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PhD School - Politecnico di Milano
Regulations of the PhD Programme in:

Environmental and Infrastructure Engineering

Cycle XXXIV

1. General Information

PhD School - Politecnico di Milano

PhD Programme: Environmental and Infrastructure Engineering

Course start: November 2018

Location of the PhD Programme: Milano Leonardo

Promoter Department: Department of Civil and Environmental Engineering (DICA)

Scientific Disciplinary Sectors

- ICAR/01 Hydraulics
- ICAR/02 Hydraulic and maritime constructions and Hydrology
- ICAR/03 Sanitary Environmental Engineering
- ICAR/04 Highways, railways and airports
- ICAR/06 Topography and Cartography
- GEO/05 Applied Geology

PhD School Website: <http://www.dottorato.polimi.it/en/>

PhD Programme Website: <http://www.dica.polimi.it/en>

Areas:

01 Water Science and Engineering - SSD ICAR/02 (Hydraulic and maritime constructions and Hydrology)

02 Transport infrastructures and geosciences - SSD ICAR/04 (Roads, railroads and airports) - SSD GEO/05 (Applied Geology)

03 Environmental and Hydraulic Engineering and Geomatics - SSD ICAR/03 (Sanitary Environmental Engineering) - SSD ICAR/01 (Hydraulics) - SSD ICAR/06 (Topography and Cartography)

2. General presentation

The PhD course is run by a Coordinator and a Faculty Board.

The Coordinator chairs the Faculty Board, coordinates the preparation of the annual Educational Programme and organises the general educational activities of the PhD course (see Attachment A1).

The Faculty Board is responsible for the Educational programme and for teaching and administrative activities related to the PhD course (see Attachment A2).

The PhD in Environmental and Infrastructure Engineering is part of the research and educational

program offered at the Department of Civil and Environmental Engineering. The program introduces doctoral students to the world of research on critical theoretical and technological elements associated with water, environment, hydraulic and transportation infrastructures, geology as well as geomatics. The program is characterized by a strong inter- and multi-sectoral structure and is organized according to the following three key thematic profiles: (i) Hydrology, Hydraulic Structures, Water Resources and Coastal Engineering; (ii) Transport Infrastructures and Geosciences; (iii) Environmental Technologies, Hydraulics and Geomatics. Educational and research activities are designed to integrate qualitative process identification, rigorous mathematical treatment and modeling according to increasing levels of complexity, and presentation and design of ensuing applications and implications to engineering problems and scenarios.

Area 01 - “Water Science and Engineering”

The main research activities of “Area 01” are centred on the field of water resources spanning from hydrology to coastal engineering. The research activity constituting the core of the profile is fully recognised by the national and international research community. Research activities place PhD students in the network of international research and allow them to improve the state of knowledge with outstanding work in the fields of hydrological sciences, hydrological extremes, network hydraulic infrastructure as well as maritime hydraulics. The research topics and methodological approach render the student curriculum fully acknowledged by major academic institutions, private enterprises and national and international organisations as demonstrated by career opportunities of former PhD students. A short description of the main research branches is given in the following.

1. *Hydrology and water resources*: addresses in-depth understanding of the main physical processes of the hydrological cycle which determine flood as well as drought phenomena and pollution migration. Measurement and modeling of variables active in water and energy budgets (radiation, evapotranspiration, snow mantle dynamics, hydrological losses) are carried out. In situ data as well satellite data of the earth's surface are used to understand the processes and their representative scales. Continuous distributed water balance models are developed for simulating and monitoring flood as well drought processes.
2. *Hydrogeological hazard and mitigation strategies* focuses on the analysis of hydrological extremes, frequency of floods, droughts and precipitation. Probabilistic, stochastic and physically based models are used together with field observation to study and reproduce rainfall fields, floods and droughts. Early warning operative systems are developed for shallow land sliding, snow avalanching and flood risk.
3. *Hydraulic networks engineering* addresses the evaluation of design variables for urban sewage and aqueducts. In particular, water quality and quantity in drainage networks and effects of local and diffused structures for flood and pollution controls are investigated. Aqueduct efficiency and monitoring of water losses and pollution in a pressurized network are investigated.
4. *Coastal engineering* addresses the hydrodynamics of wave motion, marine currents, littoral dynamics, wave-structure interactions, Lagrangian and Eulerian numerical models.

Area 02 - “Transport infrastructures and geosciences”

The main research topics considered as fundamental for the development of research activities

concerning transport infrastructures could be summed up in four main topics, reciprocally connected to the topics related to other PhD research profiles.

1. *Transport networks*. Complex transport network modelling (both homogeneous and non-homogeneous modal networks), also considering the functional interactions with regional, national and international territory.
2. *Sustainable development*. Analysis of the complex phenomenology characterizing the dynamics of development and its relations with the infrastructure system. Interaction between tunnels and underground hydraulic systems.
3. *Technological innovation*. Analysis of methods, criteria and indicators for the performance characterization of infrastructure construction and maintenance techniques.
4. *Risk management*. Analysis and development of improvement measures concerning both the construction and management of road infrastructures, aimed at reducing risk for both workers and users. Geological risk deriving from the construction of transportation infrastructures.
5. *Applied geology*. a) analysis of the hydrogeological risk linked to the underground excavation in rocks (e.g., water inflow, piezometric drawdown); b) landslide hazard (assessment of the influence of key hydrogeological parameters, such as permeability and heterogeneity coefficient, on slope instability); c) water resources identification and management, pollution problems, also in coastal aquifers.
6. *Methods*: modelling and decision process analysis, at both a strategic, tactical and operative level, characterizing road infrastructure design, construction and management (including Project Management, Pavement Management Systems, Bridge Management Systems).

