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INFLUENCE OF BANKING ON GROUNDWATER HYDROLOGY IN PEATLAND

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1. Introduction

If an artificial change, resulting from human activity occurs in peatlands, it is usually accompanied by the change in hydrological conditions. Artificial management in peatland such as drainage, reclamation, short-cutting of rivers and constructions of roads etc., will influence on the condition of peatland hydrology not only in situ, but also to its adjacent peatland area. This is due to the flatness and the hydrological continuity of the peatland.

The impact of such influence altering conditions of the entire hydrological units is less easy to evaluate. This is because of complexity of interactions of peatland with its surroundings, and to the lack of an established methods for such investigations.

In this paper, Kiritappu peatland, eastern Hokkaido, is selected for the basis of this study. A road with banking is crossing the central part of this peatland. Investigation was made on the impact resulting from the construction of road on the peatland hydrology.

2. Kiritappu Peatland

The study area was selected at Kiritappu peatland, eastern part of Hokkaido, northern Japan. The peatland, facing Pacific Ocean on its eastern side, extends for about 10 km from north to south, and has a width of about 3 km. The peatland is rather flat in topography, and its elevation does not exceed 5 m above sea level. The peatland is drained by R. Biwase-Gawa, R. Doro-Gawa and R. Shin-Kawa, which are parallel to each other and flow toward Biwase Bay. According to the soil survey map made by Hokkaido Agricultural Experimental Station, peatland in Kiritappu is composed in large

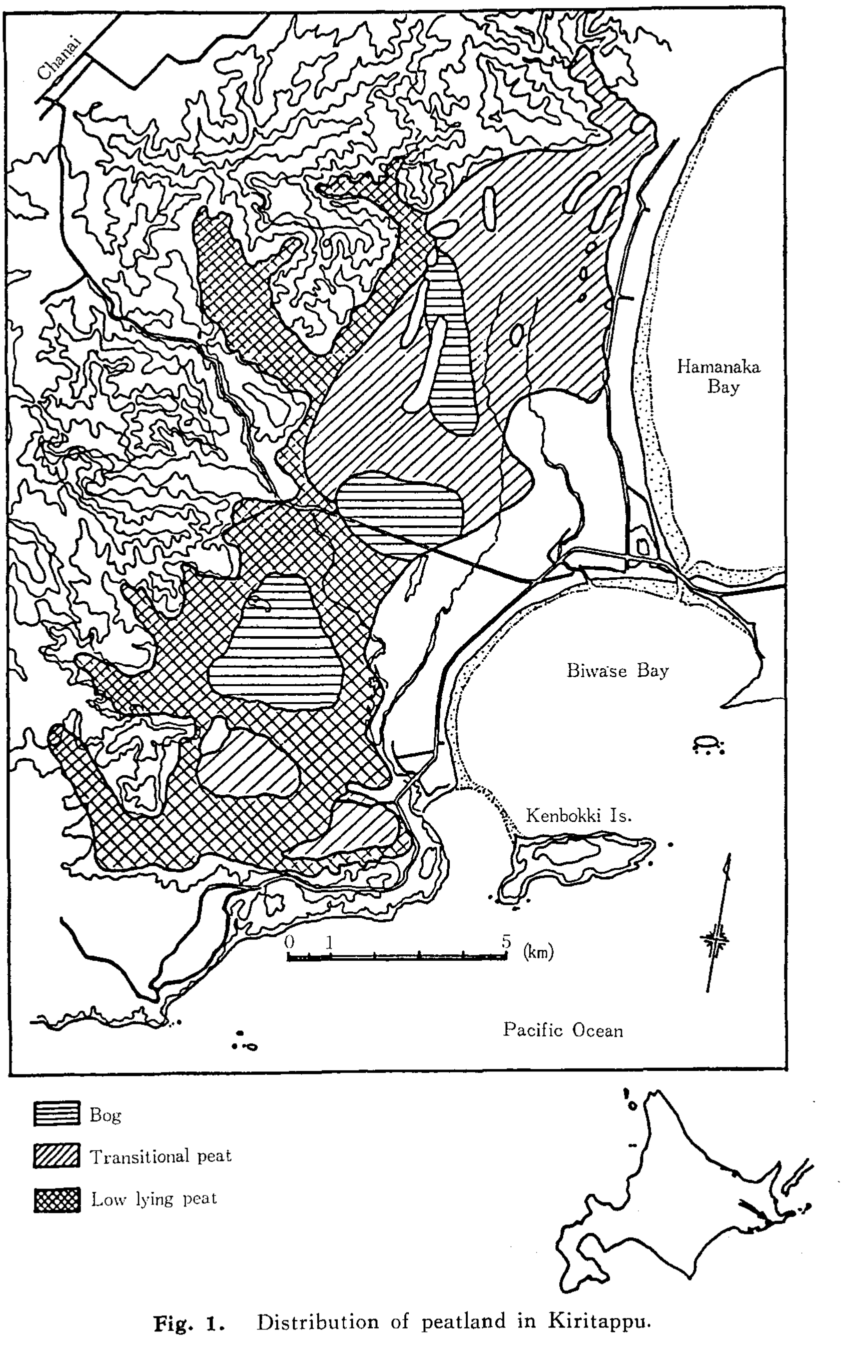

Fig. 1. Distribution of peatland in Kiritappu.

