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SEA WATER INTRUSION IN THE PLANNING OF GROUNDWATER RESOURCES PROTECTION AND UTILIZATION IN THE APULIA REGION (SOUTHERN ITALY)

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SUMMARY

The planning of a correct management of Apulian water resources, a region which mostly develops between the Ionian and Adriatic seas and being lacking in surface waters, entails the combined and well coordinated use of water coming from different areas: artificial lakes located in zones of adiacent regions, where the hydrology and the geology allow water storage; groundwater more or less affected by continental sea water intrusion; treated waste water; brackish spring waters; desalted waters; etc..

Taking into account the different origin, the waterworks are numerous and complex, also including large artificial lakes and wide equalizing resevoirs, which provide for the mixing waters with different quality and saline content in order to reach the quality needed for drinking, industrial and agricultural supplies.

The planning aspect concerning underground waters has considered the saline intrusion phenomenon as a factor strongly affecting their use.

Episodies of saline contamination caused by massive water-takings have prevented groundwaters from being used in large areas especially in southern Apulia.

The main objectives of the reorganization and use planning provided for recovery and safeguard actions. Such actions are based on the total water-taking prohibition in some particularly vulnerable areas and on the reorganization of the water-takings also by the expropriation of private wells to be run by public bodies.

Artificial recharge plans, using purified waste-water and extraregional water resources have been proposed.

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1. FOREWORD

Apulia is particularly affected by sea-water intrusion phenomenon. Such a region is mostly karst in type, almost lacking in surface water resources, but rich in underground ones.

The extensive coastal development in the region as well as the permeability features of rocks outcropping along the coast favour sea-water influence on ground-waters, further stressed by massive drawings occuring in most territory. This factor does limit the planning of all water resources integrated management throughout the territory.

At present the studies on Apulia's sea water intrusion are supposed to go through a final stage. Such an event results from a more than two decade investigations, during which the objectives, opportunely faced and solved, related to single aspects of the phenomenon; among which the dynamic behaviour of the transition zone, the hydrochemical aspects connected with the contamination phenomenon, the working out of better methodologies also for determining and quantifying a fresh water-salt water imbalance, besides of course, the acquisition of all geological, hydrogeological and hydraulic parameters helpful for the overall understanding of the manners by which sea influence on fresh-groundwater takes place in any case [3, 4, 5, 6, 8, 19, 21, 22, 23].

The scientifical research, then, in this final stage is likely to provide the users and the administrators of the «underground water resource» with the elements useful for the correct planning of its use; most of all as far as the reorder of uses, the quantifying of additional and possible water takings and recovering and safeguard actions are concerned.

What mentioned stands for an all-important factor for Apulia's economic recovery, aiming mainly at the relaunching of farming and agricultural-food industries related to it.

This can be attainable only provided that the best utilization of regional and extraregional water resources concerning the territory, allows the availability of water to be destined to such purposes.

The present work will consider in detail a portion of the Apulian territory, Murgia and Salento, showing the main problems of sea water intrusion. Moreover this work wants to deal with the methodological aspects connected with the utilization of the acquired knowledge on water-planning particularly referred to the complex aspects of sea water influence on fresh ground water.

2. GEOLOGICAL AND HYDROGEOLOGICAL OUTLINES

Fig. 1 shows the distribution of the outcropping carbonate rocks, including the mesozoic formation made up by limestones, dolomitic limestones, and dolomites generally permeable by fracturing and karstism.

