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PROBLEMS ARISING FROM SUREXPLOITATION OF COASTAL AQUIFERS IN SICILY

SUMMARY

In many regions of the world, the most important aquifers, and for this same reason the aquifers which are the most exploited, are to be found in coastal regions. The danger which is the most considerable in case of an irrational and unlimited exploitation of these aquifers is that marine water can intrude itself into the aquifers and so pollute them permanently. One of the remedies against marine intrusion is the artificial recharge of aquifers by means of superficial waters which could not be exploited otherwise. In this report we illustrate some situations which have taken place along the coasts of Sicily and the experimental plants which we have brought about to hinder marine intrusion. In a single case, Augusta-Priolo, we have illustrated how a particular geological situation has allowed the formation of a piezometric depression with negative values exceeding 100 metres under the sea level, and how a protective action against marine intrusion has been partially carried out by a clay septum.

It is commonly believed that all waters that rain brings on the ground come back to the sea through the rivers or that only a part of them is retained in lakes or in the ground itself, and therefrom it evaporates.

In fact, a great part of rain water accomplishes its periodical cycle coming back to the sea through coastal aquifers.

Along the coasts, even where there are no rivers, or when these rivers are dry, the exchange between fresh and sea water is continuous, and it become very important in those areas where particular geological conditions, besides

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being very common, make possible a hydric circulation between internal and coastal aquifers. In particular, the presence of alluvial coastal bands allows a diffusion, on large fronts, of fresh water into the sea. In normal conditions, this exchange takes place continuously, according to well known hydrodynamic laws.

The great trasformations and the intense exploitation that we have observed in so many coastal areas are frequently linked to the rich water supply which is to be found there, but precisely the exploitation – sometimes irrational and unlimited – of the subterranean hydric resources of these areas has frequently altered the balance nature had provided, thus provoking a progressive loss, and threatening the existence, of this great potential richness.

The intensive exploitation of coastal aquifers has provoked phenomena which are very visible and very important; it is sufficient to recall those subsidence phenomena – just to mention two concerning Italy – which have taken place in Venice and Ravenna, to get an idea of thier proportions.

Shiftier, but not less grave, is the phenomenon of sea water intrusion in coastal aquifers, which as a consequence are irremediably polluted, or at least polluted for a very long time, with a wealth loss which could prove very grave.

The problem of correct quantity and quality management of subterranean hydric resources is particularly important in coastal regions.

In Italy this problem has a quite special importance as, owing to the peninsula shape itself, characterized by a central ridge-line, the only flat zones, abounding in subterranean waters, are the coastal ones. The short rivers, which engrave peninsula mountains and hills, are almost all torrentlike, i.e. they discharge rapidly into the sea the waters which are gathered in their basins, especially in winter time. Where this has proved technically possible, man has intervened by building dams and basins in order to retain the water of autumn and winter rains, to be used in summer, but in many basins it has not been possible to carry out retention works, and superficial waters keep on getting lost into the sea. The contrast between the amount of this potential wealth, which gets lost, and the aridity of many southern Italian regions, is well known, and it is largely believed that there is no remedy to it.

In many regions of the world new technologies, which at present are in an experimental phase, are going to change this situation; the waters of those rivers and torrents which are abounding only in wintertime, and which cannot be stored in basins, can nevertheless be gathered and kept, in order to use them in summertime, in coastal aquifers, by means of the new artificial recharge techniques. Necessary techniques are actually improved and, already existing, plants, mostly experimental ones, have given very good results.

The artificial recharge of an aquifer can be carried out both through natural and artificial ways. In the first case, we need to find particularly permeable areas, because of porosity as well as because of cracking, on which to concentrate, through dams, big pits or long drains or through other technical devices, superficial waters coming from local rivers, even when these rivers are not near; the waters so obtained will then slowly be soaked by the ground, thus feeding the underlying aquifers; in the second case, the water is introduced into the deep of the earth through the injection wells one has created for this purpose, or taking advantage of those wells that during the following summertime will be used to draw water from the aquifers, J. Bize – L. Bourguet – L. Lemoin [7].

The principle seems rather simple, but as a matter of fact there are many problems which must be faced and solved; some of them depend on the characteristics of the waters, which are used to carry out the recharge, especially turbidness, some others depend on local characteristics of the aquifer which has to receive the water.

Artificial recharging of aquifers pursues, accordingly, these two aims:

- Allowing the storage of great quantities of water which could not be stored otherwise;
- Allowing the feeding of everexploited water bearing strata;
- Obtaining natural purification of superficial waters;
- Hindering sea water intrusion.

The attainment of these results would allow us to protect and put to their best use many of Italian coastal regions which do not possess big hydric resources because of the special natural conditions of the existing water bearing strata, or because, even though once they were rich in subterranean waters they have become poor, and threatened by pollution, owing to an exploitation which has proved both inconsiderate and excessive.

