Flood control economic survey manual (draft)

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River Bureau, Ministry of Construction

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0. Preface

0.1 Basic policy of flood control economic survey

A flood control economic survey is performed to identify the economic benefits and cost-effectiveness of constructing flood control facilities such as levees and dams.

The benefits obtained from constructing flood control facilities are increased disposable income (benefit) produced by reducing casualties and direct or indirect asset damage caused by floods, benefits from improving the productivity of land by reducing flood damage, and security obtained by improving flood control safety.

Flood control facilities are different from other social infrastructure that improves convenience such as roads. As described above, they are considered to be important foundations supporting social and economic activities. However, it is often difficult to measure the economic benefits obtained from constructing flood control facilities. Improvements to flood control facilities provide data for reviewing social and economic activities. It is generally difficult for the general public to feel the effects of constructing flood control facilities. It is also difficult to measure such effects in terms of market assets.

For example, the benefits obtained from construction in terms of land productivity are not only brought about by the construction of flood control facilities, but also by the construction of other social infrastructure. It is difficult to foresee what changes would occur in land due to the construction of flood control facilities. Consequently, it is difficult to measure economic effects. It is also difficult to measure benefits such as a sense of security in economic terms.

Therefore, the portion of damage-prevention benefits (increased disposable income produced by reducing direct or indirect asset damage caused by floods), which are possible benefits obtained by constructing flood control facilities, is calculated.

Some assumptions are required to calculate damage-prevention benefits.

One of the assumptions is a determination of the assets in the flood area.

To calculate damage-prevention benefits, it is first necessary to make certain assumptions about the assets. After the Pacific War, assets in ownership have been increasing in parallel with the expansion of the national economy. Although an assumption of future assets is an important element, it is difficult to determine them specifically and reasonably with currently available data. Basically, it should be assumed that current assets will remain unchanged in the future.

The second assumption is the time required to recover from floods and resume normal social and economic activities.

If the amount of direct asset damage caused by a flood is the same, the time required to recover from a flood and resume normal social and economic activities may vary greatly depending on the income and the assets of disaster victims, and on the strength of the local economy of the flood area and the ratio of victims in the flooded area. Therefore, to calculate damage accurately, the relation between individual income/economic strength in the flooded area and the total amount of damage (total of direct and indirect damage) should be established from past examples of flood damage. However, there are no such data.

Consequently, the calculation is based on a policy of obtaining the minimum value of damage incurred. The assumption should be that direct asset damage is immediately recovered and that indirect damage such as interruption of the businesses of companies may recover to normal social and economic activities within the minimum number of days required for physical recovery.

The third assumption is the levee crevasse point.

To calculate the damage caused by a flood, it is necessary to assume a point (levee crevasse point or overflow point) at which a levee fails to function. However, a levee is the result of historical flood control measures. And, it is difficult to specify the component materials of a levee. If a relative and qualitative reliability evaluation of a levee can only be achieved, it is almost impossible to make an absolute reliability evaluation. Therefore, the crevasse point of a flood cannot be determined deterministically, and a levee crevasse point must be assumed.

The fourth assumption is a determination of the scale of a flood that is the cause of flood damage.

Because a flood is a natural phenomenon, it is not sufficient to make an economic analysis based on the maximum flood experienced in the past. To make a comparison with other rivers or to make an economic evaluation of the validity of the target construction level, it is necessary to determine the scale of a flood based on the probability of occurrence.

To evaluate the probability of a flood occurring, it is necessary to analyze hydrological statistics based on rainfall and flow data obtained in each river basin. The future construction target of a class A river system is 1/100 to 1/200. In contrast, rainfall or flow data are available as statistics covering 40 to 50 years at most. This is not necessarily a sufficient sample size for a hydrologic statistics analysis. The situation of flooding in the future may change the probability of a flood occurring. Therefore, the scale of a flood may change.

The fifth assumption is the basic asset value or the amount of damage incurred that is used to calculate damage prevention benefits.

There are various assets and damage conditions in a flooded area. To calculate the amount of damage incurred, basic asset values as a nationwide average or in each prefecture or rate at which damage occurs should often be used.

The damage prevention benefits obtained from the flood control economic survey are virtual benefits calculated under the assumptions above. Only a portion of the benefits obtained from the construction of flood control facilities is evaluated. Furthermore, the economic effect of the calculated damage prevention benefit cannot be directly felt by the general public in the same way as the construction of roads.

Risk premium needs to be considered for projects such as flood control facilities that reduce overall risk. For example, suppose that there are the options of 10 million yen of damage at the rate of once every 50 years and a payment of 200,000 yen every year to avoid such damage. The expected annual loss is 200,000 yen in both cases, but a normal person would usually judge that the latter is more advantageous. According to the law of decreasing marginal utility of income, the sacrifice from a 10 million yen loss is larger than the sacrifice from 50 losses of 200,000 yen. The difference between the two is the risk premium. If there is a risk premium, the project should be evaluated at a lower rate than a normal investment, or the benefits should be highly evaluated.

Uncertainty also remains over the construction costs of flood control facilities.

This means there are many cases in which the period and the investment plan required for constructing flood control facilities cannot be precisely determined. Although a rough construction sequence is determined, it is impossible to determine detailed construction period and schedule. Even if the total investment is the same, the present-value total cost at the evaluation point varies greatly depending on the construction period and the amount of investment for the period. Therefore, to make an economic evaluation, the construction period and the investment plan for the period must be prepared for evaluation on the basis of similar past projects according to project type and scale.

As explained above, it is extremely difficult to cover the benefits of constructing flood control facilities and all of the construction costs that form the basic data for an analysis of cost effectiveness. A flood control economic survey must be performed while taking this point into account.

Flood control facilities are fundamental facilities that ensure the safety of people living in Japan. They are considered to be the foundations for a safe social infrastructure. This characteristic is similar to national defense or public order. From this viewpoint, it is not appropriate to differentiate the construction status solely in terms of the efficiency of constructing flood control facilities. It is important to consider the viewpoint of fairness. From the viewpoint of providing the nation with a basic level of safety within the perspective of efficiency obtained from a cost-benefit analysis, the balance of upstream/downstream and left/right banks is comprehensively reviewed for constructing flood control facilities.

This is clear in the high court's decision on the Daito flood lawsuit (January 26, 1984). Defective river control should be "judged on the basis of the standard that the facility provides a level of safety that can be recognized according to the general level of control provided for similar types or scales of rivers and socially accepted concepts." As can be seen from this court's decision, the requirement for fairness in flood control safety is very strong in Japan. According to opinion research on rivers undertaken by the Prime Minister's Office in September 1996, almost 80% answered that the target flood control safety level for large rivers is appropriate. It is said that the current level of flood control safety is reasonable as a socially accepted concept.

If a large-scale disaster occurs, the flood control safety level required is that to prevent a recurrence of the disaster under similar conditions.

As repeatedly explained, the economic evaluation obtained from a flood control economic survey is not an evaluation for an entire flood control project. A change from a negative factor to 0 is evaluated as a benefit. When the project is implemented, consideration of both efficiency and fairness is required. Various items including balance of upstream/downstream and left/right banks are considered in the evaluation. In principle, a flood control economic survey is used as one element of a comprehensive evaluation index. The evaluation must be objective and transparent. The rate at which damage occurs and the flood simulation method used for the flood control economic survey are made more reasonable by this manual (draft) to improve the flood control economic survey system. Major changes from the conventional "Flood control economic survey guideline" are as follows (Table 0.1).

Table 0.1 Major changes

<table>
<tr><th colspan="3">Item</th><th>Flood control economic survey guidelines</th><th>Flood control economic survey manual (draft)</th><th>Application</th></tr>
<tr><td colspan="3">Survey of asset data</td><td>Totalized for each municipality (Method of totalizing is not specified.)</td><td>Uniform method using national census mesh statistics (Houses and domestic items are evaluated at the re-survey price.)</td><td>Chapter 4</td></tr>
<tr><td rowspan="3">Flood simulation</td><td colspan="2">Levee crevasse point</td><td>Selection of levee crevasse point is not specified.</td><td>The point with the greatest damage in each flood block is assumed to be the levee crevasse point.</td><td rowspan="3">Chapter 3</td></tr>
<tr><td colspan="2">Flood condition</td><td>Upstream overflow or flow reduction due to flooding is not specified.</td><td>Overflow flood where there is no discharge capacity or flow reduction due to flooding is considered.</td></tr>
<tr><td colspan="2">Analysis method</td><td>Method according to flood type. Details are not described.</td><td>Method according to flood type. Channel discharge and flood discharge are traced at the same time.</td></tr>
<tr><td rowspan="5">Benefit calculation</td><td colspan="2">Evaluation method</td><td>Evaluated as annual benefit.</td><td>The method used is a total benefit evaluation.
• The period for evaluation is the construction period +50 years.
• The present-value standard point is that at the evaluation.
• The reduction rate is 4%.
(In accordance with "Uniform guideline for cost effectiveness analysis of the construction of social infrastructure")</td><td rowspan="5">Chapter 4</td></tr>
<tr><td colspan="2">General asset damage (houses, domestic items, business assets, etc.)</td><td>Damage rate in the flood damage survey from 1961 to 1967 is used.</td><td>Damage rate in the flood damage survey from 1993 to 1996 is used.</td></tr>
<tr><td colspan="2">Damage to public civil facilities (including public services and farm land.)</td><td>Rate of damage in the disaster prevention white paper and the flood damage statistics from 1962 to 1967 are used.</td><td>Rate of damage in the flood damage statistics from 1987 to 1996 is used.</td></tr>
<tr><td rowspan="2">Indirect damage</td><td>Loss from business interruption</td><td>6% of general assets</td><td>Reduction of added value of companies according to the number of days business is suspended or interrupted is calculated from the flood damage survey covering 1993 to 1996.</td></tr>
<tr><td>Others</td><td>The calculation method is not considered</td><td>Costs of emergency measures for housing and companies are calculated according to the questionnaire survey for flood damage in 1995 and 1996.
Other items such as damage due to interruption of transportation, if a reasonable measurement is available for each river, may be calculated.</td></tr>
</table>

Item		Flood control economic survey guideline	Flood control economic survey manual (draft)	Application
Cost calculation	Evaluation method	Evaluated by annual cost.	The method is total benefit evaluation. • The period of the evaluation is the construction period + 50 years. • The present-value standard point is at the evaluation. • The reduction rate is 4%.	Chapter 5
	Remaining value	Not considered.	The remaining value upon completion of the evaluation period is deducted from total costs. • Values for levees other than structures and low water channels are not reduced. • The remaining value of structures such as revetments is 10% at completion of the evaluation period. • The remaining value at completion of the evaluation period for dams is calculated according to depreciation (fixed installment method) based on the legal durable years (80 years). (Each is converted to present value.)	
	Construction cost	Required project cost including land cost (Calculation method is not specified.)	Items are organized and the cost calculation method is proposed.	
	Maintenance cost	0.5%/year of project cost (Deducted from annual benefit.)	Regular maintenance costs every year and costs of replacing equipment paid following accident or periodically are calculated.	

0.2 Basic policy for damage in flood control economic survey

Measures for flood control are reviewed for the entire river, considering drainage as a system. Therefore, the flood plain to which preventive measures are applied can be protected by a flood control system that has flood control facilities such as levees and dams as components.

Basically, the flood plain to which preventive measures are applied comprises the areas where flood river water can reach. Not all of these areas are contiguous. Usually, there are some flood plains due to features of geology and rivers. First, considering flood plains and river characteristics, the flood plains to which preventive measures are applied are classified on the basis of flood conditions in the past.

Flood plains are protected by a series of levees. Therefore, it is reasonable to evaluate the safety level of each flood plain to which preventive measures are applied as part of a system. If an individual levee is evaluated, it is the historic result of flood control measures as explained previously. It is difficult to accurately determine the soil material of a levee. Although the relative safety of a levee may be evaluated, it is almost impossible to make an evaluation of absolute safety level. Consequently, it is difficult to evaluate a specific levee. This is why the safety level must be evaluated for each flood plain to which preventive measures are applied.

The height of a levee is a large index of the evaluation. It is necessary to evaluate the safety level of the levee for infiltration and water hammer action. Not only levee height but also functions including levee quality are evaluated.

For this purpose, there are various methods. One of the judgment criteria is the safety level of river water infiltrating the levee. The safety level is evaluated for levee width. The height of the levee is then corrected by sliding a section of the ruler. Safety for water hammer action is evaluated from the presence of a high water revetment.

Based on levee height with the addition of the evaluation explained above, the channel capacity of a flow is judged by the variable flow calculation method. The amount of damage is calculated assuming that overflow flooding starts when the capacity of the flow at each flood plain to which preventive measures are applied is exceeded. As explained above, the safety level at the levee crevasse point is evaluated as a system for each flood plain to which preventive measures are applied. A levee crevasse occurs at the largest point of damage for each flood plain to which preventive measures are applied.

A flood control project has as its typical function that of a project for reinforcing historic flood control facilities. To reinforce a function, an intermediate target is usually determined to expedite reinforcement, while taking account of the balance of flood control safety level for upstream/downstream and left/right banks. When a target is determined for semi-completed construction of flood control facilities, the safety level with well-balanced flood control for upstream/downstream and left/right banks should be determined.

1. General

1.1 Purpose

Various effects of flood control projects that can be evaluated economically are considered to be the benefits of flood control projects. On the other hand, the costs of implementing flood control projects and the costs of maintaining facilities are calculated as the costs of a flood control project. The purpose of a flood control economic survey is to evaluate economic efficiency by comparing both costs.

This manual (draft) establishes the standard survey method for the purpose above. Therefore, national average, basic values for each prefecture, and damage rate are used. When costs and benefits are estimated, methods or items other than the standard survey method or item in this manual (draft) may be evaluated.

1.2 Scope

Based on this manual (draft), the construction period and the investment plan in the period can be estimated at the planning stage of the project. This manual applies to a flood control economic survey for which the economic efficiency of a project can be evaluated. Specifically, it applies to the river improvement plan, reevaluation of river and dam projects, evaluation of new projects, etc.

1.3 Definition of terms

- Flood plain

  Area that is covered by flood water if a flood due to spill or levee crevasse occurs in the subject river

- Spill flood

  Flood from excavated channel in this manual

- Overflow flood

  Flood that overflows levee

- Secondary levee

  Structure that affects time and space extension of flood water, in a continuous fill structure such as river levees or roads

- Flood block

  A block of a flood area that can be divided into channels and right/left banks by tributary, mountain levee, secondary levee by showing the same flood type from a series of flood plains. (A flood block may vary depending on flood scale. A flood block for a small flow scale should be used.)

- Flow capacity

  In this manual, the flow at a certain level in the cross-section of a channel is called the flow capacity. It is calculated from the H-Q formula obtained from a hydrologic calculation.

- Harmless flow

  Flow that can exist safely in a channel plan, allowing for levee shape, presence of revetment, and levee foundation height (ground height in levee). The water level (reverse conversion in H-Q formula) of this flow is called the harmless level.

- Harmless flow of a block

  In a harmless flow at each point of a flood block, the minimum flow is called the harmless flow of a block.

- Maximum flow capacity

  In this manual, maximum flow capacity refers to the flow capacity for a water level equivalent to the levee crown height.

- Slide down

  Minimum parallel movement of the planned levee in the downward direction so that the cross-section of the conventional planned levee may be included in the subject channel levee.

- Benefit

  In this manual, the amount of damage that can be avoided by constructing flood control facilities is the benefit. Other benefits along with construction of flood control facilities and external uneconomic status, which is a negative benefit, are not covered by the flood control economic survey. They are considered separately in the comprehensive evaluation.

- Cost

  Costs incurred for construction and maintenance of flood control facilities that produce the benefits previously described.

- Present value (present price)

  Future monetary value that is calculated at the rate of current value

  If current C_0 (yen) is managed at compound interest (rate γ), it is $C_n = (1 + \gamma)^{n-1} C_0$ n years later. C_n n years later is $C_0 = C_n / (1 + \gamma)^{n-1}$ at present value.

  If there is no variation of prices in the future, land cost C remains as C n years later, but the present value is reduced over time.

- Remaining value

  Value of facilities in the future

1.4 Basic policy of survey

In a conventional flood control economy survey, annual costs and annual benefits are compared for evaluating economic efficiency. In this manual (draft), the total costs required for construction and maintenance of flood control facilities, and total benefits (reduction of damage) obtained from flood control facilities, are indicated as present values for comparison using a reduction rate. (Refer to Fig. 1.1.) The evaluation time (year when project starts for evaluating a new project) is the standard time for present value. The evaluation period is the construction period of flood control facilities and 50 years after completion of flood control facilities. The total costs (excluding remaining value of facilities) are calculated from the present value total sum of costs required for constructing flood control facilities and maintenance costs for 50 years after completion of flood control facilities, and the total benefits are calculated from the present value total sum of the average reduction of damage expected annually.

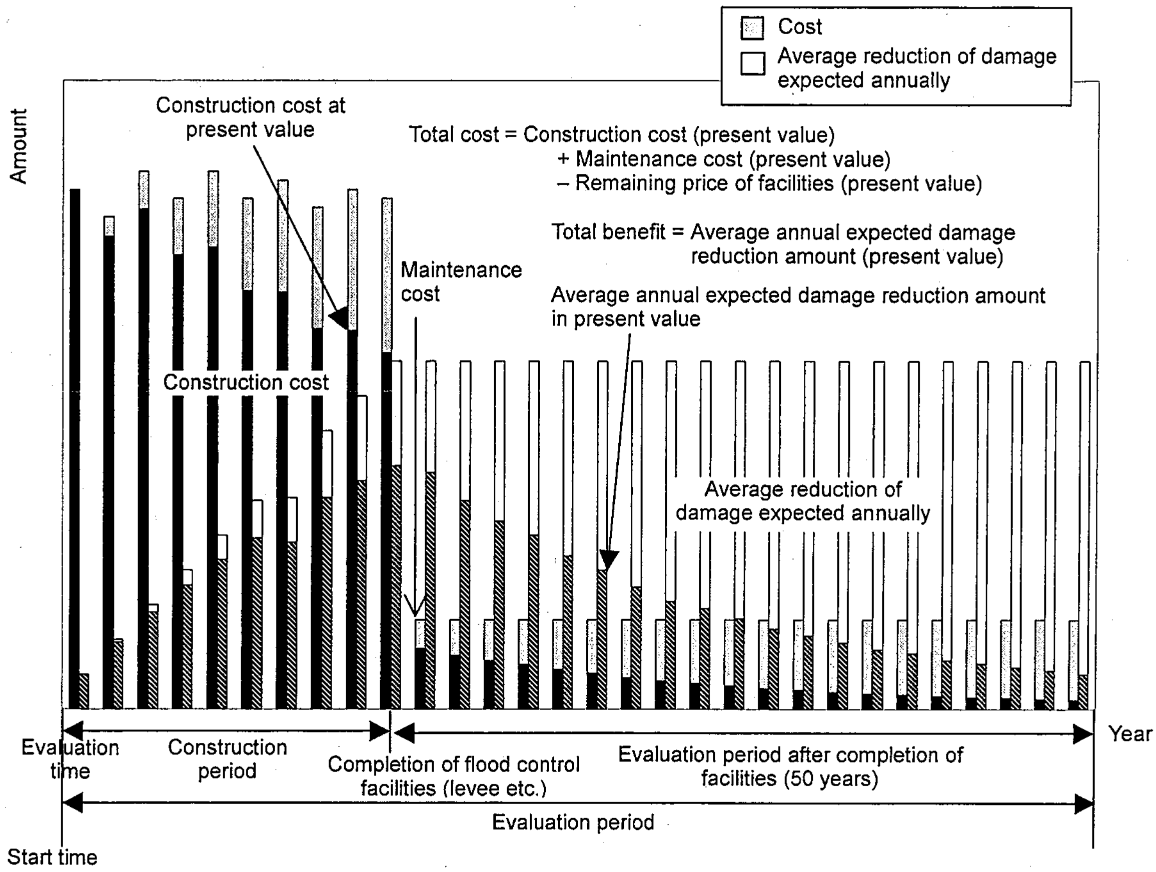


Fig. 1.1 Policy for total cost and total benefit

As shown in Fig. 1.1, when river improvement plans and river/dam projects are revaluated or when new projects are evaluated for adoption, benefits obtained from the investment plan of flood control facilities and construction of flood control facilities are indicated in chronological order. Then, construction cost, maintenance cost, average annual expected damage reduction amount for each year, etc. are indicated as a present value for calculating total costs and total benefits.

