

Introduction

In 1966 a dramatic flood of some 194cm, over a metre above the surface of St Mark's Square, alerted the world to the fact that Venice was in peril from the very waters that had, in its heyday, afforded it protection from invading armies. In the first decade of the 20th century St. Mark's Square flooded less than ten times per year. By the 1980s, flooding was occurring 40 times per year and since September 2000 over 60 flood events per year have been recorded. The 144 cm flood of 6 November 2000, 64 cm above the surface of St. Mark's Square, was one of the ten most severe events since 1900, with 93% of the city under water, followed by a greater flood of 147 cm on 16 November 2002, the fifth highest on record. A new condition also emerged in June 2002 where an unexpected summer flooding occurred, previously these events were restricted to the winter months.

The significant groundwater withdrawal from the Venice aquifer for industrial and agricultural use in 1950s to middle 1970s, which played a large role in causing subsidence and hence increasing flooding in Venice, has ceased. However Venice can not hope for a respite, there is also sea level rise to consider due to global environmental change, the uncertainty of impacts from changes in storminess and the natural subsidence of the Venice area. Venice is therefore more vulnerable to flooding than ever before.

Alongside the flooding problem, Venice faces a host of other environmental issues. There has been - and continues to be - a strong net loss of sediments from the lagoon over time. Principal causes are the diversion of all large rivers that discharged into the lagoon in 15th to 17th Centuries to prevent silting up, and long jetties, constructed at the inlets between the late 19th and early 20th Centuries, which reduced the import of marine sediments into the lagoon. Starved of new sediments and eroded by wave attack from winds, and further affected by land reclamation, the lagoon wetlands have now been reduced to a third of their former extent at the beginning of the 20th century. Major navigation canals constructed in latter 20th Century have further complicated the hydrodynamic and sediment transport conditions in the Lagoon. In addition, a number of present, and at times conflicting, interests such as port development, industrial and petro-chemical activities, agriculture, habitat conservation, fisheries, boating, tourism and recreation, pressurise the system. The movement and storage of pollutants within the industrialised lagoon arising from agricultural, industrial and urban discharges have caused major water quality problems, further exacerbating environmental degradation of the lagoon and its resilience.

If Venice is to continue to survive, all of these matters need to be managed, and solutions for the serious problems facing Venice are required, fast. These issues have been, and continue to attract much scientific attention. A great deal of important research work has already been undertaken, in Italy and around the World. Some action to protect Venice from flooding and

pollution is already underway. Importantly, the execution of substantial interventions in the form of mobile barriers to close the lagoon against exceptionally high tides and associated measures, have now been adopted by the Italian Government. The barriers present unprecedented engineering challenges. They also stimulate enormous interest within the scientific and engineering community, because of the interaction between the barrier works and other flooding safeguarding action, as well as ongoing programmes for habitat restoration, pollution and water quality control and other infrastructure works.

While the need to take action is clear, there is still apparent disagreement between scientists, engineers, managers, decision-makers and the public about what the nature of such action should be. The inter-disciplinary dimension of the problem is clear, and calls for solutions to be considered within an integrated framework: architectural and physical infrastructure of Venice, engineering and technological possibilities and impacts, geomorphology and habitats, water quality and ecology, sea level rise and climate.

With these issues in mind, Cambridge University Committee for Interdisciplinary Environmental Studies (CIES) and Churchill College Cambridge in collaboration with the Venice in Peril Fund (the British Committee for the preservation of Venice) embarked in 2001 on a three-year research project focussing on the flooding and environmental challenges for Venice and the Venice Lagoon. The project is carried out in association with the Venice based Consortium for co-ordination of research concerning the Venice Lagoon System (CORILA).

In broad terms, the mission of the project is to promote the objective study and review of information concerning key aspects of the flooding and environmental issues relevant to Venice, in an international dimension. The scope of the project is to:

- ? provide realistic analysis of the environmental issues for Venice;
- ? promote widespread recognition of the flooding issues and related environmental problems of Venice; and
- ? support through discussions, workshops and the International Meeting, the exchange of information between researchers from around the world and from different disciplines, working on similar problems to facilitate a fruitful exchange of knowledge.

The project offers an inter-disciplinary forum for discussion and involves organisations from Italy, Europe and worldwide, communicating the Venice situation internationally and showing that Venice experience can be relevant to other locations and, equally, experience from elsewhere can contribute to Venice. This initiative will address the need to establish cross-

Abstracts Volume

Flooding and Environmental Challenges for Venice and its Lagoon: State of Knowledge 2003

Discussion Meeting – Cambridge, 14th-17th September, 2003

disciplinary thinking to fully cover all the complexities of Venice's "problems" as well as the need for greater consensus on the baseline information characterising the Venice lagoon system. Taken together, these approaches will contribute to the development of a better understanding of sustainable environmental management solutions for this most unique city and its surroundings. In this context, a series of one day technical workshops was organised by the project team and held at Churchill College in September 2002. The workshops covered a variety of disciplines, under the headings: (i) Venice flooding, architectural and structural issues (ii) Engineering solutions to the flooding of Venice, (iii) Physical and ecological processes in the Venice Lagoon, (iv) Mathematical modelling of hydrodynamics, water quality and morphology of the lagoon, and (v) Global environmental change, uncertainty and risk: Venice and the North Adriatic Sea. Attendance included key scientists and engineers from Venice as well as experts from a variety of research institutions and universities worldwide.

The current international technical meeting comes under the heading "Flooding and Environmental Challenges for Venice and its Lagoon: State of Knowledge 2003", and is hosted by Churchill College, Cambridge. The meeting represents the next phase of the project. It will provide the first up-to-date international interdisciplinary synthesis addressing the problems of Venice and the lagoon, since the UNESCO Study of 1969. It is intended that the meeting will serve to highlight the current state of knowledge on Venice, and will facilitate discussion on solutions. In addition, some of the issues facing Venice apply in one way or another to other coastal locations (e.g. the Thames, England; St Petersburg, Russia; Chesapeake Bay, USA; and, Rotterdam and the Eastern Scheldt, Holland). The meeting will allow lessons learnt and solutions developed in these locations to be compared.

The meeting is cross-disciplinary and international. It involves key scientists from Venice and elsewhere in Italy, from the United Kingdom, the Netherlands, Germany, Spain, Malta, Portugal, Lithuania, Russia and the United States and all with directly relevant experience in their individual fields of research or practice. The main objective of the meeting is to promote an informed debate between experts, researchers, practitioners and decision-makers in the context of continuing efforts to safeguard Venice. It aims to develop greater consensus and cohesion regarding our understanding of the Venice Lagoon system and safeguarding measures.

FINAL PROGRAMME

The meeting is bilingual with simultaneous translation (English and Italian)

Sunday 14th September 2003	
1100-1300	<i>Tour of Cambridge</i> Gondolas and Punting on the River Cam
1400-1500	REGISTRATION (Wolfson Foyer)
1500-1530	WELCOME (Wolfson Theatre) Chair: Sir John Boyd (Master, Churchill College) Anna Somers Cocks (Venice in Peril) Dr Tom Spencer, Dr Caroline Fletcher (Department of Geography, University of Cambridge)
1530-1700	INTRODUCTORY SESSION Chair: Prof. Peter Guthrie (Department of Engineering, University of Cambridge)
1530-1600	<i>Local flood protection measures in Venice</i> Prof. Marino Folin (IUAV)
1600-1640	<i>Engineering interventions in Venice and the Venice lagoon</i> Ing. Alberto Scotti (Technital for Magistrato alle Acque)
1640-1700	<i>Venice port activities in a delicate environment</i> Dr Andrea Razzini (Autorità Portuale di Venezia)
1700-1730	TEA (Jock Colville Hall)
1730-1900	<i>PANEL DISCUSSION - What are the lessons from around the world?</i> Chair: Prof. Peter Guthrie (University of Cambridge) Thames Barrier: now and in the future Dr Sarah Lavery (UK Environment Agency Thames Region); David Wilkes (UK Environment Agency NorthEast Region) St Petersburg: EIA for Completion of the St. Petersburg Flood Barrier Dr Herman Gerritsen (WL Delft) St Petersburg: Integrated Water Management to support Sustainable Development of the St. Petersburg Region Mr Alexander Savin and Dr Rosa Mikhailenko (Morzaschita) Cardiff Barrage: Peter Hunter (Jacobs) Rotterdam Barrier: Mr René Bol (Department of Water Management Rotterdam) Eastern Scheldt Barrier: Dr. Henk Saeijs (Zeeland Directorate for Eastern Scheldt) and Mr Joris Geurts van Kessel (RIKZ, Zeeland Branch for Eastern Scheldt)
1930-2100	DINNER (Main Hall) Host: Prof. Sir Hermann Bondi
	Wolfson Theatre <i>Venice matters</i> Prof. Deborah Howard (Faculty of Architecture and History of Art, University of Cambridge)

Monday 15th September 2003 a.m.	
0730-0830	BREAKFAST (Main Hall)
	RESEARCH OVERVIEW (Wolfson Theatre)
0830-1045	Chair: Dr Tom Spencer (Department of Geography, University of Cambridge)
0830-0915	<i>Plenary: Flooding in Venice: overview of issues, approaches and research needs</i> Prof. Pier Vellinga (Free University of Amsterdam)
0915-0930	Video Speech by Prof. Paolo Costa (Mayor of Venice- Comune di Venezia)
0930-1000	Speaker to be confirmed (European Commission)
1000-1015	<i>UNESCO Activities</i> Dr Howard Moore (UNESCO-ROSTE)
1015-1030	<i>CORILA Activities</i> Dr Pierpaolo Campostrini (CORILA)
1030-1045	<i>Discussion</i>
1045-1115	COFFEE (Jock Colville Hall)
	THEME 1:
	URBAN FLOODING: ARCHITECTURAL AND STRUCTURAL ISSUES
1115-1300	Chair: Anna Somers Cocks (Venice in Peril)
1115-1145	<i>Plenary: St Marks Basilica as a case study in flooding issues for historical Venice</i> Arch. Ettore Vio (Proto della Basilica di San Marco)
1145-1215	<i>Insula: A project for Venice</i> Prof. Bruno Dolcetta (Insula)
1215-1230	<i>Methodologies and techniques for the conservation and restoration of Venetian buildings</i> Arch. Edoardo Danzi (IUAV)
1230-1245	<i>Interactions between natural and human caused phenomena with respect to the maintenance of the Venetian built environment</i> Prof. Fabio Carrera (WPI)
1245-1300	<i>Discussion</i>
1300-1400	LUNCH (Main Hall)

Monday 15th September 2003 p.m.	
	THEME 2: WEATHER AND SEA LEVEL FORECASTING Chair: Dr Ida Brøker (DHI)
1400-1515	<i>Introduction and overview</i> Prof Alberto Tomasin (Università di Venezia)
1415-1430	<i>Sea level forecasting at the Centro Previsioni e Segnalazioni Maree of Venice Municipality</i> Dr Lucia Zampato (Centro Maree, Comune di Venezia)
1430-1445	<i>Gates strategies & storm surge forecasting system developed for Venice flood management</i> Ing. Maurizio Di Donato (CVN) and Ing. Yuil Eprim (Technital)
1445-1500	<i>Satellite wind observations as possible meteorological forcing for storm surge models</i> Dr Stefano Zecchetto (ISAC CNR)
1500-1515	<i>Discussion</i>
1515-1545	TEA (Jock Colville Hall)
	THEME 3: MODELLING AND FIELD DATA: HYDRODYNAMICS AND LAGOON PROCESSES Chair: Prof. Keith Richards (Department of Geography, University of Cambridge)
1545-1745	
1545-1615	<i>Plenary: Interrelations between Venice the city and its lagoon</i> Prof. Job Baretta, Noctiluca, The Netherlands
1615-1630	<i>Measuring water exchange between the Venice Lagoon and the Open Sea</i> Dr Miro Gacic (OGS)
1630-1645	<i>Application of hydrodynamics and morphological models</i> Ing. Antonio Gozzi (Technital for MAV)
1645-1700	<i>Integrated modelling of the Venice Lagoon</i> Dr Georg Umgieser (ISMAR-CNR)
1700-1715	<i>Open problems in modelling morphodynamics in Venice Lagoon</i> Prof Giovanni Seminara (Università di Genova)
1715-1730	<i>Mobile barriers as a management tool for water quality and lagoon flushing</i> Prof. Don Harleman (MIT, USA)
1730-1745	<i>Discussion</i>
1830-1930	Poster Session and Reception (Jock Colville Hall) Web site demonstrations: UNESCO contribution to a better understanding of the Venice Urban System <i>Andrea Mancuso (IUAV) Philippe Pypaert (UNESCO)</i> CORILA – RIVELA <i>Caterina Dabalà (CORILA)</i>
1930-2100	DINNER (Main Hall)
2100-2200	<i>The ancient Magistrato alle Acque: How Venice responded to the silting up of the lagoon in the 15-17C</i> Giovanni Caniato (Archivio di Stato)

Tuesday 16th September 2003	
0730-0830	BREAKFAST
0830-1100	THEME 4: ECOLOGICAL PROCESSES AND ENVIRONMENTAL QUALITY (Wolfson Theatre) Chair: Dr Stephen Malcolm (UK Centre for Environment, Fisheries and Aquaculture)
0830-0900	<i>Plenary: Environmental quality issues in the Venice Lagoon</i> Prof. Antonio Marcomini (Università di Venezia)
0900-0920	<i>Changes in nutrients and plankton communities in the Venice lagoon</i> Dr Sandro Rabitti (ISMAR-CNR)
0920-0940	<i>Pollution in the lagoon: catchment area and Venice historical centre</i> Dr Roberto Zonta (ISMAR-CNR)
0940-1000	<i>Trace metals fluxes in the Venice Lagoon</i> Prof. Gabriele Capodaglio (Università di Venezia)
1000-1020	<i>Institutional monitoring of the Lagoon, its watershed and coastal waters of the Adriatic</i> Dr Gisella Penna (Regione Veneto) and Arch. Albertogiulio Bernstein (CVN)
1020-1040	<i>Striving towards a comprehensive knowledge of the lagoon ecosystem</i> Dr Alberto Zirino (Scripps Institution of Oceanography, University of California)
1040-1100	<i>Discussion</i>
1100-1130	COFFEE (Jock Colville Hall)
1130-1445	THEME 5: PHYSICAL PROCESSES: SEDIMENTS AND MORPHOLOGY Chair: Dr Iris Möller (Department of Geography, University of Cambridge)
1130-1200	<i>Plenary: Sediment balance, morphodynamics and landscape restoration</i> Prof. Giampaolo Di Silvio (Università di Padova)
1200-1230	<i>The influence of inlet configuration on sediment loss in the Venice Lagoon</i> Prof. Luigi D'Alpaos (Università di Padova)
1230-1330	LUNCH (Main Hall)
1330-1345	<i>The third dimension in Venice</i> Prof. Albert Ammerman (Colgate University)
1345-1400	<i>The transport and stability of sediment in northern Venice Lagoon</i> Dr Carl Amos (University of Southampton)
1400-1415	<i>Management of lagoon morphology</i> Dr Lorenzo Bonometto (Comune di Venezia)
1415-1430	<i>Morphological restoration techniques in Venice Lagoon</i> Ing. Giovanni Cecconi (CVN)
1430-1445	<i>Discussion</i>

Tuesday 16th September 2003 pm			
1445-1600	Technical Session I: Engineering Chair: Sir Alan Muir Wood Wolfson Hall	Technical Session II: Environmental Quality and Indicators Chair: Dr Caroline Fletcher (University of Cambridge) Seminar Room	Technical Session III: Habitats Chair: Dr Tom Spencer (University of Cambridge) Small Combination Room
1445-1450	Chair introduction	Chair introduction	Chair introduction
1450-1505	<i>Ing. Yuil Eprim (Technital)</i> Mobile barriers construction details	<i>Ing. Roberto Casarin (Regione Veneto) & Ing. G. Zanovello (Studio Altieri)</i> Fusina integrated project: A global approach to wastewater treatment and reuse in the central area of the Venice Lagoon	<i>Prof. Court Stevenson (University of Maryland)</i> Salt marsh restoration in Chesapeake Bay
1505-1520	<i>Dr Edoardo Faganello (Jacobs)</i> Modelling Of Cardiff Bay Barrage Control System: Revised Automatic Control Logic for the Sluice Gates	<i>Ing. Paulo Rossetto (Thetis)</i> Fusina integrated project: strategies for the management of the residual outflow. environmental problems and solutions	<i>Mike Dearnaley (HR Wallingford Ltd)</i> Beneficial use of muddy dredged material for habitat creation
1520-1535	<i>Ing. Maria Teresa Brotto (CVN)</i> High Water Protection measures in Piazza San Marco	<i>Dr Angel Pérez -Ruzafa (University of Murcia, Spain)</i> Complex cause-effect interrelationships in environmental indicators at the Mar Menor lagoon (SW Mediterranean) as a consequence of human activities	<i>John Hall (Essex Wildlife Trust)</i> Inter-tidal Habitat creation in the UK: Managed realignment
1535-1550	<i>Ing. Ivano Turlon (Insula)</i> Methodologies for the functional restoration of a historical urban system	<i>Steve Colclough (UK Environment Agency)</i> The tidal Thames and environmental indicators	<i>Dr Francesco Scarton (SELC)</i> Breeding birds and vegetation monitoring in recreated salt marshes
1550-1600	<i>Discussion</i>	<i>Discussion</i>	<i>Discussion</i>
1600-1630	TEA (Jock Colville Hall)		
1800-1900	Reception at the Fitzwilliam Museum <i>Canaletto paintings as a historical record of sea level in Venice</i> Dr Dario Camuffo (CNR-ISAC)		
1930-Late	CONFERENCE DINNER AT PEMBROKE COLLEGE, CAMBRIDGE		

Wednesday 17th September 2003	
0730-0830	BREAKFAST (Main Hall)
0830-1050	THEME 6: VENICE AND GLOBAL ENVIRONMENTAL CHANGE (Wolfson Theatre) Chair: Prof. Trevor Davies (Climatic Research Unit, University of East Anglia)
0830-0910	<i>Plenary: The facts of relative sea level rise in Venice</i> Dr Roberto Frassetto (CNR-ISMAR)
0910-0930	<i>Long term natural subsidence of Venice: evaluation of its causes and magnitude</i> Dr Eugenio Carminati (Università di Roma)
0930-0950	<i>Overview of the main findings of the IPCC Third Assessment Report</i> Dr Domenico Gaudioso (APAT)
0950-1010	<i>Ocean Climate Variability in the Mediterranean Sea: Climate Events and Marine Forecasting Activities</i> Prof. Nadia Pinardi (Università di Bologna)
1010-1030	<i>Climatology of Storm Surges in Venice: Present and Future Scenarios</i> Prof. Piero Lionello (Università di Lecce)
1030-1050	<i>Discussion</i>
1050-1120	COFFEE (Jock Colville Hall)
1120-1300	GENERAL DISCUSSION: CONCLUSIONS AND WAYS FORWARD Chair: Sir Alan Muir Wood
1300	MEETING CLOSE
1300-1400	LUNCH (Buffet in Churchill College Bar)
1400-1600	AVAILABLE FOR DISCUSSION BY OTHER GROUPS/PROJECTS

Abstracts

Editors: Caroline Fletcher, Tom Spencer, Jane Da Mosto, Pierpaolo Campostrini

Abstracts are presented in the order given in the programme with the oral presentations for the introductory session, research overview and the six scientific themes first, followed by the three technical sessions and the poster presentations. The presenting author's name is given first.

In most cases abstracts are printed as they have been received and have not been edited for content. Some "light editing" has been carried out to ensure uniformity of presentation.

Neither Churchill College, the University of Cambridge nor the Organising/ Scientific Community accept responsibility for content.

INTRODUCTORY SESSION AND PANEL DISCUSSION

What are the lessons from around the world?

Chair: Prof. Peter Guthrie
(Department of Engineering, University of Cambridge)

INTRODUCTORY SESSION

1. Local flood protection measures in Venice
Prof. Marino Folin (IUAV) (no abstract)
2. Engineering interventions in Venice and the Venice lagoon
Ing. Alberto Scotti (Technital for Magistrato alle Acque) (no abstract)
3. Venice port activities in a delicate environment
Claudio Boniciolli (Autorità Portuale) (no abstract)

PANEL DISCUSSION - What are the lessons from around the world?

1. Thames Barrier: now and in the future
Dr Sarah Lavery (UK Environment Agency Thames Region) David Wilkes (UK Environment Agency NorthEast Region)
2. St Petersburg: EIA for Completion of the St. Petersburg Flood Barrier
Dr Herman Gerritsen (WL Delft)
3. St Petersburg: Integrated Water Management to support Sustainable Development of the St. Petersburg Region
Alexander Savin and Dr Rosa Mikhailenko (Morzaschita)
4. Cardiff Barrage
Peter Hunter (Jacobs)(no abstract)
5. Rotterdam Barrier
René Bol (Department of Water Management Rotterdam)
6. Eastern Scheldt Barrier
Dr. Henk Saeijs (Zeeland Directorate for Eastern Scheldt) and Mr Joris Geurts van Kessel (RIKZ, Zeeland Branch for Eastern Scheldt) (no abstract)

Thames Barrier: now and in the future

Dr Sarah Lavery
UK Environment Agency (Thames Region)

Planning for flood risk management in the Thames Estuary: Looking ahead 100 years.

(In: The Big Flood: North Sea Storm Surges, An International Scientific Meeting at the Royal Society (London), 23 May 2003 organised by Cambridge University Centre for Risk in the Built Environment)

Over £80 billion worth of property lies within the Thames tidal flood plain, the majority in London. This property is protected to a high standard with tidal defences including the Thames Barrier, designed and built in response to the catastrophic floods of 1953. London and the Thames Estuary currently have one of the best tidal defence systems in the world which will provide a high standard of protection to well beyond 2030, but the effects of climate change present an unwelcome picture for the flood risk of future generations.

Now is the time to start planning the next generation of tidal defence for the Thames Estuary. In doing so, the Environment Agency has extended its planning horizon by 70 years to the year 2100. With over a million people at risk, this is both essential and prudent. "Planning for Flood Risk Management in the Thames Estuary" is an initiative by Anglian, Southern, and Thames Regions of the Environment Agency to develop a strategy for flood risk management in the Estuary for the next 100 years. Amongst the studies leading up to this strategy will be an examination of London's vulnerability to storm surge, today and in the future, and development of options to ensure the sustainability of London in the face of this increasing threat.