Area 03 – “Environmental and Hydraulic Engineering and Geomatics”

Research in **Environmental Engineering** covers the following topics:

1. Water supply technology and treatment, wastewater treatment and reuse, liquid waste treatment, recovery of energy and products from wastewater, liquid waste and sludges, advanced biological and physical-chemical water and wastewater treatment; sludge management and disposal; anaerobic biotechnologies.
2. Management and planning of environmental resources: source apportionment of pollutant loads and assessment of their effects on the receiving water bodies/environmental components; water quality modelling, scenario analysis and knowledge-based decision support systems of management alternatives.
3. Solid wastes and sludge minimization and management (composting the organic fraction of solid wastes, waste-to-energy plants, sanitary landfill, leachate treatment, hazardous waste solidification). Bioenergy from agricultural wastes and by-products.
4. Air quality assessment and control (statistical models of air quality data, source apportionment techniques, sampling and monitoring of fine and ultrafine atmospheric particles, emissions modelling for impact assessment), gaseous emissions treatment technologies (measurement/analysis of conventional and trace pollutant emissions at lab and field scale plants, evaluation of process techniques for pollutants removal).
5. Contaminated soil, sediment and groundwater: characterization, risk assessment, in-situ and on site remediation technologies.

Research topics of **Hydraulic Engineering** include: fluid mechanics; fluid-structure interactions; hydraulic measurements; river hydraulics; hydraulic risk quantification and management; flow and transport processes in porous systems; hydraulic networks. Experimental, modeling and methodological aspects are considered. Key research areas include:

1. *Fluid mechanics*. Emphasis is devoted to the analysis of physical processes observed at various scales and their depiction in the context of appropriate interpretive models. Research and educational activities comprise analysis of advanced methodologies of computational and experimental fluid dynamics (e.g., image analysis techniques for hydraulic processes on multiple observational scales) and modeling of processes of fluid-structure interactions for environmental, civil and industrial engineering applications.
2. *River hydraulics and sediment mechanics*. The key research topics are associated with optimization of approaches and technologies for land protection. Research and educational activities include modeling of free surface flows, local and general scour processes, hyper-concentrated flows, flooding and hydraulic risk quantification and management.
3. *Flow and transport processes in porous systems*. Key research topics include: characterization of hydraulic properties from pore-scale to aquifer systems; well testing; inverse modeling / history matching / data assimilation; flow and multicomponent reactive transport process in heterogeneous media under uncertainty; multiphase flows, including oil and gas reservoir engineering; scaling of hydrogeological quantities; mixing processes in coastal aquifers; geothermal fluxes at the reservoir and basin scales. A major focus is the study of theoretical and operational bases for the assessment of hydro-geo-chemical processes governing the distribution and residence time of solutes and fluids in the subsurface. Critical applications include quantification of environmental risk associated with polluted aquifer systems and the improvement of enhanced oil recovery approaches.

Geomatics includes all disciplines dealing with positioning, global and local reference system establishment, surface surveying and reconstruction from a global scale down to the scale of the individual architectural manifold, representing data by graphical or virtual tools, archiving and cross-referencing spatial information in terms of geographic information systems. Summarizing, we can identify the following education and research topics:

1. *Physical geodesy and satellite geodesy*, including estimation and representation of the gravity field at all scales and its geophysical interpretation.
2. *Positioning, deformation estimation and navigation*, with the use of both classical and satellite techniques, such as GPS.
3. *Surface surveying with optical or other sensors*, such as SAR, LIDAR, etc., at different scales from regional down to the manifold scale.
4. *Digital photogrammetry and image analysis*, including the development of photogrammetric software for the geometrical reconstruction of surfaces and feature extraction.
5. *Remote sensing*, namely the problem of identifying, by suitable spectral analysis, specific geographic information.
6. *Geographic information systems*, with application of the most modern technology for internet GIS and mobile GIS.
7. *Cultural heritage reconstruction and archiving*, with the solution of complex problems of

combination of different data into a unique data base, providing three-dimensional virtual models that preserve full geometrical and metrical information.

3. Objectives

The PhD degree is awarded upon completion of at least three years of advanced study and research. Within the context of these years, a minimum of 25 credits (Section 6) must be acquired through *PhD level courses*. The PhD Programme is structured according to the three areas illustrated in Section 2, i.e., 01 *Water Sciences and Engineering*, 02 *Transport infrastructures and Geosciences*, and 03 *Environmental and Hydraulic Engineering and Geomatics*.

Introductory courses provide the knowledge required as a basis for the general framework illustrated in the PhD Programme and provide the common knowledge background to PhD students. Research training is provided through mentoring by the highly qualified Faculty members. Main elements of the programme include: (a) an improved preparation of candidates at the fundamental level, as required by the PhD School, with the introduction of new opportunities for student evaluation through written exercises or oral examinations, and (b) development of a close connection with industry to foster the emergence of outstanding professional abilities attractive to industry.

PhD courses will leverage on the long-standing experience and know-how in laboratory activities of the academic board members. Of key relevance are the training and research activities associated with the Laboratories (Section 7).

Contacts with bodies other than Universities have been established through participation to specialized seminars and refresher courses provided by experts from industry, together with short training internships for PhD students at highly qualified companies.

The most qualifying activity of the entire PhD Programme is the development of the thesis/dissertation. This phase should reflect the leading and unconditioned role of research and is fully in line with the requirements and needs of authorities, public bodies and private companies.

The long-desired innovation in ecosystem services and industry should be a long-lasting product of sound research activity which only a University can provide, especially for the benefit of small and medium-size enterprises which cannot afford the burden of an in-house research centre.

A research experience at International Research Centres and/or Universities is considered to be highly relevant for PhD students to complete their education and to exchange research experience and expertise.

4. Professional opportunities and job market

A PhD in Environmental and Infrastructure Engineering provides highly qualified personnel to cover key positions and roles in research centres, top level management in Public Bodies and Authorities involved in environmental policies, as well as senior consultants for engineering companies.

5. Enrolment

5.1 Admission requirements

Italian and International citizens can apply. They are requested to have graduated in accordance with the pre-existing laws D.M. 3.11.1999 n. 509, or to have a Master of Science degree in accordance with D.M. 3.11.1999 n. 509, or a Master of Science in accordance with D.M. 22.10.2004 n. 270, or similar academic title obtained abroad, equivalent for duration and content to the Italian title, with an overall duration of university studies of at least five years.

The certified knowledge of the English language is a requirement for admission. Please refer to the PhD School website for details.

The admission to the programmes will be established according to the evaluation of the candidates' curricula, motivation letters, and an illustrative report about the development of a possible PhD research, which candidates will send contextually with their application to the admission announcement.

