Keeping Venice Afloat

Venice is in danger of slowly disappearing under the waves of the lagoon upon which it was built twelve hundred years ago. Complex mathematical models that work in MicroStation® are being used to help keep it afloat. The conservation work is being done by CREA, on behalf of Consorzio Venezia Nuova.

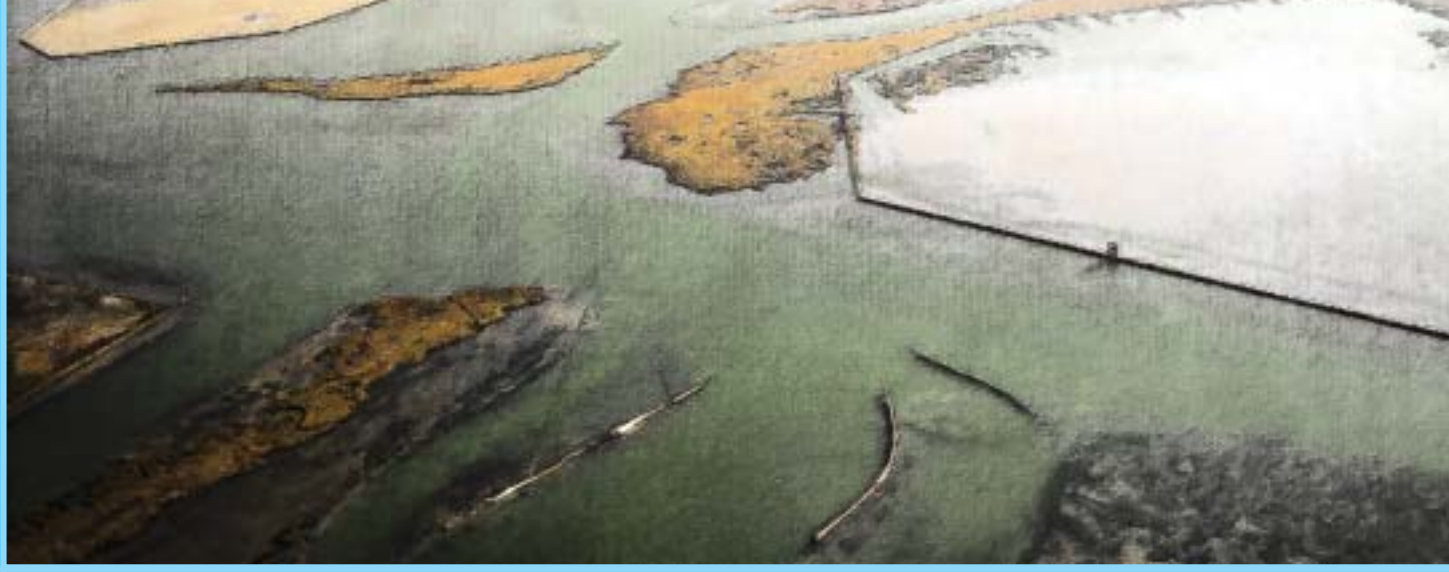
Flooding of the Piazzo San Marco.

The city known as La Serenissima is in danger of slowly disappearing under the serene waves of the lagoon upon which it was built twelve hundred years ago. To help keep Venice afloat and restore the fragile ecosystem of the surrounding Venice Lagoon, CREA, on behalf of Consorzio Venezia Nuova, is using complex mathematical models that work within MicroStation.

Slowly but inevitably, Venice is sinking. Because of the city's monumental architectural, historic, and cultural importance, as well as other environmental factors endangering the city and surrounding lagoon, the Consorzio Venezia Nuova of the Venice Water Authority (Magistrato alle Acque di Venezia) has developed plans for safeguarding the Venice Lagoon based on input from outside firms such as the engineering firm CREA Srl (Center for Research for Environmental Ecology). The firm's extensive research—conducted using complex MicroStation-based mathematical models—is playing a significant role in several of the preventive measures the Venice Water Authority is undertaking to save Venice from sinking and to halt degradation of the lagoon's ecosystem.

CREA CEO Andrea Garzon explains how MicroStation is especially suited to handle such complex formulas and the associated data they require.

