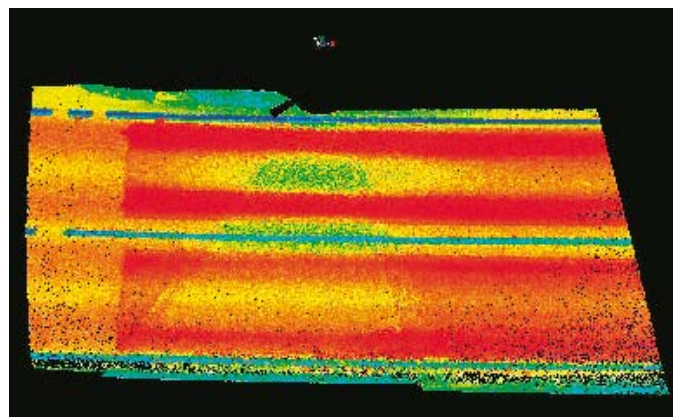


Fig. 2b: 3D-Point cloud including intensity values of the reflected laser beam caused by surface colour. The intensity values allow the interpretation of sign-posting, different tarmacs and skid mark caused by wheel abrasion.

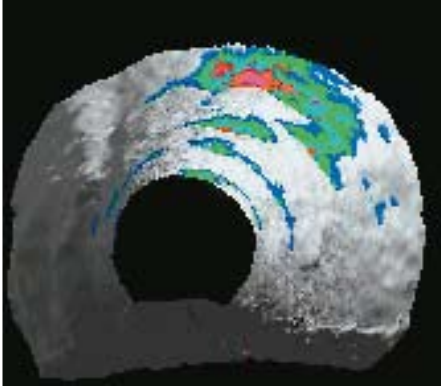


Fig. 3a (left): The metre gauge version of the swiss trolley. For positioning and attitude determination, differential GPS and inclination sensors are used. As an alternative on stretches without GPS reception, tracking totalstations can be applied. Two laser scanners generate fans skewed by 45° with respect to the track axis. By the forward motion of the measuring system, a three-dimensional point cloud is generated. Additionally, an industrial camera provides every second a high resolution image.

Fig. 3b (right): Tunnelling application: Clearance violations can be detected by the comparisons of kinematic surveys with nominal data (highlighted zones).

laser scanning. Based on the gained experiences and results of this preliminary trial as well as former investigations regarding accuracy and performance, the road area along the pilot plant was surveyed by laser scanning.

Overall, the workflow from surveying to deriving catchment areas includes surveying the road by using terrestrial laser scanning, preparing laser scanning data (for registration and geo-referencing), filtering laser scanning data (reducing noise), deriving catchment areas (3D-model), and calculation of mass balances for road runoff.

### Example 3: Kinematic scanning by the swiss trolley

geomETH developed within a joint venture project together with the University of Applied Sciences Burgdorf and private partners the track surveying vehicle swiss trolley. Point clouds are acquired by the forward motion of the swiss trolley. The track surveying vehicle swiss trolley consists of a platform equipped with sensors for positioning

and attitude determination. For the geometric determination of the track environment, two laser scanners are used.

Kinematic scanning outmatches static applications regarding the dispensable tripod stationing. Normally, the link to a primary reference frame is not realised by control point procedure as used for static scans. Instead, the sensor platform is positioned and orientated in discrete, very short time intervals. Sensors to be applied are tracking totalstations, GPS and inclinometers. Then, particular scan vectors are attached to the obtained, three-dimensional trajectory.

A further, essential feature of kinematic surveys is the synchronous acquisition of all involved sensors. For surveys with centimetre accuracy at velocities of several metres per second, synchronisation accuracies better than one millisecond are required.

The swiss trolley is successfully used for various tasks. Updates of databases of fixed assets, clearance inspections or contact free

geometrical surveys of the overhead line are some typical applications in the field of railway engineering. For a customer, a virtual scenery was created by means of the swiss trolley laser scanners. Autonomous, circulating freight wagons equipped with laser scanners compare the instantaneous environment with this nominal scenery. If differences between both models exceed thresholds, the wagon slows down.



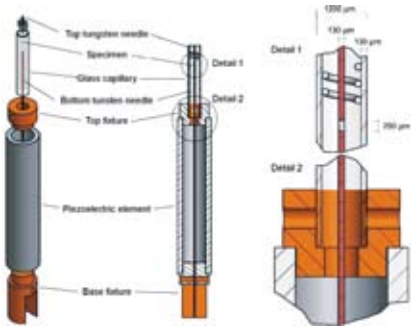
Fig. 3c (above): Principle of obstacle recognition by means of virtual nominal sceneries. The autonomous navigation system developed by the industry detects alterations from the nominal model in real-time. Thus, the bale of straw in the left image represents such an alteration. The train will slow down. The virtual landscape on the right hand side was generated from swiss trolley data. The colour coding represents distances from the track axis.

Fig. 3d (below): Comparison of a swiss trolley point cloud and the corresponding synchronised image. The high spatial resolution of the scan data allows for the contact-free, geometrical determination of the overhead line. The colour coding represents distances from the track axis.



# Highlights Structures

Fig. 2: Schematic view of the micro-tensile test arrangement: a small sample (ø 130 x 250 µm) of hardened cement paste is glued between two tungsten rods of the same diameter. The loading frame consists of a glass capillary; loading is applied by means of a piezo-electric actuator.



## Desilting chambers of hydro power plants

Ch. Ortmanns, P. Volkart / VAW

Downstream of river intakes of water power plants desilting chambers (Fig.1) are built in order to separate undesired suspended solid particles from the water interacting with the runner blades of the turbines. The sedimentation effect of any desilting chamber strongly depends on the three dimensional characteristics of the sand laden water flow in the sand traps. Hence, the flow velocity in the chamber and its approaching channel as well as the shape of the transition from the approaching channel to the desilting chamber are found as to be of high importance for the settling efficiency. Field campaigns have been performed in three different desilting chambers. Acoustic Doppler Velocimeters (ADV) were used to measure the fluctuating, three dimensional velocity components  $u$ ,  $v$ ,

and  $w$ . The curve progression of the vertical turbulence intensity  $w'_{rms}$ , could be developed universally valid over the chamber length. Based on this non linear function a new design formula has been developed to calculate the chamber length of horizontally flown through desilting chambers.

## Micro-tensile Testing of Hardened Cement Paste

P. Trtik, E. Landis, M. Stamparoni, P. Stähli, J. G. M. van Mier / IfB

In order to asses the mechanical and fracture properties of hardened cement paste a new micro-tensile test was developed at the Institute for Building Materials. The test is presumably the smallest tensile test on cement carried out ever. For visualisation of fracture processes in the specimen's interior, the test-device was designed to fit in the tomography station at the Swiss Light Source, the synchrotron radiation facility of the PSI, located in Villigen in close vicinity of ETH Zurich. The first experiments have revealed the development of fractures through the various material phases and crack face bridges at µm-scale, much in line with similar phenomena observed 15 years ago in concrete at the level of the aggregate particles (Fig.2, 3).

Fig. 1: Desilting chamber with vertical flushing system according to Bieri. The sediments are flushed out at the bottom. The withdrawal of water during the flushing process is not disturbed.

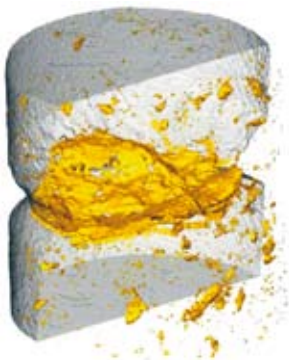
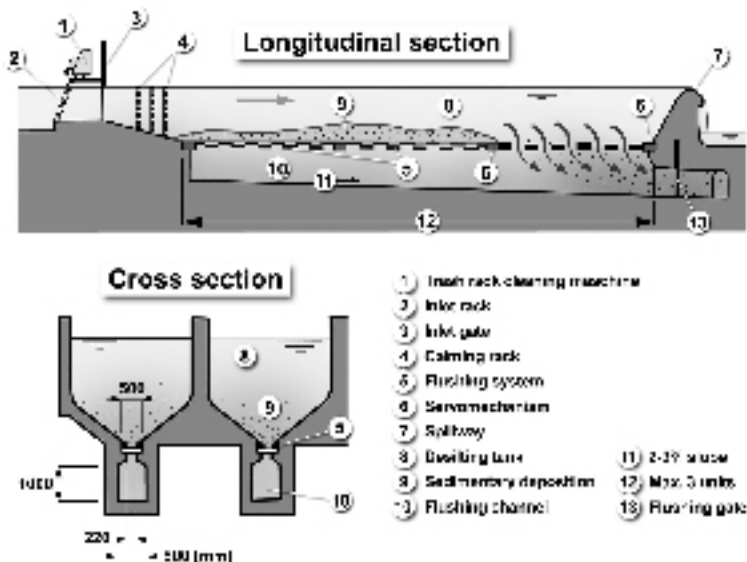


Fig. 3: Continuous fracture plane (yellow) in a cement paste sample after tensile testing. The smaller distributed voids are initial porosity and pre-existing cracks, which are difficult to distinguish. Small white patches in the main crack are crack face bridges.

