PhD School - Politecnico di Milano

Regulations of the PhD Programme in:

Environmental and Infrastructure Engineering

Cycle XXXVIII

1. General Information

PhD School - Politecnico di Milano

PhD Programme: Environmental and Infrastructure Engineering

Course start: November 2021

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: https://www.dica.polimi.it/phd/phd-in-environmental-engineering-and-infrastructure-engineering/?lang=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 Head and a Faculty Board.
The Head 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 candidates 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-sectorial structure and is organized according to the following three key thematic profiles: (i) Water Science and Engineering;

(ii) Transport Infrastructures and Geosciences; (iii) Environmental and Hydraulic Engineering 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 candidates 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 candidate curriculum fully acknowledged by major academic institutions, private enterprises and national and international organisations as demonstrated by career opportunities of former PhD candidates. 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. M*odelling 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 manufact, 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 manufact 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 candidates. 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 candidate 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 candidates 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 candidates 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 programs 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 38th PhD cycle Programmes:

https://www.dottorato.polimi.it/en/prospective-phd-candidates/calls-and-regulations

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 Head 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.
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 favours 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 clearly identify 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 2022-2023 Academic Year are summarized in the following table.

Professor	**Course name**
Armondi Simonetta	Strengthening Critical Spatial Thinking
Biscari Paolo	English for Academic Communication
Biscari Paolo	Industrial Skills
Biscari Paolo	Scientific Communication in English
Brunetto Domenico	Innovative Teaching Skills
Canina Maria Rita	Creative Design Thinking
Cardilli Lorenzo	European Culture
Di Blas Nicoletta	Professional Communication
Fuggetta Alfonso	Project Management Basics
Oxoli Daniele	The Copernicus Green Revolution for Sustainable Development
Iarossi Maria Pompeiana	Power of Images and Visual Communication for Research Dissemination
Masarati Pierangelo	Ethical Aspects of Research on Dual-Use Technologies

Mauri Michele	Research Communication. Issue mapping: exploring public debates surrounding academic topics
Ossi Paolo Maria	Sulla responsabilità tecnica
Oppio Alessandra	How to support Complex decisions: Approaches and Tools
Paganoni Anna Maria	La comunicazione nella Scienza
Pizzocaro Silvia Luisa	Practicing Research Collaboration
Raos Guido	Science, Technology, Society and Wikipedia
Sancassani Susanna	Teaching Methodologies, Strategies and Styles
Sciuto Donatella	Research Skills
Volontè Paolo Gaetano	Introduction to Academic Research
Mancini Mauro	Project Management (In Action)
Tanelli Mara	Cognitive biases and discriminations: implications, risks and opportunities
Balducci Alessandro	Approaches to Resilience: Social, Economic, Environmental and Technological Challenges of Contemporary Human Settlements Modeling and Automated Verification of Real-Time Systems

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

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

Summer/Winter Schools			

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 Inter-doctoral 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:
https://www11.ceda.polimi.it/manifestidott/manifestidott/controller/MainPublic.do?check_params=1&k_corso_la=1300&lang=EN&polij_device_category=DESKTOP&__pj0=0&__pj1=890417f7eed83670a89b5545559aa65a

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 Head 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 to the modalities established by the Faculty Board and previous approval of the study plan submitted by the candidate. These courses and workshops can be included 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 2022-2023 and 2023-2024 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

SSD *(optional, also more than one)*	***Course***	***Professor*** *(optional)*	***A.Y./Semester***	***Credits***

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	G.V. Messa	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	Alternate years	5
ICAR/01	Particle-laden flows: theory and engineering applications	G.V. Messa M. Malavasi	Alternate years	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	Sustainable 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/02	Remote Sensing and its Applications in Cryospheric Sciences	C. De Michele A.N. Arslan		5
ICAR/03	Advanced techniques for (bio)chemical reactor modelling	A. Turolla	Alternate years	5
ICAR/03	Statistics applied to Environmental Engineering	A. Azzellino		5

ICAR/04	Road material performances characterization	E. Toraldo	Alternate years	5
ICAR/06	Positioning	C. De Gaetani		5
ICAR/06	Advanced Geographycal Information Systems	D. Carrion	Alternate years	5
ICAR/06	Photogrammetry and Image Analysis	L. Pinto V. Casella	Alternate years	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

SSD (optional, one or more)	*Name of the Course*	***Professor** (optional)*	*Semester*	*Language*	*Credits*
	All courses offered by the PhD School of the Politecnico di Milano can be selected (see table on page 9)				

Table C OTHER PhD COURSES

SSD (optional, one or more)	*Name of the Course*	***Professor** (optional)*	*Semester*	*Credits*
	All doctoral courses offered by all the Phd programs 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 Head, 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. 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 defence.
As a result of each annual evaluation, the candidates passing the exam receive an evaluation (A/B/C/D) and may proceed with the enrolment at the following year. Candidates who do not pass the exam are qualified either as “Repeating candidate” (Er) or “not able to carry on with the PhD” (Ei). In the former case (Er), the candidates are allowed to repeat the PhD year at most once. The PhD scholarships – if any – are suspended during the repetition year. In the latter case (Ei) the candidates are excluded from the PhD programme and lose their scholarships – if any.
After the final year, candidates who have achieved sufficient results, but need more time to conclude their research work and write their theses, may obtain the admission to a further year.

