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Dredging of Navigable Canal in the Venice Lagoon

Dragage du canal de navigation dans la Lagune de Venise

Ausbaggerung schiffbarer Kanal in der Lagune von Venedig

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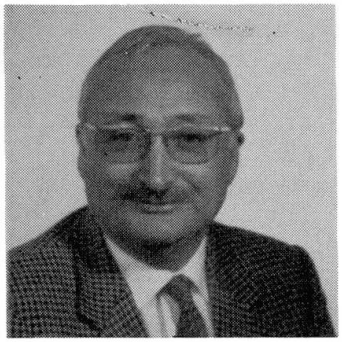

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SUMMARY

After a short description of the general design for the safeguard of Venice, an improvement is suggested, in order to reduce the impact of the newly-designed works on the ship traffic in the lagoon. In this context, a link of "barene" should be built along the existing channel Malamocco-Marghera, with two minor barrages across the Canale Rocchetta and the Canale Vittorio Emanuele. Computations show that it is possible to reduce substantially the closures of the Malamocco mouth, conserving practically, at the same time, the actual hydrodynamic situation.

Dragage du canal de navigation dans la Lagune de Venise

Résumé

Après une description du plan pour la protection de Venise, l'article présente une amélioration destinée à réduire les effets des nouveaux ouvrages sur la navigation dans la Lagune. La nouvelle idée consiste en la formation d'une chaîne de "barene" du côté du Canal Malamocco-Marghera avec la construction de deux barrages à travers le Canal Rocchetta et le Canal Vittorio Emanuele. Les calculs effectués indiquent qu'il est possible de réduire sensiblement les manoeuvres de fermeture de l'embouchure de Malamocco, tout en respectant la situation hydrodynamique actuelle.

Ausbaggerung schiffbarer Kanäle in der Lagune von Venedig

Zusammenfassung

Nach einer kurzen Beschreibung des allgemeinen Projektes für die Rettung von Venedig, präsentiert der Artikel einen Verbesserungsvorschlag, um die Auswirkung der neuen Bauten auf die Schiffahrt in der Lagune zu vermindern. Die neue Idee besteht in der Gestaltung einer "Barene"-Reihe entlang des Malamocco-Marghera Kanals mit dem Bau von zwei Sperrwerken durch den Rocchetta und den Vittorio Emanuele Kanal. Berechnungen zeigen, dass es so möglich ist, die Zeit, die für die Schliessung an der Mündung des Malamocco benötigt wird, substantiell zu verringern, dabei aber zugleich die aktuelle hydrodynamische Situation zu wahren.

1. INTRODUCTION

In november 1966 an extreme storm tide, whose peak at Punta della Salute, in the centre of Venice, reached the level of 1.94 m, flooded nearly completely the city. It was the first dramatic alarm of the "high-water" phenomenon, that in the following years occurred repeatedly, threatening public opinion, very sensitive to the safeguard of the historical and cultural heritage, represented by Venice for the whole world.
At present S. Marco Square, that is the heart of Venice, is inundated when the tide levels exceed 80 cm above the Punta della Salute tide gauge reference level, but a large part of the city is flooded with tide levels higher than 1.00÷1.10 m.
In the 1975-85 decade as much as 450 tide events exceeded 80 cm at Punta della Salute and, among them, about a hundred reached levels higher than 1.00 m.
The reasons of Venice submersion, that at the beginning of the century was a much less frequent phenomenon, are numerous and complex. Above all, the natural causes related to the joined effects of soil lowering and mean sea level raising, that can be estimated in total as 25 cm. have to be considered
Nevertheless, although with minor effects, the negative consequences of human intervention, that has deeply modified the lagune morphology, has also to be considered.
Among them the sea-entrances protection with jetties, the dredging of the navigable channels Vittorio Emanuele first and Malamocco-Marghera later, the extensive reclamation of shallow water areas for the formation of nine Industrial Zones of Marghera (Fig. 1).
During these years, many studies have been carried out in order to characterize the feasible interventions to defend the city of Venice and its lagune from the phenomenon of flooding.
However all the promoted proposal collide with the difficulty of conciliating the requirements of safeguard and protection of the peculiar environment where the city of Venice is located, with the not minor requirements, of not obstructing more than a certain limit the economical and productive activities that still concern Venice and its lagune. In such a context, it is especially felt the necessity of maintaining the port feasibility permitting even to the higher tonnage ships to enter the Porto Marghera Industrial Zone, along the navigable channel connecting this productive pole to Malamocco Entrance (Fig. 1).

2. THE ACTUAL PLAN FOR THE PROTECTION OF VENICE FROM FLOODING

The many studies, even those carried out with the aid of the most advanced and sophisticated tools of investigation, agree on the impossibility of obtaining a significant reduction of the "high-water" phenomenon within Venice lagune and in particular in the historic centre, without a drastic reduction of the cross section dimensions of the sea entrances.
However, if this action on one side could permit to solve the problem of the mean high water events, on the other side it would involve serious consequences either for the environmental aspects or for navigation and, therefore, for the port practicability.
A significant decrease of the maximum tide levels, obtained by means of a reduction of the sea entrances dimensions with fixed structures increases, as a matter of fact, considerably the current