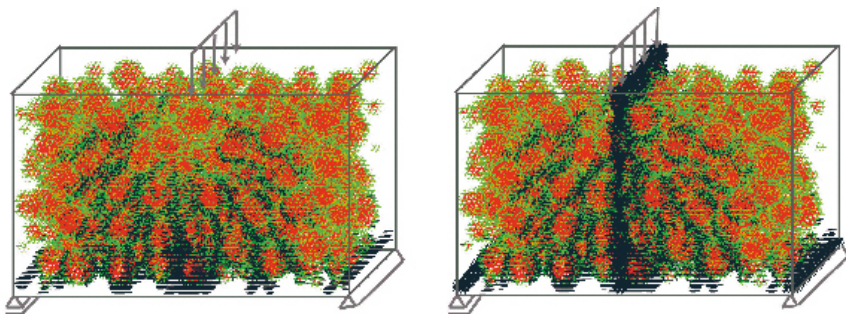


Fig. 4: Results of a 3-point-bending simulation at two stages: at maximum load (left) and shortly before collapse (right). The black colour indicates where cracks appear. In this case the heterogeneous microstructure is computer-generated. Aggregates and bond zones are shown, while matrix elements are omitted.

### 3D Numerical Simulation of Fracture Processes in Concrete

H. K. Man, J. G. M. van Mier / IfB

To study the mechanical behaviour, especially the fracture behaviour of concrete, computational models (here: beam lattice model) are used. On the so-called meso level (scale range between 10<sup>-3</sup> and 10<sup>-1</sup> m) concrete is a heterogeneous material, which is schematized as a three-phase material consisting of a cement matrix, aggregates and between them a weak bond zone. The simulations are done in three dimensions, which imply a 3D microstructure, either as an output from a scanning process (for example by means of tomography) or through computer-generated models. The results from these experiments are for example crack patterns or stress-distributions. With a self-developed post-processing tool, it is possible to view cut-open structures to visualize internal cracking and internal stresses. Consequently an improved understanding of fracture behaviour is achieved (Fig. 4).

Current research topics with computational models include the study of size/scale effects and the modelling and development of local material models for concrete.



Fig. 5: Neutron tomography: allocation of an adhesive (red) in a glued wood specimen; the wood structure (yellow) was removed in the upper part of the image.

### Neutron radiography as non-destructive testing method for wood

D. Mannes, E. Lehmann, P. Niemz / IfB

Neutron radiography is a new non-destructive testing method which is working along the same principles as X-ray. The beam is led on a specimen and afterwards registered by a detector. Depending on the composition and inner structure of the specimen the beam is attenuated to a varying amount. Unlike X-ray the neutron beam is particularly sensitive to some light elements like hydrogen and thus for hydrogenous materials like water, adhesives or wood. Due to these different interaction probabilities with varying elements the two radiation types can be considered as complementary methods. In a joint research project of the Institute for Building materials (IfB) and the Paul Scherrer Institut (PSI) neutron radiography is used for investigations on wood. These comprise the testing of penetration depth of adhesives into wood (Fig. 5), treering studies (Fig. 6) or the monitoring of water transport and allocation processes in wood or wood components (Fig. 7).

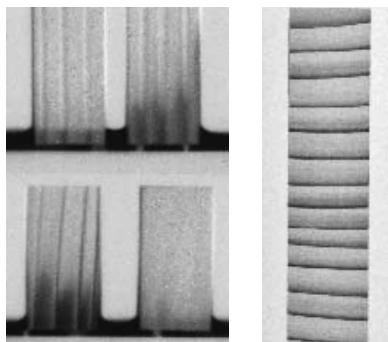


Fig. 6: Neutron radiography of a thin spruce specimen used for tree-ring analyses.

Fig. 7: Water uptake in dry wood samples after several hours ascertained with neutron radiographies (referenced on the dry status).



Fig. 8

### Ice-wall growth and frost heave in artificial ground freezing

G. Anagnostou / IGT

Artificial ground freezing is a method for stabilizing otherwise unstable ground and for preventing groundwater infiltration in tunneling, shaft and deep excavation works (Fig. 8). Although this ground improvement method has been investigated and used extensively in the last five decades there are still many cases where its application may be desired, but confident planning is not possible due to the lack of reliable models. This applies, for example, in the threshold cases where groundwater flows rapidly or where soil expansion may occur due to the formation of ice lenses. In the present research project, mathematical models are developed for the calculation of the temperature and heave distribution in flowing groundwater (Fig. 9). Model verification is based upon measuring data from own model tests performed under controlled boundary conditions. Furthermore, the influence of relevant design parameter (as, for example, the spacing between the frozen pipes, the brine temperature etc.) for typical applications will be methodically analyzed and important parameters as energy demand, time for the freezing phase and temperature distribution will be represented in nomograms.

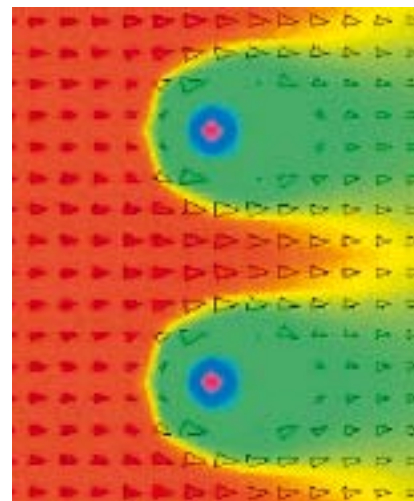
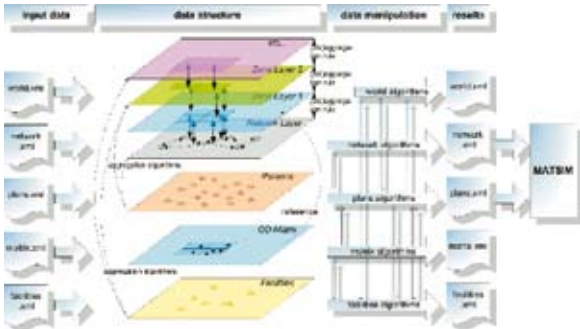


Fig. 9

# Highlights

## Infrastructure Systems

Fig. 10



### Data Models and Frameworks for Agent Based Micro-Simulations

M. Balmer, K. Meister, K.W. Axhausen / IVT

The idea of agent-based traffic simulation methods is to simulate individual persons in a defined scenario. The person's demand is defined by a schedule for a given time period. It consists of a chain of activities, their locations and associated trips. The information is kept separately for each agent/individual throughout the entire simulation process. This allows the use of a truly dynamic traffic assignment method, which is the key to a time-dependent model of travel demand.

#### Initial Modelling Framework of Demand

Similar to other assignment models some initial schedule information for all agents is needed. The challenge is to generate an individual demand out of available – typically aggregate – input data.

In practice, there is a large variety of input data. They differ in purpose, spatial resolution, attributes, etc. Therefore, a modelling framework of demand has to be flexible enough to cope with that variety. It also has to provide standardized interfaces for algorithm implementation and external models.

The framework presented here fulfils these requirements. It integrates the different input data (landuse, network, commuter data, etc.) into an internal and consistent data structure (data fusion). Unique interfaces of each data point are provided such that algorithms and models for generating individual schedules can be implemented easily.

The initial travel demand is generated without consideration of capacity limitations of the transport and activity system. The consistent final demand is determined by an iterative micro-simulation model called MATSIM (Multi-Agent Traffic Simulation, see <http://www.matsim.org>).

#### Iterative Demand Optimization

MATSIM assigns the desired travel demand of several millions of agents to a models of the traffic network and of the activity system (landuse). Since both of these have a limited capacity, the agents are faced with situations like traffic jams or overcrowded locations, which influence the required travel time or the quality of the activity performance. In turn, the agents attempt to optimise their personal time use by extending time spent in activities, minimizing time spent travelling resp. waiting and keeping desired arrival/departure times. This optimization is performed by the "planomat" mod-

ule employing a heuristic optimization algorithm.

MATSIM uses an iterative approach to find a solution to this dynamic system. This means that the traffic flow simulation (which produces travel time information) and behavioural strategies (which react on travel time information) are organised in separate modules. They are invoked alternately until a stationary condition is reached (typically after 50–100 iterations). This approximated stochastic user equilibrium is interpreted as a typical (working) day of the simulated area. Experiments for Zurich and Switzerland have shown that traffic count data can be reproduced well (Fig. 10, 11).

