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The Wells in the Central Section of the Nasuno-Basin— A Problem of the Regional Division

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In this paper the wells in the central section of the Nasuno-basin are considered, especially in connection with their depth, the depth of the water table and the thickness of the water. The areal differentiations of the wells are systematized on the basis of these fundamental characters and the results are arranged in the form of the regional division which may all serve as one of the important preliminary studies for the geographical investigations into the ground water and also for those investigations into the irrigation of paddy field which is practised widely in this basin, using the electric pumping wells.

The field survey concerning the depth of the wells together with the depth of the water table was carried out on Oct. 1, 1950 by the Ministry of Agriculture and Forestry for 128 wells distributed in the central section of the basin. The result was published under the title " The Record of the Survey on Existing Wells " being included in " The Series of Reports on the Land Reforming of the Nasuno-gahara " (Jap.). In addition to this survey, the fluctuation of the water table was observed by the same Ministry especially for nine out of those 128 wells during the period from Oct. 1, 1950 to Sep. 30, 1951. Although the character of the water table fluctuation is somewhat different according to the individual wells, yet the highest levels are recorded for those nine wells uniformly in October of the above-mentioned period. As a natural consequence it may reasonably be supposed that the observation in connection with those 128 wells, which was carried out on Oct. 1, concerns at least one of those highest water tables which occurred during the period in question.

The Method of the Regional Analysis.

Analysing the results of this observation regionally, i. e. taking especially the areal differentiations of the depth of the wells as well as the depth of the water table and the thickness of the water into consideration, the author recognized six subsections within the central

