Institute for Hydromechanics
Karlsruhe Institute of Technology (KIT)

Institute for Hydromechanics, Karlsruhe Institute of Technology
Water Research Laboratory: Status 2014

1 History

Ever since the founding of the "Polytechnikum" in Karlsruhe by Johann Gottfried Tulla in 1825, special emphasis has been placed upon teaching and research in Hydraulic Engineering. After the construction of a Laboratory for River Improvement in 1901 – the second of its kind in the world - research in this field under Professor Theodor Rehbock gained world-wide renown. The establishment of the new hydraulics laboratory by Theodor Rehbock in the basement of the now so-called Old Civil Engineering Building (Fig. 1) in 1921 was a milestone. Today, this laboratory is the Institute for Hydromechanics' water research laboratory. Through major advancements in theory and practice of hydraulic modeling the Karlsruhe school achieved worldwide reputation.

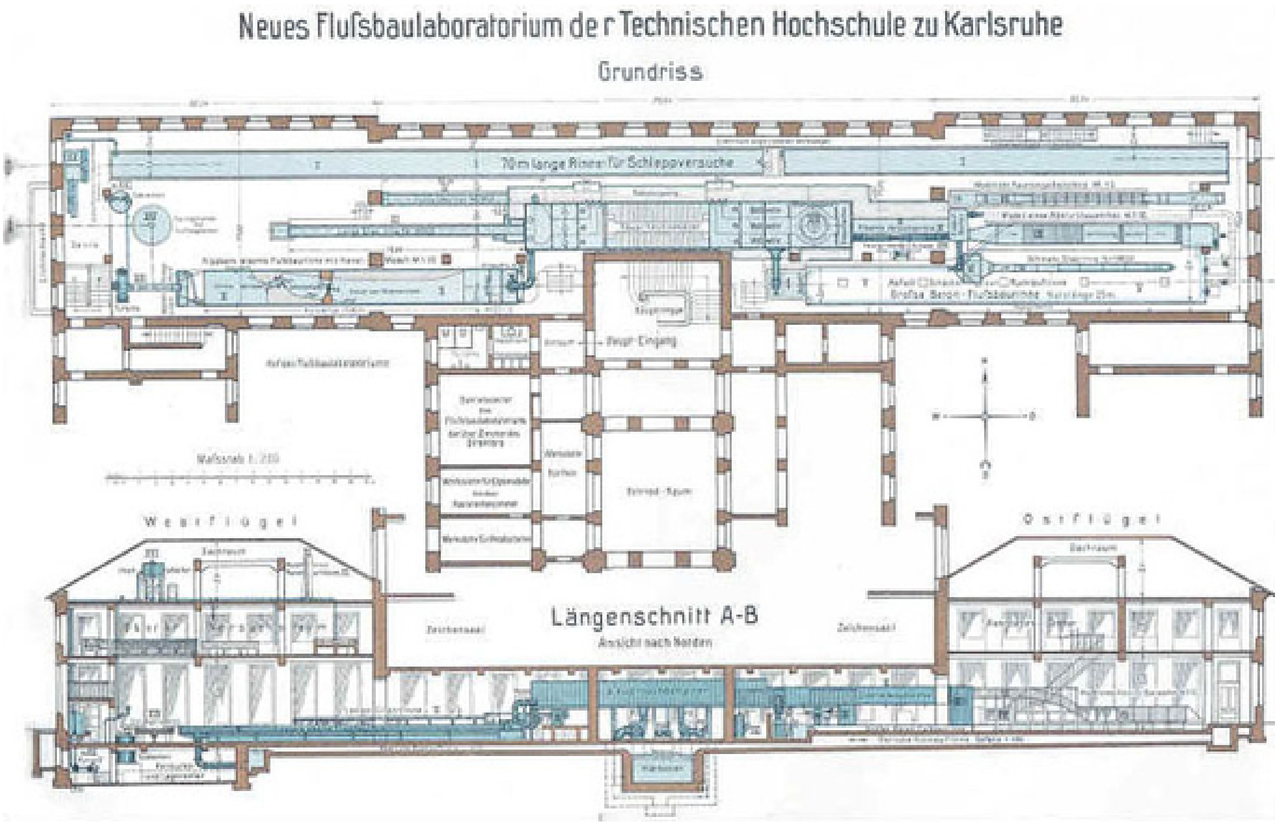

Fig. 1: Water Research Laboratory, 1921

The Institute for Hydromechanics (IfH) was founded in 1948 as one of two successor institutes to the prior Chair of Hydraulic Engineering and Water Resources. In the following years the IfH was involved in two major Special Research Initiatives (SFB) sponsored by the German Science Foundation (DFG). These were SFB 80 (1971-83) "Mixing and transport processes in flows" and SFB 210 (1983-95)

"Fluid mechanical design principles for structures". These initiatives led to the establishment of new research areas and an expansion of the laboratory installations.

Fundamental research at the IfH is aimed at an improved understanding of fluid mechanical phenomena in water (water research laboratory) as well as air flow systems (aerodynamic laboratory). Besides hydraulics in pipes and open channels, further areas of investigation are technical and environmental mixing and transport processes, groundwater flow, hydraulics of structures and building and environmental aerodynamics. Current research projects deal with basic questions and practical problems of fluid mechanics including environmental fluid mechanics and with developments of new measurement techniques in fluid flows.

So far, the following professors taught and directed water research at the IfH:

1. Paul Böss (1934-59)
2. Max Breitenöder (1964-67)
3. Eduard Naudascher (1968-94)
4. Harry Thielen (1969-95)
5. Helmut Kobus (1973-77)
6. Franz Durst (1977-82)
7. Wolfgang Rodi (since 1982)
8. Gerhard Jirka (1995-2009)
9. Bodo Ruck (since 1998)
10. Markus Uhlmann (since 2008)

At present, the position of a Full Professorship for Fluid Mechanics is vacant.

2 Present Situation

The Water Research Laboratory covers an area of 900 m² and is divided into two main sectors, East and West, each with its own pump station.

