Case History No. 9.5. Osaka, Japan, by Soki Yamamoto, Rissho University, Tokyo, Japan

9.5.1 GEOLOGY OF OSAKA

The Osaka basin surrounded by the Rokko and Ikoma Ranges is one of the typical Quaternary basins in the Kinki Triangle. The Rokko elevation reaches more than 900 m in the highest part and the sinking Osaka basin has been filled by the Pleistocene Osaka group and the later sediments which are certainly over 600 m in thickness in the central part of the basin. The horizon belonging to the lower Pleistocene which is the same one recognized at a depth of more than 500 m by boring in the Osaka basin can be confirmed at the height of 500 m in the Rokko Range. The amplitude of the folding of the basement represented by the Osaka basin and the Rokko Range is considered to reach more than 1,000 m since the early Pleistocene (Figure 9.5.1 and 9.5.2).

Complex thrust systems have developed especially along the boundary zones between uplifts and subsidences. The beds older than the middle Pleistocene are divided by thin tuff beds of Ma_0, Ma_l, Ma_2, --- , Ma_{l2}, and have been strongly disturbed by faulting everywhere around the Osaka basin. Terrace deposits have been confirmed to be displaced by faulting at many places. For example, the granite mass of Rokko has thrust up against the higher terrace deposit.

A wide terrace developed in the northern part of the Osaka basin; it is named the Itami terrace, and is the lowest one in this area. The Itami gravels composing this terrace surface gently dip to the center of the Osaka basin. A radiocarbon age determination made on a wood fragment contained in the Itami clay which is overlain by the Itami gravels is 29,800±1,200 years B.P.

The distribution of the "Alluvial deposits" in Osaka has been revealed by boring and the sonic Sparker survey. The deposits indicate the curvature of the surface of the basement and may suggest the shape of basin-forming recent subsidence of the Osaka basin (Table 9.5.1).

9.5.2 HYDROLOGY AND SUBSIDENCE

The first layer below the ground surface is an alluvial layer except on the Uemachi upland running south from the vicinity of Osaka Castle. The average thickness of this alluvial clay layer is about 15 m. The thickness becomes greater as it approaches the coastal zone. Below the Alluvium are very thick Diluvial deposits of Pleistocene age, which consist of alternations of sand and clay layers. Both alluvium and diluvium layers form an excellent aquifer in this district (Figure 9.5.3).

The ground water head was very high in the city until about 50 years ago. It is reported that even flowing artesian wells could be seen at some parts of the city. With the development of industry, however, the use of ground water gradually increased and land subsidence due to the withdrawal of ground water began to appear. Before 1928, the land subsidence in the city was very slight, being at a rate of 6-13 mm/yr. This slight subsidence is considered to be the result of the natural movement of the earth crust and of the natural consolidation of the newly deposited alluvial clay.

After that time, however, a remarkable increase in use of ground water caused an increase in the rate of subsidence (Table 9.5-2).

Since that time, precise leveling for the wider part in the city has been carried out every year by the Osaka Municipal office following the suggestion of M. Imamura. Besides the leveling, the amount of consolidation of soil layer and the artesian heads of various aquifers (O.P.* -33 m, O.P. -62 m, O.P. -176 m) were observed by self-recording apparatus by K. Wadachi at Kujoh Park in 1938. Figure 9.5.4 shows the total amount of subsidence of various bench marks in

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* O.P. (Osaka Peil) means the lowest low-water level observed in Osaka Port in 1885 and this level is used as the standard datum in Osaka area.