As an example, we can illustrate three cases which have taken place in Sicily, in coastal regions for which only the artificial recharge technique can solve the problems which have arisen from an unlimited and irrational exploitation of the aquifers. As for the first two cases, we only outline them, since their study, and their intervention plans, are still at an initial stage. For the third case we supply more detailed information because by itself it is the most important, and because the recharging plants have already been carried out and are at their experimental stage.

The first coastal zone we are speaking of is the one between Trapani to the North, Mazzara del Vallo to the South, and with Marsala in the middle. Along this coast there is a plain, stretching to the interior, especially in the South, sometimes for many kilometres, covered with sands or detrital or organogenic limestones of the Quaternary, which constitute an excellent aquifer. This aquifer was in the past well fed by the waters coming from the small mountains between Calatafimi and Salemi (Montagna Grande, Monte Polizzo and Monte Settesoli). Now, as a part of the waters of the rivers starting from these mountains are kept upriver by some artificial basins, and as the riverbeds of these streams, following the erosion, are at a lower level than the plain itself, its natural feeding has become more and more insufficient. On the other hand, the continuous digging of numerous wells has destroyed the reserves stored during past times, and has reduced to a minimum the possibility of a natural recovery of the aquifer. A general project of utilization of all superficial waters which are not kept in basins, and for which it is not foreseen another utilization, will be able to solve, we reckon rather easily and with good outlook, the problems of a situation which has become very grave. The plan provides the building of recharging works by means of leaking basins, of drains and of big tanks to be constructed on permeable terrains. It will so be possible to take advantage of the winter and valleywaters of the Forgia, Lenzi, Verderame, Prizzi, Birgi, Marsala or Sosio, Mazzara and Dalia rivers. The reclamation of this coastal area shows also some aspects of great importance for tourism and landscape. In fact, to the extreme South of this same area there is Se-

linunte, and opposite to the coast, between Trapani and Marsala, there is Mozia Island; these two are among the most famous archeological zones of Italy.

The second area is the one between Gela to the West and Pozzallo to the East, along the southern coast of Sicily. This zone is characterized by the presence of coastal dune bands and of detrital organogenic limestone deposits which constituted, until recent times, a rich and well fed aquifer. But on these terrains we have seen the development of an essentially well-watered agriculture, with horticultural products cultivated within greenhouses or outside, which has provoked a terrific water demand and, as a consequence, had determined the digging of wells more and more concentrated and near to the shore-line.

The balance between fresh water and sea water, which for ages had remained along all the coast, has been altered in many points, and in large areas sea water has invaded the aquifer and has made it impossible to use it. This has also made impossible to cultivate the superimposed terrains, if not by means of other water supplies. By the way the terrains, owing to the increased contents of salts, have a tendency to become sterile. In this case too we are bringing about a study and a plan of intervention which should lead to the use of all winter waters of the zone, which are not employed otherwise.

The intervention, in this case, foresees the recharge of the aquifers both by natural ways and by artificial ways, using the same existing wells.

In the frame of this project of recharge we are developing a partial plan which foresees the forcing of water into wells dug some metres away from the sea, in order to constitute a fresh water barrier, which can hinder the sea water intrusion.

This could allow the utilization of winter and valley waters of the Acate, Ippari, Irminio and Modica rivers, and the waters of some sources which at present are used only in the summer well-watering period. In this case too the intervention presents an influence on tourism and landscape, because through it we could rescue the spontaneous flora on the dune bands nearer to the sea, which today is threatened by the salting of the aquifers.

In this part of the coast are to be found the big tourist installations of Camarina, Marina di Ragusa and Cava d'Aliga.

The third zone is the one between Augusta and Syracuse, along the oriental coast of Sicily. On this part of the coast there is a vast plain, ending, to the west, against the last ramifications of the Iblei mountains. This plain, up to twenty years ago, was almost entirely devoted to the cultivation of citrus fruit. On this plain they have built one of the biggest petrochemical factory sets of Europe.

Unfortunately, no serious programme has preceded the development of the industrial installations, which have immediately provoked a more and more dramatic increase in water demand, an assential element for the work of the particular kind of industries which were built in the area. The most immediate consequence has been the unlimited and irrational exploitation of the present hydric resources, with no defence against the plundering of the first-comers, with no concern about their natural recharge, and even coming to the extreme of spoiling partially or completely any possibility of future use.

The public administration has proved unprepared to face a phenomenon which, for its dimensions and for its very high rate of increase, surpassed any foregoing experience and any possible immediate response.