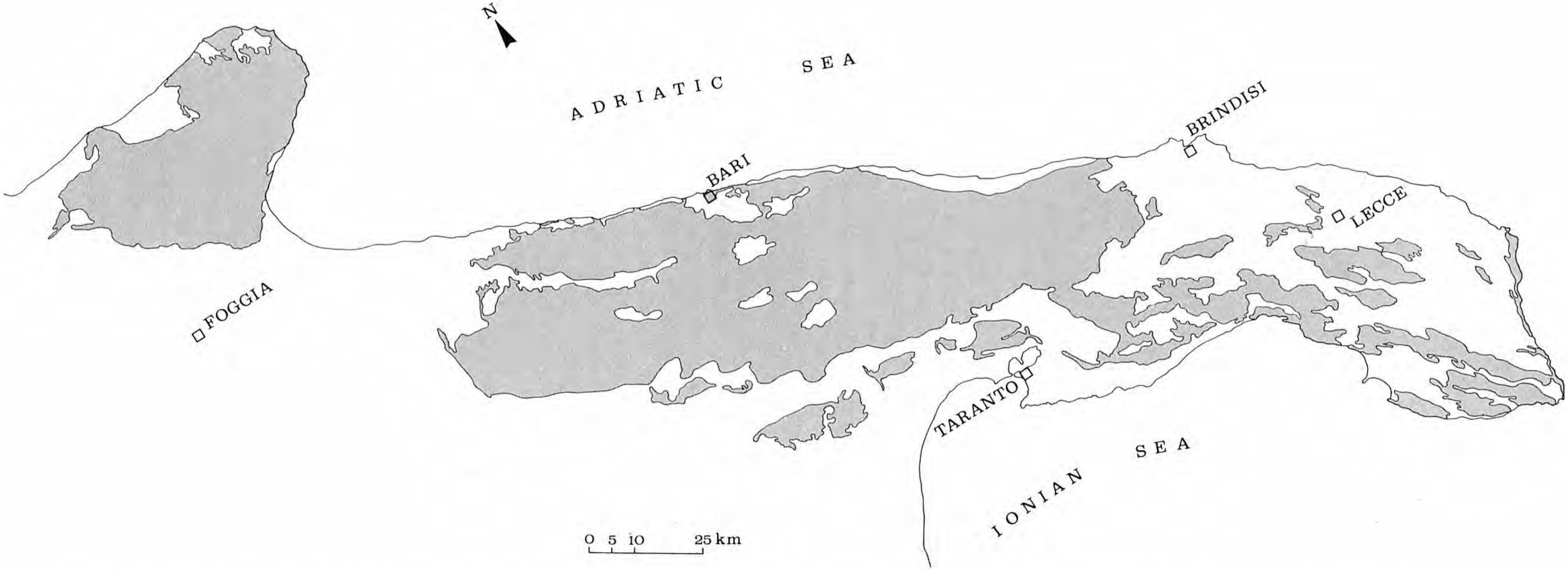

Fig. 1 - Distribution of the outcropping carbonate rocks (limestones, dolomitic limestones and dolomites).

In general the most recent transgressive calcarenite and sandy-calcareous soils, remarkably present in the Salento, only in at all particular cases, have a basic function in water circulation, since at sea level, where the uppermost part of water circulation is nearby present, there is the mesozoic carbonate formation.

Neverthless, they affect from zone to zone the modes by which the feeding process takes place.

Great differences, at times due to scarcely karstifiable facies within the mesozoic series, in the overall permeability degree of the aquifer and in its space distribution, cause Murgia's hydrogeological features to be markedly different from the Salento's ones; thus allowing the classification of the two areas in quite distinguishable hydrogeological units, with a morphological-structural hystory at all different one from the other [10, 11, 12, 13].

Fig. 2 shows the permeability features diversity in the two hydrogeological units of Murgia and Salento though these aquifers are substancially similar from the lithological point of view.

The parameter represented in the map is given by the value of the specific discharge (real discharge corresponding to 1 m depression of the dynamic level) obtained from drilled wells in the territory. Evidently said value is a direct function of the aquifer permeability degree.

By the way it is worth mentioning that the penetration into the aquifer of a drilled well has a secondary role as for the obtainable yield. Diagram in Fig. 3 shows that in some areas (Fig. 4) good values are obtained by little penetration into the aquifer provided that the aquifer has a reasonable permeability degree. In other areas great penetrations serve only to reach preferential water levels below scarcely permeable rocky horizon, also of high thickness [20, 23].

This factor too, shows quite a different behaviour, as for space distribution of permeability features, between Murgia and Salento.

As a rule, the overall low permeability of Murgian aquifer is proved by specific discharge values below 10 l/s x m, but often below 2 l/s x m, of wells at times reaching and exceeding 500 m depth from sea level, against values of about 30 l/s x m on the average, obtained in Salento for wells characterized by penetrations into the aquifer of the order of few metres (Fig. 3 and Fig. 4).

The water table contour-map in the Murgian unit and in the adjacent Salento (Fig. 5) is a further proof of the two units different hydrogeological behaviour.

The Murgian aquifer is characterized by piezometric heads also of 200 m above m.s.l. and hydraulic gradients also of 8‰, whereas Salento's aquifer shows piezometric heads seldom exceeding m 3 above m.s.l. and hydraulic gradients, on the average, are of the order of 0.2‰.

Water circulation taking place through preferential flow pathways typical of karst areas, remains a characteristic common to the two units.

In the Murgian region these paths follow Appennine direction, it is to say subparallel to the coast; whereas in the Salento region they are oriented towards draining coastal zones [9, 12].

The Salento has a much more visible coastal draining than the Murgia, for, there are extensive draining fronts, against the limited concentrated-type coastal springs along the Murgian Adriatic littoral [17, 18].

Moreover the Murgian hydrogeological system shows a discharge on the Ionian versant, particularly in correspondence to the Mar Piccolo, where submarine springs concentrated in type, are located [15, 16].