5.2 Admission deadlines and number of vacancies

The number of positions is indicated in the Call for admission to the 34th PhD cycle Programmes:

<http://www.dottorato.polimi.it/en/>

Scholarships both on general and on specific themes are available, in accordance with what is specified in the call for admission.

6. Contents

6.1 Requirements for the PhD title achievement

The achievement of the PhD title in Environmental and Infrastructure Engineering requires a study and research activity of at least three years equivalent of full time study, research and development of PhD thesis.

PhD candidates in Environmental and Infrastructure Engineering must earn a minimum of 25 course credits (see paragraph 6.3 below), and to continuously conduct studies and research.

At the beginning of the course, the Faculty Board assigns a tutor to each PhD candidate to supervise and assist him/her in the overall training programme. The tutor shall be a professor belonging to the Faculty Board. The tutors assist the candidates in the choice of courses to be included in the study plan, which is eventually submitted for approval to the Coordinator of the PhD Programme (see also section 6.4 below).

The Faculty Board may assign extra course credits to one or more candidates, in case they need to complete their preparation in specific topics, relevant for their research projects.

6.2 Research development

The main aim of all Politecnico di Milano PhD programmes is the development in the candidates of a research-oriented mind-set, with expertise and skills in a specific research topic. To this end, candidates develop a problem-solving capability in complex contexts, including the capacity of performing deep problem analysis, identifying original solutions, and evaluating their applicability in practical contexts.

These skills provide the PhD candidates with major opportunities of development in their research both in the academic field, and in public and private organisations.

PhD candidates are requested to develop an original research contribution. The PhD thesis must thus contribute to increase the knowledge in the candidate's research field. Besides, it has to be coherent with the research topics developed in the Department where the PhD Programme is carried out.

The original research results are collected in the PhD thesis, where the candidate's contribution is put in perspective with respect to the research state of the art in the specific research field.

The PhD research is developed under the guidance of a supervisor, who supports the candidate in the setting-out and in the everyday activities related to the thesis development. The supervisor is not necessarily a member of the Faculty Board, and may also belong to an institution different from Politecnico di Milano. The supervisor can be supported by one or more co-supervisors. The supervisor and the tutor may coincide.

Further activities intended to develop the candidate's personal skills and research expertise are encouraged during the PhD path.

Candidates must acquire the capability to present and discuss their work in their research community. Consequently, both the participation to international conferences and the publication of the research results in peer-reviewed journals are encouraged.

The PhD programme favors the candidates' research interactions with other groups in their research field, preferably abroad. Research visits of at least three months are strongly encouraged, as through them the candidates may acquire further skills to develop their research work and thesis.

The duration of the programme is normally three years.

6.3 Objectives and general framework of the teaching activities

The PhD Programmes and the PhD School activate teaching forms of different kind and credit value, including courses, seminars, project workshops, laboratories. Teaching activities both cover the basic research issues (problems, theories, methods), which represent the founding element of the PhD Programme and identify clearly its cultural position, and deepening in a specialist way some research issues connected with the problems developed in the theses.

Lessons are usually held in English, except when indicated otherwise. The PhD programme includes at least one complete path delivered in English language.

Structured teaching activities allow to earn ECTS credits. Other activities, typically specialised and for which it is difficult to evaluate the learning and its quantification, fall within the scientific activities of which the Faculty Board takes into account in the overall evaluation, but they do not allow to earn ECTS.

The PhD School of Politecnico di Milano proposes a set of courses aiming to train the PhD candidates in soft and transferable skills. The skills and abilities provided by these courses are expected to help candidates across different areas of their careers in order to respond to the rapidly evolving needs of the global economy and society at large. The PhD School courses activated for the 2018-2019 Academic Year are summarized in the following table.

Course name	Professor
Innovative Teaching Skills	Magli
Research Skills	Sciuto
Scientific Models: Conceptual Foundations and Philosophical Issues	Valente
The Process of Research	Volontè
Advanced Interaction Skills for Academic Professionals	Arnaboldi
Issue Mapping	Ciuccarelli
La diffusione della Ricerca	Paganoni
Professional Communication	Di Blas
Science, Technology, Society, and Wikipedia	Raos
Scientific Communication in English	Biscari
Ethical Aspects of Research on Dual-Use Products	Masarati
Ethics in Research	Aliverti
Sulla Responsabilità della Tecnica	Ossi
Technology and Society	Crabu
The ageing society: a challenge for technological and social innovation	Ranci Sabatinelli
Industrial Skills	Biscari
Project Management (in Action)	Mancini
Project Management Basics	Fuggetta
Project Management PMI-CAPM Certification Preparation	Fuggetta
Strategic Decision Making	Ferretti
Design Thinking	Deserti
Empowering Imagination	Chiodo Schiaffonati
Resource Planning and Management within Sustainable Development:	Colombo
Sustainability Metrics, Life Cycle Assessment and Environmental Footprint	Lavagna
Complementary doctoral skills	Biscari

At least 10 of the 25 course credits that each candidate is required to earn shall be obtained through soft and transferable skills courses organized by the PhD School.

The didactic structure is reported in the tables below, which summarize the candidate's path (as regards coursework activities). At the same time, the programme foresees that the candidates are devoted to research activity in a continuous way, following the lead of their supervisors, and of the Faculty Board. Evaluation procedures for each course are described in the “Manifesto”.

First and Second Year

<i>Courses</i>	<i>Possible details or reference to following tables</i>	<i>Number of credits (min-max)</i>	<i>Note</i>
<i>PhD School Courses</i>	See Table B	10 - 15	
<i>Courses characterising the PhD Programme</i>	See Table A	10 - 20	
<i>Other PhD courses and international Summer/Winter Schools</i>	See Table C	0 - 10	

Third year

In the third year the candidate should be devoted entirely to the research and to the development of the PhD thesis.

PhD Course List

A) The PhD Programme in Environmental and Infrastructure Engineering organises the **Characterising Courses** listed in table A.

For the admission to the final exam the acquisition of at least 10 credits in this list is **mandatory**.

