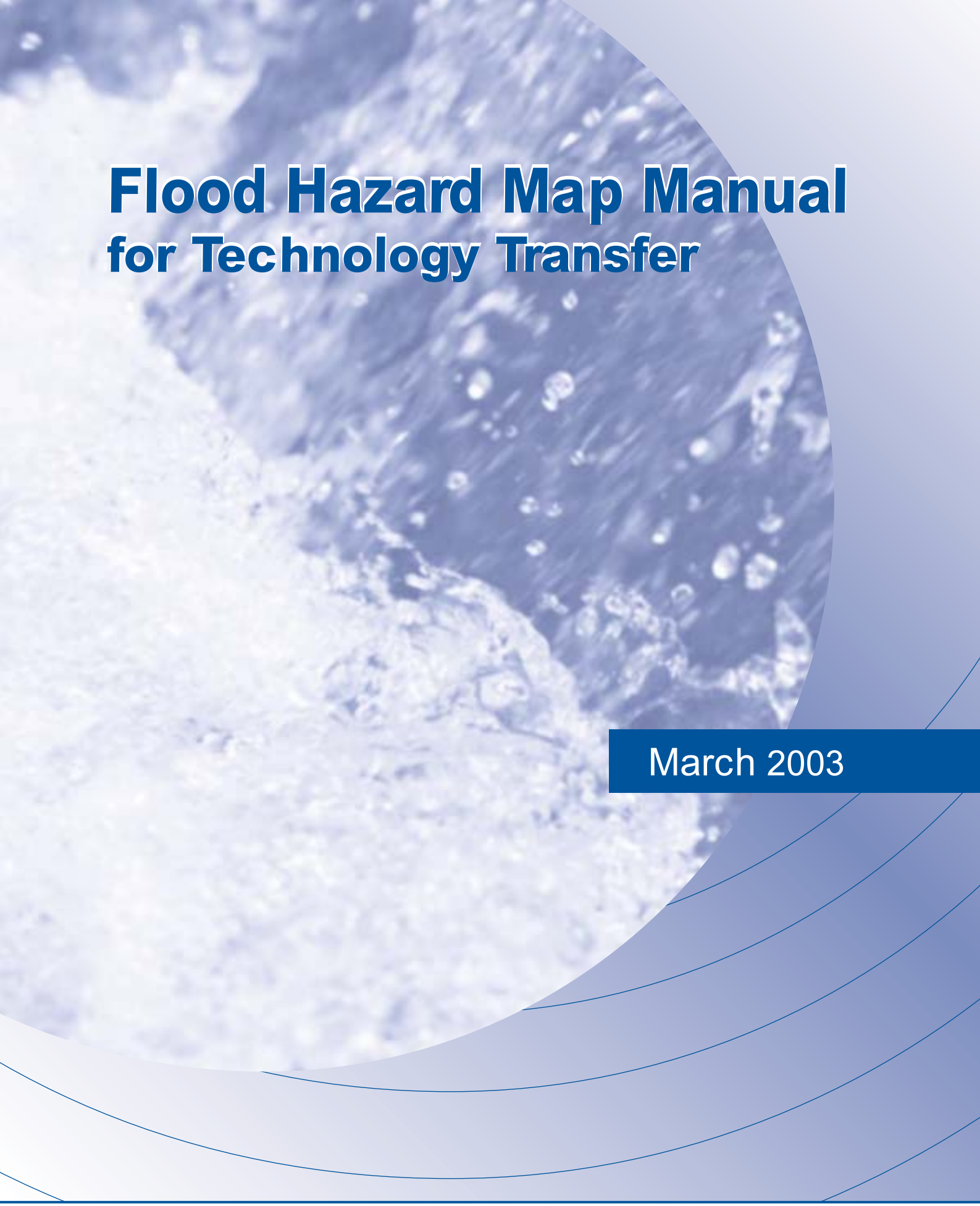


Flood Hazard Map Manual
for Technology Transfer

March 2003

Ministry of Land,
Infrastructure and Transport,Japan
Infrastructure Development Institute-Japan

Contents

Preface

This manual describes in brief the background, purpose, production and distribution of Flood Hazard Maps, as well as their verified effectiveness and current usage in Japan. Realistic questions on the evacuation of local residents in the event of flood are clarified, and the practical and effective usage thereafter of Flood Hazard Maps is reviewed in turn.

The features and characteristics of rivers, flooding mechanisms, social framework, viewpoints on flood protection, collaboration of river management and residents, and the background and circumstances of Flood Hazard Maps of Japan might be different from those of other countries.

The experience gained from the use of Flood Hazard Maps in Japan would be of significant use to other countries as well, provided the maps are used according to the specific circumstances of the respective countries.

1. Background

With economic growth, urbanization and the subsequent concentration of population and property, people who have never experienced a flood are moving in increasing numbers to flood-prone areas in many countries. Conversely, residents are less aware of the threat of floods where flood control facilities have been improved and the frequency and magnitude of inundation are reduced. In such cases, they are hardly prepared for floods and by no means assured of proper actions to take, consequently suffering more serious damage once a flood occurs.

It is time-consuming and costly to thoroughly construct flood control facilities to lower the risk of flood damage. It is advisable to enhance local residents' awareness of the importance of flood protection efforts concurrently with the steady development of flood control facilities so that overall flood damage shall be mitigated. Flood Hazard Maps are essential in achieving this goal and assist local residents in becoming aware of the vulnerability of the area they live in, the important roles that they play in disaster prevention activities and proper evacuation in the event of floods.

In Japan, the rivers generally have steep-gradient beds, and even now several urbanized areas are hit by flood damage every year. For example, Nagoya, the third largest city in Japan, and its outskirts, experienced intensive rainfall of more than 500 mm around the middle of September 2000 and suffered extremely serious damage.

Levee Break of the Shinkawa-river September, 2000 in Nishibiwajima

Flood damage mitigation in Japan thus far has primarily been developed through structural measures such as flood control dams and flood protection levees. As a result of these efforts, the frequency and magnitude of floods have definitely been reduced. The structural measures have so far had a remarkable effect; however, floods and inundations still occur year after year, demonstrating that important issues remain to be tackled:

1) Structural measures, such as dams and levees, are primarily time-consuming and costly. Until these structures are fully completed, there is a need for other effective measures for flood damage mitigation.
2) The structural measures for large rivers in Japan are based on the assumption of very heavy rain occurring, in principle, once in 100 years. In a case where heavy rain exceeds this target rain level, the structures could not prevent the occurrence of flood damage, even if they were completed. There is a need for another measure for whenever heavy rains exceed the target level.
3) Where the construction of levees has been developed, the frequency and magnitude of flooding are reduced, and accordingly, factories and dwellings will certainly be set up. In such a case, the flood damage would be even more formidable if inundation occurs even once in these areas. Although the structural measures reduce the frequency and magnitude of floods, they increase the potential damage. This issue needs to be solved.
4) The residents who live in those areas where flooding has been reduced due to the improvement of levees, might be overconfident in the structural measures, and less conscious of the potential danger. They are not able to take proper action in the event of flood occurrence, and so the extent of damage would even be greater.

To cope with these issues in Japan, non-structural mitigation measures are currently under development, hand in hand with the structural measures. Flood hazard mapping is a good example of such non-structural measures.

2. Definition of Flood Hazard Map

The “Flood Hazard Map” herein referred to is a map that graphically provides information on inundation (predicted inundation areas, inundation depth, etc.), as well as on evacuation (location of evacuation refuges, evacuation routes, dangerous spots on evacuation routes, etc.) in an easy-to-understand format. The goal is to quickly evacuate local residents in a safe and proper manner in the event of floods. The map is produced and publicized through a joint effort by those in charge of disaster prevention and those in charge of rivers and hydrology in the respective local municipalities.

3. Map Preparing Body

Flood Hazard Maps shall be prepared principally by the local disaster prevention division of the respective municipalities, in close cooperation with the local residents, qualified experts, NGOs and other pertinent bodies.

In Japan, the head of the respective local municipality, such as the city mayor, town headman, or village headman, is stipulated as the executive official in charge of the local disaster prevention division, and is authorized to issue evacuation warnings and orders. The evacuation activities in the event of flood are thereby implemented on the level of the respective cities, towns and villages. The Ministry of Land, Infrastructure and Transport, together with the Prefectural government concerned, provide the flood-related information (predicted inundation areas, inundation depth, etc.) to the respective local municipalities. They produce the Flood Hazard Maps on the basis of the presented information on the inundation.

4. Scope

This manual applies to areas that have rivers with steep stream-gradient and suffer flash floods within several hours to several days from start to peak.

5. Purpose

Flood hazard mapping in Japan commenced in 1994, when the Ministry of Construction (currently the Ministry of Land, Infrastructure and Transport) circulated an official notice to all local municipalities on the preparation of the maps.

The Government officially publicized “Past Inundated Area Maps” for about 500 rivers that historically inflicted flood damages, as well as “Flood-prone Area Maps” through 1993 into 1994 for the rivers under their ministerial jurisdiction. Since 1995, taking these opportunities, flood hazard mapping has been positively implemented by local municipalities, and as of June 2002, 173 Flood Hazard Maps had been produced.

Flood analysis results have been publicized since 1999 through such media as CD-ROMs and Internet homepages. Furthermore, the publicity of “Flood-prone Area Maps” became obligatory in 2001 under the Amendment to the Flood Fighting Law, consecutively with the Amendment in 1996 to the River Law and the Enactment in 2001 of the Sediment-related Disaster Prevention Law. Whereas structural flood mitigation measures are aimed at preventing flooding and inundation, the Flood Hazard Maps are based on the premise that flooding will inevitably occur, and are aimed at minimizing loss of life by intensively expediting the evacuation of local residents.

The purpose and advantageous effects of producing Flood Hazard Maps are summarized below:

1) For local residents (Publicizing effects of flood information)
- Local residents receive various types of information on potential flood damage and become aware of the importance of voluntary disaster prevention efforts and proper evacuation.
- When flood warnings are issued and a flood occurs, local residents are able to evacuate promptly and smoothly to avoid injury.

2) For local municipalities concerned (Administrative crisis-management effects for flood prevention and preparedness planning)
- Producing Flood Hazard Maps demands that the administrative staff in charge of disaster prevention simulate emergency drills, and thus urges local municipalities to develop disaster prevention and preparedness countermeasures.
- Local municipalities are able to promptly and smoothly accomplish the evacuation of local residents, using information on the Flood Hazard Maps.

Table 1 shows several examples of the effective use of Flood Hazard Maps.

Table 1 Use of Flood Hazard Maps

Category	Local Residents	Local Municipalities
Everyday life	- Consider proper land-use patterns and water-resistant buildings suited to the flood vulnerability of the area	- Review urban planning and land-use patterns that are resistant to flood
	- Prepare emergency kits, emergency food, etc. - Prepare boats and other appropriate means of evacuation	- Update disaster-prevention and flood-fighting plans of the area - Review refuges and evacuation routes - Update specific assistance plan to evacuate or rescue the vulnerable (elderly, handicapped, sick, injured, etc.)
	- Identify proper communication channels and systems for information on evacuation - Organize voluntary disaster prevention units	- Update communication channels and systems for information on evacuation - Develop voluntary disaster prevention units
	- Learn about past inundation history and risks of inundation of the local area - Organize educational sessions on potential flood damage, preparedness and evacuation	- Promote education on disaster prevention and conduct evacuation practice drills - Publicize importance of disaster prevention and preparedness
Emergency situations	- Confirm proper refuges, evacuation routes, emergency kits, etc.	- Identify flooded areas, inundation depth, location of refuges, and evacuation routes
	- Evacuate independently, following weather forecast, flood-related information, emergency warnings, etc.	- Provide information on weather forecast and flood forecast
	- Assist in evacuation of those vulnerable to floods	- Support and rescue those vulnerable to floods
	- Evacuate to proper refuges through safe routes, following advisory and imperative evacuation warnings	- Provide continuous flood-related information on evacuation - Set up refuges - Issue advisory and imperative evacuation warnings - Direct evacuation

The information incorporated in Flood Hazard Maps shall be those items that are practical and useful in the event of flooding, ensuring the safety and proper evacuation of local residents. Items such as predicted inundation areas and location of refuges, are termed “Evacuation-use Information,” and items that will be helpful in everyday life, by notifying the residents of potential flood damage and enhancing their awareness of the importance of flood disaster preparedness, are termed “Educational-use Information.”

To make efficient use of Flood Hazard Maps, local residents must be thoroughly convinced of the real danger of flooding. The indispensable information on evacuation and, accordingly, the evacuation-use information, shall be incorporated in the hazard maps. Educational-use information shall be appropriately incorporated or not, depending on the purpose of preparing the Flood Hazard Maps in the respective municipalities.

