DOCTORAL PROGRAM IN WATER ENGINEERING

Chair:
Prof. Alberto Guadagnini

The Doctoral Programme in Water Engineering is coordinated by the Department of Hydraulic, Environmental, Infrastructures, and Surveying Engineering (DIIAR). It offers technical/scientific curricula geared to the design, planning and management of sustainable development strategies related to the interactions between human life and environment in all aspect involving water. The programme is focused on topics associated with land protection, assessment and prevention of hydrologic, hydrogeologic and hydraulic risks; assessment of contaminant fluxes through the environment; river hydraulics and infrastructures; management of water resources, aquatic ecosystems and technological industrial networks involving water; climate change effects on water resources partitioning. Students are actively involved into national and international research projects, with Academic Institutions and/or other private/ public agencies.

Objectives and methods

The program aims at training students for a variety of careers in research, teaching and high-technology, related to theoretical and operational aspects above identified. Beginning of research activity is harmonized to the students' background and abilities. Dissertation research topics are original and innovative and are proposed at the cutting edge of the field of interest. The following general areas constitute the backbone of the educational and research programme: fluid mechanics and fluid-structure interactions; river hydraulics and hydraulic risk management; groundwater flow and transport processes; hydrological extremes; integrated water resources management; land surface processes. Fundamental fluid-mechanics is crucial in understanding physical processes observable in environmental and/or geophysical applications. Theoretical and applied aspects are tackled and strongly integrated within the programme. Main development axes therefore include the analysis of advanced methods for fluid-dynamic measurements (e.g., image analysis technologies) and direct assessment and modeling of fluid-structure interactions. River hydraulics and sediment mechanics are naturally related to the concept of hydraulic risk and its management. They involve concepts leading to optimization of land protection approaches and technologies. Key educational and research objectives include river hydraulics and scour processes, hyper-concentrated flow, modeling of flooding processes and hydraulic risk assessment and management. Flood processes are typically analyzed in the context of risk assessment, upon considering methodological aspects related to the quantification of the risk components, with particular focus on vulnerability. The Programme has a strong and active interaction with other Departments and Doctoral Programmes of the Politecnico di Milano, mainly involved in territorial planning activities.

In the context of groundwater flow and transport processes, the main objective is to understand the mechanisms governing processes of flow and transport of passive and reactive contaminants within the subsoil to provide the bases for management and development of technological tools to mitigate the impacts of contaminant fluxes on the water system. Emphasis is devoted to process understanding and modeling of the key flow and geochemical processes occurring in natural heterogeneous aquifers.

In the area of hydrological extremes, main activities include data assimilation and data fusion of rainfall observations from multiple sensors (e.g., rain-gauge network, radar telemeter and satellite - active and passive microwaves) aimed at reducing uncertainty in real-time prediction of precipitation. Information is then integrated within mathematical modeling of major hydrological processes, including rainfall storms, droughts and flash floods, debris flows, firefloods, soil slips, woody debris and snow avalanches.

Aspects related to the Integrated Water Resources Management paradigm have been integrated in all activities, to provide the student with proper perspectives in planning and managing water resource systems.

In this framework, excellent level classes deal with novel statistical estimation techniques for extreme values of hydrologic phenomena, uncertainty analysis in extreme value estimates, analysis and modeling of time and space-time random fields, mainly addressing combined scaling in time and space, and effects of non-stationarities. These courses are harmonically integrated with basic fluid-mechanics, hydraulic and hydrology programs as well as with advanced classes in groundwater, urban hydrology, hydraulic measurements, computational fluid mechanics, thermo-fluid-dynamics.

As such, the contents of the Doctoral Programme are envisioned to address the needs of:

- setting the basis for understanding the factors governing a variety of key physical processes, to achieve increased modelling and predictive capability;

- integrating methods and tools of observation, measure and representation, in order to extend spatial scales of observation and degree of space-time resolution of observable quantities;
- creating a bridge across science, technology and planning actions, in order to establish settings and operational rules for an integration of water and socio-economic policies, within a pragmatic framework of realization and modulation of structural actions, typical of civil and environmental engineering techniques, together with non-structural actions, typically associated with civil protection and land-use planning strategies.

Due to the nature of the research lines, interdisciplinary expertise is required, together with a strong level of integration. These include knowledge and understanding of hydrological, hydraulic, hydrogeological and hydro-geo-chemical processes and aspects, as well as strong analytical and numerical modeling abilities, together with field and laboratory-based expertise. These competencies are currently present in the Faculty Board of the Programme.

Perspectives

The current structure and contents of the interdisciplinary curricula offered by the Doctoral Programme in Water Engineering aim at providing appropriate skills to a variety of profiles. These include (and are not only limited to) research and development divisions of Engineering firms and Consortia for Land and Environment Agencies; industry and public/private companies devoted to management of technological networks and public service utilities, mainly in the institutional framework of management of the integral water cycle; technology innovation and development divisions of agencies / companies devoted to production, installation and management of networks of measurement instrumentation, and remote sensing for hydro-meteo-marine monitoring; public services of monitoring and environmental protection, Authorities and Agencies devoted to planning and monitoring of land and environment development, national and regional technical divisions, both at the Italian and international level; national and international Research Centers and Institutions; international Agencies at the level of the European Union and supra-nations Organizations. The experience of more than hundred of Graduates in Water Engineering, during 23 cycles of Doctoral Programme at the Politecnico di Milano established in 1985, clearly elucidates the capability of our Graduates to fit these key areas of modern engineering.