### Increasing Schedule Reliability on Zurich's S-Bahn

M. Lüthi, U. Weidmann / IVT

Ridership on Zurich's S-Bahn has doubled in the last 15 years with the addition of new routes and more frequent service. As a result schedule delays on several S-Bahn lines reached unacceptably high levels. The IVT was asked to determine the main problems and to recommend solutions.

OpenTimeTable, a computer program developed at the IVT, was used to identify the

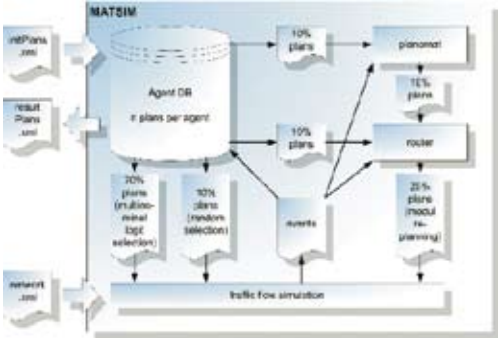


Fig. 11



Fig. 12: Schedule (8 – 9 h) for the station Stadelhofen, comparison of the target schedule (outer ring) to the actual schedule.



Fig. 13: Share of S-Bahn trains with less than 5 minutes delay.



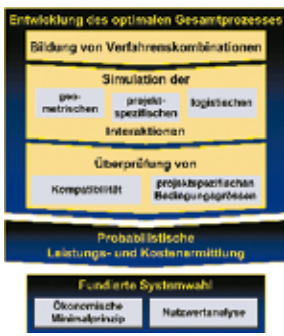


Fig. 14: Structure of the anticipated decision-making model.



Fig. 15: Tsunami run-up at (a) Khao Lak, Thailand (courtesy of Knill Family) and (b) Phi Phi Island, Thailand (courtesy of J.T. and Cardine Malatesta).

delay causes. The main problems were: increased station dwell times, cascading delays caused by trains entering the core network late and sub-optimal track/platform dispatching.

Given the importance of dwell time, a detailed analysis of passenger boarding and alighting for the S-Bahn trains was also completed. A computerized pedestrian simulation model was also used to localise bottlenecks in the stations. Statistical analysis and analytical methods were used to develop density curves for the boarding and alighting process as a function of the passenger demand.

The study recommended the following improvement measures for reducing delays on the S-Bahn network: a systematic revision of S-Bahn station dwell times; allow connections to be broken at peripheral stations; give high dispatching priority to trains entering the core network and begin implementation of a prioritized infrastructure improvement program for single-track sections (Fig. 12, 13).

### Process-based, cybernetic and system-oriented decision-making model for the selection of project-specific formwork systems

M. Kapp, G. Girmscheid / IBB

The project-specific and process-oriented selection of construction methods represents one of the core competencies of construction companies and plays a crucial role in deciding the effectiveness of the production processes and affiliated costs. In spite of its enormous relevance for the success of a project, a system-oriented and simulation-oriented decision-making structure does not exist; the majority of decisions are made intuitively. This inadequate selection process results in sub-optimal process flows combined with ancillary works that are non-value adding, but instead incur high levels of costs during the construction process.

The anticipated decision-making model is based on a constructivist research approach;

the structure within the model is defined using system theory and mathematical simulation approaches. Primary characteristics include the analysis of the geometric interactions between the formwork and the building, and an analysis of the project-specific and logistical interactions. The approach does not just focus on the interactions between individual shell construction processes, but also on the interactions with the interior work processes taking place at the same time in different locations. The possible construction measures are tested for compatibility of the process interactions and combined to create an integrated construction production process. The construction measures and the combination within the process are also evaluated using probabilistic performance, deadline and cost analyses. The minimum principle combined with a cost-benefit analysis is used to select the system from the possible process alternatives.

In terms of practical application, the project aims to minimize the non-value adding works and, in doing so, to substantially increase the efficiency of the construction production processes in the projects, enabling companies to generate higher profit margins and, as such, strengthen their competitiveness (Fig. 14).

(The project is being completed in collaboration with a major international manufacturer of formwork and Swiss construction companies.)

### TSUNAMI RUN-UP – A HYDRAULIC PERSPECTIVE

V. Heller, J. Unger und W.H. Hager / VAW

On December 26, 2004, an intense earthquake located in front of the Island of Sumatra generated a massive tsunami that severely impacted the shores of the Indian Ocean. It damaged the coastal infrastructure and caused great loss among the population. The wave celerity in the sea was typically 200 m/s and reduced to some 10 m/s on the original shoreline. Fig. 15 shows the tsunami run-up in Thailand. Impulse waves or mega-tsunamis as are cur-

rently investigated at VAW have a wave height of more than 100 m; they are generated by landslides, glacier or rock falls. Since 1997, impulse waves are explored experimentally in terms of wave generation and propagation in the Alpine environment. Fig. 16 shows the run-up of a solitary wave as a preliminary part of this project, using Particle Image Velocimetry PIV. Such tests allow for the prediction of the free surface and velocity profiles, and the energy dissipation associated with the tsunami-like wave run-up. The complexity of this process stems from the entrainment of both sediment and air into the fluid flow, resulting in an extremely unsteady three phase flow phenomenon. The hydraulic modeling of these water waves includes at least three different zones, namely: (1) a numerical model from the earthquake epicenter to the surf zone; (2) a coastal experimental model including up to some hundred meters from the coast line in which the tsunami develops into a bore; and (3) the bore propagation zone from roughly the shore line to the wave run-out.

Further reading: Heller, V., Unger, J., Hager, W.H. (2005). Tsunami run-up – A hydraulic perspective. Journal of Hydraulic Engineering 131(9), 743-747.

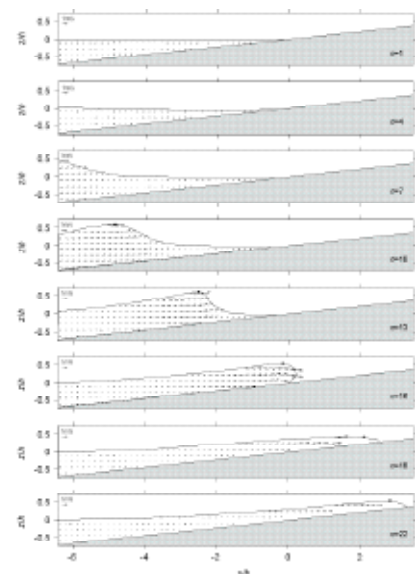


Fig. 16: Run-up of solitary wave on 1:10 sloping beach: Wave surface profiles and internal velocity distributions at various time integers n.



# Highlights Resources

## Data Based Visualisation For Landscape Quality Assessement A Multidisciplinary Approach For Urban Parks

I. Mambretti, W. A. Schmid/IRL

This PhD research provides an approach for the landscape analysis using quantitative methods to enable the estimation of existing situations and proposed variations. The conceptual base of this work is the psycho-physical theory about people’s environmental behaviour. The aim of the work is to realise a decision support system for the investigation of urban parks. Urban parks are essential components of our landscape. Nevertheless, under certain conditions urban parks are not used to their full potential. Previous studies demonstrated that the problem of underused open spaces is currently associated with the perception of personal safety. The themes of safety and criminality in European cities are pivotal in the recent research about open spaces. The concept of the crime related to urban green spaces is often associated with the “predatory petty larceny” denoting the crimes occurring in public spaces and affect the citizens as pedestrians. The combined use of visualisation and conjoint analysis experiments is adopted to identify whether and how different visual alternatives affect pub-

lic preferences and to understand how individuals experience specific landscape alternatives. People’s responses to alternative scenarios are observed to support the public understanding of urban park sites and to provide useful directions to their management. Two historical parks situated in the urban core of Zurich are investigated: Platzspitz and Zurichhorn (Fig. 17).

The images generated for the research are based on quantitative information stored within Geographical Information Systems. The main object of the visualisation is the vegetation that was inventoried, geo-referenced in a database and then calculated in high detailed 3D visualisations. The visual scenarios are evaluated with the aim to determine the relative influence of specific attributes and the combination of green space arrangements that can maximise public welfare (Fig. 18, 19).

Urban parks become new spaces of incertitude as demonstrated by the use of preventive measures such as the fencing of spaces, the payment of an entrance fee, or with increased presence of surveillance. The project’s ambition is to identify and to quantify possible physical characters in urban parks that might generate spontaneous defensive behaviour. The project started from

the belief that perceptual barriers limiting the use of open spaces contribute to generate the decadence and the impoverishment of the quality of our cities.

The PhD research was presented on the Swiss National Channel, MTW Fokus Forschung Schweiz (Fig. 20).



Fig. 20: Public preference assessment for the characteristics of: Personal Safety, Aesthetic and Overall Preference.



Fig. 18: Zurichhorn park: full enclosed prospect in winter.



Fig. 19: Zurichhorn park: open prospect in autumn.