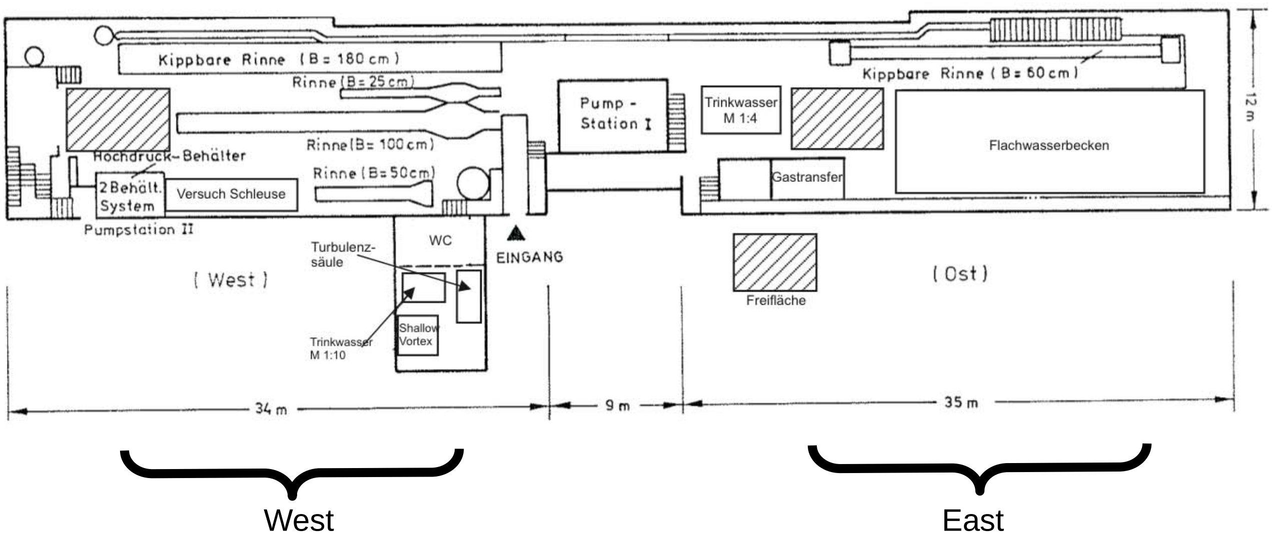

Fig. 2: Water Research Laboratory, 2014

3 Water Circulation System

The water research laboratory (Fig. 2) is fed by two pump stations with a total output of about 1100 l /sec. The historical former 70m-long underfloor towing tank with a total volume of of approximately 150 m^3 serves as a common low-level reservoir for both pump stations.

Pump station I is located in the centre of the water laboratory (Fig. 2) and consists of four centrifugal pumps which discharge 25, 80, 165 and 250 l/s respectively into the high-level tank situated above. The maximum inflow rate into the tank of pump station I is thus 520 l/sec. The tank has a volumetric capacity of approximately 40 m^3 and disposes excess water through a a fixed overfall located at 3.80 m above the laboratory floor. The major part of the laboratory flumes (see Table 1) are supplied with water by pipes from pump station I and its high-level tank.

Pump station II is situated at the western side of the water laboratory (Fig. 2) and consists of four centrifugal pumps with 250 l/sec pump capacity each. Above pump station II a two-tank system is installed, designed as a high-level tank with a volume of approximately 70 m^3 being able to supply experimental set-ups with pressure heights up to 10 m above laboratory floor in the western part of the laboratory.

A supply line (d=450 mm) is also fed by pump station II.This supply line leads along the northern side along a large part of the water laboratory further tap connections are available for the laboratory.

4 Test Facilities

4.1 Stationary test facilities

Also part of the water laboratory are five straight free-level flumes

No.	Width (m)	depth (m)	length (m)	Q_{max} (l/s)	remarks
1 West	1.80	0.60	20.00	150	tilting: +2%, -1% concrete floor and walls, 2 glass windows
2 West	1.00	0.70	12.00	250	horizontal glass walls and 2 glass floor elements
3 East	0.60	1.00	13.00	80	tilting: +5%, -1% separate water circulation, floor and walls partly made of glass
4 West	0.50	0.70	4.00	100	horizontal glass walls
5 West	0.25	0.60	3.50	50	horizontal glass floor and walls

Tab 1: Open Channel Flumes

Shallow Water Basin (eastern lab section):

variable height:	H_{max} = 0.25 m
width:	5.48 m
length:	13.50 m
discharge:	Q_{max} = 200 l/sec

The shallow water basin has its own independent circulation. It is supplied with a multiport diffuser intake and outtake. During construction of the basin, special emphasis was placed on a smooth and planar bottom surface. The possible measurement techniques include surface Particle Tracking Velocimetry (PTV) for velocity measurements of the large-scale structures and Planar Concentration Analysis (PCA) /Laser Induced Fluorescence (LIF) for concentration measurements. For small scale structures Particle Image Velocimetry (PIV) and PTV measurements can also be performed. Any location in the basin can be reached by a fully automatic 3D traversing system on which additional point measurement systems can be mounted.

Detailed Description: Carl von Carmer, Shallow Turbulent Wake Flows: Momentum and Mass Transfer due to large Scale Coherent Vortical Structures, Ph.D. Thesis 2005,
(http://www.uvka.de/univerlag/volltexte/2005/69/)

Fig. 3: Shallow Water Basin (left) and Flume No. 3

Fig. 4: Flumes No. 1 (left), 2 (middle) and 5 (right)

4.2 Other stationary research equipment

Test stand “gas water transfer” (Fig. 5):
This installation is used to investigate gas transfer at the water surface (see Figure 5). Currently a cooling system is connected to the tank, inducing a thermal instability of the Rayleigh-Benard type. In this experimental facility both Particle Image Velocimetry (PIV) and Laser Induced Fluorescence (LIF) for oxygen concentration measurement can be performed.