St Petersburg: EIA for completion of the St. Petersburg Flood Barrier

Dr Herman Gerritsen
WL Delft

An Environmental Impact Assessment (EIA) was completed as part of a Feasibility Study for the completion of the Flood Protection Barrier for the city of St. Petersburg, Russia. The city of Saint Petersburg is situated in a low-lying area where the river Neva discharges in the eastern extremity of the Gulf of Finland. Storm surges from the Gulf of Finland lead to a rise of the water level in the city by way of the river branches. Dramatic floods occurred in 1777, 1824, 1924 and 1955. In 1980, work started for a Flood Protection Barrier connecting Kotlin Island with the mainland to the South and East. The design for the 25.4km long barrier consists of 11 embankment sections, 6 water sluice complexes and 2 navigation openings, which would normally be open to allow free exchange of water, but can be closed during a storm and surge threat. Construction was halted in 1987. Full construction was not resumed due to financial constraints.

Two alternatives for the completion of the barrier were considered, with the first serving as reference:

1. 'Do minimum': reference scenario, to consolidate the barrier in its present state.
2. 'Completion of flood protection barrier function only', without accounting for a future highway (adding provisions for a highway have no effect on the EIA).

The study started with a Scoping Study, in which the Project was described, plus the characteristics of the environment in which it is located: It addressed relevant international and Russian environmental norms and standards, and resulted in priority short lists of potential impacts. An initial public consultation meeting was held to identify the concerns of the public regarding the Project and to further prioritise the aspects to be analysed in the EIA study.

The analysis of the present situation was performed on the basis of existing data, while flow and water quality model applications were developed to support the analysis. Besides the hydrodynamics, which is important for most other aspects, the analysis focused on ice cover, water quality, polluted bottom sediments, fish, biodiversity/nature reserves, and the effects of barrier construction to date. The analysis showed serious environmental problems in Neva Bay at present. These are associated with the activities occurring in and around the city of St. Petersburg, with its over 4 million inhabitants and many industries.

Flow and water quality models based on both Delft3D and the Russian CARDINAL software were applied to predict changes in water exchange, general circulation, residence time and bacterial pollution for the completed barrier, and for studying the possibility of mitigation of adverse conditions. After completion of the study, its results were published on internet and discussed at a final public consultation meeting.

The paper will present the approach and results of the EIA, including the results of the public participation process, which was part of the study.

St Petersburg: Integrated water management to support sustainable development of the St. Petersburg Region

Dr Rosa Mikhailenko
Morzaschita

Co-authors:

Mr Alexander Savin
Morzaschita
Herman Gerritsen and Hans van Pagee
WL Delft

St. Petersburg is situated at the meeting point of the Neva River and the Baltic Sea, which has a strategic value for its economic and social development.

At the moment the various economic and social uses of the water resources have a negative influence on water environment and are potential sources of an ecological risk.

Significant population growth and the extension of the city territory since 1960's, as well as increase of the industrial sector in the city economy without undertaking water protection measures have led to a deterioration of the ecological situation in the Neva river and in the Neva Bay. The water system Ladoga Lake - River Neva - Neva Bay - eastern Gulf of Finland is the important strategic region of multifunctional purpose. The complexity of ecological conditions in the ecosystems of these water objects is determined by peculiarities of anthropogenic and natural factors. As a result of the structural analysis of anthropogenic impact on the Neva Bay eleven types of effects have been named: along-coast landfill plus construction of housing and infrastructure, recreation, agricultural activity, water-supply and water-drainage, undersea quarries and dumping, hydrotechnical constructions, navigation, rafting, commercial and recreational fishing, atmospheric deposition, industrial pollution loads in the water phase.

Without relevant water protection measures and active environmental policies the economic growth will lead to acute environmental problems. It is necessary to develop a system for a sustainable and justifiable decision-making process in the area of city-planning and water protection activities. It is obvious that such a system can provide conditions for actual improvement of the water quality and safe development of the city.

Understanding that it is impossible to solve all these problems without an Integrated Water Management approach of St.-Petersburg region (IWM), at the III Annual Conference of managing staff of EBRD (1994), "Morzaschita" and WL|Delft Hydraulics presented a joint project proposal for IWM of the St Petersburg region. Some steps towards this joint project IWRM had already been made by "Morzashchita" Department.

The joint Russian-Netherlands project was conducted in 1996 – 2000. Specialists of Morzaschita together with WL/Delft Hydraulics as well as specialists of other organisations of the city have taken part in the project for development of IWM of the St Petersburg region. The main technical components of this approach are: databases of system properties, parameters, pollution loads and other anthropogenic parameters, information systems about available properties of separate water environment constituents, of bottom sediments and biota, a load model of polluting substances for definition of a general sum of system pollution, and forecasting models regarding water quality and ecological parameters.

To study the influence of manoeuvring of the water gates of the Flood Protection Barrier (FPB) on the ecological condition of Neva Bay "Morzaschita" has carried out a large-scale field experiment already before that. The study programme included the following activities: hydrometeorological and hydrological observations, analysis of the water quality on many hydrochemical and bacteriological factors, hydrobiological and ichthyologic studies, remote sensing observations; tracer observations on the pollutant distribution from the city water purification plants; study of the chemical and bacteriological composition of the sediments.

Abstracts Volume

Flooding and Environmental Challenges for Venice and its Lagoon: State of Knowledge 2003

Discussion Meeting – Cambridge, 14th-17th September, 2003

Sixteen institutes and organisations have taken part in the experiment. The results of the experiment confirmed the possibility of purposefully influencing the hydrological regime and the ecological situation of the Neva Bay water area and the eastern part of the Gulf of Finland by means of closing specific section openings of the FPB and redistributing the water volumes passing the FPB.

During the 1990-ies, as a result of a polling of 17 organisations, connected with researches of the water system, a detailed catalogue of all natural observations (both regular monitoring and specific project observations) has been made, and a detailed review of the databases was made. The tables in the catalogue contain observational information about all parts of the water system Ladoga Lake - River Neva - Neva Bay - eastern Gulf of Finland, including the list of the basic characteristics of water environment.

As part of the joint IWM project, a GIS for flood warning and flood damage assessment was developed, that already now is of applied value and interesting for a wide range of the Users. This GIS model is designed both for macroeconomic damage assessment, using aggregate indices, and for microeconomic assessment, if sufficient detail is available. Results of the GIS are already used by many city organisations. Information about flooded territories in the geographical information system can be useful for insurance, rent pricing and local taxation, development of plans of actions in emergency situations and for planning of investments and general urban planning.

In summary, the implementation of Integrated Water Management programme will allow to create a regional system of water management and to base the managerial approach for development on understanding of the best balance between the various uses of water system, leading to a stable development and rational use of the water system 'Lake of Ladoga - Neva River - Neva Mouth - eastern part of the Gulf of Finland' It will also allow to achieve significant progress in development of the flood early warning system and the method of estimation of potential damage. Implementation of the programme will make the city more attractive for investments, as the threat of flooding of the historical centre will be eliminated.

The Maeslant-barrier, storm surge barrier in the Rotterdam New Waterway.

René Bol
Department of Water Management Rotterdam

Introduction

The Maeslant-barrier is situated in the southwestern part of the Netherlands near Hook of Holland, at 30 kilometres west of the centre of Rotterdam.

The Maeslant-barrier comprises two huge sector-gates, each 22 meters high and with a width of 210 meters. The total construction of each gate has a length of about 300 meter. If standing up the Measlant barrier should be as tall as the Eiffel Tower.

Aim of the barrier

The Maeslant barrier has been build to eliminate the need of raising the dikes along the estuary, and especially in and around the cities of Rotterdam and Dordrecht. Unlike the Eastern Scheldt barrier, the Maeslant barrier could not pose an obstacle of any kind to the shipping towards the Main port of Rotterdam. A shipping channel of 17 meters deep and 360 meters width should be available under normal conditions. Closure of the barrier was limited to once per five to ten years.

The design was the result of a design competition in which 6 contractors cooperated. Building started in 1991 and the barrier was completed and taken into operation in 1997.

Operation

Under normal weather conditions the gates lie in their docks. If a severe storm is expected, the docks are submerged, so that the doors start floating. Within half an hour they can be transported to the middle of the New Waterway. Next, the hollow doors are filled with water and start sinking. This procedure is fully controlled by the computer. Within two hours the gates are landing smoothly on the concrete sill, closing the New Waterway, and protecting the area behind from flooding.

A computer system decides whether or not to close the Maeslant barrier, calculating the expected water levels at Rotterdam and Dordrecht on the basis of water and weather forecasts.

Some lessons learnt

Be aware of the effect of hydraulic phenomena like seiches (seiches are long waves with a period of 15 to 90 minutes). During construction it was recognised that strong seiches with amplitudes up to 2 meters might occur. That may result in a large negative head over the gate of about 1.5 meters, while the construction was only designed to resist a small negative head. The solution was found in changing the sinking and lifting procedure, though the operation then became much more complex.

A second lesson learnt is to be aware of the needs and capabilities of the organisation and people that has to execute the operation and maintenance. The Maeslant barrier is built as a sophisticated, high-tech barrier. The people that now have to operate and maintain it were not used to such a high-tech construction. It takes a long time to change the organisation and to get used to the demands and vulnerability of this high-tech construction compared to other barriers.

Suggestions for the Venice-lagoon

Such a huge construction as the Measlant-barrier is probably not suited in the Venice-lagoon. Though the lessons learnt might be taken into consideration.

RESEARCH OVERVIEW

Chair: Dr Tom Spencer
(Department of Geography, University of Cambridge)

1. Plenary: Flooding in Venice: overview of issues, approaches and research needs.
Prof. Pier Vellinga (Free University of Amsterdam)
2. Speaker to be confirmed. (European Commission) *(no abstract)*
3. Speaker to be confirmed. (Venice Local Authorities) *(no abstract)*
4. UNESCO Activities.
Dr Howard Moore (UNESCO-ROSTED)
5. CORILA Activities.
Dr Pierpaolo Campostrini (CORILA)

Plenary: Flooding of Venice: overview of issues, approaches and research needs

Prof. Pier Vellinga
Free University of Amsterdam

Sustainability in ecological, social and economic terms is the overarching issue regarding Venice and its lagoon. How can an ancient urban centre, its economy, its ecosystem and its population survive under ever rising sea levels?

The City was built in the 13th and 14th century in a coastal marshland when the mean sea level was about one metre lower than it is today. The natural setting was very favourable with regard to transport, trade and urban development and offered (military) protection against potential invaders. For many centuries Venice's socio-ecological interaction has been so fruitful that Venice could become one of the most important economic and cultural centres of Europe.

Now its monuments and the city as a whole, including its lagoon environment, are considered as one of the most important world heritages. However, as a result of centuries of sea level rise the quays and monuments are regularly flooded. This causes damage to the monuments and the local economy. On the other hand the flooding itself has become one of the characteristics: inhabitants have to some extent learned to live with the regular flooding and many tourists appreciate it as an additional feature of this monumental city where decay contributes to its beauty.

Major issues for discussion are:

1. Climatic change, sea level rise and related sea level surges in the Adriatic;
2. Lagoon water level, water quality and ecological response behaviour under different scenarios of climate, sea level, morphological processes and different scenarios of human intervention;
3. Effects on the ecological conditions of the lagoon by (shell) fish harvest, nutrient supply, port and industrial activities, high water protection works and the relative impact of each of these;
4. Economic aspects of conservation of the urban setting and its monuments for different hydraulic, ecological, social and economic futures;
5. Characteristics of city income now and in the future for different flooding frequency scenarios and related high water protection investments;
6. The role of the harbour and sea transport in the present and the future economy (in a European context);
7. Preferences with regard to the future of Venice and its lagoon at the different regional levels of organisation: the city, the region, the nation, the EU and the world;
8. Political and administrative arrangements with regard to the management of the high water protection works now under preparation.

These discussion issues provide the contours for an ongoing research agenda; the conference can highlight the topics that require further attention.

UNESCO's contribution to the safeguarding of Venice

Dr Howard Moore
UNESCO-ROSTE

Co-author:
P. Pypaert
UNESCO-ROSTE

For historical reasons, UNESCO had two locations in the Serenissima: from 1973, the "Liaison Office for the Safeguarding of Venice" was hosted at Palazzo Reale, Piazza San Marco, and as of 1989, the Regional Office for Science and Technology for Europe (ROSTE) was located in Palazzo Loredan degli Ambasciatori, Dorsoduro. In March 2002 the two units were brought together in Palazzo Zorzi, Castello, and now function as the UNESCO Venice Office – Regional Bureau for Science in Europe (UNESCO-ROSTE). As with all other UNESCO units away from Headquarters, the activities carried out by the Venice Bureau are primarily aimed at achieving UNESCO's and its Member States' goals in the field of science and culture. The Office has connections with more than 40 Member States, and develops active cooperation with a broad range of national and international research councils, Academies, Universities, research networks, and other international organisations and centres, some of them located in Venice.

In their paper, the authors will briefly review UNESCO's involvement in activities related to the safeguarding of Venice and its lagoon:

The International Campaign for the Safeguarding of Venice had its origin in the immediate response by UNESCO to the dramatic floods that devastated Venice and Florence on 4 November 1966. An international Campaign was launched in December 1966 by the then Director-General of UNESCO, René Maheu. Responding to the appeal of UNESCO, private bodies began to contribute funds for use in the preservation and restoration of monuments and works of art in Venice. Those private organisations were specifically created in a number of countries to collect and channel contributions. Today, 26 organisations, representing 11 countries, are still active.

Since the beginning of the 1990s, UNESCO itself has implemented various research projects in Venice that serve as concrete examples of its overall commitment to the integrated conservation of the historic city of Venice and its Lagoon. These facets of UNESCO's involvement in Venice are complementary and integral to the sustainable development and preservation of this World Heritage city:

The "Venice Lagoon Ecosystem" Project, which was aimed at providing a quantitative understanding of the major flows that make up the coupling between pelagic and benthic systems within the lagoon waters, and to relate this understanding to the processes of eutrophication.

The "Venice Inner Canals" Project, which sought to develop, calibrate and validate a Water Quality Model for the Venice inner canals. The project included additional sampling and laboratory work on the bio-chemical and microbiological characteristics of both the waters and sediments and led to the calibration of a new hydrodynamic model, as well as to the development, for the first time, of a Water Quality Model to be applied to the Venice inner canals system (results available at <http://www.unesco.ve.it>)

The project on the "Development of a Sediment Transport Model of the Inner Canals of Venice" was implemented in 1999–2000, with the strong support of Insula SpA, and that of the National Research Council's Institute for the Study of the Dynamics of Large Masses (CNR-ISDGM) Venice.

CORILA Activities

Abstracts Volume
Flooding and Environmental Challenges for Venice and its Lagoon: State of Knowledge 2003
Discussion Meeting – Cambridge, 14th-17th September, 2003

Ing. Pierpaolo Campostrini
CORILA

The Lagoon of Venice assembles almost all the problems threatening lagoons and coastal wetland zones in general – their dynamic evolution, uses and consequent anthropogenic pressures. Well before the industrial era, the fight against the three “enemies” of the lagoon had already begun: “the rivers, the sea and man” (*Sabbadino, mid 16th century*). Venice has always depended on the best scientific and technological energies of each age, for its bare existence and defence.

In a more recent period, the scientific community was the first to be asked for “solutions” to extreme flooding, after the disastrous event of 1966. A specific laboratory of CNR (later Institute for the Study of the Dynamics of Large Masses) was established in Venice, and CNR launched the International Competition of Ideas in 1970, where the first proposal of submerged mobile barriers at the inlets appeared. The Ministry of Scientific Research has always been involved in the inter-Ministerial committees ever since the “Venice problem” was declared of “prevalent national interest” by the Italian law in 1973.

CORILA’s efforts are now integral to this long history: the concept emerged in 1997, to guarantee a more specific orientation of research towards the Administrations’ management needs and consequently a more direct and immediate use of research results by decision makers. CORILA research activities started with the first Research Programme (2000-2003), involving almost 300 researchers and 70 Institutions (18 from abroad). Its Scientific Committee oversees and evaluates the orientation and quality of the research. A staff of ten in the CORILA offices manages and coordinates general organisation of research activities, administrative control and data acquisition and management, providing more instruments to the research community. Coordination of scientific research in such complex matters, more than merely an “external need” for obtaining funds, is also essential to achieve a better understanding of the environment, promote inter-disciplinary links, i.e. key to producing better science.

In Spring 2004 the final results of the First Research Program will be presented, meanwhile more than 250 scientific papers have been published in scientific journals and/or presented to scientific conferences. Two Annual Meetings have been held – giving researchers a chance to share preliminary findings and integrate with other branches of the same Research Programme. The 2002 volume of proceedings has been published already, the 2003 volume is on the way. The Second Research Program has been launched and will start in Autumn for a duration of three years. The main objectives, programme organisation and a summary of results already obtained to date will be briefly reported.

The scientific community is able of playing a strategic role in the Safeguarding of Venice, not only for its ability of answering some particular queries, but also for the wider vision which it is able to consider, developing sustainable, knowledge-based scenarios for the future. The complexity of the issues at stake calls for further work, deeper knowledge and greater evidence, especially when large scale interventions are being planned and executed.

THEME 1: URBAN FLOODING: ARCHITECTURAL AND STRUCTURAL ISSUES

Chair: Anna Somers Cocks (Venice in Peril)

1. Plenary: St Marks Basilica as a case study in flooding issues for historical Venice
Arch. Ettore Vio (Proto della Basilica di San Marco)
2. Insula: A project for Venice
Prof. Bruno Dolcetta (Insula)
3. Methodologies and techniques for the conservation and restoration of Venetian buildings
Arch. Edoardo Danzi (IUAV)
4. Interactions between natural and human caused phenomena with respect to the maintenance of the Venetian built environment
Prof. Fabio Carrera (WPI)

Plenary: Saint Marks Basilica as a case study in flooding issues for historical Venice

Arch. Ettore Vio
Procuratoria di San Marco

The flooding of the historical city of Venice is an event that has been occurring for centuries, connected to the high tides of the lagoon during the equinoctial seasons, especially in February and November. The level of the floods is increasing, having reached its maximum of 1.92 meters above the average sea level during the flood of November the 4th 1966. The growth of the tidal levels is due to the phenomenon of *bradyseism* of the ground of the city. It is a continuous phenomenon and it has been witnessed since the Roman age with an average lowering of 14 centimetres per century, more or less. This quantity increased or decreased in combination with the variations of the average sea level during each age.

The Basilica of Saint Marks is the oldest building of the city: its structure offers evidence of the subsidence of the ground; its masonry walls show the damages to the mortars and to the bricks, to the stones and the mosaics' claddings carried out by marine water. With regards to the Crypt (built in 829 A.D.) it has been calculated a lowering of the ground level of more than 1.75 meters during almost thirteen centuries. On the other side, the level of Saint Marks Square's floor has been raised, during its history, by more than 60 centimetres with the overlaying of different layers of pavings. Nowadays it is no longer possible to raise the ground level of the Square without altering the visibility of the facades of the church and without exerting further damage to the walls and to the stones of its Nartex and to the elevations of this ancient monument.

It is urgent to find solutions to avoid the construction of new layers to the Saint Marks' area and also to stop the rising damp (salty water) in the masonry walls with its consequent danger for the stability of the building and for the consistency of its stones and mosaics. To find a solution for the Basilica means discovering a way to face positively and effectively the problems generated by the tides of the lagoon for the historical architecture of the city of Venice.

Insula: A project for Venice

Prof. Bruno Dolcetta
Insula SpA

The preservation of Venice depends on the implementation of a single large project in which Insula participates to guarantee sanitary renewal and the integrity of the city's foundation structures.

Thirty years ago, the awareness that Venice and its lagoon are--for the world and above all for Italy--priceless heritage lies at the basis of the need for a special law for Venice.

After the first two versions (in 1973 and 1984) it is primarily in the 1992 version of the special law that emphasis is given to ordinary and extraordinary urban maintenance.

Many are the inconveniences, as well as inefficiency and lack of order, built up in the city until today; a wide variety of work is required to counter them: the canals have to be excavated so that the waterways can always be navigable; the bridges renovated and the pavement raised to allow pedestrian traffic to flow even in high tide conditions; the bank walls renovated to guarantee the stability of the canal sides and the buildings; the historic sewage system kept in good working order and integrated with the new sewer network to ensure the best sanitary conditions; and the underground service network (water, electric power, gas and telephone) renewed and completed.

To address the city's preservation needs, in 1994 the City of Venice prepared a vast extraordinary urban maintenance programme in response to the provisions of three important measures:

1. special law for Venice no. 139 of 1992 renders the city maintenance work structural and decrees that the work must be carried out in such a way as to guarantee technical uniformity in the planning stages, co-ordination during the fulfilment stage and integration of the financial resources;
2. the April 1993 co-operation protocol with the Ministry of the Environment, which makes possible the draining of sludge dug up from canals;
3. the 3 August 1993 programme agreement-- with the Water Board and the Veneto Region -- identifies the City as the implementers of the maintenance programme and points out the need for administrative bodies to act in co-ordination.

In 1997 to speed up the fulfilment of the maintenance programme, the city administration founded Insula spa (Insula is a limited company founded by the City of Venice (holding 52% of the capital stock) with the 12% joint participation of Enel.Hydro, Italgas, Telecom Italia and Vesta.), co-opting the companies that manage the underground services: Enel.Hydro (electric power), Italgas (methane gas), Telecom Italia (telephone) and Vesta (drinking water) are thus involved in the planning and co-ordinated -"integrated"- implementation of maintenance work in the urban underground; all the networks are being worked on simultaneously in order to avoid protracted works, inefficiency and unnecessary costs for the city.

Special law 139/92 and the Principle of Integration of Different Types of Maintenance Work
The Sanitary Renewal Work Plan (Integrated Canal Project)
From the Integrated Canal Project to Insula Spa, Urban Maintenance Company
Insula's Activities and the Territorial Area
Urban Maintenance in Venice: Problems and Work Categories
Protection from Mid to High Tides: Local Defence and "insulae" Defence
Venice's Situation after Completion of the Protection Work
The Works Carried out and Ongoing Projects

Abstracts Volume

Flooding and Environmental Challenges for Venice and its Lagoon: State of Knowledge 2003

Discussion Meeting – Cambridge, 14th-17th September, 2003

Research for conservation of the lagoon building culture: catalogue of the external plasters in Venetian buildings

Dr Edoardo Danzi
IUAV

Co authors:

Alessandra Ferrighi, Mario Piana (IUAV)

The lagoon building culture has always entrusted precise duties of protection to the external coverings. Besides their undoubted aesthetic and formal value, venetian finishes and plasters have always been applied on the external fronts also with the purpose of avoiding the masonry decay: a sort of sacrifice surface with the task of assuming the decay due to the combination of weathering, saline aerosol and capillary rise with the consequent cycles of saline crystallisation.