B) The PhD School organises every year general and Interdoctoral courses. The acquisition of **at least 10 credits** is **mandatory** among the courses of B type. The list of PhD courses organized by the PhD School is available at the website

<http://www.dottorato.polimi.it/en/during-your-phd/phd-level-courses/>

C) Other PhD courses

A maximum of 10 mandatory credits can be obtained by choosing among courses provided by other PhD programmes at Politecnico di Milano and/or external Institutions (in this case the previous approval of the tutor and the coordinator is mandatory).

SPECIALISTIC COURSES, LONG-TRAINING SEMINARS

The attendance of Specialist Courses, Workshops, Schools, Seminars cycles is strongly encouraged and (if these seminars, workshops are certified and evaluated) may permit to acquire credits according the modalities established by the Faculty Board and previous approval of the study plan submitted by the candidate. These courses and workshops can be inserted in the study plan, even if they are not evaluated (and therefore not qualified as credits), as optional “additional teaching”.

The scheduled course planning for the academic year 2018-2019 and 2019-2020 follows. Other courses may be activated during the year. In this case the candidates will be promptly informed, and will be allowed to insert these new courses in their study plan.

Table A: PHD COURSES CHARACTERISING THE PHD PROGRAMME

<i>SSD (optional, also more than one)</i>	<i>Course</i>	<i>Professor (optional)</i>	<i>A.Y./Semester</i>	<i>Credits</i>
ICAR/06	Monte Carlo-Markov chains statistical methods	G. Venuti M. Reguzzoni	Alternate years	5
ICAR/02	Modelling Extremes and Dependence in Multivariate Problems	C De Michele G. Salvadori F. Durante		5
ICAR/06	Statistical and numerical methods	R. Barzaghi G. Venuti		5
ICAR/01	Fluid mechanics	V. Armenio	Alternate years	5
ICAR/01	Groundwater	A. Guadagnini M. Riva	Alternate years	5
ICAR/01 ICAR/07	Granular Matter: from packing to flow	D. Berzi C. di Prisco		5

ICAR/01	Lifetime analysis and critical working condition of hydraulic devices	M. Malavasi G.V. Messa		5
ICAR/02	Advances in Water Engineering (Sustainable Urban Water Systems + Remote Sensing in Hydrology)	(G. Becciu) J. Sansalone M. Mancini C. Corbari		5
ICAR/02	Water and Food Security	M.C. Rulli		5
ICAR/02	Mountain hydrology and climate change	D. Bocchiola		5
ICAR/02	Sea Waves and Hydropower	A. Bianchi G. Passoni		5
ICAR/03, BIO/07, BIO/19	Environmental Chemistry and Applied Microbiology	M. Antonelli	Alternate years	5
ICAR/03	Environmental reactors and biological processes applied to environmental-sanitary engineering	E. Ficara R. Canziani	Alternate years	5
ICAR/03	Statistics applied to Environmental Engineering	A. Azzellino	Alternate years	5
ICAR/04	Road material performances characterization	E. Toraldo	Alternate years	5
ICAR/04	Pavement Management System	F. Fiori	Alternate years	5
ICAR/06	Positioning	B. Betti		5
GEO/05	Geological and hydrogeological issues in tunnelling	P. Gattinoni		5
ICAR/06	Advanced Geographical Information Systems	D. Carrion	Alternate years	5
ICAR/06	Photogrammetry and Image Analysis	L. Pinto V. Casella	Alternate years	5

ICAR/06	Data Processing meets Human Sciences	L. Mussio	Alternate years	5
ICAR/06	Dialectical critique of data processing	L. Mussio	Alternate years	5
ICAR/06	Geospatial Web, Geo Big Data and Citizen-generated Geographic Information	M.A. Brovelli		5
ICAR/06	Satellite geodesy	F. Migliaccio	Alternate years	5
ICAR/06	DTM generation	R. Barzaghi	Alternate years	5

Note: for courses with “Alternate years”, please refer to the “Manifesto” of each Academic Year.

Table B SUGGESTED CROSS –SECTORAL COURSES

<i>SSD (optional, one or more)</i>	<i>Name of the Course</i>	<i>Professor (optional)</i>	<i>Semester</i>	<i>Language</i>	<i>Credits</i>
	All courses offered by the PhD School of the Politecnico di Milano can be selected				

Table C OTHER PhD COURSES

<i>SSD (optional, one or more)</i>	<i>Name of the Course</i>	<i>Professor (optional)</i>	<i>Semester</i>	<i>Credits</i>
	All doctoral courses offered by the PhD School of the Politecnico di Milano and/or by other Institutions can be selected			

6.4 Presentation of the study plan

PhD candidates must submit a study plan, which may be revised periodically (approximately every three months), in order to adequate them to possible changes in the course list, or to needs motivated by the development of their PhD career. The study plans must be approved by the PhD programme Coordinator, according to the modalities established by the Faculty Board of the PhD Programme itself.

6.5 Yearly evaluations

Candidates present their work to the Faculty Board at least once a year. In particular, the candidates must pass an annual evaluation in order to be admitted to the following PhD year.

The third year evaluation establishes the candidate's admission to the final PhD defense. As a results of each successful annual evaluation, the candidates receive an evaluation (A/B/C/D). Candidates who do not pass the exam will be qualified as "Repeating candidate"(Er) or "not able to carry on with the PhD (Ei)".

After the final year, candidates who have achieved sufficient results but need more time to draw up their theses, may obtain a prorogation of up to 12 months.

6.6 PhD thesis preparation

The main objective of the PhD career is the development of an original research contribute. The PhD thesis is expected to contribute to the advance of the knowledge in the candidate's research field.

The PhD study and research work is carried out, full time, during the three years of the PhD course. Stages or study periods in (Italian or International) companies or external Institutions may complete the candidate's preparation.

The resulting theses need to be coherent with the research issues developed in the Department where the PhD programme is developed.

The candidate must present an original thesis, discuss its contribution to the state of the art in the research field in the research community.

The PhD research is developed following the lead of a supervisor, who supports the candidate in the setting out and in the everyday activities regarding the thesis development.

At the conclusion of the PhD studies, the Faculty Board evaluates the candidates. Candidates who receive a positive evaluation submit their theses to two external reviewers for refereeing. If the evaluation provided by the reviewers is positive (o after the revisions required by the external reviewers), the candidates defend their thesis in a final exam, in front of a Committee composed of three members (at least two of which must be external experts).