When a specific investment plan (construction cost, construction period and allocation of construction cost) is determined, the costs are calculated according to the plan. When a specific investment plan is not determined and only approximate construction costs are determined, the construction period and the allocation of construction cost are estimated on the basis of similar projects for calculating costs.

It is necessary to evaluate a flood control project as part of a series of projects. If it is not appropriate to make an economic evaluation of a project for a current channel, a retrospective evaluation to an appropriate point for an economic evaluation of a series of projects is made.

The major reasons for construction period of flood control facilities and 50 years after completion of flood control facilities being the evaluation period are as follows.

- The service lives of flood control facilities have physical and social aspects. For physical service life, appropriate maintenance can extend functions for a considerable number of years. In contrast, for social service life, the sense of value at that time or social requirement is greatly reflected on the facilities. Because the effect of such a value or a requirement is changed, it is not appropriate to forecast over a long period.
- In a reduction calculation, costs and benefits from 50 years after completion of flood control facilities are not very significant in present value terms.
- Under the taxation system, the service life of a levee is determined as 50 years and the service life of a dam is determined as 80 years.

A series of surveys should be more objective and reasonable in the future. In this sense, items that can be standardized for evaluation purposes including the concept of harmless flow are standardized as much as possible.

1.5 Flow of study

When a flood control economic survey is performed according to this manual (draft), the survey procedures for total costs and total benefits are as shown in Fig. 1.2.

After Chapter 2, the survey method is described according to the procedures of an actual economic survey in the order of benefit calculation and cost calculation.

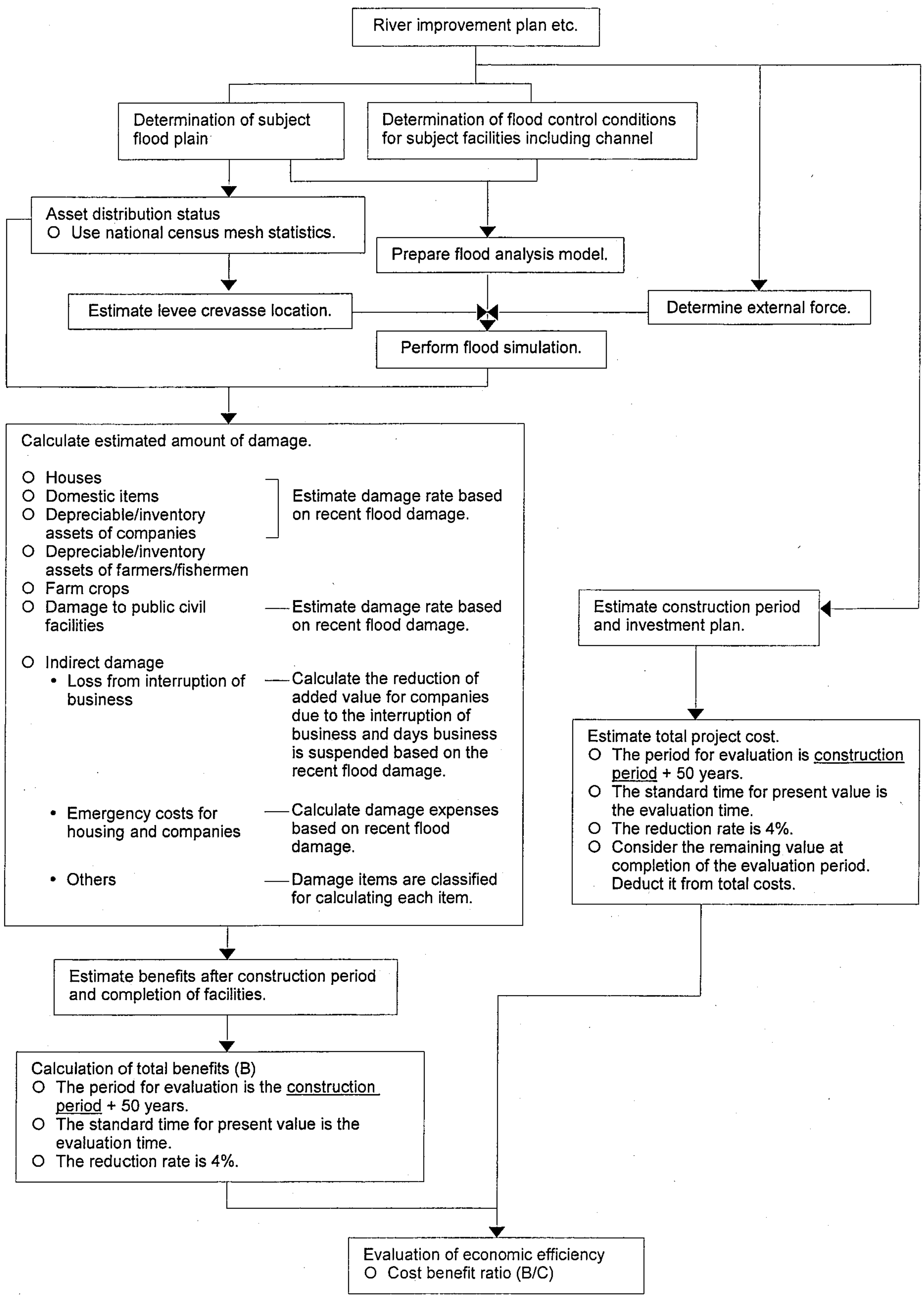


Fig. 1.2 Procedures for flood control economic survey

2. Characteristic analysis of flood plain

2.1 Determination of flood plain

Current flood plains are used. Structures that may affect flood type or expansion of inundation are incorporated into the flood calculation model as much as possible. When structures such as continuous fill currently being built or for which the project are determined to greatly affect a flood situation and their structures are clear, they must also be studied in the flood analysis model. If a specific large-scale development plan such as an industrial complex can be determined, it must also be studied in the flood analysis model or the asset calculation.

[Explanation]

Preparation of asset calculation and flood analysis mode described in Chapter 4 is based on the current analysis source. The procedures are as follows.

(1) Subject flood plain

Based on the study results of a conventional flood hazard map, the subject flood plains are determined so that the maximum flood hazard map may be covered. In general, the maximum flood hazard map is determined by geological conditions. At low land near a river mouth, the flood hazard map may be determined by artificial structures such as a river levee of an adjacent river. Based on conventional flood simulation results, the flood plain on a landform classification map for flood control, design flood level of rivers, and relation to geological altitude, areas of possible inundation are determined as subject flood plains.

(2) Estimation of flood plain in a flood analysis model

In a flood analysis model, it is necessary to consider geological altitude, continuous fill structure as secondary levee, and channels such as small or medium-sized rivers that may affect the expansion of flood water. Land forms or structures below are based on the current conditions.

- Continuous fill such as a road
- Channels such as small or medium-sized rivers that may affect transfer of flood water
- A large-scale water discharge facility such as pump

In a flood control economic survey for future flood damage after completion of flood control facilities, if specific future changes to the factors above can be determined, it is necessary to incorporate them into the flood analysis model.

(3) Estimation of flood plain in asset calculation

Assets at current flood plains should basically be calculated. If an expansion of assets in the future determined in the city plan may be specifically and reasonably determined, it may be included in the asset calculation.

2.2 Survey of assets at subject flood plain

> Ground height and assets at subject flood plain should be studied to arrange mesh data.

[Explanation]

Ground height and asset data (data required for flood simulation and calculation of damage) at the subject flood plains should be studied. (The asset survey is described later in Chapter 4.) Data for each mesh should be arranged.

(1) Determination of average ground height data

The standard survey method for ground height is the ground height measured at a single point on a mesh or the average ground height calculated at 4 corners of a mesh with a large-scale urban planning map or national base map of Japan (Geographical Survey Institute), such as 1/2,500 scale. The map should be the most recent available. In addition, points that do not represent land height on the mesh such as crown heights of continuous fill structures should be excluded. If ground height is not indicated on the drawing, the site should be surveyed as required so that the geological height may be correctly indicated as much as possible.

Instead of a map, "digital map 50 m mesh (height)" (Japan Map Center) may be used. The height data on the digital map indicate the grid point height with the interpolation calculation based on the 1/25,000 topographic map. At a lowland area where the contour lines are not dense or at the boundary where the height changes quickly on the 1/25,000 topographic map, accuracy may be low. When the height data of a digital map are used, it is necessary to check the mesh in the area or along a channel with a large-scale map as appropriate.

(2) Calculation of asset data

This is described later in Chapter 4.

When the subject flood plain is divided into meshes, it is desirable to have consistency with the standard area mesh used on the digital map 50 m mesh (height) or the calculation mesh of the flood simulation described later in order that the work required for the damage calculation may be reduced.

2.3 Feature analysis of subject flood plain

2.3.1 Division of subject flood plain

Considering differences in the flood area due to differences in basin scale, the subject flood plains must be divided into areas (flood blocks) that are considered to be a series of flood areas.

[Explanation]

The flood plains that are protected by a series of levees at left and right banks are divided into flood blocks as shown in Fig. 2.1. This division of blocks is the basis for a step-by-step modification of the channel, and is the factor that affects the estimated damage described later. It is important to divide plains carefully, considering the following points.

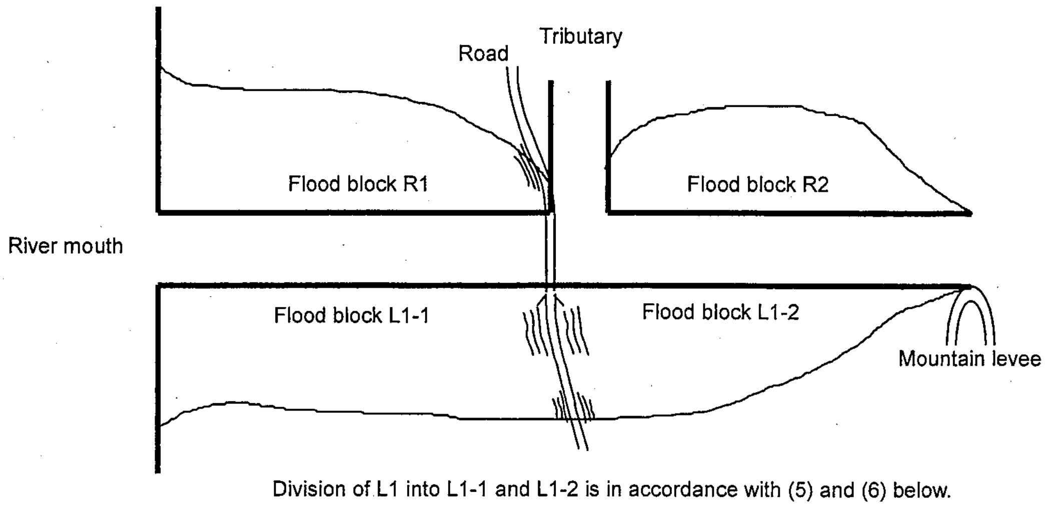


Fig. 2.1 Division drawing of subject flood plain

(1) Flood type

Depending on the geological features of flood plain and flood scale, flood types are classified into major categories: flow-type flood with flow of flood water along rivers; storage-type flood that increases the flood depth with increase of river level, but with the flooding area not greatly changed; and, diffusion-type flood that diffuses flood water in all directions. The characteristics of flood damage or applicable flood analysis method differ depending on flood type. The subject flood plains are classified into estimated areas (flood block) that may bring a series of flood types based on geological features and conventional flood analysis results. Overall, a storage-type flood area may result in a diffusion-type flood in the case of a small or medium-scale flood. In this way, flood types must be divided qualitatively.

(2) Left/right banks of subject channel

The area divided for each flood type is further divided into left and right banks using the subject river as a boundary.

(3) Tributary for junction

When flood plains are cut by the tributary levee and the flood type is changed, the area is divided by the tributary, which forms a boundary.

(4) Mountain levee

When the flood area is divided by a mountain levee, the levee is the boundary of the flood block.

(5) Flood scale and inundation area for each levee crevasse

In a large-scale flood, the flood block causes inundation from upstream to downstream areas. In a small/intermediate-scale flood, as shown in Fig. 2.2, the flood areas may be multiple due to geological factors. In this case, each area is considered to be a flood block.

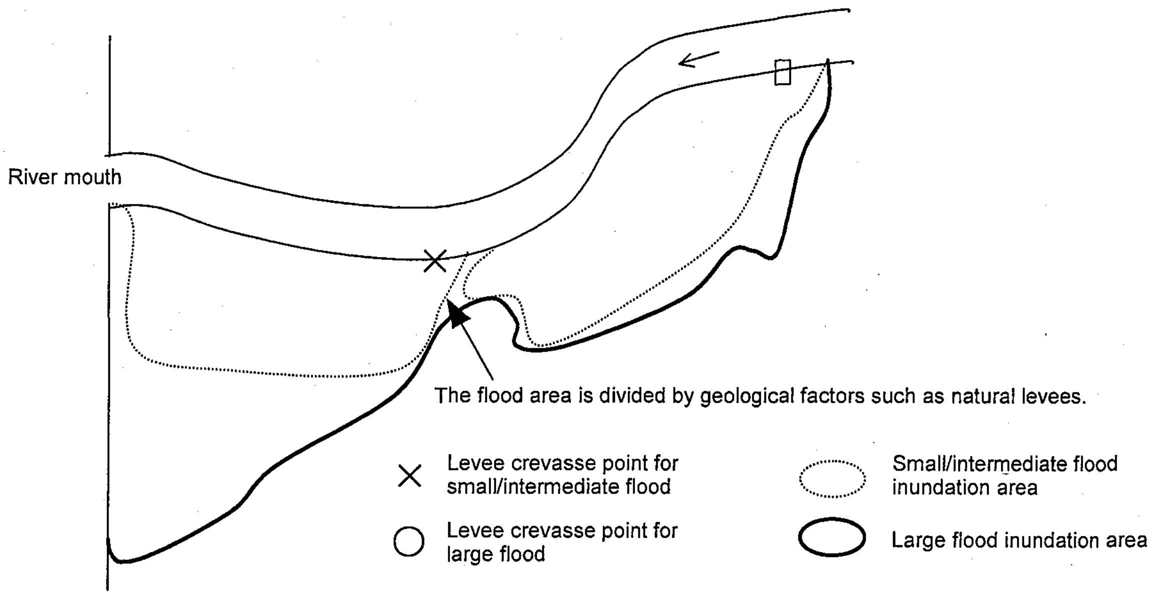


Fig. 2.2 Flood block for each flood scale

(6) Structures such as continuous fills that cut flood plains

In a small/intermediate-scale flood, if the flood area is cut by continuous fill structures that are small/medium-sized rivers or secondary levees similar to (5), each area is considered to be a flood block. (Fig. 2.2)

(7) Inundation result

For rivers that have experienced a large-scale river water flood in the past, flood blocks are divided on the basis of inundation result area.

2.3.2 Determining flow capacity

The flow capacity at left/right banks of the subject channel is calculated. The maximum flow that does not cause a flood is determined as the harmless flow for each flood block, and the probability of scale is calculated. The maximum capacity of flow at left/right banks is also calculated.

[Explanation]

As described in Section 3.1, each flood block may cause a levee crevasse flood when a flow exceeds the harmless flow at each block. When a flow exceeding the maximum capacity of a flow occurs at each point of a river, an overflow may occur. The methods of calculating a harmless flow and the maximum capacity of the flow are explained below.

(1) When flow capacity is known (subject channel)

The flow capacity is calculated for channels when a flood control project is started, and after the estimated facilities are completed.

The reason why the channels at the start of a flood control project, as well as after completion of estimated facilities, are covered here is to evaluate the effects of the flood control project by comparing flood damage before and after the flood control project.

When it is necessary to evaluate a series of flood control projects and it is not appropriate to make an economic evaluation of the project for the current channel, the evaluation should trace back to the point when it is appropriate to make an economic evaluation of a series of projects. The channel at that time should also be included.

(2) Conditions for determining flow capacity

(1) Hydrologic analysis method

To be consistent with the channel plan for evaluating the flood control economic survey, the flow capacity is calculated by the hydrologic analysis method used in the channel plan. At present, a variable flow calculation (hereinafter referred to semi-2D variable flow calculation) considering trees is used for the channel plans of large rivers. In large rivers, the semi-2D variable flow is basically used.

(2) Hydrologic condition

For the hydrologic conditions to judge the flow capacity of the current channel, the capacity for the flow calculation condition of the current channel is used in the channel plan. Specifically, the range of the dead water zone such as departing water level, roughness coefficient, range of dead water zone such as trees, boundary mixing coefficient, afflux with structures such as bridges, barrier or small-scale sand waves, water level increase due to bend of channel, and water level increase due to tributary joint should be checked in the river channel plan.

In addition, the hydrologic conditions in the channel after completion of estimated flood control facilities should be consistent with the conditions of the river channel plan.

(3) Preparation of H-Q formula

According to the hydrologic analysis method and the hydrologic conditions, the water level (H) for each flow (Q) scale is calculated to prepare the H-Q formula including $Q = a(H+b)^2$ type. In this case, the channel flow distribution is determined by the design discharge distribution.

(4) Evaluation of harmless flow

For each cross-section of the subject channel, it is assumed that the crown height deducting the design freeboard is H_1 by sliding the levee (Fig. 2.3). Capacity of flow Q_1 is calculated from the H-Q formula. It is assumed that either the levee ground height at the levee position or the flood foundation height, whichever is higher (height which is levee crevasse foundation height), is H_0 (Fig. 2.4). Flow capacity Q_0 equivalent to this is calculated from the H-Q formula.

In addition, for Q_1, when low-water revetment, high-water revetment, and drought control measures, which are designed in the channel plan for the safety of levees, are not available yet, flow Q_1' deducting appropriate values for each is calculated.

Either deducted flow Q_1' and Q_0, whichever is larger, is the minimum flow capacity for the cross-section concerned.

This minimum flow capacity is arranged in the longitudinal direction to prepare the flow-capacity diagram (Fig. 2.5).

The minimum flow capacity for each block on this flow-capacity diagram is determined as the harmless flow for each block.