DOCTORAL PROGRAM BOARD

Baldassarre Bacchi	Marco Mancini
Francesco Ballio	Enrico Orsi
Gianfranco Becciu	Alessandro Paoletti
Silvio Franzetti	Marco Pilotti
Alberto Guadagnini	Roberto Ranzi
Enrico Larcan	Renzo Rosso

ADVISORY BOARD

Roberto Bazzano (AMGA Spa)

Riccardo Casale (1. Commissione Europea - 2. ENEA)

Giorgio Galeati (ENEL Spa)

Claudio Margottini (ENEA)

Alberto Petaccia (Servizio Nazionale Dighe)

Giorgio Roth (CIMA, Centro Interuniversiatrio di Ricerca per il Monitoraggio Ambientale)

Leonello Serva (APAT, Agenzia Nazionale per la Protezione dell'Ambiente e i Servizi Tecnici)

Xavier Sanchez-vila (Universidad Politecnica de Cataluna - Barcellona, Spagna)

SCHOLARSHIP SPONSORS

Ministero degli Affari Esteri (3 borse)

INVERSE MODELING OF GROUNDWATER FLOW UNDER PARAMETRIC AND MODEL UNCERTAINTY

Emanuela Bianchi Janetti

Modeling flow and transport processes in complex porous systems is prone to uncertainty. Sources of uncertainty include boundary conditions, forcing terms and aquifer properties. These, together with uncertainties associated with the conceptual model, are conveniently tackled upon casting the governing equations in a stochastic framework.
The general aim of the Doctoral Thesis is the analysis of uncertainty in flow processes taking place in randomly heterogeneous porous systems. Parametric and conceptual uncertainties are tackled upon casting the governing equations in a stochastic framework.
This dissertation is organized into two major axes: theoretical developments and fields applications.
The first part of the work presents a stochastic moment inverse procedure that allows conditioning estimates of transient hydraulic heads, fluxes and their associated uncertainty on information about transmissivity (T) and hydraulic head (h) data collected in a randomly heterogeneous aquifer. Though it is possible to condition individual Monte Carlo realizations of hydraulic conductivity on head and/or flow rate data, the results of such conditioning are nonunique. To obtain accurate estimates of unique conditional ensemble statistics would necessitate repeating the process for many (typically thousands of) realizations, rendering the Monte Carlo based approach computationally infeasible in many cases of practical interest. The proposed approach allows estimating the conditional mean and variance-covariance of log-transmissivity, head (and flux) directly without resorting to Monte Carlo simulation. The algorithm is based on Laplace-transformed recursive finite-element approximations of exact nonlocal first and second conditional stochastic moment equations of transient flow.
It makes it possible to estimate jointly spatial variations in natural log-transmissivity ($Y = ln\ T$), the parameters of its underlying variogram, and the variance-covariance of these estimates. Log-transmissivity is parameterized geostatistically based on measured values at discrete locations and unknown values at discrete "pilot points". Whereas prior values of Y at pilot point are obtained by generalized kriging, posterior estimates at pilot points are obtained through a maximum likelihood fit of computed and measured transient heads. These posterior estimates are then projected onto the computational grid by kriging. Optionally, the maximum likelihood function may include a regularization term reflecting prior information about Y. The relative weight assigned to this term is evaluated separately from other model parameters to avoid bias and instability. We illustrate and explore the methodology by means of a synthetic example involving a pumping well.
We find that whereas Y and h can be reproduced quite well with parameters estimated on the basis of zero-order mean flow equations, all model quality criteria identify the second-order results as being superior to zero-order results. Identifying the weight of the regularization term and variogram parameters can be done with much lesser ambiguity based on second- than on zero-order results.
A second-order model is required to compute predictive error variances of hydraulic head (and flux) *a posteriori*. Conditioning the inversion jointly on transmissivity and hydraulic head data has reduced the predictive head variance in and around the pumping well in our example relative to that obtained upon conditioning on Y alone; farther from the well this effect was either reversed or not discerned.
In the second part of the work we assess the applicability and performance of the methodology on a test site located in Montalto Uffugo (Calabria, Italy). It has a global planar extension of 400 × 400 m^2. Log-transmissivity is parameterized geostatistically on the basis of an available measured value and a set of unknown values at discrete pilot points. Prior pilot point values of Y are obtained by generalized kriging. Posterior estimates at pilot points are obtained by a maximum likelihood fit of late-time (ensemble) mean head drawdowns and drawdown measurements collected during a pumping test. Information on head drawdowns is provided through self-potential signals recorded by 47 surface electrodes during the test.
We explore the effectiveness of both a zero- and a second-order closure of the mean flow equation at providing a proper geostatistical characterization of the log-transmissivity field. The adoption of a second-order mean flow model renders the sharpest definition of the regularization term and of the Y variogram parameters.
The parameters of the variogram of Y are estimated *a posteriori* using formal model selection criteria. Amongst the criteria, *Kashyap's* Bayesian measure *KIC* identifies the sill quite sharply as being equal to 2.0 and the integral scale as being equal to 4 m. We remark that it would be practically impossible to estimate the variogram parameters geostatistically based solely on the one available Y measurement, without additionally conditioning these estimates on heads, as we have done. The reconstructed spatial pattern of log-transmissivity is qualitatively consistent with the geological setting of the area.
Mean drawdowns conditioned on available information reproduce generally well measured values at a set of validation points, the measurements laying deep within the corresponding envelops of plus/minus one standard deviation of relative drawdown for most of the second-order results.
The work then ends with a large scale application, concerning a regional scale aquifer, involving a domain of about 785 km^2, where natural springs are located. We develope a methodology to reconstruct the conductivity field within a regional-scale aquifer composed by different geological facies. We apply the general approach to reconstruct the conductivity field within the Cremona (Italy) aquifer system. On the basis of available stratigraphic columns and geological sections of the area, we identify five main geo-materials (facies). The hydraulic conductivity, within each facies, is then derived according to the following two different conceptual schemes: (i) *Composite Medium*. In this conceptualization, the system is assumed to be formed by (five) distinct lithological units. In each unit the hydraulic properties, as conductivity, is considered to be constant; (ii) *Overlapping Continua*. In this conceptualization, each point in the domain represents a finite volume in which each of the (five) facies identified in the aquifer may be present in different volumetric percentage. The volumetric fraction of each facies can also be interpreted as the probability of occurrence of that facies in the point (volume) considered.
Information on hydraulic heads is provided in a set of 42 piezometric level measurements recorded in monitoring wells. These data allow estimating the hydraulic conductivity values of each facies for the two conceptual models described above. The results, examined using formal model quality criteria, show that *Overlapping Continua* approach better represents the complex flow system of the aquifer than the *Composite Medium* conceptual scheme. This is consistent with the idea underlying the two model structures. The former implies a sharp boundary between different lithofacies while the latter implies heterogeneities due to different contents of geo-materials overlapping in space. The calibrated model, coupled with appropriate transport model, can be used as an operational tool to draw protection zone for the natural springs in the area.