So far, the studies concerning the plasters in the historical Venetian building have only partially explained the technical and formal evolution of the external plasters over the centuries. Nevertheless quantitative information is still missing outlining the type, the stratification, the location in the city centre and the present condition of the Venetian plasters. A huge amount of ancient coverings are still present on the external fronts of the city buildings: for example, there are several hundred examples of plasters, generally frescoed in XIV and XV centuries, sometimes reduced in fragments, other times almost integrally preserved which, in the absence of any kind of information concerning their nature and value, run the risk of vanishing because of careless interventions of maintenance or restoration.

A sector CORILA-supported research co-ordinated by IUAV Department of History of Architecture has been thus dedicated to a systematic survey of the historical external coverings of the city building. It aims at collecting extensive information about their nature, types and causes of their decay. This catalogue is very demanding because of the large number of buildings, but this will allow to describe precisely the technical and formal evolution of the plasters, permitting a reconstruction of the city aspect over the centuries.

Moreover, the catalogue will allow the carrying out of sampling of the most interesting plasters; the following chemical-physical analyses on the samples will aim to determine the specifications of composition and technologies used in the various categories of covering (*regalzieri* and medieval decorations, *marmorini* in one layer or with *cocciopesto* background layer, etc.).

Another point is the catalogue of the most significant interventions of consolidation, restoration and integration of plasters realised in the city in the latest twenty years, to evaluate the efficacy of the adopted systems and the acceptability of the results under the architectonic and formal point of view.

The final target of this sector of the research is to provide methodological criteria, which will be useful for guiding next interventions of conservation and restoration of the external coverings of lagoon building.

The survey on the field has been almost completed (14,059 buildings on a total amount of 14,451). At present we are working at the creation of a Web platform, in strict co-operation with the CORILA system: the catalogue of venetian plasters, in the end, available for the public administration (Municipality and Monuments and Fine Arts Superintendency), will become an instrument of great value, open to future updating and integration, immediately usable for the control, the protection management and the programming of the restoration interventions on the historical building heritage.

Interactions between natural and human caused phenomena with respect to the maintenance of the Venetian built environment

Prof. Fabio Carrera
WPI

The interactions between natural and human-caused phenomena with respect to the maintenance of the Venetian built environment.

Flooding affects the physical infrastructure in Venice in a variety of ways, most of which have been recognised since the early days of Venice's existence. Manuscripts in the Venice archives report about the frequent requests for maintenance along the inner canals of the city ever since records were kept. Natural erosion due to the cycles of tides is a fact of life in a place like Venice. Construction materials will be gradually weakened by the constant wet-dry cycles and by the natural salts and unnatural pollutants contained in the tidal waters. While there is no doubt about the gradual but incessant negative effect of intermittent exposure or total immersion in the waters of the lagoon, the overall impact of flooding on the state of conservation of today's architectural and urban structures is much less clear.

What is clear is that there are several concurrent factors at play in the undermining of Venice's built environment. Perhaps flooding is not the most destructive of all of the forces participating in the constant interplay between the liquid and solid components of the city. Many see "Moto Ondoso" as a major player in this arena. Another potential – though perhaps unexpected – culprit in this milieu is sedimentation, which is accused of engendering the damage through the clogging of underwater sewer outlets, leading to underground ruptures and thus to seepage and weakening of the mortars that hold together the bricks and stones of the canal walls.

The Venice Project Centre of the Worcester Polytechnic Institute has been at the forefront of the exploration of the causal relations that cumulatively produce the physical damage that is visible everywhere in Venice. In collaboration with UNESCO, we have systematically collected a wealth of information about the phenomena connected with architectural damage and decay, both along the canals and elsewhere. Though none of these data connect flooding to structural damage per se, numerous correlations were tested out and verified, by relating a variety of independent and dependent variables that link the "waters" with the "stones", such as: traffic levels, wake-loading, sedimentation, hydrodynamics, construction and maintenance, and others. Back in 1998, thanks to our storehouse of knowledge on traffic, wall damage and bathymetries, we were able to prove fairly conclusively that the root cause of wall damage is lack of dredging, which is only later compounded by traffic and wake motion. With this knowledge, we tried to quantify relative and absolute contribution of a variety of possible sediment sources to the accumulation of debris with a study in the year 2000. In 2002 we developed the concept of a "moto ondoso index" that translates levels of boat traffic (i.e. number of boats) to levels of "wake-loading" (how much wake energy is discharged in the canal), which helps to better correlate traffic to damage.

This year (2003), we have begun to study the "turbulence index" that complements the "moto ondoso index" and captures the energy discharged into the canals by boats that are maneuvering to make turns, or stopping abruptly by shifting into reverse when an approaching boat threatens a collision, or simply moving back and forth near a dock to tie up the boat and unload people or cargo. A device of our own design, equipped with a differential GPS, a triaxial accelerometer and an RPM meter has been successfully tested this summer to produce the first ever map of "turbulent discharges" in the inner canal network. We are certain that this will be another valuable contribution of the Venice Project Centre to the protection of homes, palaces and churches along canals.

In parallel, we have also studied the floors of churches in collaboration with the Soprintendenza ai Beni Archeologici. We have measured the elevation of all churches in Castello, Cannaregio and S.Polo, as well as the dips in the floors within each church, to produce a map of flood risk that we correlated to the actual damage we found on the artefacts and materials that cover these floors.

We believe our results are solid enough to withstand close scrutiny, but we also realise the need for confirmation of our preliminary conclusions through more extended studies that could completely and finally answer the remaining questions that are listed below.

1. What are the overall as well as relative impacts on the built environment of:
 - a. Flooding
 - b. Traffic (Moto Ondoso, collisions, turbulence)
 - c. Sedimentation and sewer Clogging
 - d. Chemicals/Salts/Pollutants in the water (and in the air?)
2. Are there any other factors that are at play? If so, which?
3. What can be done to alleviate/eliminate the causes of the problems?

Of course, answering the first question will entail a whole series of studies, and the answers to all of these questions could be very difficult to obtain. But getting some answers to these questions would undoubtedly be useful in order to preserve Venice's architectural heritage, which is vulnerable to many other threats, above and beyond those related to waters and floods.

THEME 2: WEATHER AND SEA LEVEL FORECASTING

Chair: Dr Ida Brøker (DHI)

1. Introduction and overview
Prof Alberto Tomasin (Università di Venezia)
2. Sea level forecasting at the Centro Previsioni e Segnalazioni Maree of Venice Municipality
Dr Lucia Zampato (Centro Maree, Comune di Venezia)
3. Gates strategies & storm surge forecasting system developed for Venice flood management
Ing. Maurizio Di Donato (CVN) and Ing. Yuil Eprim (Technital)
4. Satellite wind observations as possible meteorological forcing for storm surge models
Dr Stefano Zecchetto (ISAC CNR)

Introduction and overview to forecasting

A. Tomasin
Università "Ca' Foscari" di Venezia

Introducing forecasting means introducing the dynamics of the sea and of its forcing factors. It also means, in this stage, to forget long-term climatic evolution: prediction in terms of hours or days is the goal. Some general idea on a yearly scale will be faced.

Elementary ideas on the processes related to Venice permit to separate the ordinary tide from the surge and to disregard the former one in the discussion, since it is well-known.

Atmospheric forcing (wind and pressure) is then dominant, but in the case of the Adriatic a relevant part of the overall dynamics is referred to the memory of the sea: its free oscillations ("seiches") occur usually for many days after the primary surge. If used carefully, they enter very easily in the forecast.

Since Venice is the site to be protected, the importance of the scientific platform of CNR, eight miles offshore the central Lagoon inlet, is evident. Since the surge, like the tide, takes about an hour from the open sea to the town, knowledge of the sea level at the platform is a useful aid.

Back to wind and pressure, the detailed discussion of models will show how their fields are analysed and predicted: their forecast, in particular, is very important for surge warning beyond three-five hours.

The general description of models separates the statistical and the deterministic ones. The former group shares the need of a long series of observations and apparently little analysis of them, since empirical correlations are used. The others go to the heart of the problem, by solving the dynamic equations that describe the phenomena. It is clear that statistical schemes easily use up-to-date observations also of sea level, while the other ones face the difficulty of assimilation: they run simulating many days up to present, and to force their results with the measured data is difficult. This is presumably the reason for the frequent better success of statistical models for short-term forecasting (three-five hours). When moving up, the equation-solving methods are favoured.

Sea level forecasting at the tidal forecasting and early warning centre of the Venice municipality

P. Canestrelli
Comune di Venezia

Co-author:
L. Zampato
Comune di Venezia

The sea level forecast for the city of Venice is one of the institutional tasks of the Centro Previsioni e Segnalazioni Maree (CPSM) (Tidal Forecasting and Early Warning Centre) of Venice. The CPSM is an office of the Venice Municipality, founded in 1981, to study and forecast storm surge events that recurrently cause the flooding of Venice. Tasks of the CPSM are:

- ? observation of sea level and relevant meteorological parameters;
- ? short-term forecast of the sea level in the city;
- ? information to the citizens and warning in case of high water events.

Monitoring the sea level and meteorological parameters is carried out through a network of 10 tide gauge-weather stations: 6 stations are located in the inner Venice Lagoon, 3 at the inlets where the Lagoon communicates with the open sea, one in the Northern Adriatic Sea at the CNR oceanographic platform 'Acqua Alta', situated 15 km off the coast. The peripheral stations transmit, in real time, the measured data to a central station, located in the CPSM office, where they are validated and saved in a database.

Data collected by the monitoring network, with some statistical elaborations, are distributed to users and published annually.

The sea level forecast is estimated through a set of statistical models of increasing complexity, based on the least squares principle. They calculate the sea level component due to the atmospheric conditions, called 'meteorological contribution' or 'surge'. It is assumed that the astronomical component, accurately calculated through the harmonic constants, can be linearly superimposed on the surge, giving the total sea level.

The statistical models use predictors of observed sea level and pressure from some sites on the Adriatic and Mediterranean coasts; the most recent versions, for example the 'Esteso' model include also predictors of forecasted pressure, produced by the ECMWF atmospheric model. The models have been tuned through a 25-year database, containing sea level and pressure data: they have reached a good level of accuracy in the operational context, with accuracy index (equal to 2 times the standard deviation) of the order of 10 cm for the 3 hours forecast, 14 cm for the 12 hours and 24 hours forecasts, and 18 cm for the 36 hours forecast. The CPSM technical staff control and interpret results of statistical models integrating them with observed data from the CPSM monitoring network and other sources (METEOSAT images, AGIP Offshore Platform) to formulate the sea level forecast for the next two days, and circulate the information throughout the city.

In the last two years, two experimental deterministic hydrodynamic models have been operationally installed at the CPSM. Presently their results are less satisfactory than those from statistical models, but they are useful to understand and simulate the dynamics of the whole Adriatic and Mediterranean seas: in these basins storm surge events originate and develop causing the 'high water' in Venice. Deterministic model results are similar to those of statistical models with large forecasting lag (greater than 36 hours), and improvement of their performance is expected in the immediate future. Deterministic models can be a strong benefit if used jointly with the statistical models.

A high quality sea level forecast is needed at the CPSM to accomplish its third task: informing and warning residents in case of severe flood tide events. The city is alerted by 16 sirens distributed over the whole municipality area, three or four hours before the event. An automated "Call Manager" system calls and warns residents living on the ground floor and shop owners via phone. Additionally, real-time digital tide level displays installed in strategic points and on-line information is available.

Gates strategies and storm surge forecasting system developed for the Venice flood management

Di Donato
Technital S.p.A

Co-author:
Yuil Eprim
Technital S.p.A

The storm surge prediction models have been continuously improving in the last 10 years, due mainly to the increasing occurrences of high water events and to the pursued optimisation of the mobile gates *closure strategies*.

The first part of the paper describes the classification of the floods events in terms of *return period* on the basis of maximum forecasted level and duration and of the local rain and wind forecasts and measures. The flood gates operation criteria and procedures, designed by Technital (TCH) are based on the combination of local meteorological and water level forecasts and observations and is aimed at providing a simple and straight forward method by which all the high water events can be grouped in few classes of closing procedures covering all the probable combinations of the lagoon level influencing factors and their uncertainties. This part of the paper concerns also with the description of the different *threshold levels* used for determining the moment of closing and hence the time to alert the Port Authorities to interrupt the navigation, and with the subsequent actions to be taken before the final decisions to start closing the gates and then start lowering the gates are taken.

The second part of the paper describes the Venice water levels forecast system developed and operated by Venice Water Authority-Consorzio Venezia Nuova (CVN) for providing the necessary operational information for the proposed mobile gates located at the lagoon inlets. The system has been continuously improved both in terms of system architecture and of automatic data acquisition. and now it is providing the experimental basis for supporting the design of the mobile barriers. The forecast system consists of 2 different set of models (Statistical and Deterministic) operating, on different theoretical basis, using meteo and water level observations and meteo forecasts. A general database for the acquisition and the retrieval of the relevant parameters is also part of the Forecast System.

Long term operational flood forecast systems, linked with databases of past model performance and historical environmental information can provide an invaluable tool for the evaluation of past performance, for simulating new assimilation techniques, and for efficient re-analysis. The database re-analysis can ultimately be used to provide updated information on short term corrections and to provide statistics on uncertainty. The paper will also describe a new procedure implemented in DVAAFS (Deterministic Venice Acqua Alta Forecast System) that allows hourly updates of the results, similar to the statistical model and capable to better predict the next levels (say 4 to 6 hours) on the basis of the raw output from the model and on the assimilation of the last observed levels. Despite its complexity, the deterministic forecast is quite flexible when new scenarios need to be implemented in the model. The scenarios can derive from new physical algorithms or simply from modified forcing functions. In the paper is presented the effect of a modified wind field for the meteo forecast of the event occurred on the 6th of November, 2000.

Satellite wind observations as possible meteorological forcing for storm surge models

S. Zecchetto
CNR - ISAC

Co-author:
F. De Biasio
CNR - ISMAR

In the Mediterranean Sea, the atmospheric phenomena belonging to the meso-scales ? and ? including spatial scales from 20 to 1000 km (*Orlansky, 1975*), are of paramount importance, because of the basin size as well as the effect of the surrounding orography and of the islands. The availability of high spatial resolution wind observations is thus of primary importance for the understanding of the basic processes occurring at the air-sea interface.

Satellite wind observations from microwave scatterometers, with a spatial resolution of about 25 km by 25 km, provide at present the best experimental wind dataset, suitable to describe the spatial meso-scale phenomena like frontal systems, orographic winds and the structure of the regional wind systems (*Zecchetto and Cappa, 2001, Zecchetto et al., 2002*).

While the temporal sampling provided by former satellites was too poor to use the winds as forcing into the oceanographic models (1 obs/day), the new generation of satellites is providing, over the Mediterranean Sea, up to four wind fields per day, thus competing with the outcome of the general circulation atmospheric models.

Thus the problem is how the satellite wind observations may be used as forcing into the storm surge models, considering both their good qualities (high spatial resolution, wind speed and direction accuracies) and their shortcomings (unavailability of data close to coast, partial coverage of the basin of interest, observation taken at the satellite pass time and not at synoptic hours).

Satellite wind observations must be integrated to other data from different sources (in-situ, satellite and models), in order to derive high quality wind and wind stress fields suitable to be used into the storm surge model.

Actually, the real forcing of the ocean is the wind stress, the computation of which requires the wind vector, the air-sea temperature difference, the humidity and the atmospheric pressure (neglecting the wave age). These quantities, obtained from models (air temperature, humidity, atmospheric pressure) and from satellite observations (wind, sea surface temperature), are input into the boundary layer models yielding the heat and momentum fluxes at the air-sea interface.

Thus, the endeavor to compute the meteorological forcing fields for the storm surge models embodies two different activities: preparation of homogeneous wind fields and computation of the wind stress taking into account the most important parameters influencing it.

The present contribution intends to stimulate, through examples of modeled and observed wind fields in the Adriatic Sea, the combined use of all the available information in order to obtain wind fields at spatial and temporal resolutions suitable for forcing the storm surge oceanographic models.

THEME 3: MODELLING AND FIELD DATA: HYDRODYNAMICS AND LAGOON PROCESSES

Chair: Prof. Keith Richards (Department of Geography, University of Cambridge)

1. Plenary: Interrelations between Venice the city and its lagoon
Prof. Job Baretta, Noctiluca, The Netherlands
2. Measuring water exchange between the Venice Lagoon and the Open Sea
Dr Miro Gacic (OGS)
3. Application of hydrodynamics and morphological models
Ing. Antonio Gozzi (Technital for MAV)
4. Integrated modelling of the Venice Lagoon
Dr Georg Umgiesser (ISMAR-CNR)
5. Open problems in modelling morphodynamics in Venice Lagoon
Prof. Giovanni Seminara (Università di Genova)
6. Mobile barriers as a management tool for water quality and lagoon flushing
Prof. Don Harleman (MIT, USA)

Plenary: Interrelations between Venice the city and its lagoon

Prof. Job Baretta
Noctiluca, The Netherlands

For over 1500 years, Venice, nestled in its lagoon, lived in symbiosis with Venice Lagoon. The lagoon protected the city from its enemies, it provided efficient goods transport, air-conditioning, sanitation, food and much more. In return, the city provided the lagoon with its organic wastes that fueled the lagoon's productivity and made it also attractive to birds. The millennium-old solution to this pollution has been dilution, driven by tidal flushing and mixing.

This flushing was sufficiently rapid --with an estimated average residence time of one day in the lagoon—to avoid over-fertilisation for a long time, but in the 1980s massive persistent blooms of macroalgae demonstrated the eutrophic status of the lagoon. This eutrophic status, inescapable with the lagoon being on the receiving end of the “nutritious” effluvia of agriculture, industry and population of the region, has been happily utilised by the aquatic communities, from phytoplankton to fish, birds and shell-fishermen. The latter regrettably have managed to severely reduce the sea-grass beds by dredging for shell-fish. This has reduced the sedimentation rate in the shallow sub-tidal areas, leading to more turbid water masses, enhancing sediment loss to the Adriatic. The downside of this openness to the Adriatic is that the water level in the lagoon faithfully reflects the Adriatic one, exposing Venice to occurrences of *acqua alta* (high water).

Protecting Venice from the insidious damages of the increasingly frequent *acqua alta* by constructing a pop-up flood-barrier is an eminently doable idea; the fear of opponents that the resultant short-term stagnation of circulation in the lagoon will result in large-scale anoxia are base-less, given the small average water depth of the lagoon and the low water temperatures in the *acqua alta* “season”. Dangers to the long-term ecological health of the lagoon –and thereby to the attractiveness of Venice—lie first and foremost in the proposed construction of jetties in front the lagoon entrances. These will reduce the exchange flux with the Adriatic, reducing the flushing of the lagoon with clean(er) Adriatic water, and reduce coastal sediment (re)supply to the lagoon, leading to increased erosion of the remaining mudflats and salt marshes. In a nutshell: flood-barrier yes, jetties no.

Temporal variations from tidal to seasonal scales of water fluxes between the Venetian Lagoon and the open sea

Dr Miro Gacic

Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS)

Co-authors:

Andrea Mazzoldi

Istituto per lo Studio della Dinamica delle Grandi Masse – CNR

Vedrana Kovacevic, Vanessa Cardin, Franco Arena and Giorgio Gelsi

Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS)

Isaac Mancero Mosquera

Escuela Superior Politécnica del Litoral, Guayaquil, Ecuador

Long-term measurements of the water flow at three Venice Lagoon inlets with the bottom-mounted ADCPs show that the main part of the variance (>90 %) is associated with the tidal variability. Semi-diurnal components (mainly M2 and S2) are responsible for about 80% of the flow variance. The residual flow is controlled to a large extent by the Adriatic seiches. Wind influence and other low-frequency forcings like freshwater discharge, are in average of negligible importance. The residual flow pattern has been analysed in details for strong forcing events. The total water flow rate (integrated over the three inlets and averaged over one tidal cycle) is on the order of 10.000 m³/sec. Phase-lag between the axial current and sea-level is on the order of two hours for M2 and four hours for the K1 component; the maximum inflow leading the sea-level maximum. Phase-difference of tidal currents between different inlets shows that Malamocco (central inlet) leads both Lido and Chioggia flows. The tidal flow is controlled by the sea-level slope between the open sea and the lagoon interior, which is due to the time-lag between the sea level in inlets and the lagoon interior, constant for all tidal components. It was shown that sea-level oscillations at Punta Salute (lagoon interior) lag those in Lido by about 45 minutes. The pressure gradient due to the sea-level slope generates the flow acceleration. Only for large current speeds (> 0.5 m/sec), the bottom friction becomes equally important as the local acceleration and the horizontal pressure gradient.

Application of hydrodynamics and morphological models

Ing. Antonio Gozzi
Technital S.p.A

Since first studies were developed for the safeguarding of the Lagoon and the city of Venice from high tides (*acqua alta*), mathematical models were used to foresee water levels in the lagoon induced by tidal events.

In the past years, for the lagoon of Venice mainly mathematical models developed “ad hoc” were used.

With the evolution of models and increased power of computers, more and more advanced mathematical models had been developed beginning with Zero and 1-D models up to the most recent 2-D and 3-D models.

After a first period during which these models were used only as an analysis tool in order to provide hydrodynamic parameters for engineering and design purposes. In the most recent period these models are used even as an integrated tool to provide hydrodynamics to study more complex phenomena like water quality or morphological evolution of estuarine systems.

Two years ago “Magistrato alle Acque di Venezia”, the Water Authority for the lagoon of Venice, decided to develop a hydrodynamic mathematical model of the lagoon of Venice. This new model uses a curvilinear mesh with finite difference schematisation that can be easily connected to water quality and/or morphological modules, to provide a hydrodynamic base for environmental analysis.

To achieve this result, a number of schematisations of the selected model had to be developed and the model had to be calibrated in the best possible way. Usually models are calibrated using water levels but, to evaluate environmental processes it is very important to know flow distribution. To achieve this result a number of intensive campaigns were done to collect flow data under controlled situation.

In this paper it will be briefly described how the model was applied to the lagoon of Venice, how measurement campaigns for calibration purposes were organised and main calibration results will be shown.