In the evaluation tracing back to the point when it is appropriate to make an economic evaluation for a series of projects, the channel at that time is evaluated using the same method. At the levee that has not been modified, it is difficult to assume that the flow corresponding to the height can safely (and definitely) continue. Flow capacity Q_0 equivalent to H_0 may be approximated as the harmless flow of the cross-section concerned. (Fig. 2.4)

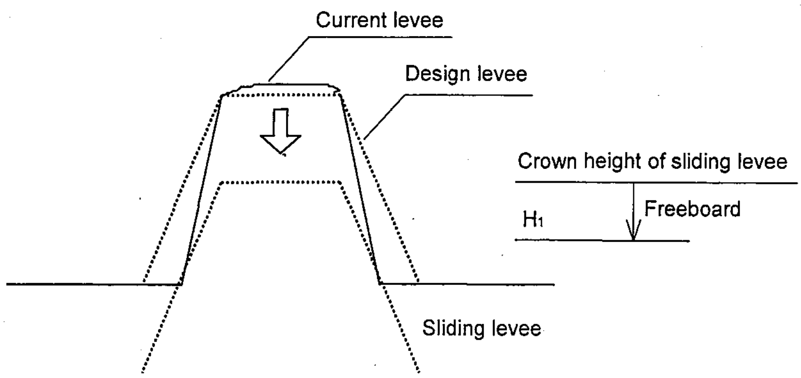


Fig. 2.3 Sliding

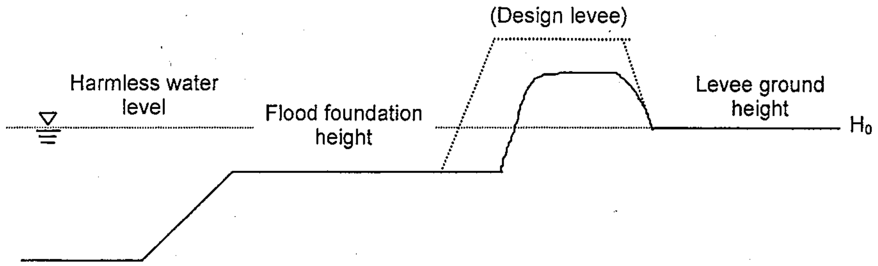


Fig. 2.4 Levee evaluation method at non-modification when determining harmless flow

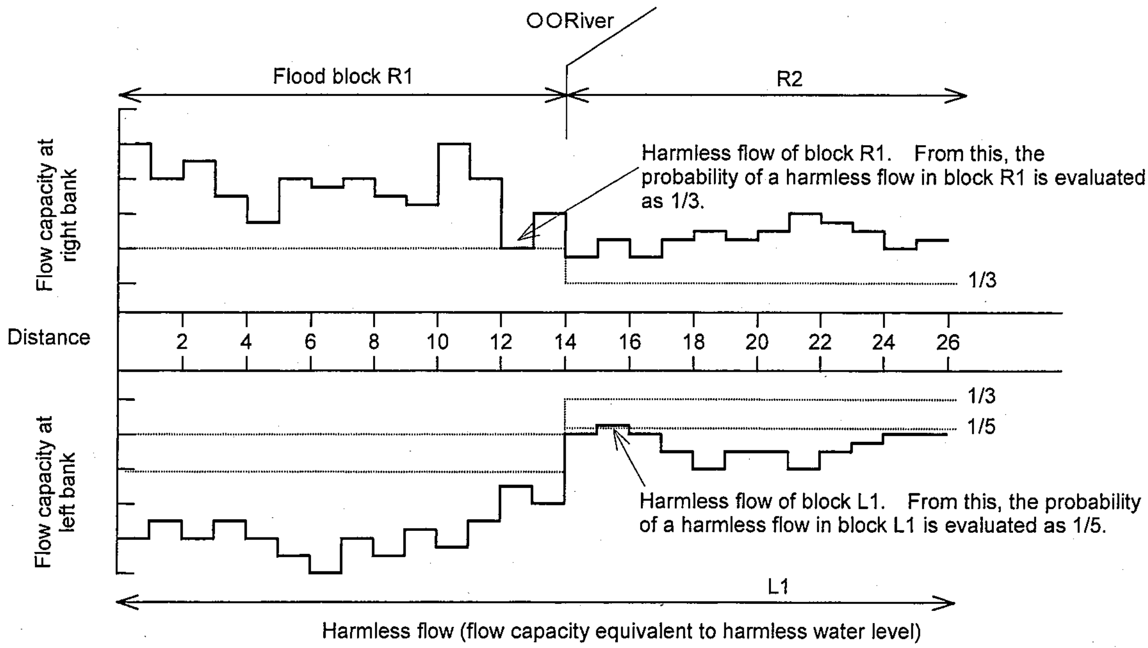


Fig. 2.5 Flow-capacity diagram at left/right banks

(5) Evaluation of maximum flow capacity

The limit flow that does not cause an overflow is defined as the maximum flow capacity.

The maximum flow capacity at the left/right banks of each cross-section is equivalent to the flow capacity of the levee crown height (Fig. 2.6). (Sliding is not used for calculating the maximum flow capacity.) It is calculated from the H-Q formula described previously.

(6) Precautions

If the flow capacity is evaluated to be extremely low or high due to structures such as weirs in the calculation of flow capacity above, the H-Q formula should not be automatically prepared from the hydrologic calculation results. Considering the hydrologic characteristics in the section to obtain an appropriate evaluation of flow capacity, the H-Q formula is corrected as required, or the calculation is excluded from the levee crevasse point described later.

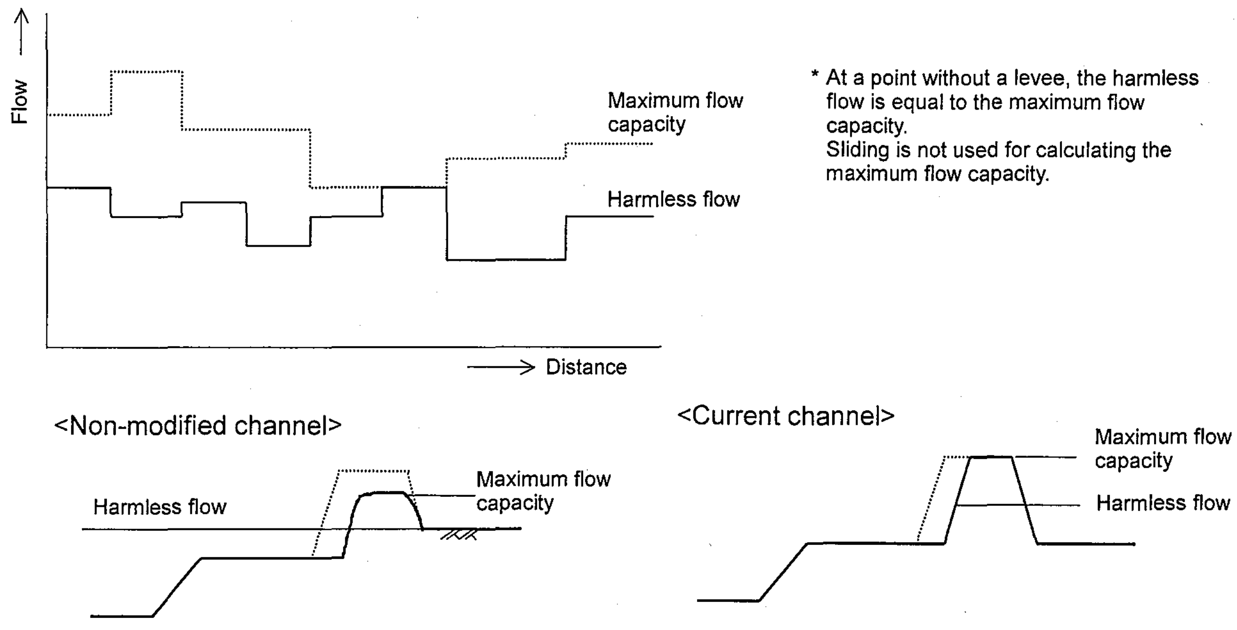


Fig. 2.6 Calculation of maximum flow capacity

2.3.3 Estimation of levee crevasse

One levee crevasse point should be estimated for each flood block.

[Explanation]

Due to the construction history of the levee, the internal materials are unknown. The duration of a flood is a probability event, and is not considered deterministically. It is difficult to specify the locations of levee crevasses. Considering that a series of levees protects against flood in a flood block, when the flow exceeds the harmless flow of the flood block, where flood phenomenon is considered in series, it is possible that a levee crevasse may occur at any point (cross-section). Although the levee crevasse point cannot be specified, the levee crevasse point must be estimated in the damage estimation of the subject channel. The maximum damage in the plan is estimated. One point where damage becomes maximum is determined as the levee crevasse point for each flood block.

The levee crevasse point — the levee crevasse point where maximum damage may occur — should be selected on the basis of the flood hazard map and the conventional survey results below.

- Survey of important flood control area
- Previous river coffer point and previous channel mark (according to the landform classification map for flood control)
- Pool dug by flood stream (ditto)
- Alluvial fan
- Joint point of main stream and tributary
- Location of crossing structures

The following items need to be considered.

- Location with small harmless flow (∵Risk of levee crevasse with overflow is large.)
- Location with large difference between calculated water level and levee crevasse foundation height (∵Risk of flood discharge is large.)

3. Flood simulation

3.1 Basic policy for flood simulation

> A flood simulation is performed for each flow scale and flood block. At a point with an insufficient flow capacity upstream, overflow (spill) should be considered.

[Explanation]

1. Flood simulation case

A flood simulation should be performed for the number of flood blocks for each flow scale. If there is a tributary, a flood simulation is performed for the number of flood blocks affected by a tributary flood for each flow scale of the tributary.

The levee crevasse point in each case should only be the levee crevasse point of the subject flood block. (Therefore, the levee crevasse point for each case is only one point.) The amount of damage in this case is that of the flood block in the flow scale concerned. If flood by main stream and flood by tributary are estimated in the same flood block, the large amount of damage in both cases is the amount of damage of the block. (Fig. 3.1, Fig. 3.2)

2. Precautions for flood simulation

When a flood is correctly reviewed to analyze the flood situation that results in maximum damage, items to be considered are as follows.

- Flood from location with insufficient flow capacity

  Upstream, an overflow (spill) occurs from the location where the flow exceeds the maximum flow capacity.
- Reduction of flow with flood

  When an overflow (spill) occurs, the flow downstream is reduced by flooding. When a flood returns to the river, such a reduction should be considered.
- Subject flood

  In the channels of the upstream/downstream and main stream/tributary, a different design flood for facilities and maximum amount of damage are reviewed. If it is necessary to change the subject flood, it should be changed for the flood block. (Fig. 3.1, Fig. 3.2)

(Example)

As shown in Fig. 3.1, when the amount of damage caused by a tributary is larger than the damage caused by the main stream in flood block 3, the amount of damage in flood block 3 should be the amount of damage due to a tributary flood. The overall amount of damage D is obtained as follows.

D = Maximum overall amount of damage

$= d_{1H} + d_{2H}$ (←For main stream levee crevasse)

$+ d_{3S}$ (←For tributary levee crevasse) ($\because d_{3S} > d_{3H}$)

Subscripts 1, 2, and 3 indicate flood blocks. H and S indicate floods by main stream and tributary.

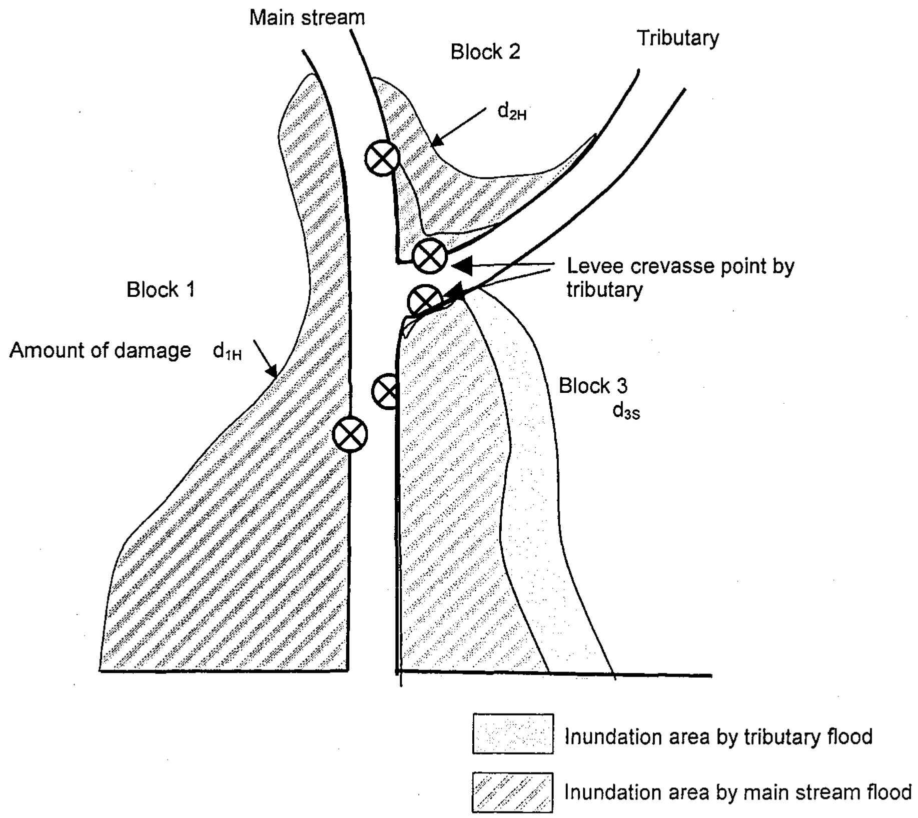


Fig. 3.1 Flood damage by main stream and tributary

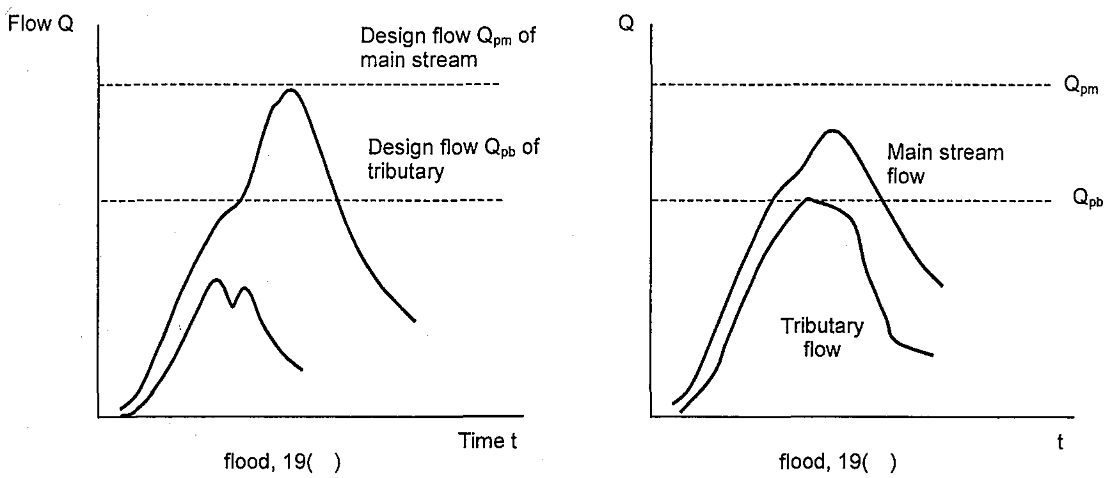


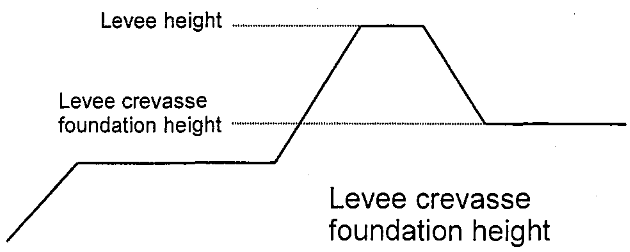
Fig. 3.2 Examples of different subject floods in main stream and tributary

3. Possibility of levee crevasse and flow estimation after levee crevasse

When the flow exceeds the harmless flow in the block, a levee crevasse may occur. In an actual phenomenon, there is no levee crevasse less than the flow of the levee crevasse foundation height.

Therefore, the harmless flow in the block and the flow of the levee crevasse foundation height calculated in the previous chapter should be compared to the flow. It is necessary to check the possibility of a levee crevasse for the flow concerned.

(The flow equivalent to the levee crevasse foundation height (Refer to page 34.) is determined as the flow of the levee crevasse foundation height.)



(Example)

Assume that the flow is 2,000 (m^3/s).

Flow > Harmless flow in the block (1,500 (m^3/s)) * Levee crevasse may occur.

Flow > Flow of levee crevasse foundation height (1,000 (m^3/s))

* Levee crevasse is estimated.

(If both relations above are not satisfied, there is no possibility of a levee crevasse. A levee crevasse is, therefore, not estimated.)

3.2 Setting flood conditions

3.2.1 Flood conditions

With the largest design scale, flood hydrographs with different occurrence probabilities including the standard point, which are larger that the harmless flow, should be set for about 6 cases.

[Explanation]

In the flood conditions, the flow scales should be those for about 6 cases that are larger than the harmless flow, and use the largest design scale. In the estimation of probability scale, the probability in the section may be gradually reduced so that the calculation of the annual average amount of damage described later may not be disturbed.

The flood waveform should be determined from the representative flood in the review of basic flood, considering the following items.

- Flood for designing administration management facilities
- Famous floods in recent years
- Large amount of damage from a large flood

The probability scale of a flood is evaluated from the standard point. If the flood waveform of a tributary is determined separately from that of the main stream, the evaluation should be made with the flood probability scale at major points of the tributary.

(6 cases)

<Good example> Harmless flow ... Future plan

$\frac{1}{3}$ $\frac{1}{5}$ $\frac{1}{10}$ $\frac{1}{30}$ $\frac{1}{50}$ $\frac{1}{100}$ $\frac{1}{150}$

<Bad example> Harmless flow ... Future plan

$\frac{1}{3}$ $\frac{1}{30}$ $\frac{1}{40}$ $\frac{1}{50}$ $\frac{1}{70}$ $\frac{1}{100}$ $\frac{1}{150}$

∵ Because the probability scale as an annual expected value is rough, the accuracy of the annual expected value is low.

In a flood simulation, a flow hydrograph should be used, in principle. At the section where a flood is of the river flow type in the mountains, only the peak flow may be used. On the flow hydrograph for each probability scale, rainfall is extended to meet the specified probability with the method (flow probability, precipitation probability) used when reviewing the basic flood discharge. The hydrograph is determined by a runoff calculation.

In an evaluation tracing back to the point when it is appropriate to make an economic evaluation of a series of projects, runoff is calculated for the flood control facilities at that time. When the current channel is used and the channel after completion of estimated facilities is used at the start of the flood control project, runoff is calculated including flood control with a dam at that time. This control method should be in accordance with the current operating regulation for the current channel and with the design operation regulation for the channel after completion of the estimated facilities.

3.2.2 Flood flow

The flood discharge at the levee crevasse point of each flood block is obtained for each flow scale. Flood (overflow, spill) upstream should be considered.

[Explanation]

1. Calculation procedures

When the flood simulation is performed, the discharge of overflow/levee crevasse is calculated according to the procedures below.

(1) Flow of overflow/levee crevasse

The discharge of overflow and the flow of levee crevasse should be calculated from the relation between the river water level at the overflow/levee crevasse point, the back protected land water level, and the levee crevasse foundation height.

(2) River water level

To be consistent with the channel plan, the channel water level is calculated with the H-Q formula using the semi-2D variable flow calculation. This water level is used only for calculating the discharge of the overflow/levee crevasse with a judgment on the possibility of overflow/levee crevasse. It is separate from the channel variable flow calculation used for calculating the water surface profile after overflow/levee crevasse.

(3) Tracing channel flood

Overflow and levee crevasse flow are handled as lateral outflows, and the reduction of the flow downstream is considered. When overflow and levee crevasse flow return to the channel through the flood plain, it should be included in the channel variable flow calculation.

In the calculation above, it is necessary to integrally perform the channel variable flow calculation and the flood analysis, while excluding the case that the flood discharge is determined only by the river water level. When existing models are calculated individually, it is desirable for the models to be changed to allow calculations between the channel and the flood plain.

2. Flood simulation method

The flow of the flood analysis previously described is shown in Fig. 3.3.