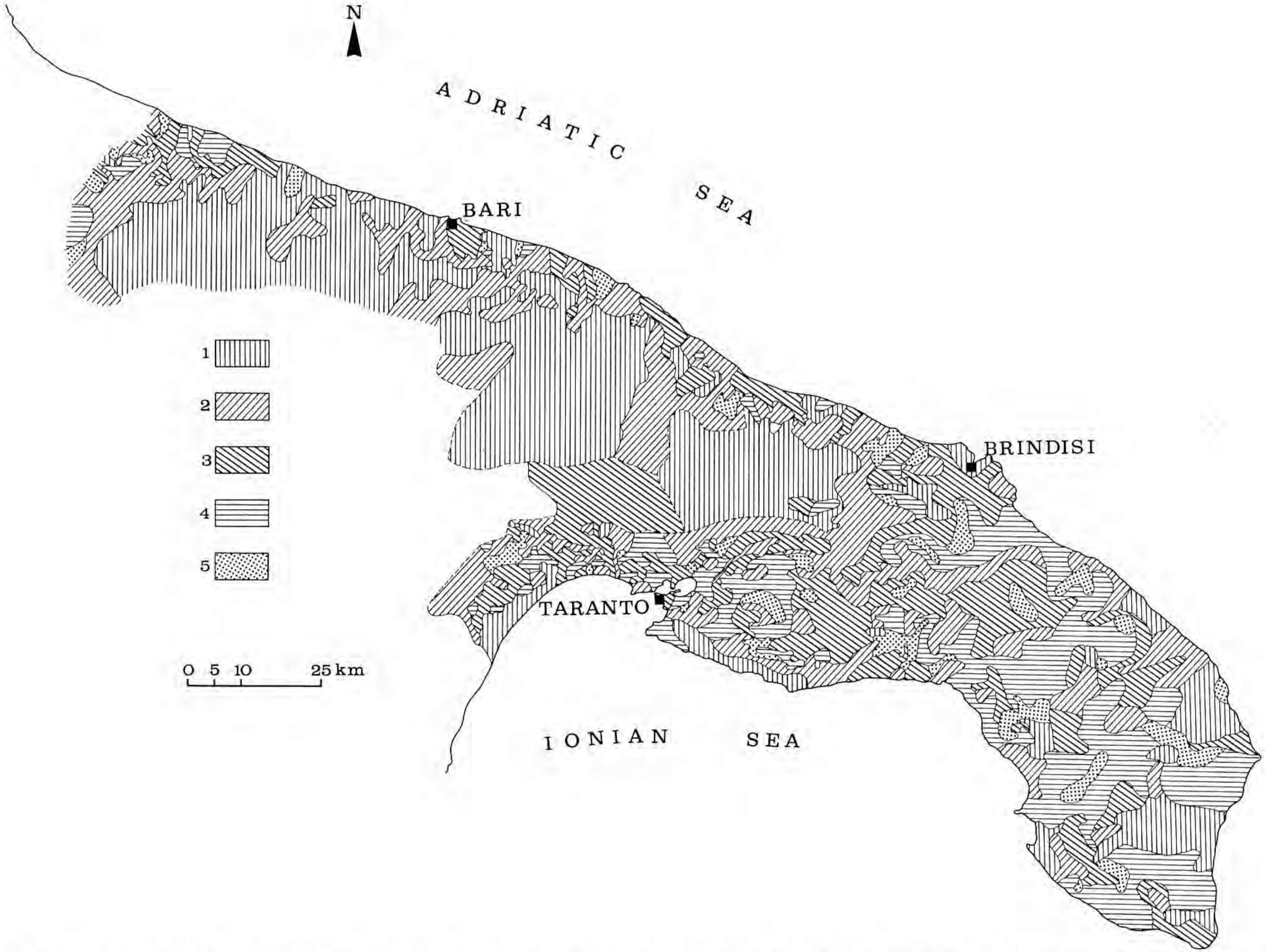

Fig. 2 – Distribution of the specific discharge values (in l/s · m) obtained from drilled wells (1: < 2 l/s · m; 2: $2 \div 10$ l/s · m; 3: $10 \div 30$ l/s · m; 4: $30 \div 70$ l/s · m; 5: > 70 l/s · m).