portion of fens distributed in its southern part and of bogs in the center. Location of Kiritappu and distribution of different type of peat deposits are shown in Fig. 1. The depth of peat layer is about 1 to 1.5 m in average. One of characteristic features of the peat layer in Kiritappu is that several layers of volvanic ash are contained between peat layers. Due to the existence of volvanic ash, the ignition loss of each layer is low, the degree of decomposition is comparatively high, and touch of peat is very rough, resembling that of sand.

Climatic conditions of Kiritappu, compared to other parts of Hokkaido are characterized by lower temperatures and lower duration of sunshine during summer, and little snowfall during winter. Mean annual precipitation here is about 1200 mm, with about 800 mm occurring from May to October. Lower duration of sunshine is caused by inflow of oceanic fog during spring and summer. During by inflow of oceanic fog during spring and summer. During the winter, the amount of snow is rather small, which is the cause for deep soil freezing.

In the center of peatland where bogs are distributed, a road is crossing through from the Chanai Town to the urban district of Kiritappu. This road has already appeared on the map of Land Survey Department published in 1897, but it probably was only a footpath or rutted road without any improvement. During the period from 1967 to 1966, this road has been improved by banking, but it is still not paved. The height of banking is 1 m in average, its width of the road and banking at the base is about 11 m, and the width of the road itself is about 6 m. The ditches, dug in the peat alongside the road are out of work at present. Reconstruction of the road is now under planned.

Meanwhile in 1922, the central part of peatland was designated for conservation as a natural monument. The designated area was about 900 ha of bog, with the road, mentioned above, crossing the center of the protected area.

The influence of the artificial banking on the peatland on both side of the road was studied mainly from hydrological point of view.

As it is generally known, the hydrological conditions are the fundamental properties of peatlands. After the disturbance occur, the changes in the condition of peatland vegetation may take a long time before becoming apparent. Though the danger in hydrological conditions usually occur quite soon. Thus, by measuring hydrological properties, the influence of human activity on peatland can be conveniently detected and evaluated. Also the hydrological measurements can be useful for describing the method conditions

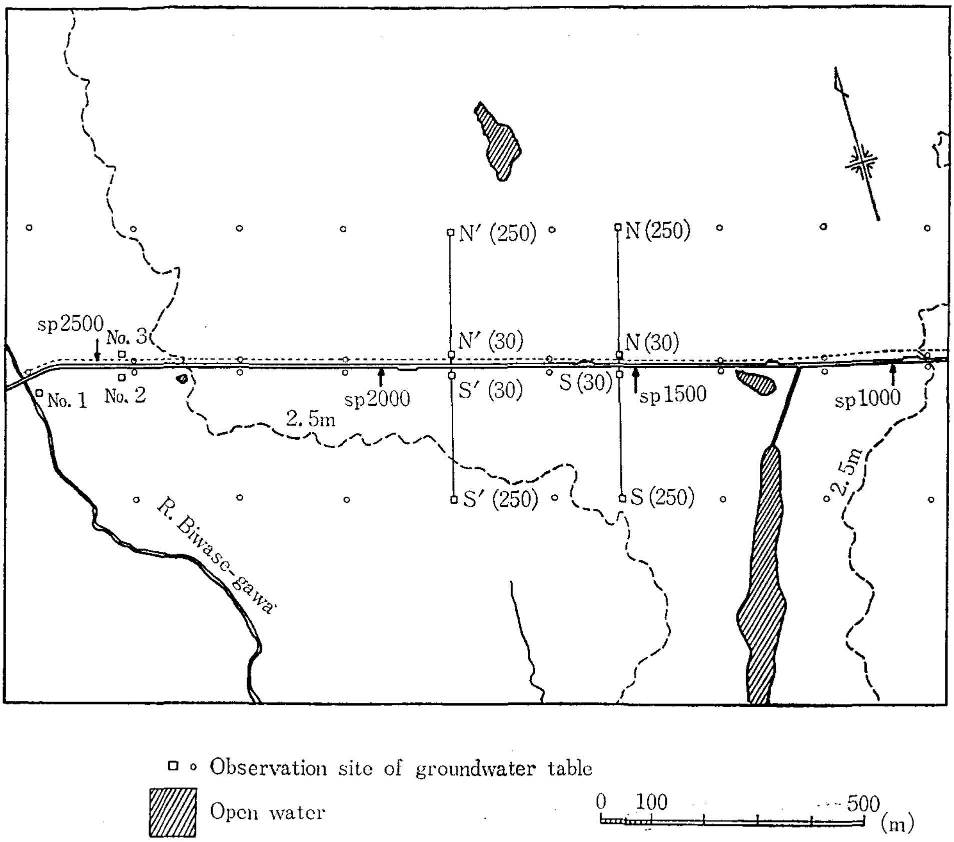

Fig. 2. Location of observation lines and groundwater table recorder.

of peatlands in general.