In 2002 and, recently in 2003, the model was used even to evaluate effects of some interventions at the inlets of the lagoon. Some example of results achieved during this study will be shown.

Integrated modelling of the Venice Lagoon

Dr Georg Umgiesser
ISMAR-CNR

The Lagoon of Venice is a complex system speaking in terms of the biological ecosystem and hydrodynamics. To understand the biological behaviour it is necessary to gain a sound understanding of the physical processes that take place in the basin, the most important of which is the hydrodynamics.

An overview is given on the past and present modelling efforts that have been carried out to model the hydrodynamic behaviour. Starting from the 1970s, different types of models in varying resolutions have been applied in order to study the propagation of the tidal wave in the lagoon, the wind induced circulation and the residual currents that are set up through these forcings. The implications on other physical and biological quantities such as the residence times are also discussed.

Two other applications are discussed. The first one is the set-up of a coupled hydrodynamic and ecological model that allows in detail to study the temporal and spatial evolution of the biological state variables in the lagoon. The model is based on the EPA model EUTRO-WASP and has been validated in various sites.

The second application is the study of the sediment transport in the lagoon. Here major uncertainties still exist that do not allow a quantification of even simple questions such as the mass balance of sediments between the lagoon and the Adriatic Sea. The modelling is made even more complicated due to the problem of different types of sediment (sand, silt, cohesive) that are at the same time present in the lagoon.

This overview shows the need of integrated modelling that will be able to explain the processes that are necessarily interconnected and cannot be tackled alone. A typical example of these processes are ecological ones that depend strongly on the hydrodynamic behaviour, but also on the sediment dynamics.

Open problems in modelling: The long term morphodynamic evolution of Venice Lagoon

Prof Giovanni Seminara
Università di Genova

Co-authors:

M. Bolla Pittaluga, N. Tambroni, V. Garotta
Università di Genova

Venice Lagoon (or Venice Bay?) has undergone through the centuries significant morphological changes. Assuming the present morphological state of the lagoon is a state of illness, the diagnosis of the disease is not too difficult. In fact, various well known factors have contributed to determine such a state, e.g. the diversion of rivers discharging into the lagoon, the construction of long jetties bounding the three inlets, the processes of eustatism and subsidence. As a result, the lagoon has progressively deepened and it is commonly stated nowadays that it exports to the sea a considerable amount of sediments each year. While the latter diagnosis is widely agreed, the prognosis is a major subject of research concerning the prediction of the long term morphodynamic evolution of the lagoon.

The practical approach to this problem is simply to rely on empirical relationships which grossly interpret the morphodynamic response of tidal basins to variations of external forcings (e.g. O'Brien, 1969, Eysink, 1990). Alternatively, *box models* describe the tidal system as a collection of interacting morphological elements (sea, channels, shoals, marshes), the geometry of which is given in terms of empirical relationships (Di Silvio, 1989, Van Dongeren and de Vriend, 1993, Stive et al., 1998).

A third approach is to pursue, both theoretically and experimentally, an understanding of *the hydrodynamics and morphodynamics of each morphological unit* composing the tidal system. The first step is to investigate the existence of a state of morphodynamic equilibrium of *tidal channels*. The second step concentrates on the exchange of sediments through the *inlet*. The third step looks at the *interactions channels- shoals* and *shoals- marshes*.

In the paper we review the state of knowledge on the latter processes which may be described as *fairly developed*, *developing* and *poorly developed* respectively. We discuss difficulties encountered in some of the available attempts to model them analytically, numerically or experimentally (e.g. Blondeaux et al., 1982, Schuttelaars and de Swart, 1996, 2000, Seminara and Tubino, 2001, Solari and Toffolon, 2001, Lanzoni and Seminara, 2002, Solari et al., 2002, Marani et al., 2002, Bolla Pittaluga and Seminara, 2003, Tambroni et al., 2003, Tambroni and Stansby, 2003, Martini and D'Alpaos, 2003, Schramkowski et al., 2003, Hibma et al., 2003) and possible implications for the pathological state of Venice Lagoon.

A fourth approach to lagoon morphodynamics, currently undertaken by various research groups, is to pursue a *fully numerical model* of the whole system attempting to describe all the above processes. It has the obvious advantage to reproduce the geometry of the system fairly accurately but it still suffers from various shortcomings briefly mentioned in the paper.

Some remarks on the research developments as yet needed in order to be able to release a reliable *prognosis* and *therapy* for Venice conclude the paper.

Mobile barriers as a management tool for water quality and lagoon flushing

Prof. Donald Harleman
Massachusetts Institute of Technology (MIT), USA

One of the recurrent themes in the controversy over how to save Venice from flooding during high meteorologically induced tides is the claim of some environmentalists that closure of the mobile barriers, even for five hours, would upset the lagoon's ecosystem. Others claim that gate closures will exacerbate problems with the build-up of sewage. There is rarely a mention that the solution to the latter problem is the collection and treatment of Venice's sewage or that the mitigation of the former problem is in the use of the gates as a management tool for improving lagoon water quality through enhanced circulation.

Three-dimensional, state of the art, hydrodynamic numerical models have demonstrated that the three sets of mobile barriers can be operated, during non-flooding periods, to augment lagoon circulation and flushing. Examples of various differential gate operation scenarios will be presented. Non-flooding periods are more frequent during the warmer months when lagoon water quality naturally deteriorates. It is also expected that efforts to control the input of pollutants to the lagoon will continue into the future.

It has been wrongly claimed that the design of the mobile barriers did not consider extreme sea level rises. In fact, the 1997 environmental impact study evaluated barrier design for a sea level rise of as much as 50 cm in the next 50 to 100 years. The barriers were shown to prevent significant flooding even under these extreme conditions.

The Netherlands has built flood control barriers at the various mouths of the Rhine during the past 30 years. Some of their barriers are normally open, as is planned in the Venice lagoon, while others are normally closed. The relevance of this experience to the long range future of Venice will be discussed.

THEME 4: ECOLOGICAL PROCESSES AND ENVIRONMENTAL QUALITY

Chair: Dr Stephen Malcolm (UK Centre for Environment,
Fisheries and Aquaculture)

1. Plenary: Environmental quality issues in the Venice Lagoon
Prof. Antonio Marcomini (Università di Venezia)
2. Changes in nutrients and plankton communities in the Venice lagoon
Dr Sandro Rabitti (ISMAR-CNR)
3. Pollution in the lagoon: catchment area and Venice historical centre
Dr Roberto Zonta (ISMAR-CNR)
4. Trace metals fluxes in the Venice Lagoon
Prof. Gabriele Capodaglio (Università di Venezia)
5. Institutional monitoring of the Lagoon, its watershed and coastal waters of the Adriatic
Dr Gisella Penna (Regione Veneto) and Arch. Albertogiulio Bernstein (CVN)
6. Striving towards a comprehensive knowledge of the lagoon ecosystem
Dr Alberto Zirino (Scripps Institution of Oceanography, University of California)

Plenary: Environmental quality issues in the Venice Lagoon

Prof. Antonio Marcomini
Università Ca' Foscari di Venezia

Co-authors:
Andrea Critto, Christian Micheletti
University Ca' Foscari

The lagoon of Venice is a complex ecosystem where natural and anthropogenic factors always interplayed very strictly. Over the last 30 years, several environmental issues arose as result of the increasing pressure of human activities (e.g. industry, agriculture, fishing activities).

During the 70s and 80s, major attention was drawn by the lagoon eutrophication causing spectacular macroalgae (*Ulva rigida*) blooms followed by frequent anoxias. Change of climatic conditions, increased turbidity caused by fine sediment resuspended material, and reduction of nutrients loads, led the macroalgal biomass (ca. 1.5 million ton as net primary production) to disappear almost completely, especially in the central lagoon.

In the 90s, the attention was addressed chiefly to the lagoon contamination by persistent and toxic pollutants (e.g., chlorinated compounds and pesticides, metals and metalloids, organometalli chemicals) associated with sediment and water redistribution (i.e., erosion and sedimentation processes) possibly affecting economical resourced (i.e. edible organisms) and recreational (i.e. bathing) activities, as well as the ecosystem biodiversity. After preliminary studies investigating the degree and the spatial distribution of the environmental biotic and abiotic contamination (MAV-CVN, 1998; Projects 2023 and DRAIN), regulations concerning the reduction of pollutants loads in the lagoon and new water quality objectives were enforced (D.M. Ronchi-Costa 23/04/1998), as well as to undertake remedial interventions.

More recently, research and management efforts focused on sustainable development and management of the lagoon environmental quality, aiming "to protect, sustain and improve a clean and healthful environment to benefit present and future generations". Accordingly, the challenge is to develop a decision-making and management process, integrating assessment and evaluation procedures and tools, in order to preserve and enhance the lagoon environmental resources. In particular, a sustainable environmental management process should provide an effective environmental conceptual model integrating several stress/impact factors, allowing a variety of information and data (e.g. chemical, ecological, physical data) to be assembled together. This process requires also the interaction of different stakeholders and actors, in order to include all management interests. Several authors (Menzie, 2002; Fairman, 1998, Tarazona, 2002) pointed out that the main methodological approach capable to respond to these requirements is Environmental Risk Assessment integrated with Environmental Risk Management. In fact, Risk Assessment applied in a screening phase permits to define risk-based Environmental Quality Criteria (EQC), while a successive site-specific analysis provides the remediation/intervention prioritisation and the planning of the monitoring activities.

According to Menzie (2002), the development of a risk-based sustainable management support system requires to face four main challenges: 1) the integration between Environmental Risk Assessment and Environmental Risk Management, through the involvement of the stakeholders and the development of specific Decision Support Systems (DSSs); 2) a better definition of the Problem Formulation phase (i.e., the base of the Risk Assessment), to allow the clear identification of the assessment endpoints (e.g. the ecological resources to be protected) in order to obtain a decision-driven procedure; 3) to include spatial, temporal and effects scales in the risk assessment framework, through GIS tools, dedicated statistics procedures (i.e., spatial statistics), environmental processes modelling (i.e., pollutants transport and transformation, populations recovery); 4) the uncertainty and communication management highlighting the needs of a tiered Risk Assessment approach in

order to reduce the estimates uncertainty, as well as a communication strategy including all steps of the risk assessment procedure.

In order to cope with these requirements, several research activities have been conducted so far in the lagoon of Venice in the last five years. A Problem Formulation phase was developed according to DPSIR scheme and US-EPA ecological risk assessment guidelines (Project 2023; Critto et al., 2003). Subsequently, a screening ecological risk assessment based on ambient quality criteria and a site-specific risk assessment for aquatic food web were conducted (Critto et al., 2002; Micheletti et al., 2003). Moreover, methods and procedures concerning a pool of lines of evidence (i.e. experimental activities such as biomarkers, bioassays, concerning the exposure and effects characterization) were standardised and evaluated in order to set up a site-specific risk assessment process based on the Weight-of-Evidence approach (Massachusetts Weight-of-Evidence workgroup, 1995). Finally, spatial analysis tools (e.g. GIS, geostatistics) supported all these activities providing an integrated multi-dimensional database and a spatially explicit exposure characterisation (MAV-CVN).

In the near future, efforts will be oriented to obtain a Sustainable Management Support System for the lagoon of Venice capable to: integrate Environmental Risk Assessment and Management, improve stakeholders participation to the Risk Assessment process, reduce the uncertainty associated with the management decisions, and to increase the communication between the actors concerned with the lagoon management and the risk assessors. In order to develop this Decision Support System (DSS), environmental quality indices/indicators, integrating TRIAD based site-specific risk assessment and weight-of-evidence approaches, need to be identified and quantified.

Changes in nutrients and plankton communities in the Venice Lagoon

Sandro Rabitti

Istituto di Scienze Marine/Biologia del Mare, CNR

Co-authors:

Giorgio Socal, in collaboration with F. Acri, F. Bernardi-Aubry, F. Bianchi, A. Boldrin, A.

Comaschi

Istituto di Scienze Marine/Biologia del Mare, CNR

A comparison of 28 years of data related to the Venice lagoon is presented, focused on dissolved nutrients and plankton distribution, obtained within the framework of differing research projects. Investigations were carried out in the central and northern basins of the Lagoon of Venice. From 1975–1980 until 1997-2002, general increases in dissolved inorganic nitrogen (DIN) and orthosilicates were observed, coupled with a parallel decrease in water transparency. These trends may be due to considerable resuspension, greatly highlighted today, because of increasing erosion induced by tide and wind, and more intensive fishing by dredging for molluscs, which causes nutrient mobilisation from sediments. Conversely, phosphates showed a general decrease from 1986-1988, because of the reduced amounts of phosphorus compounds in detergents, following Italian laws enforced in the 1980s. In the summers of 1991 and 1992, phytoplankton abundances and biomasses were higher than in the previous years, because of more frequent diatom blooms; the last data-set (1997-2002) indicates a slight although not significant inversion of this trend. As regards zooplankton, a decrease in the standing stock, more marked in winter, was revealed. Dissolved oxygen saturation percentages had values around 100% throughout the period, showing a slight increase over the last few years, excluding the presence of permanent dystrophic processes in this brackish ecosystem. These results indicate that the Lagoon of Venice, despite the evident existence of anthropic contamination, is a coastal environment not greatly compromised from the viewpoint of water quality.

Pollution in the Venice Lagoon: Catchment basin and urban Venice

Roberto Zonta
CNR-ISMAR

Co-authors:

Luca Zaggia, Flaviano Collavini, Aleardo Zuliani
CNR-ISMAR

The control and reduction of pollutant loads delivered to the Venice Lagoon are essential tasks for the safeguard of the water quality of this peculiar coastal system. The drainage basin (total surface of ca. 1850 km²) represents the major source of contaminants for the lagoon. It is constituted by an ensemble of tributary sub-basins with contrasting characteristics and hydraulic pathways. With the main objectives to measure the annual freshwater discharge into the lagoon and to estimate the related load of pollutants (heavy metals, nutrients and micro-organics), the twelve major tributaries were investigated in the ambit of the DRAIN project (1998 – 2000). These streams have different hydraulic regimes (natural, mechanical, alternate mechanical) and can be regulated and diverted. Moreover, due to the necessity of intercepting all the freshwater inputs, the measurement sections were located in the close proximity of the lagoon border and most of them were influenced by tide excursion and salt wedge intrusion. As a consequence, a very intense field activity was needed to characterise the flow, as well as the collection of a large number of water samples for chemical analysis. The study yielded a very detailed and multidisciplinary knowledge framework regarding freshwater, matter and pollutant fluxes. The main project results will be described, including the different behaviour of the various tributaries, and the role of flood events in the delivery of matter and pollutants. Finally, estimated values of the annual loads will be compared with data coming from past and recent investigations.

The pollution of the Venice canal network is a quite different environmental problem. Organic matter and pollutants from untreated sewage effluents are directly discharged into the network, where strongly reduced sediment accumulates. The canals are therefore subjected to a progressive silting, and periodic dredging operations have been performed since ancient time for maintenance and restoration. After about thirty years of no dredging, in the early 1990s a layer of sediment with a thickness up to 1 meter formed in the whole network, which represented the historical evolution of the deposited suspended matter and associated pollutant species. This material was characterised and classified to assess the appropriate disposal procedures by sampling 775 sites in the about 40 Km long canal network ("Rii" integrated project, 1995 – 2000). The analysed species were As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, total hydrocarbons, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, chlorinated organic pesticides. In the ambit of some minor projects, further investigations were also done to study the pollutant behaviour within the canal network, including water circulation and quality, sedimentation fluxes and rate of sediment accumulation, sediment resuspension due to both wet dredging and boat traffic. Main results will be described, relating the pollutants distribution in the sediment with possible diffuse and point sources.

Trace metals in the aerosol of the lagoon of Venice

G. Capodaglio
Università Ca' Foscari di Venezia and CNR

Co-authors:

A. Gambaro
G. Toscano
Università Ca' Foscari
K.J.R. Rosman
Curtin University of Technology, Australia

Few studies have been carried out to evaluate the role of aerosol in the transport of pollutants in the Lagoon of Venice. Here we will report results, which highlight the importance of this contribution to the contamination of the lagoon environment.

Aerosol samples were collected onto cellulose filters using Tish High-Volume air samplers fitted with PM₁₀ size selective inlets with a sampling rate of about 1 m³/min and classified into six size intervals with cutoff aerodynamic diameters of 7.2, 3, 1.5, 0.95, 0.49 and <0.49 µm. Samples were collected at four stations and samples have been collected selecting the speed and the wind direction, with the aim of characterising aerosols derived from the principal contaminant sources of the Venice Lagoon. Filters were weighed, mineralised and analysed for elemental composition by HR-ICP-MS and for the lead isotopic composition by Thermal Ionisation Mass Spectrometry (TIMS). The preliminary results obtained show that the elements with clear anthropogenic origin (in particular, V) had a higher concentration in the fine fraction of aerosol, while other elements such as Mn and Fe showed higher concentrations at all sites with a bimodal distribution probably due to the crustal origin of these elements. Significant differences for the isotopic lead composition was observed for the different sampling sites and for the aerodynamic diameter sizes.

On the basis of results obtained we can conclude that aerosol of different origin can significantly contribute to the pollution of the Lagoon of Venice by metals; local emissions are important sources of inorganic pollutants, especially for some elements, however, also transport by long range mechanism can have a not negligible importance.

Institutional monitoring in the lagoon, its watershed and the coastal waters of the Adriatic: a support to continuous update of the ecological quality assessment

G. Penna
Regione Veneto

A.G. Bernstein
Consorzio Venezia Nuova

Co-authors:

R. Casarin
Regione del Veneto
G. Ferrari
Magistrato alle Acque di Venezia
M.Vazzoler, P. Parati
ARPAV
L. Montobbio
Consorzio Venezia Nuova
A. Barbanti
Thetis Spa

Institutional controls and environmental monitoring activities by the Region and the State administrations are now converging in order to support an integrated evaluation of the state and the evolution of the Lagoon ecosystem. The Regione del Veneto (RdV) develops plans to reduce and/or prevent pollution and improve the quality of fresh water in the drainage basin; it also monitors rivers, groundwater and coastal sea waters for quality through its Regional Environmental Protection and Prevention Agency (ARPAV). The Venice Waters Agency (Magistrato alle Acque di Venezia (MAV)), with some support from its concessionary, Consorzio Venezia Nuova (CVN), operates in the lagoon with the general objective of restoring and preserving its ecosystem, including monitoring and managing its evolutionary trend.

At present, the assessment of the quality of the lagoon ecosystem is jointly carried out by the following:

- MAV (SAMA) which samples and collects data on wastewater inputs into the lagoon and on their effects and origins;
- MAV (SAMA) in co-ordination with CVN its specialised contractors (among them, Thetis S.p.a), which monitors the quality of Lagoon sediments, waters, biota, carries out survey to support the design of environmental works and produces quality assessments and evaluations at ecosystem scale;
- RdV, via ARPAV, which samples and collects data on rivers and coastal waters and produces quality assessments and evaluations of pollutant loads from the watershed.

The immediate objective is to obtain of an accurate description of the ecological state for the lagoon and its drainage basin *at the present time*, because this is the reference point against which the impact of further development of environmental and tide protection measure and other actions implemented both by both the *RdV* and *MAV* may be measured.

The medium term aim is to pursue a deeper and more detailed knowledge of the Lagoon and its processes, to follow up its evolution and to share the tools for its maintenance and restoring actions. This will be possible only through the general picture drawn out monitoring programmes and surveys carried out routinely at lagoon scale by the institutional Agencies integrating the essential contribution of the free research activities carried out by the scientific community on new topics and emerging issues.

The monitoring programme in the Venice Lagoon: striving towards a comprehensive knowledge of the lagoon ecosystem

Abstracts Volume

Flooding and Environmental Challenges for Venice and its Lagoon: State of Knowledge 2003

Discussion Meeting – Cambridge, 14th-17th September, 2003

Dr A. Zirino
Scripps Institution of Oceanography, University of California

Although many, many, studies have been conducted in the Venice Lagoon, in general, past efforts have generally focused on a few or individual descriptors of its ecosystem, limited in both temporal and spatial coverage. However, under the sponsorship of the Magistrato alle Acque and with the collaboration of its concessionary, the Consorzio Venezia Nuova, the last three years have witnessed the initiation and activities of MELa – (Monitoraggio Ecosistema Lagunare) a major programme designed to provide a comprehensive, synoptic, and Lagoon-wide coverage of important water quality parameters, and provide insights into the major processes affecting the concentrations and distributions of ecological variables, e.g., primary production, growth and distribution of macroalgae and sea grasses, release rates of heavy metals from sediments, transfer and accumulation of toxic substances in the food web, etc. Additionally, MELa provides water quality data in compliance with statutory requisites, base line data against which the effects of new construction may be assessed, and also, data for mathematical modelling of the Lagoon ecosystem.

MeLa is being carried out in collaboration with programmes carried out by the Regione Veneto Environmental Protection Agency, which is supplying data on inputs into the Lagoon from the catchment basin and is also monitoring the waters of the adjoining Adriatic Sea. The collaborating agencies are working together to optimize the timing of the sampling campaigns and carry out QA/QC activities among themselves and with outside laboratories.

Among many results, the integration between past data and the monitoring effort has provided a holistic vision of the process occurring in the Lagoon ecosystems. It has yielded an understanding of the spatial and temporal variability of primary production (phytoplankton, macroalgae, and sea grasses) and of the factors that “drive” the concomitant nutrient field and physico-chemical parameters. The present state of the Lagoon appears to be in a stable, mesotrophic condition, typical of similar environments. Overall, potentially toxic trace contaminants (metals, organics) in the waters of the Lagoon are low when compared to water-quality criteria. In sediments, several trace substances (Pb, Hg, As) are high near the industrial areas. However, a MELa sub-study, ARTISTA, which deals with the mobility and availability of contaminants from sediments (as well as with their distribution and concentration throughout the food web), shows little release from sediments, a condition largely attributable to the presence of excess acid volatile sulphides and binding by refractory organic matter. A study of trophic relationships at five stations dispersed throughout the Lagoon, shows that they are determined largely by physical parameters (currents, hydrodynamic residence time, sediment type, depth, turbidity, etc.) and not by the concentration of micropollutants in the sediments.

These observations strongly support the view that the ecosystem of the Venice Lagoon must be considered in its entirety and that its ecological “state” must be assessed from a comprehensive knowledge of the interactions among multiple variables, rather than from the measurements of a single parameter, as is often done.