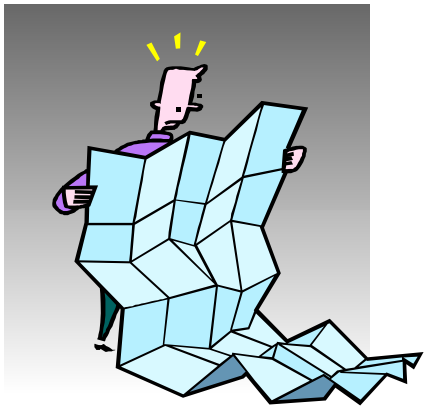
The key items to be incorporated in the maps are listed below:

Table 2 Key Items to be Incorporated in Flood Hazard Maps

Evacuation-use Information	Educational-use Information
- Predicted inundation area, inundation depth, flood concentration time - Historical inundation records - Areas to be evacuated - Location of evacuation refuges - Evacuation routes - Dangerous spots on evacuation routes - Rules to follow in the event of evacuation - Communication channels and systems for information on evacuation - Issuance criteria for evacuation warnings - Map preparing body, date of preparation	- Flooding mechanism - Topographic features, flood types - Real danger of flood, predicted extent of damage - Meteorological information - Past flood records (rainfall, inundation and damage - Rules to follow in the event of flood - Explanation and directions to use-up Flood Hazard Maps - Preparedness against flood

Note:

- The more detailed items are stated later.



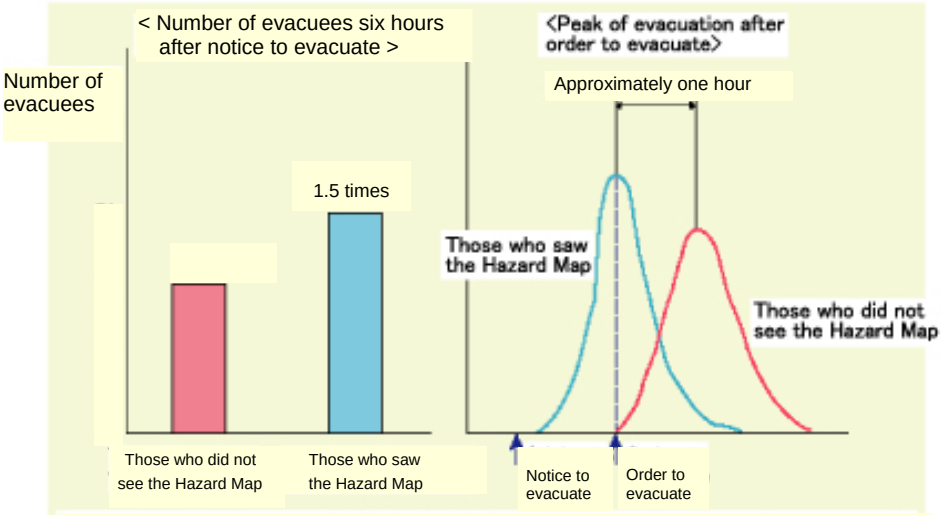
6. Effectiveness of Flood Hazard Map

In Japan, the effectiveness of Flood Hazard Maps has already been verified in several cases. The first case was the flooding of the Abukuma River in the Tohoku district in August 1998. The city of Koriyama is located in the middle reach of the Abukuma River, and the Flood Hazard Maps had been produced and distributed among the local residents well before the occurrence of the flood.

Flooding in Koroyama City, August 1998

According to the questionnaire survey conducted immediately after the flood, the effectiveness of the Flood Hazard Maps was satisfactorily verified as stated below:

1) The majority of the local residents referred to the locations of the refuges on the Flood Hazard Maps, and evacuated to the proper refuges.
2) The number of evacuees was 1.5 times more for those who referred to the maps than for those who did not.
3) Residents who referred to the maps commenced evacuation one hour earlier than those who did not.



Source : "Survey Report on Local Residents' Reaction during the Rainstorm in Koriyama at the End of August 1988"
Katada Laboratory, Faculty of Engineering, Gunma University

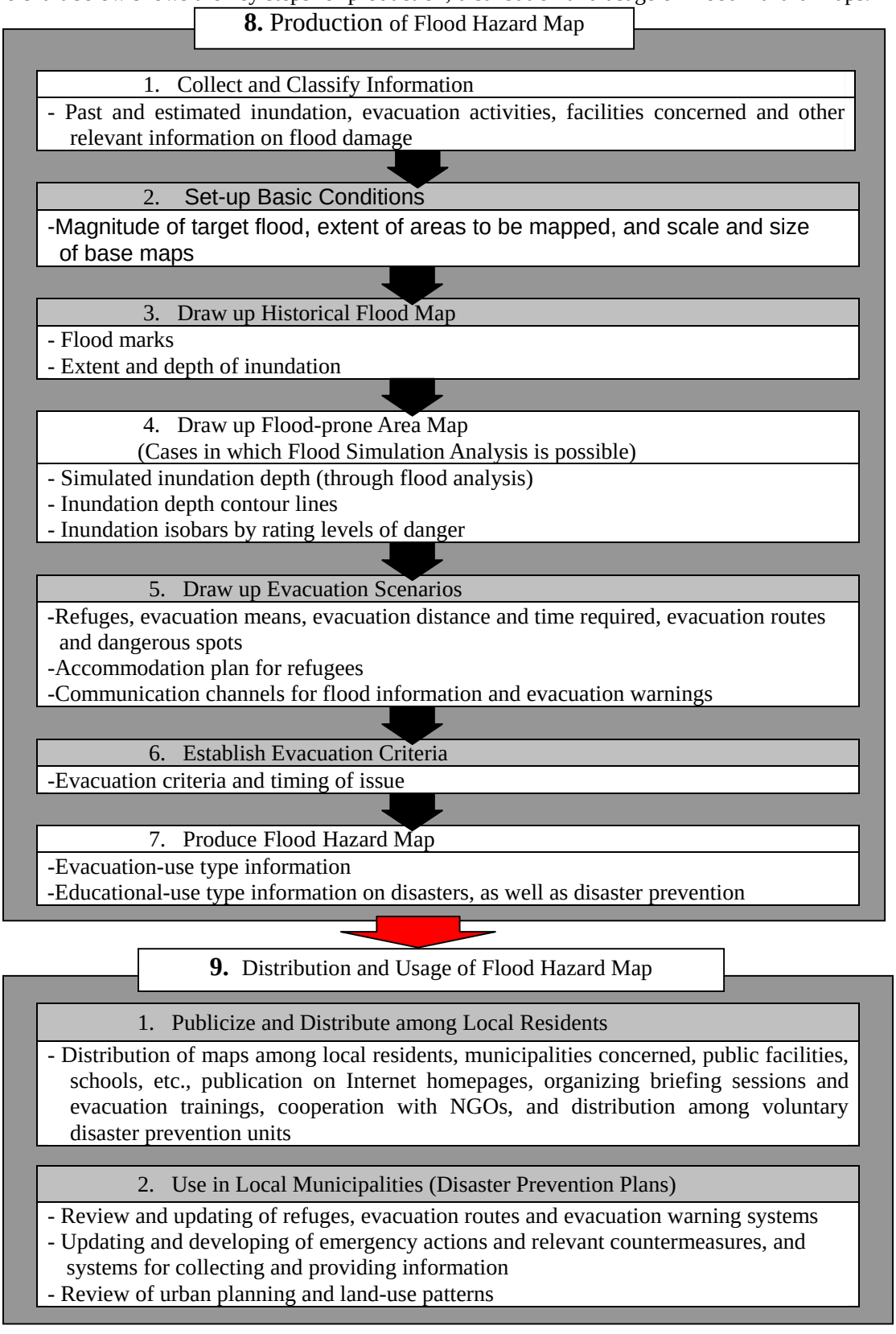
The Flood Hazard Maps of the city of Koriyama were highly effective for the risk management of the city. In the process of producing the maps, the administrative staff in charge of river management for the city were astonished that the flood-prone areas ranged so widely, and that so many residents were scattered within the areas.

Crisis Management Effects

The necessity for establishing practical and detailed evacuation plans, such as the location of refuges and the pertinent timing of issuing advisory evacuation warnings, was fully realized, and the relevant actions were immediately put into practice and implemented. Such planning played an extremely important role in the effective and efficient evacuation of the local residents during the 1998 flooding. If the Flood Hazard Maps had not been prepared, the evacuation would not have been smooth.

7. Process of Production, Distribution and Usage of Flood Hazard Map

The chart below shows the key steps for production, distribution and usage of Flood Hazard Maps.



8. Production of Flood Hazard Map

8.1 Collection and Classification of Information

It is desirable to collect the following information for producing Flood Hazard Maps.

Table 3 Information to be Collected

Category			Description
Base maps			-Base maps (topographic maps in scales of 1:2,500, 1:10,000 and 1:25,000) -General-purpose maps
Information on inundation	Past inundation		-Spill overtopping and levee-break spots, inundated areas, inundated depth -Damage suffered -Hourly water level and hourly rainfall on major spots of the river
	Estimated inundation		-Results of flood simulation analysis, such as flooded areas, inundation level, inundation depth, etc. -Flood diffusion process -Change of inundation depth with time elapsed -Flood flow velocity
Information on evacuation	Areas to be evacuated		-Boundaries of jurisdictional districts and blocks, school districts and neighboring associations' territories
	Number of residents to be evacuated		-Population by district -Households by district
	Evacuation refuges		-Refuges -Public facilities (kindergartens, elementary schools, junior and senior high schools, colleges and universities, civic centers, assembly halls, gymnasiums, etc.)
	Dangerous spots on evacuation routes		-Spots with potential steep-slope collapse, mud flows and debris torrents -Roads blocked by past inundation -Past landslide spots -Underpasses -Bridges
	Communication channels		-Communication channels and appliances for use in emergency
	Underground spaces		-Locations of underground spaces, and emergency communication system to users
	Evacuation criteria		-Evacuation criteria -Past evacuation activities (issuance and communication channels of advisory and imperative evacuation warnings, refuges set up, number of refugees accommodated)
	Facilities for those vulnerable in the event of emergency		-Number of residents to be assisted -Facilities for the vulnerable (hospitals, homes for the elderly and handicapped, and other facilities concerned)
	Other information to be collected	Bodies and agencies concerned	-Local municipal facilities -Prefectural facilities -National facilities -Firefighting facilities -Police stations and call boxes
		Disaster prevention facilities and equipment	-Administrative wireless radio stations for disaster prevention, loudspeakers, sirens -Disaster prevention centers -First-aid stations, information-display facilities on flood damage -Water level stations and rain gauge stations
		Medical facilities	-Emergency hospitals -Public health centers -Hospitals, doctors' offices and clinics
		Lifelines	-Water supply and sewerage plants, gas works, power plants and substations -Telecommunication facilities (telephone exchange offices)
		Social welfare facilities	-Homes for the elderly and handicapped

8.2 Setting-up of Basic Conditions

The following basic conditions shall be set up beforehand, taking into consideration past inundation records and evacuation activities, as well as the existing circumstances of possible inundation areas and topographic features:

- Magnitude of target flood
- Extent of areas to be mapped
- Scale and size of base maps

(1) Magnitude of Target Flood

The target flood shall, in principle, be specified among the following floods:

1) Design flood
2) Largest flood previously recorded
3) Largest flood occurring once in several years

However, in the many areas where flood analysis has not been sufficiently conducted, it is admissible to select from the largest flood recorded, historically severe flood, or the largest flood occurring once in two years.

(2) Extent of Areas to be Mapped

The extent of areas to be mapped shall, in principle, be the entire areas of the local municipalities. If the potential flood areas are only a part of the municipalities, these areas and their outskirts shall be properly mapped.

The neighboring territories shall be integrally incorporated and produced in the map when the potential flood areas extend to neighboring municipalities. Evacuation to other municipalities shall be planned and incorporated accordingly.