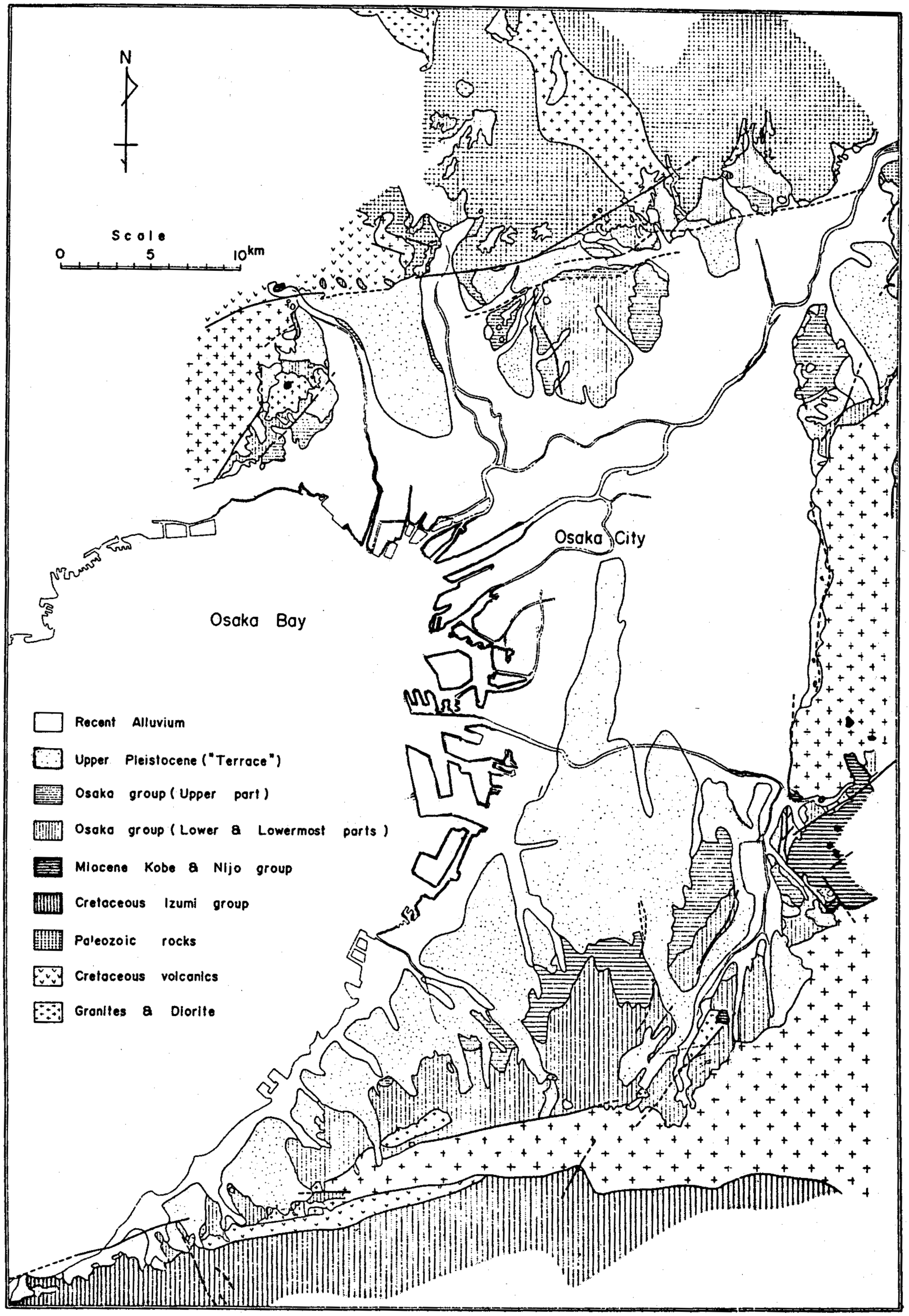


Figure 9.5.1 General geologic map.

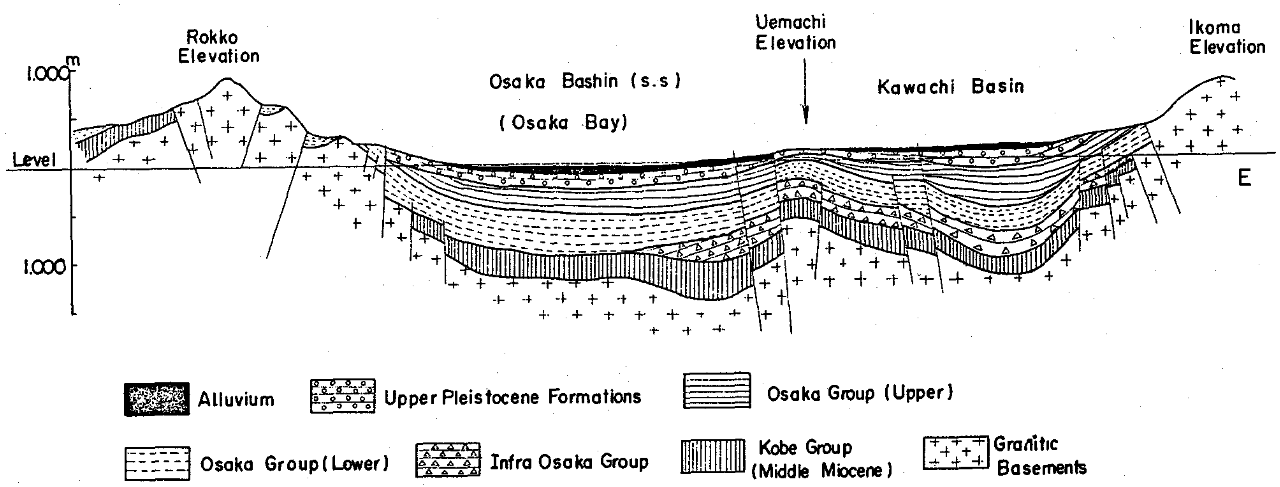


Figure 9.5.2 Diagrammatic profile of the Osaka basin (Ikebe & Takenaka).

western Osaka and secular variation of the artesian head at the Kujoh well 176 m deep. As seen in this figure, the rate of subsidence seems to be classified into four phases. In the first period from 1935 to 1943 the land subsidence was very rapid as the industry in the city developed. In the second period from 1944 to 1951, land subsidence was very slight or sometimes stopped. At that time, industrial activity was greatly depressed by the war disaster and the use of ground water decreased. It began to increase again in the third period from 1952 to 1964 because of the remarkable increase of industrial water use. From 1964 to the present, it has decreased because of the regulations against ground water use. The variation of ground water head is almost similar to that of land subsidence.