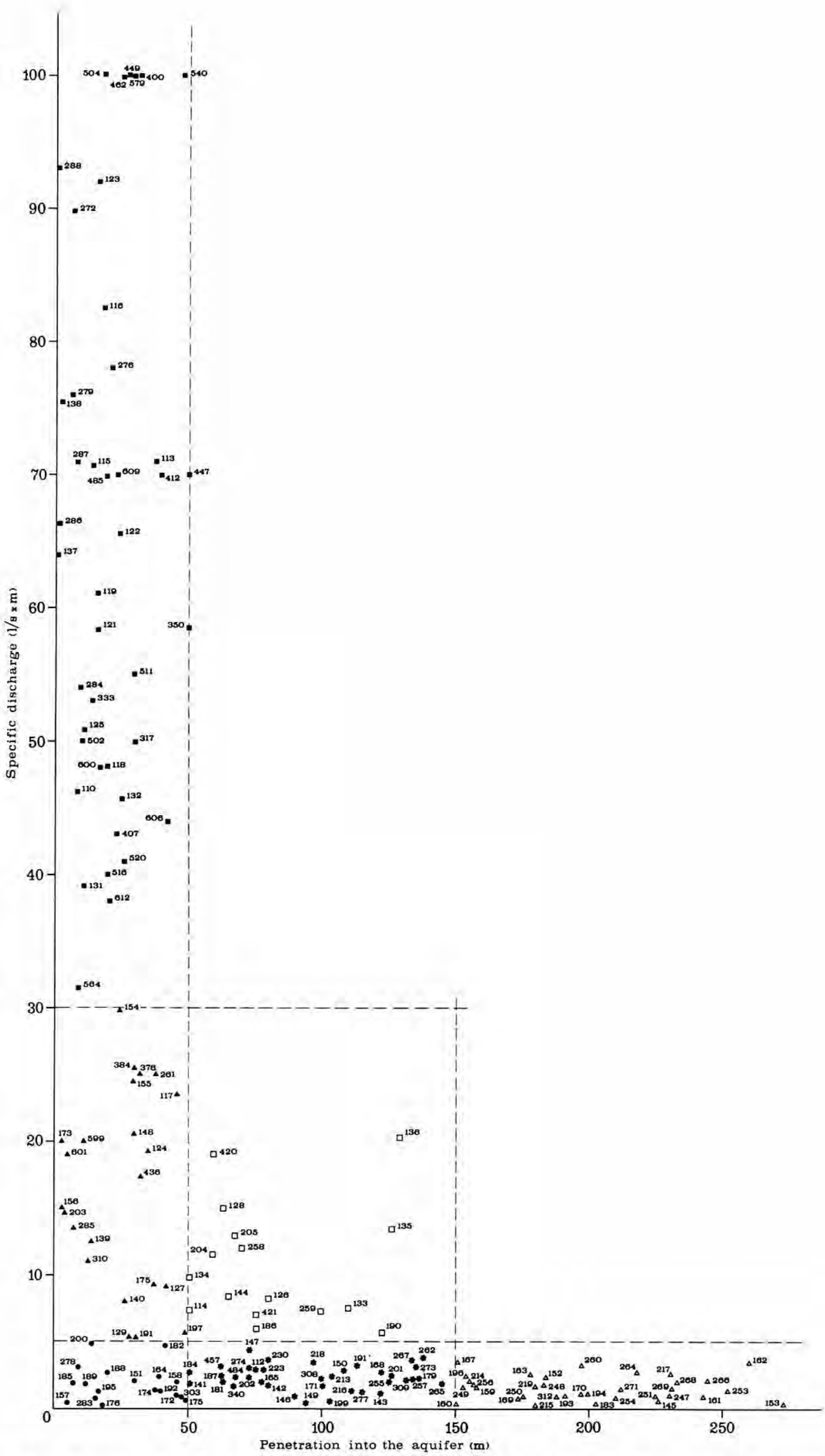

Fig. 3 – Relationship between specific discharge of drilled wells (l/s · m) and penetration into the aquifer (m).

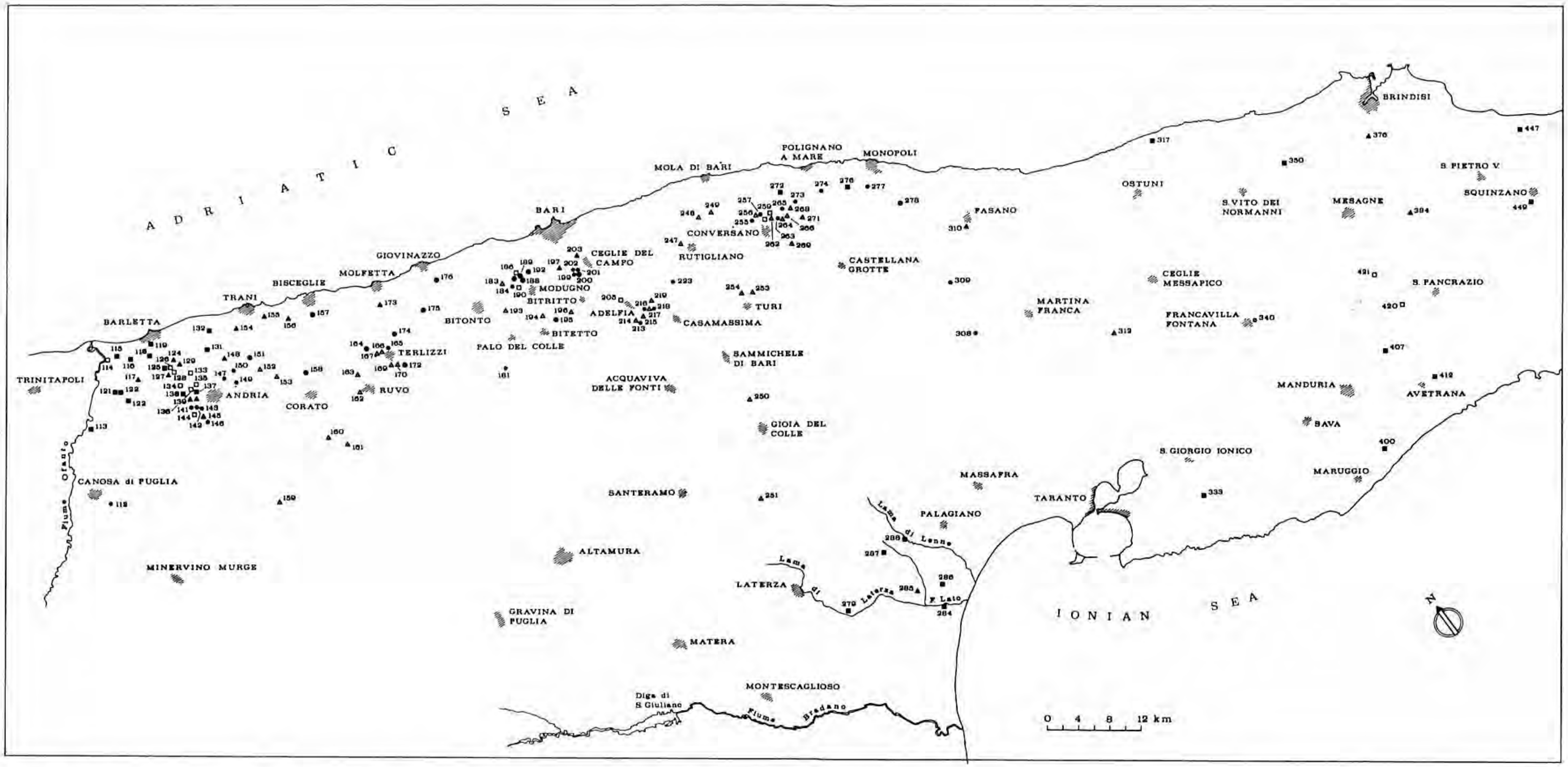

Fig. 4 - Location of wells considered on the diagram in Fig. 3. Symbols relate to groupings of the diagram in Fig. 3.

