LANDFORM CLASSIFICATION FOR FLOOD PREVENTION USING AERIAL PHOTOGRAPHS

by T. Nakano, M. Ohya and T. Kanakubo
The Geographical Survey Institute, Tokyo

Abstract The usefulness of landform classification was proved in a tragic way when the Ise-wan typhoon attacked the central part of Japan in September 1959. The high tide and the river floods, caused by this typhoon, killed more than 5,000 people. After the inundation, more than 6,000 aerial photographs of various types were taken at different dates. Analysis of these photographs showed a clear relationship between landform and the areas that had been hit by the inundation.
The results of this survey were of great value, not only for physical geographic studies, but also for the design of reconstruction works and for town planning. The idea of landform classification has also been applied to furnish the fundamental data necessary for flood prevention in the alluvial plain of the Bay of Tokyo, one of the regions most susceptable to high tide and river floods in Japan. Maps made for the purpose of flood prevention have been compiled using the results of landform analysis from aerial photographs, field checks and levelling.

Résumé La classification des formes du relief a prouvé son utilité d'une manière tragique lorsque le typhon Isewan attaqua la partie centrale du Japon en septembre 1959. La raz de marée et la crue des rivières causés par ce typhon tuèrent plus de 5.000 personnes. Après les inondations, on prit plus de 6.000 photos aériennes de différents types à différentes dates. L'analyse de ces photos a montré qu'il existait une relation évidente entre la forme du relief et les régions atteintes par l'inondation.
Les résultats de cette étude se révélèrent d'une grande valeur non seulement pour des études de géographie physique mais aussi pour les plans de reconstruction et d'urbanisme. L'idée de la classification des formes du relief a aussi été utilisée pour fournir les données fondamentales à la prévention des inondations dans la plaine alluviale de la Baie de Tokyo, une des régions les plus exposées aus raz de marée et aux crues. Dans le cadre de la prévention contre les inondations, on a établi des cartes d'après les résultats de l'analyse des formes du relief par photos aériennes et contrôle sur le terrain.

Zusammenfassung Die Nützlichkeit der Landformenklassifikation wurde unglücklicherweise durch den Isewan Taifun, der im September 1959 Mitteljapan überfiel, bewiesen. Mehr als 5.000 Personen wurden durch die Flutwelle und die Flussüberschwemmung infolge des Taifuns getötet. Nach der Inundation wurden über 6.000 Luftbilder verschiedener Typen, in verschiedenen Zeiten aufgenommen. Durch die Analyse dieser Luftbilder wurden die Zusammenhänge zwischen Landformen und Inundation klar und deutlich festgestellt.
Die Ergebnisse dieser Untersuchungen waren sehr wertvoll, nicht nur für die Forschungen in der physikalischen Geographie, sondern auch für den Wiederaufbau und die grosszügigen Urbanisierungsplanungen. Derselbe Gedanke ist auch auf den Überschwemmungsschutz für die Alluvial-Ebene entlang Tokio Bai, die eine der schwächsten Gegenden in Japan gegen Flutwellen und Flussüberschwemmung ist, gerichtet worden. Die Überschwemmungsschutzkarte ist durch Ergebnisse der Analyse der Landformenklassifikation mit Hilfe von Luftbildern, Nivellierung, und den Feldvergleich zusammengestellt worden.

Introduction

It is well known from experience that the nature of an inundation varies even within a morphological unit. The depth of stagnant water, the period of stagnation, the resulting erosion and deposition, all depend on the minor

landforms within the region. As most of the alluvial plains in Japan have been built up by repeated flooding, the history of inundation is contained in their micro-topography.

Landform classification mapping with aerial photographs, showing the relations to flooding

The authors analysed the landforms of the plains in the lower courses of the large rivers in Japan by photo interpretation and field investigation. Since 1959 they have been producing the "Topographical survey map with classification of areas liable to flood", or the "Landform Classification Map for Flood Prevention".