7. Laboratories, PhD Secretary Services

Laboratory Gaudenzio Fantoli

The **Laboratory Gaudenzio Fantoli** hosts activities related to Hydraulic Engineering and Water Science Engineering. It was first established in 1939. It comprises areas devoted to research and educational activities. Two main floors, each covering an area of about 800 m², are currently devoted to laboratory activities. The Lab staff comprises 4 people. Major hydraulic facilities include:

- *Free surface flume*: a 30m × 1.0m × 0.6m flume with adjustable floor and glass sides, a fixed floor flume with glass sides. It is provided with the tools to convert the structure into a wave flume (piston wavemaker, artificial beach, wave gauges).
- *Hydraulic channel*: a 6 m × 0.5 m × 0.5 m free surface flume designed for studying fluid-structure interaction by means of direct measurement of forces, stress distributions, displacements and velocity distributions. Image analysis techniques are employed for kinematic measurements.
- Test plant for flow resistances: a water flow loop, provided with flowmeter and pressure transmitters, dedicated to measure the loss coefficient and other characteristics of regulation devices (including, e.g. valves, resistors, connectors). The plant is also equipped with high pressure pumps.
- *Transparent pressurized duct*: specifically built for sediment transport and scour experiments with image processing measurements. The duct length is 5.8 m with a cross section 40 cm wide and 16 cm deep. In the central part of the duct is a recess section with a length of 2 m and depth of 0.5 m. The hydraulic head in the duct is imposed by a Bazin weir located in the downstream tank; the upstream tank is provided with a streamlined inlet to avoid wakes in the flow.
- *Dam-break flume*: used to investigate the dam-break wave (unsteady flow) of a hyperconcentrated mixture of water and cohesionless granular matter. It consists of a 6 m long, square section (0.5 x 0.5 m) flume of adjustable slope. Failure of the dam is simulated by means of a pneumatic rising sluice-gate (opening time $t = 0.3$ s). One of the side walls of the flume is made of glass in order to record of wave propagation by means of a digital camera.
- *Rotating drum*: this device is used to investigate the behavior of a steady dry granular flow over a loose bed. It consists of a cylinder (inner diameter $D = 1$ m and axial length $W = 250$ mm) half-filled with granular material, which is mounted on a pair of friction rollers and rotates around its axis at a constant angular velocity. One of the endplates of the cylinder is made of 10 mm thick glass to allow optical measurement of the flow fields through a progressive CCD scan camera.

Other site facilities include: a series of calibrated basins with a total capacity of 50 m³, a computer centre, an electronics workshop for construction and repair of instrumentation; a mechanical workshop for the construction of experimental facilities, laboratory instrumentation for measuring most hydraulic parameters (including an automated system to detect and measure river-bed shapes), and field instrumentation to measure hydrodynamic processes. The Lab has been certified within the SQA (Quality Assurance Protocol of the Politecnico) within the context of hydraulic parameter measurements, determination of characteristic curves of hydraulic machinery and field and

laboratory scale flow rate determination. The laboratory is a SIT certified Calibration Centre for measurement of liquid flow rates (range: 3-80 l/s). Finally, a total free area of 600 m² is available for set-up of hydraulic models. The area is served by an overhead traveling crane of 1500 kg_p and by a piping system allowing a maximum flow rate of about 600 l/s.

Laboratory of Environmental Engineering (LIA – Laboratorio di Ingegneria Ambientale)

It hosts activities related to Environmental Technologies. It currently covers 580 m² and is divided into two sections: the analytical section with different working areas (wet chemistry, sample preparation, analytical instrumentation, and biology) and the pilot-plant section. The Laboratory staff comprises 3 permanent staff (2 graduates) and one temporary position (graduate). The main activities of Laboratory are: (a) sampling and determination of pollutants in different environmental matrices (water, air, soil, sludge, solid waste); (b) evaluation of remedial technologies with laboratory pilot plants; (c) planning and management of demonstrative wastewater treatment pilot plant; (d) tests of biodegradation and treatability of wastewaters by means of titration/respirometric sensors and BMP (biomethane potential); (e) tests for the characterization of sludge and digestates with CST (capillary suction time), filtration apparatus and a zetameter. Analytical instrumentation includes: electrometry, nephelometry, molecular absorption spectrophotometry, atomic absorption spectrometry, liquid chromatography (ionic and HPLC), gas-chromatography, X-ray spectrometry, polarography, voltammetry, TOC analyser, ion-coupled plasma mass Spectrometry (ICP-MS). The Laboratory is also equipped with instrumentation for sampling of liquid, solid and gaseous pollutants.

The pilot plant section is equipped with: aerobic and anaerobic instrumented bioreactors for activated sludge and fixed biomass processes, membrane bioreactors, batch reactors for contaminated soil remediation, reactors for chemical oxidation and water disinfection, biosensors for the study of microbial activity. Experimental activity through pilot-plants is frequently carried out at public institutions and private firms.

Road Research Laboratory (RRL)

The Road Research Laboratory (RRL) refers to the Road Infrastructure Section and performs experimental activities associated with road materials (soils, rocks, inerts, binders, asphalt concrete, cement bound materials and cement concrete), soil analysis (sub layers, foundations and rises), pavement analysis, preliminary and validation investigations concerning road, railway and airport works as well as dumps and embankments. The RRL has at its disposal equipment for qualification and characterization tests related to road materials, such as inerts, soils, bituminous binders, asphalt and cement concrete. The RRL also has equipment for in-situ tests, such as bearing capacity, roughness and adherence, for the quality control of materials and working phases, in accordance with current Italian and European regulations.

The RRL is also equipped with a full scale test area of approx. 50000 m² in Carpiano (MI), at the Bacchi Enterprise, and also with equipment, work machines and plant for the implementation of full scale tests regarding road, railway and airport infrastructures (pavement, sub layer, etc.). This area is used for full scale tests when the limits of the laboratory scale need to be overcome, checking the critical states of construction techniques as well as validating laboratory tests. Much experimental analysis already carried out and in progress in the full test area show the remarkable potential and effectiveness of full scale testing which could be effectively use for both internal and commissioned

research, under the control of the RRL. Adjacent to the full scale test area is a fully equipped laboratory for carrying out further traditional tests on road materials (soils, inerts, cement and asphalt concrete, etc.), as well as innovative tests (flexion and indirect tensile fatigue tests, complex modulus, dynamical creep, etc.). The laboratory directly cooperates with plants producing asphalt and concrete cement in order to test real mixtures and overcome the limits due manufacturing mixtures in the laboratory.