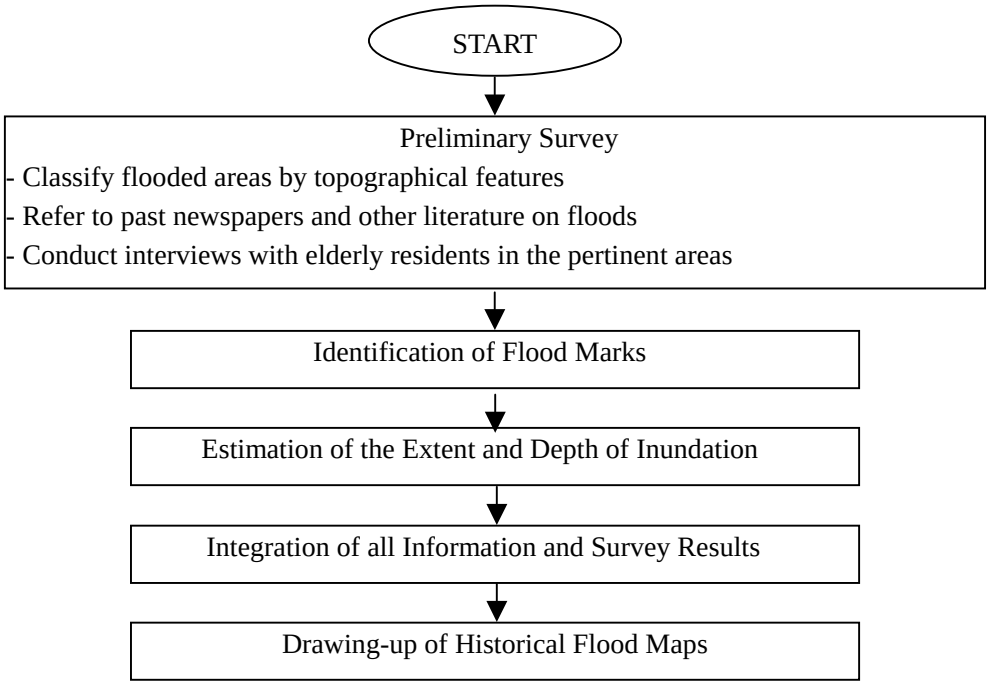
(3) Scale and Size of Base Maps

The standard scale of base maps shall be 1/10,000 to 1/15,000 in order to enable identification of not only individual houses, but also evacuation routes and extent of inundation. Topographic maps of 1/25,000 to 1/50,000 are generally undesirable because they do not allow identification of individual houses.

The standard size of base maps shall be A0 to A1. If these sizes are not appropriate, specify alternate appropriate sizes, taking into consideration relevant factors such as proper scale, number of subdivided maps, necessary cost, ease of use, etc.

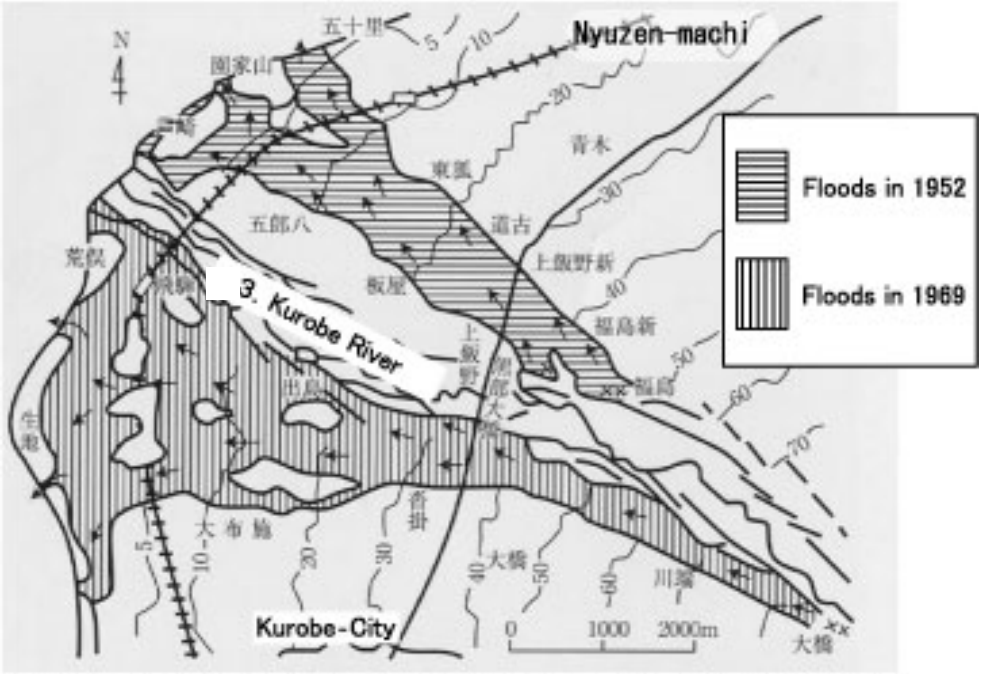
8.3 Drawing-up of Historical Flood Map

Historical Flood Maps are to be drawn up immediately following flooding.



- Example of Historical Flood Map

The Kurobe River floods of 1952 and 1969



Source: Kurobe River Alluvial Fan Story, Institute of Kurobe River Alluvial Fans

(1) Preliminary Survey

For cases in which so much time has passed after inundation that no flood marks remain:

1) On the map, identify the place names recorded in past newspapers and literature, and estimate the approximate extent of inundation on the basis of topographic features.
2) Interview elderly residents in the pertinent areas, to collect information on the extent and depth of inundation.

(2) Identification of Flood Marks

When identifying flood-level marks:

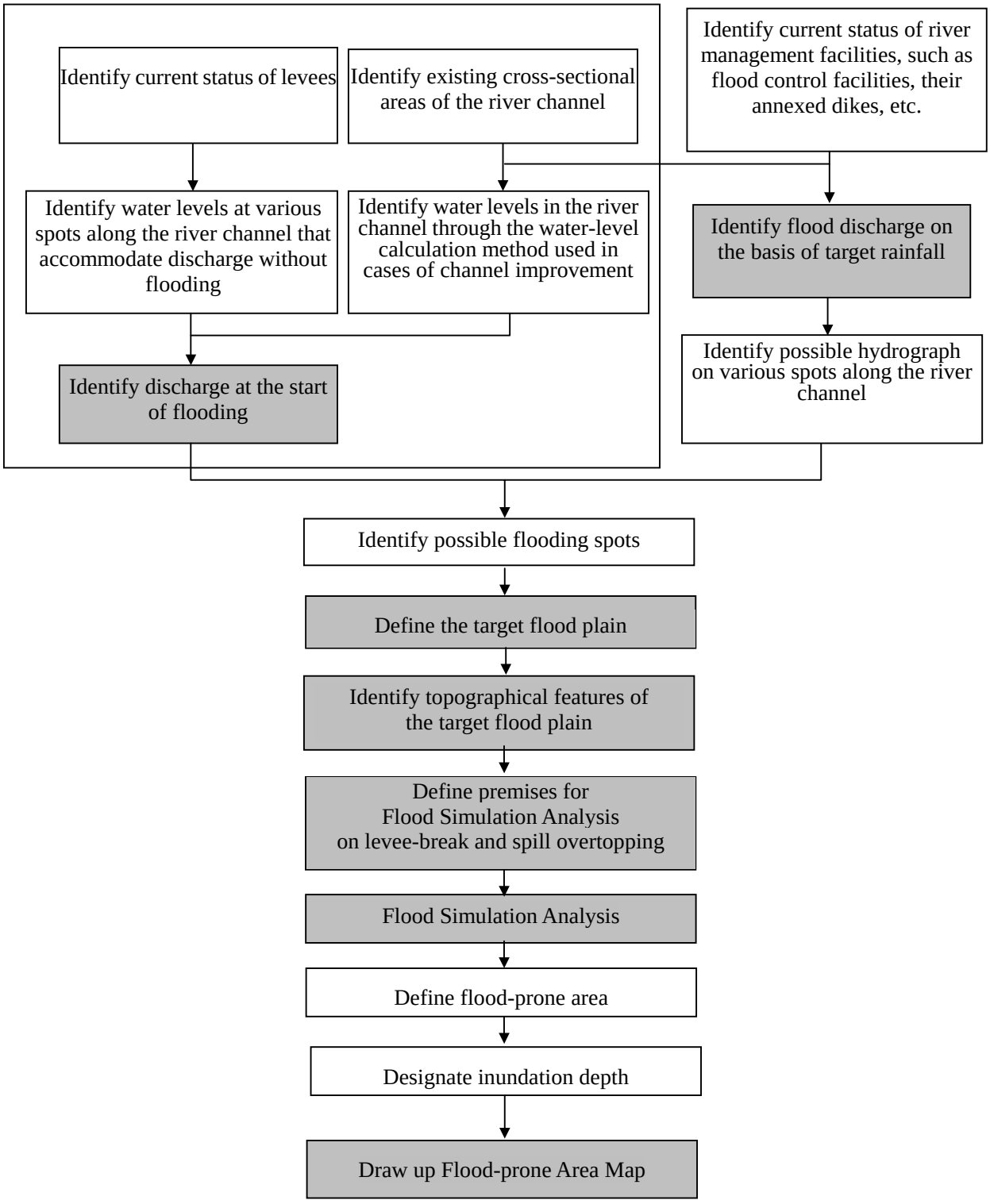
1) Identify the mark levels as soon as possible after the flood reaches its peak.
2) Specify the flood marks, preferably based on mud marks.
   Mud marks fade out in the meantime, or disappear within a short time, particularly after rain. Even if they do not disappear, they might be worked into a lower level by rain.
3) In cases of specifying the marks based on trash, look carefully and extensively around the spots beforehand, and exclude those trash levels unusually lower than the surrounding ones.
   Trash often slides down by its own weight, or might otherwise be moved unnaturally, such as by wind. Mud marks seem to offer more accurate marks than trash. Draw up a proper level-line, connecting the reasonable marks, and define its level by surveying.
4) Compare the mark levels with the peak flood levels recorded at the nearby water-level stations, if any, in order to verify them.
5) Sampling of flood marks in the flow direction shall be done at intervals of 50-100 m in a straight river channel, preferably ensuring the collection of at least one set of reliable data from both sides of the channel.

(3) Drawing-up of Historical Inundation Map

Draw up a map of past inundation, integrating all relevant data collected, that is, the surveyed flood marks, topographically classified feature maps, and estimated inundated area maps through interviews with elderly residents, etc.

8.4 Drawing-up of Flood-prone Area Map (Cases in which Flood Simulation Analysis is possible)

For cases in which Flood Simulation Analysis is possible, Flood-prone Area Maps are to be drawn up and used as basic information for producing Flood Hazard Maps.



Example of Flood-prone Area Map

Source: The Kurobe River Flood-prone Area Map

(1) Defining the Target Flood Plain

A pertinent flood simulation model is to be set up, based on the conditions of the current flood plain.

1) Target flood plain

Define the target flood plain on the basis of estimated flooded area maps from past inundation records, so as to include possible inundation areas by the target flooding, particularly the maximum extent of inundation areas corresponding to the respective assumed levee-break spots.

In lowland areas near the river mouth, the inundation area may be delimited by artificial structures such as levees of a neighboring river, and so forth.

2) Defining the flood plain for the simulation model

In order to accurately estimate the inundation depth of a flood, it is necessary to identify factors such as topographic features, existing continuous banking structures, e.g. roads or railways, and dikes of small- or medium-sized rivers, which affect the overflowing water.

(2) Identification of Ground Level and Land-use Pattern in the Target Flood Plain

To ensure the accuracy of topographic conditions, identify the ground levels in the target flood plain, and define them by 50-m meshes (commonly used in Japan). It is desirable to coordinate these meshes with 250-m flood-simulation meshes (commonly used in Japan), as described later.

1) Identification of averaged ground level

Identification of ground levels is done by specifying the averaged ground level at the center and the four corners of the respective 50-m meshes by using a large-scale urban planning map of 1/2,500 (commonly used in Japan) or the “National Land Base Map,” published by the National Geographical Survey Institute.

Supplementary field surveys shall be conducted, as needed, in order to represent all topographic features as accurately as possible. “Numerical Elevation Map of 50-m Meshes,” published by the Japan Map Center, may be used in Japan for base maps.

2) Identification of current land-use patterns and tenement rate for roughness coefficient

It is necessary to define the roughness of the flood plain for simulation analysis. Survey and define the current land-use patterns and tenement rate thereof.

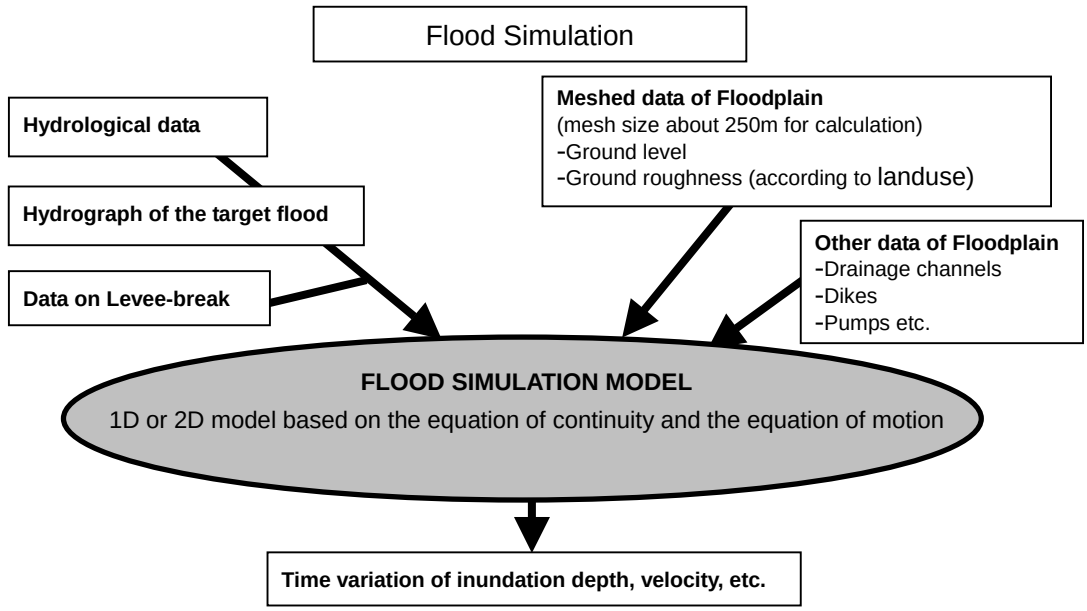
(3) Defining the Premises for Flood Simulation Analysis by Levee-break and Spill Overtopping

1) Identification of premises for flooding due to levee-break, discharge capacity of river channel and flooding-start discharge

Identify the possible flooding spots on the levees, and successively possible flooding-start water levels for the respective spots, taking into consideration the current status of protection and maintenance for the existing river channel.