Acknowledgements: The presentation was on behalf of the MELa programme work group: Andrea Barbanti, Andrea Berton, Martina Bocci, Sebastiano Carrer, Elisa Andreoli, Anna Carlin, Chiara Castellani, Magda Ciri, Alessandra Regazzi, Eugenia Delaney and Emiliano Ramieri (Thetis), Giuseppe Bendoricchio, Giovanni Caniglia and Paola Venier (University of Padova) Alberto Bernstein, Laura Montobbio and Sara Bardino (CVN environmental engineering dpt.), Roberto Rosselli and Sonia Silvestri (Venice Waters Authority information service), Giorgio Ferrari (Venice Waters Authority pollution control section), Roberto Pastres, Stefano Ciavatta, Antonio Petrizzo and Simone Libralato (INCA-Venezia), Anna Volpi, Alessandra Arizzi-Novelli, Pierfrancesco Ghetti and Giovanni Sburlino (University of Venezia) Andrea Rismondo, Daniele Curiel, Francesco Scarton, Dario Smania, Giuseppe Pessa, Daniele Mion, Martina Cazzin and Rita Zaja (SELC), Cosimo Solidoro and Giampiero Cossarini (OGS-Trieste), Luigi Albertotanza, Alessandro Rabitti, Giorgio Socal, Luisa Da Ros, Cristina Nasci, Vanessa Moschino, Stefania Salviato, Federica Braga and Davide Tagliapietra

Abstracts Volume

Flooding and Environmental Challenges for Venice and its Lagoon: State of Knowledge 2003

Discussion Meeting – Cambridge, 14th-17th September, 2003

(ISMAR-CNR), Mauro Bon (Venice Natural Sciences Museum), Bart Chadwick (Zirino Associates, San Diego-Usa), Aldo Viarengo (Eastern Piedmont University), Silvano Focardi (Siena University).

THEME 5: PHYSICAL PROCESSES: SEDIMENTS AND MORPHOLOGY

Chair: Dr Iris Möller (Department of
Geography, University of Cambridge)

1. Plenary: Sediment balance, morphodynamics and landscape restoration
Prof. Giampaolo Di Silvio (Università di Padova)
2. The influence of inlet configuration on sediment loss in the Venice Lagoon
Prof. Luigi D'Alpaos (Università di Padova)
3. The third dimension in Venice
Prof. Albert Ammerman (Colgate University)
4. The transport and stability of sediment in northern Venice Lagoon
Dr Carl Amos (University of Southampton)
5. Management of lagoon morphology
Dr Lorenzo Bonometto (Comune di Venezia) (no abstract)
6. Morphological restoration techniques in Venice Lagoon
Ing. Giovanni Cecconi (CVN)

Plenary: Sediment balance, morphodynamics and landscape restoration

Giampaolo Di Silvio
Università di Padova

Landscape restoration projects being carried out in the lagoon of Venice since several years, are strongly controlled by the prevailing morphodynamic processes. In the present conditions the Lagoon is conspicuously subject to erosion of shoals, reduction of salt marshes surface and siltation of tidal channels. The main reason of this morphological evolution is the substantial *sediment deficit* of the lagoonal basin with respect to 150 years ago (i.e. before the construction of the jetties at the inlets), and even more with respect to the XIV century (i.e. before the diversion of the rivers).

Morphological evolution is also dependent on other forcing factors, as the anthropogenic modification of *hydrodynamics* (e.g. the large navigation canal in central lagoon) and, up to a point, the long-term variations of the *relative mean sea-level*, both in terms of eustatism and soil subsidence.

Available morphological and altimetric records can be interpreted by a simple conceptual model which simulates morphodynamic processes. While eustatism and soil subsidence (apparently of comparable significance) tend to increase the flooding frequency of artificial surfaces (urban settlements), as far as natural surfaces are concerned (salt marshes) the increase of relative sea-level is somehow compensated by a corresponding continuous trapping of sediments.

Besides relative mean sea-level change, the long-term conceptual model incorporates the effects of tidal currents (dominant in the channels), local wind waves (dominant in the shoals), sea wave climate (dominant in the littoral near the inlets) as well as anthropogenic interventions (dredging of canals, sediment dumping, wave breakers and other constructions).

The morphological evolution as recorded in the last 150 years has been simulated by the model. In the paper some comments will be made on the past and present morphology and on the possible measures to be taken for slowing down or even halting degradation processes.

The influence of inlet configurations on the sediment loss in the Venice lagoon

Luigi D'Alpaos
Università di Padova

Co-author:
Paolo Martini
Università di Padova

Since a long time tidal currents in the inlets of Venice Lagoon have been leading to a negative sediment balance.

A two-dimensional finite element model (depth averaged and full non linear) has been designed to simulate both the hydrodynamics and the time evolution of bed bottom due to the sediment transport (such as bed load and suspended load).

Starting from bottom configuration as it was in the early XIX century, we have studied the hydrodynamical and morphological effects of the regulation works performed on the lagoon inlets to allow both a safe navigation and the entrance in the lagoon of the modern boats.

In particular, we estimate the hydraulic resistance crossing the mouths, pointing out the effects of the jetties construction on the tidal currents dynamics, on the sediment dynamics and, of course, on the inner tidal propagation.

The obtained results show that the actual different behaviour between the ebb and flood phase is one of the main causes (and, at least, the final one in the whole balance) of the sediment loss in the Venice Lagoon, leading to a general flattening of the shallows and to a disappearance of wide salt-marsh areas.

The computations show that after the jetties construction, unlike to what happened in the early XIX century, just a small amount of sediments, resuspended in the inner lagoon by wave action and tidal currents and crossing the mouths during the ebb period, can enter again in the lagoon in the following flood period.

From these considerations two observations arise: on one hand, a balanced sediment exchange can not be obtained maintaining an asymmetric flow configuration at the inlets; on the other hand, the morphological effects of the planned breakwaters in front of the three inlets are to be seriously estimated to guarantee a reduction of the sediment loss, while the resistance induced to the flow is, of course, negligible.

The third dimension in Venice

Albert J. Ammerman
Colgate University

The build up of anthropic surfaces over time is at the heart of the question of flooding in Venice, and yet the third dimension has only begun to receive the full attention it deserves in the last few years. One of the reasons for this is the very late start of archaeology in Venice. As late as 1985, there was no excavation based on modern methods within the area of the city. The situation has now improved. The challenge is to have proper control over both the age and the elevation of the archaeological levels at a given site. The method that we have used for tying all of the levels recovered at different sites to the 1897 tide-gauge standard is explained in the paper. The dating of the levels makes use of more than 70 C-14 dates run at Oxford. It is worth adding here that even as late as 1995 there was still confusion in the literature about the vertical position of the boundary at the base of the Venetian Lagoon. On the basis of acoustical profiling, coring, and AMS dating, this problem has now been resolved. The boundary commonly stands at about 5 m below the 1897 standard and dates to around 6,000 years ago. In 1999, we published the first curve for Venice showing the trend in the build up of anthropic surfaces over the last 18 centuries. A new curve, which is based on the evidence from nine archaeological sites, will be presented at the meeting. It gives essentially the same result. The question of post-depositional compaction is taken into account. It appears to be quite modest on the basis of preliminary studies. Thus, the curve can be regarded as a working proxy for the average, long-term rise in relative sea level at Venice. Between 4,000 B.C. and late Roman times, the average rate of change was approximately 7 cm per century. Between A.D. 400 and 1897, the rise in relative sea level was on average 13 cm per century. In the last one hundred years, as shown by tide-gauge records, there has been a rise of more than 23 cm. In the latter case, 10 cm of the change is attributed to groundwater withdrawal at Porto Marghera (1930-1970). In retrospect, it is possible to see that Venice lost a century in her battle against the sea in the twentieth century. Because of poor industrial policy (Porto Marghera and deep navigation channels), the third dimension did not keep pace with the life of the city. On the other hand, if one takes the long view and considers the situation over the next two hundred years, the long-term trend presented here, in combination with the prospect of global warming, will place Venice in a very difficult situation. So far, the solutions to flooding that have been offered do not adequately address the problems that the city will have to face in the long run. In light of the vagaries of public policy in Italy, the prospects for Venice – except perhaps as a future site for doing industrial archaeology – do not look good.

The transport and stability of sediment in northern Venice Lagoon

Dr Carl Amos
University of Southampton

Whilst it appears that Venice Lagoon is generally exporting material, the region north of Venice is one of accumulation and habitat growth. To understand what causes this distinction in evolutionary trends may provide insight into effective methods of habitat regeneration. University of Southampton has been working closely with CNR and CORILA on this subject over the last 5 years. This work has been heavily biased towards field measurement, followed by numerical simulation. Field surveys have discovered the presence of submerged beaches surrounding much of the tidal flats. These beaches appear to be formed by reworking of Holocene barrier islands described by Bonardi and others to be relict coastlines. The beaches provide the stable substrate for marsh development and they act to dissipate much of the destructive wave energy wave causing shoreline erosion elsewhere. Sensitivity analyses of numerical simulations conducted by Cappucci (2003) show that habitat development is strongly sensitive to depth of inundation, thus the sandy substrate provides a natural platform for marsh growth. Enhancement of deposition can also alter the residual fluxes of material between the Lagoon and the Adriatic. This flux is strongly controlled by the concentration gradient along the inlets, which may be reversed (to slope shoreward and hence import material) through the enhanced deposition on the tidal flats. Our work is continuing through enhancement of the sediment transport numerical models for sand and fine material (SLIM and SEDTRANS) and through the evaluation of the long-term transport pathways of SAND in Venice Lagoon.

Morphological restoration techniques

Ing. Giovanni Cecconi
Consorzio Venezia Nuova

The Venice lagoon morphology has been deeply transformed by human activities since the 15th century, when the Venetians started to redirect the rivers out of the lagoon, far from the city port of Venice, producing a starvation of muddy sediments and later, at the end of the 18th century with the construction of the inlet break-waters at the lagoon inlets, of sandy sediments.

The lack of sediment caused a vast erosion of tidal flats, salt marshes and the siltation of channels.

Over the last century man-induced subsidence and sea level rise contributed to the deepening of the lagoon basin with an overall doubling of the volume of water inside the lagoon while the volume of the tidal prism had a minor increase.

Since 1950 the sudden increase in pollution load and man induced turbidity has reduced the stabilising eel-grass and diatom habitats with a further increase of tidal flat erosion.

More recently navigational dredging of Canale dei Petroli, dredging for leisure navigation and clam fishing have contributed to the increase in the erosion of the tidal flats and salt marshes.

To restore the lagoon morphology several alternatives have been considered, but only a few of them are viable and effective:

1. redirection of the river Piave, Brenta, Adige: has been considered not feasible (because of pollution, littoral erosion, major landscape transformation), but it will be re-evaluated according to the decision of the Inter-ministerial Committee on the 4th of April 2003;
2. permanent reduction of flow at the tidal inlets: not effective (the erosion of tidal flats will increase and there is the need to introduce local mitigation inside the lagoon to impede the transfer of sediments from the tidal flats to the channels); this alternative can produce a reduction of the number of barrier closures and will be re-evaluated in association with mitigation works inside the lagoon, according to the decision of the Inter-ministerial Committee;
3. removal of jetties at the tidal inlets (non feasible for the erosion of nearby littorals and the siltation in the navigation channel);
4. sand by-pass from Cavallino into the lagoon (effective and included into the restoration plan of 1992, it will be re-evaluated according to the request of the Inter-ministerial Committee);
5. re-use of maintenance dredging sediments (very effective for compensating the loss of wetlands, it as been under way over the last 15 years);
6. protection works of tidal flat and edges of salt marshes (very effective and under way over the last 10 years);
7. Import of marine sand (from maintenance dredging of river outlets and borrow areas at sea) for capping polluted tidal flats and for shoal formation at the side of the channels to limit the transport of sediments into the canals (very effective and under way as required by the Inter-ministerial Committee for mitigating the impact of channels that are artificially maintained);

8. Inlet modifications able to produce a permanent reduction of tidal flow in excess of the adopted 5%, can reduce the frequency of flooding but at the expenses of a strong increase of the siltation of the canals by wave eroded tidal flat sediments. Inlet reduction can be evaluated only if extra confinement structures along the channels will be introduced.

The restoration of the lagoon morphology is a continuous effort of local works for the re-introduction of self-preserving hydro-morphological and biological processes. The new lines of action and the relative works are:

1. The reduction of the resuspension due to waves produced by wind and navigation and due to dredge fishing: building small break-waters along the edges of the canals and in front of the marshes;
2. The increase of the trapping capacity of the remaining natural salt marshes and tidal flats: building and maintaining sediment fences and nourishing the surface of the marshes with sediments (sediment jet-spraying);
3. The increase of the velocity of the water along the canals and the reduction of cross-flow: building shoals, submerged berms and wetlands along the border of the canals;
4. The increase of the resistance of tidal flats to the wave action: by means of the regulation of clam fishing and navigation, transplantation of eel-grass and soil modification with shells and sand.

For counteracting the on-going erosion the above works must be implemented as soon as possible, facing the critical topic of the acceptance of landscape modification with new materials and structures.

Only after the implementation of the above works and the limitation of pollution input can further reduction of tidal flow be taken into consideration.

THEME 6: VENICE AND GLOBAL ENVIRONMENTAL CHANGE

Chair: Prof. Trevor Davies (Climatic Research Unit, University of East Anglia)

1. Plenary: The facts of relative sea level rise in Venice *Dr Roberto Frassetto (CNR-ISMAR)*
2. Long term natural subsidence of Venice: evaluation of its causes and magnitude *Dr Eugenio Carminati (Università di Roma)*
3. Overview of the main findings of the IPCC Third Assessment Report *Dr Domenico Gaudioso (APAT)*
4. Ocean Climate Variability in the Mediterranean Sea: Climate Events and Marine Forecasting Activities *Prof. Nadia Pinardi (Università di Bologna)*
5. Climatology of Storm Surges in Venice: Present and Future Scenarios *Prof. Piero Lionello (Università di Lecce)*

Plenary: The facts on relative sea level rise in Venice

Dr Roberto Frassetto
CNR-ISMAR

In the last 37 years since the historical 1966 flood in Venice, a great deal of national and international scientific research has been collected and assessed to understand the nature and the dynamics of the integrated natural system of environment, climate and soil of the city of Venice and its lagoon area.

The geological and paleoclimatological evolutions have been reconstructed to reveal, model and predict the consequences of the meteo-climatological and land use variations induced by man in the XX century both locally and globally.

It is time to review and synthesise this work and assess its most interesting results through four general issues:

1. We review recent studies on the tectonic and isostatic subsidence over a time scale of 10^6 to 10^3 years to assess the stability of a reference benchmark on which to refer variable processes of soil settlement in the Venice area. The rate of natural subsidence is quantified.
2. We briefly describe the geological evolution and instability of the soil through the glacial cycles at the 10^5 – 10^3 -year time scale to understand the origin and the horizontal and vertical distribution of sediments and assess their sensitivity to compaction.
3. We describe the evolution of the local anthropogenic subsidence during the XX century comparing different results from data and observation analyses giving particular emphasis to its acceleration in the 1930-70 time period. Evidences demonstrate that the anthropogenic subsidence can be controlled and that small “rebounds” are possible with the re-establishment of hydrostatic pressure. Periodic controls however are necessary using deep mooring of benchmarks and advanced levelling technologies (geometric and spatial).
4. We review the progress of national and international studies of the variations of climate and environment of the Earth’s system, assessing the results, the variability, and the uncertainties of those components, which may have a repercussion on the Mediterranean and on the Venice areas in the XXI century. In particular, we review the meteo-climatological and ecosystem variations of the Mediterranean and Adriatic areas.
5. We conclude evidencing that the major risk for the future safeguard of Venice is the global greenhouse atmosphere and ocean warming and Sea Level Rise (SLR). The most reliable information on the rate of changes on which to rely is available on the Five-Year Assessments of IPCC, CLIVAR, MAP and ICAM and local analysis. On the other hand temperature, pressure, and winds, which affect the Venetian environment, are subject to regional and local anomalies. Their meteorological forecast remains a scientific challenge. There are limits in observation, modelling, analysis and computing time and cost to be overcome.

Long term natural subsidence of Venice: evaluation of its causes and magnitude

Dr Eugenio Carminati

Dipartimento di Scienze della Terra, Università "La Sapienza"

Co-authors:

Carlo Doglioni

Dipartimento di Scienze della Terra, Università "La Sapienza"

Davide Scrocca

Istituto di Geologia Ambientale e Geoingegneria (IGAG)-CNR

In the Po Plain (northern Italy), the natural component of subsidence can be split into:

- i) a long term component controlled by tectonics and geodynamics, active on time spans of about 10^6 yr;
- ii) a short term component, likely controlled by climatic changes (glaciation cycles), acting on periods of 10^3 - 10^4 yr (Carminati and Di Donato, 1999).

With this contribution, we address the long-term component of subsidence in the area of Venice discussing its causes and providing an estimate of its magnitude. The definition of its causes is mainly based on the interpretation of a new seismic line (CROP M18; Carminati et al., 2003), whereas the assessment of its magnitude relies on stratigraphies of industrial wells.

In seismic reflection profiles of the Po Basin and the northern Adriatic Sea, the dip of the regional monocline gradually decreases from about 22° to close to 0° . This feature has been interpreted as the effect of the flexure of the subducting Adriatic plate under the Apennines (Doglioni, 1993; Mariotti and Doglioni, 2000). Along a transect from the Bologna Pedepennines (foot of the Apennines), across the Po basin, up to the Friuli region (at least 240 km north-eastward), the foreland regional monocline related to the northern Apennines subduction can be followed and shows a decreasing pattern. In the seismic section CROP M18, which represents the portion of this transect around the city of Venice, Pleistocene sediments onlap and pinch out to the northeast. The Pleistocene-Pliocene boundary is quite undulated. However, moving toward the Friuli plain or the north-easternmost Adriatic Sea, the upper Pleistocene sediments gradually thin (due to a lowering of subsidence rates), and lie directly on Miocene sediments. Venice is located on a segment of the active monocline dipping about 1.8° to the southwest. This observation confirms that long-term subsidence in Venice related to the subduction under the Apennines.

In the Venice area, industrial wells found the base of the Pleistocene sediments between 960-1500 m. The Pliocene-Pleistocene boundary, marked in these wells by the first occurrence of *Hyalinea Balthica*, has an absolute age of 1.43 Ma. Thickness and absolute age of the Pleistocene base permit to calculate Quaternary sedimentation rates of about 0.7-1.0 mm/yr. During the last 1.43 Myr, sedimentation rates in the Po plain can be assumed to be equal to subsidence rates, since the entire sequence was deposited in shallow marine to continental environments. A paleobathymetry uncertainty of 100 m (from shallow marine to continental) would result in an error of 0.07 mm/yr in the subsidence rate estimates. In the upper part of the considered succession, however, units with prograding clinoforms can be recognized, suggesting that processes of basin filling cannot be neglected. The velocities we calculate from stratigraphic data are thus to be considered an upper bound.

We conclude that a significant part of the long-term natural component of the town subsidence (0.7-1.0 mm/yr) is related to the northeastward retreat of the Adriatic subduction. The subduction related down flexure affects the whole Po Plain basin and part of the Southern Alps, where it opposes the general uplift related to orogenesis.

Abstracts Volume

Flooding and Environmental Challenges for Venice and its Lagoon: State of Knowledge 2003

Discussion Meeting – Cambridge, 14th-17th September, 2003

An overview of the main findings of the third assessment report of the IPCC

Prof. Domenico Gaudioso

Agenzia per la protezione dell'ambiente e per i servizi tecnici (APAT)

Co-author:

Vincenzo Ferrara

ENEA-Centro Ricerche Casaccia

The paper provides an overview of the main findings of the Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC), concerning mainly the scientific aspects of the climate system and climate change. In particular, some key elements to understand the ongoing evolution of the global and regional trends are shown, with a particular emphasis on the observed variability and change, the role of greenhouse gases in the climate system and the climate processes affected by human activity. The paper also presents the IPCC projections of future climate change in relation to the IPCC different scenarios of global socio-economic development and global greenhouse gas net emissions, as well as a description of the more relevant environmental consequences following those projections. Finally, recent advancements in climate science and the evolution of IPCC findings through the different reports prepared by the Panel since 1990 are also considered. In order to understand some of the criticisms addressed to the IPCC's assessment reports, the paper explains the mandate of the IPCC and the rules governing this "intergovernmental" scientific body, compared to other international scientific and/or "non-governmental" organisations.

Ocean climate variability in the Mediterranean Sea: climate events and marine forecasting activities

Prof. Nadia Pinardi
Università di Bologna

The Mediterranean Sea long-term ocean variability has been studied intensively in the past twenty years and results illustrate the correlation between atmospheric forcing variability and ocean response at seasonal, interannual and interdecadal time scales. Major climate variability events have occurred in the eighties and nineties driven by long-term interannual variability of atmospheric forcing connected to the North Atlantic Oscillation (NAO) index during winter and to regional climate regimes, such as Etesian wind variability. In addition, teleconnections of the Mediterranean climate variability with Indian Monsoon and NAO variability have been studied. Water mass decadal variability has been detected in the observations and the model simulations.

Moreover, shorter-term ocean variability, connected with the time scales from the seasonal to the mesoscales, has been thoroughly investigated. This has produced the implementation of a Mediterranean ocean Forecasting System (MFS) to forecast the ocean variability in the Mediterranean Sea from the global scale to the shelf areas, from the hydrodynamic components to the biochemical variability at the weekly to monthly time scales. The MFS has started operational activities in January 2000. Presently it produces daily analyses and weekly 10-day forecasts of currents and temperature and salinity fields for the entire Mediterranean at approximately 10 km resolution.

The main elements of the MFS – simultaneously operating in near-real time observational data network, general circulation model and data assimilation scheme – were implemented as part of an EU funded project called Mediterranean Forecasting System Pilot Project (MFSP). The second phase is being undertaken by another EU funded project, called the Mediterranean ocean Forecasting System: Toward Environmental Predictions (MFSTEP), which is seeking further consolidation and expansion of the MFS. The main goal of the MFSTEP is the advance monitoring technology to achieve maximum reliability of the Near Real Time observing system, to demonstrate practical feasibility of regional forecasting in several Mediterranean regions (3 km resolution). One of these regions is the Adriatic Sea where forecast activities have started this year by the support of the Italian Ministry of Environment and Territory.