The measurements were carried out on two observation lines, 500 m long each, set at the right angles across the road (Fig. 2). The lines were named N-S and N′-S′. The observations were carried on the line N-S from May to August and on the line N′-S′ from August to September, 1984. The measurement set consisted on each line of four groundwater level recorders, two rain gauges and several pipes for measuring the groundwater level. The recorders were set on both sides of the road at points distant for 30 m and 250 m from the road sides. An interval of two hours was used for reading the data recorded on recording charts. The pipes for groundwater level measurement were established at the distance 0 ; 10 ; 20 ; 30 ; 40 ; 50 ; 100 ; 150 ; 200 ; 250 m from the road, Measurements of groundwater table in these pipes were carried out periodically.

3. Influence of banking on groundwater hydrology

It is very common that the load on the surface of peatland causes peat consolidation resulting in a decline of its permeability. YAMAMOTO and

TABLE Physical properties of peat in Kushiro and Kiritappu

Depth (m)	Peat forming plants	Specific gravity	Void ratio	Ignition loss (%)	Permeability (cm/s) Original	Permeability (cm/s) Consolidated (0.8 kg/cm²)
Kushiro						
1.0~1.3	*Vaccinium oxycoccus*	1.65	7.7	73	1.1×10^{-5}	2.1×10^{-6}
1.3~1.6	*Sphagnum* spp.	1.70	9.9	76	7.3×10^{-6}	6.2×10^{-7}
2.0~2.3	*Carex* spp.	1.58	8.8	79	2.0×10^{-5}	8.4×10^{-7}
2.3~2.6		1.59	13.3	77	1.3×10^{-5}	7.6×10^{-7}
3.0~3.3	(Mixed volcanic ash)	2.13	9.2	48	2.0×10^{-6}	2.0×10^{-7}
Kiritappu						
0.05~0.15	*Phragmites communis* *Carex* spp. Arborus	2.00	8.0	45	8.9×10^{-6}	4.1×10^{-7}
0.15~0.25	*Sphagnum* spp.	2.07	3.9	40	2.4×10^{-6}	4.9×10^{-7}
0.25~0.35	*Phragmites communis* Arborus	2.24	11.5	30	8.2×10^{-6}	4.5×10^{-7}

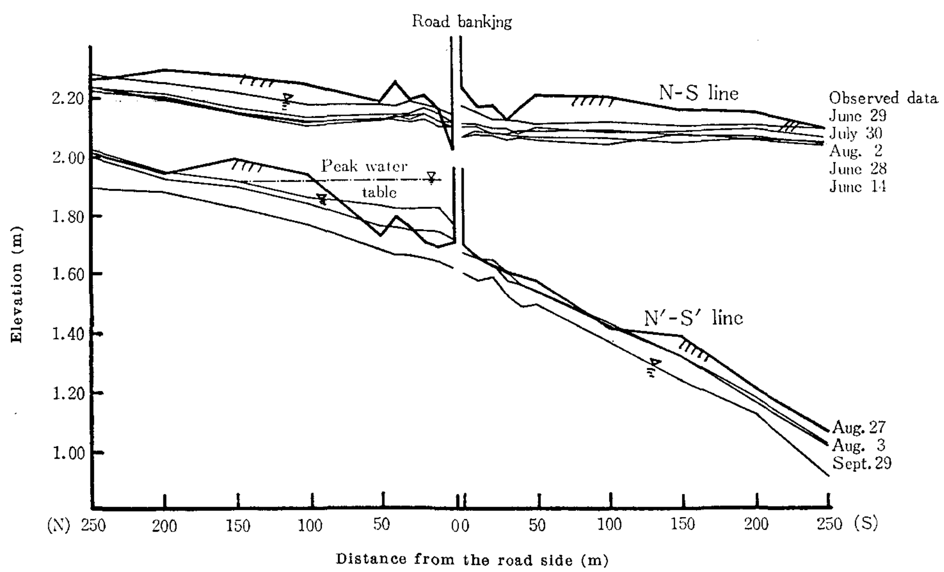

Fig. 3. Cross section of observation line showing ground surface and groundwater table, Kiritappu peatland.

UMEDA (1960) have reported the occurrence of subsidence caused by banking in Kushiro peatland, and discussed the decline in permeability of peat layer. In Table, physical properties of peat from Kushiro are shown. Also the data on initial permeability and that after the consolidation test are presented. All layers of peat show decrease of 1 to 2 orders in the permeability after the consolidation.

