School on Wireless Networking for Scientific Applications in Developing Countries

TRIESTE
Third week
19-24 Feb 2007

MOSE PROJECT AND HYDRO - MORFOLOGICAL MONITORING IN THE VENICE LAGOON

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Consorzio Venezia Nuova
OUTLINE

A: Mose flood barriers: the importance of the project and a brief presentation of the project

B. Monitoring the impact of on-going construction works and the inlet on the hydraulic properties:
   1. bathymetric evolution of the sandy bottom at the inlets
   2. energy loss through the inlets
   3. monitoring velocities and tidal flow
   4. residual flow and index of river contamination
The lagoon of Venice: an instable and complex ecosystem

Venice

Marghera

Lagoon of Venice (may 2005)
The lagoon of Venice: an instable and complex ecosystem

Fish farms – Valle Zappa

Salt marshes, channels and tidal creeks
The lagoon of Venice: an instable and complex ecosystem

Islands – Island of Torcello

Littorals – Pellestrina littoral
Is a transitional environment in a state of instability
SYSTEMS OF INTERVENTIONS

Environmental defence
Securing polluted sites, improvement of the water and sediment quality

Environmental defence
Protection and reconstruction of structures and habitats of the wetlands

Defence from high tides
Raising of the banks and pavements

Control and management
Studies, surveys, monitoring, computerised data base

Defence from high tides
MOSE system

Defence from sea storms
Reinforcement of the littoral and jetties
Frequency of high tides $\geq 110$ cm

Between 2003 and 2005, there were six cases of tides $\geq 110$ cm

<table>
<thead>
<tr>
<th>Date</th>
<th>Tidal Level (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 16, 2002</td>
<td>147</td>
</tr>
<tr>
<td>November 6, 2000</td>
<td>144</td>
</tr>
<tr>
<td>December 8, 1992</td>
<td>142</td>
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<tr>
<td>February 1, 1986</td>
<td>159</td>
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<td>December 22, 1979</td>
<td>166</td>
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<tr>
<td>February 14, 1979</td>
<td>140</td>
</tr>
<tr>
<td>November 3, 1968</td>
<td>144</td>
</tr>
<tr>
<td>November 4, 1966</td>
<td>194</td>
</tr>
<tr>
<td>October 15, 1960</td>
<td>145</td>
</tr>
<tr>
<td>November 12, 1951</td>
<td>151</td>
</tr>
</tbody>
</table>
Relative sea level rise
Flooding in Venice at the turn of the 20th century

Flooding in Venice today
High water. Chioggia

High water. Island of Murano
SYSTEMS OF INTERVENTIONS

- **Lagoon**: + 1.10
- ** Existing situation**: ≤ 1.10
- **Local defences for tides ≤ 110 cm**: ≤ 1.10
- **Closure of the inlets for tides > 110 cm**: > 1.10

**Sea**
MOBILE BARRIERS AT THE LAGOON INLETS
MOBILE BARRIERS AT THE LAGOON INLETS

HOW THE FLOOD GATES WORK

DEFENCE AGAINST EXCEPTIONALLY HIGH TIDES:
closures of the inlets for tides > 110 cm
25% of the Mose flood barrier is under construction

33% financed
THE PROJECT - LIDO INLET

SITUATION AT JUNE 2006

- Small craft harbour
  - 1 lagoon basin side
  - 2 sea side basin
- Artificial island
  - 3 lagoon side channel
  - 4 central nucleus
  - 5 bank on the Treporti side (west abutment)
- Row of gates (Treporti)
  - 6 bed protection
- Row of gates (S. Nicolò)
  - 7 bed protection
  - 8 service area
- South abutment
  - 9 prefabricated caissons
- Southern side
  - 10 reinforcement of the south jetty
- Surveying activities
  - 1 Trial areas

- Completed (1)
- Underway (10)
LIDO INLET WORK SITES

- New island
- Refuge haven
- Reinforcement of the south jetty
THE PROJECT - MALAMOCO INLET

SITUATION AT JUNE 2006

Navigation lock
1. protection on the S. Pietro Fort side
2. door housing
3. structures
   “chamber”
South abutment
4. embankment
Row of gates
5. infrastructure for prefabricating the gates caissons
Complementary structures
6. breakwater south of the inlet
Accessorial activities
6. service area - north side
7. service area - south side

Completed (1)
Underway (7)
MALAMOCO INLET WORK SITES

navigation lock

the breakwater
The new lay-out of the inlet after the realization of the MOSE System for the defence from high tides:

1. Refuge haven
2. Northern jetty (existing)
3. Row of gates
4. Southern jetty (existing)
5. Breakwater
IMPACT OF FIXED STRUCTURES ON TIDAL FLOW

- 5 cm average storm surge reduction
- <10% permanent tidal flow reduction

We are monitoring the impact on-going construction works measuring:
1. bathymetric evolution of the sandy bottom at the inlets
2. energy loss through the inlets
3. velocities and tidal flow
4. residual flow and index of river contamination

We are building up a DATABASE of monitored data for calibration and validation of hydro-morphological models
(hybrid models continuously tuned with experimental data)
Inlets evolution

