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FIELD SURVEY OF CHANNEL VEGETATION AFTER THE 1992 FLOOD OF MUKAWA RIVER

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ABSTRACT

In river management work, evaluations of the influence of vegetation on flow during floos is very important. In recent years, society has expressed an increasing desire for planting and conservation of vegetation on flood plains. However, there have been few qualitative determinations of the influence of vegetation on river flows. This paper presents a field survey of river channel vegetation after a flood.

Heavy rains fell in the Mukawa River basin in southern Hokkaido, Japan, on August 9, 1992. A survey of the channel vegetation after the flood indicated notable phenomena. From 14.1km to 15.2km from the river mouth, some trees were uprooted by the flood flow, while others remained rooted. This was investigated with field survey data and a numerical two-dimensional flow model.

INTRODUCTION

In August of 1992, typhoon number ten caused heavy rainfalls over the central and eastern Hokkaido, and floods above the designed high water level occurred at the Hobetsu River Observatory in the Mukawa River basin.

After the flood, a large quantity of driftwood which may have been due to the flood was found off Tomakomai. Driftwood generally prevents free flows at piers and weirs. Thus, driftwood prevention is very important in flood control. During the flood, numerous trees had been uprooted by the flood flow in the flood plain between Sakuraoka sluice (14.1km from the river mouth) and Ikuta No.5 sluice (15.2km from the river mouth), Mukawa.

This report will investigate the relationship between the flood flow, the condition of the river channel, and channel vegetation, by surveying the condition of trees and the flood traces.

DETAILS OF THE RIVER BASIN AND FLOOD

The Mukawa River is a 135 km long class A river with a catchment area of 1,270km^2 which lies in the westernmost part of Hidaka, Hokkaido, southwest of the Hidaka Mountains. Figure-1 shows an outline of the basin with survey points.

The total rainfall during the flood in the river basin was 210mm at Mukawa and 247mm at Hobetsu. Figure-2 shows the hydrograph at Mukawa. The flood resulted in the second highest recorded water level (the highest was in August 1922), and far exceeded the August 1981 Flood, the largest flood in recent years.

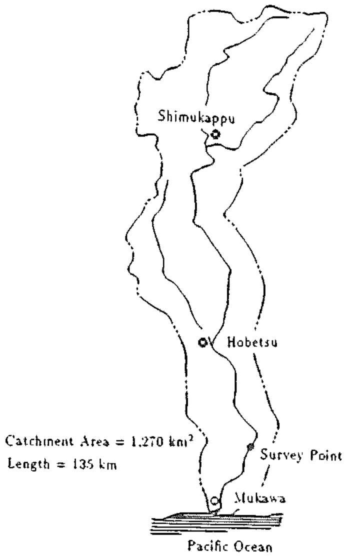

Figure-1 Outline of the River Basin

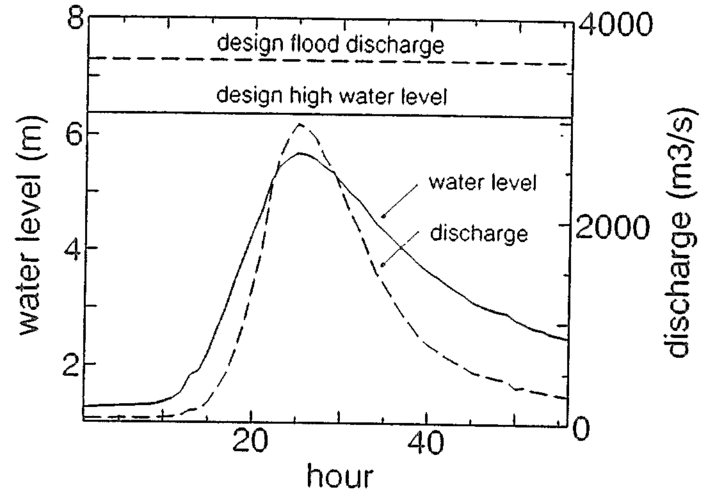

Figure-2 Hydrograph at Mukawa

DETAILS OF SURVEY POINTS

Figure-3 shows a map of the surveyed area. The low water channel had been towards the left river bank, and the channel was braided. The existing river bank of the low water channel was constructed in 1977-1978. The contour lines show minor undulations longitudinally across parts of the high water channel at the left river bank. This is a trace of the former river channel.

To investigate the flood flow, a field survey which established the extent of the flooding and the direction of flow was conducted. Figure-3 shows the direction of flow and that the flood reached the high water channel of the left river bank, converged on the micro-undulations, and returned to the low water channel.