The consolidation of deposit after the road banking in Kiritappu is considerable, even though the amount of mineral components in peat is high here, and the thickness of peat layer is low. According to the consolidation test of peat sampled from observation site in Kiritappu, permeability decreases to the order of 10^{-7} cm/sec. (Table)

As the result of small permeability of the road foundations, hindrance of water movement was seen at the observation line of N′–S′. Fig. 3 shows

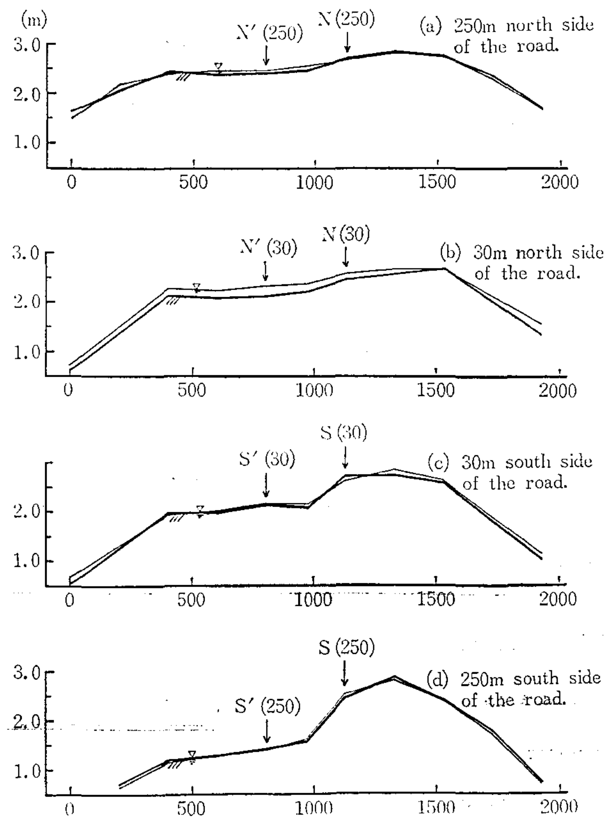

Fig. 4. Section of ground surface and groundwater table on Sept. 11, 1984. Arrows indicate the location of groundwater table recorders.

a cross sections along the observation lines of N–S and N′–S′, and several measurements of the groundwater surface. As it is shown in Fig. 3, the water level on the northern (upper) side of line N′–S′ is apparently increased by the damming effect of the road. The highest peak of groundwater table near the road appeared on August 23, after the rainfall of about 85 mm occurred. Even in August 27, the water level was still high in the northern