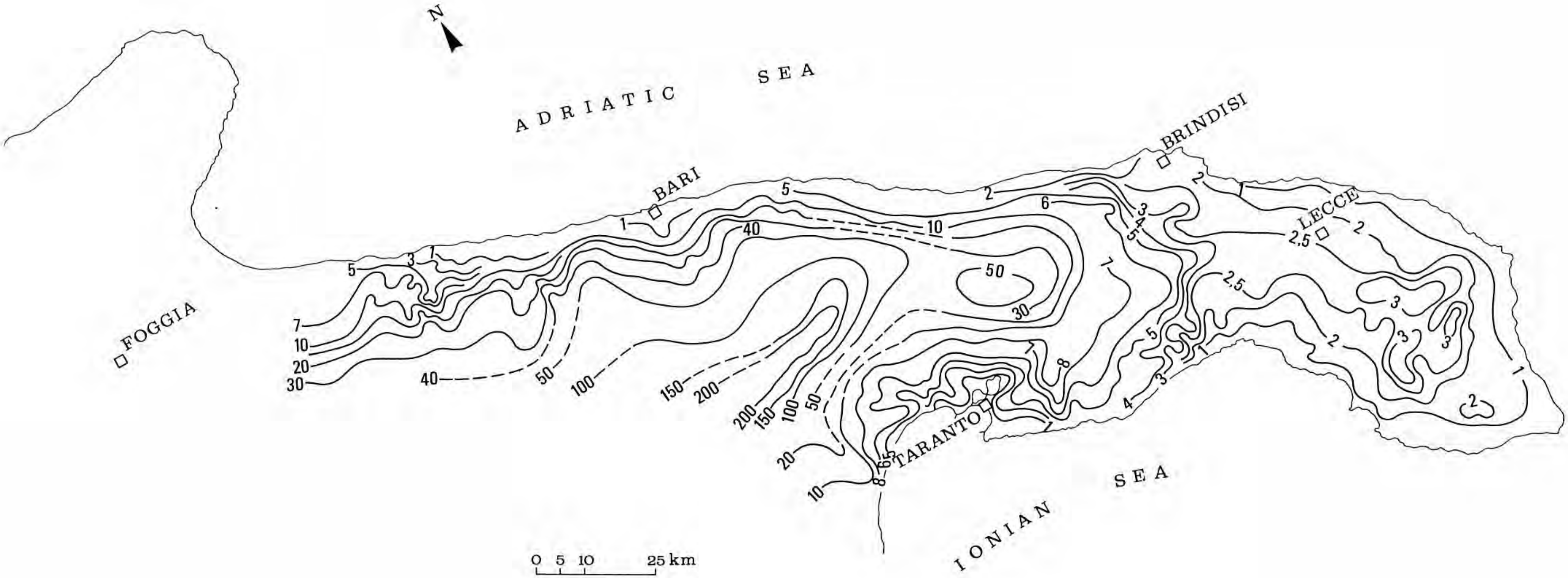

Fig. 5 – Trend of piezometric surface of groundwater in the Murgia and in the Salento.

The census of Apulian coastal springs was carried out by means of thermal infrared aereal surveys [24].

The analysis of piezometric heads distribution suggested information about the presence of salt waters underneath fresh water; such information are proved by experimental data of the zones allowing direct measurements in wells.

The Murgian aquifer reaches really considerable thicknesses; a well drilled in the north-western part of the Murgia for oil prospection found salt water beneath the aquifer at 1500 m under sea level. Elsewhere wells were drilled also at 1000 m depth, finding water with a T.D.S. of only 0.3 ÷ 0.4 g/l.

Salento stands for the typical peninsular situation, characterized by a constant presence of encroaching sea water from the Adriatic sea to the Ionian sea.

Where the aquifer assumes the greatest thicknesses, the transition zone is found at only 100 ÷ 200 m depth from mean sea level.

That is one of the reasons making the Salento's aquifer vulnerable to saline contamination brought about by drawings.

3. THE STATE OF SALINE CONTAMINATION RELATED TO THE DRAWING POSSIBILITIES

As already mentioned, a series of previous works deals with the modes of saline contamination and with field and lab-methologies used for investigating the influence of encroaching sea water on fresh ground waters.

Then the target was determining the condition of saline contamination through the territory under study. To such a purpose, saline content values of waters drained from wells on discharge tests occasions were considered, that is, it was measured the total salt content of the waters flowing in layers of greater permeability, being the most directly involved ones in the flowing [20].

Fig. 6 clearly shows the regional situation: waters with saline contents peculiar to underground waters incontaminated by the sea, that is about 0.5 g/l, are found in very broad areas of Murgia, whereas in the adjacent Salento in much more limited areas.

Saline contamination processes, then, in the Murgia are markedly noticed only in the most coastward strip, where the thickness of the aquifer is reduced, whereas in the Salento even the areas located at tens of kilometres inland are affected; here values greater than 1 g/l are by now to be considered as normal, since 3 g/l are exceeded in wide areas.