Laboratory of Geomatics

The recent development of the subject has fostered activities in new fields of advanced research such as spatial geodesy, navigation, photogrammetry, remote sensing, numerical cartography, geographic information systems (GIS), as well as a return to the field of geophysics. This research is conducted by the Department with the support of structures such as:

- the International Service for the Geoid, which can be considered as an IT laboratory for the gravity field
- the laboratory of geomatics, which is partly instrumental and partly IT.

The main instruments, software and activities conducted in the laboratory are illustrated in the following.

Surveying and monitoring: GPS instrumentation from a permanent station to low cost receivers; measurements to monitor ground, buildings and structures; photogrammetric surveying of architectural manufacts; thematic mapping; infrastructure land registry.

Data management and interpretation: Gravimetric data interpretation; geoid determination; spatial mission analysis; GPS permanent network analysis; Statistical methods in surveying and monitoring; integration of images and maps; management of GIS data bases; evaluation of uncertainty and reliability.

PhD Secretary Services

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8. Internationalisation and inter-sectoriality

Carrying out study and research activities at external laboratories is strongly recommended.

Politecnico di Milano supports joint PhD paths with International Institutions, as well as Joint and Double PhD programmes. Further information is available on the PhD School website and on the PhD programme website.

More specifically, the PhD programme in Environmental and Infrastructure Engineering collaborates with:

- University of Chemistry and Technology Prague (Czech Republic) (PhD Double Degree Agreement)
- The University of Arizona (USA) (Research collaboration)
- Imperial College London (UK) (Research collaboration)
- ETH Zurich (Switzerland) (Research collaboration)
- TU Delft (The Netherlands) (Research collaboration)
- Universitat Politecnica de Catalunya – Barcelonatech (Spain) (Research collaboration).

Interaction with and exposure to non-academic sectors provides significant benefits to doctoral candidates as well as to research and innovation intensive employment sectors. Direct exposure to the challenges and opportunities in non-academic sectors of the economy and society at large is fostered by networking, connectivity, inter-sectoral mobility and wide access to knowledge. In particular, the PhD programme in Environmental and Infrastructure Engineering collaborates with the following Research Agencies and/or Industrial partners:

- Metropolitana Milanese S.p.A. (Research collaboration and scholarship funding)
- Pibiviesse s.r.l. (Research collaboration and scholarship funding)
- Agenzia Spaziale Italiana (Italian Space Agency) (Research collaboration and scholarship funding)
- RSE S.p.A. – Ricerche sul Sistema Energetico (Research collaboration and scholarship funding)
- Lario Reti Holding (Research collaboration and scholarship funding)
- European Space Agency (Research collaboration and scholarship funding)
- Agenzia Spaziale Italiana (Research collaboration and scholarship funding)
- ENI (Research collaboration and scholarship funding).

Attachment A1 – PhD Programme Coordinator

Short CV of Programme Coordinator

CURRICULUM VITAE OF ALBERTO GUADAGNINI

Address

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Communication

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Born

October 26, 1964; Verona (Italy)

History of Employment

- 1992-1998 Assistant Professor of Hydraulic Engineering, Politecnico di Milano, Milano, Italy.
1996-1998 Visiting Professor, Department of Hydrology and Water Resources, The University of Arizona, Tucson, Arizona 85721, USA.
1998-2003 Associate Professor, Politecnico di Milano, Milano, Italy.
2003- Professor (Hydraulics and Fluid Mechanics), Politecnico di Milano, Milano, Italy.
2010- Professeur Invité: University of Strasbourg, Strasbourg, France (Jan. 2010 – Mar. 2010).
Visiting Professor: Department of Hydrology and Water Resources, The University of Arizona, Tucson, Arizona 85721, USA (Nov. 2010 - Mar. 2011; 2012, 2013, 2014, 2015, 2016). Visiting Professor: Department of Environmental Sciences and Energy Research, Weizmann Institute of Science, Rehovot, 76100 Israel (Aug. 2011; Mar. 2012).
2013- Adjunct Professor (Dept. of Hydrology and Water Resources – Dept. of Hydrology and Atmospheric Sciences, The University of Arizona, Tucson, Arizona USA).
2017- Head of the Department of Civil and Environmental Engineering (103 Faculty, 43 Non-Teaching staff), Politecnico di Milano, Milano, Italy.

University Education / Degrees

- 1989 Graduation, Civil Engineering (Hydraulics), Politecnico di Milano, Milano, Italy
1992 Doctoral Degree in Hydraulic Engineering, Politecnico di Milano, Milano, Italy

Research Experience

Research activities span both theoretical/numerical and experimental projects., being focused on subsurface flow dynamics of (variably) saturated soils, parameter estimation, inverse modeling, geostatistics, stochastic analyses of flow and transport of solutes in geo-chemically active subsurface environments, scaling in hydrology and geophysics, data assimilation, model reduction techniques for the solution of stochastic flow and transport problems, and uncertainty quantification in groundwater systems, from the pore- to the laboratory-, field- and basin-scale. He contributed to the development of exact and approximated formalisms for prediction of groundwater flow and transport processes governing the spreading of conservative and reactive solutes in heterogeneous reservoirs through

conditional moments of the state variable of interest. Ongoing research projects include (i) statistical scaling of hydrological quantities, (ii) stochastic groundwater hydrology, (iii) delineation of wellhead protection regions, (iv) multiscale flow and solute transport in porous media, (v) multiphase flows and enhanced oil recovery.