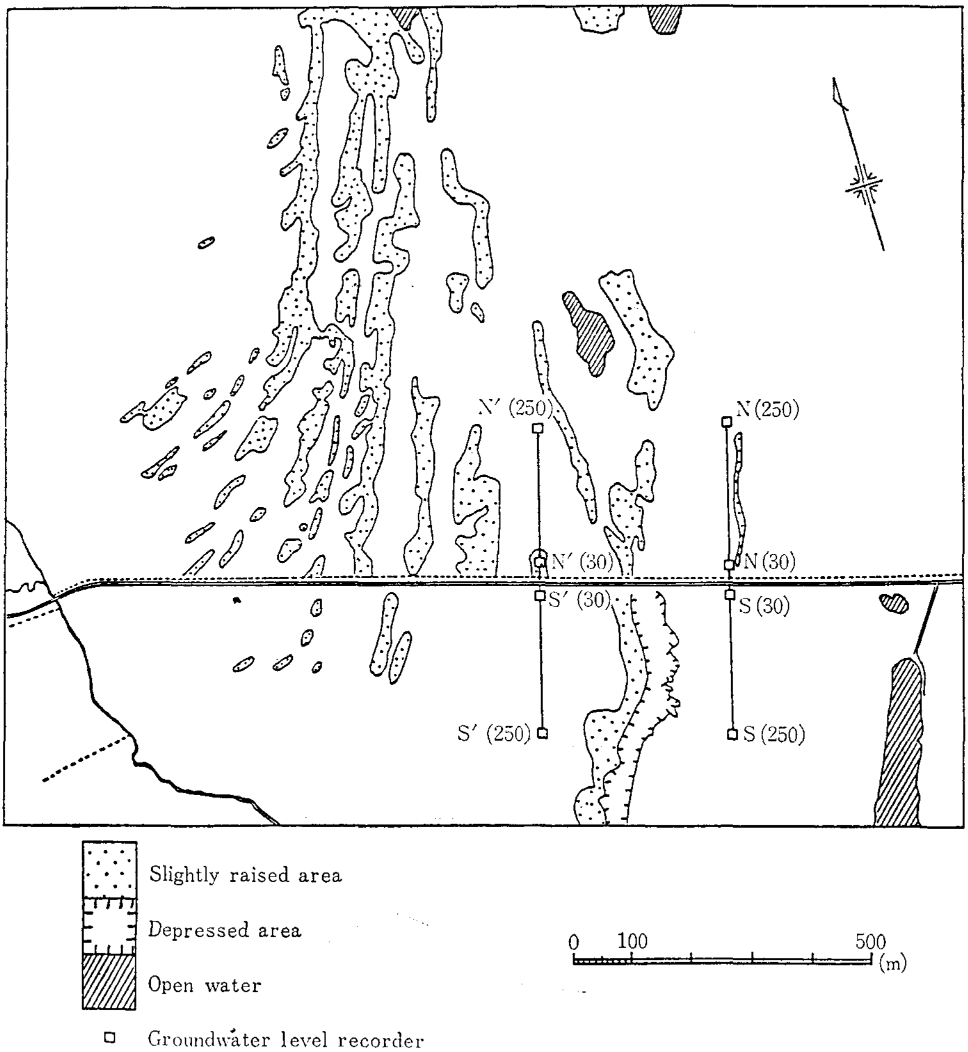

Fig. 5. Distribution of slightly raised area from the surroundings in Kiritappu peatland.

side of the road. The groundwater table at the same day on the southern (Lower) side of the road, however, did not show much difference from the groundwater table recorded on August 3.

In contrast to the data collected on line N′-S′, the data from line N-S does not show much difference between upper and lower side of the road. This disparity in the data are mainly caused by topographical characteristics of areas in which the two observation lines were set. The north-south cross-sections of the study area are presented in Fig. 3 and the east-west sections are presented in Fig. 4. It may be recognized from Fig. 3 and 4 that water mainly moves westward in the proximity of line N-S. It is concentrated near the line N′-S′ and then flows mainly towards the south. Here its movement is impeded by the low-permeable banking of the road.

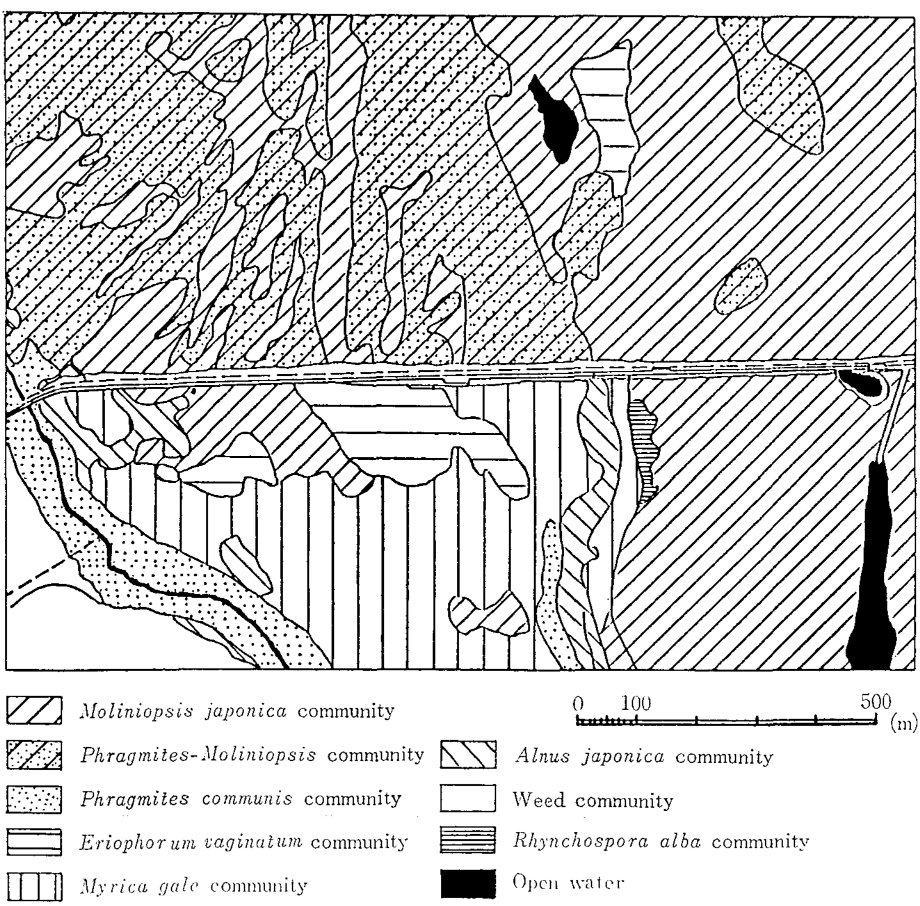

Fig. 6. Vegetation map of study area, Kiritappu peatland.

In Fig. 5, a map, based on interpretation of aerial photographs, presenting the distribution of areas, where surface is slightly raised above surroundings, is shown. Distribution of vegetation in the same area is shown in Fig. 6. The slightly raised areas are distributed in stripped pattern, mainly in the northern part of the road. They support vegetation different from that of the depressed parts. The origin of this stripped pattern on the peatland surface is supposed to be related to the development of sand dune ridges and the regression of the sea in a Post-Glacial period.