Here, it shall be assumed that levees break when the channel discharge exceeds water levels of those that could possibly start flooding for the respective dangerous spots.

The water levels shall be specified taking into consideration the levee height and current status of protection works against leakage, filtration, and erosion for the respective spots. In principle, those levels shall be estimated by means of the same analysis method as that for river channel planning.



Refer to the following notes for defining the flooding-start discharge due to levee-break:

a) River channel

The river channel for estimating the flooding-start discharge shall be the existing channel.

b) Assumption in estimating flooding-start discharge

The flooding-start discharge due to levee-break shall be estimated by the same hydraulic analysis method as that for river channel planning. Currently, in cases of planning large river channels, the non-uniform flow analysis (quasi-two-dimensional non-uniform flow analysis) is widely used, taking into consideration the existing trees and shrubs.

c) Establishment of H-Q correlation formula

Using the above-mentioned analysis method, estimate the respective water levels “H” corresponding to the respective discharge “Q” in the current river channel, and establish the H-Q correlation formula in such a form as:

$$Q = a(H + b)^2$$

d) Estimation of flooding-start discharge

For the respective cross sections of the river channel, define “Hj” as the design high-water level (HWL) for the reach where the levee is completed. Similarly, define the marginal water level, at which the river water could barely be accommodated in the channel without spill, for the reach where the levees are not yet completed. Estimate the respective discharge “Qj”, which corresponds to respective “Hj” through the H-Q formula to obtain the flooding-start discharge. It shall be assumed that flooding due to levee-break would start at a specific water level, just exceeding the “Hj” for the embanked reach. Similarly, the flooding due to spill would start at another specific water level, just exceeding the land-level in the flood plain for the non-embanked reach.

The level “Hj” for the non-embanked reach shall be appropriately specified, taking into consideration the current cross sections of the levees, and their protection against infiltration, leakage and erosion.

2) Defining possible flooding spots

It is necessary to estimate the maximum inundation depth of the flood plain, due to flooding at overall dangerous spots. Define the minimum number of flooding spots where levee-breaks bring about the maximum equal extent of inundation, wherever the target flood discharge respectively attains the flooding-start discharge for all possible levee-break spots.

(4) Flood Simulation

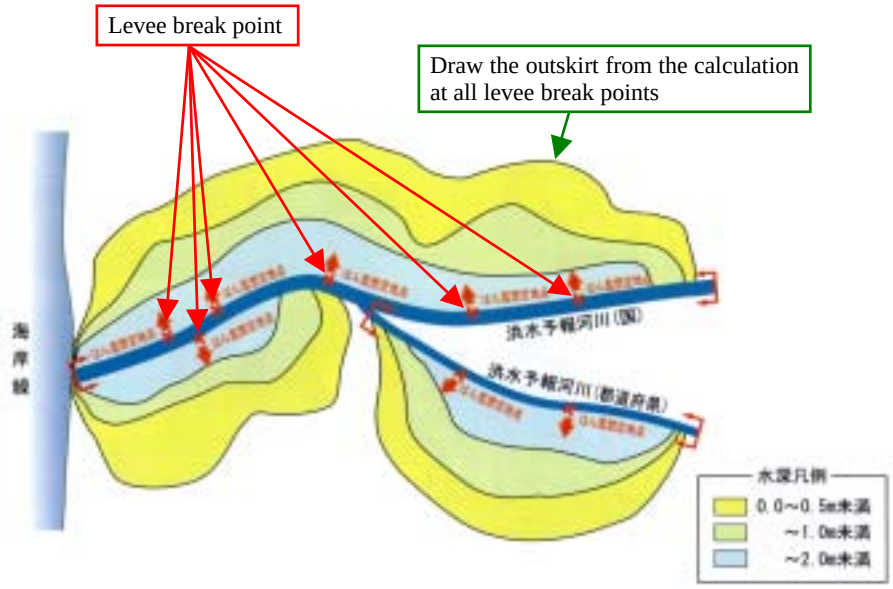
1) Basic concept of simulation analysis

a) Flood wave

The flood wave to be used in the flood simulation shall be specified on the basis of the target rainfall through the same runoff analysis method as that for river channel planning.

b) Flood simulation cases

The flood simulation shall be repeated the same number of times as that of possible flooding spots, as described above. Use only one flooding spot for each case, so that the respective maximum damage (maximum inundation depth) in the flood plain shall be estimated in correspondence to each possible flooding spot.



c) Precautions in flood simulation

i) Spill overtopping and flooding in upstream areas

The discharge hydrograph to be given at a possible flooding spot shall be the one that generates the maximum peak discharge for the respective possible flooding spots in the river channel.

For cases in which spill overtopping or flooding occurs upstream of the possible flooding spots, and the flooded water does not return to the channel (namely, diffusion-type flood), a modified discharge hydrograph is to be given for the respective possible flooding spots, taking into account the reduction of river discharge due to the aforesaid overflow.

ii) Dams and flood control channels

Runoff calculation shall be conducted, taking into account the effect of the existing flood control dams and channels, when designating the target possible flood plain. The inflow from drainage pump-stations, located upstream of the possible flooding spots, is likely to be incorporated as well.

2) Setting-up of conditions for simulation analysis

a) Analysis method of flooding discharge

i) Flooding discharge

The flooding discharge shall be estimated on the basis of the relationship between the river water level at the possible flooding spots, the water level within the protected land behind the levees and the threshold level of the levee-break spots.

ii) River water level

For consistency with river channel planning, the river water level shall be estimated on the basis of the discharge obtained by the unsteady flow analysis for the channel, following the H-Q formula through the same water-level analysis method as that for river channel planning.

iii) Determination of flooding discharge

The flooding discharge due to levee-break shall be dealt with as the transverse outflow across the possible flooding spots.

It is necessary to concurrently conduct both the unsteady flow analysis for the channel and the flood simulation analysis for the plain, with the exception of cases in which the flooding discharge is inevitably determined only by the river water level.

- Floodplain

[Equation of Continuity] $$\frac{\partial h}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0$$

[Equations of Motion] $$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}(uM)+\frac{\partial}{\partial y}(vM)=-gh\frac{\partial H}{\partial x}-\frac{gn^2u\sqrt{u^2+v^2}}{h^{1/3}}$$

$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}(uN)+\frac{\partial}{\partial y}(vN)=-gh\frac{\partial H}{\partial x}-\frac{gn^2v\sqrt{u^2+v^2}}{h^{1/3}}$$

where,

u, v : velocity in the x and y directions
M, N : flow flux per unit width in the x and y directions($M=uh$, $N=vh$)
h : water depth
H : water level
n : equivalent roughness coefficient(considering drag force by buildings)

- River channel

[Equation of Continuity] $$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=q$$

[Equations of Motion] $$\frac{1}{gA}\frac{\partial Q}{\partial t}+\frac{1}{gA}\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right)+\frac{n^2|Q|Q}{A^2R^{4/3}}=0$$

where,

Q : discharge
A : cross sectional area
R : hydraulics radius
H : water level
q : lateral flow

These partial differential equations are discretized by an explicit finite difference scheme, and solved numerically.

b) Defining of conditions for analysis

i) Spill overtopping extent

The spill overtopping range across the levee at the possible flooding spots shall be either the levee-break extent stated below, or the integrated extent up to the successive levee-break spot immediately downstream, whichever is smaller.

ii) Levee-break extent

The pattern of levee-break shall be defined by referring to past break records, if available. If not, estimate the levee break extent “y(m)”, based on the river width “ x(m)”, through the formula as shown below, whether the levee-break spot is in the vicinity of the confluence or not. Here, “the vicinity of the confluence” means that the effects of the confluence shall not be ignored, the width of the tributary is greater than 30% of the width of the main river, and the extent thus affected would be around twice the width of the main river, upstream as well as downstream of the confluence.

-In the vicinity of the confluence : $y = 2.0 \times (\log_{10}x)^{3.8} + 77$

-Not in the vicinity of the confluence : $y = 1.6 \times (\log_{10}x)^{3.8} + 62$

iii) Threshold level of levee-break spots

The levee is assumed to break down to its threshold level of the spot, which shall be either the ground level of the protected land or the level of the high-water channel, whichever is higher.

iv) Levee-break progress in time

The levee is assumed to immediately break to half of the final break extent “y/2”, simultaneously collapse to the aforesaid threshold level, and break to the full extent within one hour. The break is assumed to proceed at a fixed rate.

v) Facilities to affect flooding discharge

The structural facilities that are likely to affect flooding discharge shall be incorporated into the flood simulation model, to the degree that is possible.

-Embankments: If the relative height from the averaged ground level is 50 cm or greater, incorporate the embankments into the model. These are continuous dikes, railroads, highways or other bankings.

-Waterways: If the flooding is such that it surmounts the dike height of small- or medium-size rivers in the flood plain, the waterways are assumed to be full of water as if there are continuous embankments.

vi)Spill overtopping discharge

To estimate the spill overtopping discharge, an appropriate formula shall be selected, taking into consideration the relation between the river channel alignment and the shifting of the water route during a flood, for the respective flooding spots.

-In the case of frontal overflowing

Use Honma's formulae:

- Complete overflow ($h_2/h_1 < 2/3$) $Q = 0.35 \times h_1 \sqrt{2gh_1 \times B}$
- Submerged overflow ($h_2/h_1 > 2/3$) $Q = 0.91 \times h_2 \sqrt{2g(h_1 - h_2)} \times B$

where

h_1 = Inundation depth to the levee-break threshold, whichever is larger

h_2 = Do, whichever is smaller

-In the case of transversal overflowing

Use the formulae below:

where

Q_0 = Flooding discharge, obtained through Honma's formula

I = Riverbed slope

and the unit in parentheses of cosine is degree:

- Flooding discharge (Q) due to levee break

	I > 1/1,580	$Q/Q_0 = (0.14+0.19 \times \log_{10}(1/I)* \cos(48-15 \times \log_{10}(1/I))$
1/1,580 ≧	I > 1/33,600	$Q/Q_0 = (0.14+0.19 \times \log_{10}(1/I))$
1/33,600 ≧	I	$Q/Q_0 = 1$

- Overflowing discharge due to spill overtopping:

	I > 1/12,000	$Q/Q_0 = \cos(155-38 \times \log10 (1/I))$
1/12,000 ≧	I	$Q/Q_0 = 1$

vii)Roughness

Roughness shall be identified taking into consideration all factors, such as simulation model type, land-use patterns of the flood plain, past inundation records, etc.

The effects of existing buildings and others are approximately incorporated into the model constant. The effects of buildings and others are related in the form of roughness coefficients for the simplified one-dimensional unsteady flow model among one-dimensional models, as well as for two-dimensional models.

- Overflow pond model

With the progress of urbanization, the coefficient of discharge "c", which includes the roughness coefficient "n", increases due to the *vena contracta* effect of existing buildings. In the majority of simulation cases, the roughness coefficient is more or less defined as:

c = 0.05 to 0.1

- Open-channel pond model, flood pond model, and simplified one-dimensional unsteady flow model.

The roughness coefficient is defined in accordance with the land-use pattern, which is commonly classified into two types: "rice field and farmland" and "urbanized area." In majority of simulation cases, the roughness coefficients are more or less defined as:

- Rice field and farmland n = 0.1 to 0.25
- Urbanized area n = 0.1 to 0.3

In the flood pond model, however, the roughness coefficient often varies in accordance with the inundation depth.

- Two-dimensional unsteady flow model

The formula shown below is proposed to define the roughness coefficient of the flood plain "n", integrating the roughness coefficients, through the weighted average formula, on those facilities other than buildings, the tenement rate "θ" and the inundation depth "h". The areas of respective land-use patterns are to be identified for each divided mesh.