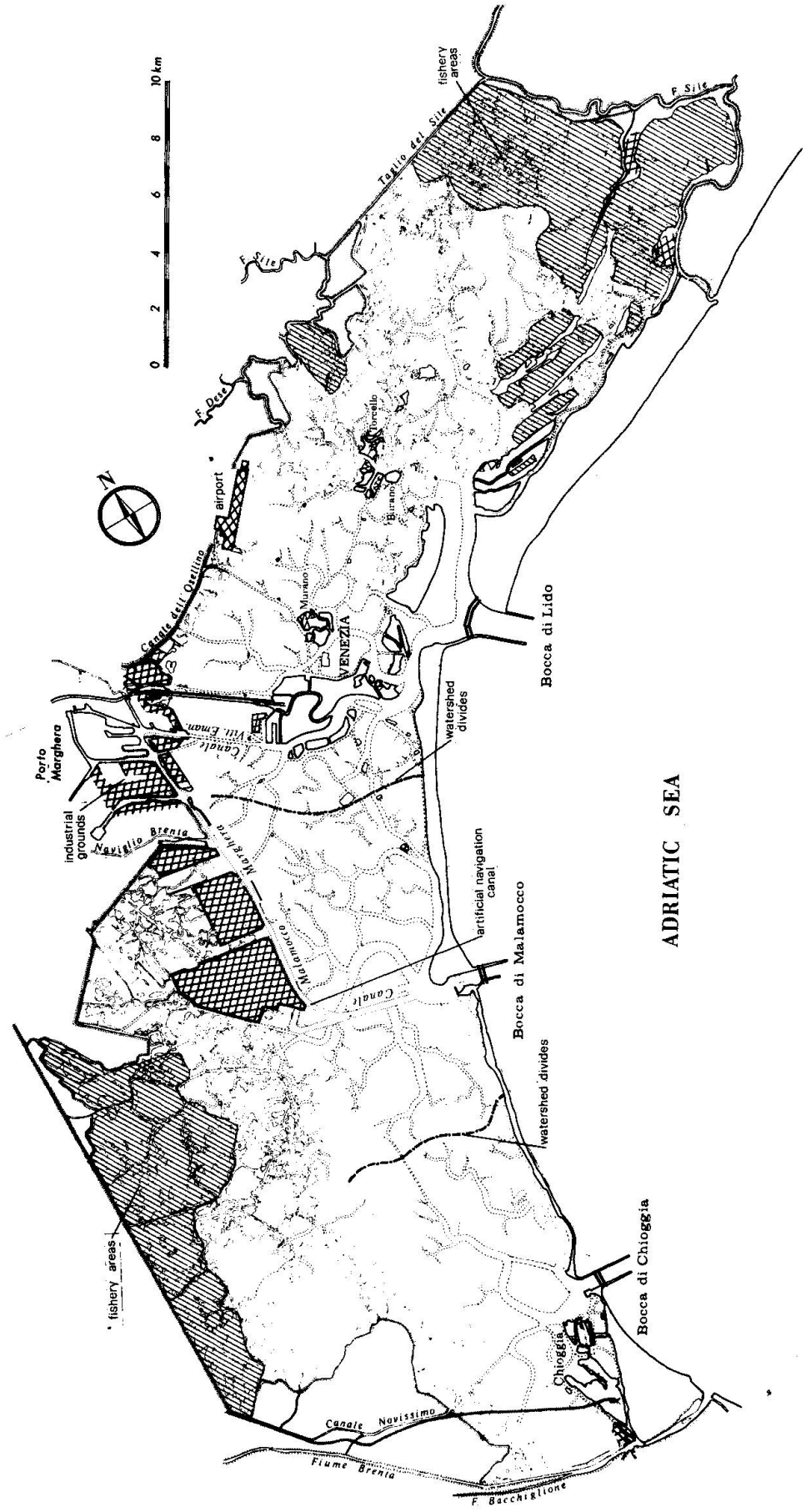

Fig. 1 A general map of the lagoon of Venice. The designed barrages in the mouths are also indicated.

velocities through the mouths even during the phases of maximum flux or ebb of the normal tides and it reduces noticeably the volumes of water exchanged between lagune and sea. While the first effect penalizes heavily the navigation, the second alters negatively the delicate balances,that already seem precarious, of the lagunar ecosystem, even though the water volumes exchanged with the sea during a normal spring tide is of the order of $300 \cdot 10^6$ m^3 and the sum of the maximum discharges exceed 20000 m^3/s.
The fear of modifying the tidal currents present capability to enliven even the most remote zones of the lagune from the mouths (in hydraulic sense), directed Consorzio Venezia Nuova, resposible for the project, toward a solution aimed, above all, to not alter, in any way, the water volumes exchanges between the lagune and the sea in normal tide conditions.
At this purpose it is foreseen the construction, at the three mouths of Lido, Malamocco and Chioggia, of three barriers consisting of a series of mobile gates, that lie on the bottom of the canals during the normal tidal conditions and are regulated until complete closure of the three entrances when the tidal level at Punta della Salute (Venice) exceeds 80 cm, in order to isolate completely the lagune from the sea.
Beyond the cost of the constructions, the principal negative aspect presented by this solution regards the obstacles to the navigation involved. It is sufficient to remind, referring to the decade 1975-85, that to avoid more or less extensive floodings of the city, the barriers at the mouths should have been operated nearly 450 times, avoiding the ships access to the lagune during the manoeuvres.
The negative inference due to the barriers presence on the harbour activity spreads, however, much beyond the time strictly necessary to the regulation manoeuvres.
The presence of the barriers and the relatively high frequence of the manoeuvres constitutes a psychological and not negligible deterrent.
Facing the possibility of not to be able to access the port, in fact, it is not improbable that a part of the traffic, once directed to Venice, chose as port of attrack another harbour in the Northern Adriatic Sea feasible with any tide condition.

3. THE PROPOSED DESIGN SOLUTION

The negative consequences on the navigation and on the harbour praticability involved by the proposed planned solution for defending Venice and its lagune from the phenomenon of flooding, leaded to examine the feasibility of an intervention complementary to the foreseen barriers at the sea entrances, in order to reduce significantly the number of manoeuvres of complete closure of the mouths, still maintaining the harbour feasibility. The proposal that herein is illustrated is based on the following observations:
- For the protection of the peculiar ecological system represented by the Lagune of Venice, are not possible interventions carring to a permanent or temporary partition of the lagunar basin;
- The Malamocco-Marghera and Vittorio Emanuele navigable channels constitute preferential ways of propagations along which the tide wave penetrates quickly from the sea into the lagune, exalting the inertial phenomenon, tending to raise the maximum levels, and reducing, on the contrary, the dissipative effects of the flow, tending to attenuate progressively the tide peaks. The presence of the two navigable channels and in particular of the Malamocco-

Marghera channel has noticeably modified the tide currents regime in the central part of the lagune, where the bottom depths have been subject during these years to a progressive deepening. Consequently it seems to be desirable whatever intervention orientated to reduce the effects due to the two channels existence and aimed to bring back the hydrodynamic behaviour of the central part of the lagune towards the once existing;

- Passing through the sea entrances, going from outside into the lagune, the maximum tide levels are reduced because of the significant flow resistances encountered by the tide wave in its propagation. The effect is the more emphasized the more, under the same conditions, is the dominated free surface extention;
- The most part of the events causing the flooding of Venice have maximum levels lower than 1.10 m, while the tide peaks exceeding such limit are relative rare (in average 4÷5/year).