REAL TIME FLOOD FORECASTS COUPLING METEOROLOGICAL AND HYDROLOGICAL MODELS

Alessandro Ceppi

In recent years, the interest in the prediction and prevention of natural hazards, related to hydro-meteorological events, has increased the challenge for numerical weather modelling, in particular for limited area models, to improve the Quantitative Precipitation Forecasts for hydrological purposes.
In mountain river basins where snow dynamics can affect both precipitation (snow accumulation) and runoff (snow melting), air temperature uncertainty has to be thoroughly investigated. The development and implementation of a real-time flood forecasting system for Alpine basins with a hydro-meteorological operational alert procedure is described in this Ph.D. thesis. The hydro-meteorological chain includes both probabilistic forecasting based on ensemble prediction systems with a lead time of a few days, and short-range forecasts based on a high resolution deterministic atmospheric model.
The hydrological model used to simulate runoff is the distributed FEST-WB model, developed at Politecnico di Milano. The analysis focuses on the Maggiore Lake basins, located in the North-West Italy and Southern Switzerland, and on the Piedmont mountain watersheds faced to Alps and Apennines. The aim of this work is to assess the reliability of a real time flood forecasting system, coupling meteorological and hydrological models, analysing the forecasting precipitation and temperature fields at different spatial scales, and in different weather conditions.
In particular, two events in the MAP-D-PHASE Project in 2007 are analysed to show the effect of the meteorological models spatial resolution on discharge forecasts over mountain basins (the June 2007 convective event), and how the effect of the initial conditions of soil moisture can influence meteorological warnings (the November 2007 event).
After this international experience, it was decided to carry out further analyses in order to investigate different sources of uncertainties that can affect the Quantitative Discharge Forecast in mountain catchments. Since the forecasting methodology is conditioned by hydrological model performance, but above all by atmospheric forcing inputs, we show how a forecasted temperature error with a significant snow line (the November 2008 event), drastically influences the whole forecasting cascade chain over Alpine basins. However, the use of early- warning systems seem to be promising in terms of predicting possible river floods in advance with a lead time of 24-48 hours before the main peak flow, as highlighted in the case studyover the Stura di Demonte basin in May 2008 and in the last flood of the River Seveso that occurred in September 2010 in Milan.

WATER RESOURCES ASSESSMENT FOR THE DAY RIVER BASIN (VIETNAM) UNDER DEVELOPMENT AND CLIMATE CHANGE SCENARIOS

Le Van Chin

Uneven precipitation in space and time together with socio-economic rapid development and climate change, have caused water shortages for water supply to large cities and irrigation areas in many regions of Viet Nam in the dry season. The rainy season (from June to October) provides the 80% of the total annual rainfall, while the water volume of dry season (from November to May of the following year) provides only 20%. Lack of sufficient water volumes occurs in many areas where the pressure of a fast increasing population (1 % per year on average in the last decade in Viet Nam), and intensive agricultural and industrial uses are causing major problems facing sustainable development.

Day river basin actually includes the entire western area of the downstream Red river. Before 1934, Day River was a natural sub-branch of the Red river. The total population in the Day river basin exceeds 8 millions inhabitants, including the Hanoi capital, Nam Dinh and other large towns. From 1934 to 1937, the Day dam was built by French with the purpose of flood relief and drainage as well as controlling the diversion of flood of the Red river into Day river. The total area of Day river basin is of 8000 km^2 with a length of 245 km starting at Yen Trung in the Ha Tay province flowing through Ha Tay, Ha Nam, Nam Dinh, Ninh Binh provinces, and then flowing into the East Sea via the Day mouth.