Low areas between the slightly raised stripes, tend to be a drainage channels for the collected water. Observation line N′-S′ was settled in one of these low areas. It is shown in Fig. 3 that water is inundating the upper side of the road in N′-S′ line.

On the other hand, water flow to the lower side of the road has been obstructed by the road banking. According to the vegetation map in Fig. 6, the plant cover in lower side of the road is different from the vegetation in the upper side.

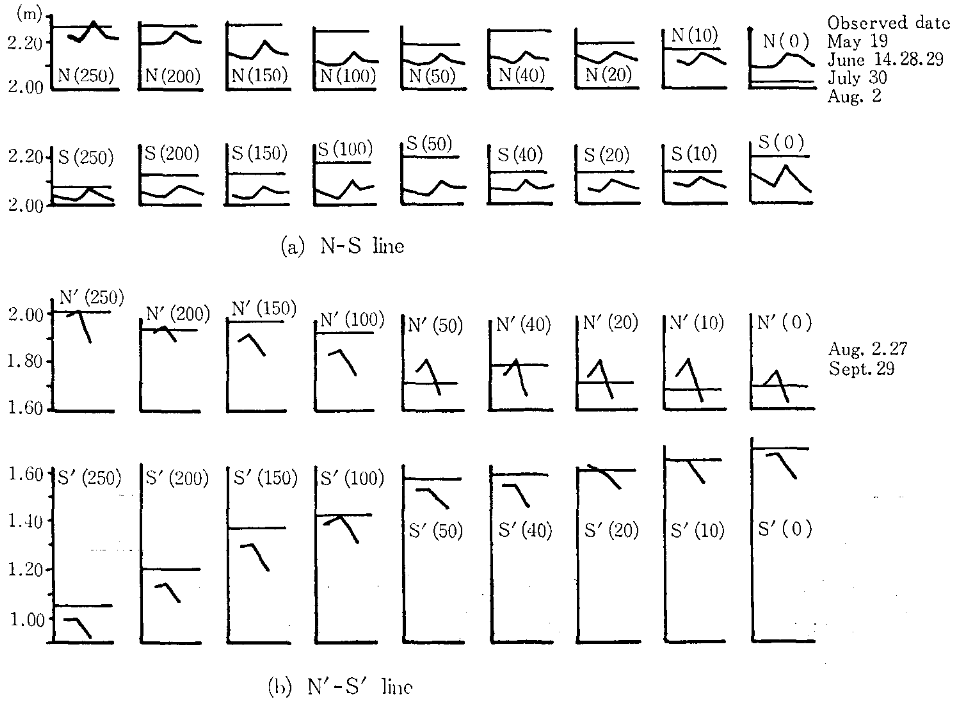

Fig. 7. Groundwater table fluctuation patterns in observation line N-S and N′-S′.

In Fig. 7, the results of periodical measurements of groundwater table are shown for each observation point. Notice that the measurements were carried at interval of about one month and there is a possibility of wider fluctuations of water table during the gap in the measuring time. Patterns of the water level fluctuations recorded periodically in points, set on the even surface of line N-S, are conspicuously similar. In the contrary, there is marked differentiation of fluctuation patterns obtained in points on line N′-S′. Moreover, the peak of water table was quite high on upper side of the road in some points on this line, especially at N′-0, N′-10, and N′-20. Also, in these points the water table was commonly above the ground surface. On the lower side to the road the water table was kept below the ground surface even on August 27, when the water level raised the highest on the upper side of the road.

The influence of banking was clearly visible also in the results of the continuous measurements of water fluctuations on line N′-S′, presented in Fig. 8. In this figure also the behaviour of the water table, calculated by the tank model for peatland groundwater table are shown by dotted lines. From the graphs shown in Fig. 8 that of point N′-30 shows a specific pattern of water table fluctuations. Here, the peak of water table shows time lag of about a day from the peak of rainfall. The height of rise due to the rainfall is considerable, and the rate of water table decline is also large, compared to those of other sites of line N′-S′. The groundwater table fluctuations of other 3 observation sites keep rather high level of the water table after rainfall. Apparent decline of water table in all sites start after the lowering of water table in N′-30. High water table is kept in these sites at the time when the water table in N′-30 is also high. It seems that the continuation of such high water table in N′-250 was caused by backing of the water by the road banking, while in S′-30 and S′-250 it is due to the continuous supply of seepage water from the upper side of the road.