The first stage in the normal procedure for making this map is the preparation of a provisional map by aerial photo interpretation. This provisional survey not only increases the efficiency of the necessary field investigation, but

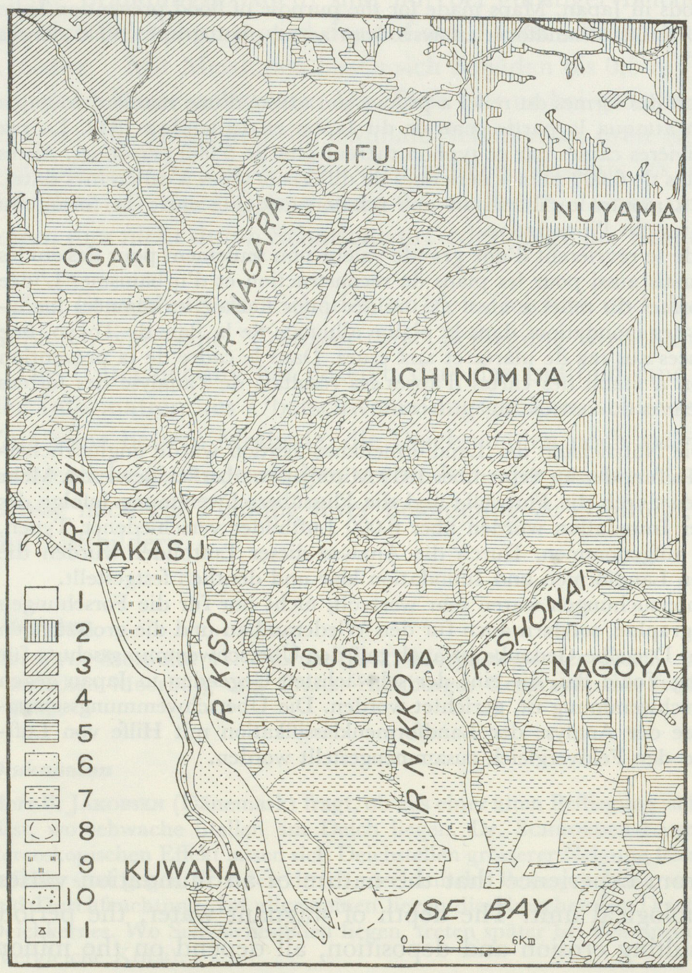

FIG. 1. Map of micro-topography classification of the lower course of the Kiso River, showing flood types of the region. 1. mountains; 2. terrace; 3. fan; 4. natural levee; 5. back marsh; 6. delta; 7. reclaimed rice field; 8. submerged agricultural land; 9. swamp; 10. dry river bed; 11. tidal limit

also makes the results of the survey more uniform in accuracy and amount of detail shown. The preliminary map is then put into its final form by field checking.

The quality of the photos was good, the images being clear and distinct. Viewed stereoscopically, they allowed a detailed landform classification of Japan to be made, especially of the plains.

The land surface is divided into three main types, the mountains and hilly areas, upland and terrace areas, and plains. The plains are then further subdivided by criteria such as form, altitude, slope, moisture, structure, vegetation and land use, into valley plains, fans, natural levees, deltas, tidal flats *etc*. Fig. 1 is an example of a landform classification map for flood prevention. From this map we can easily forecast the nature and duration of floods, should the dykes be destroyed.

Relief Map

The smallest contour interval on the 1 : 25,000 topographic map, even in the plains, is normally 2,5 m. If we wish to depict microrelief, however, a contour interval of between 0,5 and 1 m is required.

Relief maps of the plains were compiled from the aerial photographs, ground levelling, and the detailed landform classification map. Thus the contour lines show the micro-relief of the plains. Fig. 2 is part of the relief map of the Nobi Plain, at the mouth of the River Kiso.