The artesian head and rate of subsidence are closely correlated at the Kujoh well. In spite of some unconformity of peak years, however, the general features of the variation in the artesian water head and in the rate of subsidence show a close correspondence and suggest a causal connection between these phenomena. The period when land subsidence stopped corresponds to the period of recovery of the ground water head (Figure 9.5.4).

The total subsidence during 34 years from 1935 to 1968 in Osaka is shown by the isopleths in Figure 9.5.5. In this figure, it can be noticed that the subsidence is larger nearer to the coastal zone, and a zone of little subsidence is left in the upland in the middle of Osaka where no alluvial covering exists. The subsidence area covers about 570 km^2 at present, but is successfully decreasing.

In spite of the success in preventing land subsidence in Osaka City, the subsidence in eastern and northern Osaka has increased remarkably during the recent few years. These regions have been developed lately and many factories which demand much ground water have been built.

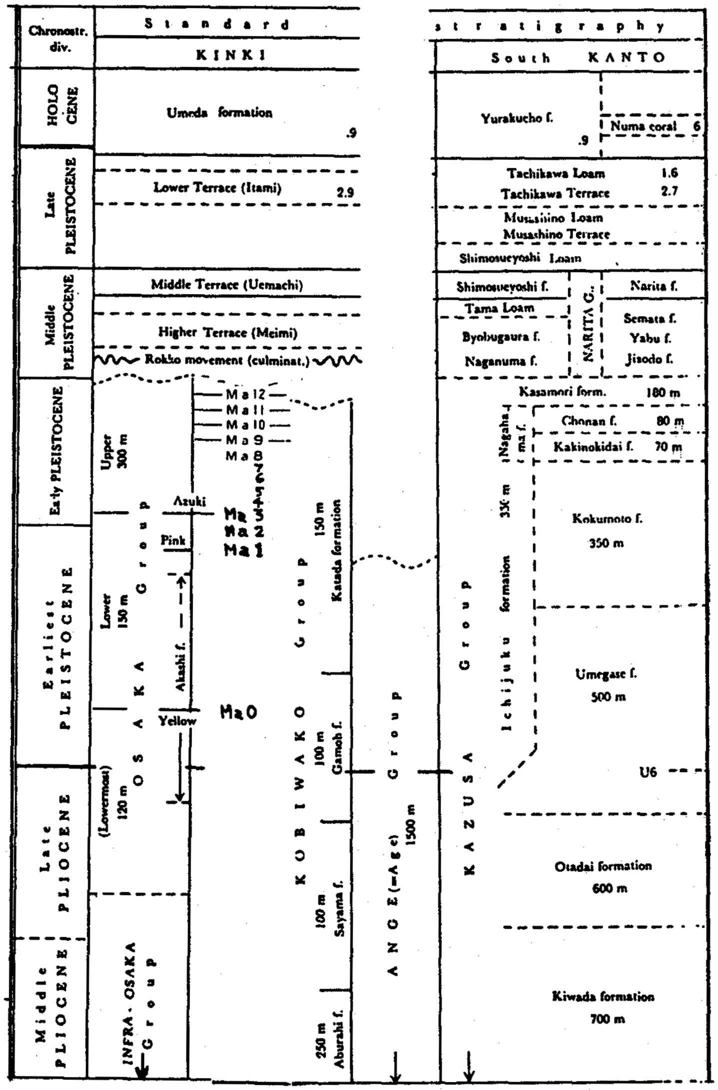
9.5.3 PARAMETERS

The compression index C_c was obtained by the standard oedometer test. The value varies from 0.2 to -1.8 and is proportional to the liquid limit w_L. The equation of the regression line is $C_c = 0.017\ (w_L - 37)$. The preconsolidation pressure varies from 2 to 50 (kg/cm^2). It increases proportionally to the depth and is generally larger than the present effective overburden pressure.

9.5.4 ECONOMIC AND SOCIAL IMPACT

This can be seen from Figure 9.5.6 easily. Total amounts of industrial products are presented in yen deflated in economic appraisal of 1965.

Table 9.5.1 Stratigraphic correlation of geology in Osaka.



9.5.5 COUNTERMEASURES WITH LEGAL REGULATION

Due to land subsidence, the ground surface of a part of western Osaka has sunk below sea level and the city is exposed to the danger of floods caused by storm surges in Osaka Bay. Subsidence areas below high tide have extended to about 100 km^2.

In 1934 a very large flood occurred, caused by the Muroto Typhoon, the biggest typhoon that ever attacked Osaka. An area of about 49 km^2 was flooded by the storm surge of O.P. + 4.20 m. In order to prevent further disasters, the dikes have been repaired and built more satisfactorily.