Detailed description: Herlina, Gas transfer at the Air-Water Interface in a Turbulent Flow Environment, Ph.D. Thesis 2005 (http://www.uvka.de/univerlag/volltexte/2005/71/pdf/Herlina.pdf)

Test stand “Turbulence Differential Column” (Fig. 6):
This facility is used to create quasi-homogeneous turbulence or vertical profiles of turbulent intensities through ten independent computer-controlled motors. The system features an automatic water sampling system, located at five vertical positionsThe main aspect is the investigation of fine sediment dynamics under the influence of turbulence and mass exchange processes in benthic boundary layers induced by turbulence.

Detailed description: Gregor Kühn, Untersuchungen zur Feinsedimentdynamik unter Turbulenz-einfluss, Ph.D. Thesis 2007 (http://www.uvka.de/univerlag/volltexte/2008/299)

Figure 5: General view of the oxygen transfer facility

Figure 6: General view of the Turbulent Differential Column

Test stands “Drinking Water Tanks”:

Two models of a rectangular water tank with two different geometric scales (smaller-scale model fully glazed and large-scale model) were set up for the experimental investigation of flow through drinking water tanks in the context of the BMBF project „Optimised planning and management of drinking water tanks to avoid micro-biological pollution – field studies, physical and numerical experiments”. The smaller tank with a total volume of 180 l is made of glass and is thus completely transparent, including the bottom side. It is fed through its own low-level/high-level reservoir circulation system. The larger tank is has a total volume of about 1800 l, is made of plywood with one transparent plexiglass side wall and is easily adaptable to different sizes and inflow/outflow configurations. It is fed through the laboratory’s pump station II and can be run in water recirculation or discard modes. Both tanks are equipped with systems for bulk conductivity measurements and for dye visualisations.

This project is focused on the understanding of the scale effect, normally included on the laboratory analysis of the dynamics of water storage tanks agitated by a turbulent jet. It is the final aim of this project to understand, through laboratory experiments, the flow structure within a water storage tank and to identify zones of low mixing that can produce water quality problem due to bacteriological contamination.
(http://www.ifh.uni-karlsruhe.de/science/envflu/research/mixing-tank/default.htm).

4.3 Free laboratory space

Sufficient laboratory space is still available for setting up temporary experimental models. Water supply is possible through the main supply line from pump station II with several taps available with up to with up to 200 l/sec flow rate.

4.4 Measurement Systems

- Velocity measurement with multi-component devices: laser and acoustic doppler-velocimetry (LDA, ADV), laser tomography, particle tracking and image velocimetry (PTV, PIV), hot wire and hot film anemometry. The imaging-based equipment includes for example:
  - Laser System 1: Continuum Inlite-II PIV (double-pulsed Nd:YAG) 2x20Hz, 120mJ (@532nm), pulse width 5-7nsec
  - Laser System 2: Spectra-Physics Stabilite 2016 8W cw argon-ion laser
  - Cameras: 2x Allied Vision Prosilica GE1650, gigabit ethernet cameras, 1 inch CCD 1600x1200 px², 12bit monochrome, 32Hz, additional various single piv cameras with 1-1.3MP/8-16Hz
- Lenses: 2x AF-Nikkor 50/1.8, Nikon F-Mount, 2x Sigma 24/1.8, Nikon F-Mount, various wide angle C-mount lenses in identical pairsMass concentration measurement: laser induced fluorescence (LIF) in combination with LDV or PIV
- Particle size analyzer
- Pressure and force transducers for hydraulic and soil mechanic parameters
- Automatic experimental control and data acquisition with LabView