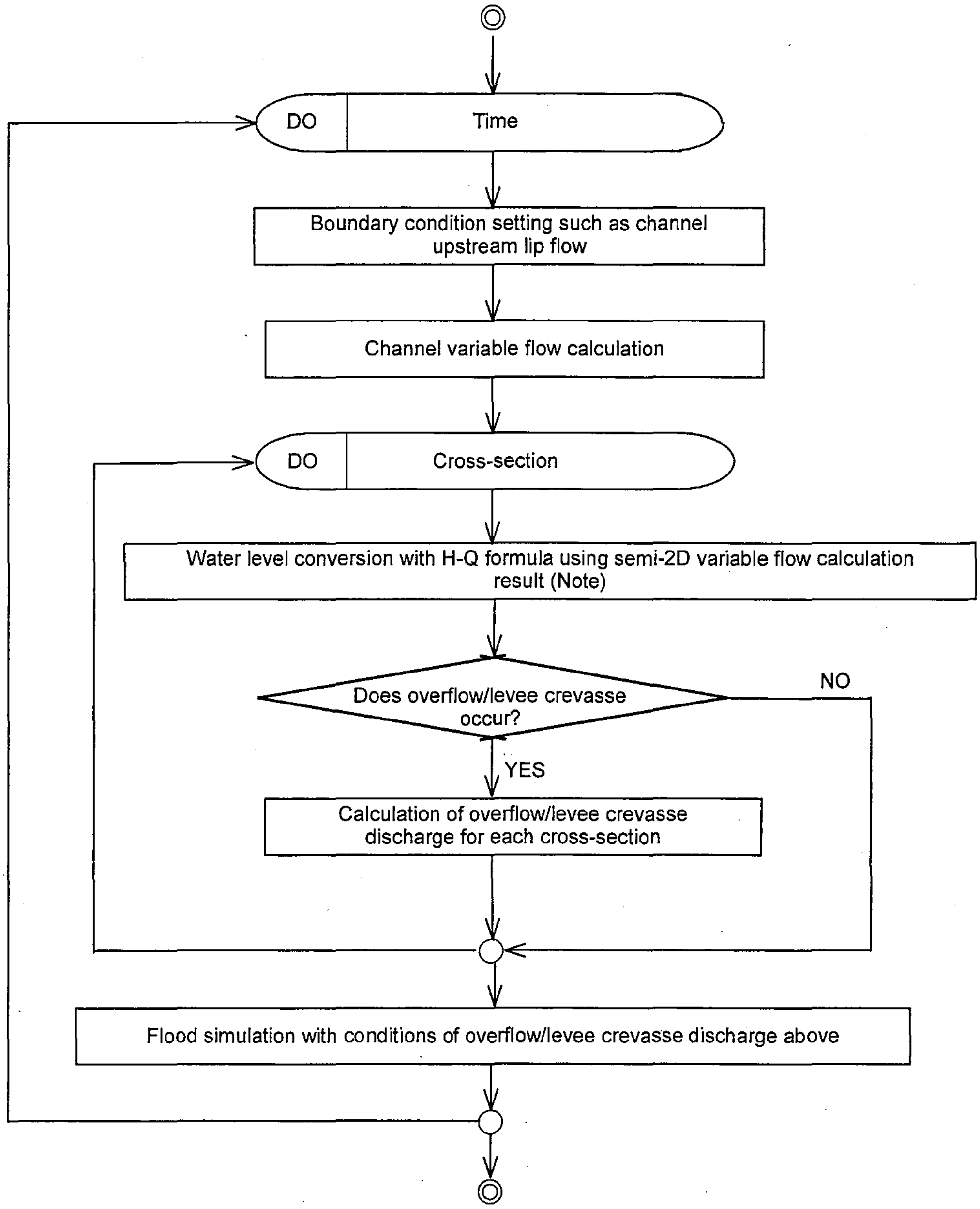


Fig. 3.3 General procedures of flood simulation

(Note) This objective is to determine the real-time flow distribution with the channel variable flow calculation, and to determine the water level corresponding to the flow calculated in the water plan as the most probable estimated value. Therefore, it is necessary to exclude a tidal zone, for which it is difficult to specify the H-Q formula.

3. Setting calculation condition

To set conditions such as levee crevasse shape for calculation, the following procedures should be followed, based on the "Flood simulation manual (draft)" (Public Works Research Institute, Ministry of Construction, February 1996).

(1) Overflow width

The overflow width at the levee crevasse point from the levee crown is either the levee crevasse width described later or the distance to the flow levee crevasse point, whichever is smaller.

(2) Levee crevasse width

When there are proven values for the levee crevasse shape, they are used for reference. If proven values are not available, levee crevasse y (m) is calculated by the following formula using river width x (m), based on a judgment as to whether the levee crevasse point is near a joint or not.

The point near a joint means a confluence of rivers for which the effects of the joint cannot be ignored. The guideline for such an effect is that the river width of the tributary is 30% or more of the river width of the main stream. The guideline for the affected section is twice the river width of the main stream upstream/downstream from the joint.

- Near the joint : $y = 2.0 \times (\log_{10} x)^{3.8} + 77$
- Not near the joint : $y = 1.6 \times (\log_{10} x)^{3.8} + 62$

(3) Levee crevasse foundation height

A levee crevasse should occur at the bottom of the levee. Either the levee ground height or the channel flood foundation height, whichever is higher, is determined to be the levee crevasse foundation height.

(4) Time progress of levee crevasse

Immediately after a levee crevasse occurs, half of the width of the final levee crevasse (y/2) is broken. Then, the breakage reaches the final levee crevasse width within one hour. The expansion speed of the levee crevasse should be constant during this time. The levee crevasse foundation height should immediately become the foundation height in (3).

(5) Treatment of facilities

Facilities that may affect flood phenomenon are incorporated into the flood analysis model as much as possible, based on the judgment of an engineer considering the following points.

- Fill -- Fill with relative height of 50 cm or more from the average ground height is incorporated into the model. Specifically, it refers to levee, secondary levee (including open levee), railway, major road, or other fills. Fill is laid out on the fill crossing mesh boundary on the calculation mesh of the flood simulation. Therefore, fill is laid out in steps as viewed from the horizontal plane.
- Pump -- The pump should be considered in accordance with the actual operating regulation. If it is unknown, the operation should be estimated. (The pump should discharge water at the maximum capacity as soon as an inundation occurs.)
- Sluice gate -- The formula of (6) (c) below proposed by Public Works Research Institute, Ministry of Construction should be used.
- Culvert -- The same calculation formula as the sluice gate should be used.
- Waterway -- To reproduce the behavior of flood water in the waterway, it is desirable to use the variable flow model excluding the inertia term. If the change of flow with time is limited, a simple calculation model may be used at the discretion of an engineer. Similar to fill, the waterway is laid out on the calculation mesh boundary of the flood simulation. If the waterway incorporated is too small, the calculation may be unstable, so attention should be paid to the selection of waterways.
- Sewer -- If a sewer is considered, it is desirable to use the same calculation method as that for the waterway.

(6) Overflow and flow from facilities

To calculate overflow, an appropriate overflow formula is used from the relation of channel shape in the area and the water route of the flood. Because the calculation using the overflow formula does not consider the balance with the channel flow, an excessive overflow may be calculated in some cases. Therefore, it is necessary to confirm that overflow Q_B obtained with the overflow formula is smaller than flow Q_D, which is above the levee crevasse foundation height. If it is larger, control for $Q_B = Q_D$ is required. If the water level in the levee is larger than the water level in the channel, a reverse flow may occur from the levee to the channel.

(a) Front overflow

Overflow is calculated using Honma's formula.

Honma's formula

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

Submerged overflow ($h_2/h_1 \geq 2/3$) $$Q = 0.91 \times h_2\sqrt{2g(h_1 - h_2)} \times B$$

Where, h_1 and h_2 are the water depths measured from the levee crevasse foundation height. The greater depth is h_1 and the smaller depth is h_2.

(b) For side overflow

Side overflow is calculated using the formula below.

When the flow obtained with Honma's formula is Q_0 and the bed slope is I, overflow Q is expressed as follows. The unit in the parentheses of cos is °.

- Flood discharge Q in levee crevasse

$I > 1/1580$ $\quad Q/Q_0 = (0.14 + 0.19 \times \log_{10}(1/I))^* \cos(48 - 15 \times \log_{10}(1/I))$

$1/1580 \geq I > 1/33600$ $\quad Q/Q_0 = 0.14 + 0.19 \times \log_{10}(1/I)$

$1/33600 \geq I$ $\quad Q/Q0 = 1$

- Overflow Q in spill

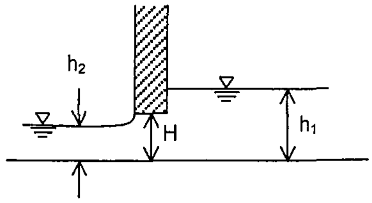
$I > 1/12000$ $\quad Q/Q_0 = \cos(155 - 38 \times \log_{10}(1/I))$

$1/12000 \geq I$ $\quad Q/Q_0 = 1$

(c) Discharge flow from sluice gate/culvert

Discharge is calculated using the formula below, which is proposed by Public Works Research Institute, Ministry of Construction.

Where, height of the sluice gate/culvert is H, width is B, the greater water



depth measured from the foundation height of the outlet is h_1 and the smaller water depth is h_2.

Submerged discharge: $h_2 \geq H$

$$Q = CBH\sqrt{2g(h_1 - h_2)} \quad , \quad C = 0.75$$

Intermediate discharge: $h_2 < H$ and $h_1 \geq 3/2H$

$$Q = CBH\sqrt{2gh_1} \quad , \quad C = 0.51$$

Free discharge: $h_2 < H$ and $h_1 < 3/2H$

$$Q = CBh_2\sqrt{2g(h_1 - h_2)} \quad , \quad C = 0.79$$

When $h_1 / h_2 \geq 3/2$ in free discharge, it is converted to $h_2 = 2/3\ h_1$.

(7) Roughness

Roughness should be judged comprehensively from the calculation model, the land use condition in the basin, and the flood results in the past. The method that represents roughness by the function of water depth and building occupancy described in the "Flood simulation manual (draft)" should also be used for reference.

(8) Setting calculation time interval

The calculation time interval is set considering the calculation time (cost of calculation) until the calculation is constant.

When a small waterway in the flood plain is included, the calculation may be unstable, so attention should be paid to the selection of small waterways.

3.3 Implementation of flood analysis

Flood is analyzed from the previous flood discharge to calculate the inundation area and the inundation depth.

[Explanation]

The standard channel calculation is a non-uniform calculation with a mesh. If the calculation is inappropriate for the geological conditions of the flood plain, other methods may be used. When the mesh is divided, it should be as consistent as possible with the mesh (digital map information or digital national land information) used for asset data.

The basic mesh length should be 250 m. If a larger mesh can be used for calculation accuracy or if the number of meshes is enormous when using a 250 m mesh, which does not allow for practical calculation, a 500 m mesh may be used. The following should be verified.

Because a fill with a specific height of 50 cm or more from the average ground height is incorporated into the model, the difference in height between meshes on a slope should be maintained at 50 cm or less.

In this case, restrictions can be indicated with the formulas below. Where, Δx: Mesh width (m), Δt: Calculation time interval (sec.), A: Flood block area (km^2), Δz: Average height difference (m) between meshes, I: Slope.

Considering restrictions of calculation time (cost for calculation) or stability, Δx and Δt are determined to verify validity with the formulas below.

(1) $\Delta z = I \times \Delta x \leq 0.5\,m$

(2) $\Delta x > 10\sqrt{A}$

(3) $\Delta t \leq \Delta x/25$

3.4 Calculating amount of flood damage

The amount of flood damage is calculated with mesh data such as those for assets and land forms, and with the inundation depth obtained from the flood analysis result.

[Explanation]

The amount of flood damage for each mesh is calculated with the mesh data (ground height, asset, slope, etc.) and the inundation depth from the flood analysis result. From the total value of these results, the amount of flood damage for each probability scale on the flood plain is calculated. In addition, multiplying this value for flood damage by the flood occurrence probability results gives the average annual expected damage reduction amount. (This is explained in detail in Chapter 4 Calculating benefits.)

4. Calculating benefits

4.1 Subject benefit of economic evaluation

> In a flood control economic survey, the preventive effects of flood damage are considered to be benefits.

[Explanation]

Economic effects of flood control project are classified into major categories of preventing damage to effect assets at the flood plain and flow effects of project. Stock effects involve direct/indirect flood damage preventive effects and upgrading effect of land use with the improved level of flood control safety. At present, however, all damage preventive benefits are not always measured. It is not technically easy to measure the upgrading benefits of flood control facilities, and it is difficult to completely separate the benefits of upgrading from the benefits of preventing damage.

- Flood control project
  - Flow effect
  - Stock effect
    - Damage preventive effect
    - Upgrading effect

Direct damage to general assets has been based on a valuation of general assets. After a flood, people who will live in the same place often repurchase houses or furniture to restart their lives. Therefore, direct damage is calculated from replacement cost.

In this manual (draft), for direct/indirect damage with flood in Table 4-1, the effects of preventing damage that can be economically evaluated at present are evaluated as benefits.

In this case, for projects that might generate benefits from the construction of flood control facilities during the construction period, benefits during the construction period are known in chronological order. Thus, an evaluation including the construction period of flood control facilities is performed.

Construction of a levee is as outlined in the figure. Even during the construction period, the effect of levee construction appears along with investment costs.

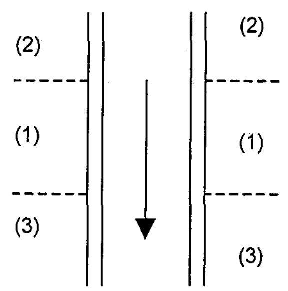
In contrast, for a dam, effects appear after completion of the dam and at the stage of use (e.g. stage of initial impoundment).

As described above, it is important that benefits from the construction of facilities during the construction period should be known in chronological order to make an appropriate evaluation.

[Construction of levee]

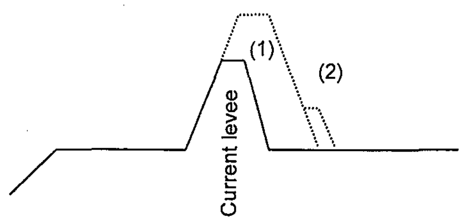
- Vertical construction in stages

When a levee is constructed vertically in stages, that portion in higher dangerous areas (e.g. order of Section (1) → Section (2) → Section (3) as shown in the left figure) are constructed first. The effects appear before all sections of (1) to (3) are completed. When each section is completed, the effects gradually appear.



- Horizontal construction in stages

When a levee is constructed horizontally in stages (e.g. levee widening in the order from (1) to (2) as shown in the left figure), the effects appear before all sections of (1) and (2) are completed. The effects gradually appear upon each completion of widening in (1) and completion of widening in (2).



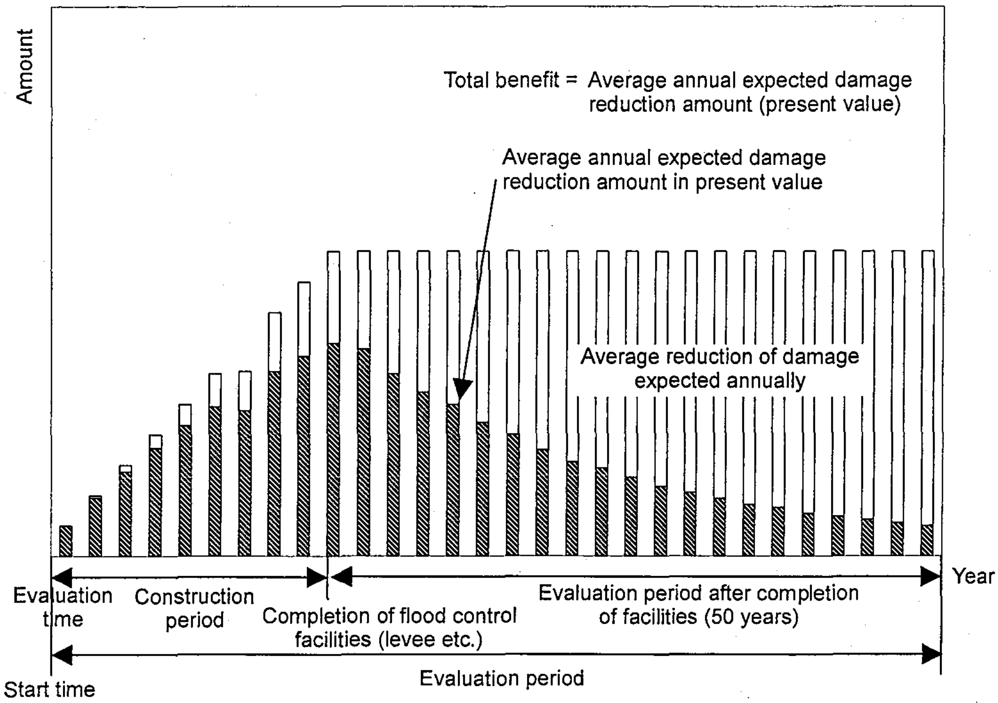


Fig. 4.1 Appearance of benefits of levee

[Dam]

The effects for a dam appear at the stage when facilities become effective after their completion.

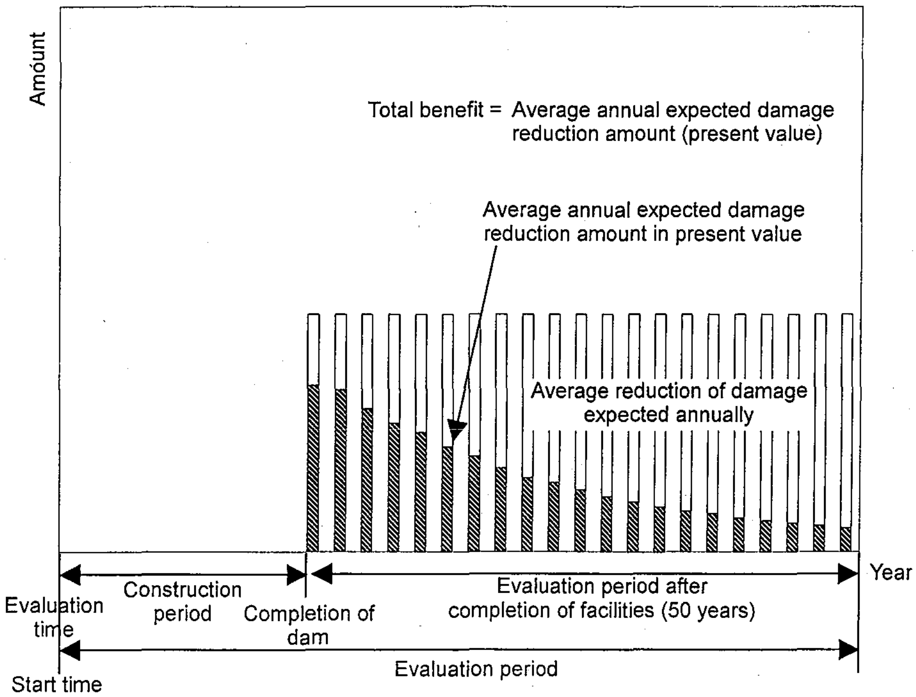


Fig. 4.2 Occurrence of dam benefits

When the amount of damage (benefit of flood control project) is calculated, it is assumed that the current assets will not be changed in the future. When expansion of assets in the flood area in the future can be determined with specific and reasonable values, such expansion may be included in the calculation of assets. Thus, the amount of damage to assets may be calculated.

It is necessary to estimate the time from a flood to the resumption of normal social and economic activities.

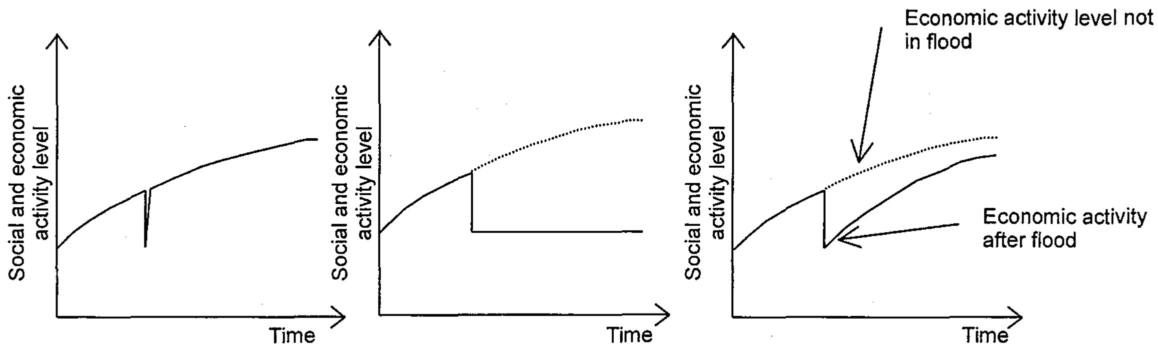


Fig. 4.3 Time from flood to resumption of normal social and economic activities

Even if the amount of direct damage to assets caused by a flood is the same, the time required to resume normal economic activities varies greatly as shown in Fig. 4.3, depending on the assets and the incomes of victims, economic strength of flood area, local characteristics such as city or rural area, and percentage of victims in the area. Therefore, to accurately calculate the amount of damage, relation of individual income, economic strength and total amount of damage (total of direct and indirect damage) may be used from flood damage examples in the past. However, there are no such data.