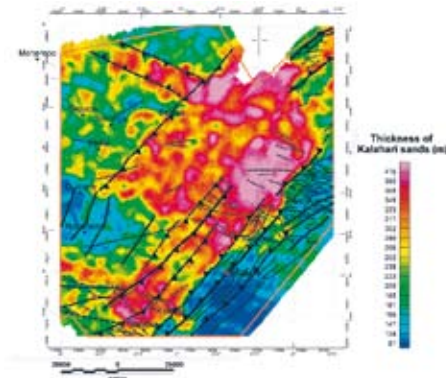


Fig. 23: Thickness of the Kalahari Aquifer.

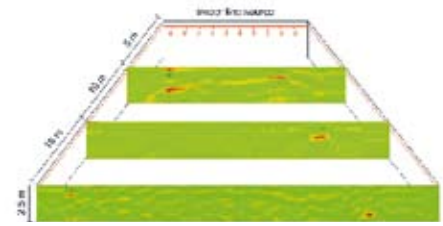


Fig. 24: Visualisation of preferential flow paths with ground penetrating radar (flow path locations indicated by red colours).

## On the Predictability of Ice Avalanches

M. Funk, A. Pralong / VAW

Following the 1965 catastrophe at Allaligletscher, different studies performed on hanging glaciers showed that the velocity of unstable large ice masses increases as a power-law function of time prior to failure. Due to positive feedback mechanisms the velocity of the unstable ice mass approaches a finite time singularity; that is, theoretically the velocity increases to infinity at a finite time according to  $u(t) = u_0 + a(t_f - t)^m$ , where  $u(t)$  is the velocity at time  $t$ ,  $u_0$  is a constant velocity,  $t_f$  is the time of failure and  $a$  and  $m$  are positive parameters. This characteristic acceleration is used for forecasting icefalls by fitting data of glacier motion and identifying  $t_f$ .

Measurements performed on a hanging glacier (Fig. 21) above Randa (Valais) were analyzed. The residuals of the data set show log-periodic oscillations. They are superimposed on the motion with a frequency proportional to  $\log(t_f - t)$ . The amplitude, frequency and phase of the oscillations appear to be spatially homogeneous over the entire unstable ice mass (the velocity of four material points located on the glacier were recorded), whereas the shape of the global acceleration is spatially inhomogeneous. The influence of

these oscillations on the forecast is significant and must be considered in order to achieve an accurate prediction (Fig. 22).

Reference: A. Pralong et al. (2005). On the Predictability of Ice Avalanches, Non-linear Processes in Geophysics, vol. 12, 849-861.

## Determination of the thickness of the Kalahari Aquifer below the Okavango Delta

L. Kgotlhang, W. Kinzelbach / IfU (IHW)

One objective of our NSF funded Okavango Delta research is to determine the spatial distribution of the Kalahari aquifer below the Delta. The Delta has an area of about 30 000 km<sup>2</sup> and the conventional way of using drill hole information to determine aquifer thickness will not only be exorbitantly expensive but also environmentally questionable given the pristine nature of the Delta. We make use of an aerial magnetic survey covering the whole delta at a line spacing of 250 m to estimate the thickness of the Kalahari sands.

The Kalahari sands are non-magnetic compared to the underlying metamorphic and igneous rocks. This is the basis for the interpretation of aeromagnetic surveys which assumes that all magnetic sources lie below

the base of the sedimentary cover.

3D Euler Deconvolution of the signals yields the depth to the magnetic rocks which basically corresponds to the thickness of the aquifer. It is shown in the Figure 23 together with the known faults for orientation. Thickness is quite variable over the Delta. It is highest in the grabens (red tones) and smallest on the horsts (blue tones).

## Identification of subsurface storm flow mechanisms in an approach combining hydrometry, tracers and geophysics

P. Kienzler, F. Naef, W. Kinzelbach / IfU (IHW)

Fast subsurface flow in the vadose zone in hillslopes is an important factor in the formation of extreme floods. Such floods have caused enormous damages in the last years and are expected to occur with increased frequency in the future. At a test slope in northern Switzerland, where subsurface flow responded extremely quickly to rainfall events despite the low hydraulic conductivity of the deep soil, new methods were applied to understand the relevant processes. The use of <sup>222</sup>Rn as natural tracer showed that the subsurface storm flow was to a high degree directly fed by precipitation and only little interaction with the soil matrix occurred.



Fig. 21: Hanging glacier on Weisshorn.

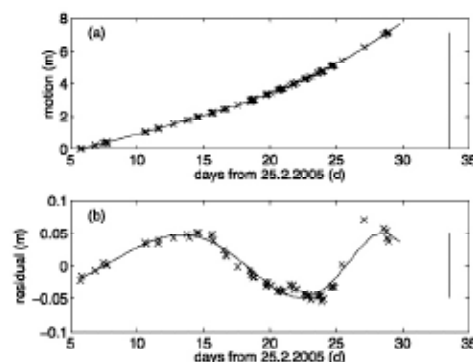
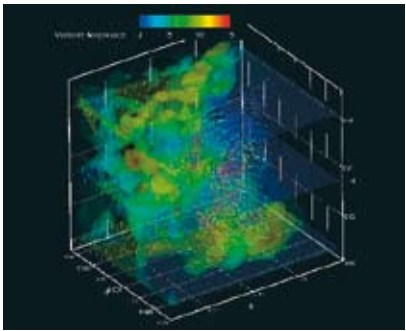


Fig. 22: (a) Motion versus time (crosses) measured on the hanging glacier and its associated fit (solid line) using the integrated form of the power law equation for the velocity. The predicted failure time was April 7, 2005. The breaking off (vertical solid line) occurred one week prior to the forecast. (b) Residuals of the fit. The solid line indicates the fit of the log-periodic oscillations.

Fig. 27: Turbulent jet generated by an oscillating disk with iso-vorticity contours and entraining particle trajectories. The flow field is characterized by a steep border between the jet fluid having high vorticity (red) and the surrounding fluid, which is essentially free of vorticity (blue). Data density is about 4500 particle tracks in the observed volume (30x30x30 mm<sup>3</sup>).



Instantaneous tracer injections indicated high subsurface flow velocities over a large distance. This can only be explained with preferential flow in long and well-connected lateral flow paths. These were located with ground penetrating radar (GPR). To enhance the radar reflections, highly concentrated NaCl-solution was injected as a line source into the soil. GPR-profiles were taken before and after the tracer injection. Figure 24 shows the difference between these two measurements at different distances down slope of the tracer source. After the tracer injection, radar reflections were clearly visible near to the surface indicating shallow lateral soil pipes (red colours). The penetration depth of the GPR was limited to about 2.5 m.

### A look at the future of an Alpine region

A. Grêt-Regamey, S. Kytzia / NSL-IRL

The sport events, climate change, or international trade: All these factors change alpine regions on a long-term basis. Those who want to take charge of the development process must look further ahead. In the project ALPSCAPE an integral modelling framework was developed to take a look at the landscape of Davos in the year 2050. More specifically, an integral modelling

framework was developed, which links sub-models of land-use allocation, resource consumption and economic development to simulate future scenarios for Davos (Fig. 25). It is a joined project of the SLF Davos, the ETH Zurich and the IGT St. Gallen funded by the Swiss National Science Foundation within the NRP48-Programme.

The model is used to simulate how Davos (Fig. 26) will change under different economic and ecological conditions. In general, results show that the system is highly dependent on tourist demand and the local economy is largely decoupled from regional resources. Landscape changes are driven by an increase of forest cover and settlement area. Under a scenario of elimination of agriculture subsidies, these factors will lead to a drastic expansion of forest (26% until 2050). Economically the losses are relatively small in the short-term (-2% factor income) but have to be considered together with significant changes in the sustainability indicators. A climate change scenario (temperature increase of 2.4°C) has – from all considered scenarios – the highest impact on the economy with a potential loss of 10% in factor income and employment.

The model was developed in cooperation with regional stakeholders. The following statement of Maria von Ballmos sums up their expectations, “Politicians do not want to get advice in decision-making from scientists. We need scenarios which show us what can happen when certain conditions change.”

### Turbulent velocity field obtained using Scanning Particle Tracking Velocimetry

K. Hoyer, K. Kinzelbach / IfU (IHW)

Particle tracking velocimetry determines seed-particle trajectories in a flowing liquid and derives from those the time dependent 3D-velocity field. The movement of the seed particles through the observation volume is recorded under different angles by four video cameras. From these images the complete space- and time-dependent flow field is reconstructed using photogrammetric methods. A high seeding density within a large observation volume could be achieved through scanning image acquisition.

Identification of particle positions and tracking robustness can be improved considerably if instead of single points one uses tetrahedra formed by four points lying close to each other. While the tetrahedron is invariant under rotation and translation it is deformed by shear and elongation. If time steps between images are small the deformation stays small and an individual tetrahedron can be identified in the following time step using correlation methods. From the tetrahedron motion, the local velocity derivatives can be computed, which then allow predicting the expected positions of nearby particles. Tracks are established, when simultaneously a number of actual particles match – within a defined distance – the predicted locations (Fig. 27).