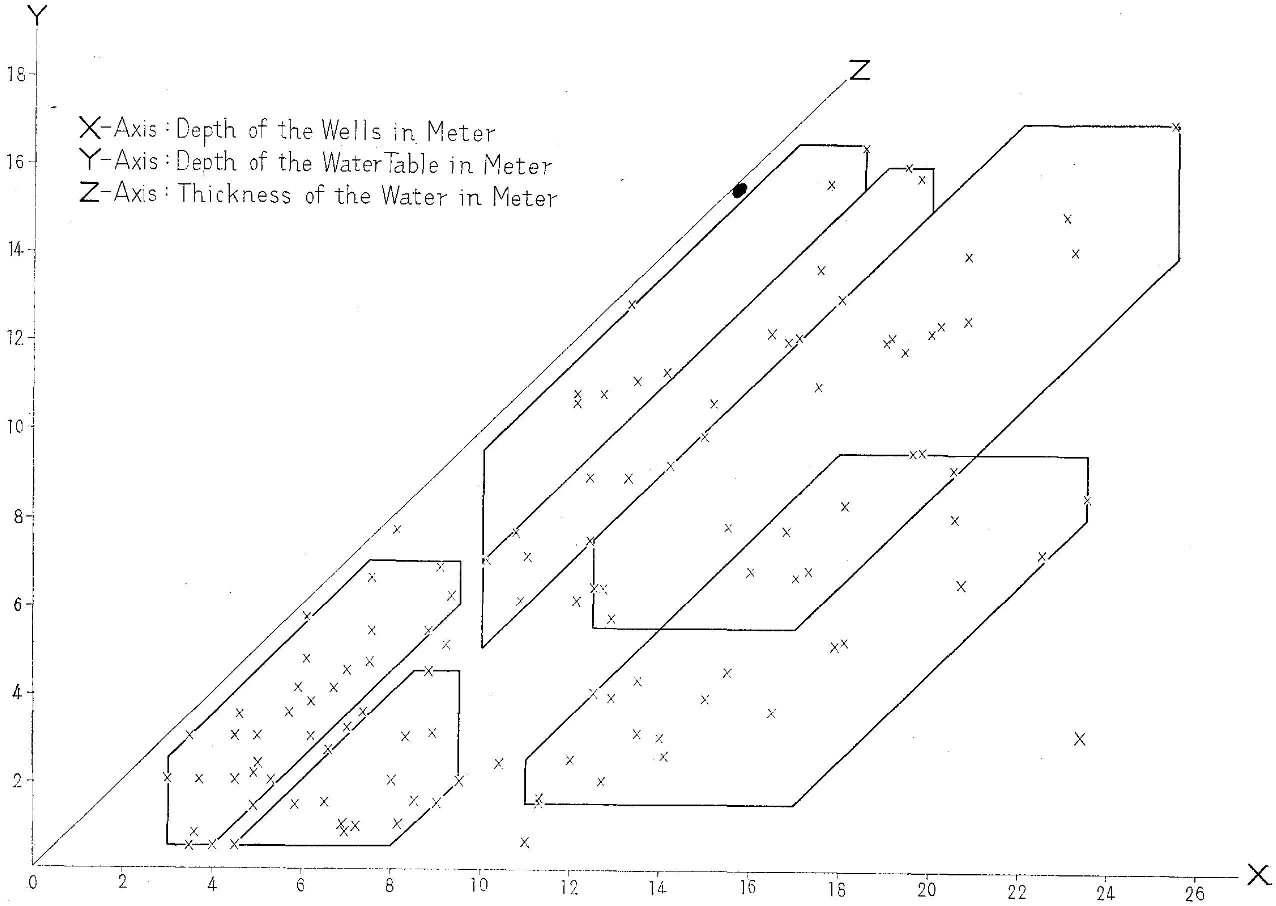

Fig. 1. A coordinate to illustrate the relationships among x, y and z, i. e. the depth of the wells, the depth of the water table and the thickness of the water in connection with the wells being situated in the central section of the Nasuno-basin, which were surveyed on Oct. 1, 1950. The wells are represented on the coordinate by the symbols $\times$ and are brought together into six regional groups which are illustrated in Figs. 2 and 3. The z-axis is explained in the text.

section of the basin. The rectangular coordinate (Fig. 1) on which the x- and the y-axis represents respectively the depth of the wells and the depth of the water table, is used for this regional analysis as an effective tool. The wells are represented on this coordinate by the symbols $\times$ which correspond to the respective value of x and y as shown in Fig. 1.

On this coordinate the thickness of the water, i. e. $x-y$ is measured conveniently by the aid of the diagonal line z, i. e. the z-axis which passes through the original point and inclines at an angle of 45 degrees to the x- and the y-axis respectively. Since the point of intersection between the z-axis and the line that passes through any point $a(x_1, y_1)$ and runs parallel to the y-axis is given by a point b (x_1, x_1), the thickness of the water of a well which is represented by the point a, i. e. the thickness x_1-y_1 is measured exactly by the distance between these two points a and b. Now, turning to the x-axis we can apparently see that the distance in question is equal to the distance between the original point and the point of intersection between this axis and the line that passes through the point a and runs parallel to the z-axis.

Using this character of the coordinate as a method of diagramatic representation, the wells are grouped into six polygons, everyone of which is confined by five or six lines running parallel to the x-, the y- and the z-axis respectively. These lines which correspond to certain respective value of x, y and z, represent those limiting values regarding the depth of the wells, the depth of the water table and the thickness of the water, which are characteristic of each individual group. These limiting values are given in Table 1.

Corresponding to these six groups which are expressed by the symbols A, B, C, D, E and F on the present coordinate as shown in Fig. 2, six subsections A, B, C, D, E and F in the central section of the basin are delimited on the basis of the same limiting values

Table 1. Upper and Lower Limits of Depth of Wells, Depth of Water Table and Thickness of Water

Symbols of Subsections	Upper and Lower Limits		
	Depth of Wells	Depth of Water Table	Thickness of Water
A	3 — 9.5	0.5— 7	0.5— 3.5
B	4.5— 9.5	0.5— 4.5	4 — 7.5
C	11 —23.5	1.5— 9.5	8.5—15.5
D	10 —18.5	7 —16.5	0.5— 3
E	12.5—25.5	5.5—17	5 —11.5
F	10 —20	5 —16	3 — 5