The industries which have settled down in the area have managed, each one on its own account, to get, no matter how, the water they needed for

their functioning. Once the possibilities of obtaining the limited quantities of existing water – the water of the local torrents and of the few sources – were exhausted, also because in summertime they were completely dry, they started to use the existing wells, which the farmers had dug to water their terrains, these terrains being abandoned as a consequence of the rapid expansion of the industrial settlements, and later on they began digging their own wells at a more and more frantic pace. By the way, the individual industries did not care to dig their wells according to a rational programme, but they mostly followed criteria which we can define more or less water-devining. The outcome is that at present the linking networks between the wells of an industry and the industry itself intersect the wells and the networks of other enterprises, so that any future control will be very complicated.

On the whole, in the said zone, on a surface of about 30 square kilometres, they have dug 162 wells; of these wells 121 are permanently used, and 42 now and then, A. Aureli [1, 2, 3, 4, 5, 6].

The quantities dug out from the aquifer have progressively increased from 1960 up to the present day, and now they can be valued between 60 and 65 x 10^6 m^3. Of this quantity, on the average, up to 1980, 42 x 10^6 m^3 were used by the industries, with continuous average extraction of 1,330 1/s, whereas, during recent years, following the authorities drastic interventions, and owing to the fact that in winter the industries can now use superficial waters coming through big aqueducts from near basins, the consumption has been reduced to 34 x 10^6 m^3, and industrial wells are kept inactive at least for three months.

Another 10 x 10^6 m^3 per annum are used by the municipalities of the zone for drinkable water supply, drawing an average 320 1/s.

Irrigation for agricultural aims is performed only in summer; for this period, we can value the quantity of water drawn from the aquifer as corresponding to 825 1/s, i.e. to a total of 13 x 10^6 m^3.

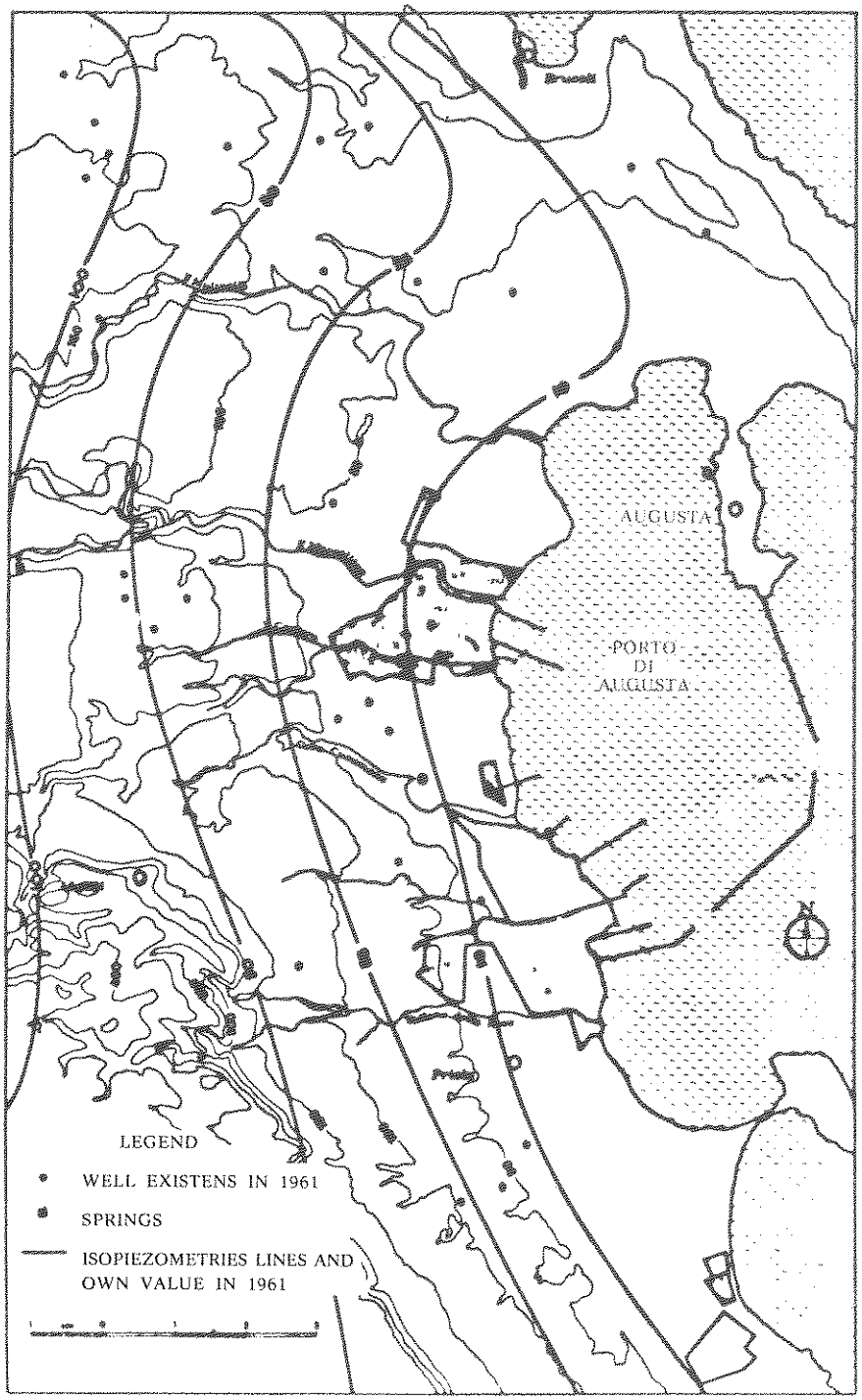
Hydrogeological studies, carried out by means of a mathematical model of definite differences type, has allowed us to value the volumes which on the average year go feed the aquifer, through efficient infiltration, through infiltration from the streams and through transfer from karst systems of neighbouring areas, to an amount of 54 x 10^6 m^3.