In order to assess water resources in the basin under socio-economic development and climate change scenarios, a use of reference evapotranspiration, water demand and water balance equations was performed.

The work of the study is described as in the followings:

In the first part, a water assessment and balance at the river basin scale is provided to manage the exploitation and appropriate use of water resources and plan future development. The study describes the river basin water balance and the analysis of drought problems for the Day River Basin, within the Red River delta in Viet Nam, for the period from 1990 to 2004.

In the second part, we focused on the study of the water balance assessment and on the analysis of drought problems for the investigated basin by year 2020 and 2050 with means of data projections of socio – economic development scenarios and using the 1990-2004 rainfall and temperature time series.

In the third part, we carried out the water balance assessment and analysis of drought problems for the basin under both socio – economic development and climate change scenarios. In this part, the 1990-2004 rainfall and temperature time series are projected to the 2020 and 2050 time window accounting for percentage precipitation changes and temperature bias for the North Delta in view of high green-house gases emission scenario (SRES.A2) and medium emission scenario (SRES.B2). Water demand is expected to rise because of socio-economic and population growth: by the year 2020, it is expected to rise by 25 % on average relative to th eyear 2000 with total water volume of $6887 \cdot 10^6$ m^3. And water demand will continue to rise by the year 2050, it is expected to rise by 16% on average relative to 2020 with total water volume need of $7959 \cdot 10^6$ m^3.

Water demand in the basin will increase when considering the impact of climate change scenarios. Namely, total water demand is expected to increase by 0.91% in 2020 and 2.63% relative to the socio-economic development scenario in 2050 for medium emission scenario (B2), by 2.1% in 2020 and 3.1% relative to socio-economic development scenario in 2050 for high emission scenario (A2). Also due to climate change, rainfall is projected to decrease by 1.0-1.5% in dry season by the 2020s. This, combined with an increase in temperature of about 0.5-0.7 °C, would result in a significant impact on water needs, with a small increase of mean deficit duration, but an increase of 7 to 8 % on mean deficit severity and 7 to 9 % relative to mean deficit intensity for the same period under socio-economic development scenario. By the year 2050, with a decrease of rainfall expected to be 3 to 5% in the dry season and an increase of temperature of about 1.2 to 1.5 °C, water deficit would become more serious in terms of severity and intensity, namely, an increase of annual mean deficit severity would be 7 to 8% relative to the socio-economic development scenario for 2050.

Possible adaptation measures to such changes include structural and non-strucral measures. We can use intakes to convert more water from Red river and combine developing varieties of better yielding crops under water scarcity, selecting drought tolerant varieties, replacing crops that consume large amounts of water with those which consume less water. Some important measures in water deficit mitigation are early warning, water deficit response policy and corresponding organizational structures.

One Poster presentations is presented to by Le V.C., and Ranzi R., EGU - European Geosciences Union being "River Basin Water Assessment and Balance in fast developing areas in Viet Nam", Research Abstracts Vol. 12, EGU2010-3107, 2010. Other one abstract is already submitted to EGU - European Geosciences Union being "Water resources assessment for the Day river basin (Vietnam) under development and climate change scenarios", April, 2010.

FLOOD EARLY WARNING SYSTEMS PERFORMANCE
An approach at the warning chain perspective

Daniela Molinari

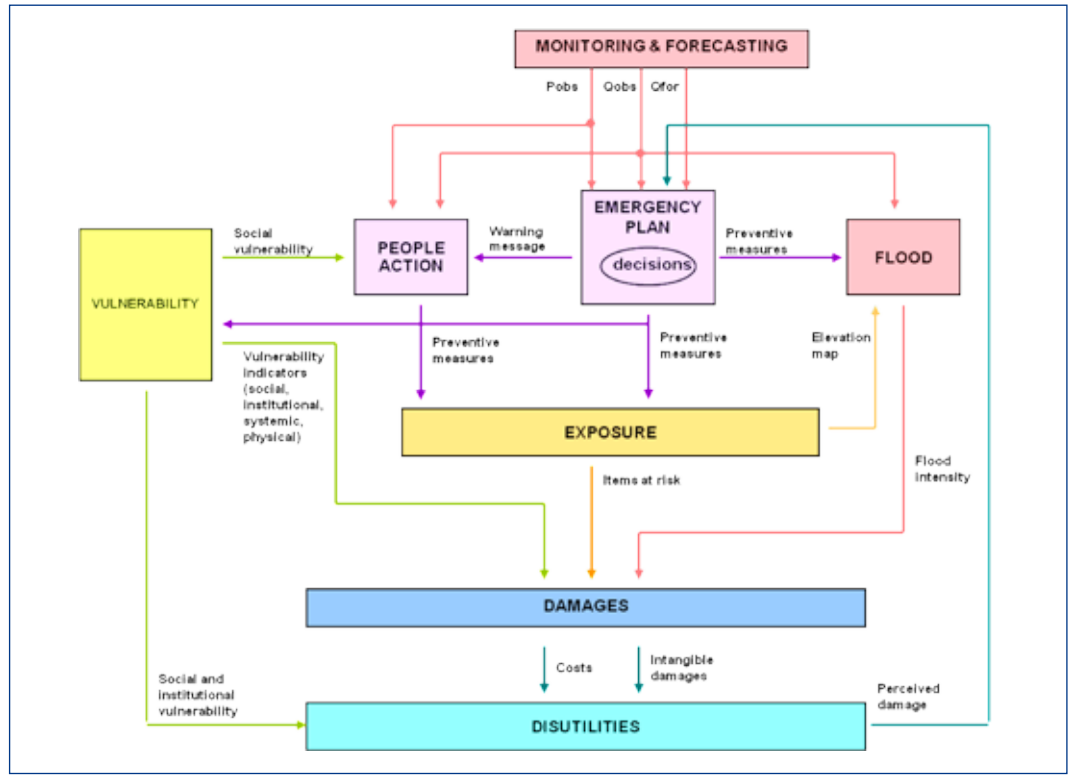
This research started with the intent to understand why Flood Early Warning Systems (FEWSs) fail. However, such an objective required first to define what a FEWS is and which the goals of its performance evaluation are; then, a first attempt was possible to evaluate FEWSs performance. In line with this, the thesis is organised in two parts. In part I, preliminary "open questions" about the definition and the role of FEWSs are handled; in part II, concepts and tools to assess FEWSs performance are consequently provided.