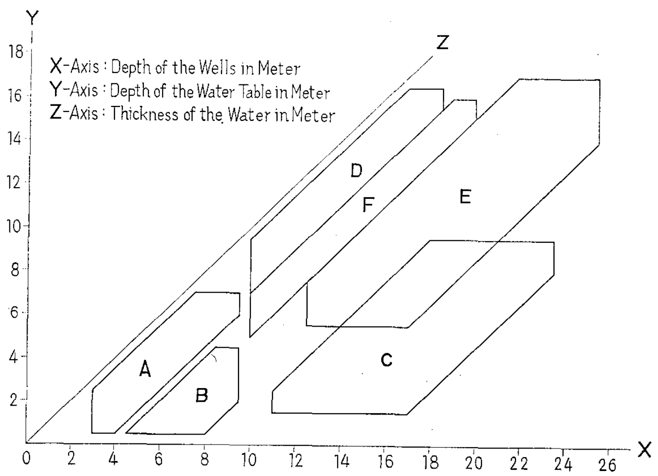

Fig. 2. A coordinate to illustrate the limits of six regional groups of the wells, which are represented by A, B, C, D, E and F. Compare with Fig. 1.

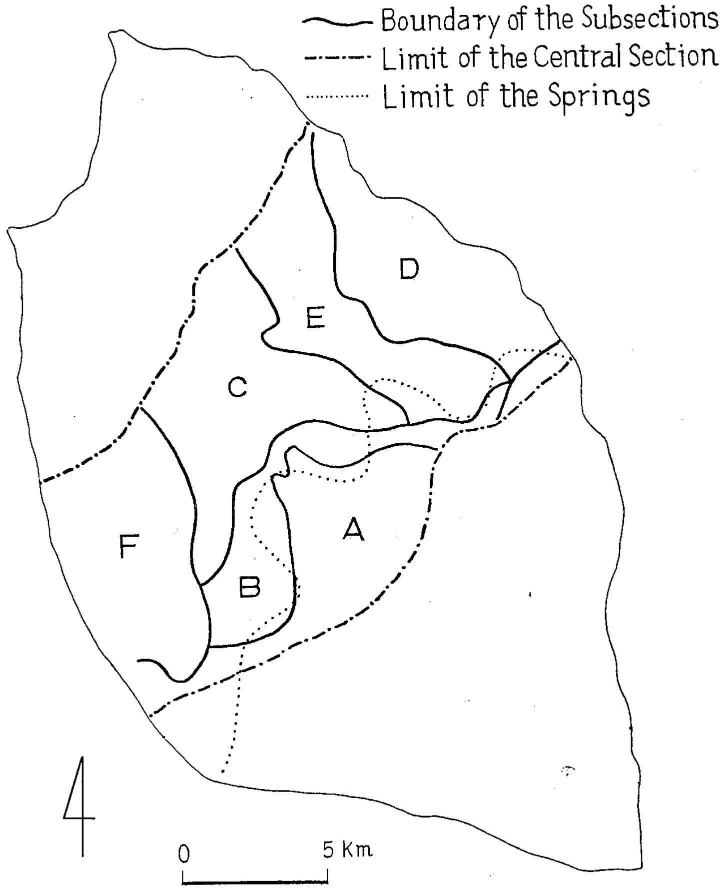

Fig. 3. A map to illustrate six subsections A, B, C, D, E and F composing the central section, each one of which corresponds respectively to the group A, B, C, D, E and F represented in Fig. 2.

regarding the depth of the wells, the depth of the water table and the thickness of the water. These six subsections which constitute a system of contiguous region, are illustrated in Fig. 3.

The fact that the points which represent the position of the wells on the coordinate are grouped into those six polygons points out a series of similar functional relationships existing between x and y, i.e. between the depth of the wells and the depth of the water table within these six subsections: in every subsection the depth of the water table increases, as a general rule, keeping pace with the depth of the wells. This relationship is expressed by the function $y=x-c$, in which c means a value which is proper to the respective subsection, or in other words, which varies within the range of the upper and the lower limits of the thickness of the water characteristic of each subsection.

The Six Subsections.

In connection with these subsections some important characteristics are summarized as follows, by reference to Figs. 1, 2 and 3 and also to Table 1.

(A) This subsection occupies the southernmost part of the central section. As for the depth of the wells as well as for the thickness of the water, A is one of the smallest in the central section. As will be mentioned later, the wells which attain a depth of more than 6 m are distributed, so far as A is concerned, mainly in the southwestern corner of this subsection.

(B) This subsection which is situated north and northwest of A, extends as a long and narrow belt being contiguous to A. As compared with A, though the depth of the wells ranges within similar limits, the water attains, on the other hand, considerably greater thickness. Consequently the depth of the water table remains within the limits of those values comparable to the smaller depth in A.