- Inlet cross sections
- Tidal flow ↔ Lagoon basin
- Reduction of the inlet cross section
- Flow reduction and velocity increase
- Erosion of the sandy bottom at the inlets
acoustic multibeam survey for monitoring bathymetric changes

Erosions or fills can be part of the construction works (dredge of a new navigation channel, building of a new reef…) or the result of velocity changes due to the ongoing construction works

Chioggia inlet:
1. building of a break-water
2. dredge of the navigation channel
evolution of Malamocco inlet from 1999 to October 2006

- Evoluzione della barra di foce
- Progressione dello scavo in bocca
- Rinforzo testata molo nord
- Scavo generato dalla protezione del ‘relitto delle ceppe’
- Scavo in prossimità del molo delle ceppe
ENERGY LOSS THROUGH THE INLETS

1. Every inlet has different friction coefficient (depending on bottom surface, length of the reefs..)

2. Every inlet has different volumes of vortex and different volumes of moving flow

3. The situation is different at flood and ebb flow

\[ \Delta E_{TOT} = \Delta E_{FRICTION} + \Delta E_{VORTEX} \]
\[ \Delta E_{TOT} = \Delta E_{FRICITION} + \Delta E_{VORTEX} \]
ENERGY LOSS THROUGH THE INLETS

\[ \Delta E_{TOT} = \Delta E_{FRICTION} + \Delta E_{VORTEX} \]
ENERGY LOSS THROUGH THE INLETS

CURVE DI CONTROLLO

intensity of tidal flow

energy loss

\[
y = 34.5 \ln(x) + 4.9
\]

\[
y = -39.6 \ln(x) + 16.8
\]

\[
y = 33.4 \ln(x) - 1.2
\]

\[
y = -35.8 \ln(x) + 18.3
\]

\[
y = 35.7 \ln(x) - 7.9
\]

\[
y = -26.2 \ln(x) - 6.8
\]
MONITORING VELOCITIES AND TIDAL FLOW

TIDAL GAGES

in the lagoon

in the see
MONITORING VELOCITIES AND TIDAL FLOW

INSTALLATION OF THE ACOUSTIC FLOW METERS
Calibration of the acoustic flow meters:
- Bathimetric survey
- ADCP shape velocity factor

\[ Q = k A v^{-8.5} \]
MONITORING VELOCITIES AND TIDAL FLOW

misure di VELOCITA’ DI CORRENTE LIVELLI
MONITORING VELOCITIES AND TIDAL FLOW

BOCCA DI LIDO
MONITORING VELOCITIES AND TIDAL FLOW

BOCCA DI MALAMOCO
MONITORING VELOCITIES AND TIDAL FLOW

BOCCA DI CHIOGGIA
MONITORING VELOCITIES AND TIDAL FLOW

BOCCA DI LIDO:
experimental installation of a radar tidal gage and waverecorder
Evidence of ground-water recharge into the lagoon

RESIDUAL FLOW as a percentage of the tidal flux (5333 m³/s)

- 2.96% - 5.60% = 2.65%
- 140 m³/s
RESIDUAL FLOW AND INDEX OF RIVER CONTAMINATION

First estimation of the ground-water recharge into the lagoon
RESIDUAL FLOW AND INDEX OF RIVER CONTAMINATION

installation of salinity probes MICROCAT CTD at the inlets at different depth
Tidal flushing at the lagoon inlets: water recirculation at sea

\[
\text{Renewal} = \frac{V(\text{new})}{V(\text{in})}
\]

\[
\text{Renewal} = \frac{\text{Sin,mean} - \text{Sout,mean}}{\text{Sin,max} - \text{Sout,mean}}
\]

\[
V(\text{in}) = V(\text{old}) + V(\text{new})
\]

\[
\text{Recirculation} = \frac{V(\text{old})}{V(\text{in})} = 1 - \text{Renewal}
\]
## Residual Flow and Index of River Contamination

### Tidal flushing at the lagoon inlets: water recirculation at sea

<table>
<thead>
<tr>
<th>Data campagna di misura</th>
<th>Bocca di porto</th>
<th>Salinità max in ingresso</th>
<th>Salinità minima in rilusso</th>
<th>Volume scambiato (m³)</th>
<th>Carico di sale in ingresso (t)</th>
<th>Carico di sale in uscita (t)</th>
<th>Ricambio</th>
<th>Ricircolo</th>
<th>Efficienza del ricambio rispetto al ricambio ideale in assenza di ricircoli</th>
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<td>34.68</td>
<td>31.83</td>
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<td>4 282 000</td>
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<td>34.90</td>
<td>88 260 000</td>
<td>3 139 000</td>
<td>3 106 000</td>
<td>0.52</td>
<td>0.48</td>
<td>0.37</td>
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RESIDUAL FLOW AND INDEX OF RIVER CONTAMINATION
CONCLUDING REMARKS

The Venice storm surge barriers are a good example of artificial device for flood protection without impacting the sensitive hydro-morphological system.

A monitoring system has been set up for controlling the process.

In order to improve the reability of the survey system a wi-fi sensor communication system will be tested.