Mapping flooded areas from aerial photographs

Maps have also been made of these areas, showing the actual flooding caused by typhoons and cloudbursts. A provisional map is compiled from aerial photographs taken immediately after the flood. These are analysed for the extent of the inundation, the direction of the flood current, erosion and deposition, and damage to dykes, lines of communication, houses, bridges *etc*.

After the high tide caused by the Ise-wan Typhoon, over 6,000 aerial photos, taken over a period of time, were analysed. Using infrared photography, not only was it possible to delimit the maximum extent of the inundation, but also a distinction could be made between areas flooded by salt, and those flooded by fresh water.

Completion work consisted of field measurements of the period and depth of stagnation, the duration of the inundation, the depth of deposition, and the limits of the tidal waves.

The relationship between inundation and landform

The flooding of the lower reaches of the River Kiso resulting from the Ise-wan Typhoon (Typhoon "Vera") in 1959, was an invaluable test of the usefulness of the flood prevention maps. On 28th September, 1959, the city of

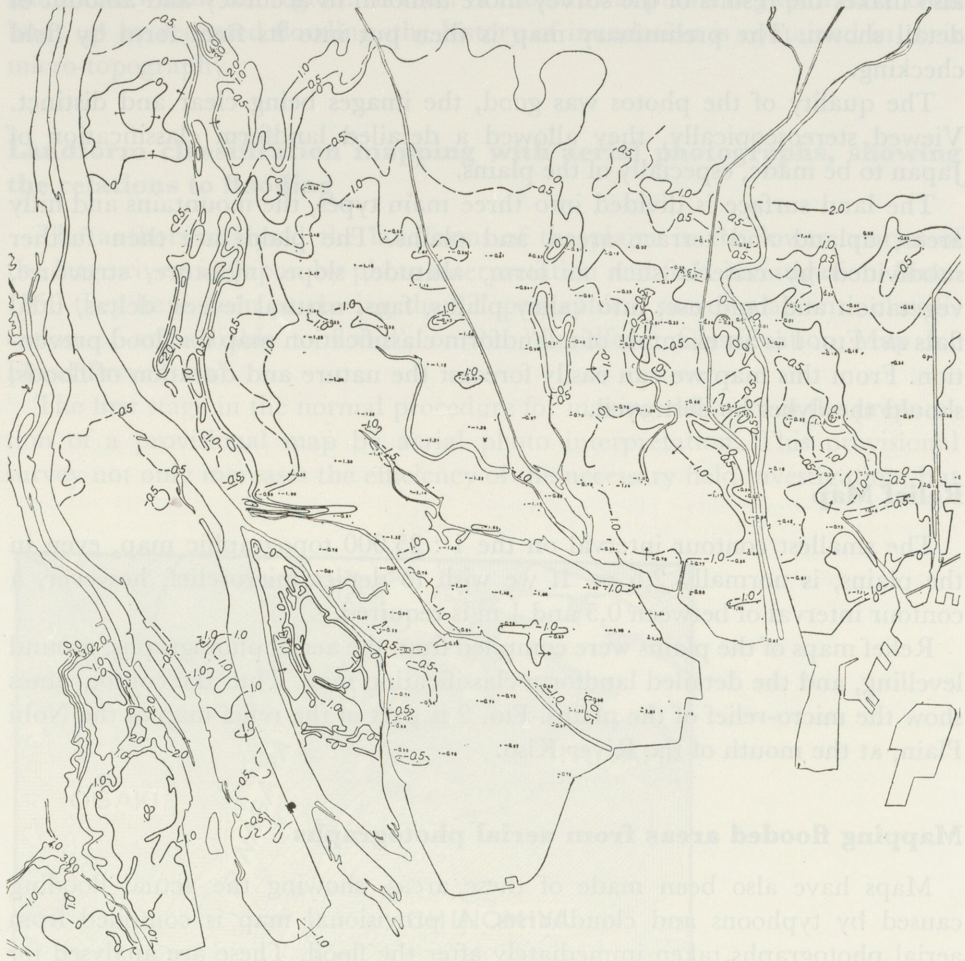

FIG. 2. Map showing the Nobi Plain

Nagoya and the surrounding area were devastated by the high tide of the Isewan Typhoon. The tide is reported to have been as high as 5.15 m in the harbour at Nagoya. In the disaster, 5,200 people were drowned, and property losses amounted to 530,000 million yen (about $ 1,472,000,000).