5 Applied research projects in the Water Research Laboratory during 2005-2013

In addition to the already completed as well as ongoing doctoral theses and research projects mentioned above, the following applied research and contract projects were carried out in the flumes and on the open areas during the last seven years (see also Annual Reports of the Institute for Hydromechanics, http://www.ifh.kit.edu/130.php):

2005:
- Fluid Mechanical Optimization of Electro-Deposition Process for Thin Film Solar-Cell Production – Angew. Forschung Electricite de France (Jirka, Lang, Weitbrecht)
- Cooling Water Recirculation QAFCO 4, Qatar – Auftrag UHDE Dortmund (Freifläche West), (Lang)

2006:
- Experimentelle Untersuchungen zur Auswahl eines Rührwerks im Belebungsbecken der Kläranlage Stuttgart-Mühlhausen – Auftrag Stadt Stuttgart (Rinne 1,0 m und Freifläche Ost), (Lang, Pickert)
- Regenwasserbehandlungsanlage FluidControl – Industrieauftrag (Freifläche Ost), (Lang)

2007:
- Rehabilitation of Navigation Look Portile de Fier I, Donau Rumänien – Auftrag DSD NOELL Würzburg (Pumpstation II - Hochdruckanlage), (Lang, Balachandran)
- Modelluntersuchung eines Grundwasserzirkulationsbrunnens – Industrieauftrag (Freifläche West), (Mohrlok)

2008:
- Experimentelle Untersuchungen zur Entfernung des Leitrohrs am Rührwerk, Kläranlage Stuttgart-Plieningen - Auftrag Stadt Stuttgart (Freifläche Ost), (Lang, Detert)
- Testmessungen mit ADV-Sonden in Ölströmungen der Daimler AG – Industrieauftrag (Freifläche Ost), (Bleninger, Stache)

2009:

- Cooling Water Recirculation SORFERT, Algeria – Seawater Blow Down System – Auftrag UHDE Dortmund (Freifläche Ost), (Lang, Stache)

Due to staffing difficulties in the IfH no applied research projects could carried through in 2010 und 2011

2012:

- Modelluntersuchung Durchmischung Trinkwasserbehälter – Auftrag Bodensee-Wasserversorgung (Freifläche Ost), (Vaas, Lang)

2013:

- Entwicklung und Konstruktion Strömungskanal für die Ausstellung *"bodenlos - durch die luft und unter wasser"* des Staatlichen Museums für Naturkunde (http://www.bodenlos2013.de/), Karlsruhe (Freifläche West), (Lang, Klausmann, Ulrich, Ziegler)

6 Additional Information

6.1 Academic Courses

Academic courses are offered by the IfH within the diploma, B.Sc. and M.Sc curriculums in civil engineering at the University of Karlsruhe. This includes fundamental and applied lecture courses in the area of hydromechanics, technical hydraulics, environmental fluid mechanics, and aerodynamics. Instruction covers the theoretical foundations as well as experimental simulation and computational methods. Applications are offered through practice-oriented examples, special projects and demonstrations in the student fluid mechanics instructional laboratory. For further information see here: http://www.ifh.kit.edu/english/28.php

6.2 Research in the Group Turbulent Flows

http://www.ifh.kit.edu/english/105.php

6.3 Research in the Laboratory of Building and Environmental Aerodynamics

http://www.ifh.kit.edu/english/112.php

6.4 Contact Persons

Dr.-Ing. Cornelia Lang, http://www.ifh.kit.edu/211_223.php

Dipl.-Ing. Markus Vaas, http://www.ifh.kit.edu/235_940.php

Dr.-Ing. Herlina, http://www.ifh.kit.edu/235_726.php

Dipl.-Ing. Katharina Klausmann, http://www.ifh.kit.edu/235_1122.php

Dipl.-Ing. (FH) Dieter Gross, http://www.ifh.kit.edu/233_182.php