(C) This subsection is situated north of B and occupies the recent flood plains of those rivers Sabi and Kuma. Concerning the depth of the wells C together with D, E and F, all of which is distinguished by the depth attaining more than 10 m, exhibit a striking contrast with A and B. The depth of the water table which is the smallest as compared with the water table in D, E and F, remains, on the other hand, quite similar to that of A. Even while the depth of the wells is so large, it is the most conspicuous character of C that the depth of the water table is so small, which is due to the large thickness of the water during the high water season.

C constitutes a contiguous series of subsections along with A and B, which series is characterized by the depth of the water table being far smaller as compared with the group D, E and F. In this series of A, B and C the depth of the wells and especially the thickness of the water, on the other hand, increases generally from south to north, i. e. from A through B to C, thus exhibiting a striking contrast with regard to x and z among these subsections (Figs. 4 and 5).

(D) This subsection occupies the northeastern margin of the central section. D together with E and F constitutes a group in which not only the depth of the wells but also the depth of the water table remains commonly and characteristically great. The thickness of the water, on the other hand, is rather different among these subsections, the order from small to large being D, F and E. Concerning the thickness of the water D is one of the smallest among the six subsections and is quite comparable with A, though the depth of the wells as well as the depth of the water table are markedly greater as compared with A. Among others D is the most unfavorably equipped for the utilization of the ground water.

(E) This subsection is situated contiguously between C and D and extends from southeast to northwest. As for the depth of the water table E is quite similar to D, though concerning the depth of the wells and especially the thickness of the water, E is larger compared with D. D and E constituted formerly the main part of the so-called Higashi-hara (Eastern-wilderness), the greater part of which was settled for the first time after the Meiji era, being hindered chiefly by the unfavorable conditions of the ground water.

(F) This subsection which formed the main part of the ancient Nishi-hara (Western-wilderness), is located along the western border of the Nasuno-basin and is situated contiguously to the west of C. Just like the above-mentioned D which extends along the eastern border of the basin, the characteristic features of F are the large depth of the wells as well as that of the water table. The thickness of the water which exists just between those in D and E, remains considerably small. These conditions combined, retarded the cultivation of the greater part of the Nishi-hara until the Meiji era, in a similar way as the reclamation of the Higashi-hara mentioned above.

The Distribution of the Depth of the Wells.

The general distribution of the depth of the wells is shown in Fig. 4 by means of the isopleth connecting the points of same depth. For constructing this distribution map, the simultaneous survey concerning both the depth of the wells and the depth of the water table, which was carried out by the Ministry of Agriculture and Forestry on Oct. 17, 1961 and which was published in "The Report on the Survey in the Nasuno-ga-hara" (1962, Jap.), is taken into consideration together with the survey analysed in the preceding chapter. This new survey covered 111 wells which are found in the area including the southernmost part of the central section treated above and extending southward to some extent. In Fig. 4 the boundary line of this extended central section is illustrated.

In connection with the distribution of the depth of the wells the most significant facts are summarized as follows:

Although in general the present isopleths represent roughly parallel lines which trend eastwest in the northern part of the central section, showing the general increasing tendency regarding the depth of the wells from south to north or from the terminal to the apex area of the fan, they turn abruptly towards the south especially in the southwestern part where the depth increases rather from southeast to northwest. Taking this characteristic pattern of the isopleths into consideration, the central section may be reasonably divided into the eastern and the western parts which are compared and contrasted with each other. In the eastern part, the isopleth representing 6 m depth is situated far up to the north as compared