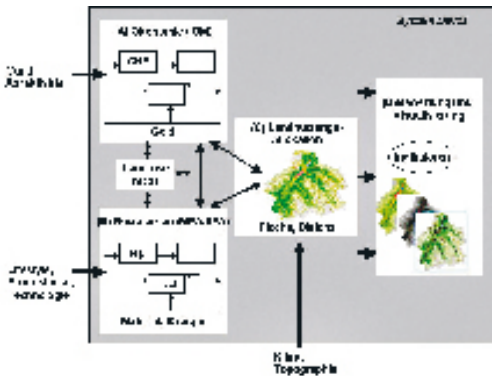


Fig. 25: Modelling framework of ALPSCAPE.



Fig. 26: Landscape of Davos – how will it look in 2050?



# Highlights

## Geo-, Structural and Environmental Data

### New school map of Schaffhausen: Tradition and modern technology united

B. Jenny, S. Räber, L. Hurni / IKA

A new school map for the Canton of Schaffhausen has been published in 2005. The design takes account of the special needs of teachers and students: The majority of the place names are labelled in dialect. The original relief designed by Professor Eduard Imhof, which was lost during 50 years, was processed digitally at the Institute of Cartography and gives the map an extraordinary plasticity. Using a special scanner, the four 100 by 80 cm drawings which are mounted on aluminium plates were digitised. The four parts have then been recombined on the computer screen and the overall lightness has been adjusted. According to the wishes of the teachers, the well proven colour modulation and the relief drawing of Imhof's map should be adopted true to original. For colouring of the original grey tone shading a special computer software has therefore been developed. The software assigns a yellowish light tone to the sunny sides of the terrain. On the other hand, shadowed slopes are provided with a bluish shadow tone and planes with a bluish green (Fig. 28).

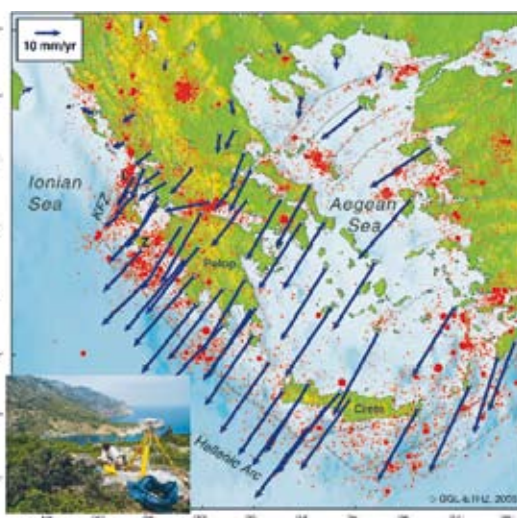


Fig. 29: Recent crustal movements, obtained by GPS measurements. The earthquakes of the last 10 years are marked in red; the larger circles represent earthquakes with magnitudes larger than 5 and 6, respectively. Bottom left: GPS measurements on an Aegean island. KFZ: Kefalonia Fault Zone, L: Lefkada, Pelop.: Peloponnisos, Z: Zakynthos.

### Geodynamics in Greece: Crustal deformation and seismicity

Ch. Hollenstein, H.-G. Kahle / IGP

Greece is located in the collision zone between the Eurasian and African plate. Is characterized by relatively large crustal motion and high seismicity. GPS measurements are being carried out by the Geodesy and Geodynamics Lab (GGL) (professorship Kahle) in order to quantify and interpret these crustal movements. Based on data of more than 90 measurement points, 15 thereof continuously operating stations, a detailed velocity field was calculated. Apart from the large-scale motion of the Anatolian-Aegean plate towards southwest, reaching velocities of up to 4 cm/yr relative to Eurasia, new interesting features were detected, such as the systematic southward movement of several mm/yr in northern Greece and arc-parallel extension of 2 cm/yr along the Hellenic arc. The island of Zakynthos is of particular interest, because the measurements show a continuous stretching of about 6 mm/yr (Fig. 2). The earthquake activity that occurred during the last year in the vicinity of this island can be related to accumulating strain energy. GPS time series made it possible to detect co-seismic displacements of several cm. For the first time, the results also allow a statement about height changes: The area of the Ionian is-

lands has inter-seismically subsided by about 2 to 4 cm during the last 8 years. Work currently concentrates on the detection of pre-seismic displacements and on the measurement of post-seismic deformation (Fig. 29, 30).

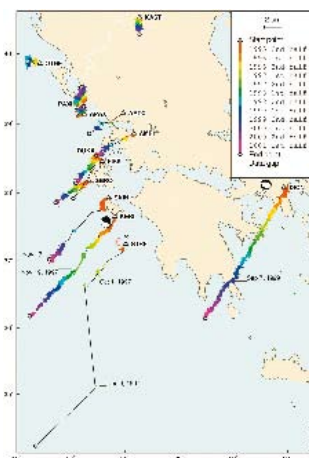


Fig. 30: Horizontal crustal movements 1995-2001 (relative to Eurasia), obtained from continuous GPS measurements, represented as trajectories (continuous daily positions). The start points of the trajectories mark the locations of the sites. The black and white fault plane solutions and the red circles represent large earthquakes which occurred on November 18, 1997 near STRF (M = 6.6) and on September 7, 1999 near DION (M = 6.0) (Harvard CMT solutions and USGS-NEIC). S: Strofades, Z: Zakynthos. (Hollenstein et al., GJI, 164, 2006).

Fig. 28: The four original relief drawings of Prof. Imhof from the early fifties, hold by ETH cartographers Bernhard Jenny (left) and Stefan Räber (right).



Fig. 34: Toni Mair, relief builder.



Fig. 35: Bietschhorn Nestgalcier 2005.



Fig. 36: Bietschhorn model Nestglacier 1938.

## Model helicopter over Pinchango Alto

A. Grün / IGP

During the past few years UAVs (Unmanned Aerial Vehicles) have found increased interest in various application fields. In Switzerland the ETHZ spinoff company WeControl retrofits model helicopters with low cost GPS/INS systems for navigation and stabilizing platforms to carry cameras along (Fig. 31).

We used such a system in two projects – (a) an archaeological application to generate a 3D model of the Pre-Inka site of Pinchango Alto in Peru (a cooperation with the DAI, Fig. 32) and (b) an agricultural application in cooperation with the Institute of Plant Sciences, ETHZ, where a Digital Surface Model of a cornfield had to be generated for the modeling of pollenflight in simulated genetically modified fields (Fig. 33).

The trajectory of the model helicopter and the orientation of the camera(s) can be pre-programmed, together with the image acquisition program. The cameras to be used can be selected freely. The helicopter can operate fully autonomously, with the possibility of manual interference.

Based on previous R&D work with satellite and aerial images we developed a full suite

of software for all stages of dataprocessing (calibration, georeferencing/triangulation, DSM generation, orthoimage generation, texture mapping), which was adapted to this particular case.

In Pinchango Alto we produced 90 aerial images. They were processed to generate a DSM fully automatically with an accuracy of 7.3 cm (if compared to terrestrial laserscan data). The DSM was textured with a mosaicked orthoimage and dynamically visualized as a flyover with Maya software.

The goal for future research is twofold: (a) to improve the helicopter navigation by integrating image-based methods and (b) to develop our processing methodologies and software into an on-line processing system, which would allow to do most of the processing in the field on a laptop.

We see great potential for many more applications of this system in the future.

## Renovation of the historical Bietschhorn relief

S. Räber, L. Hurni / IKA

The plaster relief model of the Bietschhorn which was modelled in 1938/39 by Professor Eduard Imhof for the Swiss National Exhibition in Zurich has been entirely renovated. Throughout the years this object of national cultural value was exposed to damages due to transports, exhibitions and storage. More over during the renovation the three single parts of the relief were assembled to one block. The work was carried out by the geographer Toni Mair, the only professional relief builder in Switzerland who also designed the Masoala relief in the Zurich Zoo. The freshly renovated relief persuades on one hand by its richness in details but also as an artistic masterpiece. It is also a scientific contemporary document by showing the state of the glaciers in the 30ies of the last century when the snouts of the glaciers were significantly longer than today. The model can serve scientists to study geologic and geomorphologic processes (Fig. 34, 35, 36).



Fig. 31: Model helicopter Helicam. The platform is equipped with a GPS/INS-based navigation system and a stabilizer and stillvideo or videocamera for image acquisition.



Fig. 32: View onto the textured 3D model of Pinchango Alto (part of a dynamic flyover, produced in Maya).