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 (or 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 Secretariat 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 m^2, 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 m^3, 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 m^2 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 m^2 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 an 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.

Research Laboratory on Transportation Infrastructures (InfraLab)
The Research Laboratory on Transportation Infrastructures (InfraLab) is nowadays a European leading laboratory for both university education and experimental scientific research. Regarding education activities, InfraLab, recently renewed, is equipped by a teaching room, offering to the candidates the possibility of performing several standard tests on construction materials. From the experimental research point of view, the activities of InfraLab are mainly focused on the study of new materials, methods and technologies for construction and maintenance of transportation infrastructures, at different scales, including both laboratory tests, and real scale assessments by on-site test tracks, thanks to an experimental area of 50.000 m^2 located in Carpiano (Mi). Quality controls of materials and pavements during construction and in-service infrastructures' monitoring are two other key activities of the Laboratory. InfraLab is equipped by a set of machines and apparatus for materials' characterization according to European and US standards, also including specific and performance-related tests. In this view, the Laboratory also designs and develops in-house test equipment, up to the prototype level, both independently and in collaboration with companies. Moreover, InfraLab is able to assist authorities and enterprises during the development, design, construction and maintenance of transportation infrastructures.

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. These researches are 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 instruments (geodetic and low-cost receivers); Total stations and levelling instruments; UAV; 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 Secretariat Services

Elena Raguzzoni
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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 Warwick (UK) (Joint Thesis Sponsorship)
- Pontificia Universidad Católica De Chile (Chile) (PhD Double Degree Agreement)
- Federal Rural University of Pernambuco (Brazil) (PhD Joint Degree Agreement)
- University of Lausanne (Switzerland) (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-sectorial 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)
- 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)
- ENI (Research collaboration)
- ENEL Foundation (Research collaboration and scholarship funding)
- Bracco Imaging S.p.A. (Research collaboration and scholarship funding)
- ERSAF – Ente Regionale Servizi all'Agricoltura e alle Foreste (Research collaboration and scholarship funding)
- Banca d'Italia (Research collaboration and scholarship funding)
- Rea Dalmine S.p.A. (Research collaboration and scholarship funding)
- Acque Bresciane (Research collaboration and scholarship funding)
- Gruppo CAP (Research collaboration and scholarship funding)
- Geolog Technologies srl (Research collaboration and scholarship funding)
- Regione Lombardia – ENEA (Research collaboration and scholarship funding)
- Piksel s.r.l. (Research collaboration and scholarship funding)
- Arianet s.r.l. (Research collaboration and scholarship funding)
- Appflue s.r.l. (Research collaboration and scholarship funding)
- Autorità di bacino distrettuale del fiume Po (Research collaboration and scholarship funding)

Attachment A1 – PhD Programme Head

Short CV of Programme Head

CURRICULUM VITAE OF RICCARDO BARZAGHI

Address
Dipartimento di Ingegneria Civile e Ambientale (DICA)
Politecnico di Milano
Piazza L. Da Vinci, 32 - 20133 Milano (Italy)

Communication
Tel. +39-02-2399-6528
Fax: +39-02-2399-6530
e-mail: riccardo.barzaghi@polimi.it

Born
December 14th, 1958, Milano (Italy)

History of Employment

1990-1992	Assistant Professor of Surveying and Mapping at the Engineering Faculty, Politecnico di Milano, Milano, Italy
1992-1994	Associate Professor of Surveying and Mapping at the Engineering Faculty, University of Reggio Calabria, Reggio Calabria, Italy
1994-2003	Associate Professor of Surveying and Mapping at the Engineering Faculty, Politecnico di Milano, Milano, Italy
2003-	Full Professor of Surveying and Mapping at the Engineering Faculty, Politecnico di Milano, Milano, Italy
2007-2009	Deputy-Dean of the School of Civil and Environmental Engineering, Politecnico di Milano, Milano, Italy
2009-2011	Deputy-Director of the DIIAR, Politecnico di Milano, Milano, Italy
2018-	Deputy-Dean of the School of Civil and Environmental Engineering, Politecnico di Milano, Milano, Italy