The specific objectives of the MFSTEP are to improve and expand the existing large scale monitoring system; to add new observing system components in terms of biochemical measurements and new automated technology; to improve 10-day basin-scale forecasts and to demonstrate feasibility of near real time five-day forecasts in different shelf areas (Adriatic Sea and few others); to develop asynchronous ocean-atmosphere coupling over regional and shelf areas; to develop three-dimensional biochemical models coupled to the forecasting system for future prediction of ecosystem variability; to consolidate and disseminate forecasts in a wide users community and develop applications for end users. Products of MFSTEP are already available at www.cineca.it/mfspp and www.ingv.it/adricosm.

The climatology of the storm surge in Venice: the present and future scenarios

Prof. Piero Lionello
Università di Padova

Any change in storminess and in the prevalent cyclonic regimes in the Mediterranean area could have relevant consequences for the frequency and the height of surges in the Northern Adriatic Sea. It is therefore important to improve our understanding on the air-sea interaction and of the atmospheric dynamics responsible for the flooding of Venice, in order to be able to understand its present trend and possible evolution in a future climate scenario. The presentation briefly reviews the mechanism responsible for the storm surge in the Northern Adriatic Sea and its relation with the meteorological patterns in the Mediterranean region. The present weak trend and variability are discussed as an introduction to the problem of the evaluation of the future storm surge scenario. Such prediction includes the aspects of both a downscaling problem and an impact study. The description of the surge dynamics requires the knowledge of air-sea interaction and sea level pressure distribution at a sub-regional scale that is in the Adriatic Sea, which is not resolved in global climate simulations. Therefore, a downscaling procedure is needed to produce wind fields with resolution sufficient to be used as the input information for the computation of the actual surge level. The impact of a different climate scenario can be assessed after the computation of time series long enough to produce the statistics needed for the analysis of variations in the frequency of large surges and in the intensity of extreme surge events. The results of a scenario computation which evaluated the variation of storm surge extremes in a 2*CO₂ climate are presented and their uncertainty is discussed. These results suggest that there will be no large variation in the extreme surges due to a variation of storminess in a 2*CO₂ climate. These results are substantially consistent with the analysis of the present climate, which actually suggests a weak negative trend in the occurrence of the meteorological conditions responsible for the flooding of Venice.

Technical Session I: Engineering

Chair: Sir Alan Muir Wood

1. Mobile barriers construction details
Ing. Yuil Eprim (Technital)
2. Modelling Of Cardiff Bay Barrage control system: revised automatic control logic for the sluice gates
Dr Edoardo Faganello (Jacobs)
3. High water protection measures in Piazza San Marco
Ing. Maria Teresa Brotto (CVN)
4. Methodologies for the functional restoration of a historical urban system
Ing. Ivano Turlon (Insula)

Mobile barriers construction details

Ing. Yuil Eprim
Technital S.p.A

The method of construction of the mobile barriers has been developed with the objective of minimising:

- interference with navigation
- in-situ work to minimise traffic due to movement of workers
- effects on the hydrodynamics of the inlet channels during construction
- dredging/excavation volumes

To achieve this, the construction method is based on:

- prefabrication of the barriers main elements in basins away from the inlet channels
- use of temporary or permanent sheet piling to reduce the dredging/excavation volumes

Thus, the main structures are prefabricated in appropriate dry basins or on floating basins, floated, transported to site, sunk to their final position and permanently ballasted.

Some of these structures need finishing works that can be carried out in dry conditions.

Almost all the structural and construction details are conventional and are covered by well consolidated engineering and construction practices.

Special attention is required for the following four aspects:

1. the durability of the structures. (100 years useful life)
2. the installation of the female connector units on the barriers caissons. (precision necessary for the hinge anchoring of the flap gates)
3. the installation of the rubber (Gina) joints on one end of the barriers caissons and the contact plates on the other end. (accuracy required to achieve full efficiency of the water tightness)
4. the positioning of the barriers caissons in their final locations. (precision required for the proper functioning of the flap gates).

The durability of the concrete structures is achieved by adopting appropriate reinforcement detailing, using special concrete mixes and by adopting controlled procedures for concreting, prestressing and curing.

To control the correct positions (horizontally and vertically) of the female connector elements, these will be installed at least three to four months after the caisson concreting has been completed. In this period the movements of the caisson will be continuously monitored.

Also the installation of the rubber joints and the contact plates will be done three to four months after the caisson concreting has been completed.

To control the correct position of the barriers caissons, these will be initially supported on hydraulic jacks. Ballasting of the caissons will be carried out and the elevation of the caissons will be adjusted as necessary. Only after the adjacent caisson has been sunk in position, partially ballasted and connected to the first one, the latter can be completed by injecting cement mortar to fill the underside gap and the hydraulic jacks deactivated.

The modelling of Cardiff Bay barrage control system: the revised automatic control logic for the sluice gates

Dr Edoardo Faganello
Jacobs

Co-author:
Steve Dunthorne
Jacobs

Cardiff Bay Barrage is a tidal exclusion barrier forming a 200 ha freshwater lake by impounding the flows from the Rivers Ely and Taff. It was designed as a flood control structure to pass river floods and exclude high tides, allow passage for migrating fish and continued navigation between the bay and the Severn Estuary as well as to provide a public amenity with 12 km of attractive waterfront.

The principal structures and ancillary works associated with the barrage comprise five 9 m wide x 7.5 m high automatically controlled sluices with double-leaf vertical lifting gates, an 8 m wide fish pass and three navigation locks (8 m to 10.5 m wide) with hydraulically operated sector gates.

The 700 m long embankment, formed from rock and marine dredged sand, not only impounds the fresh water lake but also prevents both the loss of fresh water and contamination by sea water.

The outer harbour (formed by two breakwater arms comprising a series of pre-cast reinforced concrete caisson units) provide a tidal, sheltered and 'harbour of refuge' for small boats waiting to use the locks.

Following comments received from the Environment Agency, Cardiff City Council appointed GIBB LTD (February 2000) to construct a further mathematical hydraulic model of Cardiff Bay.

The model was commissioned to examine the reasons for frequent gate movements experienced in the prototype during the sluice gate commissioning tests and to explore measures which could be taken to reduce the number of movements whilst maintaining adequate discharge capacity during extreme flood events.

A fully automatic system controls gate movements and maintains the normal bay level between +4.0 m OD and +4.5 m OD by responding to and/or predicting rises in bay and sea water levels. Sensors within the bay and downstream of the gates continually record the water levels (with an accuracy of ± 5 mm). The accurate measurements are stored in a database. The rates of change of bay water level and sea level are then calculated and the Programmable Logic Controllers (PLCs) determine the appropriate raising or lowering of a gate or series of gates by applying predetermined operational rules.

The paper describes the construction, calibration and verification of the model, the reasons for the frequent gate movements as well as the work undertaken to reduce these by altering the operational rules used by the PLC'S.

High water protection measures in Piazza San Marco

Ing. Maria Teresa Brotto
 Consorzio Venezia Nuova (CVN)

Safeguarding Venice and its lagoon

The Italian Republic has defined the problem of safeguarding Venice and its lagoon as of "primary national interest". Contributing to safeguarding the lagoon are: the State, responsible for defending Venice, Chioggia and other urban areas from high waters, protecting coastal areas from sea storms and restoring the environmental balance of the ecosystem; the Veneto Region, responsible for pollution abatement; the local authorities, responsible for socio-economic development, maintenance and restoration of the architectural and built fabric.

The system of safeguarding measures is directed, coordinated and controlled by a committee, chaired by the President of the Council of Ministers, consisting of representatives of local and national authorities and institutions.

The plan to protect the San Marco area from the most frequent flooding is described here. This plan was drawn up by the Ministry of Infrastructure and Transport - Venice Water Authority through the Consorzio Venezia Nuova and is part of the General Plan of Interventions delegated to the State. This is the main instrument for planning and financing the safeguarding work.

The local defence of Piazza San Marco is an integral part of the system of measures to protect the city and lagoon from flooding which includes the MOSE system to defend the entire lagoon area from all high waters, including extreme events.

Where

The lowest-lying areas of Venice, usually the oldest, are subject to the most frequent floods. Particularly liable to high waters is the "insula" of San Marco, once the political, religious and administrative heart of the Serenissima, today symbolic of the city itself in the eyes of the world. This is an exceptionally evocative architectural and monumental area, containing the city's most precious and representative buildings. These include the Basilica, constructed at the beginning of the 11th century following Byzantine models and partly modified during subsequent centuries with the addition of significant decoration and ornamentation; the Palazzo Ducale, residence of the Doge and seat of the government and magistracy, built as a fortress with a square plan and transformed and extended between the 14th and 15th centuries to become one of the most important examples of Gothic art; the Procuratie Vecchie and Procuratie Nuove, once the seat of the procuratori of San Marco, the highest functionaries in the Republic after the Doge and the Biblioteca Marciana, an important example of Renaissance architecture.

How the square is flooded today

The problem of high waters has worsened considerably during the last century as a result of a rise in sea level (eustatism) and a lowering in land level (subsidence). Together the two phenomena have caused a loss of about 23 cm in the land level in Venice.

During recent decades, high water in Piazza San Marco has become an almost daily event. About 250 times a year, when the tide reaches a height of 60 cm, the water starts to invade the narthex of the Basilica and the paving in front of the entrance. The flooded areas increase as the tide gradually rises. With a tide of 80 cm, the water fills large areas of the square and with 90 cm, almost two thirds of the surface is flooded. With 100 cm (an average of seven times a year), the square and surrounding areas are almost completely submerged.

As well as causing problems for the inhabitants of Venice and for socio-economic activities, the repeated high waters damage the paving and subsoil of the square. Deterioration of the stone blocks, the presence of generalised surface damage and the collapse of the underground rainwater drainage conduits are the main symptoms of widespread degeneration which has accelerated during recent decades.

The water invades the square in three ways: flowing over the lagoon bank, rising up through the drains and seeping through the subsoil.

How the problem is tackled

The general plan: To combat flooding caused by water flowing over the lagoon bank, only the bank itself and adjoining paving will be raised to at least 100 cm, while the level of paving in the square will not be modified. The raising operation will be accompanied by consolidation of the bank to oppose the deterioration caused by wave motion resulting from the intense motorised water traffic.

To avoid flooding caused both by flowback through the drains and by seepage through the subsoil, the old system of underground conduits will be isolated from water coming from the small canals surrounding the area. The structural deterioration of the conduits, resulting in the collapse of the paving in many points, will necessitate their complete restoration. At the same time, a new rainwater collection and conveyance system will be constructed, linked to a pumping station to be installed in the Giardini Reali, to enable the water to flow out to the lagoon during high tides. Consideration will also be given to the possibility of locating a waterproof bentonite membrane under the paving in the square to counteract flooding caused by seepage through the subsoil. As part of this work, the network of underground infrastructure will also be systematized, unifying the course of existing lines along established routes. This will simplify future maintenance and avoid the generalised tampering with the paving which occurs today.

Bearing in mind the importance of the San Marco area, its strategic position and its symbolic value, the entire programme of work will be carried out in such a way as to avoid closing the square, involving a single limited area at a time.

The first phase: The first phase, begun in March 2003, involves a total of 150 m of quayside along the basin. The work includes raising, restoration and consolidation of the quayside, also with a view to protecting it from wave motion; interception of discharges by construction of a new rain water drainage system and restoration of paving.

The criteria and procedures for implementation of the plan have been agreed with Venice Local Authority and the Superintendency for Architecture and the Landscape.

The sequence of work has been established in agreement with those involved. The site will proceed with two successive 75 m sections and will include provision of provisional landing stages and protected access for craft.

Objectives and criteria

Objectives: To defend the San Marco insula from the most frequent high waters and ensure its accessibility up to +110 cm (with respect to the tidal datum), eliminating the destructive effects of the flooding; to restore the paving in the square and improve the condition of the subsoil.

Constraints and criteria: To draw up, partly through specific study and survey campaigns, a complete, detailed and up-to-date picture of the area concerned including all elements defining the “current situation”; to avoid modifying the height of the paving in order avoid altering the architectural and compositional relationship between the buildings and between the buildings and the paving itself; to avoid compromising the static condition of buildings in the square, avoiding alteration of the relationships established between the foundation land, the presence of water in the subsoil and the stresses produced by the weight of the buildings; to employ conservative restoration techniques.

Studies and surveys: The choice of general solution and design of specific interventions was based on studies, surveys, monitoring and historical-archaeological research involving every aspect of the San Marco area affected by the project. Activities involved general planimetric and topographic surveys to define the height of public surfaces (to draw up a map of areas flooded at various tidal levels); specific surveys of paving in the square, lagoon banks and ground floors of buildings affected by flooding to analyse the architectural, constructional and functional characteristics; studies and verification of the subsoil, both to determine the nature and characteristics of the land (composition, permeability, chemical-physical properties) and to assess the condition of areas underlying the square, surveying archaeological elements requiring protection, identifying the network of old rainwater drainage tunnels and the system of underground infrastructure and verifying their state of preservation. Further specific analyses involved data on rainfall in order to size the new rainwater collection and drainage system and on water depth near the lagoon bank in relation to consolidation work.

Methodologies for the functional restoration of a historical urban system

Ing. Ivano Turlon
Insula S.p.A

BRIDGES

Pathologies

- ? Cast iron
- ? Masonry

Interventions

- ? Fibre aramidiche
- ? Carbon fibres

EMBANKMENT WALLS

Pathologies

- ? Loss of the mortar di alettamento
- ? Siphoning
- ? Displacement
- ? Materials loss
- ? Loss of function

Interventions

- ? Injection of colloidal mortar
- ? Protection at the base of the foundations
- ? "Scuci-cuci", integration, reconstruction
- ? Recupero materico, protezione da moto ondoso

UNDERGROUND SERVICES

Pathologies

- ? Network obsolescence
- ? Incompatibilità of material and form
- ? Vetustà dei materiali

Interventions

- ? Functional renewal of the network
- ? New materials and sections of network
- ? New materials

Technical Session II: Environmental Quality

Chair: Dr Caroline Fletcher (Department of Geography, University of Cambridge)

1. Integrated project: A global approach to wastewater treatment and reuse in the central area of the Venice Lagoon
Ing. Roberto Casarin (Regione Veneto) & Ing. G. Zanovello (Studio Altieri) Fusina
2. Fusina Integrated Project: Strategies for the management of the residual outflow: Environmental problems and solutions
Ing. Paulo Rossetto (Thetis)
3. Complex cause-effect interrelationships in environmental indicators at the Mar Menor lagoon (SW Mediterranean) as a consequence of human activities
Dr Ángel Pérez-Ruzafa (University of Murcia, Spain)
4. The tidal Thames and environmental indicators
Steve Colclough (UK Environment Agency) (no abstract)

Fusina Integrated Project: A global approach to wastewater treatment and reuse in the central area of the Venice Lagoon

Ing. G. Zanovello
Studio Altieri

Co-author

Ing. Roberto Casarin, A. Padoin, G. Penna, F. Strazzabosco (Regione Veneto)
R. Hooley
P. Rossetto

This paper describes the Master Plan that the Veneto Region has recently approved to give a global solution to the municipal and industrial pollution that threatens the central area of the Venice lagoon and to optimise water management both for drinking and non drinking purposes.

The Fusina Integrated Project (that's the name) deals with the most densely populated part of the lagoon basin. It is based on simple concepts: use water twice, reduce sewage flow, treat all waters to higher standards, disperse the residual outflow in the sea, away from the lagoon. The target is to reduce dramatically, but with sustainable costs, the mass discharge of micropollutants and eutrophic nutrient compounds in the lagoon. The plan considers:

- ? an extensive restoration of the old combined municipal sewage networks aimed at reducing the spurious inflow of groundwater by 50%.
- ? the separation of industrial wastewater collection and treatment (flow type B) from municipal wastewater sewerage and treatment (flow type A).
- ? the upsizing and renewal of the main municipal WWTP (400.000 EI) in order to reach a great reliability both in dry and in wet seasons; most of rainwaters will be stored and treated partly by biological processes, partly by chemically enhanced primary treatments (CEPT) and wetlands.
- ? the WWTP effluent refinement by a huge constructed wetland (100 hectares) in order to produce a large amount (75.000 m³/d from type A flow) of fresh water for non drinking reuse; this flow will substitute the actual industrial abstraction of drinking water from Sile river, which will be switched to the big water supply scheme of the Central Veneto Region.
- ? a new pipeline to supply low cost non drinking water to the whole Marghera industrial zone (1000 hectares with 4 power plants that need large quantities of cooling water and many chemical industries that need process and washing water).
- ? a new sewage system dedicated to collect and transfer all the industrial waters to a centralised post-treatment plant; the industrial process waters will be pretreated by industries then pumped to the central plant; the rain polluted waters coming from industrial areas will be stored locally then gradually sent to the central plant; the polluted infiltration waters drained along the impermeable barriers that separate the industrial areas from the lagoon will be sent to a dedicated section of the central plant.
- ? a post-treatment plant aimed at controlling and reducing the residual pollution of type B flows; due to the great variability of the inflows quality and to the high quality standards required this plant will be composed of big storage tanks and many treatment devices (physical, chemical and biological); a complex pilot plant will address the choice of the best technology and setting-up.
- ? a long discharge pipe (20 km) across the lagoon to disperse into the Adriatic sea the residual outflow with its low chemical and organic residual pollution.

FUSINA integrated project: Strategies for the management of the residual outflow. Environmental problems and solutions

P. Rossetto
Regione del Veneto

Co-author:

R. Casarin, A. Padoin, G. Penna, F. Strazzabosco (Regione)
R. Hooley (CH2MHILL, Thetis SpA)
G. Zanovello (Studio Altieri)

The Fusina Integrated Project is the heart of the "Sanitary Stripe" provided for by the Master Plan 2000 to control the pollutant loads flowing from the mainland into the lagoon. The Fusina plant treats an important share of total urban wastewaters and rain waters from the lagoon drainage basin, and controls the main process wastewater outflows from the neighbouring Porto Marghera industrial area.

Critical environmental issues of the project were the evaluation of different strategies for the management of the residual outflow from the treatment plant, especially with respect to the very restrictive allowable pollutant loads imposed by law to the Lagoon of Venice, and the opportunity to make available a significant share of the outflow for the industrial re-use.

As far as the discharge strategies are concerned, three alternative options were taken into consideration. The first option considered to locate the final outflow discharge within the lagoon, in a point located next to the Malamocco inlet, so that the treated wastewaters would quickly flow out to the sea. Large areas located next to the lagoon border were to be converted into treatment wetlands for the refinement of the Fusina residual outflow, in order to ensure that the quality limits for the lagoon were met. The second option considered the residual outflow to be discharged into the Brenta river, flowing into the Adriatic sea just south of the Lagoon. The third option considered to lay an underground pipe across the lagoon and discharge the residual outflow directly into the sea, about 10 km offshore.

The analysis of the different options took into consideration, from a wide area viewpoint, the main environmental quality issues related to present and future scenarios, including the realisation of the mobile barriers at the lagoon inlets.

The compatibility of the outflow quality with the environmental characteristics of the different recipient bodies was the lead objective of the analyses. The environmental impact analysis was carried out together with the preliminary design phase, so enabling to optimise the design of the discharge options from the environmental point of view.

The analysis provided the decision makers with the information needed to take the final choice, which eventually was to bring the residual outflow from the Fusina treatment plant directly offshore into the Adriatic sea. This option ensures a safer preservation and a further reduction of the overall pollutant load discharged into the lagoon, while the very low pollution levels of the outflow was deemed to be compatible with the preservation of the Adriatic sea environment.

The analysis of the construction impacts of the large treatment wetland (100 ha), to be realized in a reclaimed area next to the treatment plant (Cassa di Colmata A) in order to allow the re-use of a relevant share of the refined outflow (75.000 m³/day), was carried out with special reference to the natural habitats of the site and gave positive results.

Complex cause-effect interrelationships in environmental indicators at the Mar Menor lagoon (SW Mediterranean) as a consequence of human activities.

Ángel Pérez-Ruzafa
University of Murcia

Co-authors:

Concepción Marcos and Javier Gilabert (University of Murcia)

The Mar Menor is a hypersaline coastal lagoon, with a surface of 135 km², located on the Southwestern Mediterranean coastline (37°42'00" North – 00°47'00" West) with a mean depth of 3.6 m and maximum over 6 m. As an emblematic environment of the Región de Murcia, in which it is located, it has great socio-economical interests and it is supporting a wide range of uses. It is considered as a key factor in the regional development plans providing high tourist and recreational services and maintaining important fisheries based on the quality and price of its natural products. The lagoon is, however, object of social concern due to its high rate of change in the last decades with detrimental impact on its biological assemblages structure and dynamics. Some of the changes are induced by coastal works for tourism facilities (land reclamation, the opening or deepening and extending channels, urban development and associated wastes, building sporting harbours, artificial beaches creation, etc.), meanwhile others relates with changes in agricultural practices in the watershed, changing from extensive dry crop farming to intensively irrigated crops, increasing agricultural wastes and nutrient inputs into the lagoon. Many of the consequences of these actuaciones, as loses in water quality, invasion of alloctonous species, increasing in eutrophication processes or proliferation of jellyfishes, involve potential risks to human uses and local economy. This situation makes the Mar Menor a good reference to analyze the biological patterns and processes affected by changes in hydrographical conditions, nutrient inputs, biological assemblages and lagoon characteristics. The large amount of information compiled during the last twenty years permits to establish the general guidelines of cause-effect relationships among human activities and environmental indicators in order to draw conceptual models to establish priorities in management actions and research lines.