"MicroStation has been fundamental to the success of our models because they require a lot of different data sets to run," Garzon says. "Without such a powerful and efficient application, we wouldn't



Reconstruction of salt-marshes.

be able to process the enormous amount of information we need to manipulate in these models effectively. Only MicroStation has been able to manage vast territories of geographical information with extreme facility, flexibility and speed."

The Dangers of Ebb and Flow

Several factors are contributing to the lagoon's deterioration.

The combined effect of eustasy, the variation in sea level associated with changes in the earth's climate, and subsidence, the compaction of alluvial soil leading to a drop in land level, has resulted in a drop in the lagoon's land level by about nine inches (23 cm) over the last century. At the same time, the tidal level has increased by approximately three inches (8 cm), due to organic structure growth on the barrier reef in the lagoon basin and changes in atmospheric pressure and wind on the Adriatic Sea.

In addition to high waters and wave motion, another factor endangering the lagoon is erosion. The effects of natural dynamics and human intervention, such as the dredging of large shipping channels and the construction of jetties at the lagoon inlets, has resulted in deteriorating smaller islands, disappearing mud flats and salt marshes, a steady increase in water depth, and silting up of channels. The lagoon is losing the physical characteristics of a wetland and is being transformed into a marine environment.

Shoring Up with MicroStation

Venice, Chioggia and other historic towns in the lagoon are being flooded with water more frequently. The lowest lying zones, usually the oldest with the most architectural and historic value, are now flooded almost every day, especially during the winter. The Piazza San Marco now becomes fully submerged during the autumn and winter's highest tides.

CREA has been using its mathematical model MefLag on behalf of The Venice Water Authority to examine the problem caused by "acqua alta," or high tide, inside the lagoon, and offer a solution by simulating the tidal wave propagation with a finite element model of the lagoon.

To manage the huge set of input data for the mathematical models, CREA has developed two vertical applications working together inside MicroStation: PreNet and PostNet.

Garzon and his team were able to develop a schematization of the Venice Lagoon to accurately represent the contours of the channels, islands, and shorelines of the lagoon using MicroStation. The schematization also included elements such as water depth, speed, and motion throughout the lagoon.

"Using MicroStation as the platform for our MefLag model offered many advantages," says Garzon. "We found that this method was unconditionally stable and was able to handle all the data we entered into the model to come up with a solution. We were able to produce, without any distortion, the jagged contours of the lagoon—the lagoon has a lot of deep tunnels and flat areas and barrens that are difficult to simulate precisely. We were also able to follow the flow lines in this complex hydrodynamic system easily. We worked with other applications that simply could not handle the amount and complexity of data we were working with.

"To calibrate a 2D model of the Venice Lagoon in which the morphological and hydraulic characteristics were accurately represented, the application had to handle several types of data—not only mathematical, but also GIS

The Venice Lagoon

The Venice Lagoon, Italy's largest lagoon, has a surface area of about 550 square km—of which 418 square km are open to the expansion of the tides of the Upper Adriatic. Three inlets—Lido, Malamocco, and Chioggia—connect the lagoon to the sea.

Boundary stones define the lagoon's perimeter. Within its boundaries are mud flats, salt marshes, islands, fish farms, reclaimed areas, and coastal strips.

The lagoon's land system—both natural and artificial—represents about eight percent of its overall surface. Venice occupies the second largest land surface area.

Safeguarding Venice

Consorzio Venezia Nuova of the Venice Water Authority is a consortium responsible for executing Venice's General Plan of Interventions. To carry out its work, it draws on the consultancy of national and international institutes and academic institutes in Italy and abroad.

The General Plan of Interventions contains the conclusions of years of comparisons, studies, and general design work, allowing planners to examine various alternatives and evaluate their feasibility.

The plan includes eight specific projects:

1. Mobile barriers
2. The local defense of islands from medium to high waters
3. Coastal reinforcement
4. Restructuring the jetties
5. Morphological restoration
6. Arresting and reversing degradation
7. Reopening of fish farms
8. Eliminating oil tanker traffic from the Venice Lagoon

Safeguarding Venice has required major studies and experimentation on the dynamics and evolutionary trends of the lagoon environment, as well as on the ecosystem and the relationship between the physical environment and socio-economic aspects of the region. Environmental engineering firms such as CREA are playing a significant role in conducting these studies.