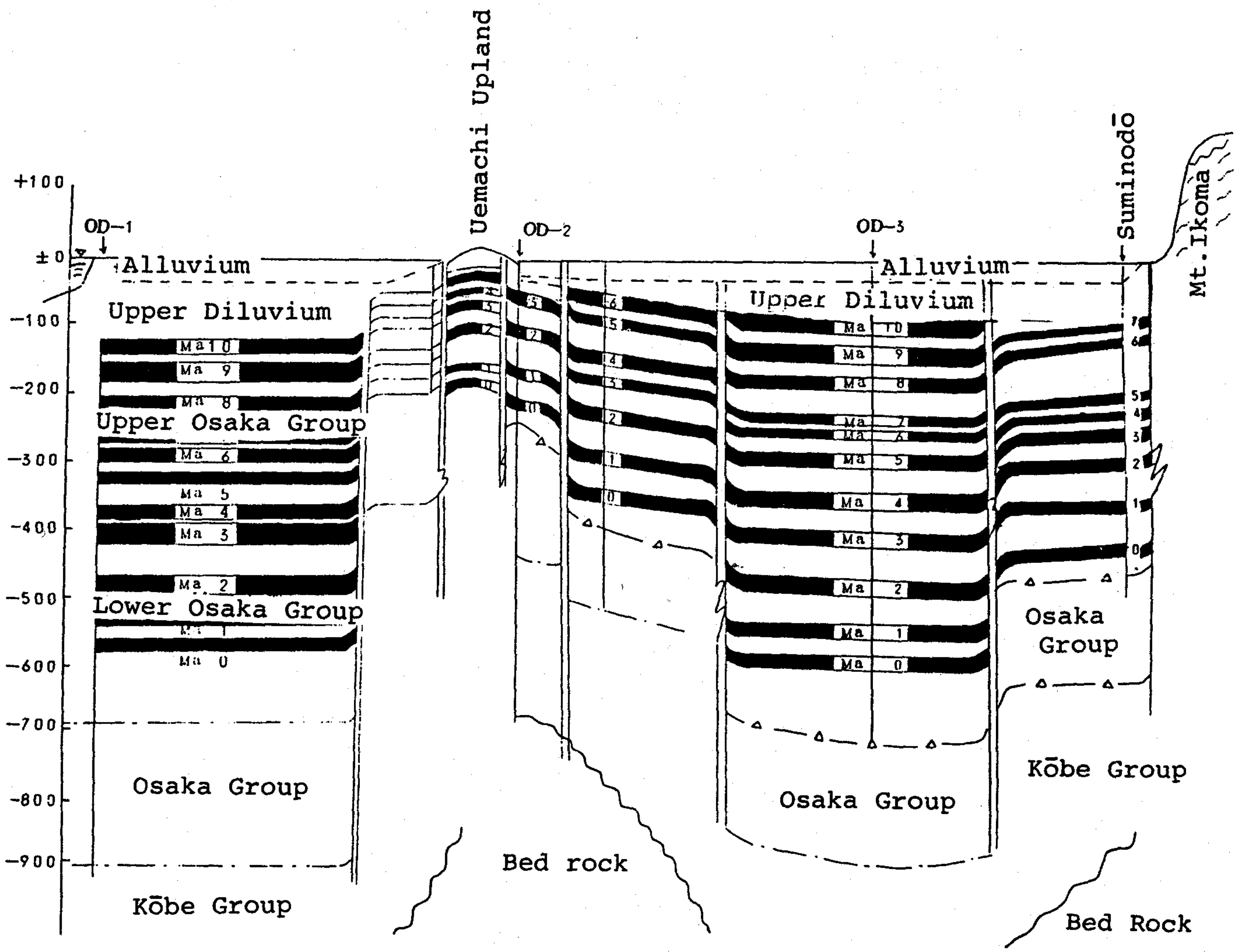


Figure 9.5.3 Geologic cross section of Osaka.

Table 9.5.2. Change of ground water withdrawal in Osaka

Year	Discharge amount x 10^3 m^3/year	Year	Discharge amount x 10^3 m^3/year	Year	Discharge amount x 10^3 m^3/year
1920	956	1956	65060	1963	94780
1930	6386	1957	93120	1964	79190
1940	18997	1958	110720	1965	56120
1945	19309	1959	130420	1966	34410
1953	30000	1960	144100	1967	15400
1954	37440	1961	130420	1968	4660
1955	57440	1962	123680	1974	42