In this manual (draft), as described above, based on the policy that the minimum amount of damage is calculated, direct asset damage is immediately recovered. It is also estimated that social and economic activities after indirect damage including interruption of businesses of companies can return to normal within a minimum number of days.

However, the relation between individual and local social/economic activities and a flood needs to be reviewed.

Other benefits described in *4.6*, which can be measured with a survey of individual rivers, are evaluated as benefits. In evaluating benefits, it must be noted that there should be no duplication.

Table 4.1 Major effects of flood control project

Classification					Description of effect (damage)
Benefits of preventing damage	Direct damage	Effects of preventing asset damage	General asset damage	Housing	Damage to buildings including housing due to inundation
				Domestic items	Damage to furniture or automobiles due to inundation, excluding fine art and precious metals
				Corporate depreciable assets	Inundation damage to depreciable assets among a company's fixed assets excluding land and buildings
				Company inventory assets	Inundation damage to company inventory
				Depreciable assets of farmers/fishermen	Inundation damage to depreciable assets among fixed assets of farmers/fishermen excluding land and buildings
				Inventory assets of farmers/fishermen	Inundation damage to farmers/fishermen's inventory assets
			Damage to farm products		Damage to farm products due to inundation
			Damage to civil facilities	Road, bridge, sewer, city facilities, electricity, gas, water, railroad, telephone, farmland, farm facilities, etc.	Inundation damage to farm facilities such as civil facilities, utility facilities, farmland, and waterway.
		Preventive effects on death/injury			Death or injury
	Indirect damage	Effects of preventing damage to operations	Damage from business interruption	Household budget	Damage that disturbs household work and leisure activities of families exposed to inundation
				Company	Suspension of production at companies exposed to inundation (reduction of turnover)
				Public and utility service	Suspension of public and utility services
		Effects of preventing post-flood damage	Emergency costs	Household budget	Extra costs for cleaning houses after inundation or purchase of items such as drinking water
				Company	Damage similar to household budget
				National and local authorities	Damage similar to household budget and interest for emergency financing or sympathy money given by local municipalities
			Damage due to interruption of transport	Road, railway, airport, harbor, etc.	Spread of damage including peripheral areas due to interruption of road or rail transport
			Spread of damage due to disconnection of utilities	Electricity, water, gas, communication, etc.	Spread of damage including peripheral areas due to interruption of supplies of electricity, gas, water, etc.
			Spread of damage due to interruption of business		Reduced production of peripheral companies due to insufficient intermediate products or spread of damage including peripheral areas due to interruption of public/utility services such as hospitals
		Preventing adverse mental effects	Due to asset damage		Mental shock due to asset damage
			Due to operational damage		Mental shock due to operational damage
			Due to injury/death		Mental shock due to injury/death
			Due to post-flood damage		Mental shock due to labor for cleaning
			Due to spread of damage		Mental shock due to spread of damage
Upgrading benefit					Increased land prices due to improved flood control safety

* There are other effects of preventing damage due to inundation of underground shopping arcades.
(□ in the table refers to items indicating damage rate and damage unit cost in this manual (draft).)

4.1.1 Assets applicable to direct damage

Damage to the following assets that are exposed to inundation should be obtained as direct damage.

- Houses
- Farm products
- Domestic items
- Public facilities
- Depreciable/inventory assets of companies
- Depreciable/inventory assets of farmers/fishermen

[Explanation]

(1) Housing

Residential buildings for general families and other buildings of companies are applicable.

(2) Domestic items

Furniture, electric appliances, clothes, cars, etc. at home are applicable.

(3) Depreciable/inventory assets of companies

Production facilities and inventory among company assets excluding land and building are applicable.

(4) Depreciable/inventory assets of farmers/fishermen

Production facilities and inventory of farmer/fishermen assets excluding assets of general families and land and building are applicable.

((1) to (4) are referred to as General assets. The same applies to the sections below.)

(5) Farm products

Flooded rice and field crops are applicable.

(6) Public facilities

Road, bridge, sewer and city facilities, utility facilities such as electricity, gas, water, railroad, telephone, etc., assets of farmland and farming facilities damaged due to inundation are applicable.

4.1.2 Applicable indirect damage

Damage that allows economic evaluation should be obtained from indirect damage spreading from direct damage.

[Explanation]

Spread of damage from flood inside/outside the inundation area. Damage varies depending on social and economic activities of the inundation area and on the scale of inundation. It is difficult to describe all forms of damage. A method to measure damage economically and reasonably has not yet been established for all items.

For indirect damage, the following items that can be economically and statistically estimated at this stage are obtained for the time being. If an objective and reasonable measuring method that reflects the characteristics of the river for other damage can be established in the survey of each river, such damage may be included among indirect damage.

- Loss from interruption of business
- Emergency costs at home
- Emergency costs at company

4.2 Survey of asset data

In principle, assets, basic figures such as number of families and number of employees, etc. required for calculating the amount of damage in the flooded area are used for each calculation mesh of the flood simulation.

[Explanation]

Based on local mesh statistics (Statistical Information Institute for Consulting and Analysis), the following basic figures are surveyed for each calculation mesh (basically 250 m) of the flood simulation.

- Population and number of families (in accordance with census mesh statistics)
- Number of employees for each classification of industry (in accordance with

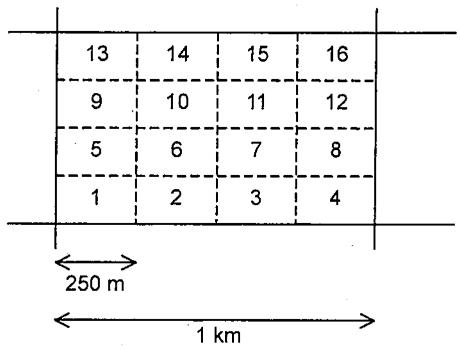
company mesh statistics)

- Number of farmers/fishermen (in accordance with census mesh statistics)
- Total floor area (in accordance with mesh data prepared by Japan Construction Information Center)
- Rice paddy and field area (in accordance with map or digital map (1/10 segmented land data) (Japan Map Center)

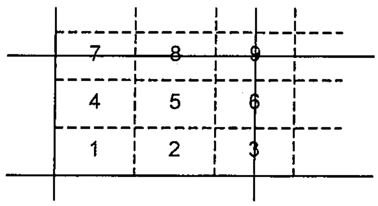
In mesh statistics, figures for a 1 km mesh are generally collected. Division of figures into a 250 m mesh is performed as follows with the housing area ratio.

Where population, number of families, and number of farmers/fishermen of the 250 m mesh is P_i (i = 1, 2, ... 16), 1 km mesh value is P and the 250 m mesh housing area is a_i, p_i is calculated using the following formula.

$$p_i = P \times \frac{a_i}{\sum_{i=1}^{16} a_i}$$



The total floor area is prepared for the 100 m mesh. Although the boundary of the 250 m mesh is not consistent with that of the 100 m mesh, a calculation is performed assuming that the asset density is uniform in the mesh not included.



Where the 100 m mesh total floor area is α_i and the mesh number on the figure above is i, total floor area α for the 250 m mesh is:

$$\alpha = (\alpha_1 + \alpha_2 + \alpha_4 + \alpha_5) + (\alpha_3 + \alpha_6 + \alpha_7 + \alpha_8) \times \frac{1}{2} + \alpha_9 \times \frac{1}{4}$$

To study basic figures, in addition to using 1 km mesh data, a method of using the 100 m mesh data prepared by Japan Construction Information Center is available. The data prepared by Japan Construction Information Center is based on the following surveys.

- Census in 1990

- Company statistic survey in 1991 (converted to the value in 1990)

Using these basic figures, the following assets are surveyed.

- Housing
- Domestic items
- Company depreciable/inventory assets
- Farmer/fishermen's depreciable/inventory assets
- Farm products

4.2.1 Housing

Housing assets are calculated by multiplying the unit price for each prefecture by the floor area.

[Explanation]

Housing assets are calculated by multiplying the valuation amount in Table 4.2 by the floor area.

If the value obtained by multiplying the average floor area per family by the number of families is used as the standard floor area, a company building is not evaluated. There is, therefore, an underestimate. The total floor area of the building using the 100 m mesh data of Japan Construction Information Center based on the "General survey on fixed asset prices (Ministry of Home Affairs)" should be used.

Table 4.2 Valuation of house per m2 for each prefecture

(1,000 yen/m^2)

Prefecture	Valuation in 1998	Valuation in 1999	Prefecture	Valuation in 1998	Valuation in 1999
Hokkaido	155.8	156.5	Shiga	163.2	163.9
Aomori	146.6	147.7	Kyoto	184.5	185.3
Iwate	144.9	145.9	Osaka	193.6	193.8
Miyagi	152.1	152.9	Hyogo	176.0	176.6
Akita	141.3	142.5	Nara	175.7	176.6
Yamagata	143.4	144.6	Wakayama	163.0	163.7
Fukushima	147.9	148.9	Tottori	155.7	156.7
Ibaraki	153.8	154.7	Shimane	164.1	165.3
Tochigi	151.6	152.3	Okayama	158.9	159.7
Gunma	149.7	150.6	Hiroshima	152.1	152.8
Saitama	172.2	172.9	Yamaguchi	159.5	160.3
Chiba	177.2	177.9	Tokushima	148.0	148.7
Tokyo	206.2	206.4	Kagawa	159.8	160.6
Kanagawa	186.9	187.4	Ehime	145.5	146.2
Niigata	152.0	153.1	Kochi	153.6	154.5
Toyama	151.1	152.1	Fukuoka	149.6	150.2
Ishikawa	168.2	169.3	Saga	150.3	151.2
Fukui	159.5	160.4	Nagasaki	147.0	147.9
Yamanashi	169.7	170.7	Kumamoto	141.2	142.0
Nagano	165.4	166.4	Oita	147.8	148.6
Gifu	156.7	157.4	Miyazaki	131.5	132.2
Shizuoka	158.0	158.7	Kagoshima	142.9	143.6
Aichi	161.1	161.6	Okinawa	156.6	156.0
Mie	154.6	155.3			

<Remark>

- The 10-year valuation is obtained from the weighted mean of the wooden building valuation and the non-wooden building valuation for each prefecture obtained by the method below at the rate of the wooden building total floor area and the non-wooden building total floor area in the prefecture.

  Wooden (non-wooden) building evaluation amount
  = Building cost per m^2 of wooden building (non-wooden) × Correction factor

  Note)
  1) The building cost per m^2 of wooden (non-wooden) building is in accordance with "Building status statistics survey in 1998" (Ministry of Construction).
  2) The correction factor is the average of the unit price correction factor for the past 5 years in the statistical surveys.
  3) The total floor area of the wooden (non-structural) house is in accordance with "General survey on fixed asset prices in 1998" (Ministry of Home Affairs).

- To obtain the valuation in 1999, the average of actual building costs for the past 10 years is converted into the nominal increase rate with the general building deflator, and the value is multiplied by the valuation in 1998.

4.2.2 Domestic items

Valuation per family is multiplied by the number of families to calculate domestic item assets.

[Explanation]

The valuation unit price per family is multiplied by the number of families to calculate the domestic item assets.

1,000 yen/family

Valuation in 1998	Valuation in 1999
14,933	14,893

<Remark>

1. Valuations other than for automobiles are calculated from the "Furniture valuation table" in the "Simple valuation handbook," which is uniformly used in the General Insurance Association of Japan and on the census.
   1) According to the "Simple evaluation handbook," the valuation is determined for each family organization and head of family.
   2) According to the census result, the rate of each family group previously described is obtained for entire families. The domestic item valuation per family is calculated with a weighted mean.
2. The valuation of automobiles is calculated from the Automobile insurance vehicle standard price and the "Automobile almanac."
   1) Number of vehicles of each model is obtained from the "Automobile almanac."
   2) The average price of each model is obtained from the Automobile insurance vehicle standard price, and the average price per vehicle is obtained from a weighted mean from the number of vehicles.
   3) According to the "National consumption status survey report," the average number of vehicles per family is obtained and multiplied by the average price per vehicle to obtain the average price per family.

The data classification "Number of general families [Value not concealed]" (data No. 185) in "Classification of family types" of the census mesh statistics is used for the number of families to provide the basic figure.

4.2.3 Company depreciable/inventory assets

The number of employees for each industry category is multiplied by the valuation unit price per person to calculate the company depreciable/inventory assets.

[Explanation]

For large categories or medium-sized categories of industry, the number of employees is multiplied by the valuation unit price in Table 4.3 to calculate the company depreciable/inventory assets. In industry categories, the categories of company mesh statistics are not always consistent with the medium-sized categories in Table 4.3. Large categories may be used as the base. At this time, the corresponding data item numbers for industry categories are as follows:

Large industry categories	Company mesh statistics	
	Industry category name	Data item No. for number of employees
D Mining	Mining	8
E Construction	Construction	11
F Manufacturing	Manufacturing	14
G Supply of electricity, gas, water, or heat	Supply of electricity, gas, water, or heat	89
H Transportation or communication	Transportation or communication	92
I Wholesale or retail	Wholesale, retail or restaurants	95
J Finance or insurance	Finance or insurance	149
K Real estate	Real estate	152
L Service	Service	155
M Civil service	Civil service (Not classified into others)	227

(Note: The data item numbers are in accordance with the company statistics mesh data in 1991.)

Table 4.3 Depreciation asset valuation and inventory asset valuation per employee for each industry

(1,000 yen/person)

Industry category			Depreciable asset		Inventory asset	
Large category symbol	Medium-sized category symbol	Industry name	Valuation in 1998	Valuation in 1999	Valuation in 1998	Valuation in 1999
D		Mining	8,456	8,678	834	1,839
E		Construction	1,713	1,758	4,707	4,721
F		Manufacturing	5,165	5,369	4,268	3,855
	12,13	Food, beverage, feed, cigarette, manufacturing	4,256	4,424	2,316	2,091
	14	Textile industry	3,859	4,011	2,814	2,541
	15	Clothe and fabric product manufacturing	1,234	1,282	1,205	1,089
	16	Wood and wooden product manufacturing	3,594	3,736	4,229	3,819
	17	Furniture and fixture manufacturing	3,239	3,367	2,767	2,499
	18	Pulp, paper and paper coat manufacturing	9,040	9,397	3,350	3,026
	19	Publication, printing, and related business	4,870	5,063	1,526	1,378
	20	Chemical industry	11,286	11,732	7,436	6,716
	21	Petroleum product and coal product manufacturing	43,227	44,934	33,770	30,501
	22	Plastic product manufacturing	4,705	4,890	2,317	2,092
	23	Rubber product manufacturing	3,686	3,832	1,780	1,608
	24	Tanning, tanned product, and fur manufacturing	1,891	1,966	3,123	2,821
	25	Ceramic industry and soil/stone product manufacturing	6,211	6,456	3,970	3,586
	26	Steel industry	15,457	16,067	7,879	7,116
	27	Non-ferrous metal manufacturing	9,835	10,223	6,549	5,915
	28	Metal product manufacturing	4,538	4,717	3,646	3,293
	29	General machine manufacturing	4,233	4,401	6,992	6,315
	30	Electric appliance manufacturing	3,783	3,932	4,311	3,894
	31	Transportation machine manufacturing	5,419	5,632	4,135	3,735
	32	Precision machine manufacturing	2,764	2,873	3,682	3,325
	33	Weapon manufacturing	6,889	7,161	34,560	31,215
	34	Other manufacturing	3,469	3,606	3,941	3,560
G		Supply of electricity, gas, water, or heat	130,806	134,233	1,752	1,757
H		Transportation or communication	7,988	8,197	641	643
I		Wholesale or retail	2,181	2,238	3,056	2,920
	48-53	Wholesale	2,394	2,457	5,060	4,836
	54	Retailing of various products	2,036	2,090	3,031	2,896
	55	Retailing of textile, clothe and personal effects	2,036	2,090	21,006	20,075
	56	Retailing of food and beverage	2,036	2,090	606	579
	57	Retailing of automobiles and bicycles	2,036	2,090	2,260	2,159
	58	Retailing of furniture, fittings, and fixtures	2,036	2,090	3,320	3,172
	59	Retailing of other products	2,036	2,090	16,973	16,220
J		Finance or insurance	4,756	4,881	368	369
K		Real estate	25,035	25,691	21,278	21,339
L		Service	4,756	4,881	368	369
M		Civil service	4,756	4,881	368	369

Note) Industry classification is in accordance with Japan standard industry classification (revised in October, 1993).

<Remark>
Inventory assets of manufacturing are in accordance with "Industry statistics (Industry)" (Ministry of International Trade and Industry), inventory assets of non-manufacturing are in accordance with "Financial statistics annual report feature (company statistics annual report feature)" (Ministry of Finance) and inventory assets of wholesale/retail are in accordance with "commercial statistics flash report" (Ministry of International Trade and Industry).

4.2.4 Farmers'/fishermen's depreciable assets/inventory

Evaluation unit price per house is multiplied by the number of farmer/fishermen families to calculate the farmers'/fishermen's depreciable assets/inventory.

[Explanation]

The following evaluation unit price is multiplied by the number of farming/fishing families to calculate the farmers'/fishermen's depreciable assets/inventory. Because this evaluation unit price is the national average, the farm production characteristics for each local area are not always evaluated. If a reasonable unit price that can evaluate farmers'/fishermen's depreciable assets/inventory for each local area can be determined, it may be used.

1,000 yen/house

	Valuation in 1998	Valuation in 1999
Depreciable asset	3,012	3,042
Inventory	278	287

<Remark>
The calculated amount is based on the "Farm management statistics" (Ministry of Agriculture, Forestry and Fisheries).

For the number of farming/fishing families as a basic figure, the sum of the "Number of families engaged in agriculture, forestry and fishery" (data No. 205) and the "Number of mixed families not engaged in agriculture, forestry and fishery" (data No. 206) in the data classification "General families for each economic organization" in the census mesh statistics is used.

4.2.5 Farm products

Farm product evaluation unit price per area is multiplied by the rice paddy area and the field area to calculate the farm product assets.

[Explanation]

The average annual crop yield per area is multiplied by the rice paddy area. The result is then multiplied by the rice unit price to calculate the rice assets (Table 4.4 and Table 4.5).

Considering the farm products in the subject flood area during the flood period, the average year crop yield per area is multiplied by the planted area for major farm products. The result is then multiplied by the unit price to calculate the field crop assets (Table 4.5). If the calculation is limited to a representative crop type, it is necessary to pay attention so that the average asset valuation of field crops can be obtained for the flood period.

For the average unit price, prefectural statistics data are used. For example, average valuation c per field area is calculated and the mesh field area is multiplied by c (1,000 yen/a) to calculate the field crop asset amount.

$$c = \Sigma p_i \cdot x_i / \Sigma A_i$$

Where i refers to crop type during the flood period, p refers to price (1,000 yen/t), x refers to yields (t), and A refers to planted area (a).