For many years, as we have seen, the whole extraction of water from the aquifer has surpassed of 10 x 10^6 m^3, more or less, natural feeding. Total volume drawn from reserves from 1960 to 1980 is valued between 100 and 120 x 10^6 m^3.

The most evident consequence has been the almost complete disapperance of pre-existing sources, whereas instruments showed a progressive lowering of piezometric levels.

In Fig. 1 we show the variations of piezometric levels as observed during 1961; it may be remarked that everywhere piezometric level was at a higher level than the sea level.

In Fig. 2 we have noted average piezometric variations in 1981; we can observe that, where the industrial concentration is at its highest level, isopiezometric curves show negative values, even exceeding 70 m under the sea level. All this has created a sort of hole in the shape of a reversed cone which goes farther than the shore-line. This situation, apparently absurd as the sea water presence should bring back to zero isopiezometric lines along the coast, is provoked by the presence, quite occasional and exceptional, of an impermeable septum consisting of pliopleistocene clay deposits which separate the water bearing stratum from the sea.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WELL EXISTENS IN 1961
SPRINGS
ISOPIEZOMETRIES LINES AND
OWN VALUE IN 1961

Fig. 1

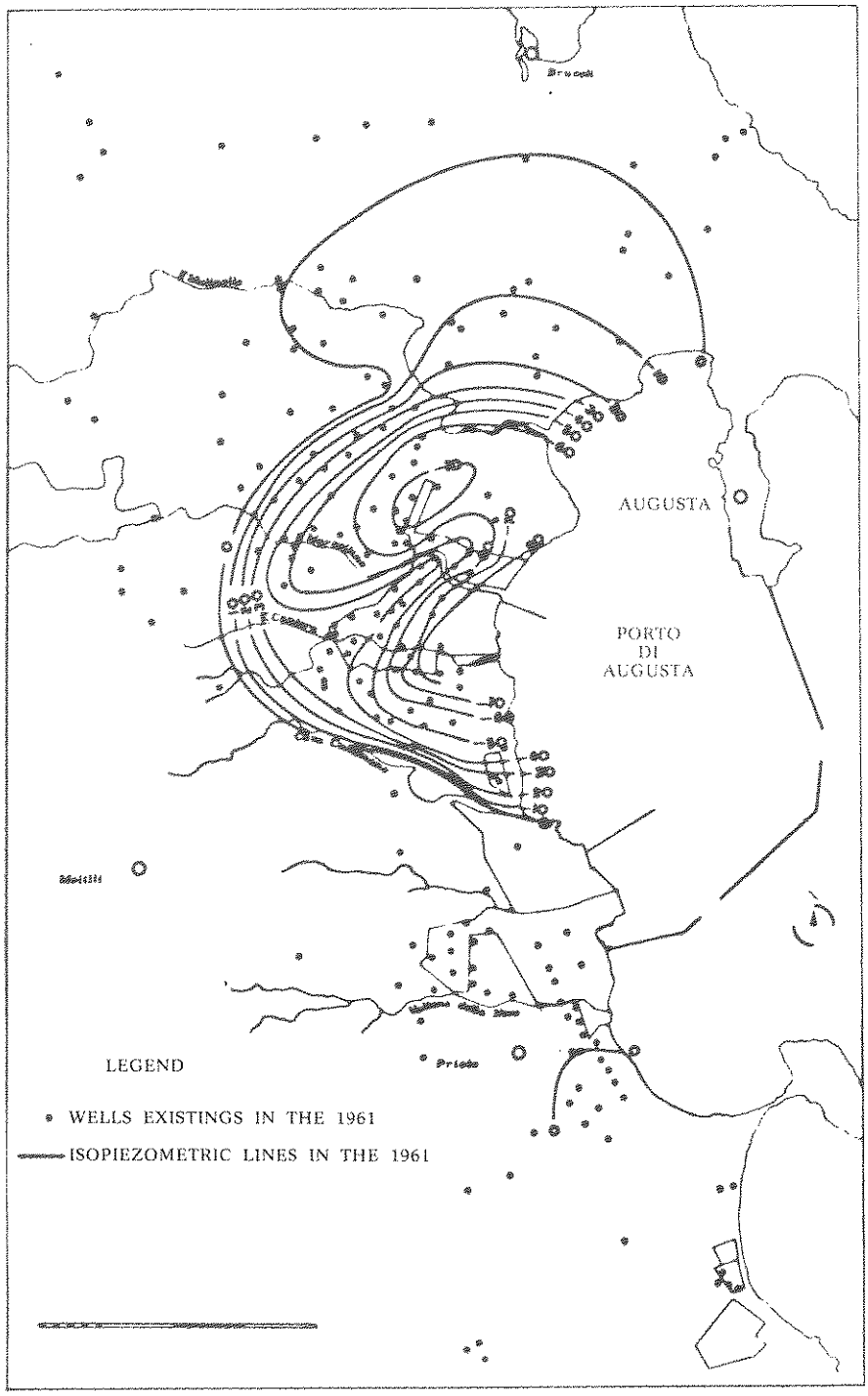
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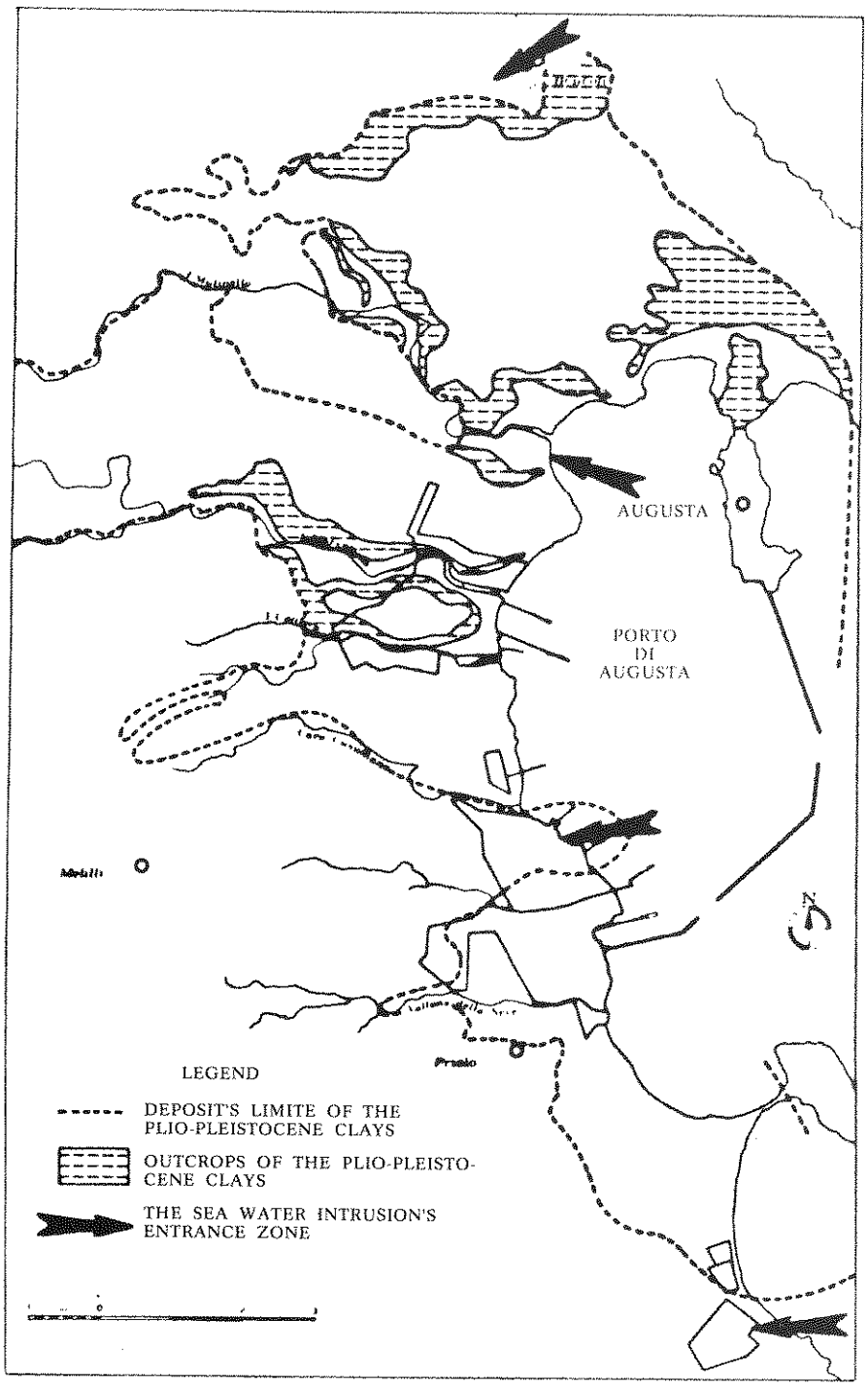