- Agricultural land:
  A_1 = Area of rice field, farmland, forest, orchard, bamboo thicket, etc.
  n_1 = Roughness coefficient for agricultural land
- Roads:
  A_2 = Area of national highways and major local roads, including sidewalks
  n_2 = Roughness coefficient for roads
- Other types of land-use:
  A_3 = Area of wasteland, grass lawn, marshland, salt field, etc.
  n_3 = Roughness coefficient for other types of land use

$$n^2 = n_0^2 + 0.020 * \frac{\theta}{100 - \theta} * h^{4/3}$$

$$n_0^2 = \frac{n_1^2 A_1 + n_2^2 A_2 + n_3^2 A_3}{A_1 + A_2 + A_3}$$

where

n_1 = 0.060, n_2 = 0.047, and n_3 = 0.050

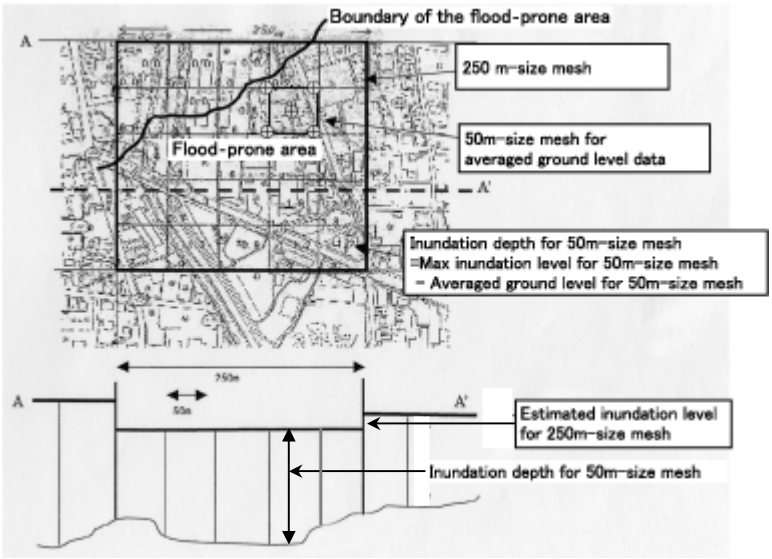
3) Performance of Flood Simulation Analysis

The two-dimensional unsteady flow analysis is commonly applied, although other analysis methods may be used if appropriate in view of the topographic features of the flood plain. When dividing the flood plain into meshes, they should be consistent with the meshes for the averaged ground level data, coinciding with the "Numerical Map Information" or "National Land Numerical Information" data.

(5) Defining the Flood-prone Area

Identify the highest inundation level, through the flood simulation, of each divided mesh for overall cases of possible flooding spots and, in turn, define the maximum one for the respective divided meshes.

Estimate the inundation depth of each mesh by subtracting the averaged ground level (commonly, 50-m mesh in Japan) from the maximum inundation level as defined above, and finally, define the boundary of the flood-prone area, taking into consideration the relevant factors such as existing continuous structures and micro-topographic features.

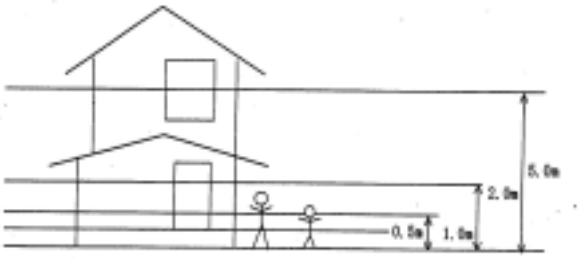


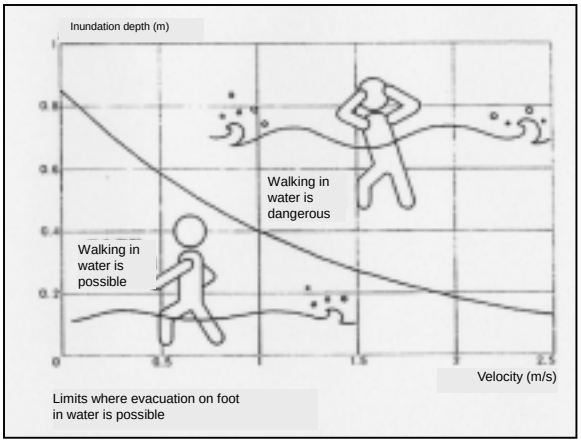
(6) Designation of Inundation Depth

Designation, by using colors, the inundation depth so that the local residents are able to easily understand accurate inundation information.

Inundation depth is normally classified into five ranks, as shown below. Whenever necessary, other ranks such as 2.0 to less than 3.0 m, 3.0 to less than 4.0 m and 4.0 to less than 5.0 m are acceptable.

Category of inundation depth	Reference description
0.0 m	no inundation
0.5 m	around the level of the knee of an adult
1.0 m	around the level of the waist of an adult
2.0 m	around the level of the eaves of the first floor
5.0 m	around the level of the eaves of the second floor





Evacuation on foot in flowing water would be substantially difficult and dangerous. Accordingly, evacuation well in advance of the start of flooding, is strongly recommended.

8.5 Establishment of Evacuation Plans

1) Identification of Evacuation Refuges

Identify existing buildings and facilities suitable for use as refuges. It may be possible to set up the temporary refuges in the flood-prone area, which flood-resistance and number of stories have been affirmed in relation to the potential inundation depth.

2) Determination of Evacuation Means

It is not advisable to use cars to escape from flooding, except under special circumstances. Traffic jams and unexpected accidents may result from many residents evacuating by car at the same time. Evacuation on foot is a primary rule.

3) Identification of Evacuation Distance and Timing

It is desirable that the distance of evacuation on foot shall be less than 2 km in all cases. Identify proper refuges for the respective areas to be evacuated, taking into consideration the distance and the accommodating capacity of the respective refuges.

4) Identification of Evacuation Routes

Identify the evacuation routes that are safe from flooding and other disasters, such as mudflows and debris torrents. If recommended routes exist, clearly specify them on the map.

5) Identification of Dangerous Spots on Evacuation Routes

Identify flood-prone roads, bridges and other potential dangerous spots, and clearly show them on the map.

6) Zoning of Areas to be Evacuated and Appropriate Evacuation Refuges

Establish zonings for proper refuges, in correspondence with the location and population of the relevant areas to be evacuated, and the location and accommodating capacity of the respective refuges.

7) Establishment of Positive Assistance Plans to Vulnerable Residents

Establish evacuation means for those who are vulnerable, such as the elderly and handicapped (preparation for evacuation, issuance of advisory evacuation warning, specifically-prepared refuges, etc.).

8) Establishment of Communication Channels

Establish reliable communication channels for urgent, essential information, ensuring safe evacuation (TVs, radios, walkie-talkies, cable broadcast telephones, CATV, ordinary telephones, Internet homepages, messengers, loudspeaker vans, sirens, electric-light notice boards, etc.).

8.6 Establishment of Issuance Criteria for Evacuation Warnings

Evacuation warnings are issued in the following order and steps:

-Preparation warning for evacuation	Warning to residents to make preparations for possible evacuation (earlier preparation warning is particularly effective).
-Advisory evacuation warning	Warning to residents advising start of evacuation.
-Imperative evacuation warning	Warning to residents ordering immediate evacuation.

(1) Issuance Criteria for Imperative Evacuation Warning

1) Define flooding-start levels

Define possible water levels (such as HWL) for levee-break or spillover water levels for the reaches without levees.

2) Define necessary time for evacuation

It is desirable, in principle, that evacuation would be completed by the time the floodwater reaches the above-mentioned reference levels. The necessary time for complete evacuation after the issuance of the imperative evacuation warning is to be specified.

3) Define reference water levels for issuance of respective warnings

Assuming that the necessary time for evacuation is n hours, find the water level from which the river water reaches the specified flooding-start level n hours later. Define this level as the reference water level for issuance of the imperative evacuation warning. To predict specific water levels, it is conceivable to use the predicted flood-forecast results in cases of jurisdictionally-designated rivers. However, such flood-forecasts are not yet sufficiently accurate, and, in some areas, more accurately predicted water levels may simply be derived by correlating the observed water levels at nearby stations with the predicted water levels.

(2) Issuance Criteria for Advisory Evacuation Warning

The issuance of the advisory evacuation warning shall be done well in advance of the imperative evacuation warning, and the timing of issuance of the advisory evacuation warning shall be one or two hours earlier, depending on the specific conditions of the respective areas.

(3) Issuance Criteria for Preparation Warning for Evacuation

When urging evacuation prior to inner-basin inundation, the advisory evacuation warning shall be issued before the occurrence of inner-basin flooding and accordingly, the timing of the issuance of the advisory evacuation warning shall be one or two hours ahead, estimating the starting time of the inner-basin flooding.

8.7 Production of Flood Hazard Map

Flood hazard maps shall be produced in easy-to-understand format, integrating various types of information on inundation and evacuation, as well as evacuation intent.

Table 4 Principal Items and Information to be Incorporated in Flood Hazard Maps

Category			Description
Evacuation-use Information	Information on inundation	Past inundation	Historical records of inundation (maximum or latest)
		Predicted inundation	Inundation-prone areas, other possible inundation areas Inundation depths, inner-basin water, time of flood concentration, flood flow velocity Degree of hazard when inundated
	Information on evacuation	Areas to be evacuated	Endangered areas
		Evacuation refuges	Names, locations and phones number of refuges Family's notes on disaster prevention activities
		Dangerous spots on evacuation routes	Dangerous spots on evacuation routes with potential mudflows, debris torrents, steep-slope collapse and underpasses
		Rules to follow in the event of evacuation	Hints for evacuation
		Communication channels for flood forecasts	Communication channels for flood forecasts (usually the same as those for information on evacuation)
		Communication channels for information on evacuation	Channels for information on evacuation (Evacuation Preparation Warning, Advisory Evacuation Warning and Imperative Evacuation Warning)
		Underground spaces	Information on evacuation for underground spaces (recognition of danger in underground spaces, locations of spaces, communication system to users)
		Evacuation criteria	Criteria on evacuation warnings and guidelines for successive action
		Facilities for the vulnerable	Names, locations and phone numbers of facilities, such as specific hospitals, welfare facilities and schools, ready to accommodate the vulnerable
	Base maps		Base maps to identify location and extent of inundation areas to be evacuated
	Other information		Title, explanation, scale, azimuth, local municipalities, authors, phone numbers, date of production, and local organizations concerned for disaster prevention activities
Educational-use Information	Past inundation		Data on hydrological and meteorological conditions (rainfall, water level, flood discharge), inundation records (extent, depth and duration of inundation), damage suffered and evacuation records at inundations
	Rainfall		Correlation of hourly rainfall, flood status and successive evacuation, to be represented in easy-to-understand format with illustrations
	Communication channels for information on disaster prevention efforts		Information in easy-to-understand format on meteorological warnings, flood forecasts, evacuation warnings, etc.
	Mechanism of flooding		Flooding mechanism with local characteristics
	Rules to follow in everyday life and in the event of flood		Hints in brief to follow in everyday life and in the event of flood
	Staying in refuges		Rules to follow when staying in refuges
	Directions for familiarizing oneself with Flood Hazard Maps		How to familiarize oneself with Flood Hazard Maps
	Directions for using the Flood Hazard Map		How to determine the route between one's house and a proper refuge on the Flood Hazard Map, and how to specify family's actions in the event of emergency
	Other information		Other valuable information to encourage effective use of the Flood Hazard Map in everyday life, such as: Emergency evacuation from a flooded house Rope knotting Rescue procedures when one falls in a river First-aid to the injured

9. Distribution and Usage of Flood Hazard Map

9.1 Distribution among Local Residents

(1) Public Relations

Once Flood Hazard Maps have been produced and distributed, the local municipalities shall make efforts to enhance the local residents' awareness of the purpose and advantageous effects of the maps through educational activities and flood evacuation practices. Consideration shall be given to the following activities:

1) Providing information to local media (hometown newspapers and magazines)
2) Organizing briefing sessions at voluntary disaster prevention units, schools, private companies, etc.
3) Sending questionnaires to households, voluntary disaster prevention units, schools, private companies, etc., with the goal of stimulating interest in the maps, active use of the maps by residents, and collection of their opinions on the information contained in the maps, as well as increasing their involvement in disaster prevention activities
4) Distribution at various events (voluntary and administrative disaster prevention fairs, emergency evacuation practices, etc.)
5) Using CATV (local channels, teletext broadcasting)
6) Using notice boards at public or district facilities
7) Cooperating with mass media (TV and radio stations, newspapers, etc.)
8) Insertion in telephone directories (Yellow Pages)
9) Using Internet homepages

(2) Target Users

It is desirable to distribute Flood Hazard Maps to all local residents for the most effective use of them. However, it may be conceivable to restrictively distribute them to residents in the areas to be evacuated.

- Distribute to local residents in the entire administrative areas concerned
- Distribute only to specified districts and their town-block associations, covering the possible inundation areas
- Distribute only to households that will inevitably be evacuated
- Distribute through Internet homepages

Possible distribution to pertinent institutions, bodies and agencies other than local residents, such as:

- Community centers and other public services (pin-up notices)
- Schools (pin-up notices and teaching materials)
- Private companies (pin-up notices to employees and visitors)

9.2 Administrative Use

It is important to identify various levels of risks and specific issues to be developed in the respective areas, referring to the Flood Hazard Maps, and to successively update the emergency evacuation plan as well as disaster prevention plans.