Table 4.4 Average year yield of rice per 10 a for each prefecture

(Unit: kg)

Prefecture	1998	1999	Prefecture	1998	1999
Hokkaido	519	518	Shiga	472	471
Aomori	591	589	Kyoto	479	478
Iwate	538	536	Osaka	452	451
Miyagi	529	527	Hyogo	474	473
Akita	577	575	Nara	486	485
Yamagata	594	592	Wakayama	464	463
Fukushima	534	532	Tottori	487	486
Ibaraki	504	503	Shimane	471	470
Tochigi	535	533	Okayama	485	484
Gunma	499	498	Hiroshima	501	500
Saitama	493	492	Yamaguchi	486	485
Chiba	524	523	Tokushima	448	447
Tokyo	394	393	Kagawa	480	479
Kanagawa	470	469	Ehime	482	481
Niigata	520	519	Kochi	419	418
Toyama	516	515	Fukuoka	478	477
Ishikawa	496	495	Saga	495	494
Fukui	493	492	Nagasaki	443	442
Yamanashi	524	523	Kumamoto	494	493
Nagano	609	607	Oita	478	477
Gifu	450	449	Miyazaki	461	460
Shizuoka	513	512	Kagoshima	464	463
Aichi	478	477	Okinawa	313	313
Mie	443	442			

(Remark)
The average annual yield of rice in 1997 for each prefecture according to "Crop statistics (product in 1997)" (Ministry of Agriculture, Forestry and Fisheries) is multiplied by the average rate of increase of the national average year yield from 1993 to 1997 to obtain the value in 1998. The value is then multiplied by the rate of increase above to obtain the value in 1999.

Table 4.5 Price of farm products

(1,000 yen/ton)

Farm product		1998	1999
Rice		290	285
Wheat		167	166
Bean	Soy bean	246	247
	Red bean	345	345
	Peanut	440	440
Potato	Sweet potato	123	123
	Potato	85	85
Fruit and vegetable	Cucumber	236	229
	Egg plant	247	242
	Tomato	264	248
	Pumpkin	139	128
	Water melon	136	125
	Strawberry	989	910
	Green pepper	268	243
	Melon	369	339
Leaf and stalk vegetable	Chinese cabbage	83	75
	Cabbage	104	92
	Lettuce	223	209
	Spinach	510	449
	Green onion	373	321
	Onion	94	87

Farm product		1998	1999
Leguminous plant vegetable	Snow pea	977	899
	Green bean	607	558
Root vegetable	Radish	91	87
	Carrot	149	137
	Burdock	268	247
	Aroid	166	163
Fruit	Apple	201	185
	Mandarin orange	203	170
	Chinese citron	115	113
	Pear	281	278
	Persimmon	231	227
	Grape	633	633
	Peach	414	406
Craft farm products	Tea	847	779
	Sugar beet	17	17
	Alimentary yam paste	123	123
	Leaf tobacco	1,913	1,913
	Orchid	282	282
Petal	Chrysanthemum	68	66
	Rose	66	63
	Carnation	43	41
Orchid		1,561	1,561

(Remark)
1. The value in 1998 is in accordance with "Farm village price index (1998)." (Ministry of Agriculture, Forestry and Fisheries)
2. The value in 1999 is obtained by multiplying the value in 1998 by the rate of price increase in accordance with "Agricultural forecast (1999)" (Ministry of agriculture, forestry and fisheries).
3. The unit for blooms (chrysanthemum, rose, carnation) is 1,000 yen/1,000 flowers.

4.3 Calculation of direct damage amount

The asset value is multiplied by the damage rate corresponding to the inundation depth to calculate the damage amount. However, damage to civil facilities is calculated from the relation to the general asset damage amount.

[Explanation]

The damage due to inundation is calculated for each asset item in *4.1.1*. The basic calculation method is based on the damage rate determined from the maximum inundation depth for each mesh. Because it is difficult to estimate direct damage to assets of civil facilities, it is calculated from the relation to general asset damage amount.

4.3.1 Housing damage

The asset amount is multiplied by the damage rate corresponding to the inundation depth to calculate housing damage. At this time, the asset distribution in the mesh should be considered.

[Explanation]

The damage rate in Table 4.6 is used. In Table 4.6, completely or partially collapsed houses due to increase of inundation depth is already considered.

Table 4.6 Damage rate for each inundation depth

Inundation depth / Ground slope	Under floor	Above floor					Sediment deposit (above floor)	
		Less than 50 cm	50-99	100-199	200-299	300 cm or more	Less than 50 cm	50 cm or more
Group A	0.032	0.092	0.119	0.266	0.580	0.834	0.43	0.785
Group B	0.044	0.126	0.176	0.343	0.647	0.870		
Group C	0.050	0.144	0.205	0.382	0.681	0.888		

A: Less than 1/1000 B: 1/1000 to 1/500 C: 1/500 or more

Note: Damage rate obtained from "Flood damage survey" from 1993 to 1996. (Conventional damage rate is used for sediment deposit.)

(1) Determination of floor height

It is necessary to determine the floor height appropriately when using the damage rate. Considering the features of residential houses and company buildings, the floor height should be determined. To be consistent with the Building Standard Law, the inundation above floor level is generally 45 cm or more of the mesh water depth.

(2) Ground slope

The reason for using different damage rates for the ground slope is to consider differences in the fluid force of flood water. The ground slope is determined from geological features of the flood area and the average mesh ground height for each mesh. If the slope is automatically determined from the relative height difference of peripheral meshes for each mesh, a mesh with a very different slope from peripheral areas may be obtained. If it does not represent the actual landform, it is necessary to take average values from a wider range.

(3) Height distribution

In a high-rise building, if the water depth at the building location is equivalent to the depth under floor, all families in the building are exposed to housing damage equivalent to inundation under floor. This may overestimate the damage. It is desirable for the housing asset exposed to inundation to be corrected with the average number of building floors in the mesh. In general, the water depth is several meters at most. If the 3rd and higher floors are ignored, the following correction may be available. (Height distribution needs to be considered for company assets.)

<Example of housing asset correction exposed to inundation>

$$P = P_0 \times \gamma$$

Where P_0 refers to housing asset of the mesh, γ refers to correction factor and f refers to the average number of building floors;

When $f < 3$ $\quad \gamma = 1.0$

When $f \geq 3$ $\quad \gamma = 2/f$

Considering local conditions, the average number of building floors can be determined with the following methods:

Method using mesh data

The census mesh data has the number of families for each floor. Because these data indicate the number of families for each floor, it is necessary to draw a line at a certain value when using the data. If families up to the 2nd floor, for example, are included in the damage, correction factor γ may be determined.

<Reference>

When a statistical index is used

According to the existing survey examples of the Japan Construction Information Center, the average number of floors f and the density of population and company employees m in a certain area have the relation $f \fallingdotseq f(m) \fallingdotseq a + b \cdot m$. If f can be estimated using this simple method, it may be used.

4.3.2 Damage to domestic items

> The asset amount is multiplied by the damage rate corresponding to the inundation depth to calculate the domestic item damage amount. At this time, the height distribution of the asset in the mesh should be considered.

[Explanation]

The damage rate in Table 4.7 should be used. Refer to *4.3.1* for the determination of floor height and correction with height distribution.

Table 4.7 Damage rate for each inundation depth

Inundation depth	Under floor	Above floor					Sediment deposit (above floor)	
		Less than 50 cm	50-99	100-199	200-299	300 cm or more	Less than 50 cm	50 cm or more
Damage rate	0.021	0.145	0.326	0.508	0.928	0.991	0.50	0.845

Note: Damage rate obtained according to "Flood damage survey" from 1993 to 1996. (Conventional damage rate is used for sediment deposit.)

4.3.3 Companies' depreciable asset/inventory damage amount

Asset amount is multiplied by the damage rate corresponding to the inundation depth to calculate the companies' depreciable asset/inventory damage amount. At this time, the height distribution of assets in the mesh should be considered.

[Explanation]

The damage rate in Table 4.8 should be used. Refer to *4.3.1* for the determination of floor height and correction with height distribution.

Table 4.8 Damage rate for each inundation depth

Inundation depth / Asset	Under floor	Above floor					Sediment deposit (above floor)	
		Less than 50 cm	50-99	100-199	200-299	300 cm or more	Less than 50 cm	50 cm or more
Depreciation	0.099	0.232	0.453	0.789	0.966	0.995	0.54	0.815
Stock	0.056	0.128	0.267	0.586	0.897	0.982	0.48	0.780

Note: Damage rate obtained according to "Flood damage survey" from 1993 to 1996. (Conventional damage rate is used for sediment deposit.)

4.3.4 Farmers'/fishermen's depreciable asset/inventory damage amount

Asset amount is multiplied by the damage rate corresponding to the inundation depth to calculate the farmers'/fishermen's depreciable asset/inventory damage amount.

[Explanation]

The damage rate in Table 4.9 should be used. Refer to *4.3.1* for the determination of floor height.

Table 4.9 Damage rate for each inundation depth

Inundation depth	Under floor	Above floor					Sediment deposit (above floor)	
		Less than 50 cm	50-99	100-199	200-299	300 cm or more	Less than 50 cm	50 cm or more
Depreciation	0.0	0.156	0.237	0.297	0.651	0.698	0.370	0.725
Stock	0.0	0.199	0.370	0.491	0.767	0.831	0.580	0.845

4.3.5 Damage to farm crops

> Asset amount is multiplied by the damage rate corresponding to the inundation depth and the days of inundation to calculate the farm crop damage amount.

[Explanation]

In principle, farm crop damage is obtained for local agricultural production. Specifically, actual farm crop damage from recent inundation or relation between inundation depth and farm crop are surveyed. The damage rate that meets local agricultural management should be used, considering species that are very vulnerable to inundation (no product value with inundation (100% damage rate)) or species that are resilient to flooding.

If the actual status for a case with no recent inundation is not clear, the farm crop amount may be calculated from the damage rate in Table 4.10.

Days of inundation are determined from the inundation depth reduction rate or local landform features and inundation results based on flood analysis results. When the individual crop type cannot be determined, the field average value may be used.

Table 4.10 Damage for each inundation depth

(%)

Item		Submerged water												Sediment accumulation		
Submerged water depth		Less than 0.5 m				0.5-0.99 m				1.0 m or more				Sediment accumulation depth from ground		
Crop type	Days of inundation	1-2	3-4	5-6	7 or more	1-2	3-4	5-6	7 or more	1-2	3-4	5-6	7 or more	Less than 0.5 m	0.5-0.99 m	1.0 m or more
Rice paddy	Rice	21	30	36	50	24	44	50	71	37	54	64	74	70	100	100
Field	Upland rice	20	34	47	60	31	40	50	60	44	60	72	82			
	Sweet potato	11	30	50	50	27	40	75	88	38	63	95	100			
	Chinese cabbage	42	50	70	83	58	70	83	97	47	75	100	100			
	Vegetable	19	33	46	59	20	44	48	75	44	38	71	84			
	Root vegetable	32	46	59	62	43	57	100	100	73	87	100	100			
	Cucurbitaceous fruit	22	30	42	56	31	38	51	100	40	50	63	100			
	Beans	23	41	54	67	30	44	60	73	40	50	68	81			
	Field average value	27	42	54	67	35	48	67	74	51	67	81	91	68	81	100

Note) 1. "Vegetable" refers to green onion, spinach, and others. "Root vegetable" refers to radish, aroid, burdock, and carrot. "Cucurbitaceous fruit" refers to cucumber, melon, and watermelon. "Beans" refers to red bean, soy bean, peanuts, onion, etc.

2. Damage rate of sediment accumulation is also caused by flood sediment of rivers. In "debris flow," the value should be modified for the actual situation.

4.3.6 Public civil facilities

General asset damage amount is multiplied by damage rate to calculate the damage amount of public civil facilities.

[Explanation]

From the relation of general asset damage amount (total damage amount from *4.3.1* to *4.3.4*), public civil facility damage amount, public utility facility damage amount, and farm land/agriculture facility damage amount are calculated using the rate in Table 4.11.

Table 4.11 Rate of public civil facility damage amount for general asset damage amount

(%)

Facility	Road	Bridge	Sewer	City facility	Utility	Farm land	Agricultural facility	Subtotal
Damage rate	61.6	3.7	0.4	0.2	8.6	29.1	65.8	**169.4**

Note: Value obtained from the national average based on the flood statistics and the statistics of Ministry of Agriculture, Forestry and Fisheries for major floods in the nation using the "Flood statistics" for the last 10 years (1987 to 1996).

In large cities, if the calculated public civil facility damage amount is based on the rate for the general asset damage amount using the value obtained from the national average, it is overestimated. It should be calculated using the rate of public civil facility damage amount for the general asset damage amount in the area concerned or a similar area known from flood statistics.

In this case, whether damage for rivers is included in the public civil facility damage amount or not is a subject for discussion.

(1) The benefits of a flood control project are to reduce damage to general assets such as houses or roads by constructing flood control facilities. In this manual (draft), it is estimated that the functions of flood control facilities are completely effective within the evaluation period (50 years) and the benefits from preventing damage are always obtained without change every year.

(2) When damage for rivers is included in the public civil facility damage amount, the estimation in (1) is changed. It is necessary to allow for a reduction of

the flood control facility function when the benefits of preventing damage are calculated.

Because of the problems described above, the damage value of public civil facilities other than rivers (169.4%) is used in this section.

These points need to be further reviewed in the future.

4.4 Calculation of indirect damage amount

For flood damage due to inundation other than direct damage, the amount of damage for items that can be evaluated as indirect damage at the current stage is calculated with an objective and reasonable method.

[Explanation]

As explained in *4.1.2*, the following damage for which the unit price of damage can be determined at the current stage should be calculated.

- Loss from business interruption
- Emergency costs at homes
- Emergency costs at companies

4.4.1 Loss from business interruption

The number of employees at a company that is subject to inundation is multiplied by the total days lost due to business interruption or stagnation, and multiplied by added value per day to calculate the loss from business interruption.

[Explanation]

Damage amount D is obtained using the formula below for each large industry category. The loss from business interruption is calculated from this total sum.

$$D_i = M_i \times (n_0 + n_1/2) \times p_i$$

Where, i refers to large industry category, M refers to number of employees, p refers to value added amount (yen/(man-day)), and n_0 and n_1 refer to the number of days of business interruption and stagnation determined by inundation depth.

Business interruption experienced by a company is not only caused by inundation of the company's premises, but also by inundation of peripheral areas. The correction described in *4.3.3* is not made.

(1) Days of business interruption and stagnation

The days of business interruption are as shown in Table 4.12. The days of business stagnation is twice the days of business interruption.

Table 4.12 Days of business interruption

(day)

Inundation depth	Under floor	Above floor				
		Less than 50 cm	50-99	100-199	200-299	300 cm or more
Days of interruption	3.0	4.4	6.3	10.3	16.8	22.6

Note: These days of interruption or stagnation are obtained from the "Questionnaire on floods" performed for floods occurring in 1995 and 1996.

(2) Value added per day per employee

Value added per employee is shown in Table 4.13.

Table 4.13 Value added per day per employee

(yen/person)

Industry category		Value added	
Large category symbol	Industry name	Valuation in 1998	Valuation in 1999
D	Mining	31,263	35,519
E	Construction	23,357	22,070
F	Manufacturing	28,687	29,242
G	Electricity, gas, water, and heat supply	131,528	135,053
H	Transportation and communication	30,855	31,376
I	Wholesale and retail	23,245	24,715
J – M	Services and others	22,839	23,815

Note: Industry classification shall be in accordance with Japan Standard Industry Classification (revised in October, 1993).

4.4.2 Emergency costs at home

Labor costs for cleaning at home or increase of expenses due to alternative activities are calculated.

[Explanation]

(1) Labor costs for cleaning

The number of families is multiplied by labor cost per family below and the total number of days required for cleaning in Table 4.14 to calculate the labor costs for cleaning at homes.

Cleaning and cleanup jobs are mainly repairs to houses or domestic items due to inundation. Considering cleaning around a residential area or activities of a residents' association in an apartment building, the correction in *4.3.1* is not made.

(yen/day)

Valuation in 1998	Valuation in 1999
10,810	10,988

<Remark>

1. For the evaluation amount in 1998, the value for light work employees (male) in "Wages for construction and harbor transport work in 1999" (by Policy Planning and Research Dept., Secretariat of Labor Minister) was used.
2. For the evaluation amount in 1999, the average increase rate for the previous year over 5 years from 1994 to 1998 was obtained. Then, the value was multiplied by the value for 1998.

Table 4.14 Total number of days required for cleaning

(day)

Inundation depth	Under floor	Above floor				
		Less than 50 cm	50-99 cm	100-199 cm	200-299 cm	300 cm or more
Number of days	4.0	7.5	13.3	26.1	42.4	50.1

Note: According to: Questionnaire on flood: for floods in 1995 and 1996, the total number of days required for cleaning and cleanup in Table 4.14 are obtained.

Labor cost above is based on cleaning by victims themselves. According to contract terms and conditions of non-life insurance companies, the cost of removing and disposing of a house due to inundation is approximately 10% of the new house price.

Therefore, if many houses are expected to be partially or totally destroyed, 10% of the house asset may be used included in the cleaning labor cost.

(2) Expenses for alternative activities

The number of families is multiplied by the damage amount in Table 4.15 to calculate the damage amount for alternative activities such as purchase of drinking water or alternative measures for commuting.

Table 4.15 Unit price of damage

(1000 yen/family)

Inundation depth	Under floor	Above floor				
		Less than 50 cm	50-99 cm	100-199 cm	200-299 cm	300 cm or more
Unit price	82.5	147.6	206.5	275.9	326.1	343.3

Note: This unit price was obtained from "Questionnaire on flood" for floods in 1995 and 1996.

4.4.3 Emergency costs at company

Increase of expenses due to cleaning or alternative activities at companies is calculated.

[Explanation]

(1) Cleaning labor cost

In general companies, employees are used to do cleaning. In this case, added value from cleaning labor is set off with expense as the value. Damage due to business interruption or stagnation during cleaning is calculated separately as loss from business interruption. To avoid duplication when evaluating damage, cleaning labor cost at a company is not calculated in this section.

(2) Expenses for alternative activities

The number of flooded companies is multiplied by the damage unit price in Table 4-16 to calculate the damage amount for alternative activities.

Table 4.16 Damage cost

(1,000 yen/company)

Inundation depth	Under floor	Above floor				
		Less than 50 cm	50-99 cm	100-199 cm	200-299 cm	300 cm or more
Unit price	47.0	92.5	1,714	3,726	6,556	6,619

Note: This unit price was obtained from "Questionnaire on flood" for floods in 1995 and 1996.

4.5 Calculation of benefits

Benefits of a flood control project are evaluated by the difference in damage amount between implementation of project and non-implementation of project. The total benefits during the evaluation period are calculated.

[Explanation]

In the re-evaluation of a river improvement plan and river/dam project, and in the evaluation of a new project, in principle, the economic efficiency of the project is evaluated from the current channel.

However, it is necessary to make the evaluation for a series of projects. If it is not appropriate to make an economic evaluation of a project for the current channel, instead an evaluation tracing back to the point that is considered appropriate for an economic evaluation of a series of projects should be made. At that point, the economic evaluation of the channel should be made.

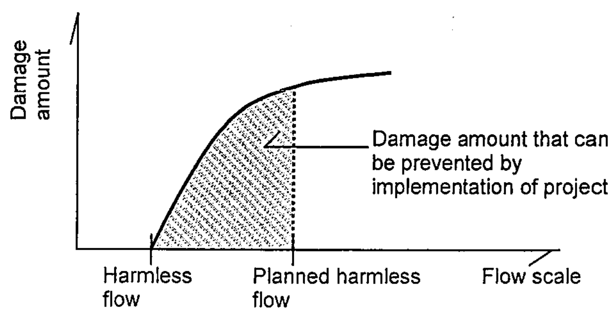


Fig. 4.4 Benefits of flood control project

When calculating the benefits of a flood control project, the damage amount that can be prevented by implementing the project is calculated from damage amounts with or without business. (Fig. 4.4)

4.5.1 Expected annual average reduction of damage

> The probability of a flood occurring is multiplied by reduced amount of damage. The expected reduced amount of damage for the planned level is totaled to calculate the expected annual average reduction of damage.