The main result of the first part can be identified in the definition of a possible framework to describe the flood warning process (see figure 1).
The framework is based on the concept of "Total Warning System", promoting thus a systemic vision of the warning problem in which (i) technical and non-technical aspects are merged (ii) each FEWS component is considered as a link of a chain whose performance affects the performance of the whole warning process as well.
Just by analysing the warning process, in terms of its components, its actors as well as the decisions they perform, the framework supported the specificication of the objective of this research, being the development of a suitable tool to assess FEWSs performance in terms of their capacity to reduce expected damages.
Such a tool would allow analysts to evaluate systems from three different perspectives (which are all crucial for FEWSs effectiveness): first, from the forecasting point of view, meaning looking at the goodness of flood forecasts in term of their capability to predict the features of incoming floods; second, at the perspective of risk scenarios, that is considering the capacity of the system to proper figure out expected damages in case of flood; finally, from the point of view of damage reduction, that is investigating the ability of the system to lessen expected damages.
Such an approach goes beyond the traditional assessment of FEWSs which instead is only focused on the evaluation of monitoring and forecasting abilities.

Part II represents instead the practical section of the thesis where a procedure is proposed to evaluate FEWSs from the three different perspectives identified above. In addition, a case study is provided to describe how such evaluations can be carried out in practice. Part II is organised, in turn, in two sections. A first section supplies all the theoretical knowledge that is required to face the problem at stake, with particular attention to damage assessment and damage reduction; with respect to this, a literature review has been carried out in order to provide an organised synthesis of available tools. The second one, instead, implements the theory (and the procedure) to the case study.

It can be state that the starting objectives of this work have been generally met. Specifically, the proposed framework allows not only to identify which are the main components of a FEWS but also to define the objective of its evaluation (i.e. the capacity to reduce expected damages). From this perspective, then, a possible procedure has been proposed just to assess FEWSs performance.

The thesis represents "per se" an innovation with respect to the traditional approach to the problem under investigation, particularly, accounting for (i) the whole warning chain and the role each of its component plays in the definition of FEWSs performance (ii) damages, among the variables on which FEWSs performance assessment is grounded.
More in detail, it can be state that the thesis presents one main strength being that of proposing an operational tool, for the evaluation of FEWSs, which (i) is complete, meaning that it allows to evaluate the whole warning process, as described by the framework (ii) is fixed and involves defined steps/ methods. With respect to this, it must be stressed that, unlike for seismic risk, no standards exist in the field of flood risk for related analyses but few scientific attempts/guidelines; from this perspective, the contribution this thesis brings is relevant.
On the other hand, the current limits of such an approach stand out as well: first of all, a lack of tools to estimate damage and its reduction has been observed. Second, a problem concerns the scale(s) of the analysis (i.e. the stakeholder perspective); indeed, whilst in hazard assessments the spatial and the temporal scales of the analyses are dictated by the phenomena under investigation, in damage assessments they depend on the point of view that is adopted or, in other words, on the stakeholder(s) the analysis is carried out for. Third, the role of uncertainty clearly stands out; scientific and non-scientific uncertainty affects every step of assessment, limiting the reliability of results. All of these aspects represent critical issues on which further research should focus on.



1. The figure displays the warning decision making process, as conceived in this research. Arrows represent variables while rectangles represent processing steps which need to be modelled.

REAL TIME FLOOD FORECASTING IN THE LO RIVER WITH SURFACE OBSERVATIONS AND EXTENDED KALMAN FILTERING

Nguyen Hoang Son

Since 2007, the distributed hydrological model DIMOSHONG is applied at the NCHMF-National Center for HydroMeteorological Forecasting and the Water Resources University in Hanoi for flood forecasting in the Red river basin. The model simulated severe floods occurred since 1971 in Vietnam, with rainfall forecast from BOLAM meteorological model and observed rainfall. First applications showed encouraging results and its being planned to be applied in different basins in Vietnam.

This thesis improvements including the implementation of an EKF-Extended Kalman Filtering technique to update the state of the hydrological system based on river level observations in the Lo river, North of Vietnam. The Lo river is one of the main branches of Red river, flowing from Yunnan, China to Vietnam at Viet Tri with a basin area of 38135 km^2. The river length is 470 km while 275 km are in Vietnam. In the Lo river two large reservoirs are Tuyen Quang with a volume capacity of 2 260 $.10^6$ m^3 and Thac Ba reservoir with 2490 $.10^6$ m^3. There are two main stations for the Vietnam forecast system at Tuyen Quang, one of the main cities in East North part of Vietnam, and Vu Quang. Close to Tuyen Quang, 4.5 km upstream, one pilot automatic station was set up in 2008 at Ghenh Ga, on the Lo river. The data collected there were used for testing a near-real time flood forecasting system with model update, as was described in this research.