Once taken into account all the above considerations, the design solution coming up is synthetically illustrated in Fig. 2. It substantially requires the realization of some interventions complementary to the sea mouth barrage works, already planned.

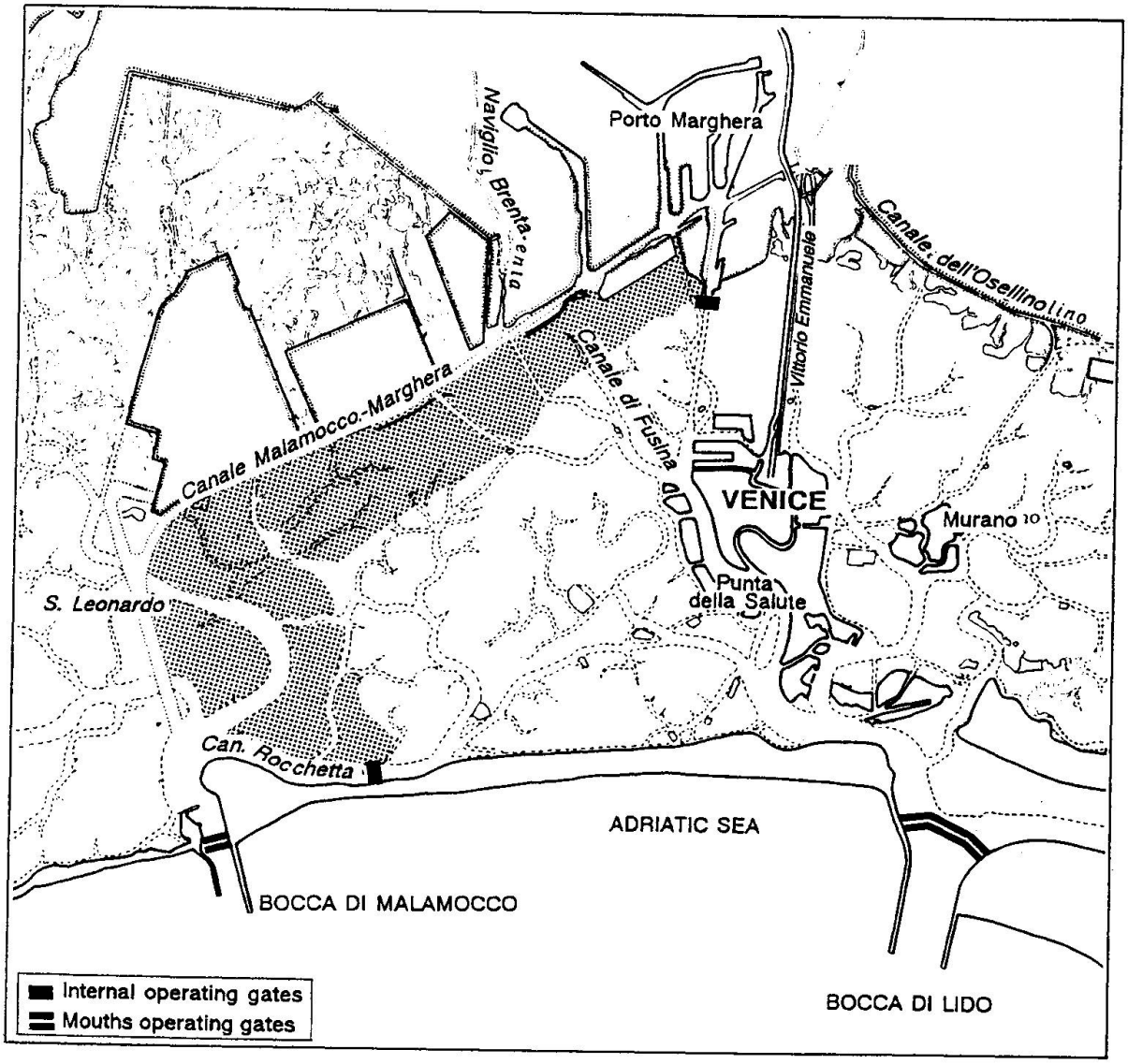

Fig. 2 A map of the central part of the lagoon showing the design solution.

In particular, the construction of a minor barrage, regulated by gates, is planned to limit the effects of the fast tide propagation along the Malamocco-Marghera navigable channel.

The same intervention is planned on the Rocchetta channel (Fig. 2), that links the Malamocco entrance to the basin dominated by the Lido mouth.

The realization, along the Malamocco navigable channel, of a strip of sandbanks (named "barene") nearly 1 km wide, obtainable raising the present bottom , deep 1÷1.5 m, to a level of 0.00÷0.10 m above the mean sea-level, is considered together with the two barrages.

This sandbanks strip, overflowed during the high tide phases, even if crossed by a series of minor canals, linking the Malamocco-Marghera channel to the central basin, reduces the direct influence of the channel itself on the tide currents regime in the whole central part of the lagune, promoting expecially in this zone the water feeding coming from Lido mouth.

The realization of these complementary works permit a different managent of the existing barriers at the three sea entrances.

For the tides with maximum heights up to 1.00÷1.10 m the limitation of the water levels in the the centre at Venice to values below 0.80 m could, in fact, happen with a regulation consisting of the complete closure of Lido mouth together with an analogous operation on the two internal barrages, but leaving completely open both Chioggia and Malamocco mouths. The barriers foreseen for these two mouths should be operated only when the provided regulation could not allow to limit the water levels in the centre of Venice below the specific value of 80 cm.

Operating in this way, for a wide range of events presently causing the flooding of a part of the city, it would be possible the limitation of the maximum water levels within the provided limits, maintaining the port feasibility and penalizing the navigation along the Malamocco-Marghera channel during only few days per year, that is at the occurence of the extreme storm tides, when it would be necessary to proceed to the complete closure of all the three barriers at the mouths.

4. EFFECTS OF THE DESIGN SOLUTION ON THE GENERAL AND LOCAL TIDE CURRENTS REGIME WITHIN THE LAGUNE

The effects due to the complementary works and the proposed regulation on the lagune regime, and in particular on the tide levels behaviour in Venice, were examined with the aid of two mathematical models set up on behalf of Consorzio Venezia Nuova by Ipros (Padova) and its consultants.