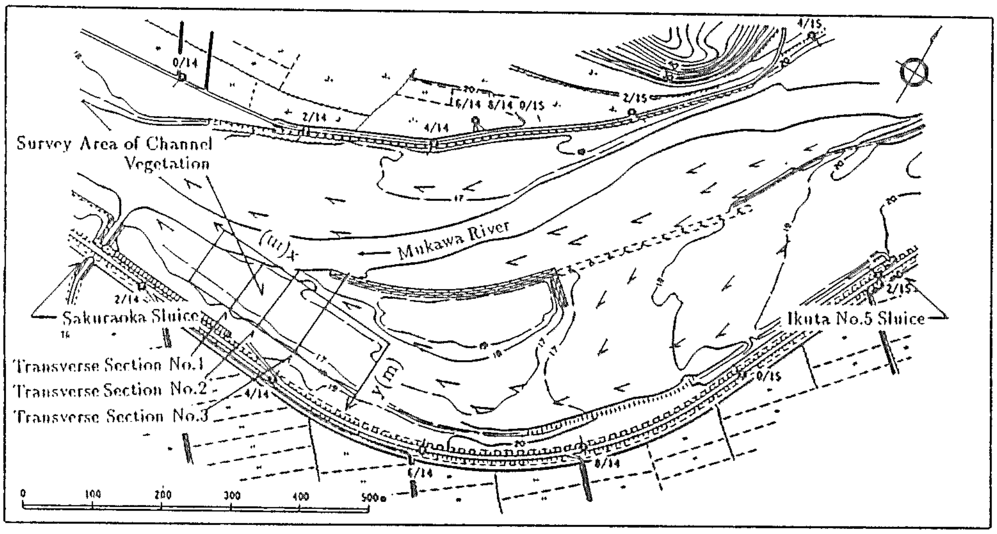

Figure-3 Topography and Direction of Flood Flow in the Surveyed Area

To determine the channel vegetation coverage in the area, the vegetation maps in Figure-4 were drawn from aerial photographs taken in September of 1978, 1983, and 1992. The 1992 map was verified by a field survey. Most of the major bed at the left river bank was bare ground and broad-leaf scrub (willow and alder) in 1978, and grassland and forest in 1983. However, in the 1992 survey, after the flood, the ground was bare due to sedimentation, and the scrub had become forest. In 1983 scrub (willow) extended to the revetment of the left low water channel bank constructed in 1978. In 1992 the scrub had become forest, and the area of scrub had increased. Vegetation in the revetment area developed early, and expanded steadily, compared with areas of bare ground in 1978. This may be because the revetment provided an environment promoting the rooting of tree seeds and impeding the growth of weeds.