Here are the results of uncontrolled drawings, which far from decreasing, up till now are keeping on increasing due to the shortage of other water resources (the surface ones are necessarily derived from artificial basins located in neighbouring regions) which do not satisfy the actual needs of the territory.

In the meantime the map (Fig. 6) points out that safeguard and recovery actions are needed. A first step of these actions is constituted by the classification of the whole territory related to the present drawing intensity and to further drawing possibilities.

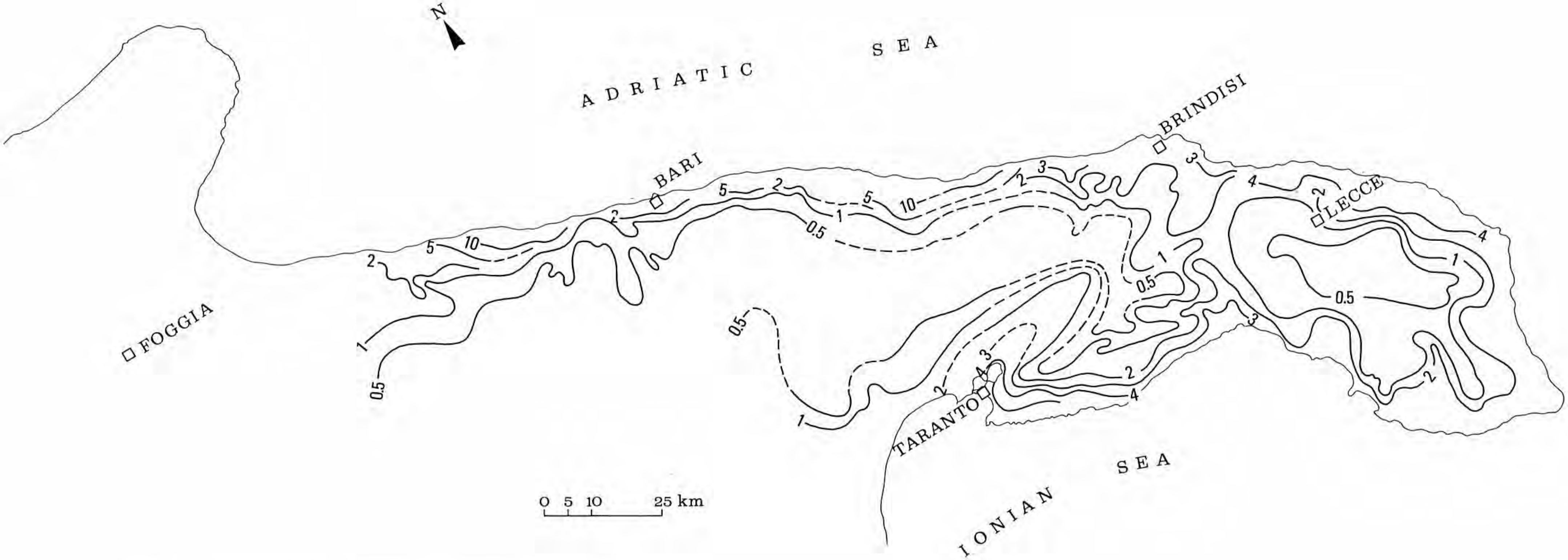

Fig. 6 – Distribution of saline content in groundwaters.

To this purpose, a census of the thousands wells scattered all over the territory was carried out; however, the results had only indicative value.

In fact no difficulty was encountered while collecting data relative to public works, but the verification of the numerical amount and of the technical features of wells drilled by private persons, turned out to be unsuccessful.

A datum of comparison was given by the census of irrigated areas allowing better information about wells occurrence.

For recovery and safeguard planning purposes [14], the real evolution of utilization state of underground waters, based on the effects resulted from drawings, appears more useful. This very fact shows importance of the map in Fig. 6 previously illustrated.

The outcoming classification is shown in Fig. 7, according to which, while in Murgia there are still areas allowing further drawings, in Salento a reorder of drawings in progress is needed. This should lead, also by means of a better utilization of underground water resource, to a drastic reduction of the same drawings.

Already in the past, studies conducted for Salento on the ground water hydrological regimen did point out an overall drawing possibility of $200 \cdot 10^6$ m^3 yearly, equal to continuous discharge of 16 m^3/s if referred to a 4 month irrigation period, against a yearly recharge volume of $950 \cdot 10^6$ m^3 corresponding to a continuons yearly discharge of about 30 m^3/s [1].

Nowadays such a limit has been exceeded and the distribution of drawing points has further contributed to worsen the hydrological imbalance.

The wells have been concentrated in particular areas just considering the best productivity of soils and the easiest accessibility to ground water resources through wells as shallow as possible.

The same map in Fig. 7 indicates the possible uses of ground waters likely to be further drawn. These are evaluations not only connected with the present verified qualitative characteristics, but also related to the vulnerability degree of ground water as against possible anthropic pollutions.

4. INTEGRATED UTILIZATION OF CONVENTIONAL AND NON-CONVENTIONAL WATER RESOURCES

A basic management tool, involving aspects connected with the recovery of those undergound water resources, which can not be used owing to their high salinity, is given by the water supply scheme in the Salento's irrigation land.

Such a scheme is based on the intersectorial use of local, fresh or brackish, conventional and non-conventional water resources (Fig. 8).