The first is a one-dimensional model [1], [2] simulating the non steady flow of the lagune by means of a net of multi-connected channels (Fig. 3).

From a physical point of view, it is based on the peculiar lagune morphology where the many actual channels, endowed with deeper dephts, constitute preferential propagation directions for the tide wave, while the contiguous water zones or sandbanks characterized by shallow dephts act prevalently as storage. In the model these shallow zones contribute at most to convey the flow in the sole direction of the feeding channel.

The structure of the one-dimensional model permit to describe the effects due to manoeuvres of the barriers at the mouths or of the internal barriers, on the basis of a connection between the flowing

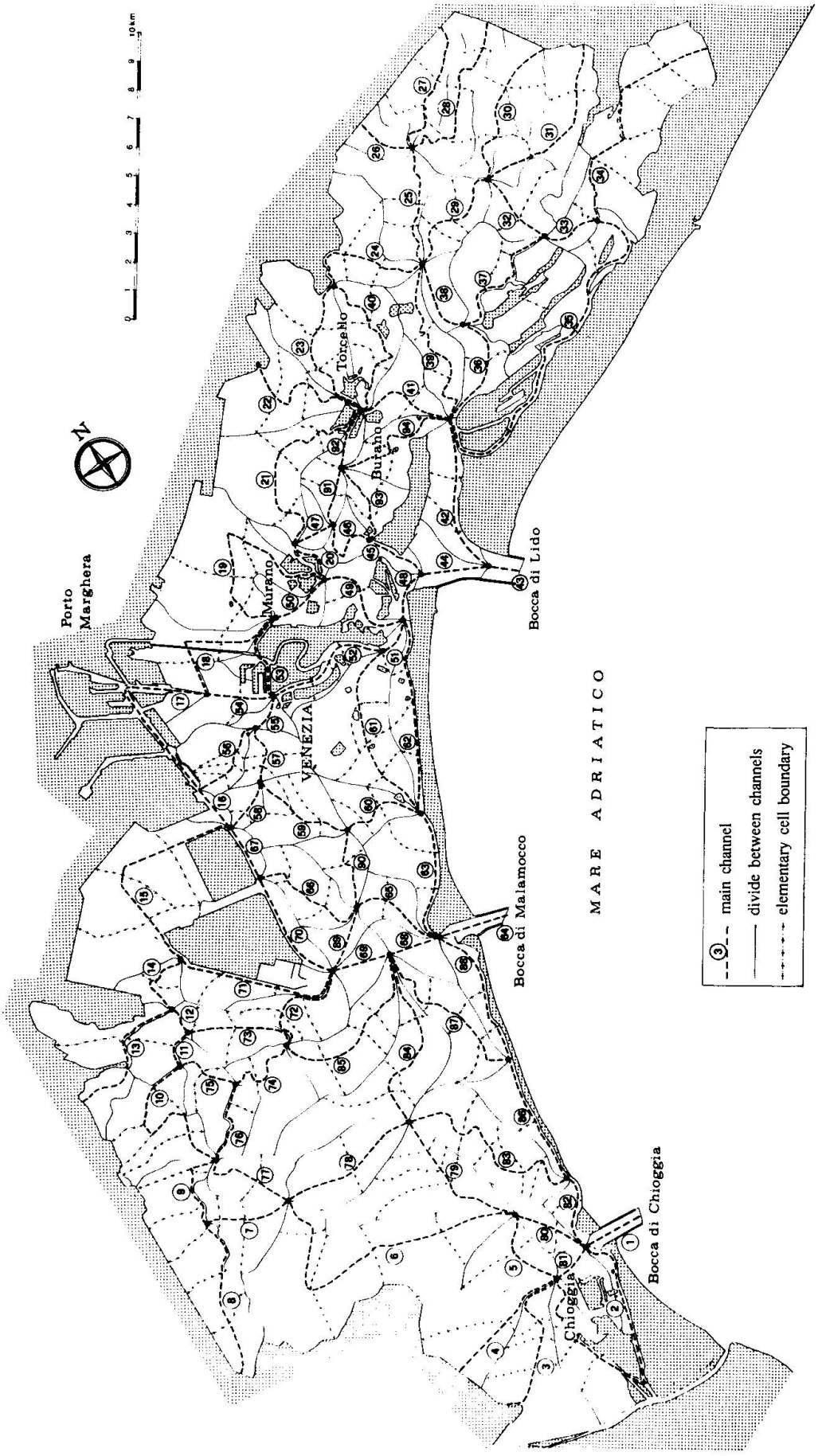

Fig. 3 The scheme of the one-dimensional mathematical model.

discharges and the instantaneous water level differences, coming out between upstream and downstream of each barrage, that depend on the particular geometry of the works.
The bidimensional model used is, instead, a finite elements model [3], particularly suitable for describing the complex lagune geometry, considering, not only the presence of the principal channels but also of the minor (Fig. 4).
The equations of motion of a long wave is shallow water are integrated using, in the discretization of the time-depending terms, a two levels semi-implicit scheme [4] and discretizing the flow field by means of a series of triangular elements.
As a whole the lagunar basin, whose extension is nearly 450 km^2, is described by the finite elements model with about 5000 elements, introducing about 2900 computation points.
The two mathematical models have been previously calibrated utilizing both the results of some field campaigns for the discharges measure through the mouths and across the sections of the principal internal channels and the contemporary water levels recordings of about fifteen tide gauges installed within the lagune.
Water levels and discharges are reproduced by the two models with a good precision in the different locations within the lagune. It is obvious to notice that the bidimensional model, because of its own peculiarities, permit to investigate the flow field characteristics even punctually, in particular in the central zones of the lagune whose dephts are lower than in the channels but not negligible.
The efficiency of the proposed solution is demonstrated by the results obtained simulating, with the mathematical, models the propagation of a sinusoidal tidal wave with total amplitude of 1 m and period of 12 hours, oscillating around a mean value of 0.60 m.