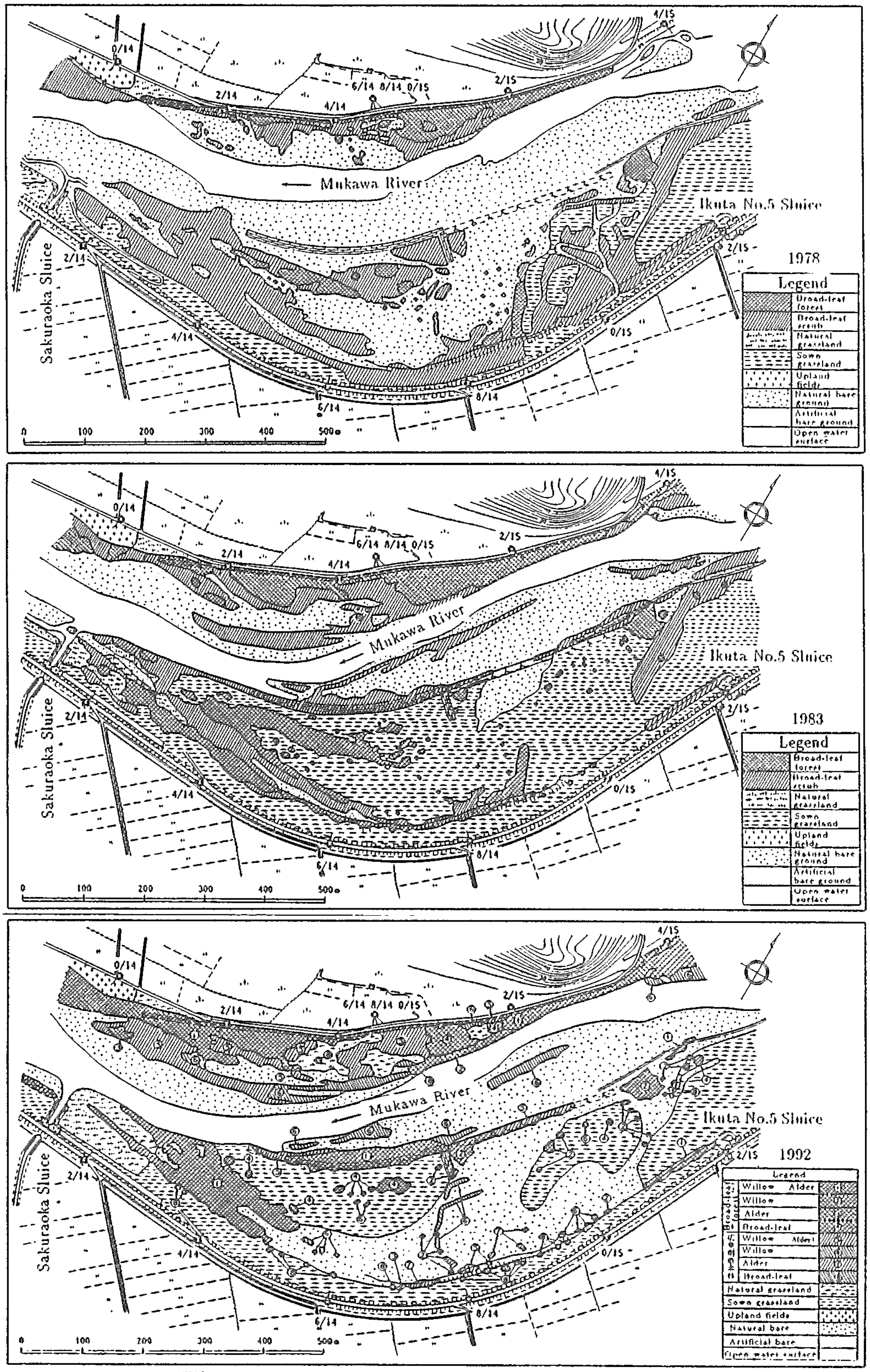

Figure-4 Changes in Channel Vegetation

To determine the details of vegetation in the high water channel of the left river bank, vegetation in three zones was observed (No.1, 2, and 3 in Figure-3). Figure-5 shows the appearance and extent of trees. Each of the zones was divided, transversely, into three blocks depending on the micro-topography of the high water channel: the undulating ground in the center of the high water channel is B, the slightly higher ground on the low water channel side is A, and the area on the levee side is C. The average height of trees in A is 8.9-10.2m. This was higher than the 6.3-7.7m in block B and 6.0-7.6m in block C. There were a few tilted and uprooted trees in block A. The average height of trees in zone No.1 of block B is nearly equal to those in zone No.1 of block C, (B; 7.7m, C; 7.6m). In zone 2 block C, trees are taller than in zone 2 block B (B; 6.3m, C; 7.4m). Most trees in block B are tilted and uprooted. Overall, the trees on the slightly lower ground are relatively low and tilted and uprooted by the flood flow, but the height and growth of trees is not significantly different.