The table below shows several issues to be fully reflected in the prevention disaster plans.

Table 5 Examples of Issues to be Reviewed in Disaster Prevention Plans

Category	Description
Evacuation routes and refuges	- Review evacuation routes and refuges currently used, taking into consideration specific risks involved in the areas
Emergency activity system	- Review and update mobilization plan, taking into consideration widely scattered dangerous areas - Review and update arrangement and assignment plans for flood-fighting materials, equipment and staff members
Communication channels for emergency information	- Establish more reliable channels for emergency evacuation activities - Provide more accurate and effective information on evacuation
Evacuation encouragement	- Review and update organization and assignment of staff for safe evacuation - Review and update assistance plans for evacuation of the vulnerable (infants, elderly, sick, and handicapped) - Review and update voluntary activities

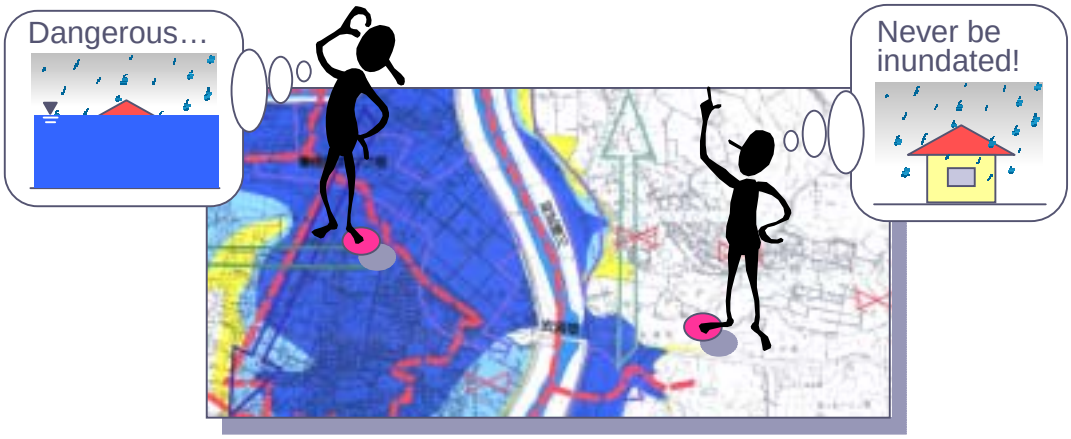
Furthermore, Flood Hazard Maps shall be referred to in the design of flood-resistant buildings and urban planning, as well as land-use patterns.

9.3 Issues on Flood Evacuation

Much effort has recently been made on the prevention of flood disaster in Japan through the production of hazard maps and their distribution to local residents, and the establishment of communication systems for disaster information, providing timely and accurate evacuation information in the event of a flood occurrence. It can not be said, however, that the smooth evacuation of local residents in the event of a flood occurrence is ever practiced based on these systems. There are still many issues to be addressed in order to improve the current situation. Those issues are mainly related to a lack of awareness of disaster, as well as a lack of understanding of disaster information among the residents.

When the water level of a river rises and evacuation is deemed necessary, the mayor issues an advisory evacuation warning and/or an imperative evacuation warning (the residents are, however, not charged a penalty if they do not follow the warnings). Generally, the evacuation rate of residents is fairly low. In Japan, the following particulars are pointed out as reasons why the residents do not evacuate in the event of a flood occurrence.

1) The number of residents who have experienced the fierceness of flooding is becoming fewer due to the development of structural flood countermeasures.
2) From the standpoint of disaster psychology, the view called “normalcy bias” predominates in the residents’ minds, and accordingly, they feel disengaged from those who are suffering from a flood disaster, even though the adjacent river has flooded.
3) The opportunities for playing in a river and learning about rivers have decreased due to river pollution and the dangerous image of rivers. More and more residents do not recognize the strong power of stream flow, and believe that they can evacuate even after the onset of flooding.
4) Those who have had property damaged by a flood, but not to a serious extent, often mistakenly believe that the flood was not serious, and that the next flood will not be serious either. They do not care about evacuation at all.
5) Even when it is certain that their houses will be inundated due to flooding, residents prefer to shift their household effects to safe places rather than evacuate themselves. They hardly realize that they are in serious danger.



9.4 Issues on Residents' Understanding of Flood Hazard Map

The issues on Flood Hazard Maps presented here are related to the local residents' understanding of the information. These issues are of great importance in developing practical, effective Flood Hazard Maps.

1) Even though Flood Hazard Maps have been distributed among the residents, many of them are thrown away or lost. The number of residents who lose their Flood Hazard Maps increases as time goes by. The main reasons for losing the maps are that the residents are unconscious of the real dangers of a flood, they have little interest in the information shown on the maps, and they do not recognize the importance of the information. Once a flood evacuation is imminent, the Flood Hazard Maps serve as evacuation manuals. It is of great significance to remind the residents of their importance and to encourage them to keep the maps.

2) Sometimes, the information that is shown on the Flood Hazard Maps leads to the residents' mistaken assumption that the information is correct and unchanged. Once the residents read the predicted inundation depth for their houses on the Flood Hazard Maps, they misjudge the depth on the map as being the maximum. If the depth is shallower than they expected, they feel a sense of relief, and either completely stop evacuation or wait until the water level reaches the level in question. This is, however, a serious misunderstanding. The Flood Hazard Maps present merely one possible result obtained through a simulation based on the assumed rainfall patterns (once in a hundred years probability is commonly used in Japan), and levee-break spots in accordance with the designated scenarios. For cases in which the actual rainfall is heavier than that of the designated scenario, the inundation depth will be deeper than that shown on the Flood Hazard Map.

3) There is another issue: how to represent information on Flood Hazard Maps. The predicted inundation depths are usually shown in different colors on Flood Hazard Maps, while it is difficult to show the flow velocities in the same way.

   In the case of flash floods, the flow velocity, which is inundating city areas, is normally high, and the inundation depth will be shallower as a result. When the flow velocity is high, it is extremely dangerous to evacuate on foot in the water, even if the water depth is shallow. Safe evacuation is not guaranteed. Even though flow velocities can be shown on Flood Hazard Maps, it is difficult for residents to understand the actual danger of high-flow velocity. The flow velocity is primarily important information for the evacuation procedures.

4) In some cases, a Flood Hazard Map can mistakenly be interpreted as a "safety area map in the event of a flood occurrence." Non-colored areas on the hazard maps (non-inundation areas) are merely results from the flood simulation, based on the designated scenarios.
   The residents in those areas, however, believe that the areas will never be inundated during a flood occurrence.

9.5 Effective Use of Flood Hazard Map

In Japan, the reason why local residents do not evacuate in the event of a flood occurrence is, as mentioned above, that they hardly recognize the necessity for evacuation. Flood Hazard Maps are expected to play a major role in settling these issues.

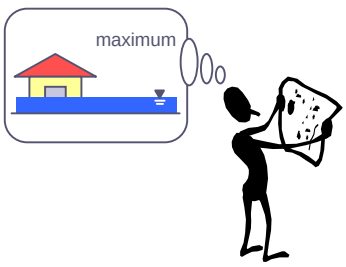
In view of the relationship between flood evacuation and Flood Hazard Maps, there are several steps of roles of the Flood Hazard Maps:

1) The first role of the Flood Hazard Map is to function effectively as an evacuation manual during a flood occurrence. The residents can confirm the safe refuge and safe evacuation route through the maps and attached explanation. In the cases of the floods at Koriyama City in 1998 and Tajimi City in 2000, it was reported that the Flood Hazard Maps were of great use as an evacuation manual.

2) The second role of the Flood Hazard Map is to provide the respective households with information on the flood danger level of their own houses. The flood danger level is usually shown as inundation depth, which is expected to increase the residents' awareness of the necessity of evacuation.
   On the other hand, the information shown on the Flood Hazard Map explicitly suggests several issues to be settled concerning the residents' understanding. These issues include the risk that residents might think of the flood danger level as unchanged information and not understand the meaning of the information, which may result in an extremely dangerous situation.

3) The third role of the Flood Hazard Map is to offer the residents an incentive to realize the fierceness of a flood, and how to properly protect themselves from the flood disaster. The residents are expected to fully understand that the information shown on hazard maps presents merely one result out of many possible scenarios that might occur around them. They are requested to decide themselves what actions should be taken to protect their families' lives during a flood occurrence, in correspondence with the designated scenario as well as unexpected situations beyond the scenario. The Flood Hazard Maps therefore work as preliminary instructive materials.

If Flood Hazard Maps are simply distributed among the local residents, without any educational activities, they can not fulfill their role. The residents will not be aware of the importance of Flood Hazard Maps, and will consequently throw them away. To fulfill their role, educational activities using hazard maps as teaching materials, are essential. The local residents should be encouraged to actively participate in the development of Flood Hazard Maps through discussions with the relevant local municipality staff on what actions should be taken during a flood occurrence.



Concluding Remarks

In Japan, the importance of Flood Hazard Maps has undoubtedly been recognized in recent years, and now the preparation of the maps is progressing in a positive direction. It has not been long since their preparation began, and yet various efforts are devoted to producing more advantageous and more effective maps.

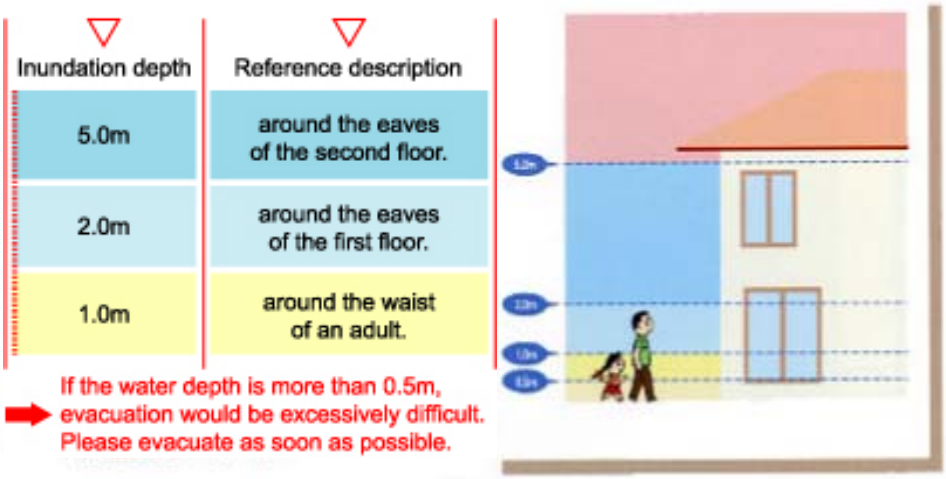
The experience of producing Flood Hazard Maps in Japan is hereupon briefly introduced. The respective staffs of the local municipalities involved are highly expected to make their utmost efforts, with marked enthusiasm, in preparing reliable and effective Flood Hazard Maps.