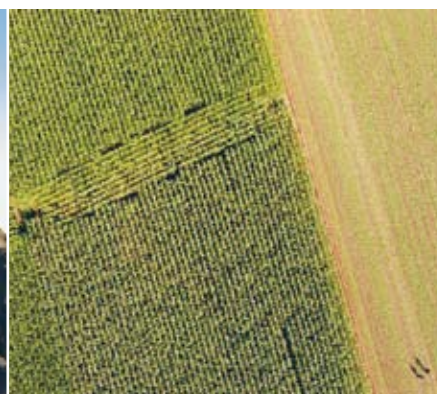


Fig. 33: Aerial image taken from a model helicopter used for DSM generation of a simulated genetically modified cornfield.



# Highlights

## High-Tech Measuring Systems



Fig. 39: ESA's Planck deep space telescope with the primary reflector.

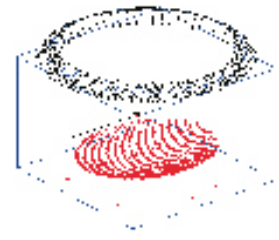


Fig. 40: Hyper-image videogrammetric network design and simulation for heuristic accuracy studies.

### The digital Zenith Camera DIADEM (Digital Astronomical Deflection Measuring System))

A. E. Müller, H.-G. Kahle / IGP

The automated Zenith Camera DIADEM, developed at the Geodesy and Geodynamics Laboratory (GGL, chair Prof. Kahle), determines the physical plumb line ( , ) by directional measurements to the stars using a CCD camera. Two orthogonally mounted inclination sensors control permanently the orientation of DIADEM referring to the local plumb line. Besides highly-precise epoch information as well as geodetic coordinates ( , ) are provided by a GPS receiver. The combination of Zenith Camera and GPS allows the determination of deflections of the vertical ( , ) with an accuracy better than 0.15". In May 2005 a four-week campaign took place on several isles and at the coastline of the North Aegean Sea, Greece. In addition to DIADEM (Fig. 37) also GPS-, buoys- and tide-gauge measurements were carried out. Furthermore, current data of the altimeter satellite JASON are being retrieved (GPS and JASON tracks, see Fig. 38). A first evaluation of the DIADEM and GPS buoy measurements indicated a distinct low in the sea surface that can be associated with the submarine continuation of the seismically active North Anatolian Fault zone. After an in-depth error

analysis the data will be used for high precision geoid determination and geodynamic interpretation.

### Breaking the 1 Million barrier

A. Grün / IGP

Videogrammetric measurement systems usually operate at accuracy levels between 1:5'000 and 1:50'000. For industrial quality control purposes very often much higher accuracies are required. In cooperation with ESA-ESTEC and Alenia Spazio we developed and tested an image-based videogrammetric measurement system which can operate at the 1:1'000'000 accuracy level.

ESA's Planck deep space telescope is designed to image the anisotropies of the Cosmic Background Radiation Field over the whole sky, with unprecedented sensitivity and angular resolution. Planck's objective is to analyze, with the highest accuracy ever achieved, the remnants of the radiation that filled the Universe immediately after the Big Bang, which we observe today as the Cosmic Microwave Background. To achieve this aim well-manufactured reflectors are used as part of the Planck telescope receiving system. The system consists of two reflectors which are sections of two different evolving ellipsoids with

mean diameters of 1 and 1.6 meters. The requested parameters are surface accuracy, conic constant and radius of curvature. Deformations of the reflectors which influence the optical parameters and the gain of receiving signals are investigated in vacuum and at very low temperatures by ALCATEL ALENIA SPACE under ESA-ESTEC contract.

For deformation measurements we have developed a hyper-image videogrammetric system, based on a commercial CMOS camera and our own processing software. Special considerations had to be taken into account at different steps of design and processing, such as determinability of additional parameters under a given network configuration, datum definition, reliability and precision issues as well as workspace limitations and propagating errors from different sources of errors.

We have designed an optimal close range photogrammetric network by heuristic simulation with an accuracy better than 1:1'000'000 (1 micron at 1m) to achieve the requested accuracies. For the evaluation of the global and local deformations of the reflector, a least squares surface-modeling for ellipsoid fitting was developed based on the given model of the reflector. First results indicate a successful operation of the system. Now the test series are in progress (Fig. 39, 40, 41).



Fig. 37: Deployment of DIADEM (Digital Astronomical Deflection Measuring System).



Fig. 38: Sea surface profiles and tracks of the JASON satellite in the North Aegean Trough (NAT). The sea surface above the NAT clearly shows a distinct low of 1.80 m. Ski=Skiathos, Sko=Skopelos, KiPa=Kira Panagia, Kass=Kassandra.



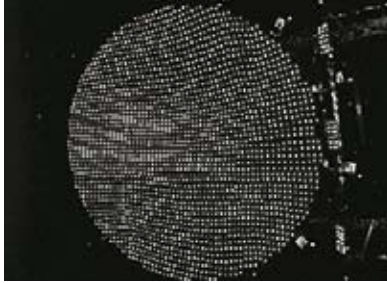


Fig. 41: One real image of the targets on the primary reflector as produced with a CMOS camera of 2Kx3K pixels.



Fig. 43: Sun-tracking telescope of GEMOSS and Water Vapor Radiometer operating on the island of Alonnisos in 2005.

# NASA/CNES OSTM Mission: Validation of Jason Microwave Radiometer by ground-based Solar Spectrometry and Water Vapor Radiometry

A. Somieski, B. Bürki, H.-G. Kahle / IGP

The ocean's sea level and its variability in space and time is being measured by means of Radar Altimeter satellites. Since tropospheric water vapor causes a delay of the propagation time of the radar altimeter signal, modern satellites carry microwave radiometers on board in order to determine the integrated water vapor content used to mitigate significant errors in the sea surface heights. The validation and calibration of these microwave radiometers is essential in order to provide precise corrections. A new measuring system for high-precision determination of tropospheric water vapor has been constructed at the Geodesy and Geodynamics Laboratory (GGL, ETH Zurich, Switzerland) of the chair Prof. Kahle in collaboration with the Institute for Analytical Sciences (ISAS, Berlin, Germany): the GEodetic MOBILE Solar Spectrometer (GEMOSS). The spectrometer allows to simultaneously measure numerous water vapor absorption lines between 728 and 915 nm. In order to validate Jason's radiometer (JMR), GEMOSS and a ground-based water vapor radiometer were operated on the island of Alonnisos in the North Aegean Sea

(Greece), close to the tracks of Jason. Long-time series of integrated water vapor content have been measured over a period of four months in 2005. The results of the comparison with JMR are extremely encouraging and indicate GEMOSS as an excellent ground-based calibration and validation system for space-borne radiometers GGL, Co-Investigator of the NASA/CNES "Ocean Surface Topography Mission" (OSTM), is operating GEMOSS for validation and calibration of JMR near the Cap Senetosa in-situ calibration site (Corsica, France) since November 2005 (Fig. 42, 43).

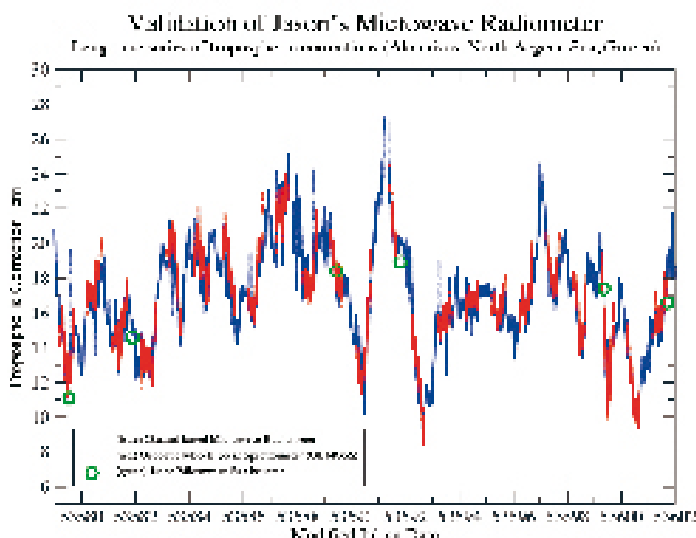


Fig. 42: Time series of tropospheric corrections measured by GEMOSS, ground-based water vapor radiometer and Jason microwave radiometer. The strong effect of the tropospheric water vapor (up to 20 cm) is clearly visible. Without corrections a change of the sea level of about millimeters per year is not detectable.

# Studying at the Department of Civil, Environmental and Geomatic Engineering



## Why on Earth Civil Engineering?

I was often asked this question: why would a woman want to be a civil engineer? ...The rough world of building! ...You won't have a chance! ...etc. And needless to say, I have asked myself this question many times before and still do today.