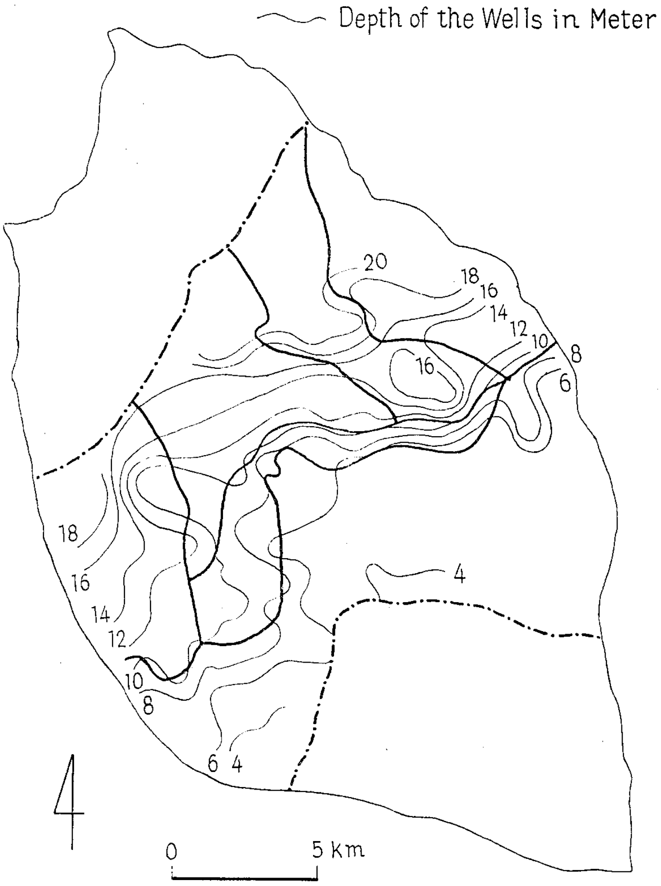

Fig. 4. A map to illustrate the distribution of the depth of the wells, which is represented by means of the isopleth. The boundaries of six subsections are entered in the map. The area of the central section which is taken into consideration is extended, using the survey on Oct. 17, 1961 jointly with the survey on Oct. 1, 1950.

with the western part, thus leaving a wide area which is characterized by the depth less than 6 m and which constitutes the main portion of A. In the western part, on the other hand, where the isopleths representing 6, 8, 10 and also 12 m advance far southward, considerable area with the depths greater than 6 and even 8 m is included in A. For determining the plane figure of B which turns characteristically to the south within the western part, this peculiar pattern of the isopleths acts directly as a decisive factor.

From the northern and the western border of A, i. e. just from B, the depth of the wells which exists between 6 and 8 m there, increases rapidly northwards and also westwards until it reaches more than 20 m. The area which is situated north and northwest of A and which is characterized by such rapid increase is divided among those subsections B, C, D, E and F. As compared with A and especially as compared with the main portion of this subsection, such rapid increase regarding the depth of the wells toward certain directions signifies a distinctive characteristic common to these subsections.

The Distribution of the Thickness of the Water.

Fig. 5 represents the distribution of the thickness of the water in the central section, the limits of which is restricted in the present case exclusively to the area surveyed in 1950. As shown clearly in

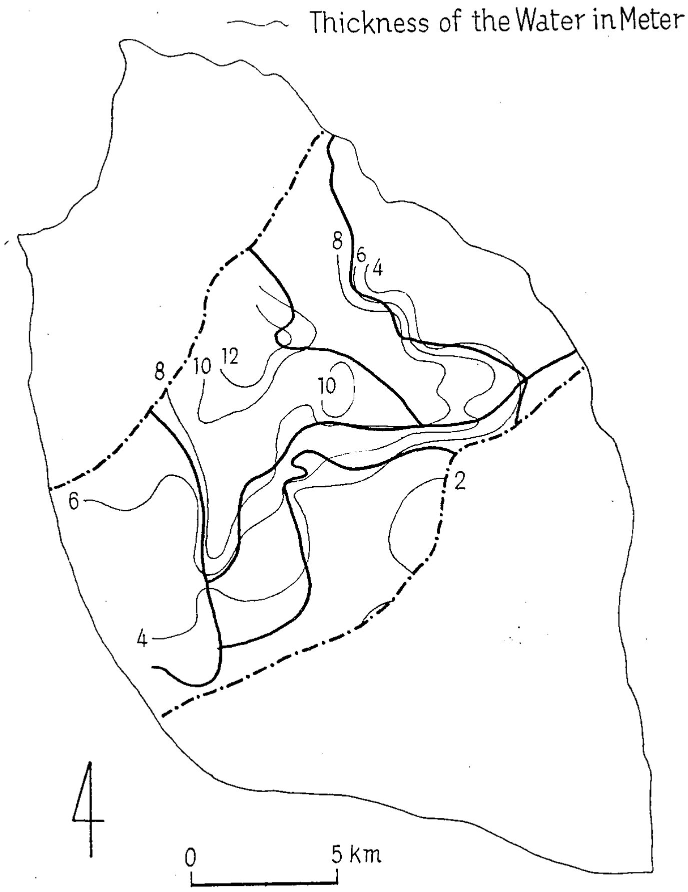

Fig. 5. A map to illustrate the distribution of the thickness of the water by means of the isopleth.