Rainfall in the Lo basin is relevant, with 1,880 mm annual average, but uneven in distribution and highly variable in space and time. The runoff regime on the Lo river has two seasons depending on rainfall season. The flood season lasts for five months from June to October. The runoff volume of Lo river basin in the flood season represents 73-74% of total yearly runoff volume.

All the available data related to thesis are collected such as rainfall, observed runoff, water level, reservoir water level, reservoir operation scenarios. Other relevant data such as river system maps, soil maps, landuse map, climate condition, topography, are also collected.

The DIMOSHONG distributed model was tested for the Lo river basin with fourteen near real time water level observing station in Vietnam in two ways: a) in deterministic mode b) with EKF inflow updating. Another near real time data such as rainfall, and reservoir water level is also used. Floods occurred in 2003, 2006, 2007, 2008, and 2009 are simulated with 6h and 24h steps for deterministic mode and 24h for EKF. The results between simulated and observed are encouraging. In 2006 with step 6h, Nash-Sutcliffe efficiency coefficient at Ham Yen is 0.69, Chiem Hoa 0.61, Tuyen Quang 0.85, Vu Quang 0.64.with step 1 day in 2006, Nash at Chiem Hoa is 0.68, Ham Yen 0.74, Tuyen Quang 0.84, Vu Quang 0.74. In 2009 with step 6h, Nash coefficient at Chiem Hoa is 0.71, Ham Yen 0.45, Tuyen Quang 0.86 , Vu Quang 0.81. With step 1 day, Nash at Chiem Hoa is 0.88, Ham Yen 0.58, Tuyen Quang 0.86, Vu Quang 0.72.

To apply EKF with distributed model DIMOSHONG, the Lo river is divided to 14 sub-basin gauged by the 14 observing stations.

If one station losses observed data, the station downstream will be used to update the upstream basin.

The key state variable used for updating is water volume stored in surface stream channels.

The channel volume is assumed as a non linear function of runoff at the outlet. When channel volume is updated, other factors such as inflow to and outflow from each subbasin are also updated.

EKF combined with the distributed model DIMOSHONG show good results, as well.

The results show that, in 2006 Nash at Chiem Hoa increase from 0.77 to 0.87, in Tuyen Quang from 0.90 to 0.92, but in Ham Yen Nash decreases from 0.74 to 0.65, in Vu Quang from 0.82 to 0.80. In 2008, Nash at Chiem Hoa increases from 0.91 to 0.92, Ham Yen the same with 0.51, Vu Quang from 0.57 to 0.73, at Tuyen Quang Nash from 0.72 to 0.85. In 2009, Nash at Chiem Hoa go up from 0.88 to 0.89, at Vu Quang from 0.72 to 0.74, in Ham Yen decreases from 0.58 to 0.54, and in Tuyen Quang is almost stable, from 0.86 to 0.85. In 2009, in Chiem Hoa 25 out of 39 days exhibit runoff errors with EKF smaller than in the deterministic run, at Ham Yen 20 out 39, in Tuyen Quang 24 out of 39, and in Vu Quang 24 out of 39. So, on average, the EKF procedure enhances the model performances.

From the point of view of current forecast practices in Vietnam, the application of DIMOSHONG distributed model with EKF updating is a promising tool, and in the future, the DIMOSHONG model will likely be an important reference for flood forecasting practices in Vietnam.

To prepare knowledge for the thesis, some useful courses were taken at Milano and Brescia University such as: Meccanica dei fluidi, Idrogeostatistica, Hydrometeorological monitoring systems, Risk assessment in subsurface hydrology, Stochastic methods for flow and transport in heterogeneous aquifers, Idrologia con Laboratorio B …etc.

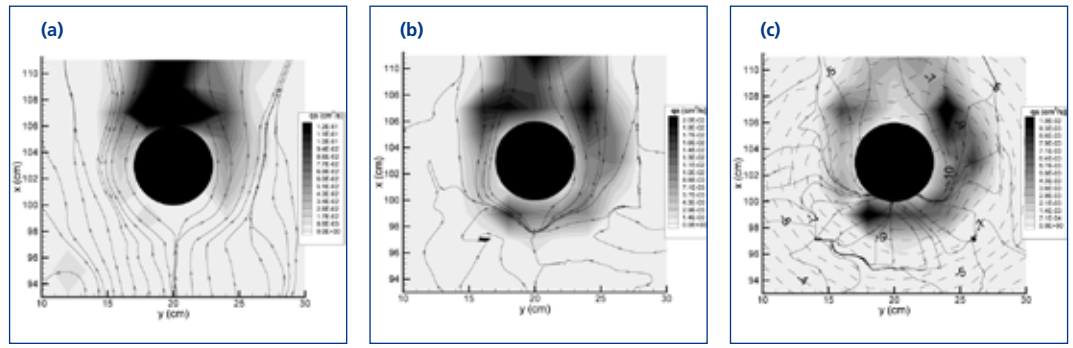
One abstract is already submitted to EGU - European Geosciences Union being "Real time forecast with Extend Kalman Filter on the Lo river basin (Vietnam)", EGU2010-2854, 2010. Another paper is processing writing following thesis results.