Fig. 2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DEPOSIT'S LIMITE OF THE PLIO-PLEISTOCENE CLAYS
OUTCROPS OF THE PLIO-PLEISTOCENE CLAYS
THE SEA WATER INTRUSION'S ENTRANCE ZONE
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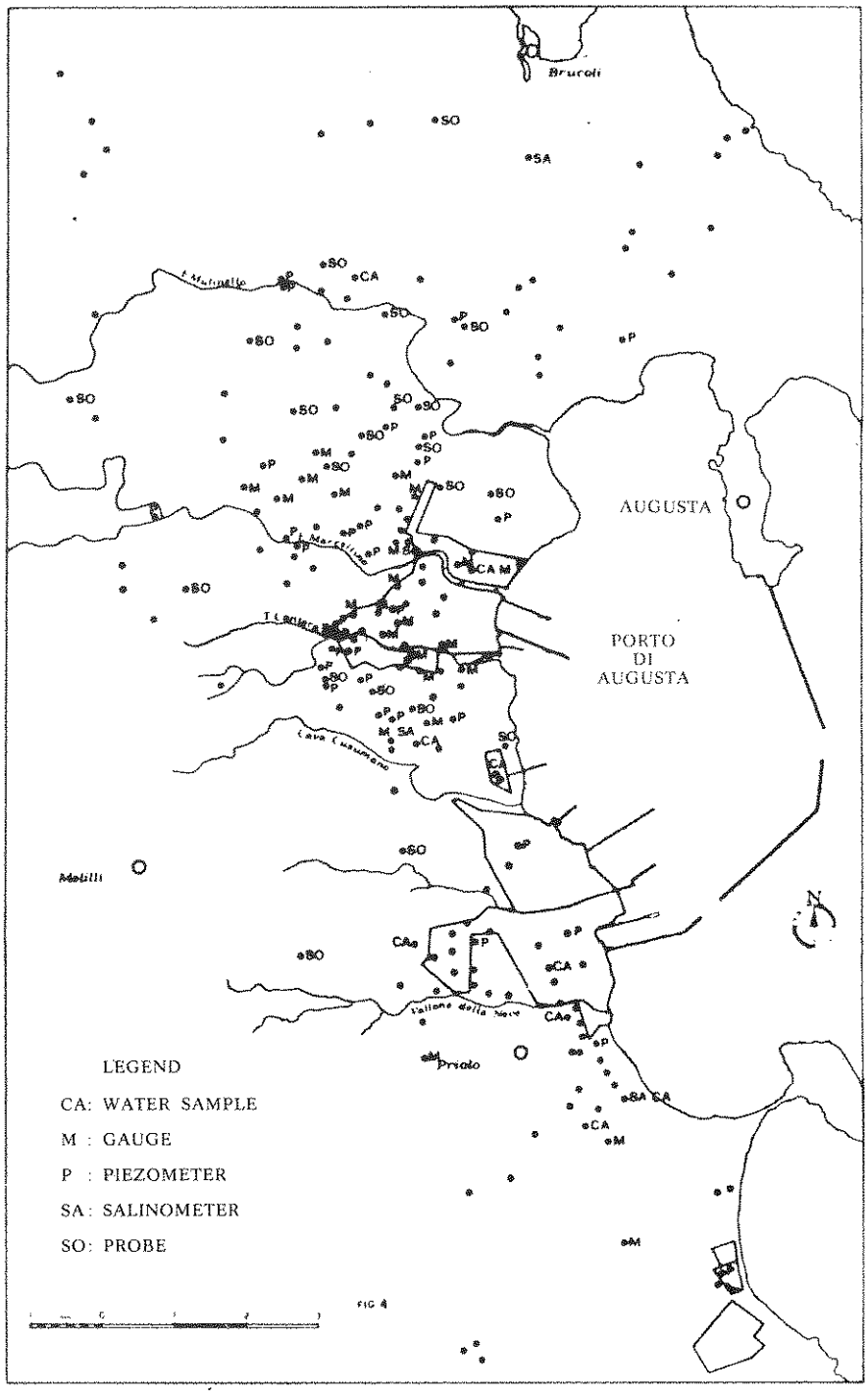
Fig. 3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Melilli
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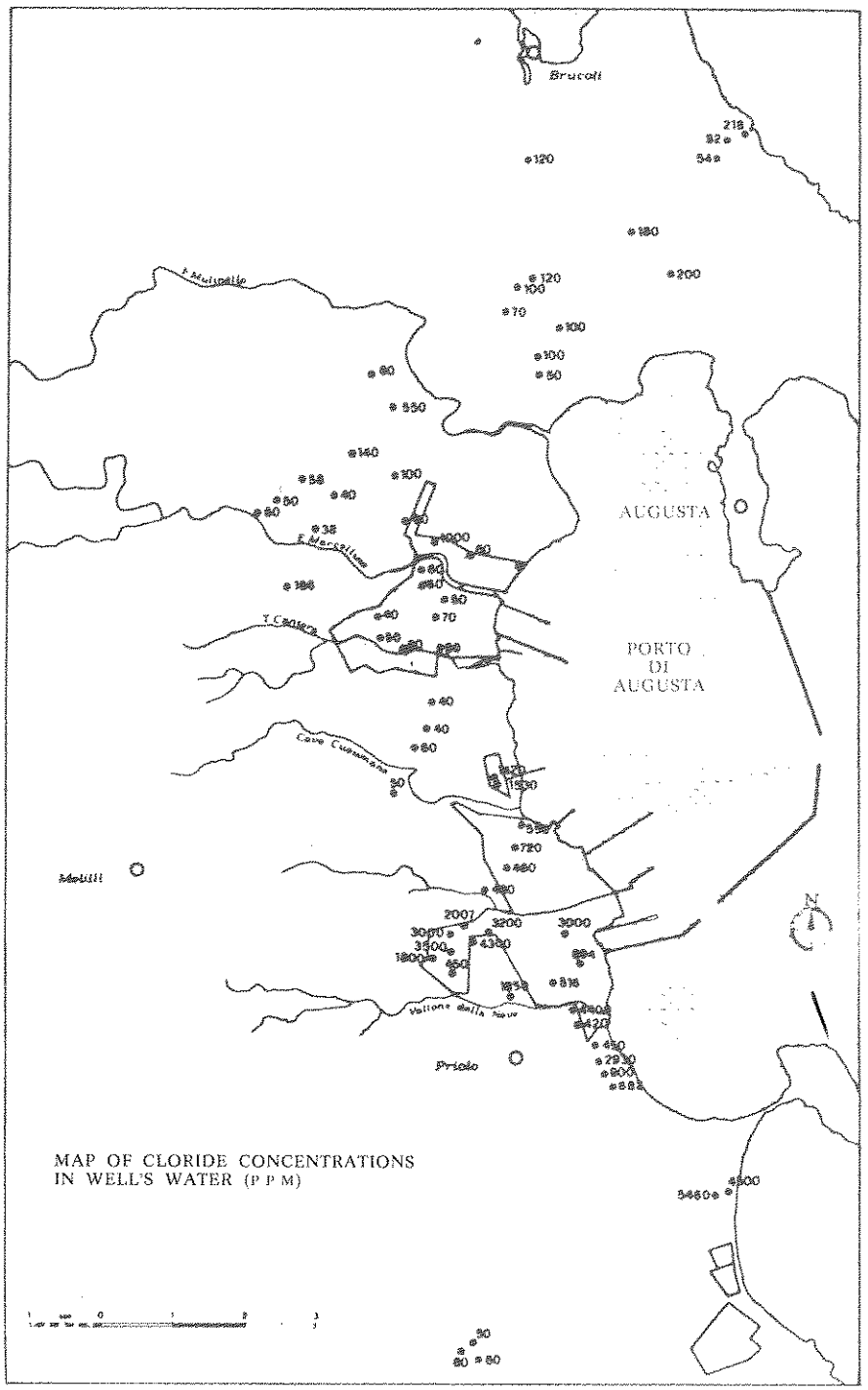
CA: WATER SAMPLE
M : GAUGE
P : PIEZOMETER
SA: SALINOMETER
SO: PROBE
FIG 4