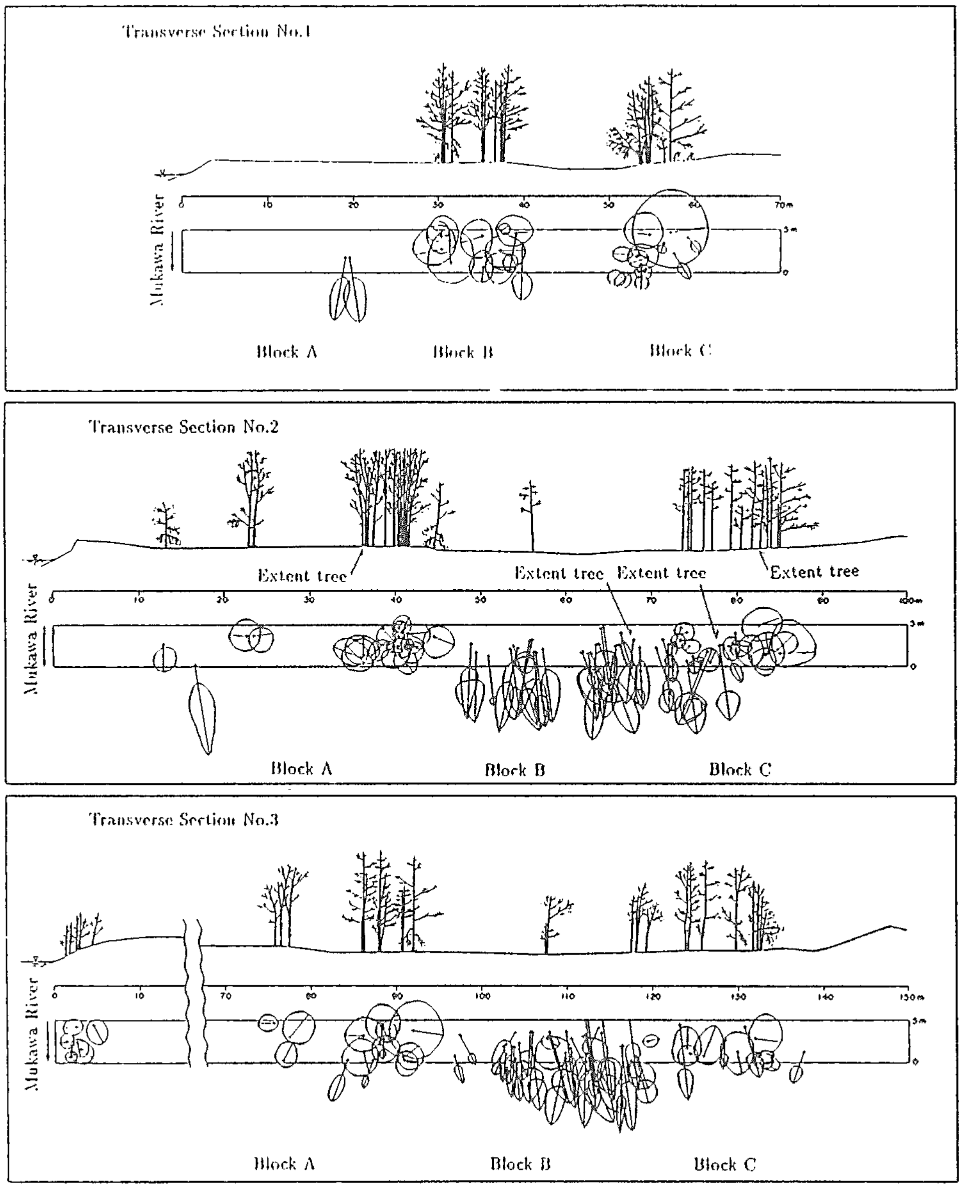

Figure-5 Appearance of Trees

To quantify the growth of trees in the surveyed area, four randomly selected trees were subjected to stem analysis, and compared with yield estimate tables established by the Forestry Planning Society(1960). Figure-5 includes location data of the sampled trees. The yield estimate table shows the standard growth in forests, heights diameters, and volume in the A and B classified areas, and indicates the general growth level of trees. The yield estimation data was obtained from an alder forest in a river area in Kushiro close to the surveyed area. It was based on a survey of uniform alder forests in grave ground along rivers and in fertile wetlands. The A and B class lands are established by considering the growth conditions, location, and climate; it is not an absolute standard. Forests with "good" and "normal" growth are considered to belong to class A and B land. Figure-6 shows the relation between the height, diameter, and age of trees, and includes the results of the stem analysis of the selected trees. The heights of all the observed trees exceed that of trees on class A land, and the diameter is nearly equal to that of trees on class A land. This leads to the conclusion that the vegetation in the surveyed area is well grown.