SEDIMENT TRANSPORT KINEMATICS IN BRIDGE SCOUR PROCESSES

Tran Kim Chau

Local pier and abutment scour is a crucial topic in hydraulic engineering, due to the significant social and economical impact of bridge failure. Therefore, reliable tools for scour prediction are necessary for both design and vulnerability evaluation of the structures.
As research progressed over time, different approaches were taken to study this problem.
An initial approach aimed at deriving predictive equations of practical use. Typical formulae took into account flow depth, foundation size, flow intensity, sediment characteristics, foundation type, shape and alignment to estimate equilibrium scour depth at an abutment and a pier. Other approaches provided, based on extensive experimentation, equations for the temporal evolution of the scour depth. Despite the engineering relevance of black-box experimental studies, these are inappropriate for phenomenological characterization of process mechanics.
Some researchers understood the need to have more than that. So they started to investigate features of the flow field in both numerical and experimental studies. Obtained results have been used to describe flow field patterns, turbulence intensity distribution and boundary shear stress distribution.

Few approaches considered the sediment motion characteristics as the objects of the investigation. The research group in Milan applied an image processing technique to measuring of sediment transport kinematics in local abutment scour.
Only another example is known from the scientific literature, dealing with sediment kinematics around a circular pier.
The thesis presents the results about sediment motion characteristics on the bottom of abutment and pier erosion holes in steady clear-water conditions. The data from two experimental campaigns have been used. The first experimental test was done for a vertical-wall abutment prior to the beginning of this Ph.D. research, in 2006. The second one was performed in 2010 for a circular pier. Both tests were run in the same conditions (flow discharge, sediment and channel). In each campaign, two types of test have been done. The first one was run for measuring the scour depth, while the other one for visualizing the sediment motion field. In the first type, during the test the scour depth was frequently measured at some locations to observe the development of the scour hole. Moreover, several surveys were made of the entire scour hole for proper geometrical characterization of the latter. In tests for visualization of particle motion, the experiment in progress has been filmed many times by means of a digital motion camera; in addition, an experimental technique for the image-processing-based measurement of sediment kinematics in solid transport processes has been used.
The results of the thesis can be divided into two parts.
In the first part, as mentioned, data from a previous experiment of local abutment scour have been processed. In the developed stages of the erosion process, the particle motion presents significant bimodality, which suggests to attribute different causes to the different motion events: it has been hypothesized to divide movements into "turbulence-dominated motion" "and gravity-dominated motion". The former is related with action of the principal vortex, while the latter involves geotechnical sliding of the particles along the slopes of the hole. We have decided to recognize the GD events based on two criteria, namely (i) a direction of motion similar to that of the local gradient of the scour hole and (ii) a velocity bounded by the maximum ideal velocity of sliding over an inclined plane. A relevant difference has been found between the dynamics of gravity-dominated and turbulence-dominated events.
GD events direction always consists with slope direction



1. Time-averaged sediment motion pattern (sediment transport rate obtained as the time-averaged magnitude of instantaneous vectors) for times (a) 4', (b) 20', (c) 6h20'→7h.

(which is obvious based on the first criterion for definition), while TD events tend to move in inverted way. Concentrations of sediments involved in GD events and TD events are the same in magnitude and variation. On other hand, velocity and solid discharge of TD events are much greater and more space- and time-fluctuating than those of GD events. Eventually, it was found that the presence of geotechnical effects in the erosion hole may significantly alter the scour rate. Spatially-averaged scour rate of ALL events is 0.0024 cm/s, for TD is 0.0044 cm/s, with a reduction of almost 50% as a consequence of the presence of GD events. The findings suggest that a separate modeling of hydro-dynamic and geotechnical events may improve the predictive capabilities for these processes, even if no strategies for modeling have been proposed here.

In the second part, a local scour experiment with a circular pier has been performed. 6 surveys of the scour hole were made during the test to describe the development of the scour hole. The parts of the hole in front and beside the pier are more inclined than that downstream of the obstacle. An appreciable self-similarity of the scour hole was assessed, limited to its upstream part. Similarly with what done in the first part of this work, concentration, velocity and solid discharge were measured by image processing. The observation of the sediment kinematics has enabled hypotheses to be made about the major scouring agents at different evolution stages of the process. The sediment pattern consists with the expected flow field around the pier. In addition, some locations are considered to study solid discharge rate. We found that the solid discharge is initially largest downstream of the pier, but reduces strongly during the test. The solid discharge in front of the obstacle presents opposite trend, it being insignificant at the beginning and increasing in the following stages. Direction of grains is different at the successive stages. In the beginning, the grains mainly move in well defined way, consisting with the main direction of the flow deviating around the obstacle. But in the end, particle direction is widely spread. Finally, despite the sediment motion pattern at a circular pier is much different from that at a vertical-wall abutment, it has been recognized that the small-scale dynamics of the sediment transport process is likely to be similar in the two cases. The last consideration encourages attempts to generalize findings to any geometry of the obstacle, even if this shall be thoroughly checked in follow-up studies.