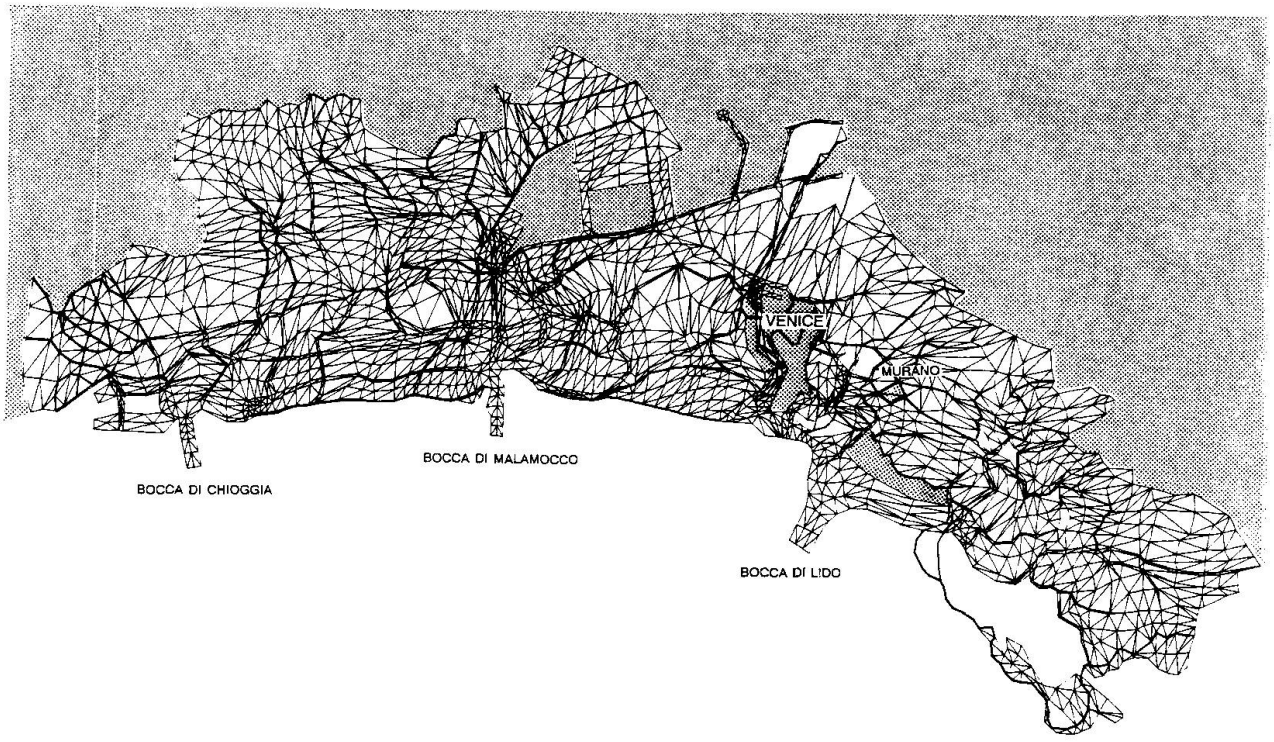

Fig. 4 The mesh of the two-dimensional finite element mathematical model.

Thinking of maintaining the Malamocco and Chioggia mouths completely open it has been simulated a 30 minutes closure manoeuvre of the barriers located at Lido mouth and in corrispondance of Vittorio Emanuele and Rocchetta channels, starting when the sea level reaches the value of 80 cm.
Afterwards the barriers have been maintained closed all the time, while the sea level exceeds the above mentioned limit and then reopened, still with a 30 minutes manoeuvre, in the descending tidal phase.
Along the Venezia (Punta Salute)-Marghera historic centre directrix, the maximum tidal water levels undergo a significant reduction, compared with the actual situation, and do not exceed 80 cm (Fig.5).

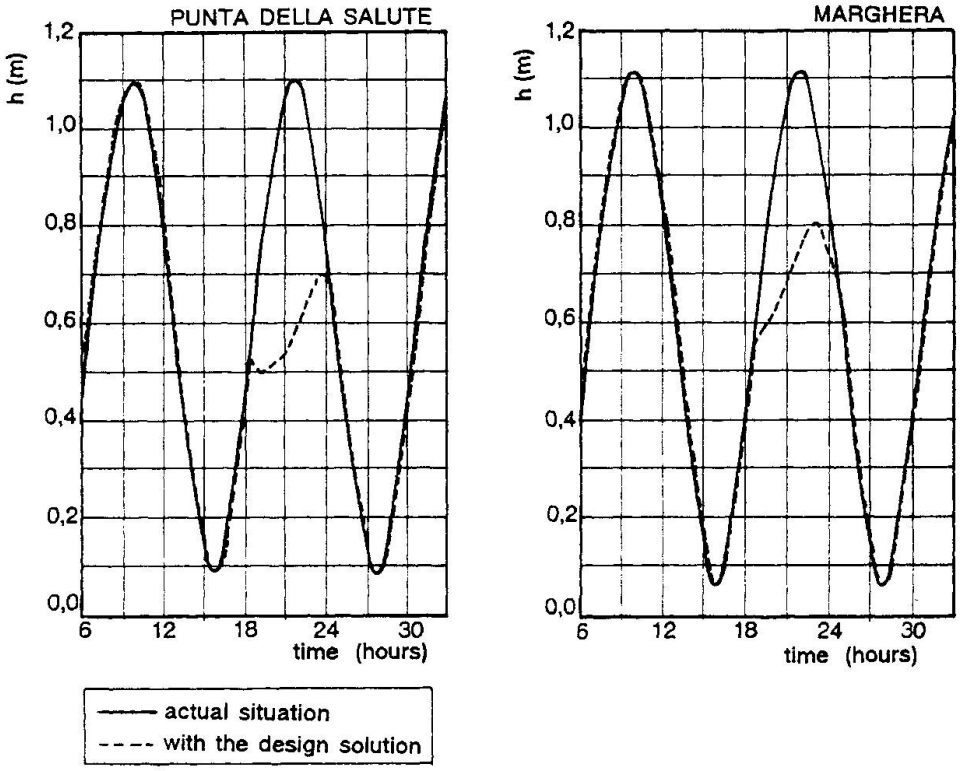

Fig. 5 Effects of the designed solution on tide level at Punta della Salute (Venice) and Marghera.