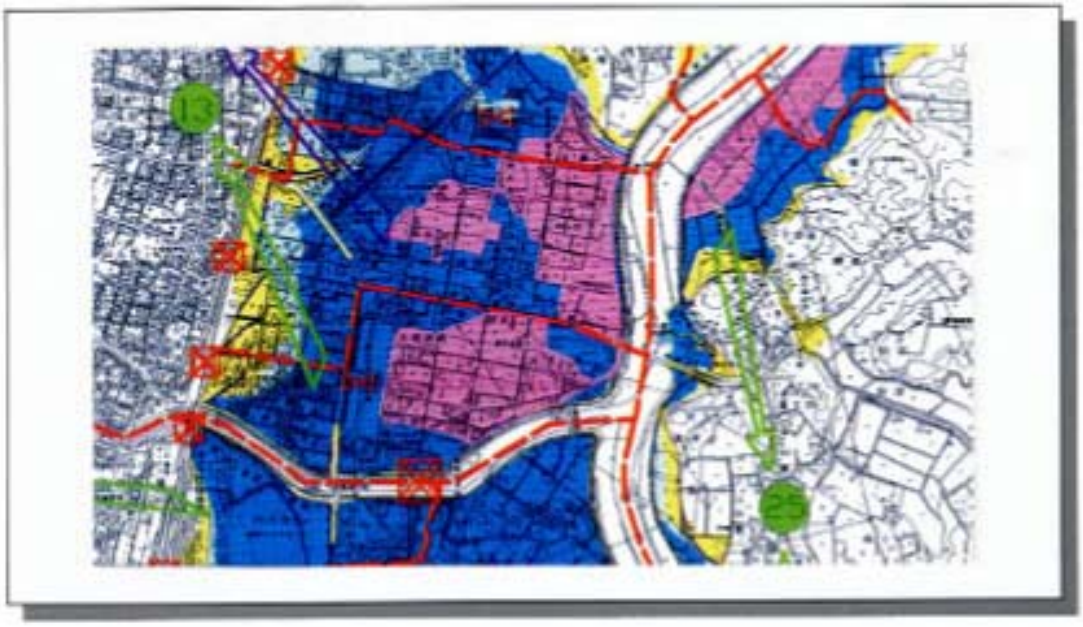
Appendix

Examples of Flood Hazard Map for Educational-use

Example of Integrated Flood Hazard Map

- Predicted Inundation Depth
(The city of Koriyama)



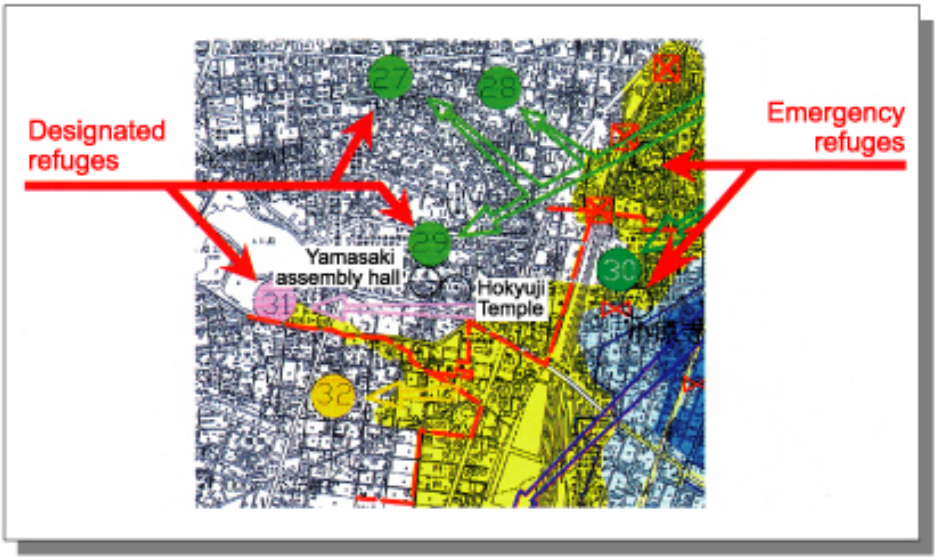


- Refugee
(The city of Koriyama)

Identify your refuge !

Flood Hazard Maps designate proper refuges for respective town blocks, so that the evacuation time and distance would be minimized, and as well show the location of the refuges and the direction of evacuation with arrows. The names of refuges designated for respective town blocks are listed in a table.

Flood Hazard Maps further indicate Emergency refuges (to be used for emergency evacuation), when unable to evacuate to the designated refuges.

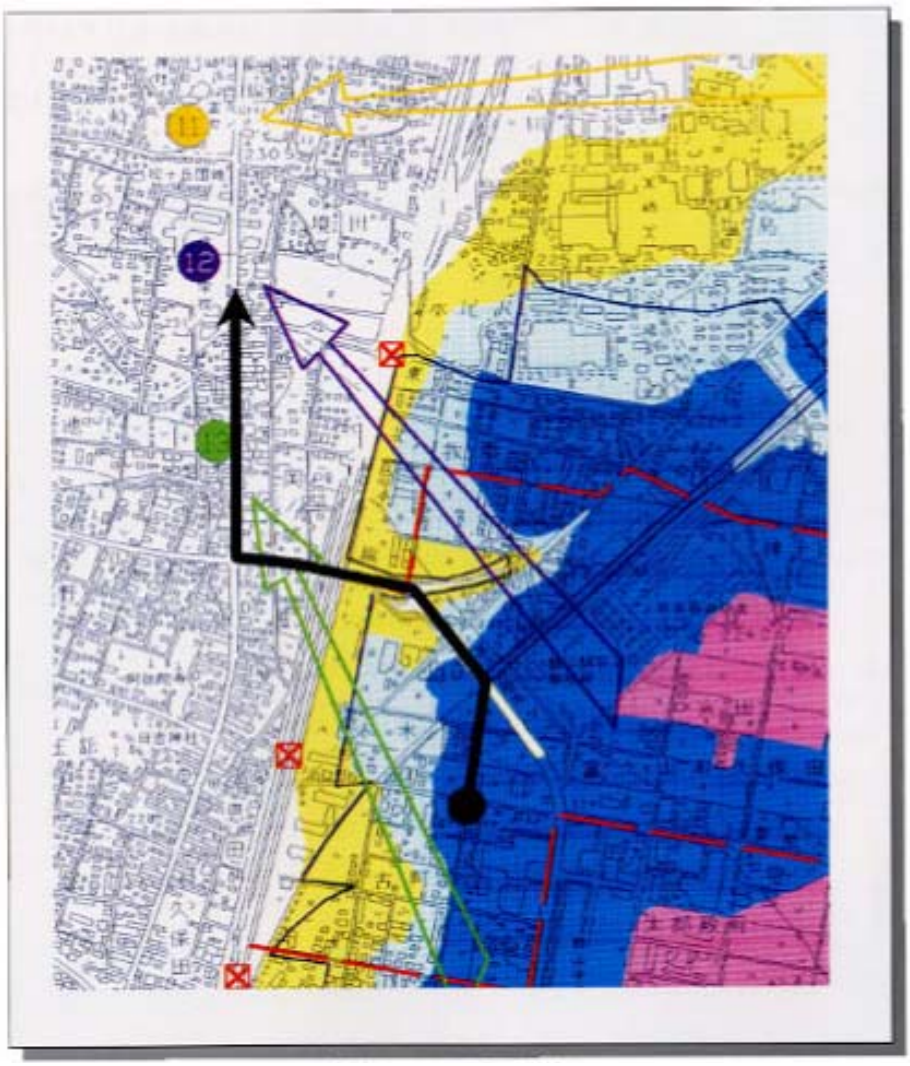


Markings of Refuges

Name of Town-blocks	Nos in Map	Name of refuges
高倉第一，二，三町内会 下萱沼町内会	①	高倉小学校
上萱沼町内会	②	上萱沼集会所
梅沢町内会	③ ④	日和田公民館梅沢分館 延命寺
鬼生田３，４区	⑤	鬼生田小学校
三町目平町内会、芹沢区	⑥	西田地区交流センター
八丁目町内会	⑦ ⑧	日和田公民館八丁目分館 花かつみ豊心園体育館
堂坂町内会	⑨	堂坂集会所

Zoning and designation of refuges

- Evacuation Route
(The city of Koriyama)



Mark down evacuation route on the Map!

- Emergency Kits
(The city of Koriyama)

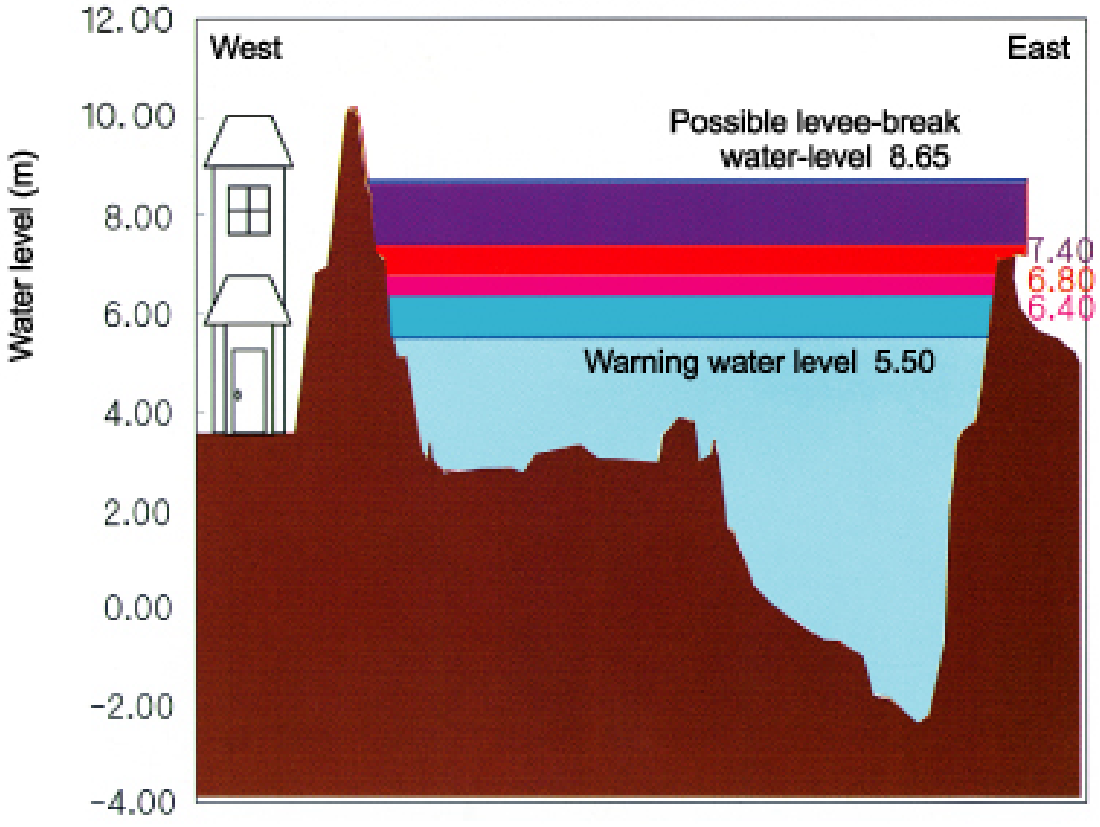
Portable radio : Make sure if it is well in order. Don't forget extra batteries.
Flashlights : Make sure if it is well in order. Don't forget extra batteries.
First-aid kit : Band-Aids, disinfectant, and other essential medicines.
Candles : Don't forget matches and lighters.
Emergency food : Choose food such as canned or instant food, easy-to-prepare and of no necessity of much water.
Potable water : Mineral water bottles.
Cash and valuables : Keep in a fixed place so as to immediately carry them out in an emergency.
Ropes : Quite useful for emergency escape or rescue.

- Issuance Criteria for Evacuation
(The city of Koriyama)

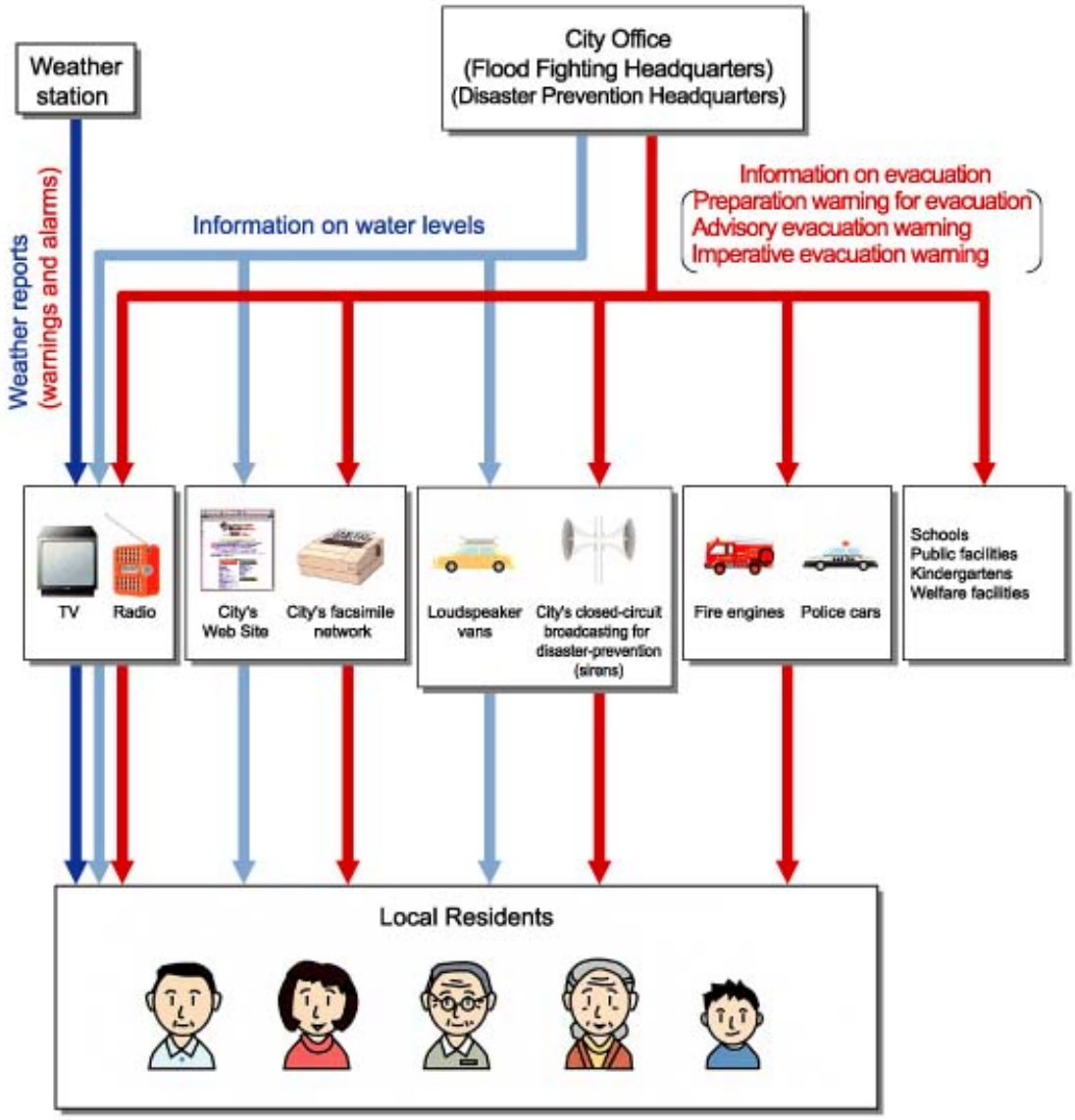
Specified reference water-levels for issuance of evacuation warnings
(Akutsu Water-level Station, the Abukuma River)