It is worth mentioning this scheme also as an example of the annual water resources management by huge storage, regulating and mixing reservoirs, in a region where climate and morphology do not allow the traditional water supply.

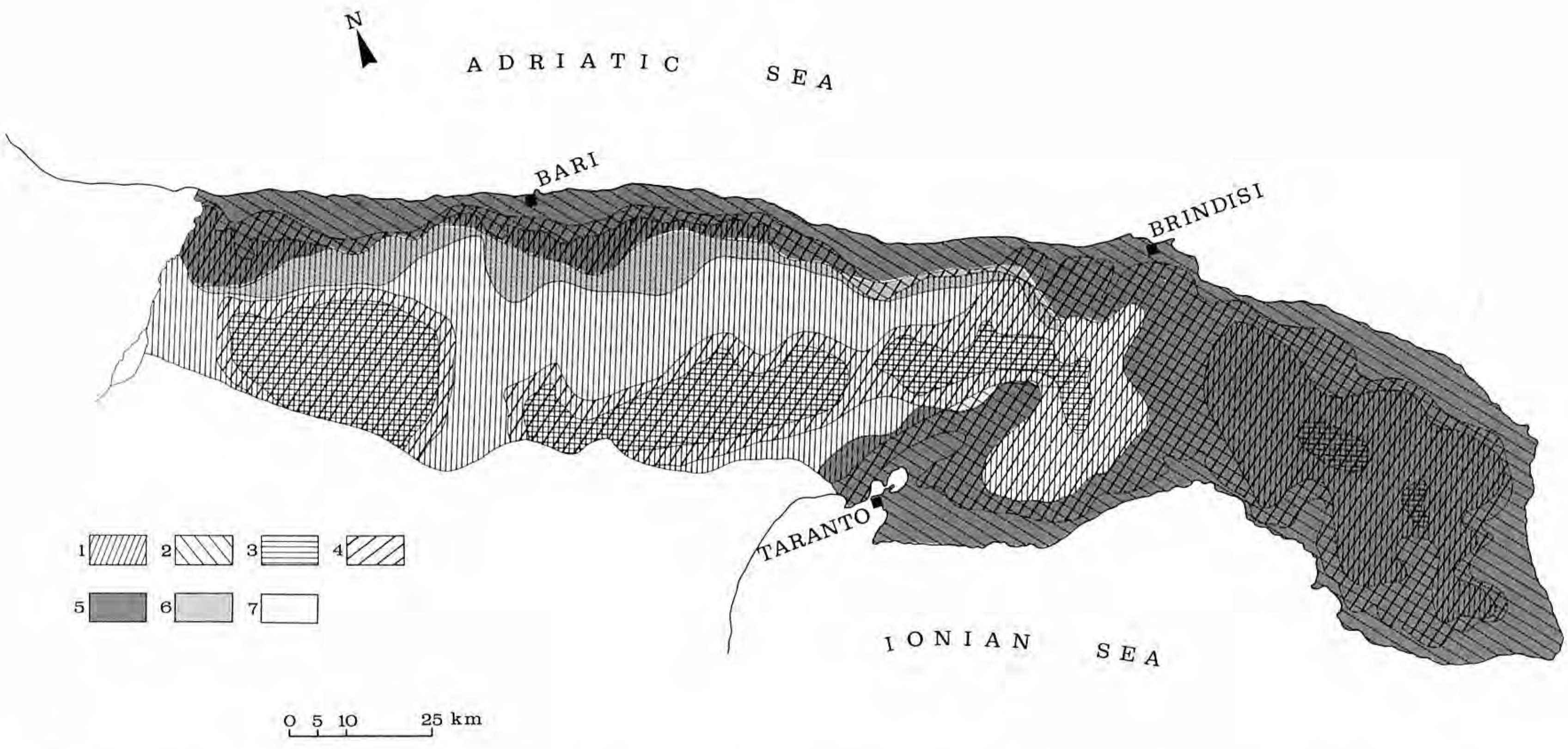

Fig. 7 – Map of the present state of utilization of underground waters and of possible further uses (1: areas likely to be drawn; 2: no water taking areas; 3: areas of potable uses drawing; 4: safeguard areas). Present state of utilization (5: massive; 6: medium; 7: low).