## So why Civil Engineering?

### Decision

After receiving my high school diploma, engineering appeared to be an ideal option. The prospect of a many sided job was the main reason for this decision. During a one-day visit at an engineering firm, I was able to get to know the vocational fields of environmental and civil engineering. Well, I considered developing a concept for a luggage distribution machine more interesting than planning a water conduit. Based on this perception, I spontaneously decided to study Civil Engineering. As easy as that!

### Amazing!

The first semester started with our first field trip to the "Wassen"-Bridge over the river Reuss in canton Uri. Due to a flood, one of the bridge's pillars had subsided around 1.20m and the bridge sagged. I was amazed to learn that the pillar with its entire load could be lifted back into the original position. Since this day, I am fascinated by successfully built constructions that consider given conditions in an aesthetical way. It is precisely this fascination that inspires me time and again to find an optimal solution for a given problem: therefore Civil Engineering!

### Aha-Experiences

Well, at first, the course was just pure hard work. The basic lectures did not seem to have anything in common with the future topic. Why Civil Engineering? Oh well ...

But suddenly, especially in the specialisation courses (today's master courses), the rare aha-experiences became more frequent. All of a sudden, newly obtained information was understandable due to previous courses and dull lectures became colourful due to short – and sometimes longer – anecdotes told by professors while talking about their practical work experience.

This process was strengthened by various projects. Semester theses helped achieve interdisciplinary insights. During various internships with engineering and construction firms, I was able to experience the work ambience of civil engineering. An undergraduate teaching assistant position for the construction course provided me with the opportunity to further enhance my knowledge of this subject. As soon as the individual puzzle pieces slowly started to become a







integral whole and the numerous lectures became a coherent topic, the original decision was valid again. Civil Engineering? Of course!

#### Team Spirit

Everyone talks about team spirit but in comparison with other subjects, I consider this to be one of our biggest fortes, thanks to the following reason: our student work area functioned as a "flat share" work room. During various teamwork projects and semester theses we were obliged to learn to develop unanimous solutions despite opposed work techniques and opinions. And in a way, this was extremely educational.

#### Fun

To enjoy studying is not a privilege entitled solely to students of Civil Engineering but it sure was an important component during my studies. Small highlights "sweetened" the often dull student life. During hard times, our student coffee group received biscuits, sponsored by private firms, enabling a sufficient energy input.

...but...

Well, of course, there were also tough times and there were problems among us students. Sometimes the daily grind was accompanied by everyday stress. What would I do differently today? Well, there were times when I lacked courage: courage to concentrate consequently and specifically on fewer subjects, courage for a semester abroad.

And today?

Looking back on three years of practical experience, I now realise that my studies were a good basis. However, the actual training started with the subsequent professional practise. During this time, I experienced my limitations almost every day and also broadened my horizon in many aspects. Due to my actual assignment as an assistant, I am now "on the other side" with the ambition to share my fascination for civil engineering.

So, why Civil Engineering? Because, it is not just a job but a way of life. And because it is fun!

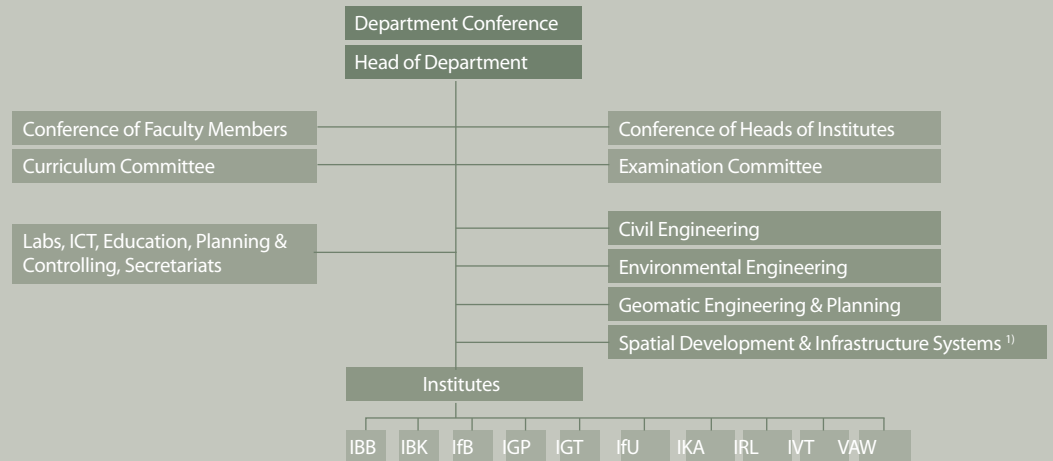
Barbara Ebert, Dipl. Bauing. ETH, IBK





# Facts & Figures

## Organisation Chart D-BAUG



## Institutes

IBB Institute for Construction Engineering and Management  
Proff. G. Girmscheid, H.R. Schalcher



IBK Institute of Structural Engineering  
Proff. M.H. Faber, M. Fontana, P. Marti, T. Vogel, A. Dazio



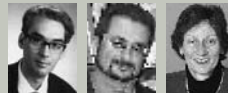
IfB Institute for Building Materials  
Proff. J. G. M. van Mier, H. J. Hermann, P. Niemz



IGP Institute of Geodesy and Photogrammetry  
Proff. A. Carosio, A. Grün, H. Ingensand, H.-G. Kahle, C. Giger, A. Geiger



IGT Institute for Geotechnical Engineering  
Proff. G. Anagnostou, A. Puzrin, S.M. Springman



IHW Institute of Hydromechanics and Water Resources Management <sup>2)</sup>  
Proff. P. Burlando, W. Gujer, W. Kinzelbach, S. Hellweg, M. Boller, H. Siegrist, F. Stauffer



IKA Institute of Cartography  
Prof. L. Hurni



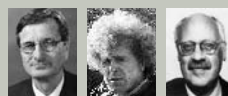
IRL Institute of Spatial and Landscape Planning  
Proff. W.A. Schmid, S. Kytzia



IVT Institute of Transport Planning and Systems  
Proff. K.W. Axhausen, U. Weidmann, P. Spacek



VAW Laboratory of Hydraulics, Hydrology and Glaciology  
Proff. H.-E. Minor, M. Funk, W. Hager



<sup>1)</sup> Master programme starting in WS 2006/07

<sup>2)</sup> From January 2006: Institute of Environmental Engineering (IfU)

## Faculty

### Retirements

Prof. Dr. Edoardo Anderheggen Computer Sciences September 30, 2005

### Appointments

There were no new professorial appointments in 2005.

### Students (Date: December 31, 2005)

	AC 01	AC 02	AC 03	AC 04	Higher Semsters DS	Vacation	Special Students	Guest Students	Total	MAS
Students										
Civil Engineering	130	69	57	74	48	24	12	3	417	–
Environmental Engineering	48	44	30	3	19	43	6	1	194	–
Geomatic Engineering & Planning	23	21	19	2	18	24	1	7	115	26
Total	201	134	106	79	85	91	19	11	726	26

	PhD-Students	PhD-Diploma
Civil Engineering	85	16
Environmental Engineering	30	8
Geomatic Engineering & Planning	48	5
Total	163	29

AC = Annual Course, DS = Diploma Students, MAS = Master of Advanced Studies

### Staff D-BAUG (Date: December 31, 2005)

	Professors (P, AP)	Senior Staff (incl. TP)	Assistants, PhD-Students, Scientific Staff	Technical Staff	Administrative Staff	Apprentices	D-BAUG Staff total (Capita)	FTE total [%]
Dept.	0	8	0	6	2	0	16	1320
IBB	2	2	14	–	2	1	21	2015
IBK	5	5	36	5	5	3	59	5028
IfB	1	2	12	5	4	2	26	2155
IGP	5	7	36	3	6	2	59	5259
IGT	3	7	23	13	5	0	51	4490
IHW	3	5	25	3	4	0	40	3095
IKA	1	5	17	4	2	0	29	2410
IRL	2	7	19	1	1	0	30	2580
IVT	2	10	28	3	3	0	46	4170
NSL <sup>1)</sup>	0	6	1	3	3	0	13	510
VAW	1	11	25	17	3	1	58	5420
Total	25	75	236	63	40	9	448	38452

P = Professor, AP = Assistant Professor, TP = Titular Professor

FTE = Full Time Equivalent

FTE Figures without Student Assistants, Hourly Wage Employees, Trainees, "occupied Workplaces"

<sup>1)</sup> financed by D-BAUG (NSL = Network City and Landscape)

### Master of Advanced Studies (MAS), Postgraduate Courses (ZLG), Short Courses

	Institute	Title
MAS	NSL	Spatial Planning
MAS	VAW/IHW (IfU) + EPFL	Water Resources Management and Engineering
ZLG	IBK / LSA / EPFL et al.	Risk and Safety of Technical Systems
ZLG	NSL	Spatial Development
Short Course / Seminar	IBB	Construction Company Management
Short Course / Seminar	IBB	Construction Equipment and Inventory Management
Short Course	IGT	Ground Improvement
Postgraduate Cours	IGT/UPC Barcelona Spain	Constitutive modelling of Geomaterials