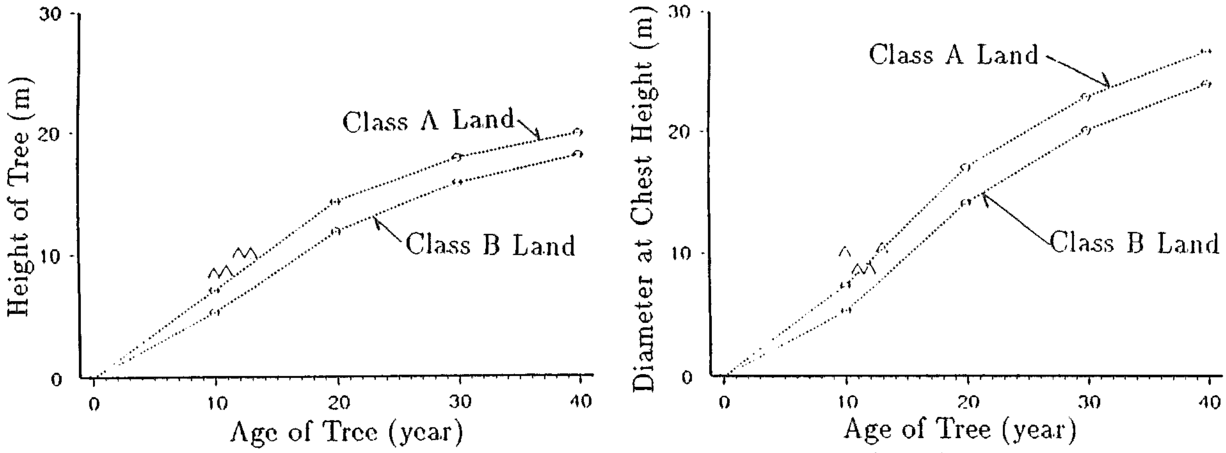

Figure-6 Growth of surveyed Trees and Yield Estimation Data

SURVEY OF UPROOTED TREES

Numerous trees were uprooted in the forests of the high water channel at the left river bank, the vegetation was surveyed in the areas shown in Figure-3. Details of the survey are:

- Location of trees: the survey used the fixed survey points on levees.
- Tree species: Japanese common names (different kinds of willows are grouped under willow).
- Tree height: measured by staff or tree height measuring poles with 0.1m accuracy.
- Leaf cover: maximum from right to left with 0.1m accuracy.
- Height of the lowest branch: measured by staff or tape measure, 0.1m accuracy (parallel to trunk).
- Trunk circumference: measured 1.2m from the ground using tape measure with 0.01m accuracy (Trees less than 1.2m high were not recorded).
- Base circumference: measured with tape measure, 0.01m accuracy.
- Angle of inclination: measured with clinocompass with five degree accuracy (The angle of inclination of arched trees is measured 1.2m from the ground, and completely uprooted trees are assigned 90^0).
- Direction of inclination: measured with clinocompass with five degree accuracy (North is 0^0).
- Root condition: unusual roots were recorded, and the thickness and spread of roots were measured on completely uprooted trees.
- High water level: determined by traces of the flood level.

The species of trees in the surveyed area were mainly alders (1,267) and willows (1,197) with very few other species. Figure-7 shows the location of the trees. Alders grow throughout the area with some spacing between the trees, and willows are concentrated in specific areas. Figure-8 shows the location of completely uprooted trees in the surveyed area. There are uprooted trees in the central slightly lower ground, and areas with and without uprooted trees are distinctly separated transversely. As shown in Figure-3, the flood flow upstream in the high water channel converged on the location of the uprooted trees due to the micro-topography and passed at a very rapid velocity. There are 379 alders and 233 willows uprooted. Table-1 shows the measurements of the spread and thickness of the roots. The averages for alders were 116cm and 49cm, and for willows 111cm and 49cm with no difference between the two species. There is a positive correlation between the thickness and spread of the roots.

