SAVE OUR CITY!

The Italian government is building a series of massive barriers to protect Venice from flooding. But scientists are still arguing over whether the plan will work, says Nicola Nosengo.

Water feature: advocates of the MOSE project hope that installing retractable barriers (above right) across the three inlets to Venice's lagoon (seen here from a satellite) will put an end to the city's flood misery (right).

In the turbulent history of Venice, 4 November 1966 counts as one of the most notorious dates. Rain had been falling incessantly for two days, a prolonged low-pressure system had caused the sea level to rise dramatically, and a powerful wind forced wave after wave into the city's canals.

This exceptional coincidence of extreme meteorological conditions eliminated the tide's normal rhythm, and the water kept rising over three consecutive tides. By six o'clock that evening, it was almost two metres above average, and much of Venice was under water. Homes and businesses were devastated, and precious artworks destroyed. And it could so easily have been worse — had the wind blown for just a couple more hours, parts of the city would almost certainly have been swept away.

Venice sits in a lagoon, separated from the Adriatic Sea by a series of barrier islands. Originally, the lagoon consisted largely of mudflats, which helped to dissipate rising tides. But centuries of human intervention — including the diversion of rivers, widening of the lagoon's entrances and dredging of channels to accommodate shipping, and the draining of mudflats for construction and agriculture — have disrupted the lagoon's equilibrium with the sea. Today, the islands are eroded and the mudflats are largely submerged. When the sea surges, there is little to prevent the city's historic streets and squares from being inundated.

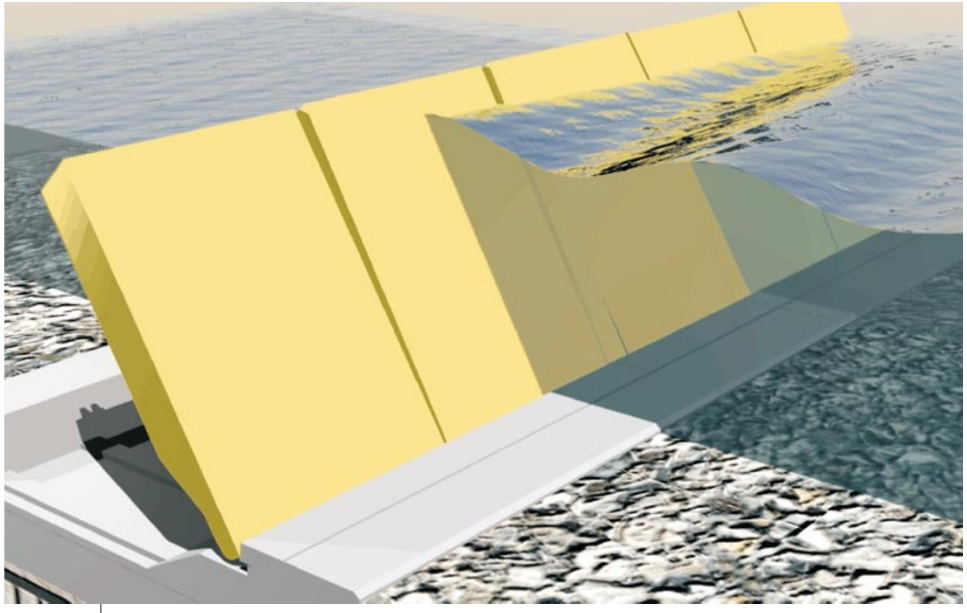
Although the events of November 1966 were extreme, flood frequency had been increasing since the start of the twentieth century, and Venetians realized that something had to be done. Experts put forward various solutions, but arguments about their relative merits paralysed progress. In the meantime, people began to leave: since 1966, Venice's population has fallen from 127,000 to 65,000.

Costly solution

Finally, in December 2001, Italian prime minister Silvio Berlusconi declared that the most ambitious of the engineering solutions would put into action. Known by its Italian acronym of MOSE, the €2.3-billion (US$2.6-billion) scheme will incorporate 78 hollow metal gates, each about 20 m high and 5 m thick, placed at the three main inlets of the lagoon. Each gate will lie flat on the sea floor under normal circumstances, with one end fixed to its foundations. In advance of particularly strong surges — exceeding 87 cm above the current average sea level — air will be pumped into the hollow gates, displacing the water inside them and causing the unfixed end to rise. Within an hour, the lagoon should be separated from the sea. Construction of the gates is set to begin in 2006, and should be completed by 2011. In the interim, three stone reefs will be built outside each inlet to reduce the strength and speed of incoming tides.

The plan has been contested ever since it was proposed in the 1980s. Environmentalists claim that even brief interruptions of water exchange with the sea — MOSE's designers expect closures to last for four to five hours — could upset the lagoon's ecosystem. Many local politicians fear that the project will divert money needed for restoration within the city, and argue that 'softer' engineering solutions could be more effective. On 14 May this year, when work on the first stone reef began, Gianfranco Bettin, Venice's deputy mayor, reiterated his view of MOSE to the media: "Expensive, hazardous and probably useless."

Supporters and opponents of MOSE are still slugging it out almost daily in local newspapers and public debates, with scientists playing starring roles. One of the project's strongest critics is Venice-born Paolo Antonio Pirazzoli of the Laboratory for Physical Geography in Meudon, France, part of the CNRS, France's national research agency.