Technical Session III: Habitats

Chair: Dr Tom Spencer (Department of Geography,
University of Cambridge)

1. Salt marsh restoration in Chesapeake Bay
Prof. Court Stevenson (University of Maryland)
2. Beneficial use of muddy dredged material for habitat creation
Mike Dearnaley (HR Wallingford Ltd)
3. Breeding birds and vegetation monitoring in recreated salt marshes
Dr Francesco Scarton (SELC)
4. Inter-tidal Habitat creation in the UK: Managed realignment
John Hall (Essex Wildlife Trust) (no abstract)

Salt marsh restoration in Chesapeake Bay

Prof. J. Court Stevenson
University of Maryland

Tide gauge data in Chesapeake Bay indicate there has been an increase in sea-level over the last 100 years of at least 3.2 mm yr^{-1} or about double that of global sea-level rise (1.8 mm yr^{-1}). Part of the apparent rise in sea-level appears to be attributable to land subsidence, which to varying degrees is driven by groundwater withdrawals from underlying aquifers. Thus, in Chesapeake Bay the combination of global sea-level rise and subsidence allow us to predict the consequences which can be expected to occur widely along the world's coastlines over the next century. Wetland areas in this large estuary are particularly vulnerable due to declining external riverine sediment inputs as well as land subsidence and low tidal amplitudes (which lowers primary productivity). The declining health of Chesapeake marshes is reflected in reduced biomass, canopy thinning, channel enlargement, and salt pans as well as ultimate conversion to mudflat and open water, which are all identifiable using remote sensing. Landsat 7 imagery reveals that over 50% of Chesapeake marshes have now been impacted by rising sea-levels which often suffer from high sulphides in sediments. Additional problems occur in seagrass beds adjacent to marshes as they decline and erode. Several strategies are now being pursued to preserve marshes including re-creation on artificial islands and thin layer applications at Blackwater National Wildlife Refuge (on the Eastern Shore of Maryland). The most costly, (almost 1 billion US dollars) is the restoration of Poplar Island which was re-built using stone dikes and 6.1 million cubic meters of dredged materials. Although marsh plantings have just begun, already the new marshes have shown remarkable growth and vitality with two orders of magnitude lower sulphide concentrations in sediments than in nearby reference marshes. Also thin layer applications at Blackwater suggest that although dredged materials were applied more thickly than originally specified, marshes are showing positive growth responses a year later. Other strategies including use of a highly productive invasive pest species, *Phragmites australis*, which is highly efficient in promoting inorganic sedimentation and long term organic accretion, have yet to be implemented.

UK experience of beneficial use of muddy dredged material for habitat creation

Dr Mike Dearnaley
HR Wallingford Ltd

In the UK only small quantities of muddy dredged material have been used beneficially for habitat creation and flood defence works. The principle barrier to the use of material has been the interpretation of the Habitats Directive and the concern that beneficial use of dredged material in the form of direct placement of material onto an existing intertidal surface represents a degree of smothering. Further concern has been raised over the use of hard or soft structures to retain directly placed material. As a result, experience to date of direct placement schemes has been small scale (tens of thousands of cubic metres of material) and focused on the practicalities of construction rather than on the subsequent performance of the habitats created.

Greater volumes of material (hundreds of thousands of cubic metres of material) have been used in so-called trickle charge schemes where material is introduced into the estuarine environment so that the natural energy of the tide disperses the material, feeding a proportion of it onto the intertidal habitats. Both subtidal placements and water column recharge methods have been used. In both cases the concept being that through this process the risk of smothering of habitats is reduced and the entire activity is working with the natural estuarine processes.

The largest direct placement scheme in the UK is presently under construction in Harwich Harbour in East Anglia. This scheme involves the use of clay arising from capital dredging to retain maintenance dredged silts. This scheme was permitted because it was deemed that the foreshore on which the placement has taken place is of low ecological value and that by using the clay, fine grained sediments, for the containment the whole process is sustainable, working with the natural estuarine processes.

Breeding birds and vegetation monitoring in recreated salt marshes of the Venice Lagoon

Dr Francesco Scarton
SELC

In the Lagoon of Venice, 58 dredge islands have been created since the beginning of the nineties as a new tool to dispose of sediments dredged from lagoon channels. These islands are soon used by birds, and I present results gathered in the period 1993-2003.

Most of the islands, ranging in size between 5 and 30 ha, are made of silty-clay sediments, whereas the remaining are mostly sandy. The elevation of the former is below 0.8 m above sea level, which means the islands are flooded, completely or in part, during high tides; the sand islands have higher elevation, with most of the surface exposed during high tides.

Data on bird use come from regular monitoring at several sites and from opportunistic observations for others.

About 70 species were observed at least once, and gulls, waders and herons were the most abundant groups. Most of the species used the islands as feeding sites (especially wintering waders such as Dunlin *C. alpina* and Numenius *arquata*, but also Little Egret *Egretta garzetta* and Grey Heron *Ardea cinerea*) or resting sites (mostly gulls, Yellow-legged Gull *Larus cachinnans*, Black-headed Gull *Larus ridibundus*, and herons), whereas nine species nested.

Among these latter, Italian rare or localised species are breeding (such as Shelduck *Tadorna tadorna*, Avocet *Recurvirostra avosetta*, Oystercatcher *Haematopus ostralegus* (with about 20% of the Italian breeding population), Redshank *Tringa totanus*, Kentish Plover *Charadrius alexandrinus* and Little Tern *Sterna albifrons*); an invasive species like *L. cachinnans* is the most abundant species. Number of breeding species increases over the first four-five years, and then stabilizes or decreases.

Management of these islands, i.e. control of vegetation cover increase, creation of intertidal ponds and creeks, reduction of *L. cachinnans* colonies are at the moment almost completely lacking, nevertheless it is urgently needed to increase or maintain their importance for waterbirds.

Vegetation cover and species composition seems to depend mostly on soils characteristics, elevation above sea level and age of the sites. Silty-clay islands become covered with halophytes (mostly *Salicornia* spp., *Puccinellia palustris*, *Sarcocornia fruticosa* and *Spartina maritima*) after at least three years since the end of the works; after five-six years, at least 60% of the islands results covered with vegetation, and most of the sites are completely covered after ten years or more. Sandy islands show a very different trend of vegetation development; after a few years, halophytes or truly psammophilous species become restricted to the lowest areas, whereas most of the sites become covered with dense stands of nitrophilous or ruderal species (i.e. *Calamagrostis epigejos*, *Agropyron repens*, *Oenothera biennis*).

A few transplanting test showed a good success for *P. palustris* and *S. maritima*, whereas the results with *S. fruticosa* and *Halimione portulacoides* were poor.

Since 2002, as it was in natural salt marshes and for the first time in Italy, the *Spartina x townsendii* has been also observed; it grows at both mean and low elevation, but it is more quickly expanding in bare mud surfaces.

Abstracts – Posters

Posters List

Title	Authors	Institution
On various mechanisms controlling the morphodynamic equilibrium of tidal channel	M. Bolla Pittaluga, N. Tambroni, G. Seminara	Dipartimento di Ingegneria Ambientale, Università di Genova
Menace to Venice: Hydrodynamic, morphodynamic and tracer analysis of proposed storm surge barriers in front of the Lagoon	Jan .G. Boon <i>Co-authors:</i> E.D. de Goede, M. van Ormondt and J.A. Roelvink	WL Delft Hydraulics
A Deterministic Storm Surge Forecasting System	Ida Brøker <i>Co-authors:</i> Dale Kerper , Lars Christian Larsen , Maurizio Di Donato, Giovanni Cecconi	DHI Water & Environment; Consorzio Venezia Nuova
Managing scientific information in the CORILA projects: RIVELA	Pierpaolo Campostrini <i>Co-authors:</i> Caterina Dabalà, Stefania De Zorzi, Matteo Morganitn Renzo Orsini	CORILA; Università Ca' Foscari - Venezia
Integration to the monitoring in the channels of the historical centre of Venice (WATERS system)	Pierpaolo Campostrini <i>Co-authors:</i> Caterina Dabalà	CORILA
Canaletto paintings as a historical record of sea level in Venice	Dario Camuffo	CNR - Institute of Atmospheric Sciences and Climate, Padova
Archaeology exploration in the lagoon of Venice by high resolution acoustic techniques: project for the realisation of a map of the past lagoon environment	G. B. Cannelli, S. Buono E. Canal, S. Cavazzoni	Istituto di Acustica "O. M. Corbino", CNR
Benthic fluxes of trace metals in the Venice Lagoon, Italy	F. Corami, C. Turetta, S. Rabar, G. Capodaglio and P. Cescon	Università Ca' Foscari; CNR – Institute for the Dynamics of Env. Sciences, Venice
APAT's remit and techno – scientific activities regarding safeguarding in the Venice Lagoon	Maurizio Ferla	APAT, Venice

Development of a flood forecasting system for St. Petersburg	Herman Gerritsen WL Delft Hydraulics <i>Co-authors</i> Olga Gliantseva, Konstantin A. Klevanny, M.S.W. Mostamandi	WL Delft Hydraulics
UNESCO contribution to a better understanding of the Venice Urban System	A. Mancuso <i>Co-author</i> P. Pypaert	UNESCO-ROSTE, Venice
Evaluating the economic costs of flooding to economic activities in Venice, and assessing the effectiveness of structural mitigation measures	Paulo Nunes <i>Co-authors</i> A. Sgobbi, G. Gambarelli, M. Breil	Fondazione ENI Enrico Mattei, Venice
Challenging transient flooding effects on dampness in brick masonry in Venice by a new fully reversible technique: the case of a front Narthex in San Marco	F. Sandrolini <i>Co-author</i> E. Franzoni	Dept. Appl. Chem. and Materials Science, Faculty of Engineering, University of Bologna

On various mechanisms controlling the morphodynamic equilibrium of tidal channels

M. Bolla Pittaluga
Università di Genova

Co-authors:

N. Tambroni, G. Seminara
Università di Genova

This contribution investigates the morphodynamic evolution of tidal erodible channels. The problem of the possible existence of a long term longitudinal equilibrium profile of tidal channels has been recently tackled theoretically by Schuttelaars & de Swart (2000) and by Lanzoni & Seminara (2002).

In spite of various simplifying assumptions, i.e. sediment transport in equilibrium with local and instantaneous hydrodynamic conditions, the latter work suggests that tidal channels closed at one end and connected at the other end with a tidal sea, reach a morphodynamic equilibrium characterized by vanishing net sediment flux in a tidal cycle and the formation of a beach close to the landward end of the channel. The latter restriction is now removed by the use of a model of transport in suspension recently developed by Bolla Pittaluga & Seminara (2003), suitable to flows fields which are slowly varying in space and time. Moreover, the effect of overtides, contributing to the forcing tidal oscillation, and the effect of the exchange of sediment with the adjacent sea are taken in account. Each of the latter effects turns out to affect the long term morphodynamic equilibrium of a tidal channel but none of them prevents channels from reaching equilibrium.

In order to check the main mechanisms controlling the morphodynamic evolution of tidal channels, emerged from the theoretical works mentioned above, a set of controlled laboratory experiments is also performed at the laboratory of the Department of Environmental Engineering of the University of Genoa (Italy).

Experiment results confirm the latter findings and further interesting observations emerge on the formation of large and small scale bedforms.

In particular, the formation of tidal ripples is observed, while free bars form in the channel in accordance with recent theoretical predictions of Seminara & Tubino (2001).

The latter experimental findings also point out that one of the several factors which significantly contribute to determining the sediment balance and the equilibrium configurations in a tidal channel is the exchange of sediments with the adjacent sea forced by the inlet hydrodynamics.

In order to determine the latter in some detail a two-dimensional numerical model for shallow-water flow, based on the assumptions of hydrostatic pressure has been applied to oscillatory flow in a tidal erodible basin.

Hydrodynamic results confirm that, in the fixed bed case, the flow field in the sea region around the channel is highly asymmetric throughout the tidal cycle, being nearly 2D irrotational during the flood phase and behaving like an unsteady turbulent jet during the ebb phase.

Such 2D model has been recently further developed by allowing for sediment transport in equilibrium with local and instantaneous hydrodynamic conditions. Some preliminary results on the morphodynamic evolution of the tidal basin show the generation of an intense scour in the near inlet portion of the basin and the presence of a large sediment deposition in form of an outer delta located seaward.

References

Abstracts Volume
Flooding and Environmental Challenges for Venice and its Lagoon: State of Knowledge 2003
Discussion Meeting – Cambridge, 14th-17th September, 2003

- Bolla Pittaluga M. and Seminara, G., Depth-integrated modelling of suspended sediment transport, *Water Resour. Res.*, 39(5), 1137, 1-1/1-11, 2003.
- Lanzoni, S. and Seminara, G., Long term evolution and morphodynamic equilibrium of tidal channels, *J. Geoph. Res.*, 107 (C1), 1-13, 2002.
- Schuttelaars, H. M. and de Swart, H. E., An idealized long-term morphodynamic model of a tidal embayment, *Eur. J. Mech., B/Fluids*, 15, 55-80, 1996.
- Seminara, G. and Tubino, M., Sand bars in tidal channels. Part one: Free bars, *J.Fluid Mech.*, 440, 49-74, 2001.
- Sumer, B. M. and Bakioglu, M., On the formation of ripples on an erodible bed, *J.Fluid Mech.*, 144, 177-190, 1984.
- Tambroni N., Bolla Pittaluga M. and Seminara G., Long term morphodynamic equilibrium of tidal channels. Laboratory observations, submitted to *Water Resour. Res.*, 2003.

Menace to Venice: Hydrodynamic, morphodynamic and tracer analysis of proposed storm surge barriers in front of the Lagoon

Jan .G. Boon
WL Delft Hydraulics

Co-authors

E.D. de Goede, M. van Ormondt and J.A. Roelvink
WL Delft Hydraulics

A deterministic storm surge forecasting system

Ida Brøker
DHI Water & Environment

Co-authors:

Dale Kerper
DHI Inc.
Lars Christian Larsen
DHI Water & Environment
Maurizio Di Donato, Giovanni Cecconi
Consorsio Venezia Nuovo

Storm surge prediction models for the operation of flood gates for Venice Lagoon have been co-developed and operated by DHI Water & Environment (DHI) and Venice Water Authority-Consorzio Venezia Nuova (CVN). Empirically-based statistical forecast models have been in operation for many years. Within the last six years a deterministic 2-dimensional numerical model based on DHI's MIKE 21 Hydrodynamic model has been added to the suite and is operating in parallel with the statistical models. The advantage of the deterministic model is that it is possible to include the effect of gate closure in forecast scenarios. During the years of operation, a large database of measurements, meteorological forecasts and flood model results has been compiled. Long-term operational flood forecast systems, linked with databases of past model performance and historical environmental information provide an invaluable tool for the evaluation of past performance, for the simulation of new assimilation techniques and for efficient re-analysis. The database re-analysis can ultimately be used to provide updated information on short-term corrections and to provide statistics on uncertainty. The poster presents the elements of the forecasting system.

Integration of the monitoring of the quality of the water of the channels of the historical centre of Venice (waters system)

Pierpaolo Campostrini
CORILA

Co-author:
Caterina Dabalà
CORILA

The historical centre of Venice and its channels are closely connected to the overall lagoon environment, of which they are essentially an extension. They influence the system via the tidal flux, that is both an element of revivification and the means for dispersing contaminants. The project "WATERS system" (2001-2002), carried out for Venice's Magistrato alle Acque, via its concessionaire Consorzio Venezia Nuova, investigated the levels and effects of contamination in the historical centre and contiguous areas of the lagoon, in order to establish the role and impact of anthropic pollution from the city on lagoon water quality.

WATERS consisted of semi-continuous multiparametric probe measurement of chemico-physical parameters, total heavy metals (Fe, Mn, Pb, Cu, Zn, Hg), dissolved and total nutrients and microbiological analyses, via instrumentation attached to boats, that repeatedly carried out defined routes through the main canals. Additional chemical and biological analyses were carried out in an integration project, managed by CORILA, at some points along the same sampling routes. In particular, the presence of endocrine disruptor (estrogenic) substances and their effect on sensitive species of mussels were deeply investigated.

Furthermore, the presence of humic matter was evaluated in terms of the natural capability of the environment to remove and deactivate the effects of certain organic and inorganic pollutants. The effects of resuspension of the bottom mud by water traffic was also studied as the canals, which cover only the 10% of the surface area of the city of Venice, concentrate organic and inorganic matter and associated high levels of some pollutants.

The presence in the water of "*endocrine-disruptor*" substances which interfere with an organism's hormonal system, are connected to civil and industrial waste; in the city of Venice most urban wastewaters are directly discharged into the canals. Observed levels of estrogenic substances don't show significant differences between sites, but, even if the mean values are low, the results underline the presence of significant peaks of concentrations (in some cases the values are highly significant) in the waters of Venice and adjacent areas of the lagoon.

Biomarkers and genetic measurements in *Mytilus galloprovincialis* were used to classify sampling stations, with regard to the presence of a specific or generic (not related to a specific contaminant) stress. The trend of impact grows from the stations of the historical centre to the sites of the lagoon. The comparison with data recorded in previous years suggests an improvement in the environment over the last twenty years.

The humic substances analysis on the particulate component shows a wide concentration range, related to different parameters. The portion with less molecular weight (younger humic material) is predominant. The analysis confirms the *scavenging* role of the humic compounds, which is strongly dependent on the metal considered.

Considering the resuspension effect, motorized water traffic causes the re-suspension of the bottom mud and the re-mobilisation of high quantities of metals associated with the particulate matter, as demonstrated by the research results. Remarkable increases of the metal concentration are not observed in the dissolved phase: the phenomena of metal release from the particulate matter to the water column are not significant, at least as regards the study conditions. Dissolved nutrients which are more related to urban wastewaters are good tracers

of the provenance and quality of the water. Nutrients bonded to the particulate matter are not highly influenced by the re-mobilisation of the bottom mud.

Measurements and the evaluations were performed by different groups lead by the following people:

- ? Estrogenic substances: A. Marcomini, University of Venice
- ? Biological effects of the pollution: C. Nasci, M. Cervelli and A. Libertini, ISMAR –
CNR
- ? Humic substances: B. M. Petronio, University of Roma
- ? Resuspension effects: F. Collavini, ISMAR-CNR
- ? The logistic support for the sampling has been provided by Ecotema srl.

CORILA project to develop it tools for managing scientific information

Pierpaolo Campostrini
CORILA

Co-author

Caterina Dabalà, Stefania De Zorzi, Renzo, Matteo Morgantini
CORILA
Orsini
Università Ca' Foscari

An essential aspect of the institutional tasks of CORILA is the acquisition and management of scientific information produced by the various research programmes and projects, their secure, permanent systematic storage, and the sharing of the collected information within the research community. The *Istituto Veneto di Scienze, Lettere ed Arti (IVSLA)* had already started a programme of data acquisition from different sources and publication on Internet, in the '90s, hence CORILA supports IVSLA by continuing and enlarging their efforts and web site (www.istitutoveneto.it). While IVSLA's site is more directed at the general public, CORILA has developed an instrument which is more oriented to the scientific community, known as RIVELA (database for the Researches on VEnice and the Lagoon).

The Information System of CORILA has been recently reengineered to satisfy four essential goals:

1. safety, both in the sense of access control and to avoid data loss;
2. stability, in terms of quantity of stored and managed data;
3. speed of information access through the Word Wide Web;
4. speed of search and data elaboration.

The system is now considered to be sufficiently secure and reliable, and it is easily scalable.

The Information System deals with different kinds and formats of documents and information. The main thematic channel RIVELA, accessible via the web site www.coria.it, is made of several sub-channels where specific tools are available. Users identification and profile access rights procedures have been recently improved and also permit the Information System to regulate visible parts and the operational capability of each user.

Three mail tools are currently available:

1. a document research engine, which allows free text search on text documents (any format) in files;
2. a data research engine, for alphabetical data queries;
3. a geographical research engine – WebGIS.

Benthic fluxes of trace metals in the Venice Lagoon, Italy

F. Corami
Ca' Foscari University

Co-authors:

S. Rabar, G. Capodoglio
Ca' Foscari University
B. Turetta, and P. Cescon
CNR-Institute for the Dynamics of Environmental Sciences

To assess the exchange of trace metals from sediment and water in the Venice Lagoon, studies were carried out by benthic chamber experiments in two different sites of the lagoon, characterised by high anthropic impacts. One (Canale delle Trezze) was located close to the industrial area of Porto Marghera, while the second (Campalto) was located close the bridge connecting Venice to mainland. The experiments were carried out in two different period; the first one was carried out during the summer of 2001, while the second one are during the fall 2002. The chambers were monitored for pH, dissolved oxygen, Eh, salinity, and temperature, by a multiparametric probe, and for trace elements, by collecting samples every 3-4 hours, for approximately 50 hours.

The concentration of trace elements were determined by Inductively coupled Plasma-Sector Field Mass Spectrometry, ICP-SFMS, coupled with a desolvation unit and by direct injection of diluted (1:10 with ultrapure water) aliquots of samples and the quantification was carried out by calibration curve. The accuracy was tested by certified reference coastal seawater (CASS-4); always the results were within the certified intervals.

The change of the concentrations of metals was evaluated in function of oxygen concentration and fluxes were calculated. For many of the studied elements, the experiments showed an initial increase of concentration deriving from remobilisation during the setting of the benthic chambers and followed from a flux from the water column to the sediment (0-15 hours), in the second part of the experiments some elements (Cd and Mn) showed a positive flux from the sediment to the water column while other elements, such as Cu or Zn, the evident initial negative flux was followed from a null flux until the end of the experiments for both the sites.

Canaletto paintings as a historical record of sea level in Venice

Dario Camuffo
CNR - Institute of Atmospheric Sciences and Climate

Venice risks being submerged as a consequence of two problems: ground subsidence and sea level rise due to global warming. The frequency of sea surges flooding the city has increased, as well as the level reached by waters. Regular tide gauge monitoring was started in 1872 and shows a relative sea level rise (RSLR, i.e. the combination of ground subsidence and eustatism) of about 30 cm. In the last three decades, the rising seems uncertain, i.e. a change in trend or a temporary negative fluctuation of the sea level. A sound answer requires a wider temporal scale.

The RSLR over the last three centuries has been investigated with a multidisciplinary approach, based on two keys. The first key is constituted by some special paintings. In the first half of the XVIII century, Canaletto and his pupil Bellotto made 'photographic' paintings with an optical camera obscura accurately drawing Venice buildings. The key was a proxy biological indicator of the mean sea level: the height of the green belt of the *laminaria alga* which lives in the tidal range and its front indicates the average high tide level. This belt, known as *Comune Marino* (CM) is accurately reported in the paintings. An analysis of the algae belt displacement allows establishing the long-term trend of RSLR and distinguishing between natural and recent anthropogenic contributions.

The period from Canaletto to today has been characterised by global warming that included the end of the Little Ice Age and the recent warming. The information drawn from the paintings showed that the CM has risen on average by 70 ± 10 cm since the first half of the 18th century. The limited scattering of the data (12 cm) is further confirmation of the self-consistency of the method and the reliability of the chosen paintings.

Part of the observed shift is not due to RSLR. Waves generated by motor boats have about twice the height compared to the 18th-century row-boat traffic. In addition, after the excavation of two deep channels, the penetration of sea water into the Lagoon was facilitated and the tidal wave amplified contributing for another 3-cm. In conclusion, in the Canaletto and Bellotto times, the relative sea level was 62 ± 10 cm lower than nowadays.