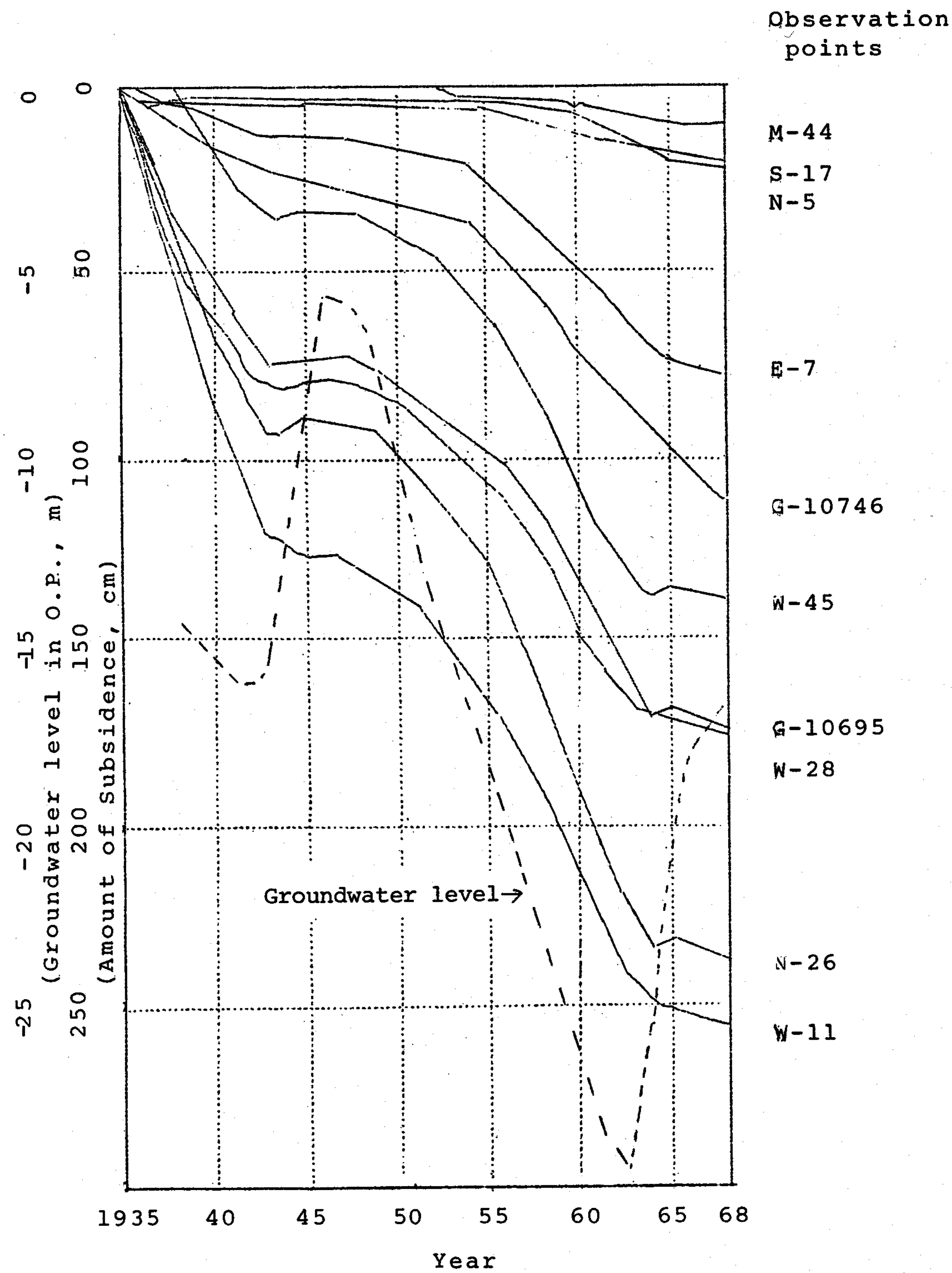


Figure 9.5.4 Secular changes of land subsidence and ground-water level in Osaka.