the present figure, the thickness increases generally from southeast to northwest, characteristically indicating a sharp change in values within a short distance or a narrow discontinuous belt which runs from west to east along the eastern part of B. Similar discontinuous belts are found between D and E on the one hand and between C and F on the other. As mentioned earlier both D and F are the subsections characterized by the small thickness of the water. In C which is the largest among the subsections regarding the thickness of the water, the values increase also to the northwestern direction till they exceed 12 m and exceptionally even 20 m in the northernmost portion of the subsection concerned. According to the survey which was carried out by *Hasebe through the period from May 24 to 29, 1938, i. e. the season of the low water level, the wells of which the thickness of the water reaches more than 7.5 m were observed in the northernmost portion of the present subsection.

The Distribution of the Depth of the Water Table.

As far as the general pattern is concerned, the similarity between the isopleths representing the depth of the wells (Fig. 4), on the one hand, and those representing the depth of the water table (Fig. 6),

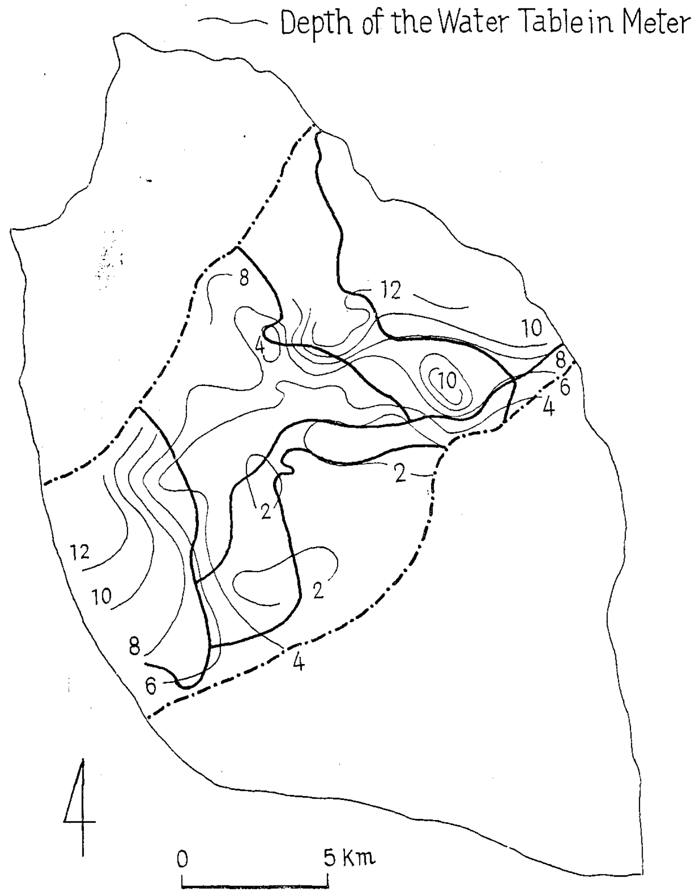

Fig. 6. A map to illustrate the distribution of the depth of the water table by means of the isopleth.

on the other, evidently illustrates the existence of the simple functional relation $y=x-c$ which is found between the depth of the wells and the depth of the water table as mentioned above. In connection with the depth of the water table, the isopleths, in the same way as the isopleths concerning the depth of the wells, run generally east-west within D, E and C and turn sharply to the south as soon as they enter into F, showing the general increasing tendency of the

* Hasebe, Y.: A Study of Nasuno by the YT-Method. Rikusuigaku-Zasshi, 9 (1939), 28-44. (in Japanese).

depth of the water table from south to north in D, E and C and from southeast to northwest in F. This characteristic pattern is also pointed out for the isopleths being illustrated by *Hasebe, which represent the distribution of the depth of the water table during the latter part of May 1938.