[Explanation]

As described in the table below, the reduced amount of damage is multiplied by the probability of a flood occurring and is totaled to the specified level to calculate the expected annual average reduction of damage. (Table 4.17)

Table 4.17 Expected annual average

Flow scale	Annual average excess probability	Damage amount (1) Project is not implemented	Damage amount (2) Project is implemented	Damage amount (3) Reduced amount of damage ((1) − (2))	Average damage amount in section	Probability in section	Annual average damage amount	Total of annual average damage amount = Expected amount of annual average reduction for damage
Q_0	N_0			$D_0(=0)$	$\frac{D_0+D_1}{2}$	N_0-N_1	$d_1=(N_0-N_1)\times\frac{D_0+D_1}{2}$	d_1
Q_1	N_1			D_1	$\frac{D_1+D_2}{2}$	N_1-N_2	$d_2=(N_1-N_2)\times\frac{D_1+D_2}{2}$	d_1+d_2
Q_2	N_2			D_2	⋮	⋮	⋮	⋮
⋮				⋮				
Q_m	N_m			D_m	$\frac{D_{m-1}+D_m}{2}$	$N_{m-1}-N_m$	$d_m=(N_{m-1}-N_m)\times\frac{D_{m-1}+D_m}{2}$	$d_1+d_2+\cdots+d_m$

4.5.2 Construction period and estimation of benefits during construction period

To evaluate a flood control facility allowing for the construction period, if benefits may be generated by constructing flood control facilities during the construction period, such benefits should be appropriately evaluated.

[Explanation]

When a specific investment plan (construction cost, construction period and distribution of construction cost) is determined, benefits accordingly generated should be appropriately calculated.

When a specific investment plan is not determined and only the approximate construction cost is determined, benefits generated are appropriately estimated based on similar projects in the past.

4.5.3 Total benefits in evaluation period

Total benefits in the evaluation period should be calculated. Future benefits should be evaluated with a certain allowance.

[Explanation]

Where, expected annual average reduction of damage is b, construction period is S, evaluation period is S+50 years, allowance rate is r, total benefit B for S+50 years is calculated from the start of construction.

$$B = \sum_{t=0}^{S+49} \frac{b}{(1+r)^t}$$

According to "Uniform guidelines on cost effective analysis for social capital improvement" (Ministry of Construction, March 1999), the allowance rate is $r = 4\%$.

4.6 Other benefits of flood control project

The following benefits that can be measured in a flood control economic survey for each river are evaluated as benefits. When evaluating benefits, attention should be paid so that duplication does not occur.

- Disturbance of normal activities at homes
- Emergency costs borne by national and local authorities
- Spread of damage due to disconnection of traffic means
- Spread of damage due to disconnection of lifelines
- Damage to peripheral companies due to business interruption of victim company
- Personal damage such as death and injury
- Damage due to inundation of underground mall
- Risk premium
- Upgrading benefits

[Explanation]

As explained in *4.1*, in this manual (draft), damage prevention effects for which economic efficiency can be evaluated at the current stage from direct/indirect damage due to flood are described as benefits. There are also damage prevention benefits that are not measured and upgrading benefits that are not known.

When the above benefits can be measured by flood control economic surveys for each river, they may be evaluated as benefits. However, in an evaluation of benefits, attention should be paid to prevent any duplication in calculations.

Considering evaluation results and improvements to evaluation techniques in the future, these benefits are incorporated into the benefit calculation of this manual (draft) for further improvement.

The policy for other benefits and important points in the evaluation are described below:

4.6.1 Interruption of normal activities at homes

Effect that preventing the interruption of normal activities at homes including domestic services and leisure activities can be considered as benefits.

[Explanation]

(1) A house that has been exposed to inundation has difficulty in providing its inhabitants with a normal life due to movement of furniture, cleaning, and cleanup. These impair the daily lives of people. Effects that prevent these can be considered flood control benefits.

(2) In the conventional survey example, the daily life value is expressed as the sum of production value and consumption value. The production value is indicated in the unit price from domestic service hours and the applicable wage for each occupation. The consumption value is indicated from the amount of expenses for leisure activities. The unit price per day of these values is multiplied by the days of inundation for each depth to obtain the value for damage to daily life.

(3) However, the number of survey examples is limited and it is difficult to determine a standard unit price at this stage. The method of determining domestic services as production also needs to be reviewed. A standard calculation method is not indicated here.

4.6.2 Emergency costs of national and local governments

Emergency costs of national and local governments are considered as benefits.

[Explanation]

(1) Emergency costs of national and local governments for disasters include interest on various emergency loans, sympathy money, expenses for disposal

of wastes and cleaning, etc. Reductions of taxes and pension payments are considered to be reductions of revenue, although they are not an expense.

(2) These damage amounts can be known from data survey or interviews following an actual flood. Labor is required and it is estimated that the results may vary depending on local, social, and economic characteristics or flood scale. It is difficult to determine an average unit price at this stage.

4.6.3 Damage due to transport interruption

Preventing the spread of damage such as transport interruption due to inundation of roads can be considered as benefits.

[Explanation]

(1) When roads or railways are flooded or damaged due to the action of a flow, means of transportation are stopped, resulting in damage to peripheral areas.

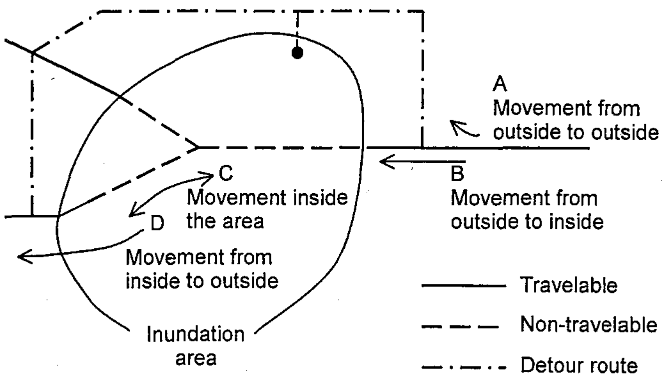
(2) In theory, additional costs incurred by detours can be calculated in damage amount.

(3) The calculation of damage amount caused by detours is shown in "Cost benefit analysis manual of road (draft)." If the traffic volume in the inundated area can be isolated, the amount can be calculated. At this time, the period with no transportation can be determined from the number of inundation days using the results of existing flood damage data in the flood plain.

Damage amount = Time loss + Distance loss

$$\text{Time loss} = \sum_{\text{Link}} \sum_{\text{Vehicle model}} \text{Time value unit} \times (\text{Time required for detour} \times \text{Number of vehicles} - \text{Time required in normal time} \times \text{Number of vehicles})$$

$$\text{Time loss} = \sum_{\text{Link}} \sum_{\text{Vehicle model}} (\text{Traveling cost unit in detour} \times \text{Traveling distance in detour} \times \text{Number of vehicles} - \text{Traveling cost unit in normal time} \times \text{Traveling distance in normal time} \times \text{Number of vehicles})$$



[Traffic volume is divided into A to D. To avoid counting loss due to business interruption twice, A and B should be covered.]

Fig. 4.5

(4) In this case, companies in the flood area have calculated damage separately as loss from business interruption. The amount for companies in the flood area should be deducted from the traffic volume based on the traffic census. Otherwise, the values may be counted twice.

(5) In addition to roads, the additional costs due to detours following inundation of public facilities such as airports may be calculated as damage amount.

4.6.4 Spread of damage due to disconnection of lifelines

Preventing the spread of damage due to loss of electricity or gas supply can be considered as benefits.

[Explanation]

(1) If electricity or gas has been suspended, damage spreads throughout the area. In this case, the number of these facilities in the flood area or how the backup system is prepared varies depending on the local area. It is difficult to develop a uniform nationwide calculation method.

(2) When the details are known directly from utility suppliers for each local area, it is necessary to avoid counting the loss due to business interruption twice. (If physical damage is also known directly from suppliers, attention should be paid to double-counting the damage amount for public civil facilities.

4.6.5 Spread of damage to peripheral companies due to business interruptions at flooded companies

Preventing damage from reduced production at peripheral companies due to insufficient intermediate in-process products following business interruptions at flooded companies can be considered as benefits.

[Explanation]

(1) Peripheral companies that have business relations with a victim company may be forced to interrupt business due to the business interruption at the flooded company.

(2) (1) Cost effectiveness in the flood control economic survey is analyzed assuming the entire community is a complete market. This kind of secondary effect is compensated for by production in other areas from the viewpoint of the nationwide economy. Therefore, it should not be included among flood control benefits. (2) When the actual flood damage is reviewed, it is

considered that secondary effects occur for a relatively short period and the area is limited. When the area is limited to a prefectural level, damage prevention may be considered as a flood control benefit.

(3) Therefore, if a company is producing special products that can be produced only in the flooded area, and if such production cannot be compensated for by production in other areas, preventing the spread of damage from business interruption in relation to the flooded company may be calculated as a damage prevention benefit. Other cases may also be used as reference when implementing a flood control project.

(4) Specifically, a method that combine the industry relation table and linear programming may be available. In the industry relation table, there is no business interaction between companies in the same industry classification. In this way, the damage calculated is much smaller than the actual amount.

(5) For a large-scale flood, the industry itself is considered to be transformed. It should be noted that the estimation using the industry relation model could be meaningless.

4.6.6 Injury and loss of life

Effects that prevent injury and loss of life, as well as adverse mental effects can be considered as benefits.

[Explanation]

(1) Effects on people are calculated as losses by the Hoffman method. However, the number of deaths may vary depending on natural factors such as time flood occurs or social factors such as evacuation instructions. It is difficult to quantify human effects.

(2) Adverse mental effects of a flood have been surveyed in the past. Problems include that data acquired are not constant or that data evaluation may be

duplicated with other items of damage.

4.6.7 Damage due to inundation of an underground mall

At an area with underground mall, preventing damage due to inundation can be considered as a benefit using a damage rate that allows for local characteristics such as landforms.

[Explanation]

(1) When the damage to assets in the underground mall is calculated, the evaluation becomes small using the normal damage rate. It is necessary to use a damage rate that considers local characteristics such as landforms.

(2) The mesh data used combine data above ground and data for an underground mall as plane data. Note that data should be carefully analyzed to prevent double-counting.

(3) In addition to the direct damage above, indirect damage due to inundation of the underground mall includes loss due to business interruption. When this is calculated, a reasonable method should be used considering local characteristics.

4.6.8 Risk premium

Effects of preventing devastating flood damage can be evaluated separately with a lower discount rate.

[Explanation]

(1) According to Professor Yukio Noguchi at the Institute for Advanced Technology, Tokyo University (Economy Seminar Mar. 1982),

(a) Project to reduce (or eliminate) the overall risk in a risk system must be evaluated with a discount rate that is lower than the expected marginal efficiency of a normal investment,

(b) Benefits gained under a critical condition must be evaluated with a shadow price that is higher than the normal price, and

(c) The public investment projects for which the evaluation methods above may be justified are disaster prevention projects including erosion and flood control dam, preservation forest, storm surge protection projects, and projects for earthquakes, as well as the levee mentioned above. He also says: "The common characteristic of these projects is that they are effective in a situation when overall business activities decline (critical condition)."

(2) With these points in mind, we consider how to evaluate the risk premium of flood control investment. First, a calculation with a discount rate that is lower than that of a general public investment is considered. However, when cost effectiveness is analyzed by the Ministry of Construction, the "Uniform guidelines for cost effectiveness analysis of social infrastructure improvement (March, 1999)," which stipulates uniform rules for precautions and common values, in principle, show the cost benefit converted into the present value with a discount rate of 4%. Therefore, it is difficult to use a lower discount rate only for flood control investment.

(3) Then, the expected damage reduction (benefit) may be highly evaluated. In this case, it is necessary to know the risk premium quantitatively. The expression risk premium as an insurance term means the difference between the expected value of received coverage and paid premium. For non-life insurance, the ratio of received coverage to paid premium for all insurance items of all insurance companies for 10 years (1987 to 1996) is 53.75%. (The ratio can be known year by year from *Non-life Insurance Sstatistics* of the *Insurance*.)

Therefore, it is considered that the benefits of flood control investment may be evaluated as being approximately twice that of general public investment.

4.6.9 Upgrading benefit

If land use is changed due to improved safety from flood control, an increase of the land price can be considered to be a benefit of upgrading.

[Explanation]

(1) In addition to the damage-prevention benefit mentioned above, the land usage model should be estimated according to the relation between the flood control safety level and land usage condition, and the increase of the land price along with land usage should be calculated as an upgrading benefit.

(2) Although upgrading of land use is the primary purpose of a flood control project besides damage prevention benefits, an increase of land price, which is the basis of the upgrading benefit calculation, theoretically includes the present value of future damage that can be avoided by the flood control project, therefore, it may be counted twice with the damage prevention benefit.

(3) When safety due to the flood control project is improved, land usage may be upgraded from wasteland or farmland to housing land. It is considered that the increase of the land price may be calculated as an upgrading benefit. In this case, it is also possible to calculate the future value of assets as the damage prevention benefit instead of evaluating only the land price increase.

5. Cost calculation

5.1 Costs covered

The total construction costs from the start of the flood control project until completion of the flood control facility, and maintenance costs during the period of the evaluation are covered.

[Explanation]

In principle, economic efficiency is currently evaluated for a river improvement plan, reevaluation of river/dam project and selection of a new project. Therefore, costs required in future for completing a flood control facility, and maintenance costs during the evaluation period are covered (Fig. 5.1). The construction cost of facility, the land cost, the compensation cost, and the maintenance cost are calculated separately. Maintenance costs for 50 years are estimated. Any remaining value at the end of the evaluation period is deducted from the costs.

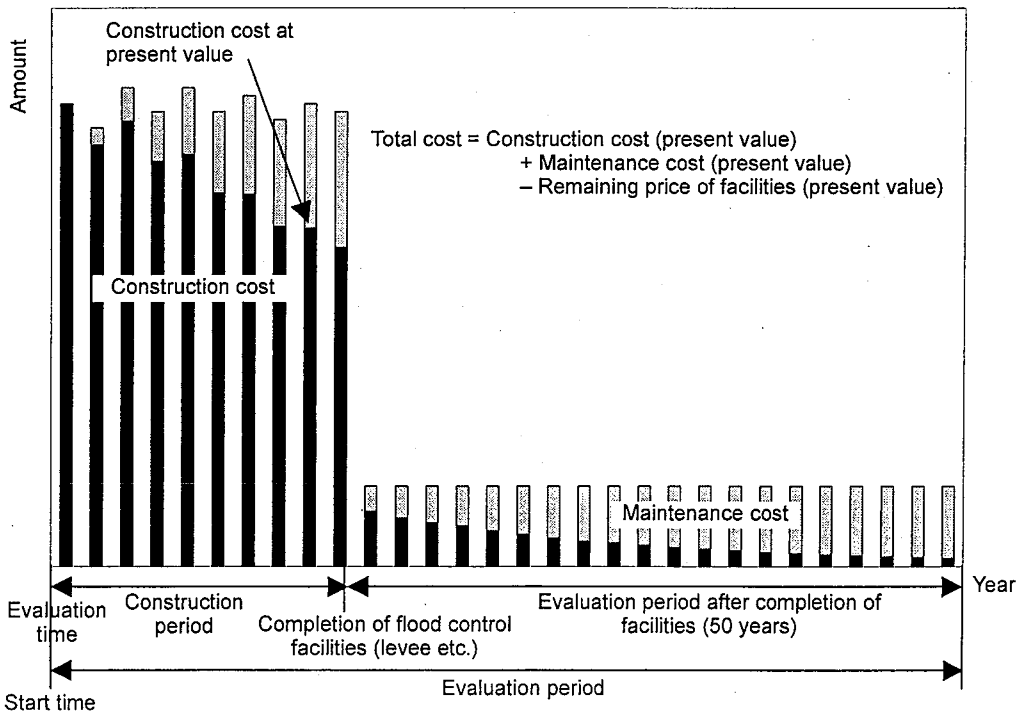


Fig 5.1 Cost of levee

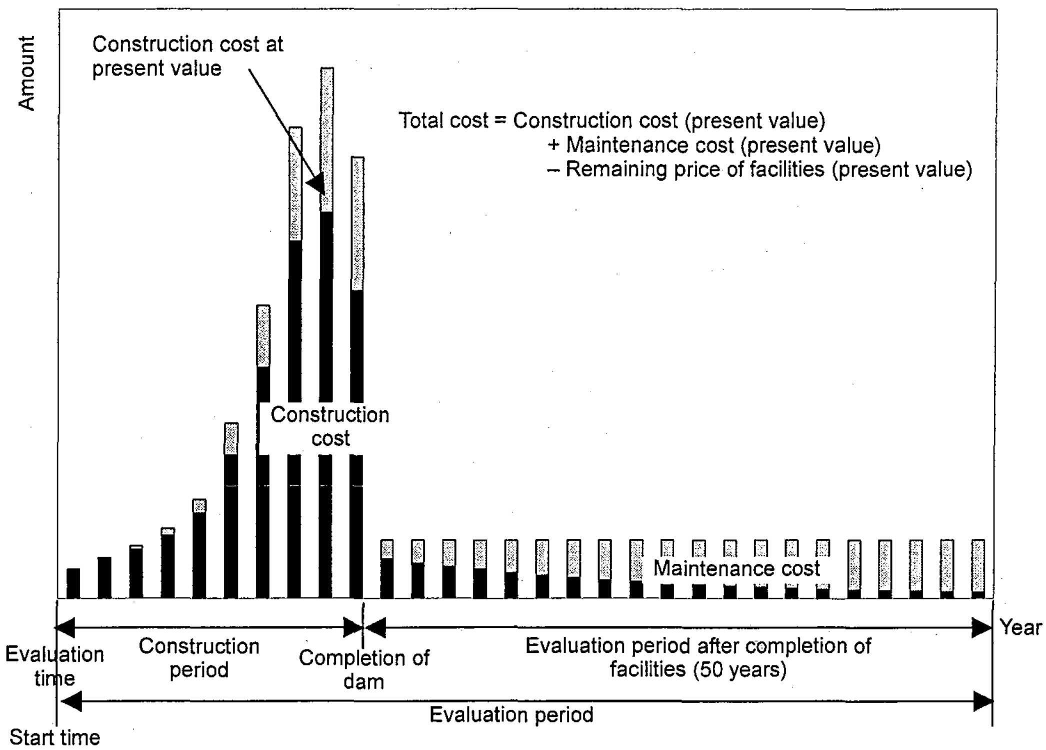


Fig 5.2 Cost of dam

However, if it is necessary to evaluate a flood control project as a series of projects, and if it is not appropriate to evaluate the economic efficiency of the project based on the current status of a river channel, the evaluation can be traced back to the point in time when it is appropriate to evaluate economic efficiency for a series of projects.

In this case, past cost is converted into present value from the actual records of construction cost, land cost, compensation cost, etc.

5.2 Estimating construction period and investment plan

Construction period and investment plan are estimated for the evaluation, allowing for the construction period of the flood control facility.

[Explanation]

If a specific investment plan (construction cost, construction period and allocation of construction cost) is already determined, the cost is calculated accordingly.

If no specific investment plan is determined and only the approximate construction cost is determined, a similar project in the past is used for estimating the construction period and allocating construction costs, and for calculating the total cost.

5.3 Construction cost

In evaluating the current channel at the start of a flood control project, the total cost of the project required for completing the project flood control facility is calculated for the cost estimation.

[Explanation]

The main project costs, costs for peripheral item work, land cost, compensation cost, indirect cost, and project expense are calculated.

5.3.1 Main project costs

The unit price is multiplied by various phases of the project to calculate direct construction costs (main project costs) for constructing a flood control facility.

[Explanation]

- Soil volume for banking, bank setback, and levee heightening is calculated. Then, the volume is multiplied by the cost of direct work per unit volume calculated separately to calculate cost.
- Construction area for bank revetment is calculated. Then, the area is multiplied by the cost of direct work per unit area calculated separately to calculate cost.
- Soil volume for the channel floor excavation is calculated. Then, the soil volume is multiplied by the cost of direct work per unit volume calculated separately to calculate cost. When setting the unit price, costs for transporting and disposing of excavated soil are considered.
- Construction cost of a multi-purpose dam is calculated by multiplying the approximate

amount project cost by the cost burden rate for flood control which is calculated in the allocation estimation.