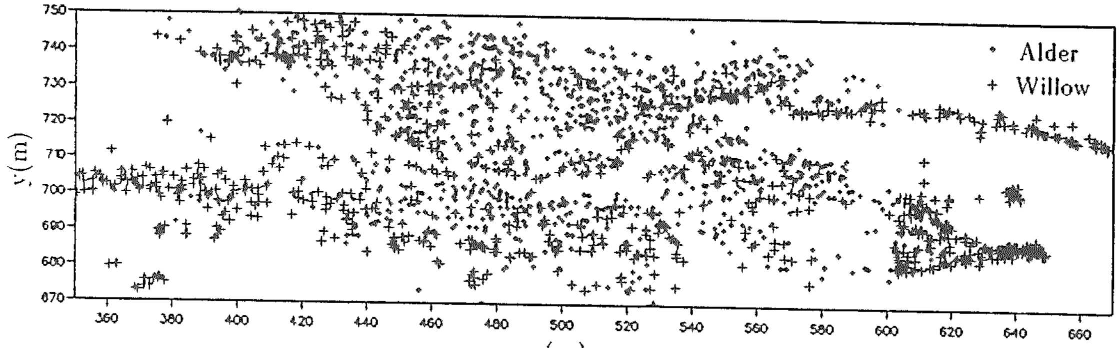

Figure-7 Survey of Tree Species Affected by the Flood

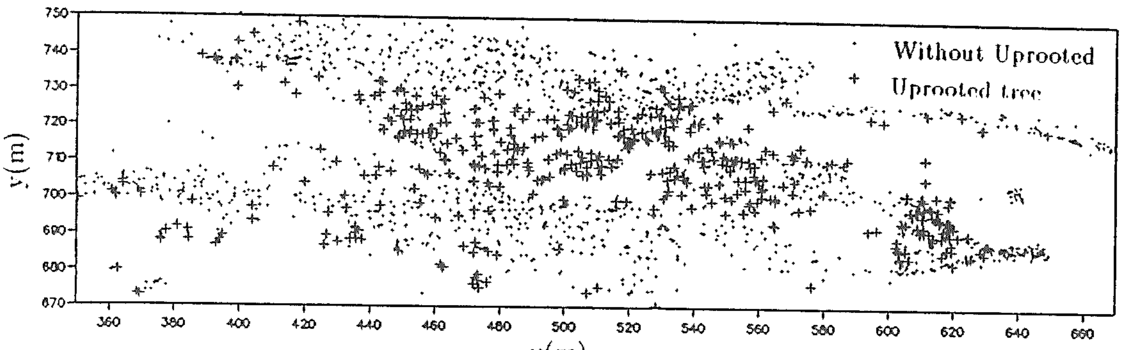

Figure-8 Uprooted Trees

Table-1 Spread and Thickness of the Roots of Uprooted Trees

Alders		Thickness (cm)					
		10	30	50	70	90	110
Spread (cm)	10	0	0	0	0	0	0
	30	0	2	0	0	0	0
	50	0	17	2	0	0	0
	70	0	28	21	0	0	0
	90	0	18	54	4	0	0
	110	0	10	55	13	0	0
	130	0	2	54	8	0	0
	150	0	1	32	11	0	0
	170	0	0	15	4	0	0
	190	0	1	6	3	0	0
	210	0	0	3	10	1	0
	230	0	0	3	0	0	0
	250	0	0	0	1	0	0
	270	0	0	0	0	0	0

Willows		Thicness (cm)					
		10	30	50	70	90	110
Spread (cm)	10	0	0	0	0	0	0
	30	2	2	0	0	0	0
	50	0	18	3	0	0	0
	70	0	18	15	0	0	0
	90	0	10	31	4	0	0
	110	0	6	30	11	0	0
	130	0	0	25	11	0	0
	150	0	0	11	4	0	0
	170	0	0	3	13	0	0
	190	0	0	2	1	0	0
	210	0	0	2	6	1	0
	230	0	0	1	0	0	0
	250	0	0	0	1	0	0
	270	0	2	0	0	0	0

INVESTIGATION OF FLOOD FLOW

In order to determine the flow velocity which uproots trees and the influence of channel vegetation on the flow duration, two-dimensional flow analysis for river channels, with forests and scrubs was performed with the survey data. This flow analysis was established by Watanabe et al (1993). The basic equations of the analysis are:

$$\tilde{u}\frac{\partial \tilde{u}}{\partial \tilde{s}} + \tilde{v}\frac{\partial \tilde{u}}{\partial \tilde{n}} + \frac{\tilde{u}\tilde{v}}{\tilde{r}} = -g\frac{\partial\left(\tilde{h}+\tilde{z}\right)}{\partial \tilde{n}} - \frac{\tilde{\tau}_s}{\tilde{\rho}\tilde{h}} + \frac{\partial}{\partial \tilde{s}}\left(\tilde{\varepsilon}\frac{\partial \tilde{u}}{\partial \tilde{s}}\right) + \frac{\partial}{\partial \tilde{n}}\left(\tilde{\varepsilon}\frac{\partial \tilde{u}}{\partial \tilde{s}}\right) - \frac{\tilde{a}}{2}C_d\tilde{u}\sqrt{\tilde{u}^2+\tilde{v}^2} \quad (1)$$

$$\tilde{u}\frac{\partial \tilde{v}}{\partial \tilde{s}} + \tilde{v}\frac{\partial \tilde{v}}{\partial \tilde{n}} - \frac{\tilde{u}^2}{\tilde{r}} = -g\frac{\partial\left(\tilde{h}+\tilde{z}\right)}{\partial \tilde{n}} - \frac{\tilde{\tau}_n}{\tilde{\rho}\tilde{h}} + \frac{\partial}{\partial \tilde{s}}\left(\tilde{\varepsilon}\frac{\partial \tilde{v}}{\partial \tilde{s}}\right) + \frac{\partial}{\partial \tilde{n}}\left(\tilde{\varepsilon}\frac{\partial \tilde{v}}{\partial \tilde{n}}\right) - \frac{\tilde{a}}{2}C_d\tilde{v}\sqrt{\tilde{u}^2+\tilde{v}^2} \quad (2)$$