Although such similarity is found between Figs. 4 and 6, some discrepancies are pointed out if compared in detail. These discrepancies result directly from the term *c* which ranges between the upper and the lower limits characteristic of the respective subsection. Among them the most conspicuous feature is that within the limits exclusively of C the isopleth representing 6 m depth in Fig. 6 is pushed far up to the north as compared with the isopleth representing 10 m depth in Fig. 4, which fact is brought by the large thickness of the water distinctive to this subsection. Consequently from A through B to C, within the middle portion of the central section, which is stretching along the rivers Sabi and Kuma, a more or less extensive zone with shallow water table is recognized. Excepting its northernmost part, this zone is characterized by the water table remaining at a depth less than 6 m. In D, E and F or in the eastern and the western portion of the central section, on the contrary, the depth of the water table exceeds 6 m, as a general rule, exhibiting a striking contrast with the middle portion.

The Fluctuation of the Water Table.

Since the above-mentioned regional division deals exclusively with the conditions of the wells in October, i. e. the season of the high water level, a brief supplementary survey is made regarding the fluctuation of the water table during a year. For this purpose the average values of the height of the water table for every successive ten days through January to October 1962, which was observed by the Ministry of Agriculture and Forestry and published in "The Report on the Survey in the Nasuno-ga-hara" (1963, Jap.) is analysed, taking the delimited subsections into consideration.

Though satisfactory examination could not be made because the present survey was chiefly practised within the limits of A and B and because only few wells were observed in the other subsections, yet A and B are compared and contrasted distinctly regarding the seasonal fluctuation of the water table, in other words, while the annual range of the water table within A is restricted under 3 m, excepting few wells which are found in the southwestern corner of this subsection, the range in B, on the other hand, reaches between 3.5 and 6 m in general. In brief, with regard to the rise of the water table during the high water season, it is to a certain degree larger in B compared with A.

Viewed from the fluctuation of the water table, a somewhat large area where the thickness of the water exceeds 5 m may probably be expected in the eastern part of F. This and other problems, the solution of which is beyond the limits of the present survey, will be reexamined later.

Summary and Conclusion.

The central section of the Nasuno-basin, which is treated in the present paper, is divided on the basis of the depth of the wells, the depth of the water table and the thickness of the water in the wells into six subsections A, B, C, D, E and F (Figs. 1, 2 and 3), in a systematic way, taking the general relationship $y=x-c$ into consideration, which is found with regard to these subsections, where y and x means respectively the depth of the water table and the depth of the wells while c signifies a value which exists between the upper and the lower limits of the thickness of the water, both being characteristic of the respective subsection. These six subsections are compared and contrasted, in connection with the upper and the lower limits regarding x, y and z as shown in Table 1.

The isopleths which express the distribution of the depth of the wells (Fig. 4) and the depth of the water table (Fig. 6), run in a similar way, nearly eastwest in D, E and C and turn abruptly to the south in F. This represents the increasing tendency of both values from south to north or from A through B to the northern portion of D, E and C on the one hand, and from southeast to northwest or from A through B to the northwestern portion of F, on the other. A similarity rather than an identity, however, is found between these isopleths, because of c which is different among the six subsections; the most conspicuous disimilarity is recognized in connection with C where the isopleths are pushed far north as compared with those showing the same depth of the water table in D, E and F, leaving a wide area of small depth from A through B to C (Fig. 6). Such small depth of the water table during the high water season, as well as the large thickness of the water, both characteristic of C (Tab. 1) may partly be due to the subdrainages of the rivers Sabi and Kuma. Regarding the distribution of the thickness of the water, which ranges within a certain limit proper to the respective subsection (Tab. 1), rapid transitions are pointed out between D and E, on the one hand, and between C and F on the other (Fig. 5).

The subsection B which occupies a sharp transition belt with regard to the depth of the wells as well as the thickness of the

water (Figs. 4 and 5) and in which the water table fluctuates to a certain extent larger compared to A, resulting consequently in a conspicuously shallow water level during the high water season (Fig. 6), coincides to a considerable degree with the upper limit of the springs (Fig. 3). These facts which are important in connection with the relationship between the ground water and the agricultural land use, especially from the regional point of view, may be studied later.

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