LEFT AND FAR LEFT: CONSORZIO VENEZIA NUOVA

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The project has two main problems, Pirazzoli says. First, it was designed with an event similar to the 1966 flood in mind. But such a freak disaster is likely to occur no more than once every 165 years, Pirazzoli calculates. This makes MOSE a misdirected solution, he argues, as it will do nothing to combat the frequent minor floods that plague the city. "Last winter, there were more than 100 high-water events in Venice," says Pirazzoli. Many parts of the city were flooded before the water reached the 87-cm threshold, he says.

Rising discontent

What's more, claims Pirazzoli, MOSE will not be able to cope with the sea-level rise expected as a result of global warming. The Intergovernmental Panel on Climate Change predicts that seas will rise by an average of 50 cm over the next century, but MOSE is based on the assumption that the local sea level will rise by only 22 cm over the same period. Pirazzoli does not agree that the Adriatic Sea will be affected so mildly, and last year in *Eos*, the American Geophysical Union's newsletter, he argued that rising sea levels will render the barrier "obsolete"[1].

Pirazzoli believes the gates would have to remain raised for longer periods than their designers intended — up to several days at a time. Rain, drainage and the entry of seawater through gaps between the gates would then cause the lagoon's water to rise. In January, Pirazzoli and Georg Umgiesser, an oceanographer at the Institute for the Study of Large-Mass Dynamics in Venice, part of the CNR, Italy's national research council, published an analysis of five historical surges, including the 1966 flood. They added 50 cm to their model's sea level and concluded that, in each case, the gates would not have prevented flooding, because of water accumulating in the lagoon[2].

Pirazzoli favours softer interventions to control regular floods. These include reducing the depths of the inlets by raising their beds, and narrowing the large canals that enter the city's harbour. The idea is to impede the flow of rising tides. If these measures fail, Pirazzoli argues that it may be necessary to separate the lagoon completely from the sea, apart from a few narrow canals — much as was done between 1924 and 1932 in the Netherlands, when a dike was erected along the country's coast, blocking off the North Sea and creating a huge freshwater lake called the IJsselmeer.

MOSE's supporters contest Pirazzoli's assumptions. "His analysis is completely flawed," claims Andrea Rinaldo, a hydraulic engineer at Padova University, near Venice, who was a member of an international expert group asked to assess the project for the Italian government[3]. Like Pirazzoli, Rinaldo was born and grew up in Venice, and the 1966 flood left a deep impression on him. "Furniture was floating around my flooded room," he recalls.

Rinaldo argues that water will not rise as rapidly as Pirazzoli assumes when the gates are closed. MOSE will not prevent occasional floods in the city's lowest parts, Rinaldo concedes, but he argues that without intervention, the 1966 calamity could be repeated at any time. "We should not be too confident of living in a world in which the probability of extreme events is minimal," he says. "Not protecting the city would be irresponsible."

Rinaldo, who with other members of the international expert group published a response to Pirazzoli's criticisms in the same issue of *Eos*[4], argues that his opponent overestimates the extent to which today's flooding is a consequence of the construction of shipping channels. Rinaldo points instead to the fact that Venice has subsided by 13 cm as a result of pumping water from the aquifers beneath the city from the 1950s to the 1970s.

Species barrier

Even if MOSE provides effective flood defence, the question remains of how it will affect the lagoon's environment. During construction, five million cubic metres of sediment will be excavated from the areas next to the inlets, which are the richest in species diversity. Environmentalists fear that the lagoon's sea grasses, on which its ecosystem is based, will be choked by mud. They also argue that prolonged gate closures will exacerbate problems with the build-up of sewage.

A team at the National Institute of Oceanography and Experimental Geophysics in Trieste is now assessing the risk of increased pollution. Their radar measurements of sea currents suggest that the lagoon will rapidly be cleansed by the tide even after gate closures lasting up to five days[5]. "What became quite clear is that water is exchanged between the sea and the lagoon at an extremely fast rate," says Miroslav Gacic, who led the study. "When the tide enters the lagoon, it brings in new, oxygenated water. It is not the same water that came out six hours before." Indeed, Gacic argues that Pirazzoli's preferred solution of restricting the lagoon's inlets entails greater risk, as it would alter the exchange of water between the lagoon and the sea.

But MOSE's critics remain defiant in what has become a politicized debate: advocating MOSE implies support for Berlusconi's right-wing government; criticism is seen as backing for the left.

Scientists hope that an international meeting on Venice's flooding problems, planned for September in Cambridge, UK, will restore some objectivity. But as the arguments rage, it seems that the protagonists can agree on only one thing: their hope that the nightmare of 4 November 1966 doesn't return to haunt Venice before some means of protecting this historic treasure has been put in place. ■

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1. Pirazzoli, P. A. *Eos* **83,** 217, 223–224 (2002).
2. Pirazzoli, P. A. & Umgiesser, G. *CNR Technical Report* **256** (2003).
3. Collegio di Esperti di Livello Internazionale. *Report on the Mobile Gates Project for the Tidal Regulation at the Venice Lagoon Inlets* (1998).
4. Bras, R. L. *et al. Eos* **83,** 217, 224 (2002).
5. Gacic, M. *et al. Eos* **83,** 217, 221–222 (2002).

http://ccru.geog.cam.ac.uk/events/venice2003