Alberto Guadagnini has established a highly active and diverse Groundwater Hydrology research group. The group currently includes two faculties (a full professor, and an assistant professor), 4 Ph.D. students, 5 post-doctoral fellows, consultants, and other visitors and temporary students; the group varies in size from 8-15 members at any given time. Advised and graduated 15 Ph.D. students, and hosted >10 post-doctoral fellows and many visiting senior scientists. He has participated in several European Union projects and proposals (Coordinator; Supervisory Board member; and PI/scientist-in-charge). Close collaborations with many research groups in Israel, Europe and the USA. Published more than 140 research papers in ISI rated, international, peer-reviewed journals, 90 of them over the last 10 years. Total of >2000 citations; h-index: 26.

Over the last 5 years, 15 invited/keynote presentations at international conferences and workshops, as well as lectures at universities and research institutions in Europe, North America, and China (AGU, EGU, Gordon Research Conference, IAHR - International Association for Hydro-Environment Engineering and Research, Jinan University, University of Strasbourg, University of Arizona, Heriot-Watt University, University of Edinburgh, and more).

Memberships

American Geophysical Union (since 1990); European Geosciences Union (since 2010); Society of Petroleum Engineers (since 2016); National Council of Engineers (Italy, since 1992).

Service to the Community and Selected Professional Activities

- 2000-2004 Associate Editor, *Reviews of Geophysics* (American Geophysical Union).
- 2001- Expert, Research Proposal Evaluation Panels: European Commission; Swiss National Science Foundation (Switzerland); Israeli Science Foundation (Israel), National Science Foundation (USA), Ministero dell'Istruzione, dell'Università e della Ricerca - MIUR (Italy).
- 2002- Technical Committee for Hydrological Sciences Section- Sub-Division on Groundwater Hydrology (EGS - EGU).
- 2004- Associate Editor, *Water Resources Research* (AGU).
- 2004-2008 Associate Editor, *Vadose Zone Journal* (Soil Science Society of America).
- 2007-2010 Head of the Doctoral Program in *Water Engineering*, Politecnico di Milano.
- 2008 Scientific Committee of the H+ observatory (France).
- 2008- Corresponding Member of the Istituto Lombardo, Accademia di Scienze e Lettere (Classe di Scienze Matematiche e Naturali).
- 2009- Editor, *Hydrology and Earth System Sciences* (EGU); Editorial Board, *Advances in Water Resources* (Elsevier).
- 2011- Editorial Board, *Stochastic Environmental Research and Risk Assessment* (Springer).
- 2011- Vice Chair of the Committee on Groundwater Hydraulics and Management (**International Association for Hydro-Environment Engineering and Research**).
- 2013- Head of the Doctoral Program in *Environmental and Infrastructure Engineering*, Politecnico di Milano.

- 2014- **Executive Editor: *Hydrology and Earth System Sciences*** (EGU).
- 2015- Member of Committee of the *Witherspoon Lecture Award* (AGU).
- 2016- Faculty Advisor: of the Society of Petroleum Engineers (SPE) Student Chapter at Politecnico di Milano, Italy.
- 2016- Chair of Communication Committee of the **International Society for Porous Media (InterPore; www.interpore.org)**.

List of Selected Publications (years 2016 - 2017)

1. Ceriotti, G., G.M. Porta, C. Geloni, M. Dalla Rosa, and A. Guadagnini (2017), Quantification of CO₂ generation in sedimentary basins through Carbonate/Clays Reactions with uncertain thermodynamic parameters, *Geochim. Cosmochim. Ac.*, *in press*.
2. Hassane Maina, F., P. Ackerer, A. Younes, A. Guadagnini, and B. Berkowitz (2017), Benchmarking numerical codes for tracer transport with the aid of laboratory-scale experiments in 2D heterogeneous porous media, *J. Contam. Hydrol.*, *in press*, doi:[10.1016/j.jconhyd.2017.06.001](https://doi.org/10.1016/j.jconhyd.2017.06.001).
3. Mara, T.A., N. Fajraoui, A. Guadagnini, and A. Younes (2017), Dimensionality reduction for efficient Bayesian estimation of groundwater flow in strongly heterogeneous aquifers, *Stoch. Environ. Res. Risk Assess.*, *in press*, doi:10.1007/s00477-016-1344-1.
4. Riva, M., A. Guadagnini, and S.P. Neuman (2017), Theoretical analysis of non-Gaussian heterogeneity effects on subsurface flow and transport, *Water Resour. Res.*, 53, 1-15, doi:10.1002/2016WR019353.
5. Scanziani, A., K. Singh, M.J. Blunt, and A. Guadagnini (2017), Automatic method for estimation of in situ contact angle from X-ray micro tomography images of two-phase flow in porous media, *J. Colloid Interface Sci.*, 496, 51-59, doi:10.1016/j.jcis.2017.02.005.
6. Bianchi Janetti, E., M. Riva, and A. Guadagnini (2017), Effects of pore-scale geometry and wettability on two-phase relative permeabilities within elementary cells, *Water*, 9(4), 252, 1-18, doi:10.3390/w9040252.
7. Libera, A., F.P.J. de Barros, and A. Guadagnini (2017), Influence of pumping operational schedule on solute concentrations at a well in randomly heterogeneous aquifers, *J. Hydrology*, 546, 490-502, doi:[10.1016/j.jhydrol.2016.12.022](https://doi.org/10.1016/j.jhydrol.2016.12.022).
8. Colombo, I., G. Porta, P. Ruffo, and A. Guadagnini (2017), Uncertainty quantification of overpressure buildup through inverse modeling of compaction processes in sedimentary basins, *Hydrogeology Journal*, 25, 385-403, doi:10.1007/s10040-016-1493-9.
9. Zhang, Y., M.G. Schaap, A. Guadagnini, and S.P. Neuman (2016), Inverse modeling of unsaturated flow using clusters of soil texture and pedotransfer functions, *Water Resour. Res.*, 52, 1-14, doi:10.1002/2016WR019016.
10. Menafoglio, A., A. Guadagnini, and P. Secchi (2016), Stochastic Simulation of Soil Particle-Size Curves in Heterogeneous Aquifer Systems through a Bayes space approach, *Water Resour. Res.*, 52, 1-19, doi:10.1002/2015WR018369.
11. Dai, C., L. Xue, D. Zhang, and A. Guadagnini (2016), Data-worth Analysis through Probabilistic Collocation-based Ensemble Kalman Filter, *J. Hydrology*, 540, 488-503, doi:10.1016/j.jhydrol.2016.06.037.