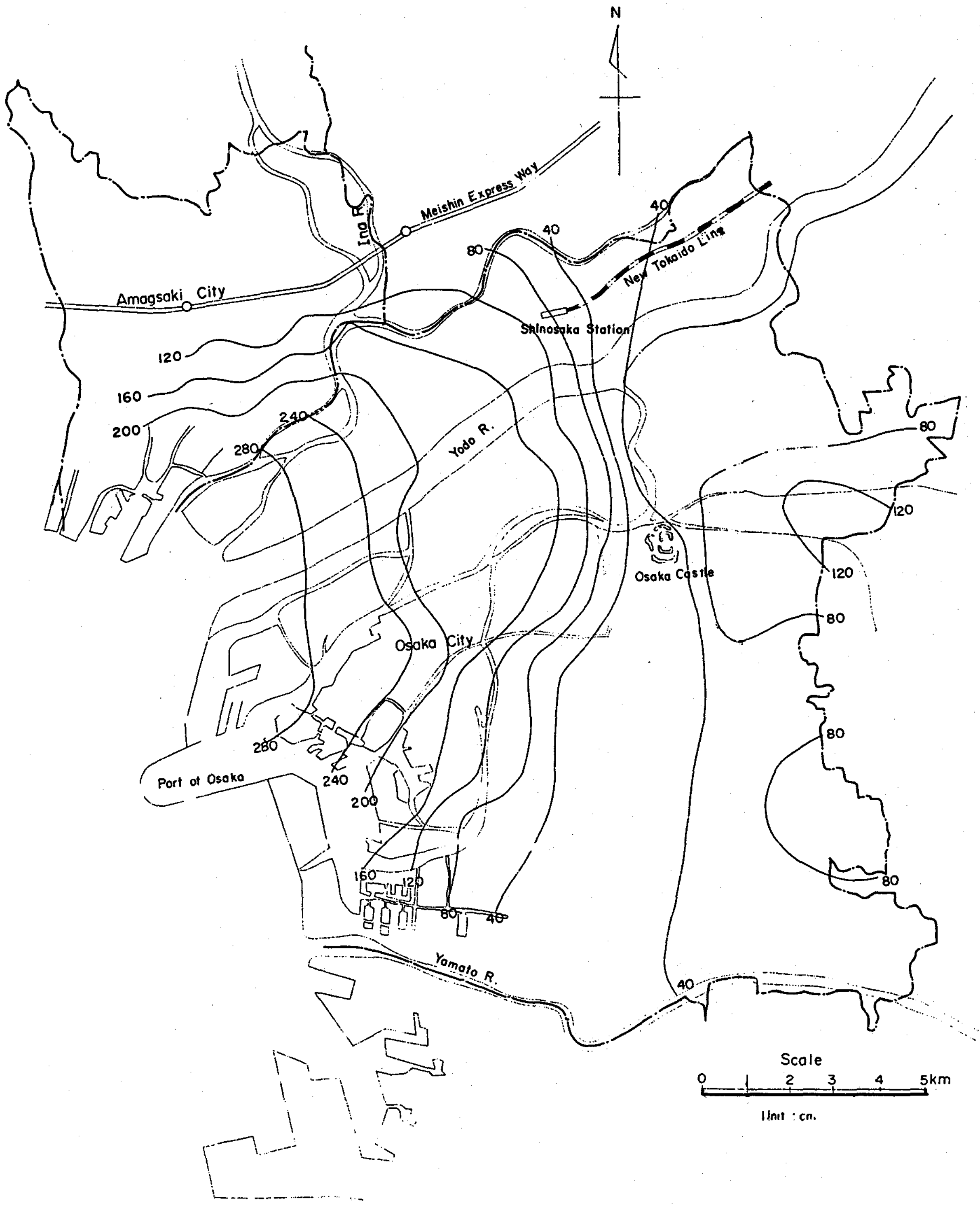


Figure 9.5.5 Isopleths of amount of land subsidence in Osaka area from 1935 to 1968