The analysis shows that the average RSLR was 2.3 ± 0.4 mm yr⁻¹. The continuity of the trend, although affected by human impact to different degrees in different periods, suggests a dominant role of deep tectonic mechanisms combined with eustatism.

Near the half of the XIX century, the invention of the photography gives a further opportunity of knowing the position of the algae belt on buildings in the gap between Canaletto and the instrumental period.

The long term information is fundamental in view of deciding measures to save Venice. The palaces were originally protected against water rise by a belt of non-permeable Istria stone, but now the protective belt has sunk with the city. The flooding waters are reaching brick and plaster which are rapidly destroyed by salt crystallisation cycles.

Archaeology exploration in the lagoon of Venice by high resolution acoustic techniques: project for the realisation of a map of the past lagoon environment

G. B. Cannelli
Istituto di Acustica "O. M. Corbino", CNR

Co-authors:

S. Buono
Istituto di Acustica "O. M. Corbino", CNR
E. Canal
Sovrintendenza Archeologica di Venezia
S. Cavazzoni
Istituto di Scienze Marine, CNR, Venezia

An archaeological approach to the reconstruction of the history of the Venice Lagoon appears indispensable today in order to give a certain grade of reliability to the framework of the historical, environmental and socio-economical evolution of this territory. Over the centuries the Lagoon of Venice has suffered continuous modifications by natural processes whose more evident manifestations are the alternation of appearing and disappearing of "barene". Some isles of the Lagoon, for example those interesting the ancient Roman settlement of Altino, have definitely disappeared while other ones have appeared, like those of Venice whose origin is rather later than that of Altino. A few core drilling and scuba diving and recent archaeological explorations carried out in a shallow water area in the North Lagoon of Venice have revealed the presence of large manufacts belonging to an ancient Roman settlement [1]. These discoveries have encouraged historians, archaeologists and scientists to undertake together a systematic investigation in the above mentioned area in order to throw a new light on the origin of Venice. To this aim, preliminary surveys of this area have been performed using an ultrasound echographic system, which showed details of structures of great interest buried in sediments. This experiment has proved acoustical techniques to be extremely valuable in this field of research, thus suggesting to join to the traditional acoustic devices a new technique by means of an innovative acoustic system [2] which has already given positive results in landscape archaeology [3], and which was properly improved for marine archaeology, in the frame of the Italian "Special Project on the Safeguard of Cultural Heritage". The proposed technique [4], particularly suitable for archaeological explorations in very shallow water, enables to produce underwater maps of the sea floor and subbottom, collecting and processing acoustic data as high-resolution images of structures buried in sediments. The presence of buried archaeological sites in the sea subbottom is correlated to particular marine and environmental evolution, so their detection and unearthing also help to better know the geological vicissitudes of the area and can yield new evidence on trends in sea-level change for the Lagoon of Venice.

[1] Canal, E., *Testimonianze archeologiche nella Laguna di Venezia. L'età antica. Edizioni del Vento, Venezia 1998*; [2] Buogo, S., Canal, E., Cannelli, G.B., and Cavazzoni, S., *High-resolution acoustic prospecting for detecting the ancient Roman Port of Altino in the Lagoon of Venice, 3rd International Congress on: "Science and Technology for the Safeguard of Cultural Heritage in the Mediterranean Basin, (Alcalà, Madrid, 9-14 July 2001)*; [3] Cannelli, G.B., D'Ottavi, E. and Alippi, A., *Acoustic Methods in Archaeology, in: The Archaeology of the Mediterranean Landscape: Non Destructive Techniques Applied to Landscape Archaeology, Vol.4, Oxbow Books, Oxford, 2000, p.155-165*; [4] Cannelli, G.B., "Tecnica acustica ad alta risoluzione e alta potenza per l'esplorazione sottomarina ed apparecchiatura per la sua attuazione", *Italian Patent N. RM 2002 A000581, Nov. 19, 2002.*

APAT duties and techno-scientific activities regarding of the Lagoon of Venice

Ing. Maurizio Ferla

Agenzia per la Protezione dell'Ambiente e per i Servizi Tecnici (A.P.A.T.)

In 2002 a new Italian Agency for Environmental Protection and Technical Services was created, under the direct control of the Environment Ministry. Responsibilities and tasks of the pre-existing National Environment Agency, National Hydrographic and Oceanographic Service and the National Geological Service were regrouped within the new agency. Generally speaking, APAT carries out tecnico-scientific activities of national interest as regards protection of the environment and water resources. In the specific case of Venice and its lagoon, the Agency has inherited the responsibilities of the hydrographic office, a dedicated structure which, since 1907, has been operational in the lagoon - initially as the hydrographic office of *Magistrato alle Acque* and then, since 1991, as the Venice office of the National Hydrographic and Mareographic Service (directly under the *Presidenza del Consiglio dei Ministri*, i.e. cabinet).

Its responsibilities include:

- ? Systematic observation of water levels and the parameters influencing meteo-marine phenomena in the lagoon and along the north Adriatic coast; the Agency manages its own network of 52 observation stations of which 25 are remotely measured in real time, a system of radio bridges, a central unit for data acquisition and exchange with other subjects;
- ? Daily tidal forecasting service and forecasting and warning for exceptionally high tides (flooding or *acque alte*) for the benefit of all institutions associated with safeguarding the lagoon, civil protection, as well as coastal risk and hydrological risks at the large river mouths of north-east Italy, lagoon navigation and the general population;
- ? Elaboration, validation and distribution of data, especially analyses regarding observations from extreme tide events;
- ? Analyses of historical time series for tide data, also in relation to subsidence and eustatism in the northern Adriatic region;
- ? Measurement of current velocities at the inlets in relation to lagoon-sea exchanges under different tide conditions.

All these tasks have been attributed to the Protection of Inner and Marine Waters Department of the Agency and are carried out specifically by the ***Servizio per la Laguna di Venezia*** (Venice Lagoon Service), based in Palazzo "X Savi", ex-Hydrographic office of Venice.

The poster illustrates the results of these activities as well as the key issues characterising measurement activities, with special regard for the value and importance of systematic observations in relation to the peculiarities of the environmental aspects of the Venice Lagoon.

Development of a flood forecasting system for St. Petersburg

Herman Gerritsen
WL Delft Hydraulics

Co-authors

Olga Gliantseva, Konstantin A. Klevanny, M.S.W. Mostamandi
WL Delft Hydraulics

The city of St. Petersburg is located in the low lying Neva river delta at the eastern end of the Baltic Sea. The mean annual discharge of the river Neva is 2500 m³/s. Storm winds over the Baltic Sea regularly lead to flooding of the central historical parts of the city, with the potential of causing significant human, social and economic loss. Since 1703, about 300 floods have been recorded and 3 of them were catastrophic. Construction of a Flood Protection Barrier across Neva Bay was started in 1980, but work was halted in 1990. In 2002, a successful EBRD funded feasibility study for its completion was conducted. Subsequently, in December 2002, a consortium of international banks led by EBRD agreed on a loan to the Russian Federation to enable accelerated completion of the Barrier. A high quality operational flood forecasting system is required for the proper environmental management of the Neva Bay water body and the decisions on when to close and open the Barrier.

The present poster describes the development of the model-based water level forecasting system for St. Petersburg, which at the moment is in pre-operational use at the St. Petersburg Hydrometeorological Department (NWHMS). The model-based water level forecasts are used by the forecaster on duty as background information in preparing the 12 hour forecasts, which until 1999 were still based on the use of meteorological forecasts, observations and regression formulae only.

The first development phase (1998-2000) consisted of the development and calibration of a depth-integrated water level model application for the whole Baltic Sea, with refinement in the Eastern Gulf of Finland. As software the CARDINAL modelling system developed at the City Flood Defence Agency Morzaschita was used. Subsequently, the model was transferred to NWHMS and staff was trained in its use and interpretation of results. In this pre-operational stage, the model uses HIRLAM meteorological forecasts, provided by the Swedish SMHI as wind and pressure forcing. In a subsequent phase (2001-2003), the model was further tested and the 48 hour forecast results were evaluated against those obtained with the synoptic approach. Already in the present stage, the use of the model-based forecasting gives a significant improvement over the traditional approach, both in enlarged forecast window, and in forecast accuracy. In parallel to the completion of the Barrier, the forecasting system will be further validated and official tests will be conducted, in anticipation of its full operational status, as foreseen for management of the Flood Protection Barrier.

The poster presents the area details, examples of model evaluation results, the data flows and examples of the forecast bulletins that are prepared by the forecasters. The development was the result of a joint Russian-Netherlands project funded by SENTER and coordinated by WL|Delft Hydraulics, with Morzaschita and NWHMS being the main partners. One of its key issues was capacity building and the realisation of a system which is feasible within existing local infrastructure.

Abstracts Volume

Flooding and Environmental Challenges for Venice and its Lagoon: State of Knowledge 2003
Discussion Meeting – Cambridge, 14th-17th September, 2003

UNESCO contribution to a better understanding of the Venice Urban System

B. Mancuso
IUAV

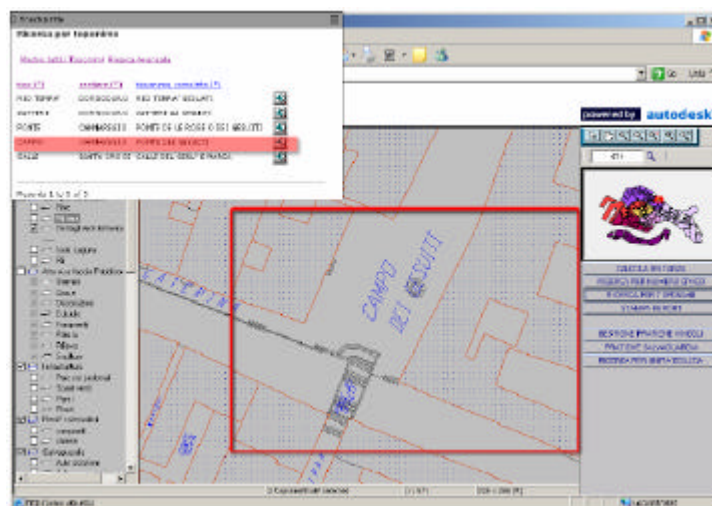
Co-author:
P. Pypaert

Since the beginning of the 90s, the UNESCO Regional Bureau for Science in Europe (UNESCO – ROSTE) implemented various research projects in Venice which are concrete examples of its overall commitment for the integrated conservation of the Historic City of Venice and its Lagoon. These facets of UNESCO's involvement in Venice are complementary and integral to the sustainable development and preservation of this world heritage city.

As a direct follow-up of The “*Venice Inner Canals*” Project, which was aimed to develop, calibrate and validate a first Water Quality Model for the Venice Inner Canals, and during which very extended databases and related Geographical Information System (GIS) were developed on subjects such as canal bathymetries (depths), hydrodynamics, boat traffic, sewer outlets or damage to foundations (see also <http://www.unesco.ve.it>), UNESCO – ROSTE developed a web-based GIS application intended as a Decisional Support System for the urban planning and management of the City of Venice.

This system, which is now running as a prototype, allows the access to, and exchange and management of, data related to the urban structure and various objects such as monuments, gardens, bridges, canals, wells, etc. It also includes information related to physical planning and safeguarding procedures as implemented in Venice.

This system (which is accessible at <http://www.intelligencesoftware.it/unesco/venezia>) will be demonstrated during a poster session.



Evaluating the economic costs of flooding to economic activities in Venice, and assessing the effectiveness of structural mitigation measures

Paulo Nunes

Fondazione ENI Enrico Mattei

Co-authors:

Alessandra Sgobbi, Gretel Gambarelli, Margaretha Breil

Fondazione ENI Enrico Mattei

Flooding has always been part of life in Venice, which has learned to deal with it. However, the frequency, the intensity and the severity of flooding events have significantly increased over the last decade. This has led the Italian Government to adopt long term protection measures to reduce flooding of the city. These, however, do not offer much relief in the short term. It is therefore necessary to investigate what mitigation measures inhabitants and economic operators of Venice have adopted, as well as to assess and discuss their efficiency in containing the monetary damages from flooding.

This work focuses on the analysis and assessment of the monetary damages due to flooding, incurred by the different economic activities in Venice, crucial stakeholders for sustainability of the city. The purpose of the work is threefold: (1) assess whether we can detect some indication that the economic structure of Venice has changed in response to flooding of the city; (2) assess the effectiveness of structural/ architectonic mitigation measures in limiting monetary damages to economic activities; (3) quantify the monetary damages to the activities.

Using existing data from a questionnaire, and data from a new survey, we find that:

- there are indications that the economic activities have evolved in response to flooding, by choosing different locations in the city depending on the type of activity. It would seem that less vulnerable activities (e.g. hotels) are located predominantly in low areas, whereas shops tend to be in higher areas of the city. By pointing to the possibility that flooding has caused the city's structure to adjust, new research lines and mitigation measures can be suggested.
- The empirical data provide mixed evidence with respect to the effectiveness of mitigation measures. For some typology of damages (e.g. damages to furniture, walls, floors, etc.) mitigation measures seem effective in limiting the damage. This can be explained by the fact that the goods are relatively unmovable. On the other hand, when dealing with hours of work lost, mitigation measures do not seem to be very effective – this is quite intuitive, as economic agents do not have control over some critical variables (e.g., inaccessibility to the area).

These results will play an important role in terms of policy guidance, namely in the discussion and ranking of alternative mitigation measures. Future work will need to look at the broader picture, and consider the dynamic adjustments taking place in the city.

The analysis on the humic substances on the particulate show a wide concentration range, related to different parameters (i.e. quantity of new matter which enter in the system, rate of sedimentation, greater or lesser adsorption of dissolved humic matter). The portion with less molecular weight (humic substance younger) is predominant. In the structural point of view, there are no substantial differences between the samples. The complexation capability of the total humic matter is high. The analysis confirm the role of *scavenging* of the humic compounds, but the bond values between fulvic acids in the particulate matter and the bonded metal change according to its nature.

The canals, which cover only the 10% of the city of Venice, concentrate organic and inorganic matters, associate with high concentrations of some pollutants. The aqueous motorised traffic causes the re-suspension of the bottom mud and the re-mobilisation of even high quantities of metals associated to the particulate matter, as the research results evidence. Remarkable increases are not observed in the dissolved phase: the phenomena of metal release from the particulate matter to the water column are not relevant, in the study conditions.

Dissolved nutrients which are more related to urban wastewaters are considerable tracers of the provenience and the quality of the water. Nutrients bonded to the particulate matter are not highly influenced by the re-mobilisation of the bottom mud.

Challenging transient flooding effects on dampness in brick masonry in Venice by a new fully reversible technique: the case of a front narthex in San Marco

F. Sandrolini
University of Bologna

Co-author:
E. Franzoni
University of Bologna

Recently, the right front narthex of S. Marco in Venice has been subjected to a wide experimentation of techniques to reduce/eliminate raising dampness in brick masonry. Among these, authors experimented a new, simple and fully reversible technique based on spontaneous and automatic governing the electrokinetic phenomena arising from water migration in porous building brickworks (1-4), such those of the studied narthex. The method does not require any external energy supply or controlling apparatus and has been successfully tested in several restoration yard of ancient buildings against the raising dampness in Italy.

As preliminary results, the technique exhibited a good control of raising dampness; however, in the investigated narthex a challenge between raising and condensing dampness occurs, exactly due to flooding transient phenomena, so this is requiring further developments in the application of this technique.

The principles of this new technique are briefly described as well as the results so far obtained and the future developments to help in safeguarding the future of Venice architectural heritage.

Forthcoming Publications

The scientific papers and a synthesis from this meeting will be published in the form of a peer-reviewed book subject to speakers submitting papers, which are accepted by anonymous reviewers and subject to the Editor's acceptance of all papers as a thematic issue. Please visit the website for author instructions in October 2003 and for updates on publication progress: <http://ccru.geog.cam.ac.uk/events/venice2003/>

A non-technical bilingual publication for a wider audience will also be published with support from Venice in Peril and the J. Paul Getty Trust, the basis of which will be the Conference itself.

Acknowledgements

For their help with this discussion meeting “Venice State of Knowledge 2003”, the Project team would like to thank the funders and sponsors who made this meeting possible. We would like to thank Churchill College for their help in hosting it, especially Janet Milne, Angela Railton, Gillian Dickinson and the conference team. The Fitzwilliam Museum and Pembroke College for hosting the Conference Reception and Dinner. We are also grateful to Eurosis for providing the translation services.

Finally, we would like to thank the participants for their time and all the speakers for their presentations.

Appendix: Glossary of represented organisations

ORGANISATION	DESCRIPTION
ITALY	
Agenzia per la Protezione dell'Ambiente e per i Servizi Tecnici (APAT)	National Agency for Environmental Protection and Technical Services Internal, coastal and marine waters division, Venice branch- State of the Environment and Environmental meteorology, Rome www.sinanet.anpa.it
Autorità Portuale di Venezia	Port Authority of Venice www.port.venice.it
Comune di Venezia – Centro Previsione e Segnalazioni Maree (CPSM)	Town Council – Tide Forecasting and Early Warning Centre www.comune.venezia.it
Consorzio Venezia Nuova (CVN)	Consortium of construction and engineering firms engaged in planning and execution of works for the Magistrato alle Acque www.salve.it
Consorzio per la gestione del centro di COordinamento delle attività di Ricerca inerenti il sistema LAGunare di Venezia (CORILA)	Consortium for managing the co-ordination of research concerning the Venice Lagoon System: University of Venice, University of Padua, Venice University Institute of Architecture and National Research Council www.corila.it
Ente Nazionale per le Nuove tecnologie, l'Energia e l'Ambiente (ENEA)	Italian National Agency for New Technologies, Energy and the Environment - Special Project on Global Climate www.enea.it
Insula S.p.A.	Public/private company engaged in urban maintenance (canal dredging and local defences, infrastructural services etc.) www.insula.it
Istituto di Acustica "O. M. Corbino" - Consiglio Nazionale delle Ricerche	Institute of Acoustics "O. M. Corbino" - National Research Council www.idac.rm.cnr.it
Istituto di Scienze dell'Atmosfera e del Clima - Consiglio Nazionale delle Ricerche (ISAC-CNR)	Institute of Atmospheric Sciences and Climate - National Research Council www.isac.it
Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS)	National Institute of Oceanography and experimental Geophysics www.ogs.trieste.it
Istituto per Scienze Marine - Consiglio Nazionale delle Ricerche (ISMAR- CNR)	Institute for Marine Sciences - National Research Council, incorporating also the Venice based Institutes for Study of the dynamics of large masses (CNR-ISDGM) and Marine biology (CNR-IBM) www.ismar.it
Istituto Universitario di Architettura di Venezia (IUAV)	Venice University Institute of Architecture www.iuav.it
Magistrato alle Acque (MAV)	Venice Water Authority, part of the Ministry of Public Works www.magisacque.it
Regione Veneto	Venice Regional Administration – Environment, Special Law and Public Works divisions www.regione.veneto.it
Società per l'Ecologia delle Lagune e delle Coste (SELCO)	Private environmental consulting company with interdisciplinary expertise in biology, ecology, geology and architecture www.selc.it
Technital S.p.A.	Engineering consultancy working extensively for Magistrato alle Acque through its concessionaire, CVN
UNESCO – Regional Bureau for Science in Europe	Originally the Liaison Office for the Safeguarding of Venice, it now has a broad mandate to achieve UNESCO's and Member States' goals in the fields of science and culture http://portal.unesco.org
Università di Bologna, Corso	University of Bologna, Environmental Sciences

di Scienze Ambientale	www.unibo.it
Università di Genova - Dip. Ingegneria Ambientale (DIAM)	University of Genoa, Environmental Engineering Department www.unige.it
Università di Lecce	University of Lecce
Università di Padova - Dip. Ingegneria Idraulica, Marittima e Geotecnica (IMAGE)	University of Padua - Dept. of hydraulic, maritime and geotechnical engineering www.unipd.it
Università degli studi di Roma "La Sapienza" Dip. Scienze della Terra	University of Rome – La Sapienza, Earth Sciences Dept. www.uniroma1.it
Università Ca' Foscari di Venezia	University of Venice "Ca' Foscari" www.unive.it
UNITED KINGDOM	
Cambridge Coastal Research Unit	Department of Geography, University of Cambridge www.geog.cam.ac.uk
Faculty of Architecture and History of Art	University of Cambridge www.cam.ac.uk
Martin Centre	University of Cambridge www.arct.cam.ac.uk
Department of Engineering	University of Cambridge www.eng.cam.ac.uk
Centre for Environment, Fisheries and Aquaculture Science (CEFAS)	England and Wales Government Scientific Advisory Agency for the marine environment. Also a research and consultancy centre www.cefas.co.uk
UK Environment Agency	UK government body: Thames Region - responsible for the Thames Barrier; www.environment-agency.gov.uk
HR Wallingford Ltd	UK engineering and hydrodynamics research consultancy specialising in the water environment www.hrwallingford.co.uk
Jacobs	Engineering consultancy www.jacobs.com
University of East Anglia	Tyndall Centre www.tyndall.ac.uk
University of Southampton	Southampton Oceanography Centre www.soc.soton.ac.uk
Venice in Peril Fund	British Committee for the Preservation of Venice www.veniceinperil.org
DENMARK	
DHI Water and Environment	Hydraulics Laboratory, Denmark www.dhi.dk
THE NETHERLANDS	
Department of Water Management Rotterdam	Government body www.dzh.rws.minvenw.nl
Noctiluca	Research consultancy
RIKZ, Zeeland Branch for Eastern Scheldt	National Institute for Coastal and Marine Management www.rikw.rws.minvenw.nl
Vrije Amsterdam Universiteit	Free University of Amsterdam www.vu.nl
WL Delft, Holland	Hydraulics Laboratory, Holland www.wldelft.nl
Zeeland Directorate for Eastern Scheldt	Local administration www.zeelandnet.nl
RUSSIA	
Morzaschita	Government Body, Russia
SPAIN	
University of Murcia	Department of Ecology and Hydrology, Faculty of biology

	www.um.es
USA	
Colgate University	Department of Classics www.colgate.edu
Massachusetts Institute of Technology (MIT)	Ralph M. Parsons Laboratory, Department of Civil and Environmental Engineering http://web.mit.edu/
University of California (San Diego)	Scripps Institution of Oceanography http://scilib.ucsd.edu/sio/
Worcester Polytechnic Institute (WPI)	Interdisciplinary and Global Studies Division www.wpi.edu

Notes

Notes

Notes