The specific properties of point N′-30 resulting of the water ponding effect are also expressed by the coefficients applied in the thank model. These coefficients of discharge holes 'A_2' and 'A_3' are smaller than those in the models for other sites. This means that water is not flowing out of site N′-30 easily as from other ones. The values of 'A_3' are equal to 1.0 in N′-250, S′-30, and S′-250. This indicate that if the water level is as high as the 'H_{A_3}' (the ground level), the water will discharge rapidly. But in point N′-30, the coefficient of 'A_3' equals to 0.1, which means that only 10% of water accumulated above the ground surface will discharge in the same period of time. A large value of 'B_2' indicates the tendency for water con-

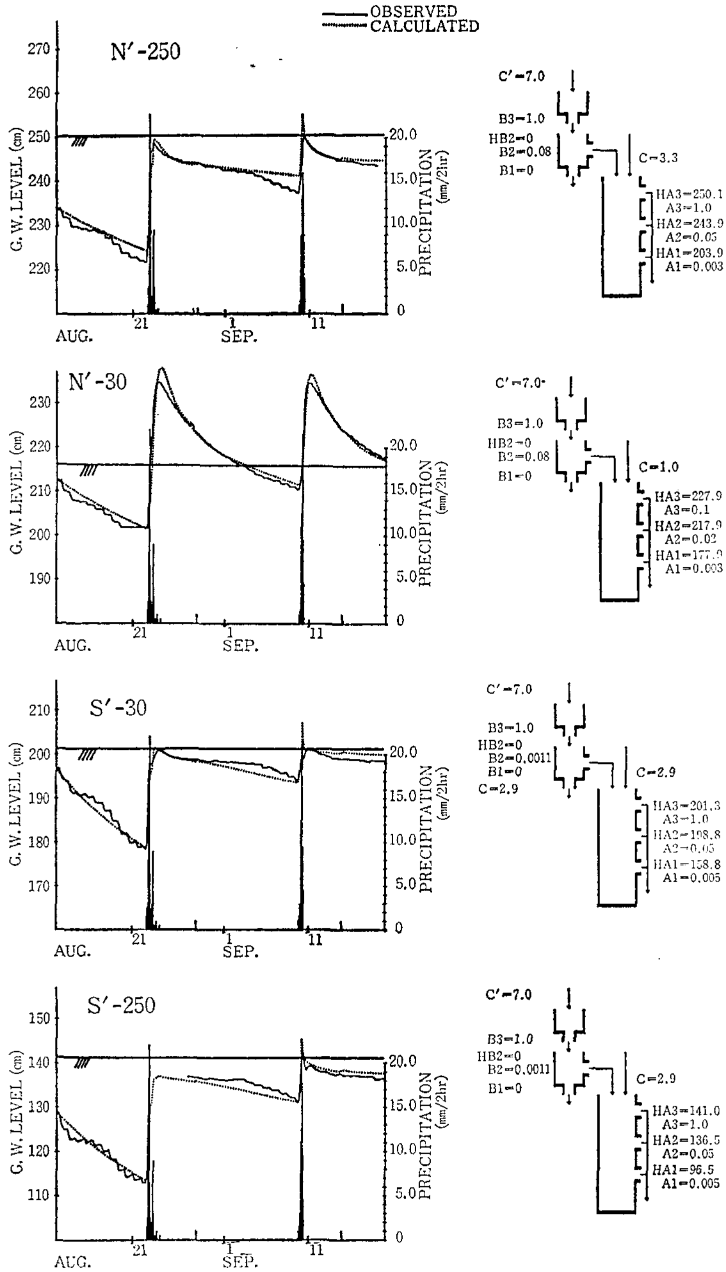

Fig. 8. Groundwater table fluctuations in observation line N′-S′, Kiritappu peatland.