$$\frac{\partial\left(\tilde{u}\tilde{h}\right)}{\partial\tilde{s}} + \frac{1}{\tilde{r}}\frac{\partial\left(\tilde{r}\tilde{u}\tilde{h}\right)}{\partial\tilde{n}} = 0 \tag{3}$$

where $\tilde{s}$ and $\tilde{n}$ are the axes along and across the river channel; $\tilde{u}$ and $\tilde{v}$ the depth averaged velocities in the $\tilde{s}$ and $\tilde{n}$ directions; $\tilde{r}$ is the radius of curvature of the river channel; $\tilde{h}$ the water depth; $\tilde{z}$ the river bed level; $\tilde{\varepsilon}$ the coefficient of eddy viscosity; $\tilde{\rho}$ the water density; $\tilde{g}$ is gravity; $\tilde{a}$ the tree density $(= \tilde{d}/(\tilde{l}\tilde{m}))$; $\tilde{d}$ the tree diameter; $\tilde{l}$ and $\tilde{m}$ the cross and long intervals between trees; and C_d is the drag coefficient. Here $\tilde{\tau}_s$ and $\tilde{\tau}_n$ are the shear stresses on the river bed in the $\tilde{s}$ and $\tilde{n}$ directions, expressed by:

$$\frac{\tilde{\tau}_s}{\tilde{\rho}\tilde{h}} = \frac{\widetilde{g n_m}^2}{\tilde{h}^{4/3}}\tilde{u}\sqrt{\tilde{u}^2+\tilde{v}^2} \quad , \quad \frac{\tilde{\tau}_n}{\tilde{\rho}\tilde{h}} = \frac{\widetilde{g n_m}^2}{\tilde{h}^{4/3}}\tilde{v}\sqrt{\tilde{u}^2+\tilde{v}^2}$$

Here $\widetilde{n_m}$ is the Manning coefficient of roughness. At lattice points in tree groups, the values of $\tilde{a}$ and $\widetilde{n_m}$ are designated considering the assumption that the velocity distribution in the vertical direction is uniform due to the influence of the tree groups.

The numerical analysis can be performed by differentiating (1)-(3) like Shimizu et al (1986). The calculated section was between KP13.0-KP18.0. An approach section up- and downstream was included. Figure-9 shows the lattice between KP14.0-KP15.4 in the survey area. In Figure-9 the white dot refers to groups of trees. The calculations gave a discharge of Q=3,000m^3/s and a Manning's coefficient of roughness of $\widetilde{n_m} = 0.03$. The tree density was the average of trees in the surveyed area (= 0.03), and the drag coefficient of the trees was 1.2 since the lowest branches are relatively high with the many tall trees.

The calculated results in Figure-10 adequately reproduce the flood flow which spread to the high water channel at the left bank at KP15.0, and ran down into the low water channel at KP 14.2. In addition, the flow may converge on the observed point due to the slightly lower ground, the former river channel, and as the high water channel becomes narrower downstream. Comparing flow velocities in and around groups of uprooted trees, indicates that large hydraulic forces act on the trees.