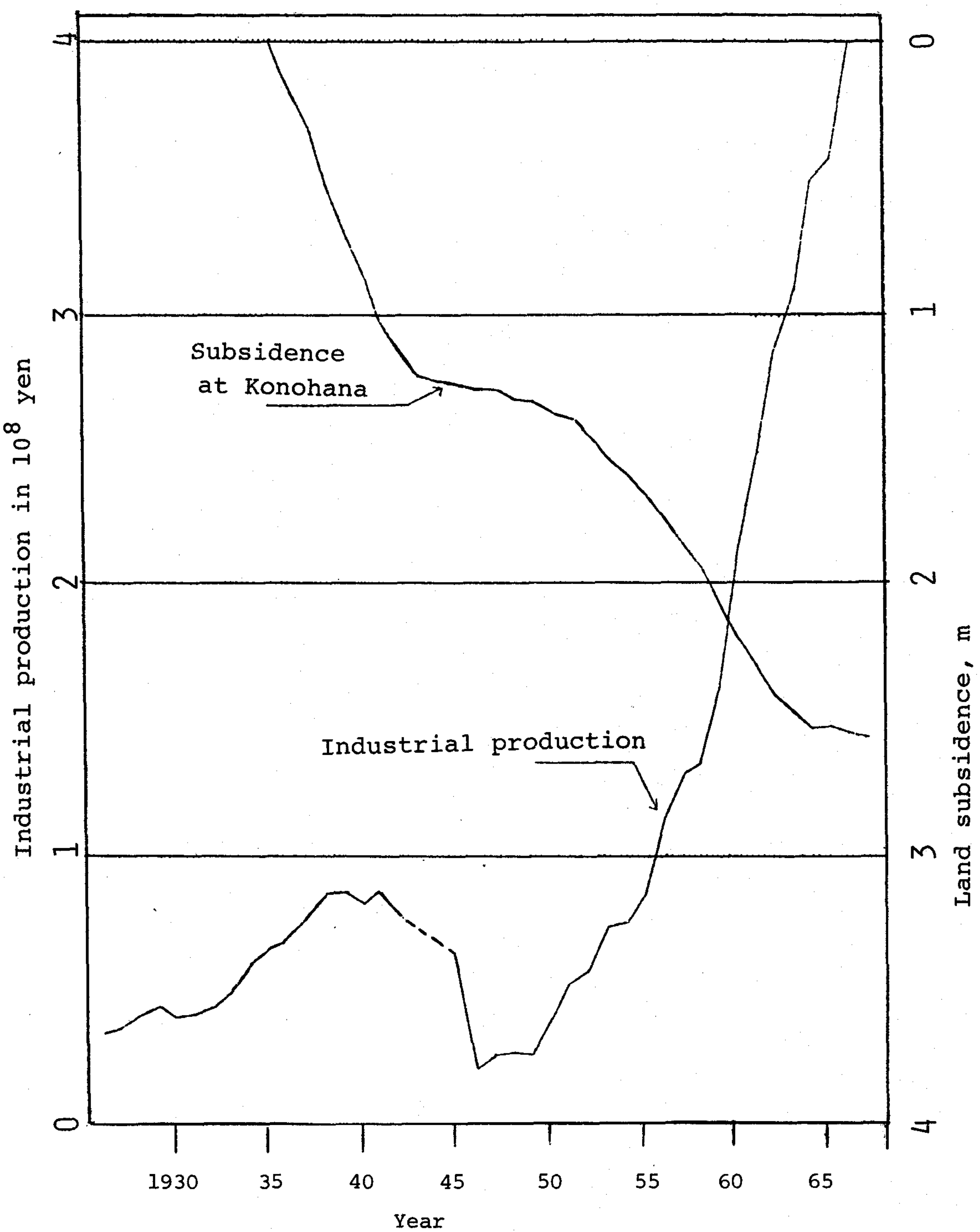


Figure 9.5.6 Land subsidence and industrial production in Osaka Prefecture. (Industrial production is inflated to the value of 1965.)

Besides these prevention works, the use of ground water has been gradually regulated in accordance with the progress of the industrial water supply works for delivering surface water, which was planned as the substitute for ground water. In 1962, Osaka City constructed industrial water supply works and in 1970, the Osaka prefectural government also constructed industrial water supply works introducing water from the River Yodo which started from Lake Biwa, the biggest lake in Japan.

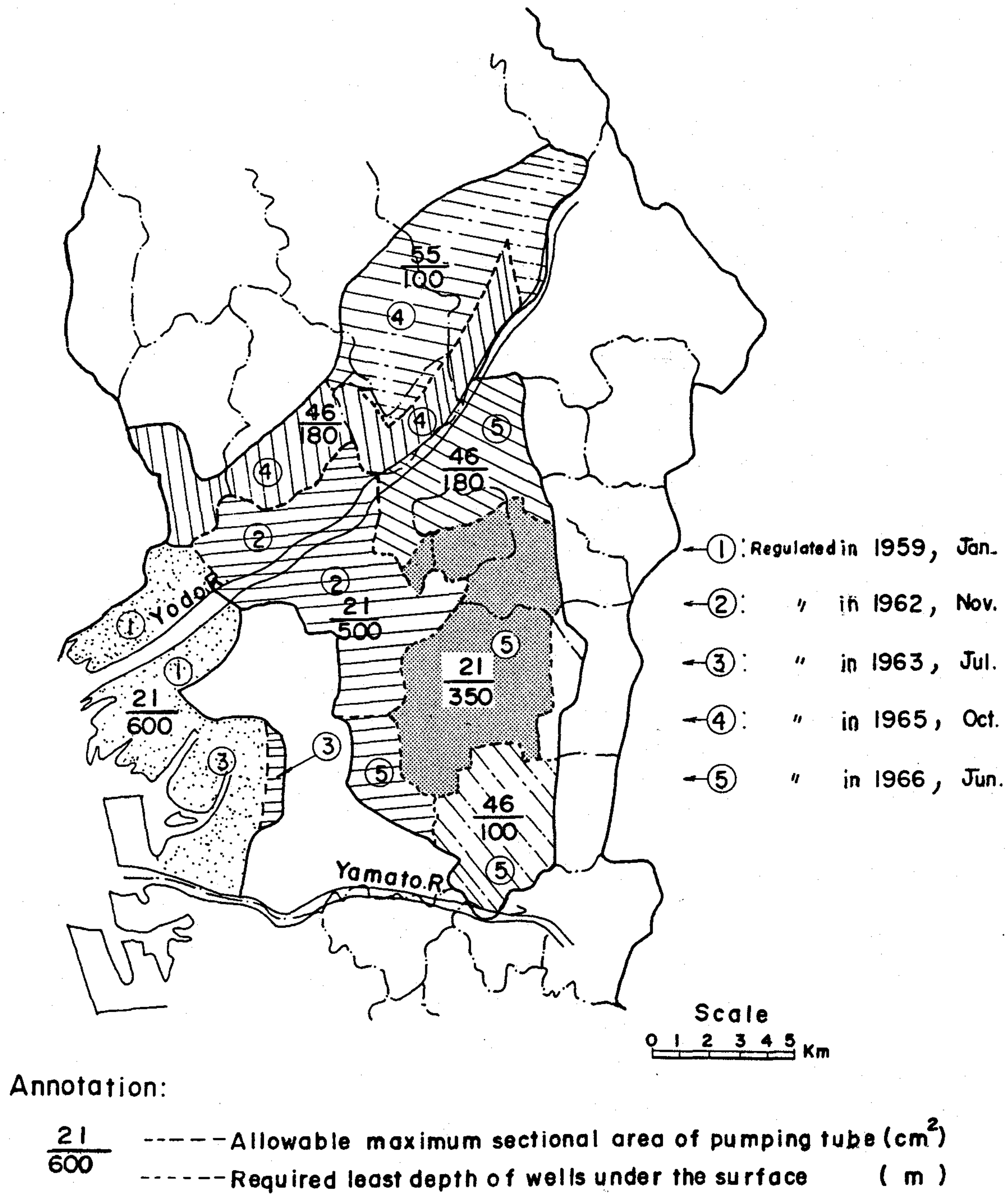


Figure 9.5.7 Regulated areas against use of ground water for industry.