## Workshops, Symposia, Congresses

Event	Institute	Topic	Date (in 2005)
Workshop	VAW	Sustainable Management of Rivers: Rhone-Thur Project	March 9
Conference	IVT et al.	5th Swiss Transport Research Conference	March 9–11
IBK-Seminar	IBK	Risiko und Sicherheit: Information zur Gruppe und den aktuellen Projekten	April 25
Congress	IGP	International Conference “Advanced Remote Sensing for Earth Observation: Systems, Techniques and Applications”	May 7–11
LCC04, International Workshop	IBK / Michigan University	Life-Cycle Cost Analysis and Design of Civil Infrastructure Systems	May 8–11
Workshop	IGP	Meeting of ISPRS Council with Swiss Geomatics Organisations and Firms (ISPRS = International Society for Photogrammetry and Remote Sensing)	May 13–15
Workshop	IVT	Viriato / Open Track	May 19–20
Congress	IVT / SMA + Partner	Data and IT Systems for Railways	May 20
IFIP, 12th WG 7.5 Working Conference	IBK / Aalborg University	Reliability and Optimization of Structural Systems	May 22–25
Congress	IGP	International Workshop “Recording, Modeling and Visualization of Cultural Heritage”	May 22–27
Conference OMAE 2005 Technical Session 2-10	IBK / ASME	Risk Based Inspections and Maintenance II	June 12–17
Congress ICOSAR 2005 Special Session 7	IBK / Rome University	Decision Making in Engineering	June 19–23
Seminar	IVT	Current large scale regional and national transport demand models	June 23
Workshop	IGP	ISPRS Student Consortium Summer School “Satellite Data Processing and Spatio-Temporal Analysis for Resource and Disaster Mapping, Monitoring and Management”	June 19–26
Workshop	IGT / BOKU Vienna	Modern Trends in Geomechanics	June 27–29
Workshop	IGP	4th Image Sensing Seminar on “3D Measurement, Modeling and Visualization by New Digital Sensors”	August 15–16
Workshop	IGP	ISPRS WG V/4 Workshop “3D Virtual Reconstruction and Visualization of Complex Architectures”	August 22–24
Workshop	IBK / AIT Bangkok	Sustainable Management of Natural Hazards in the Region of South-East Asia	August 22–26
Workshop	IBK / Lignum / BUWAL	Development of Successful new Timber Products and Technologies	August 25
Symposium	IGP / Leica Geosystems	Geomatics News at ETH Zurich	September 1
Congress	IGP / geomETH	1st -Range Imaging Research Day	September 8–9
Congress	VAW	IAHR 70 Years	September 14
PhD Workshop	IBK / VAW / IKA	Natural Hazards in an Alpine Valley	September 19–22
Congress	IGP	7th Optical 3D Measurement Techniques	October 3– 5
Symposium	VAW / EAWAG / WSL / EPFL	VAW 75 years	October 7
Congress	IGP	ISPRS Tutorials, AfricaGIS 2005	Oktober 31– November 4
Congress	IBK / SAH	37th Congress of Swiss Society for Wood Research	November 2–3
Congress	IBB	ZipBau Workshop: Simultaneity of Shrinking and Growing in Spatial Development	November 9
Symposium	IBB	Tunneling Innovation - Back-Cutting Technology	November 17
Workshop	IGP / geomETH / DVW	Terrestrial Laserscanning	November 21–22
Workshop	IBK / BOKU Vienna	Technical Systems and Natural Hazards	November 24–25
Congress	IGP	SGPBF Workshop “Digital Aerial Cameras – Experiences and methodological Developments”	November 25
Workshop	IBK / JCSS / IABSE	Robustness of Structures	November 28–29
Symposium	IBB	Integrated Construction - The Swiss Construction Market in the International Context	December 1
Symposium	IVT	Traffic flow at the interface between traffic engineering and transport planning	December 1
Workshop	IGP	ISPRS Caravan Workshop “Remote Sensing and GIS for Watershed Management”	December 5–9
Colloquium	IfB, Timber Physics	Wood sciences “Innovative Utilisation and Products of large dimensioned Timber including the whole Forest-Wood-Chain”	December 19



## Honours

Name	Institute	
Prof. Dr.-Ing. Gerhard Girmscheid	IBB	John O. Bickel Award for the best original paper published by ASCE in 2003 concerning the design and/or construction of a rail or vehicular tunnel
Prof. Dr.-Ing. Gerhard Girmscheid, Prof. Christian Brockmann	IBB	Best Paper Award, CIB 11th International Symposium "Combining Forces" in Helsinki
Prof. Dr. Mario Fontana	IBK	"Owl 2005 VSETH" for Best Professor in Teaching in D-BAUG
Prof. Dr.-Ing. habil. Peter Niemz	IfB	Collano Innovation Prize
Prof. Dr. Alain Geiger	IGP	Supervisory Board/Editorial Committee European J. Navigation
Prof. Dr. Armin Grün, Fabio Remondino, Dr. Zhang Li	IGP	E.H. Thompson Award 2005, Remote Sensing and Photogrammetry Society (RSPSoc., GB) for their article "Photogrammetric Reconstruction of the Great Buddha of Bamiyan, Afghanistan"
Prof. Dr. Hilmar Ingensand	IGP	Honorary Guest Professor of Technical University Wuhan (China)
Prof. Dr. Hans-Gert Kahle	IGP	Chairman Scientific Advisory Committee GeoForschungsZentrum Potsdam
Prof. Dr. Sarah M. Springman	IGP	Elected Life Fellow of the Royal Society for the Encouragement of Arts, Manufactures & Commerce RS
Prof. Dr. Peter Spacek	IVT	Titular Professor ETH Zurich
Dr. sc. techn. Thorsten A. Busch	IBB	"Construction Operation Support Award" for an excellent doctoral thesis in 2005
Dr. Daniel Straub	IBK	Silver Medal for an excellent doctoral thesis, ETH Zurich and René-Hornung Medal, Swiss Society of non-destructive Testing (SGZP), EMPA, Dübendorf
Dr. Jana Niederoest	IGP	Eratosthenes Prize 2005, Supporting Circle of Surveying and Alignment Museum Dortmund/Germany
Dr. Zhang Li	IGP	Carl Pulfrich Prize 2005, Z/I Imaging
Kazuyoshi Nishijima, PhD-Student	IBK	Japan Association for Wind Engineering Award - Japan Association for Wind Engineering
Jafar Amiri Parian	IGP	Leica Geosystems Prize 2005, Swiss Society for Optics and Microscopy (SSOM)
Anton Sres, PhD-Student	IGT	Best Presentation at GeoDACH Meeting in Graz, Austria
Daniel Bucher, Dipl. Bau-Ing. ETH	IBB	Construction Operation Support Award: "Baubetriebliche Analyse von Vortrieb und Baulogistik im Teilabschnitt Sedrun des Gotthard-Basistunnels"
Philipp Niederegger, Dipl. Bau-Ing. ETH	IBK	Culmann Award: "Tragverhalten von C-Profilen bei Brandeinwirkung"
Michael Müller, Dipl. Geom. Ing. ETH	IGP	ETH Diploma Medal for excellent Diploma Work: "Ionosphärenmodellierung mittels GPS-Messungen"
Hannes Eugster, Dipl. Geom. Ing. ETH	IGP	Willi-Studer Award for best Alumnus in 2005: "Geoidbestimmung des Bodensees"
Stephan Landtwing, Dipl. Geom. Ing. ETH	IGP	Geosuisse-Prize: "Airborne Laser Scanning - Genauigkeitsinformationen für den Auswertungsprozess".
Michael Iten, Dipl. Bau-Ing. ETH	IGT	Culmann Award: "Gründungssanierung A2 Schopflibachbrücke (UR)"
Stephan Pfister, Dipl. Geom. Ing. ETH	IHW	ETH Diploma Medal for excellent Diploma Work: "Usage of an Aquifer as Underground Reservoir for Irrigation"
Christoph Ort, Dipl. Kulturingenieur ETH	IHW	Poul Harremoës Award, best Paper of a young Author: "Sampling for representative Micropollutant Loads in Sewer Systems"
Alexander Erath, Dipl. Bau-Ing. ETH	IVT	VSS Prize: "Zahlungsbereitschaften im Einkaufsverkehr"
Matthias Huss, Dipl. Natw. ETH	VAW	Willi-Studer Award for best Alumnus in 2005 and ETH Diploma Medal: "Gletscherseeausbrüche und Massenbilanzabschätzungen"
David Felix, Dipl. Bau-Ing. ETH	VAW	Willi-Studer Award for best Alumnus in 2005 and ETH Diploma Medal: "Stabilisierung von Flusssohlen mit Traversensystemen - Experimentelle Untersuchung"

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