Significant reductions in the maximum water levels take place also in the whole central part of the lagune included between Vittorio Emanuele and Malamocco-Marghera channels and in the North-Eastern lagune where Murano, Burano and Torcello isles are located.
As a consequence of the manoeuvre, the tidal water levels behaviours in the basin dominated by the Chioggia mouth appear, instead, pratically uncharged.
Therefore the hypothesis on which the herein illustrated project is based, are confirmed by the results from computation. During the closure period of all barriers a considerable increase of the basin dominated by the Malamocco mouth takes palce , but, at the same time the direct feeding of the central part of the lagune from the Malamocco-Marghera navigable channel is obstructed.
Even with the Malamocco mouth completely open,the sandbanks strip planned close to the channel reduces the total tidal currents flow toward the central lagune,that is feeded prevalently by the minor

channels branching off the Malamocco-Marghera navigable channel, however characterized by a rather small scale discharges-curves.
The tidal water level behaviours in the different locations of the lagune agree with the variations, as compared to the actual situation, of the discharges through the sea-mouths, the Malamocco-Marghera channel and the minor channels branching off from it (Fig. 6).
The planned works and the above mentioned regulation manoeuvre allow, therefore, to limit below 80 cm the maximum tidal water level of the "normal high-tide events" up to nearly 1.10 m, without obstructing by no means the feasibility of the harbour, serving the Porto Marghera Industrial Zone, achievable in any case through the Malamocco-Marghera navigable channel.
Furthermore the manoeuvres frequence of complete closure of all the three sea-mouths is significantly reduced, changing from about fifty per year to only 4-5 times per year.

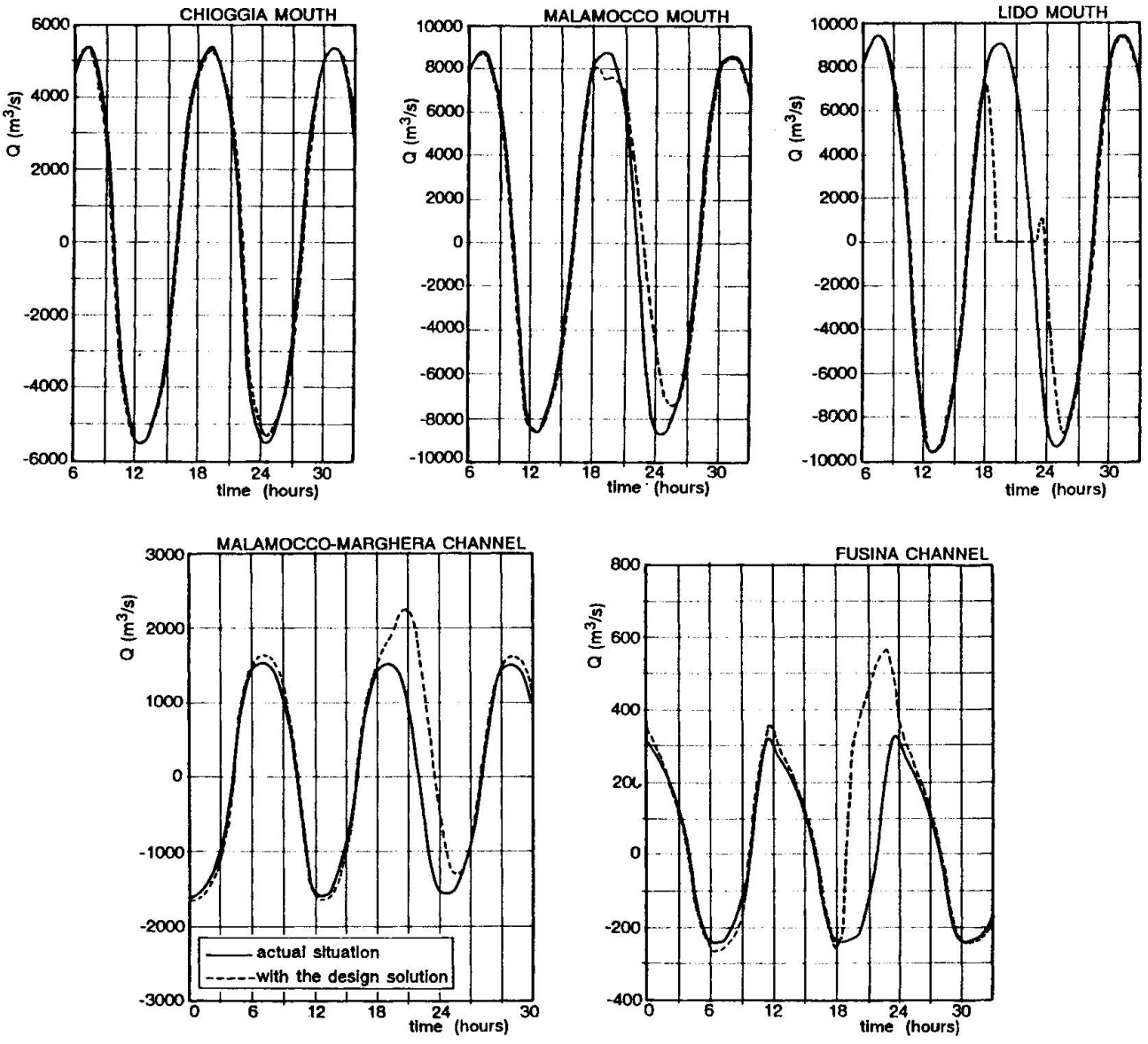

Fig. 6 Effects of the designed solution on the discharges through Chioggia, Malamocco and Lido mouths, and through Malamocco-Marghera and Fusina channels.

The manoeuvring only the Lido mouth barrier and the two internal minor barrages cannot guarantee the control of the extreme "high-tide" events.
Examining the effects of this operation on a real tide with a principal peak of 1.68 m and a secondary peak of 1.20 m, only for the last that would be reduced below 80 cm, it could be avoided the flooding of the city (Fig. 7).
For the principal peak this measure would not be sufficient and the complete closure of all the barriers planned at the three sea-entrances should be provided, avoiding, for a period of about twelve hours, the ship admittance to the lagune.
Finally, the permanent effects that the proposed works and in particular the realization of the sandbanks close to the navigable Malamocco-Marghera channel involves on the central lagune tidal currents, have been examined.