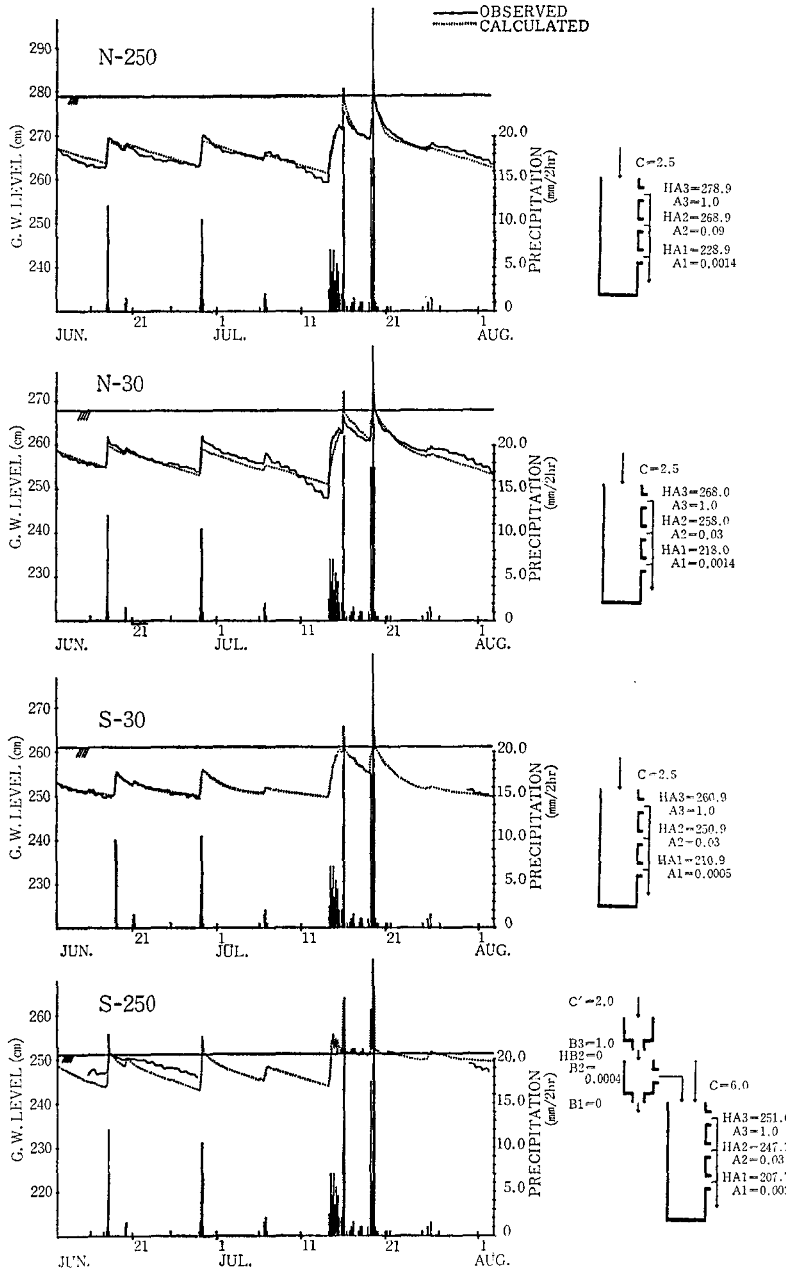

Fig. 9. Groundwater table fluctuations in observation line N–S, Kiritappu peatland.

centration. Also the value of 'C' indicates the magnification of rise of water table caused by water input. In N′-30, 'C' is 1.0. This means that the recharge, occurring in the form of inflow and precipitation expressed in mm, will rise the water table by the same value. The reason for such value of 'C' is that in point N′-30 water covers the ground surface for almost the whole time. Higher values of 'C' in other observation sites indicate that the water recharges into peat, causing the water table to rise by more than the value of input.

According to the watertable data recorded in four sites of line N-S (Fig. 9), the influence of banking is absent. All data, except one from S-250, are similar in fluctuations pattern. According to the tank models of these 3 observation sites, there are no inflows from surroundings. This features is indicated in the tank model as the lack of upper series of tanks. Only in S-250, the tanks for surroundings were added above the peatland tank. Also the value of 'C' and 'A_1' is rather large than those for other three sites. These characteristics are due to the topographical situation of S-250 located on the middle of the slope.

4. Conclusion

There are several works contributed to recognition of the relationships between peatland hydrology and the vegetation. For example, TSUJII *et al.* (1963) related the composition of vegetation to the groundwater table fluctuations. These works suggest that there are possibilities of inducing the change in vegetation by the change in hydrological conditions. Actually, distribution of vegetation in Kiritappu is somewhat different between both side of the road. Here, the influence of embankment was appeared to the difference of hydrological conditions which mentioned so far.

To prevent influence of banking to the hydrological conditions, it is necessary to dissolve ponded water in upper side of the road. Also the water should be supplied to the lower side of the road fluently, to keep water table balanced in both side of the road. Eventually, this management intending to keep hydrological conditions equal in both side of the road.

Patterns of groundwater table fluctuations are one of exact indicators of conditions of peatland. It will be possible to predict the transformation in vegetation from the patterns of water movement, with the accumulation of further knowledge of relation between the patterns of water table movement and the vegetation.

Summary

Influence of road banking in peatland was investigated from groundwater hydrology. The study area was selected at Kiritappu peatland, eastern part of Hokkaido, northern Japan. A road is crossing in the center of this peatland where bogs are distributed. This road was improved by banking during the period from 1964 to 1966.

Observation of groundwater table was carried by using several water table recorders and measuring pipes. The measurement was operated in two observation lines crossing the road. One (line N′-S′) was set in the section where the influence of banking is apparent, and the other (line N-S) in the section where influence is negligible.

From the aerial photographs, slightly raised areas distributed in stripped pattern were found. Lowareas between the slightly raised stripes tends to be a drainage channels for the collected water. Observation line N′-S′ was settled one of these low areas.

The water table on the upper (northern) side of road in line N′-S′ is apparently increased by the damming effect of the road, while the water table in lower (southern) side showed low peak and slow decline. Apparent decline of the water table in all sites start after the lowering of water table in N′-30. Influence of baking up of the water kept the rate of water table decline slow in N′-250. Also the ponded water influencing lower side of the road by supplying seepage water. In contrast, groundwater table fluctuations in line N-S shows no influence of banking. These characteristics of ground-water movement were apparently express to the coefficients and the structure of tank model for peatland hydrology.

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