The characteristics of the flood (the direction of the flood current, variations in the inundation, duration, and depth of stagnant water), were found to be almost exactly the same as could be predicted from the flood prevention map.

Thus local landforms, such as plateaux, terraces, valley plains, fans, natural levees, back swamps and deltas have a definite effect on the inundation of the area.

The relationship between "Tsunami" inundation and landform

On 24th May, 1960, the abnormal tidal waves, or "Tsunami", caused by

the Chilean earthquake, reached the Pacific coast of Japan. In this disaster, 139 people were drowned, 5,015 houses were destroyed, and many ships were lost.

The same procedure as after the Ise-wan Typhoon was followed. The photographs taken by the Defence Army of Japan and the Asia Aero Survey Company, Tokyo, were used for micro-geomorphological analysis and to obtain details of the destruction. The 1 : 15,000 photos taken immediately after the disaster were particularly useful. In the photo interpretation we could analyse:

a. the movement of the tidal wave over the land;
b. the area inundated;
c. areas of erosion and deposition;
d. damage to houses, bridges and other constructions, and
e. micro-landforms.

The field survey included a description of the area itself, the maximum depth of inundation, the time at which the water reached its highest level, the time when the inundation by each tidal wave started, the velocity of the tidal waves, and the magnitude of the disaster.

A landform classification map of the coasts devastated by the Tsunami was compiled, together with one showing the size of the tidal waves and the damage caused by them. From these we could formulate the following relationships between the abnormal tidal waves and landforms.

1. There are distinct regional differences in the character of the tidal waves. These are caused by differences in coastal morphology.
2. The main routes taken by the tidal waves, their maximum extent, and their period of stagnation, are closely related to the coastal landforms.
3. The penetration inland of the tidal waves varies with the morphological details such as the valley plain, wave-cut benches, deltas, sandspits, sand-dunes, artificially filled-in areas, the beach, and the dry river bed.

Application to town planning

The nature and duration of flooding can thus be forecast from the micro-relief of the plains. By studying this, we can foretell the type of future floods, and the amount of damage which they may cause. Planning of future cities and villages along the coasts will be greatly influenced by considerations of landform and flooding.

The results of this survey were thus valuable not only as a study in physical geography, but also for reconstruction work and town planning. The same ideas have been applied to give the fundamental data for flood prevention in the alluvial plain of the Bay of Tokyo, one of the regions most liable to flood. The landform classification map for flood prevention in the city of Tokyo and its vicinity, has been compiled from aerial photographs and field investigation.

From these landform maps, the project of flood prevention most suited to a particular area can be planned.

Discussion

Mr. TRÉMOLIÈRES (France) asked the speaker if he was of the opinion that aerial photographs taken at sufficiently close intervals during a period of inundation and retreat of the water, could replace a sufficiently detailed topographic map in establishing a management plan for a watershed. Dr. NAKANO answered that as the length of the rivers in Japan is generally short with a steep gradient, the plains are frequently flooded. The alluvial plains have been built up by repeated flooding. Conversely, if we analyse micro features of the alluvial plains, we can determine the areas which will be easily flooded. For this purpose photographs on scales of 1 : 10,000 to 1 : 40,000 are being used. Besides these, there are maps on scales 1 : 25,000 and 1 : 50,000, which are also used for geographical surveys, but all information regarding land surface such as landform, hydrography, land use *etc.* is obtained by interpretation of aerial photographs.