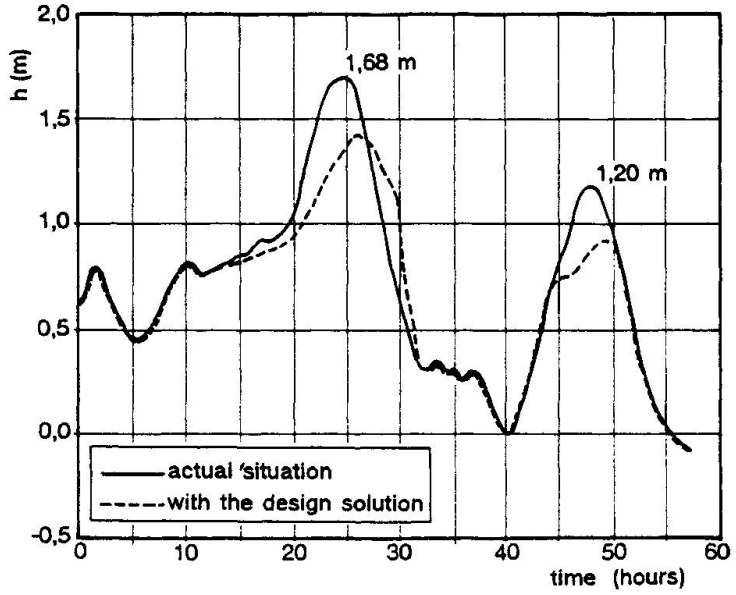

Fig. 7 Effects of the design solution on tide level at Punta della Salute for a real tide.

For the normal tides, for which no regulation at the barriers is required to limit the water levels in the historic centre, the effects are pratically negligible. This comes out from the comparison of the velocity fields relative to the actual (Fig. 8) and to the design (Fig. 9) situations, obtained with the bidimensional model and considering a sinusoidal tide with a 12 hours period and a total amplitude of 1 m oscillating around a mean value of 30 cm.
In the maximum ebb phase, negligible velocity increases are evident only in corrispondance of some of the minor channels crossing the planned sandbanks strip, but the general aspect of the field motion is substantially unchanged.

The presence of the sandbanks strip close to the channel turns also away from Venice the position of the watershed that tends to move towards the Malamocco mouth (Fig. 9), in a position closer to that previous to the dredging of the Malamocco-Marghera navigable channel.

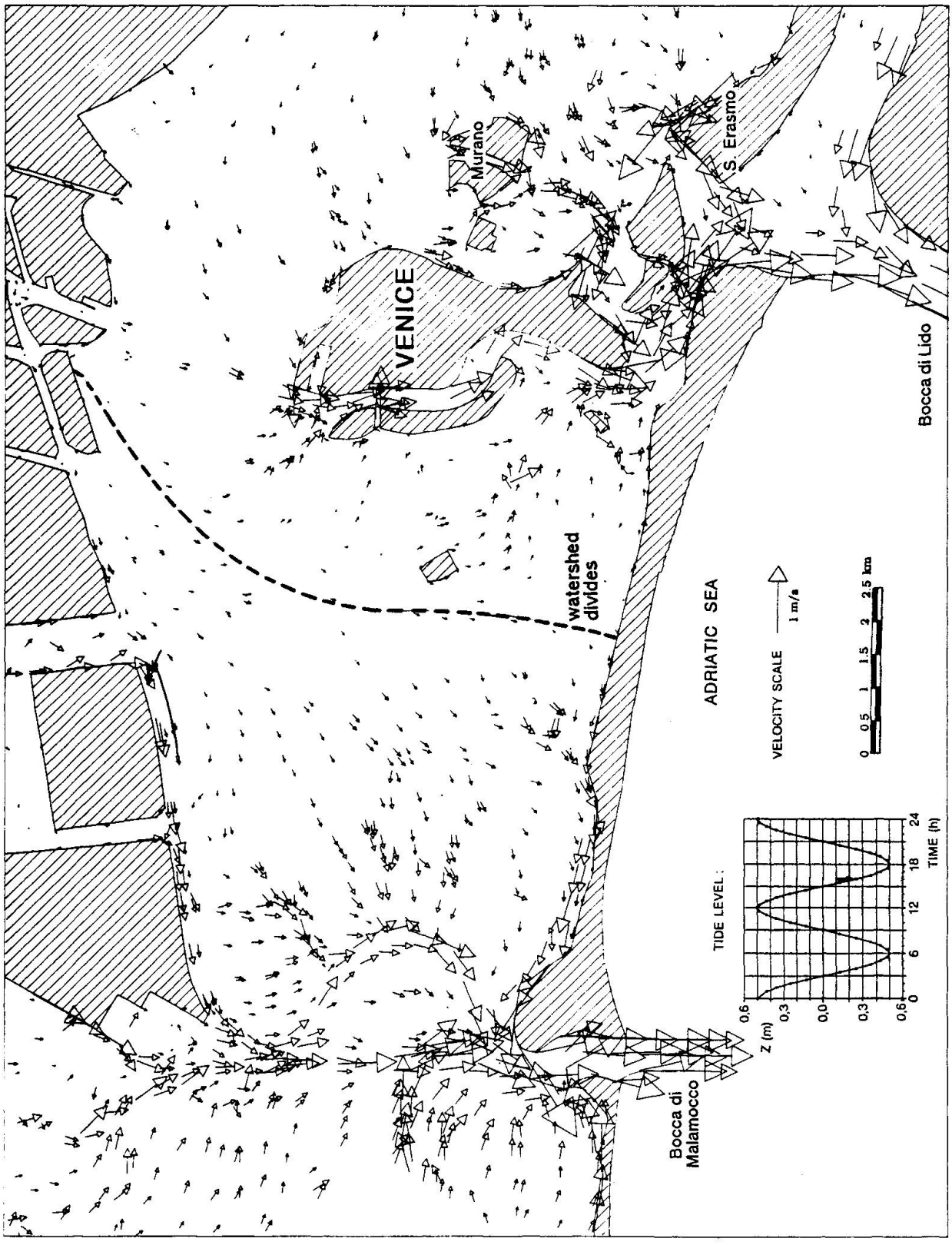

Fig. 8 Velocity field in the central part of the lagoon for the actual situation during the maximum outflow of a sinusoidal tidal wave.