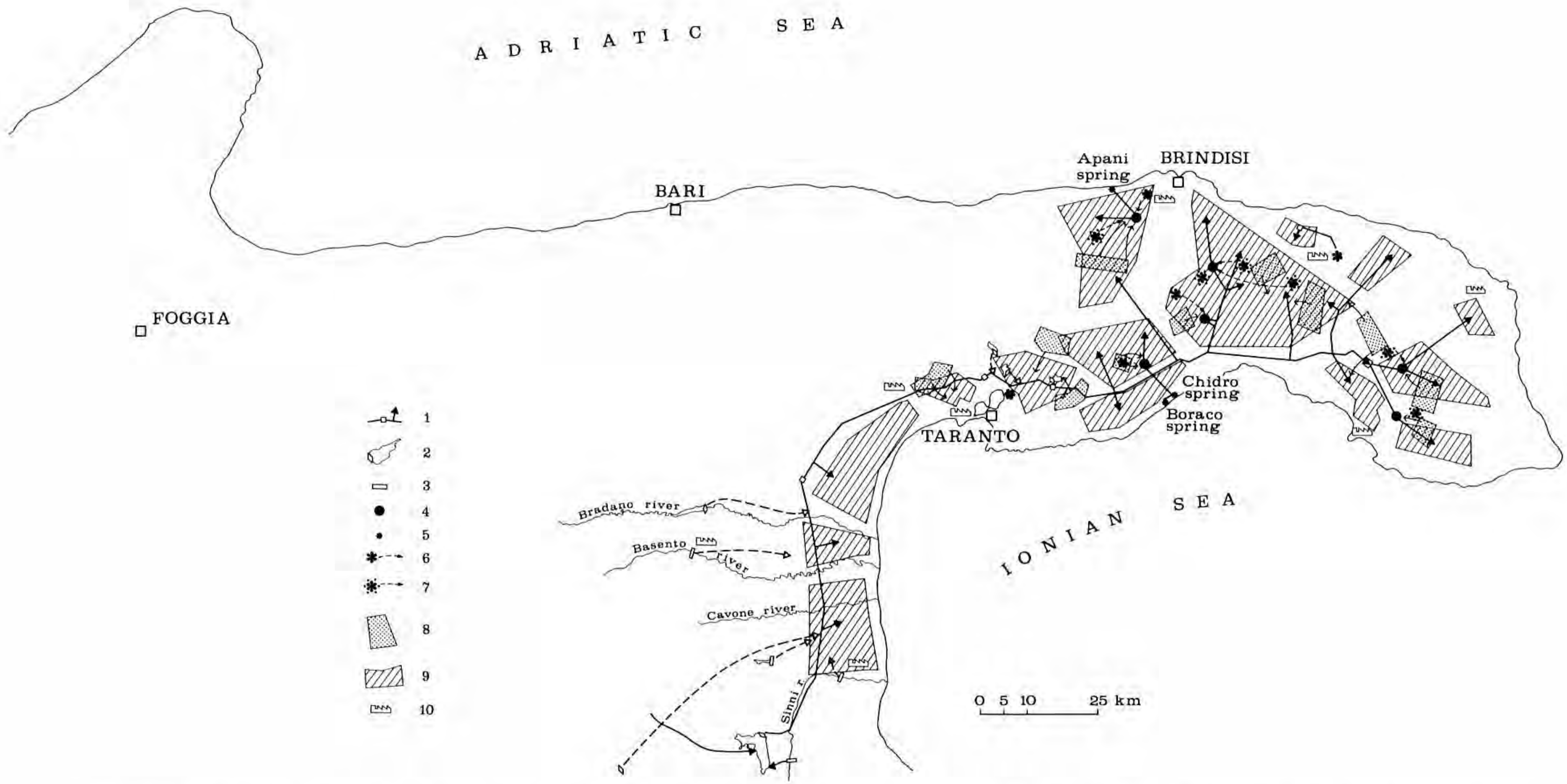

Fig. 8 – Integrated utilization of conventional and non-conventional water resources. 1: irrigation and industrial pipe and relative branchings of the Salento; 2: dams belonging to the scheme (accomplished and proposed); 3: barrages (accomplished and proposed); 4: peripherical dam reservoir (proposed) and relative irrigation directions of intervention; 5: springs; 6: single purification plants and relative delivery; 7: collective purification plants and relative delivery; 8: underground water taking areas and relative delivery; 9: irrigated zones to be served; 10: industrial zones to be served.

The system is meant to transform the irrigation system of 140,000 hectares utilizing about 330 x 10^6 m^3 of water in a standard irrigation season of 175 days.

The availability of this volume will be obtained through regional and extraregional water resources. The extra-regional resource is represented by the storage of the Sinni river water (160 x 10^6 m^3/year) during summer and winter periods. Such waters are located into the multiple-purposes reservoirs of M. Cotugno in Lucania, then conveyed to Salento by a great-diameter pipe, whose realization, reaching the beginning of Salento territory, will be carried on as far as the southernmost parts of Salento.

Regional water resource depends on the fresh ground water (30 x 10^6 m^3/year) drawing by means of drilled wells taking water from the deep aquifer, and on the interception of 65 x 10^6 m^3/year of brackish water discharged by a series of big coastal springs of both the Adriatic littoral (Idume and Apani springs) and the Ionian one (Chidro and Boraco springs) [2, 7, 17, 25].

Today thanks to the mixing with the above mentioned fresh waters, these springs, characterized by a very high salinity, can be used.

Added to this, the possibility of utilizing conspicuous volumes of waste waters (70 x 10^6 m^3/years), properly treated, outcoming from single and collective purifying plants whose building has been accomplished or is still in progress, but anyway concerning 66 Communes of Salento.

The management of all mentioned water resources coming from different places both in the winter period and the irrigation one is assigned to seven resevoirs, able to store 150 x 10^6 m^3 during the winter, and to return this volume during the irrigation period through satellite water networks and the main Sinni's one, where among other things, the mixing of the Chidro spring brackish waters takes place with a 1 to 3 proportion.

The system stands for a modern important example of intersectorial utilization of water resources providing the recovery of groundwaters subject to the effects of sea water intrusion.

The system in question is the most successful work (geographically speaking) of the wider system termed Ionio-Sinni which will utilize 1.2 x 10^9 m^3 / year of waters coming from Lucania and Apulia in order to satisfy the drinkable, industrial and irrigation demand.

The winter surplus of the listed water resources could be destined to the artificial recharge of those areas compromising by saline contamination.

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