Arial view of Valle Figheri.

data, which MicroStation could easily handle," he continues. "We had to figure in a hydraulic friction coefficient to simulate how various factors affect the velocity and volume of water as it flows throughout the lagoon system. These factors included the varying levels of sand and grass at the bottom of the lagoon, as well as the varying widths of lagoon channels and canals.

"After some very complicated work of calibration, which consisted of refining the mesh everywhere to better approximate the lagoon's real physical conditions, the model's results have paid for our efforts," he added. "The model can then be used to evaluate the tidal effects provoked by the safeguard works. Without MicroStation, I simply wouldn't have been able to create a schematization of such complexity."

Pollution Dispersion Simulation

One of the Venice Lagoon's biggest problems is pollution. The lagoon is a unique environment, consisting of a large city inside a delicate ecological system that is surrounded by a densely populated area. Large amounts of pesticides and other pollutants inevitably enter the lagoon. One valuable tool in the management of pollution is to simulate and compute the effects of the pollutants and their interaction among the different biological constituents. For this simulation, the "Servizio Informativo" of The Venice Water Authority uses CREA's 2D dispersive finite element model.

"The dispersive finite element model that CREA has developed has been a very useful tool to simulate the effects of pollution inside the lagoon—and, again, MicroStation has proven to be invaluable," says Garzon. "CREA is working with a highly specialized team directed by Professor Alberto Zirino of San Diego University Scripps in California on this aspect of the project."

New Technology Boundaries – Satellite Imagery

CREA is going a step further by exploring the possibility of linking the models with satellite images. For example, satellite images of temperature are being used as boundary initial conditions for the temperature finite element model. The simulation results are then compared with other maps. CREA is working on this portion of the project with Sonia Silvestri of Padova University for the Servizio Informativo of The Venice Water Authority.

"We believe that this constitutes a new technology boundary," says Garzon. "Uniting the most advanced technologies to analyze the maps produced by the model, introducing a large amount of data relative to the metereological data, managing the vast amount and variety of information involved—all this is made possible with a flexible tool like MicroStation."

Salt Marsh Restoration

Maintaining the lagoon system also entails reconstructing mudflats and salt marshes using sediment obtained during lagoon channel dredging. Wave and current motion, high waters, the rise in sea level, and the drop in land level have led to mudflats and salt marshes slowly eroding and crumbling, slipping into the channels, and silting them up. Rather than restore the original shape of the lagoon, the Venice Water Authority's goal is to restore the hydrodynamic and environmental functions of these areas to stimulate flushing, moderate wave motion, and limit sediment dispersion in the lagoon and out

to sea. Applying the MicroStation-based formula CREA developed makes this possible.

Step-by-Step Salvation

Using MicroStation, CREA has developed a very efficient tool to simulate tidal propagation and water quality inside the Venice Lagoon and manage the complex geometry of the lagoon. According to Garzon, managing a system of such complexity would have been impossible without MicroStation. The optimum results obtained from the model of the lagoon are now being used to predict the effects of the safeguarding measures. With several safeguarding projects well underway and some complete, it is estimated that all projects will be completed by 2008.

For more information about CREA, visit http://www.creaurl.com/index_4up.html.

For more information about the safeguarding of the Venice Lagoon, visit http://www.salve.it/uk/default.htm.

Pellestrina coastline. The new beach as constructed today.

CREA – Center of Research for Environmental Ecology

Founded in 1992, CREA Srl (Center for Research for Environmental Ecology) provides software products and services for the hydraulics and environmental ecology sectors. Its innovative mathematical models operate as vertical applications within MicroStation, integrating GIS data for effective water resources design and management. CREA uses these models for the analysis, planning, design, and optimal management of hydraulic systems around the world, including:

Shallow waters—bays and lagoons
CREA's MefLag consists of three different mathematical models that simulate tidal wave propagation and environmental-ecological conditions in shallow bodies of water, like bays and lagoons.

Pressure networks—aqueducts and gas networks
CREA's HydNet simulates pressure networks by means of a mathematical model embedded in a GIS system—operating within MicroStation. It simulates the transient factors in pressure networks and plants optimizes the design and management of pressure networks.

Surface networks—reclamations and sewage systems
CREA's FlowNet package simulates reclamation and sewage system networks.

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