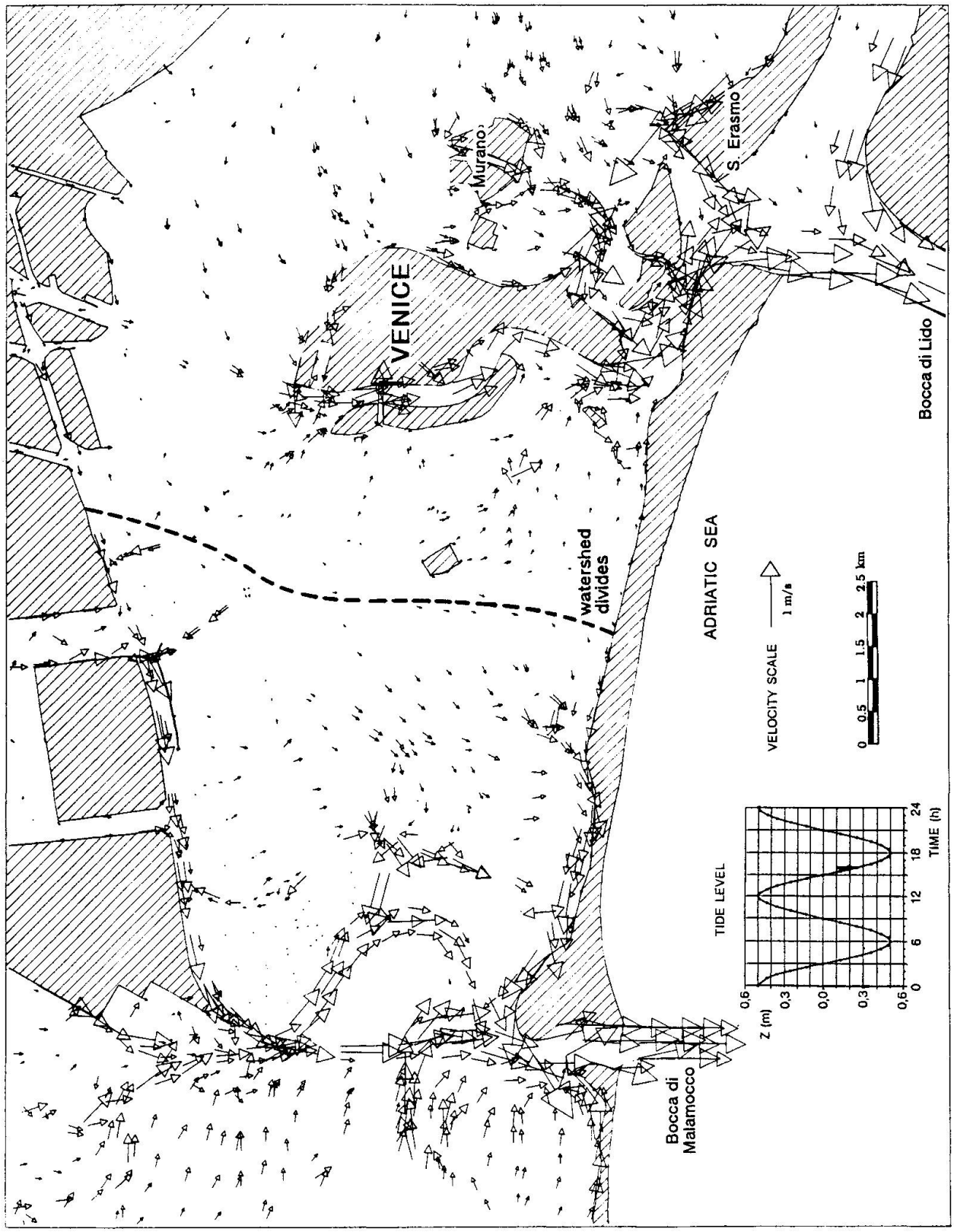

Fig. 9 Velocity field in the central part of the lagoon for the designed solution during the maximum outflow of a sinusoidal tidal wave.

5. CONCLUSIONS

To defend from flooding Venice and its lagune it is foreseen the realization of three mobile barriers at the sea-mouths of Lido, Malamocco and Chioggia. If the construction of two mobile barriers on the Vittorio Emanuele and Rocchetta channels and of a sandbanks strip along all the navigable Malamocco-Marghera channel are connected to the foreseen works, it will be possible to reduce significantly the number of tide events for which it is necessary to proceed to the complete barriers closure.
The normal high-tide events, up to maximum levels of 1.00÷1.10 m, can be controlled with a combined manoeuvre of only the barriers placed at Lido mouth and in corrispondance to the internal channels (Vittorio Emanuele channel and Rocchetta channel). By means of these manoeuvres the tide levels in the lagune are reduced, avoiding the submersion of Venice that begins to be flooded when the water levels exceed 80 cm.
The proposed projectual solution involves remarkable benefits to be the navigation because the barrier regulations to be operated effectively during the normal high-tides do not concern the Malamocco and Chioggia mouths and allow the harbour praticability and the ships access towards the Porto Marghera Industrial Zone.
The formation of a strip of sandbanks on the eastward side of the navigable Malamocco-Marghera channel do not modify substantially the currents regime during the normal tides.
The simulations performed with the aid of the mathematical models show a minor influence of the Malamocco-Marghera channel on the central lagune feeding and point out a moving of the watershed between the mouths of Lido and Malamocco toward the second, in a position closer to that existing before the dredging of the navigable channel itself.

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REFERENCES

1. D'ALPAOS L., Correnti residue e numeriche nei modelli di propagazione unidipensionali. C.N.R., AC/2/288-300, Roma 1982.
2. D'ALPAOS L., Modello matematico unidimensionale della laguna di Venezia. Consorzio Venezia Nuova. Internal Report, Padova 1984.
3. IPROS S.r.l., Modello matematico bidimensionale agli elementi finiti della laguna di Venezia. Consorzio Venezia Nuova. internal Report, Padova 1988.
4. GRAY W.G. and LYNCH D.R., Time stepping schemes for finite element tidal model computations. Advances in Water Resourches, Vol. 1, n. 2, 1977.