- Construction cost of a retarding basin is calculated by the methods described above for each bank/excavation. Cost for construction of a sluicing outlet is calculated by the methods described in the following section.
- Construction cost of a discharge channel is calculated by the methods described above for each bank/excavation.

5.3.2 Costs for peripheral work

Construction cost incurred incidentally to construction of a flood control facility (costs for peripheral work) is calculated by multiplying the number of sites by the unit price or by multiplying total length by unit price.

[Explanation]

Only the cost incurred by the river administrator (costs for item peripheral work) is calculated.

If it is not appropriate to consider costs of all peripheral work incurred by the river administrator; costs for category peripheral work are excluded from the calculation.

- For road bridges, railway bridges and waterway bridges, the number of areas where replacement or other work is required is obtained. Then, the construction cost is calculated by multiplying the number of sites by the construction cost per site.
- For weirs, sluice gates, and sluice pipes, the number of areas where replacement is required is obtained. Then, the construction cost is calculated by multiplying the number of sites by the cost per site.
- For pump stations, the number of areas where new construction or replacement is required is obtained. Then, the construction cost is calculated by multiplying the number of sites by the cost per area. For waterways, the total length of construction is calculated. Then, the construction cost is calculated by multiplying the total length by

the cost per unit length.

- The total length (or area) of road requiring relocation is obtained. Then, the construction cost is calculated by multiplying the total length (or area) by the cost per unit length (or area).
- For peripheral work other than that described above, the construction cost that is indispensable for the accuracy of the cost estimation is calculated separately for each area and type of work.

5.3.3 Cost of land purchase

Cost of land purchase is calculated from the land price.

[Explanation]

- Land area required for the facility construction is calculated. Then, the cost of land purchase is calculated by multiplying the area by the unit land price.

5.3.4 Compensation for relocation

Compensation for relocation is calculated according to recent examples of compensation.

[Explanation]

- Unit cost of compensation is calculated according to recent examples of compensation. Then, compensation for relocation is calculated by multiplying the unit cost of compensation by the amount for compensation.

5.3.5 Indirect cost

Indirect cost is calculated as 30% of the sum of main project costs and peripheral work costs.

[Explanation]

- Indirect cost is calculated as 30% of the sum of main project costs and peripheral work costs.

  If there is a specific value allowing for the conditions of each river, such a value may be used.

5.3.6 Project expense

Project expense is calculated as 20% of the sum of main project costs, peripheral work costs, land purchase cost, compensation for relocation, and indirect cost.

[Explanation]

- 20% of the sum of main project costs, peripheral work, land purchase cost, compensation for relocation, and indirect cost is considered as the project expense.

  If there is a specific value allowing for the conditions of each river, such a value may be used.

5.4 Maintenance costs

Maintenance costs within the evaluation period are calculated. Regular costs paid annually for routine maintenance and incidental/regular costs such as replacement of machinery are calculated separately.

[Explanation]

- Basically, costs incurred annually for maintenance such as weeding and for pump operation and costs incurred every 10 years etc. for replacing equipment (incidental/regular maintenance cost) are estimated for 50 years.

- If it is difficult to perform the above calculation, the average ratio of maintenance costs to construction costs is calculated from the record covering recent years, and the costs are considered as the regular maintenance cost.

5.5 Total cost

Total cost is calculated by adding maintenance costs to construction costs, and by deducting construction cost of which the remaining value can be evaluated at the end of the evaluation period.

[Explanation]

- Total cost is the sum of construction costs and maintenance costs converted into present value, from which the remaining value of the facility at the end of the evaluation period (construction period + 50 years) converted to the present value is deducted. The discount rate for conversion to the present value is 4%. ("Uniform guidelines for cost effectiveness analysis of social infrastructure improvement," Ministry of Construction, March, 1999)
- Construction cost C is calculated as annual construction costs c_t^A converted into present value for construction period S.

$$C = \sum_{t=0}^{S-1} \frac{c_t^A}{(1+0.04)^t}$$

- Maintenance cost M is calculated as annual maintenance costs m and incidental/regular maintenance costs M^t for facility replacement, for which payment is scheduled every $S + t$ years, converted into present value.

$$M = \sum_{t=S}^{S+49} \frac{m + M_t}{(1+0.04)^t}$$

- The remaining value is calculated as follows:

River channels are classified into non-structural levees, low water channels, and structures such as revetments. Then, the remaining value at the end of the evaluation period (construction period (S) + 50 years) is evaluated and deducted from the cost. Because non-structural levees and low water channels are maintained to prevent a reduction of the flood control function, it is considered that their values do not degrade until the end of the evaluation period. Therefore, the remaining value of non-structural levees and low water channels at the end of evaluation period C^1_{S+50} is as follows:

$$C^1_{S+50} = \frac{\sum_{t=0}^{S-1} c^1_t}{(1+0.04)^{S+49}}$$

Where, c_t^1 refers to the annual construction costs of non-structural levees and low water channels, excluding costs of land purchase, costs for compensation, indirect costs, and project expenses.

For structures such as revetments, the value at the end of the evaluation period is 10% of the total cost. Accordingly, the remaining value C^2_{S+50} at the end of the evaluation period is as follows:

$$C^2_{S+50} = \frac{0.1 \times \sum_{t=0}^{S-1} c^2_t}{(1+0.04)^{S+49}}$$

Where, c_t^2 refers to the annual construction cost of structures such as revetments excluding costs of land purchase, costs for compensation, indirect costs, and project expenses.

For a dam, the concept of depreciation (straight line depreciation method) according to legal durable years is used. The residual value at the end of evaluation period D_{s+50} is as follows, and is excluded from the cost.

$$D_{S+50} = 0.9(1-\frac{50}{80}) \times \frac{\sum_{t=0}^{S-1} d_t}{(1+0.04)^{S+49}} + 0.1\frac{\sum_{t=0}^{S-1} d_t}{(1+0.04)^{S+49}}$$

Where, d_t refers to the annual construction cost of the dam excluding costs of land purchase, costs for compensation, indirect costs, and project expenses.

For land cost, it is considered that the value is not reduced until the end of the evaluation period. Therefore, the remaining value at the end of evaluation period K_{50} is as follows, and is excluded from the cost.

$$K_{S+50} = \frac{\sum_{t=0}^{S-1} k_t}{(1+0.04)^{S+49}}$$

Where, k_i refers to the annual cost of land purchases.

6. Evaluation of economic efficiency

6.1 Cost and benefit for comparison

For the survey on the economic efficiency of flood control, total cost and total benefit gained from the investment are compared.

[Explanation]

For example, it is assumed that a flooded area is divided into 4 blocks as shown in Fig. 6.1 for each of which levee projects with costs C_1 to C_4, respectively are planned.

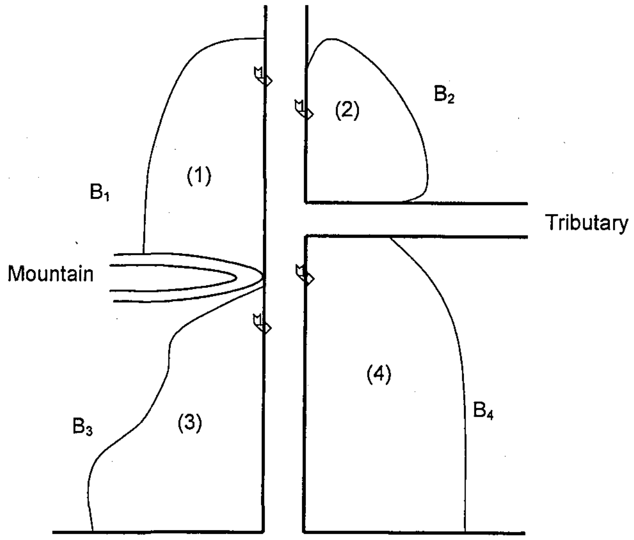


Fig. 6-1 Cost and benefit for comparison

Damage amounts caused by flood due to levee crevasse in each block are defined as B_1 to B_4 respectively.

When evaluating a river improvement plan, reevaluation of river/dam project and evaluation for acceptance of a new project, the following formula is used:

$\Sigma B_i / \Sigma C_i$ (B_i and C_i cover the range of influence.)

The points of levee crevasse are determined for each flooded block for the flood calculation, and the total sum of benefits is compared to the total sum of costs for a cost effectiveness analysis due to the following reasons:

(1) In the actual flood control project, flood control facilities are built to cover unregulated peak discharges of each flooded block. Therefore, it is appropriate to use the calculation method above so that the cost is consistent with the benefits.

(2) Although there is an opinion that multiple floods would not occur simultaneously within each block and that weighting should be performed instead of simply summing the benefits in each flooded block, it is difficult to specify the probability of a levee crevasse, because it is a natural phenomenon. (Further study is required on this point in the future.)

6.2 Method of documenting results

A series of study results is documented according to the format shown in the appendixes.

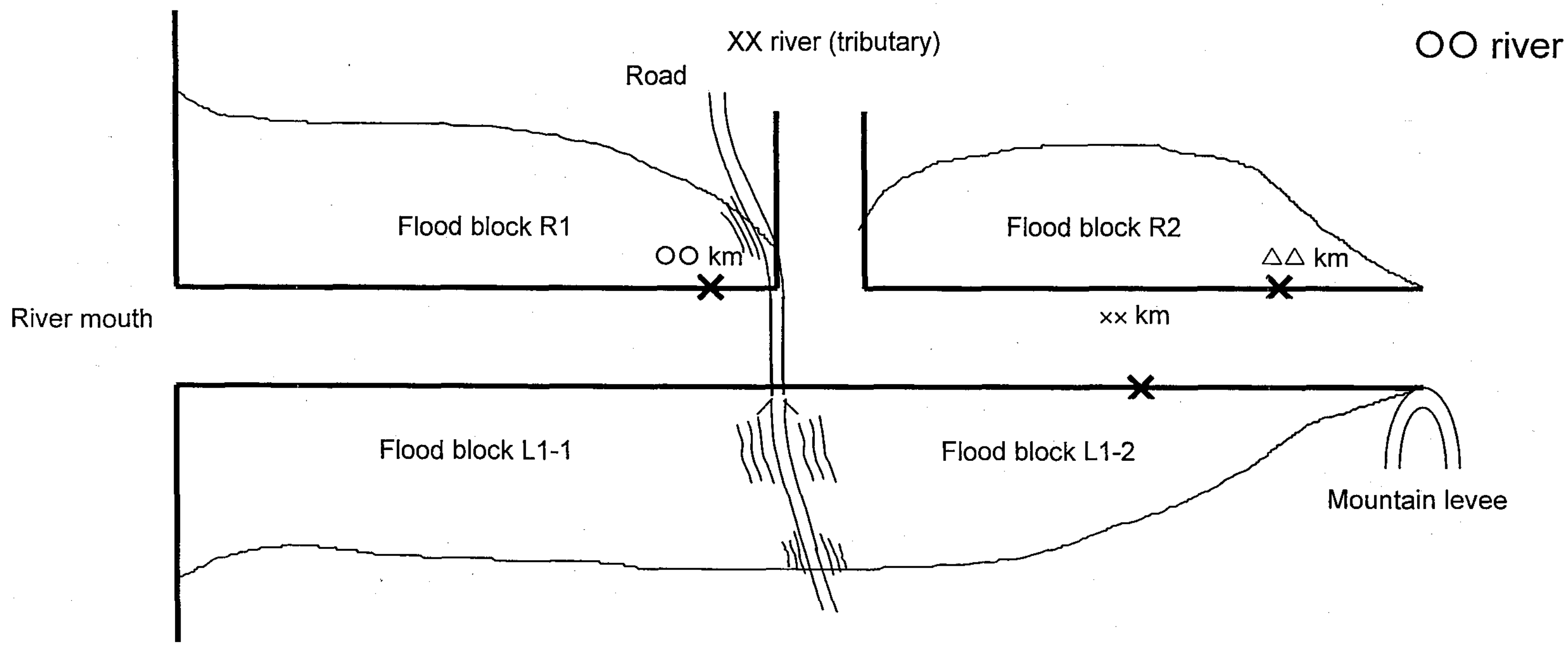
[Explanation]

A series of study results is documented according to the format shown at the end of this manual. The purpose of this format is to record process, condition, and results of a series of studies for verification and for future records. It is not necessary to adhere to the details of the format. Formats, styles, and items may be added as required.

Format 1 Flooded block division map

(Division of flooded blocks is presented on a map such as a topographic map with a scale of 1/50,000. If the flooded area is large and use of a commercial map makes the division map less comprehensible, a sketch drawing is used instead. Names of major river, distance marks, names of continuous landfill structures provide boundaries for blocks, block names, names of major cities within the flood plain, the point of levee crevasse, large-scale water distribution facilities, etc. are presented on the map.)

(Example)



Format 2 Flow capacity evaluation sheet

Channel system name: River name: Subject river channel:

Distance mark	Inland height [(1)]		High-water foundation height [(2)]		Design high-water level [(3)]		Levee crown height [(4)]		Slide-down levee height [(5)]		Design margin height [(6)]		Levee crevasse foundation height flow capacity [Higher flow capacity of (1) or (2)] [(7)]		Maximum flow capacity [Flow capacity of (4)] [(8)]		Slide-down flow capacity [Flow capacity of water level in (5) – (6)] [(9)]		Discount rate with/without design low-water revetment facility [(10)]		Minimum flow capacity [Larger value of (9) × (10) or (7)]		Flooded block	
	Left bank	Right bank	Left bank	Right bank			Left bank	Right bank	Left bank	Right bank			Left bank	Right bank	Left bank	Right bank	Left bank	Right bank	Left bank	Right bank	Left bank	Right bank	Left bank	Right bank

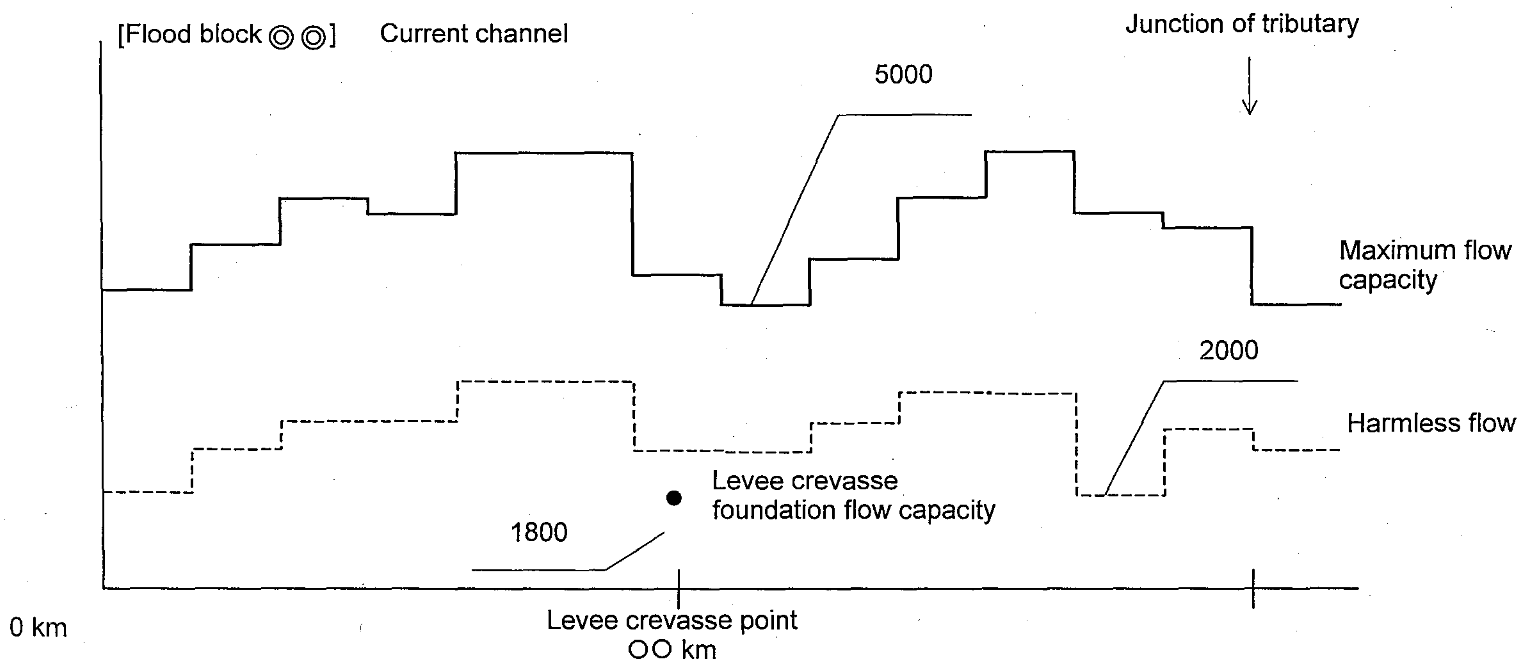
Note:

- Enter the columns for the flooded blocks so that the range and the block name can be understood.
- Shade the flow rate equivalent to the block harmless flow rate (column for minimum flow capacity).
- Place formula H to Q used for calculating the flow capacity in a separate document.
- Place presence/absence of planned facility, which becomes the basis for the discount rate (= $(1 - 0.05)^n$), in a separate document.
- Indicate the columns that are irrelevant to the flood calculation due to mountains so that the reason can be clarified.

Format 3 Flow capacity drawing

Tracing back to the point when it is appropriate to make an evaluation of economic efficiency for the flooded block as a series of projects, maximum flow capacity, harmless flow, levee crevasse point (levee crevasse foundation flow capacity), distance mark, etc. are indicated on the flow capacity drawing for the channel at that time and current channel.

(Example of flow capacity drawing)



Format 4 Asset data

Channel system name: Name of river: Year of national census: Year of company statistics:

		Basic quantity of general assets							Amount of general assets							Farm product assets				
											Company asset		Farmers'/ fisherman's assets							
Flooded block	Block area	Population	No. of families	No. of employees (calculated for each industrial category)	No. of farmers/ fishermen	Total floor area	Paddy field area	Field area	Houses	Domestic items	Depreciation	Stock	Depreciation	Stock	Subtotal	Paddy rice	Field crop	Subtotal	Total amount of general assets	Remarks
																				Urban area of OO

Format 5 Damage amount

Channel system name: River name: Scale of flow:

Flooded block	Damage to general assets							Damage to farm product			Damage to public civil facilities	Damage due to business interruption	Emergency cost at home			Emergency cost at companies	Other indirect damage	Subtotal	Total	Remark
	House	Domestic items	Company assets		Farmers'/fisher men's assets		Subtotal	Paddy rice	Field crop	Subtotal			Labor cost for cleaning	Alternative activities	Subtotal					
			Depreciation	Stock	Depreciation	Stock														
Total																				

Format 6 Expected annual average damage reduction

Channel system name: River name: Subject river channel:

Flow scale	Excess probability	Amount of damage			Average amount of damage in stretch (4)	Probability in stretch (5)	Annual average amount of damage (4) × (5)	Cumulative annual average amount of damage = Expected annual average damage reduction	Remark
		Project not conducted (1)	Project conducted (2)	Amount of reduction (3)=(1)−(2)					

Format 7 Cost effectiveness

Channel stream system name: Name of river name:

Year	*t*	Benefit		Cost								Cost benefit ratio B/C
		Benefit	Present value	Construction cost (1)		Maintenance cost (2)		(1)+(2)		Remaining value (3)	Total (1)+(2)+(3)	
				Cost	Present value	Cost	Present value	Cost	Present value			
Construction period (S)	1											
	2											
	3											
	4											
	5											
	⋮											
	S											
Evaluation period after completion of facility (50 years)	S+1											
	S+2											
	S+3											
	⋮											
	S+48											
	S+49											
	S+50											
Total			=B								=C	