University Education / Degrees

1982	Degree with honors in Physics, University of Milano, Milano, Italy
1987	PhD in Geodetic and Surveying Sciences, Politecnico di Torino, Torino, Italy

Research Experience

The main research activities are on Physical Geodesy, Satellite Geodesy, gravity inversion and GNSS networks for real-time positioning and deformation analysis. He coordinates a research group in Geodesy that includes two Associate Professors, two Assistant Professors and one PhD. He cooperated with Istituto Geografico Militare for the definition of the height reference system in Italy. In this context he computed the official Italian geoid, which is currently used for estimating the orthometric heights from GNSS observations. He is involved at international level in the refinements of the methodology for improving the geoid estimate at local and regional level by using collocation. Particularly, he is the PI of the ESA funded project GEOMED2 aiming at estimating the geoid and the ocean circulation in the Mediterranean Sea. Furthermore, he cooperated with ENI for the analysis of gravity data from satellite missions (CHAMP, GRACE and GOCE satellites) in oil prospecting and for the definition of the Italian Moho. From 2000 to 2006, he was the responsible of Rus at Politecnico di Milano in four COFIN projects that were devoted to the estimation of the deformation style of seismogenic areas in Italy. From 2007 to 2010, he was responsible of the geodetic RU in the ASI funded project named SISMA for the analysis of the ongoing crustal

deformation over Italy. From 2021 he is PI of the PRIN202 Italian national project named "Establishing the absolute gravity and physical height systems in Italy".
He advised and graduated 7 PdD candidates (3 of them were international students, 2 from Brazil and 1 from Iran). He is author/co-author of 160 research papers (more than half on peer-reviewed journals, h-index=18, number of citations >1000 on Scopus). He was also involved in teaching activities in several editions of the "International School for the Determination and use of the Geoid" (1999-Milano; 2000-Johor, Malesia; 2003-Salonicco, Grecia; 2005-Budapest, Ungheria; 2010-St. Petersburg, Russia; 2013-Loja, Ecuador; 2016-Ulaanbaatar, Mongolia).

Memberships
American Geophysical Union; European Geosciences Union; International Association of Geodesy (IAG); IAG fellow since 1995.

Service to the Community and Selected Professional Activities
- Editor of Journal of Geodesy (1995-1998; 1999-2002)
- Editor of Bollettino di Geofisica Teorica ed Applicata (since 2015)
- Member of the Editorial Advisory Board of the Journal of Geodetic Science (since 2018)
- Editor of the volumes 144 and 148 of the International Association of Geodesy Symposia by Springer
- Chair of the Scientific Organizing Committee of the 3rd International Gravity Field Service (IGFS) General Assembly (2014)
- Member of the Scientific Organizing Committee of the 1st Joint Commission2 and IGFS Symposium GGHS2016 (2016)
- Member of the Scientific Organizing Committee of the 2nd Joint Commission2 and IGFS Symposium GGHS2018 (2018)
- Head of the Geoid Service of the International Association of Geodesy (2007-2012)
- Chair of the International Gravity Field Service of the International Association of Geodesy (from 2013)
- Member of the Executive Committee of the International Association of Geodesy (2011-2015; 2015-2019)
- Member of the Executive Committee of the Global Geodetic Observing System (GGOS) of the International Association of Geodesy (since 2016)
- Reviewer of international research proposals (ARRS-Slovenia, Research Foundation of Flanders, Estonia Research Council, German Research Foundation)
- Opponent in international PhDs abilitation committees (TTU, Estonia, 2017; UNB, Canada, 2018; Universitè Toulouse III "Paul Sabatier", 2021)
- President of the ASN Commission of the 08/A4-GEOMATICA area (from 2018)
- Member of the Scientific Organizing Committee of the 3nd Joint Commission2 and IGFS Symposium GGHS2020 (2022) and of the Hotine-Marussi Symposium on Mathematical Geodesy (2022)
- Reviewer of the Kingdom of Saudi Arabia (KSA) geoid project under request of the General Authority for Survey and Geospatial Information (GASGI) of KSA

List of Publications (years 2020 – 2021)

1. S. Ebadi, A. Safari, R. Barzaghi, A. Bahroudi. A recovered Moho model by joint inversion of gravity and seismic data in Iran. Heliyon 6, 2020 e03636. https://doi.org/10.1016/j.heliyon.2020.e03636.

2. A. Borghi, R. Barzaghi, O. Al-Bayari, S. Al Madani. Centimeter Precision Geoid Model for Jeddah Region (Saudi Arabia). Remote Sensing, 2020, 12, 2066; doi:10.3390/rs12122066.