Fig. 4


Brucoli
AUGUSTA
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Priolo
MAP OF CLORIDE CONCENTRATIONS
IN WELL'S WATER (P P M)

Fig. 5

In Fig. 3 we can see the variations of clay deposit along the coast, in the said area, in picture n. 6 we have the local geological scheme, simplified.

The hole which has been created in piezometric levels behaves as a funnel which attracts all waters circulation in the region, and would certainly provoke a sea water intrusion on huge quantity were not there, to hinder this intrusion, the presence of the clays. But we can see, still by picture n. 3, that this impermeable septum has limited dimensions, so that sea waters show a tendency to outflank it, and to pour themselves in the said hole.

The clear evidence of the call provoked by the so called funnel is given by the chlorine contents increase observed in the waters of those wells which are near to the boundaries of the clay septum. This increase is proved by Fig. 4, where we have the chlorine percentages observed in the waters of the wells of the area in 1981.

The ascertainment of these exceptional phenomena, i.e. the lowering, sometimes exceeding 100 m, of piezometric levels, and the danger that the water bearing stratum could be completely salted, which would involve the loss of an unreplaceable wealth, plus the fact that we began to observe subsidence phenomena, have greatly concerned authorities who have intervened by ordering the carrying out of all possible technical interventions capable of hindering these phenomena and of recreating the original conditions of the aquifer.

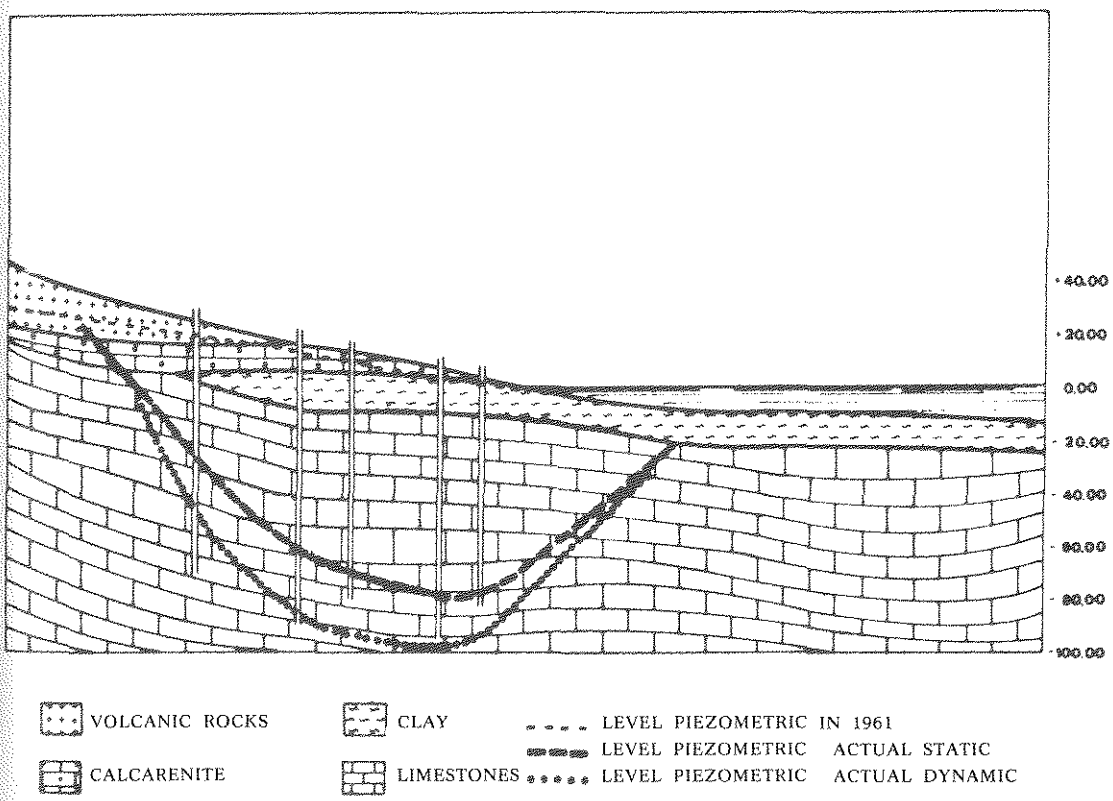

Fig. 6 – Stratigraphie's simplified schema zone: Augusta Priolo,

We have then come to the building of a series of plants which take the water from two rivers which are one to the North of the area, the Simeto river, and one to the South, the Ciane river. These streams allow, at least in wintertime, the feeding of the industries and one can put at a stop the drawing of the well water.

Unfortunately, the mere suspension of the pumping during the four months of winter has not allowed any recovery for the aquifer, so we have also carried out an experimental plant for artificial recharge by which, through thirteen wells, we pour into the aquifer 350 l/s of water coming from the Simeto river, duly clarified in a clarification plant. All details of the recharge and the outcoming results in the aquifer, are carefully checked by means of a series of automatic devices: piezographs, salinometers, thermographs, mounted on 39 wells.

In Fig. 5 we can see the whole of the network of the checked wells, as well as the thirteen wells used for the recharge. This is a pilotplant of exceptional experimental importance, among the most important carried out in the world, and from which we hope we will obtain useful information for all future and similar plants, where the conditions are more or less the same, in other coastal areas of Italy.

The three foregoing examples, though limited only to Sicily, can give an idea of the importance that the problem of a correct management of hydric resources in coastal area can have, and they can give an idea of the fact that in many of these zones it is possible to store, into the local aquifers, big quantities of water coming from the internal basins and which otherwise would not find any other utilization and would flow into the sea.

Now it is only to be said that this kind of plant is certainly the one that disfigures less the landscape, since drains and subterranean pipes which take the water to the recharge wells, are practically invisible.

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