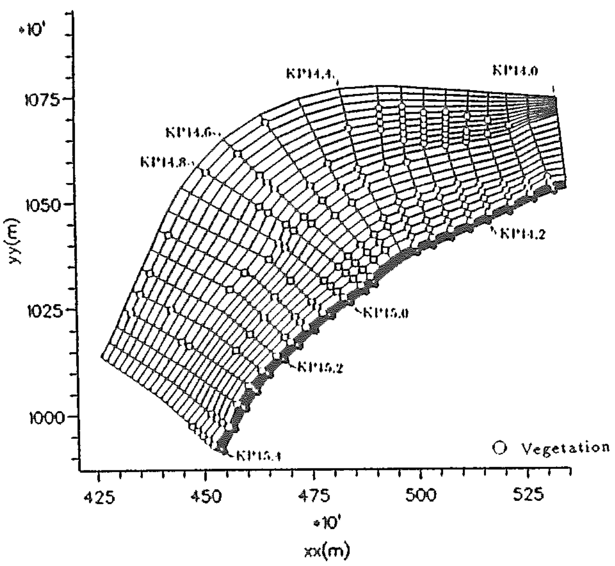

Figure-9 Calculation Lattice for Two-dimensional Flow Analysis

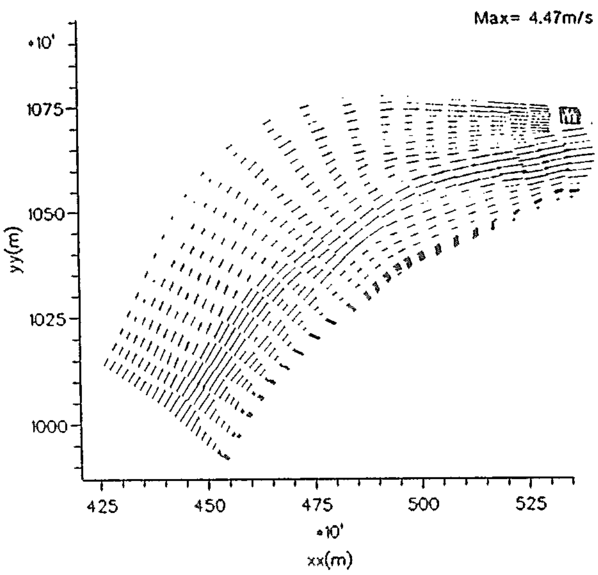

Figure-10 Calculated Results of the Two-dimensional Flow Analysis

Watanabe et al (1988) estimated the flood flow velocity from the tree inclination assuming the tree to act as a cantilever as Equation (4).

$$\tilde{V} = \sqrt{\frac{23}{112}\frac{\pi\tilde{g}\tilde{E}}{\tilde{w}C_d}\theta(\frac{\tilde{d}}{\tilde{h}})^3} \tag{4}$$

Flood flow velocities calculated by (4) are shown in Figure-11 as a contour diagram. Here $\widetilde{V}$ is the flow velocity; $\widetilde{E}$ is Young's modulus; $\widetilde{w}$ the unit volume weight of water; and θ the angle of trees. The results indicate that the flow velocity in this section may be 4-5m/s. The two-dimensional flow analysis, assuming that trees do not uproot, gives smaller flow velocities in groups of trees. However, with a surrounding flow velocity of about 4m/s, an initial flow velocity of about 3m/s may convert into a large force on the upstream side of the forest, uproot trees upstream, and eventually develop into about 4m/s flow at the observation point.

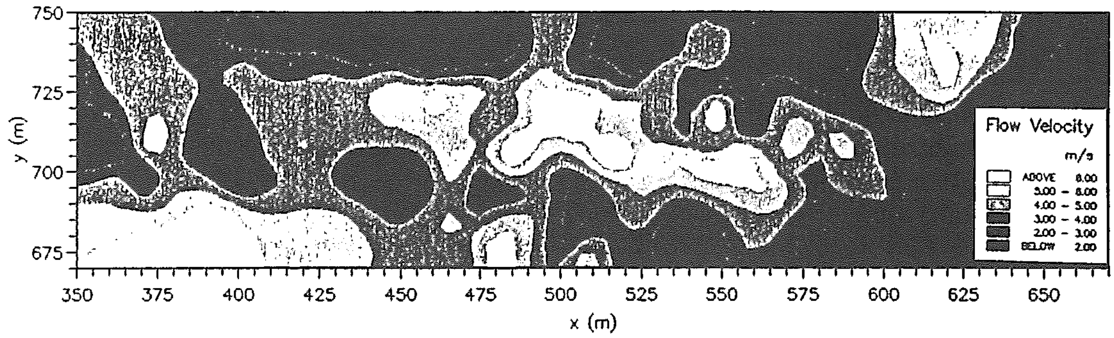

Figure-11 Contour Diagram of Flow Velocity Calculated from the Angle of the Trees

SUMMARY

A field survey of uprooted trees in the river channel after the 1992 flood of the Mukawa River and an analysis of the behavior of the flow during a flood were conducted. The results are:

1. Tree seeds easily took root around revetment blocks, and trees develop quickly.
2. The channel vegetation (alder and willow) in the survey area was classified as "good" according to the yield estimation table, and they may be uprooted at a flow velocity of 4-5m/s.
3. The root spread and the root thickness were 110cm and 50cm on average.
4. The flood flow expanded to the high water channel, and may converge at some point to develop into a force large enough to uproot trees due to the slightly lower ground of the former channel, and as the major bed becomes narrower downstream.

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