Types of Evacuation Warning	Specified Reference water-level
Preparation waarning for evacuation	6.40m
Advisory evacuation warning	6.80m
Imperative evacuation warning	7.40m

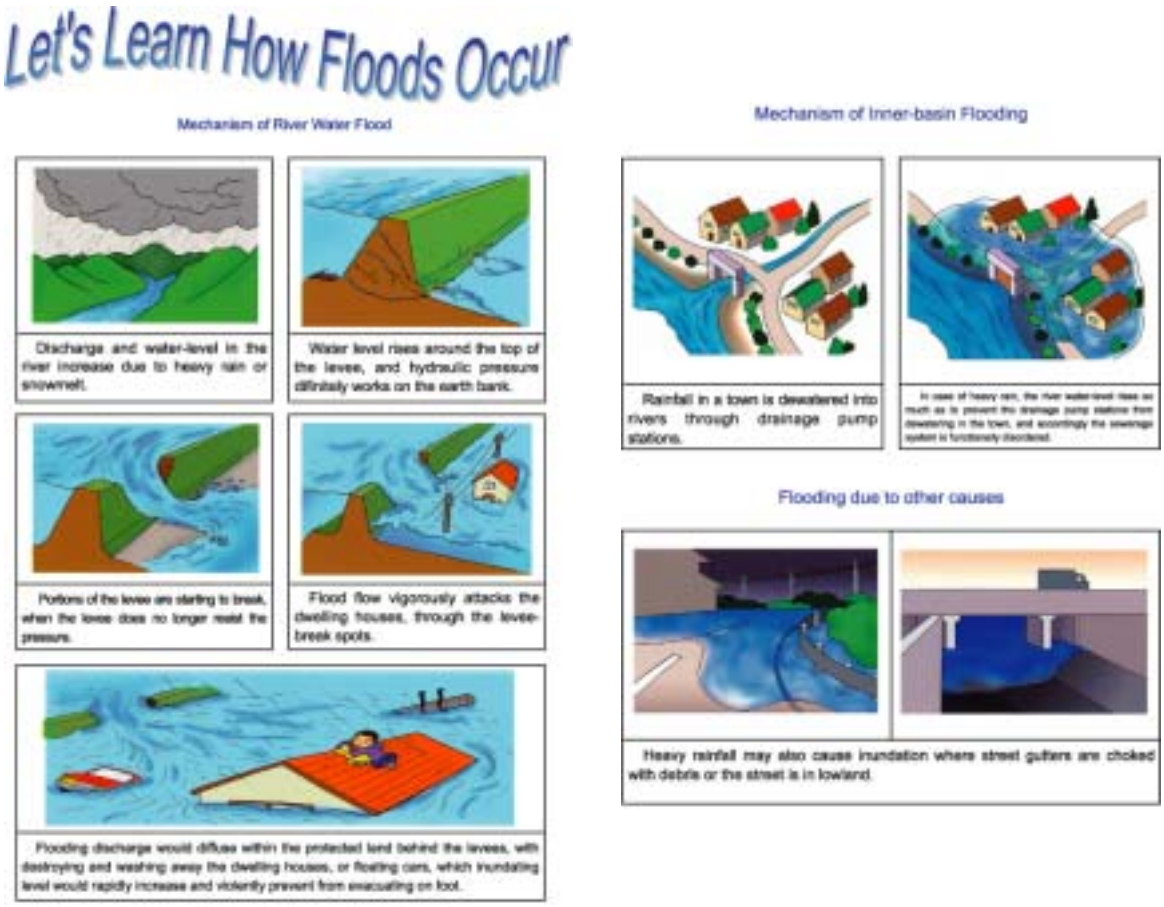
Relation between levee and water-level
(Akutsu Water-level Station, the Abukuma River)



- Communication Channels and Systems for Evacuation Information
(The city of Koriyama)

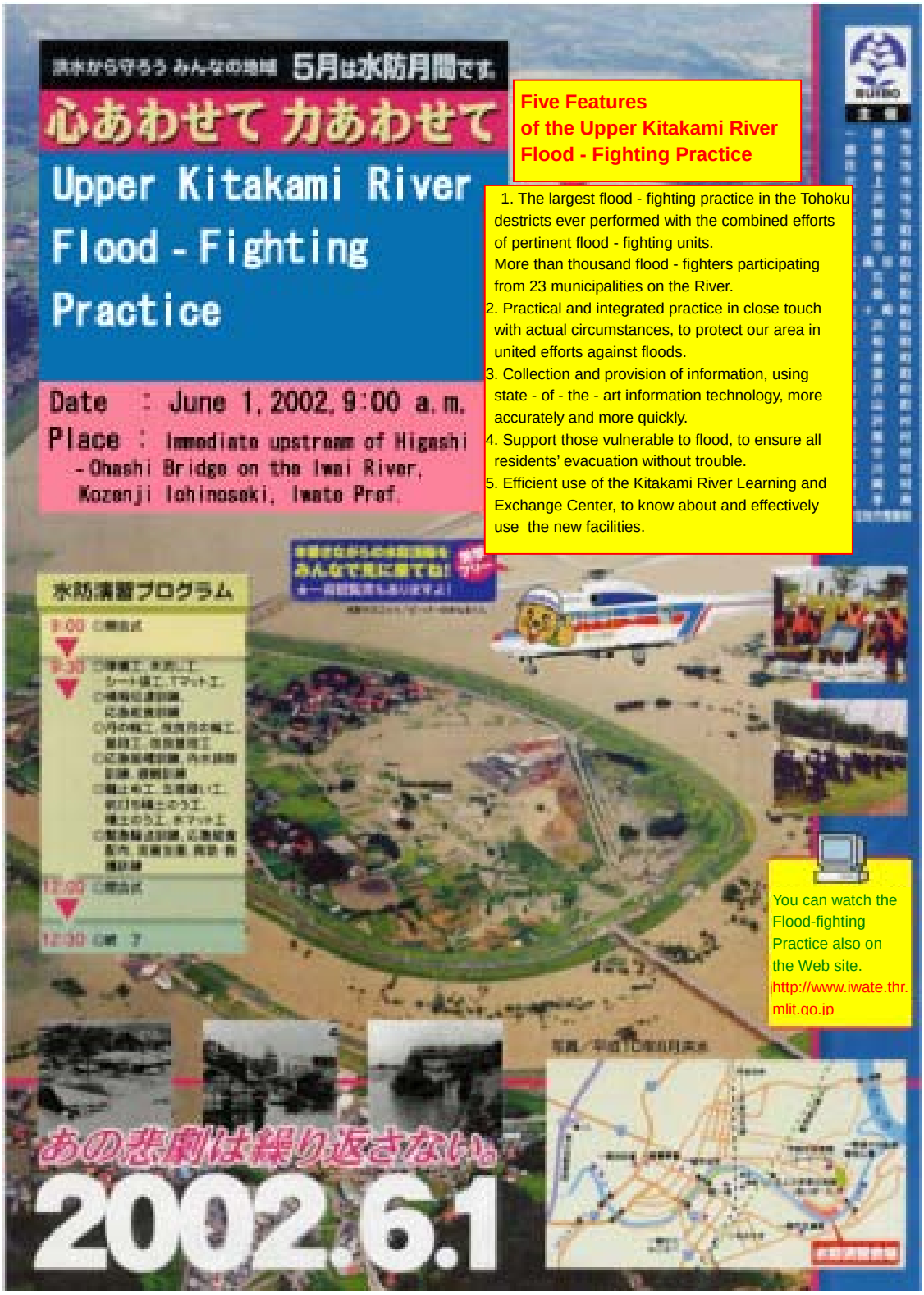


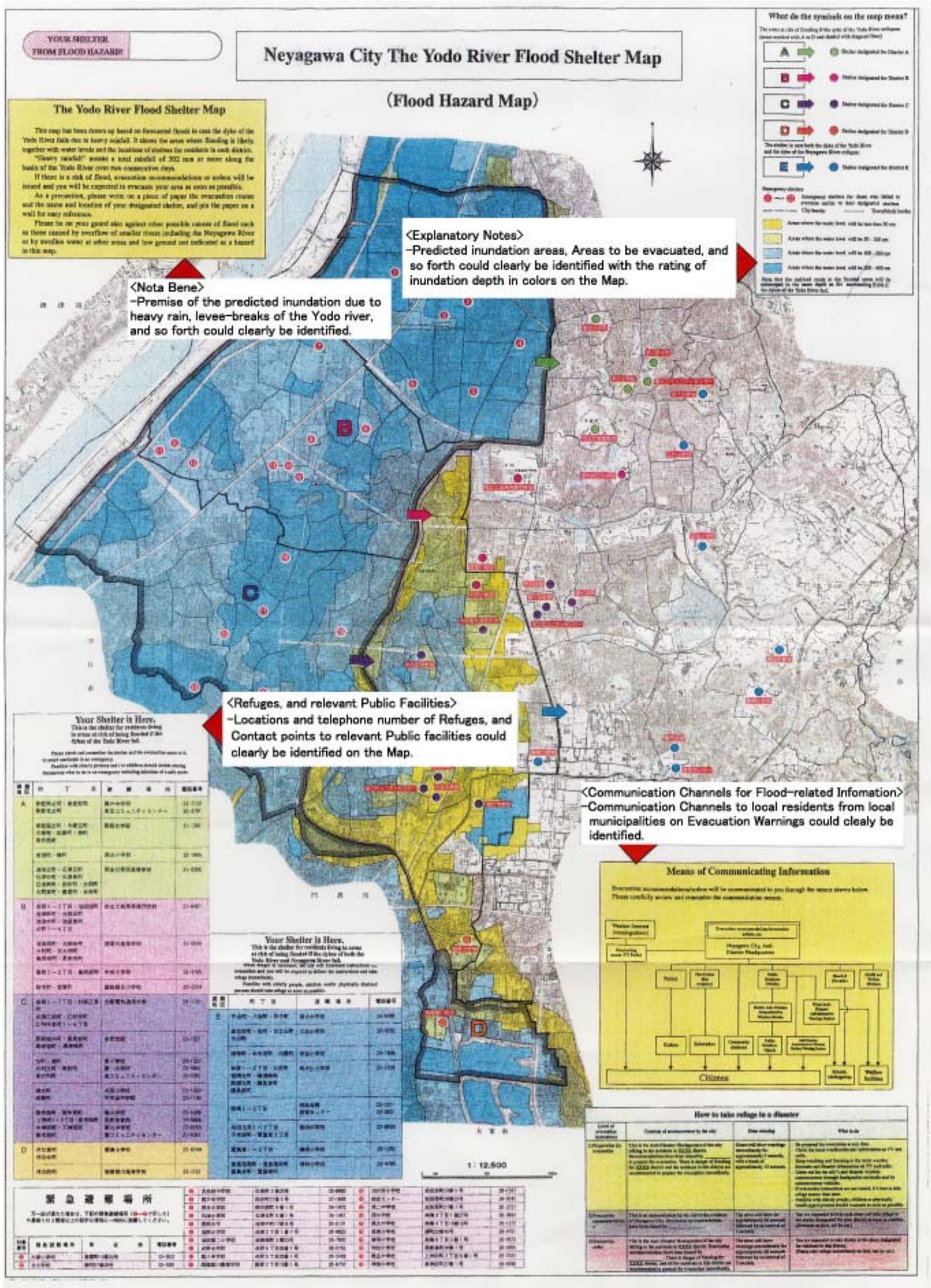
- Flooding Mechanism
(The city ot Koriyama)



Source: Foundation of River & Basin Integrated Communications, Japan

- Flood Fighting Practice
(Upper reaches of the Kitakami River)





- Example of Integrated Flood Hazard Map
(Neyagawa city Flood Hazard Map)