Because of the regulation against the use of ground water in Osaka City land subsidence in the city gradually decreased and has almost stopped at present (Figures 9.5.7 and 9.5.8).

9.5.6 SELECTED REFERENCES

MURAYAMA, S. 1969. Land subsidence in Osaka, IASH Pub. No. 88, p. 105-130

NAKAMACHI, H. 1977.Land subsidence in Osaka, Soil and Foundation, 25-6, p. 61-67.

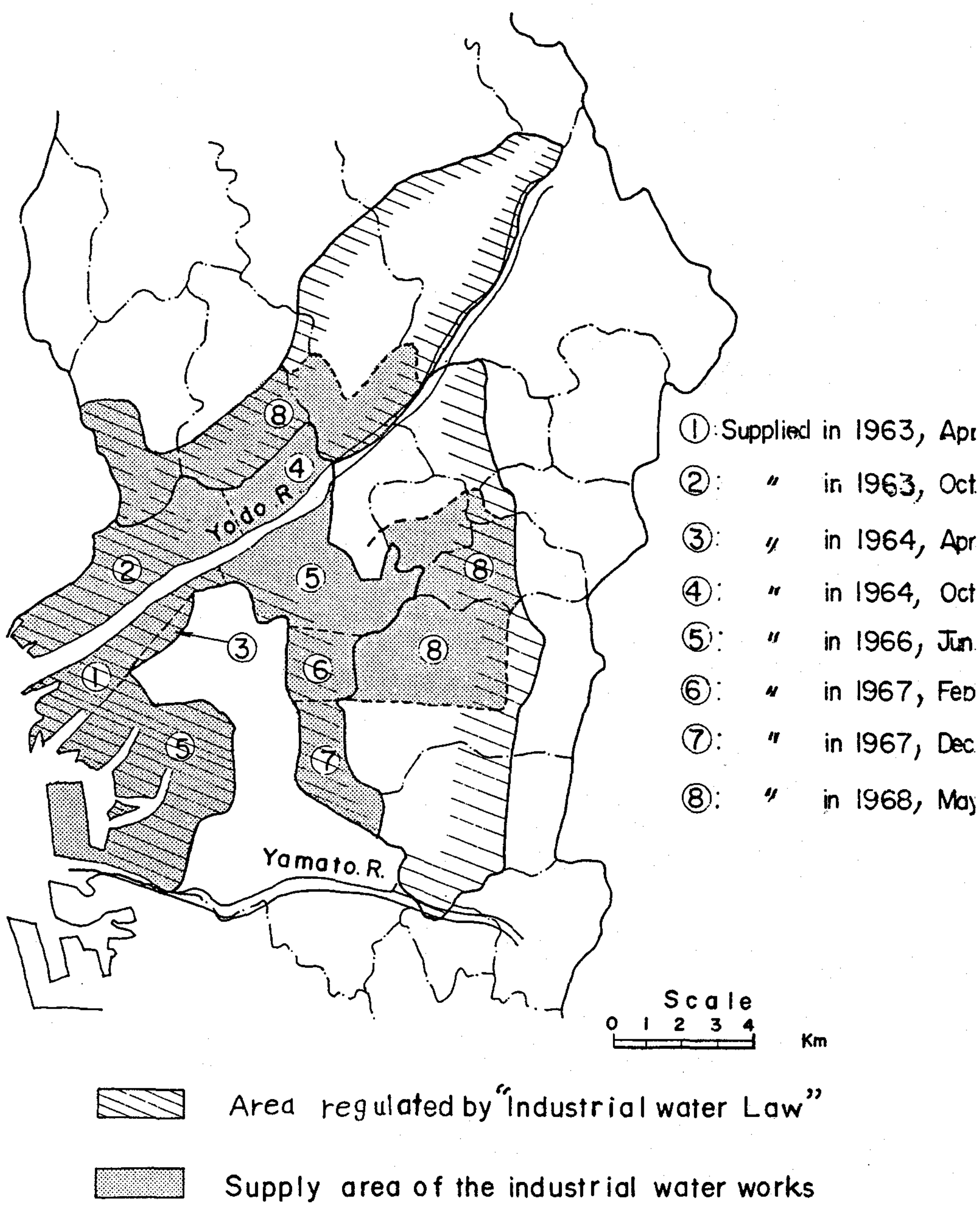


Figure 9.5.8 Supply area of industrial waterworks.