12. Moghadasi, L., A. Guadagnini, F. Inzoli, M. Bartosek, and D. Renna (2016), Characterization of Two- and Three-Phase Relative Permeability of Water-Wet Porous Media through X-Ray Saturation Measurements, *J. Petrol. Sci. Eng.*, 145, 453-463, doi:10.1016/j.petrol.2016.05.031.
13. Edery, Y., G. M. Porta, A. Guadagnini, H. Scher, and B. Berkowitz (2016), Characterization of bimolecular reactive transport in heterogeneous porous media, *Transp. Porous Media*, in press, doi:10.1007/s11242-016-0684-0.
14. Ranaee, E., M. Riva, G. Porta and A. Guadagnini (2016), Comparative Assessment of Three-Phase Oil Relative Permeability Models, *Water Resour. Res.*, 52, 1-16, doi:10.1002/2016WR018872.
15. Panzeri, M., M. Riva, A. Guadagnini, and S.P. Neuman (2016), Theory and Generation of Conditional, Scalable Sub-Gaussian Random Fields, *Water Resour. Res.*, 52, 1-16, doi:10.1002/2015WR018348.
16. Sanchez-Vila, X., P. Ackerer, F. Delay, and A. Guadagnini (2016), Characterization of reciprocity gaps from interference tests in fractured media through a dual porosity model, *Water Resour. Res.*, 52, 1696-1704, doi:10.1002/2015WR018171.
17. Marinoni, M., F. Delay, P. Ackerer, M. Riva, and A. Guadagnini (2016), Identification of groundwater flow parameters using reciprocal data from hydraulic interference tests, *J. Hydrology*, 539, 88-101, doi:http://dx.doi.org/10.1016/j.jhydrol.2016.05.019.
18. Panzeri, M., E.L. Della Rossa, L. Dovera, M. Riva, and A. Guadagnini (2016), Integration of Markov Mesh Models and Data Assimilation Techniques in Complex Reservoirs, *Computat. Geosci.*, 20, 637-653, doi:10.1007/s10596-015-9540-5.
19. Bianchi Janetti, E., M. Riva, and A. Guadagnini (2016), Analytical expressions for three-phase generalized relative permeabilities in water- and oil- wet capillary tubes, *Computat. Geosci.*, 20, 555-565, doi:10.1007/s10596-015-9508-5.
20. Siena, M., A. Guadagnini, E. Della Rossa, A. Lamberti, F. Masserano, and M. Rotondi (2016), A Novel EOR Screening Approach based on Bayesian Clustering and Principal Component Analysis, *SPE Reservoir Evaluation & Engineering*, 1-9, SPE-174315-PA, doi:[10.2118/174315-PA](https://doi.org/10.2118/174315-PA).
21. Menafoglio, A., A. Guadagnini, and P. Secchi (2016), A Class-Kriging predictor for functional compositions with application to particle-size curves in heterogeneous aquifers, *Math. Geosci.*, 48, 463-485, doi:10.1007/s11004-015-9625-7.

Attachment A2 – PhD Faculty Board

Description of the composition of the Faculty Board

Name	Affiliation	Scientific Disciplinary Sector
Guadagnini Alberto (coordinator)	Politecnico di Milano - DICA	ICAR/01 Hydraulics
Azzellino Arianna	Politecnico di Milano - DICA	ICAR/03 Sanitary Environmental Engineering
Barzaghi Riccardo	Politecnico di Milano - DICA	ICAR/06 Topography and Cartography
Becciu Gianfranco	Politecnico di Milano - DICA	ICAR/02 Hydraulic and maritime constructions and Hydrology
Betti Barbara	Politecnico di Milano - DICA	ICAR/06 Topography and Cartography
Bocchiola Daniele	Politecnico di Milano - DICA	ICAR/02 Hydraulic and maritime constructions and Hydrology
Canziani Roberto	Politecnico di Milano - DICA	ICAR/03 Sanitary Environmental Engineering
Crispino Maurizio	Politecnico di Milano - DICA	ICAR/04 Highways, railways and airports
De Michele Carlo	Politecnico di Milano - DICA	ICAR/02 Hydraulic and maritime constructions and Hydrology
Lonati Giovanni	Politecnico di Milano - DICA	ICAR/03 Sanitary Environmental Engineering
Longoni Laura	Politecnico di Milano - DICA	GEO/05 Applied Geology
Malvasi Stefano	Politecnico di Milano - DICA	ICAR/01 Hydraulics
Malpei Francesca	Politecnico di Milano - DICA	ICAR/03 Sanitary Environmental Engineering
Mancini Marco	Politecnico di Milano - DICA	ICAR/02 Hydraulic and maritime constructions and Hydrology
Migliaccio Federica	Politecnico di Milano - DICA	ICAR/06 Topography and Cartography
Papini Monica	Politecnico di Milano - DICA	GEO/05 Applied Geology
Radice Alessio	Politecnico di Milano - DICA	ICAR/01 Hydraulics
Riva Monica	Politecnico di Milano - DICA	ICAR/01 Hydraulics

Rulli Maria Cristina	Politecnico di Milano - DICA	ICAR/02 Hydraulic and maritime constructions and Hydrology
Saponaro Sabrina	Politecnico di Milano - DICA	ICAR/03 Sanitary Environmental Engineering
Toraldo Emanuele	Politecnico di Milano - DICA	ICAR/04 Highways, railways and airports
Venuti Giovanna	Politecnico di Milano - DICA	ICAR/06 Topography and Cartography

Attachment A3 – PhD Advisory Board

Description of the composition of the Advisory Board

Name	Affiliation
Sanchez-Vila Xavier	Politechnical University of Catalonia, Barcelona (SP)
Ackerer Philippe	Université de Strasbourg (F)
Ruffo Paolo	ENI
Sansalone John J.	Florida University (USA)
Burlando Paolo	ETH Zurigo (CH)
Marino Carlo	ARPA Lombardia
Bortone Giuseppe	ARPA Emilia Romagna
Losa Massimo	Università di Pisa
Marti Urs	SwissTopo, Berne (CH)
Dermanis Athanasios	Aristotle University of Thessaloniki (GR)
Radicioni Fabio	Università di Perugia