MEASUREMENT, ANALYSIS AND MODELLING OF INTERNAL WAVES PROPAGATION IN ISEO LAKE

Giulia Valerio

This Ph.D. Thesis addresses the problems and challenges related to monitoring and modelling the propagation of internal waves in a deep lake in northern Italy.
The related experimental and numerical activities were carried on at the University of Brescia, where a new line of research, dealing with physical limnology, started in 2007; this project included a scientific collaboration with one of worldwide leading group in the field of limnology (Centre for Water Research, CWR – University of Western Australia).
Lakes constitute a precious water resource for human existence on Earth, offering a wide range of services to society; these multiple uses induce in turn multiple pressures on the water ecosystems that in the last century have yielded to a progressive degradation of their quality status.
Accordingly, management of lakes quality is a urgent and critical environmental issue, especially when contextualized in a long-term climate-change scenario. In this context, the role of physical limnology is crucial, since both the chemical and biological processes that develop in natural water bodies and control the quality status of lake water are strongly coupled to the hydrodynamic response of the aquatic system.

As a case study, the choice has fallen on Lake Iseo which is the fourth largest Italian lake and epitomizes many of the aspects that make this issue complex and alive: a very peculiar bathymetry; the presence of relevant periodic wind forcing capable to excite strong internal oscillations; its being located in an area of transition between pre-Alpine and Alpine setting, where environmental landmarks and important industrial settlements coexist. Over the last decades this strong human pressure brought the lake initial oligotrophic status to the present anoxia of the hypolimnion, condition that now the local community perceives as unsustainable, looking for solutions to revert the original situation.
In order to provide an understanding of the hydrodynamic processes that control mixing and transport phenomena in Iseo lake, the research has been developed by integrating the analysis experimental, theoretical and numerical aspects.
Altogether, they have led to the comprehension of the horizontal and vertical structure of the internal modes in a complex natural basin, and to the reproduction of long-period internal oscillatory motions through a simplified model of its internal hydrodynamic.
As a preliminary step, the research focused on the theoretical comprehension of mid-size lakes hydrodynamics and in the acquisition of the past knowledge about this case. Besides, during the period 2009-2011, a wide field campaign has been developed in order to provide data that have shed light on the hydrodynamics of Iseo lake. This activity was aimed to obtain the experimental data that are needed to support theoretical and numerical considerations. First of all, the analysis of field data has assured a first understanding of the acting phenomena.
From the wind studies it emerged in particular that the complexity of the topography surrounding the lake generates an high degree of spatial variability on the wind field both in time and space. The interpretation of most of the effects of the spatial variability, such as the deflection due to the valley morphology, the sheltering induced by 3D obstacles and the wind fetch, where supported by a literature review and by simplified numerical simulations of the wind pattern. Water hydrodynamic modelling, on the other side, highlighted the deep influence that these wind pattern have on the mixing processes occurring in the upper water layer, so legitimating the modelling choice of a temporally and spatially varying wind field, reconstructed through the interpolation of the wind data available at the different lake locations. With regards to the temperature data, the resolution of the T-chains measurements allowed to give evidence of very energetic internal waves occurring in Iseo during the stratified period. This response is mainly characterized by a dominant uninodal response both in the vertical and horizontal direction, and by the occasional excitation of a second vertical mode H1V2. The analysis of the seasonal evolution of the thermal regime in relation with the wind one, allowed to interpret these oscillatory features as the consequence of a quasi-resonant condition between wind and wave motions. It is of real interest to underline how in Iseo Lake the changes induced in heat distribution in time and depth yields in turn to a seasonal evolution of the uninodal free motions periodicity that keeps it in resonance with the wind for the main part of the stratified period.
The assimilation and interpretation of the huge quantity of data collected during these experimental campaigns provided the basis for the development of the modelling activity, that deals with the results of the basin-scale internal wave propagation obtained through the application of a layered, modal code developed by CWR. Despite the strong simplification operated in the vertical density stratification, in fact, these models can operate in a computationally efficient way on a 3D arbitrary bathymetry. In addition, thanks to the separation of the whole solution into individual modes, they can provide a useful interpretation key of the internal waves structure in relation to the forcing acting on the lake.
With regards to the horizontal structure of the free modes, a key finding was the role played by the peculiar Iseo lake topology. The IV*th* horizontal mode is in fact characterized by a wave rotating anticyclonically around Monte Isola perimeter. The presence of this particular oscillatory motion close to the main island has been observed from an experimental point of view and explained theoretically, by deriving analytically for an annulus-shaped basin. On the basis of these considerations, it was possible to conclude that, when an horizontal mode with a wavelength close to the island radius develops, a Poincarè-like wave is trapped around the island itself. Concerning the internal waves simulated under forced conditions, the modal code showed good capabilities in the reproduction of the main features of both the spatial and temporal structure of measured internal waves. Generally, a very good simulation of the V1H1 metalimnion interfaces oscillations, in term of phase and amplitude, was achieved under ordinary daily winds, so confirming to be the dominant oscillatory response of Iseo lake. The model was also able to reproduce oscillations of longer period, occasionally measured at the lower interface of the metalimnion. Operating a separation of the whole solution into individual modes, it was possible to interpret these motions as second vertical mode oscillations excited by exceptionally strong or long-lasting wind events.
The scientific work described in this Thesis opens a wide set of possible future development of the research project.
In particular, the urgency of facing the degradation of the quality status of lake Iseo has now led to open a new research line aimed to couple the hydrodynamic model to a chemical-biological one in order to understand the effects of the physical processes that have been detached with the quality conditions of the water body.