3. G. Cambiotti, M. Palano, B. Orecchio, A.M. Marotta, R. Barzaghi, G. Neri, R. Sabadini. New insight into long-term aseismic deformation and regional strain rates from GPS data inversion: the case of the Pollino and Castrovillari faults. Remote Sensing, 2020, 12, 2921; doi:10.3390/rs12182921.

4. R. Barzaghi, C. I. De Gaetani, B. Betti. The Worldwide Physical Height Datum Project. Rend. Fis. Acc. Lincei, 2020. https://doi.org/10.1007/s12210-020-00948-0

5. V. N. Grigoriads, G. S. Vergos, R. Barzaghi, D. Carrion, Ö. Koç. Collocation and FFT-based geoid estimation within the Colorado 1 cm geoid experiment. Journal of Geodesy (2021) 95:52; https://doi.org/10.1007/s00190-021-01507-7

6. M. Reguzzoni, D. Carrion, C. I. De Gaetani, A. Albertella, L. Rossi, G. Sona, K. Batsukh, J. F. T. Herrera, K. Elger, R. Barzaghi, and F. Sansò. Open access to regional geoid models: the International Service for the Geoid. Earth Syst. Sci. Data, 13, 1653–1666, 2021, https://doi.org/10.5194/essd-13-1653-2021.

7. C. De Gaetani, A.M. Marotta, R. Barzaghi, M. Reguzzoni, L. Rossi. The gravity effect of topography: a comparison among three different methods. In Geodetic Sciences - Theory, Applications and Recent Developments, IntechOpen, DOI: 10.5772/intechopen.87697, ISBN: 978-1-83962-767-5, Print ISBN: 978-1-83962-763-7, eBook (PDF) ISBN: 978-1-83962-768-2

8. R. Barzaghi, D. Carrion, J. Kamguia, , L. H. Kande, L. Yap, B. Betti. Estimating gravity field and quasi-geoid in Cameroon (CGM20). Journal of African Earth Sciences, volume 184, https://doi.org/10.1016/j.jafrearsci.2021.104377

9. A. Abulaitijiang, B. O. Andersen, R. Barzaghi and P. Knudsen. Coastal marine gravity modelling from satellite altimetry – case study in the Mediterranean. Journal of Geodetic Science, vol. 11, no. 1, 2021, pp. 29-37. https://doi.org/10.1515/jogs-2020-0200

10. Y. M. Wang, L. Sánchez, J. Ågren, J. Huang, R. Forsberg , H. A. Abd-Elmotaal, K. Ahlgren, R. Barzaghi, T. Bašic, D. Carrion, S. Claessens, B. Erol, S. Erol, M. Filmer, V. N. Grigoriadis, M. S. Isik, T. Jiang, Ö. Koç, J. Krcmaric, X. Li, Q. Liu, K. Matsuo, D. A. Natsiopoulos, P. Novák, R. Pail, M. Pitooák, M. Schmidt, M. Varga, G. S. Vergos, M. Véronneau, M. Willberg, P. Zingerle. Colorado geoid computation experiment – Overview and Summary. Journal of Geodesy (2021) 95:127 https://doi.org/10.1007/s00190-021-01567-9

Attachment A2 – PhD Faculty Board

Description of the composition of the Faculty Board

Name	Affiliation	Scientific Disciplinary Sector
Barzaghi Riccardo (Head)	Politecnico di Milano – DICA	ICAR/06 Topography and Cartography
Antonelli Manuela	Politecnico di Milano – DICA	ICAR/03 Sanitary Environmental Engineering
Becciu Gianfranco	Politecnico di Milano – DICA	ICAR/02 Hydraulic and maritime constructions and Hydrology
Bocchiola Daniele	Politecnico di Milano – DICA	ICAR/02 Hydraulic and maritime constructions and Hydrology
Canziani Roberto (Deputy Head)	Politecnico di Milano - DICA	ICAR/03 Sanitary Environmental Engineering
Corbari Chiara	Politecnico di Milano - DICA	ICAR/02 Hydraulic and maritime constructions and Hydrology
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
De Gaetani Carlo	Politecnico di Milano - DICA	ICAR/06 Topography and Cartography
Grosso Mario	Politecnico di Milano - DICA	ICAR/03 Sanitary Environmental Engineering
Guadagnini Alberto	Politecnico di Milano - DICA	ICAR/01 Hydraulics
Lonati Giovanni	Politecnico di Milano - DICA	ICAR/03 Sanitary Environmental Engineering
Longoni Laura	Politecnico di Milano - DICA	GEO/05 Applied Geology
Malavasi Stefano	Politecnico di Milano - DICA	ICAR/01 Hydraulics
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
Ravazzani Giovanni	Politecnico di Milano - DICA	ICAR/02 Hydraulic and maritime constructions and Hydrology
Riva Monica (Deputy Head)	Politecnico di Milano - DICA	ICAR/01 Hydraulics
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