CHAPTER 3. HYDRAULIC AND HYDROLOGICAL ANALYSES

3.1 Basin Flood Runoff Analysis

The significant increment of basin flood runoff discharge in the study area was simulated through the "Quasi-linear Flood Simulation Model" in the Phase 1 study (Part 1). The results of simulation were further verified and at the same time the basin runoff discharge from the priority drainage areas were re-estimated, as shown in Table 3-1, taking the following conditions into account:

(1) Model Hyetograph

A large storm occurred in the objective study area of Sungai Petani on September 03 to 05, 1999. The 1999 flood recorded the highest 12-hour rainfall intensity among the annual maximums recorded since 1948. The flood was, however, not reflected in the Phase 1 study (Part 1), because it occurred after the completion of that study. Due to the additional background information, the model hyetographs were revised in this Feasibility Study taking the rainfall data of the 1999 flood into account, and the basin runoff simulation was re-estimated based on the revised model hyetographs.

(2) Sub-basin Boundary

The basin flood runoff simulation in the Phase 1 study was based on the topographic map of 1 is to 50,000, which caused difficulties in confirming details of sub-basin boundaries particularly in the flat low-lying area. To cope with those difficulties, developed were the topographic maps covering the four (4) priority drainage areas with a scale of 1 is to 2000. Based on these topographic maps, the basin boundaries as well as the catchment areas for the four (4) priority areas were revised. The revised catchment areas are as shown below:

Name of Basin	Catchment Area (km^2)	
	Estimated in Phase 1	Revised in Phase 2
(1) Sg. Air Mendidih in Sungai Petani	3.40	3.62
(2) Line G in Sungai Petani	3.19	2.73
(3) Pokok Mangga in Melaka	3.71	4.71
(4) Area of Sg. Ayer Salak in Melaka	16.68	17.30
Total	26.98	28.26

(3) Land Use

Revisions of land use in the Phase 1 study were made through the detailed field reconnaissance and reflected in the basin runoff simulation (refer to Section 2.3).

(4) Flood Runoff Conditions Effected by Basin Gradient

It was confirmed through the aforesaid detailed topographic survey that among the priority areas, Prt. Pokok Mangga has an extremely gentle slope of about 1 is to 20,000. Such gentle basin slope could significantly affect the flood runoff conditions, so that the basin runoff discharge for Pokok Mangga was re-estimated taking the basin slope conditions into account.

3.2 Channel Flow and Flood Inundation Analysis

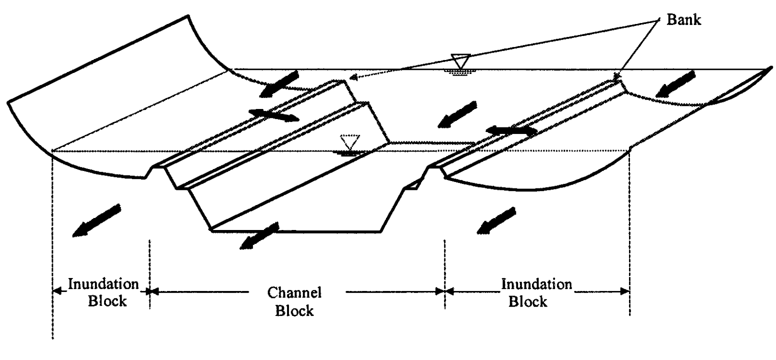
3.2.1 Purpose of Analysis

The present habitual flood inundation area is going to be converted to a high value-added land, therefore, the existing drainage channels have to be improved to eliminate channel overflow in the future. From this point of view, the Phase 1 study performed a channel flow simulation on the premise that channel improvement is made so as not to cause any channel overflow. This means that the channel discharge simulated in the Phase 1 study is regarded as the design discharge and far different from the present actual channel flow discharge.

However, the flood discharge currently often overflows from the trunk drains and stagnates in the low-lying area. As the result, the flood discharge is hardly propagated from upstream to downstream, and the peak flow discharge of the drains is reduced in appearance. Such actual channel flow discharge as well as the extent of flood inundation is estimated in this Phase 2 Study based on the detailed topographic maps newly developed. The results of the simulation are used as the essential information for economic evaluation of the alternative drainage plans.

3.2.2 Simulation Model

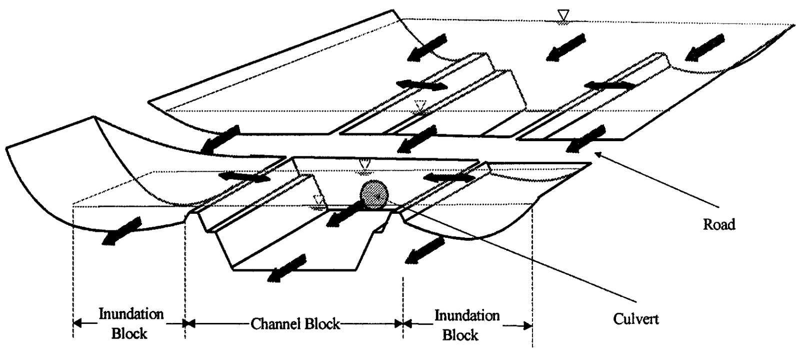
Most of the existing trunk drains have extremely small channel flow capacities that could not cope with even the probable peak flood discharge of 2-year return period, as described in Section 2.1. The bank level of most of the trunk drains is almost the same or slightly higher than the hinterland ground level and flood tends to gradually overflow



from the trunk drains and extensively inundates the flat low-lying hinterland. The flood flow will have various flow directions as illustrated in the conceptual figure above.

As illustrated, the channel flow discharge will have a flow direction toward downstream, and at the same time toward the inundation area in the hinterland of channel when the channel water level is higher than the inundation level. The flood discharge in the inundation area also flows toward the lower ground level and a part of the discharge returns to the channel when the inundation water depth is higher than the channel water level.

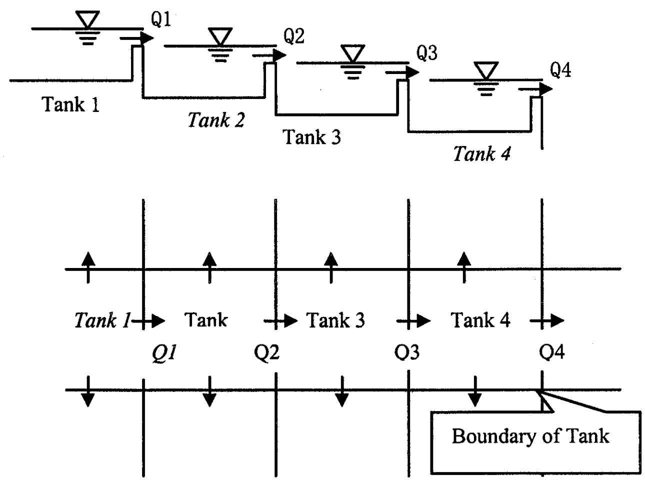
The roads across the drains further accelerate the inundation. Culverts are often used to pass the roads over the drains, but their sizes are far smaller than the upstream open channels. As a result, the culverts greatly hinder the channel flow and inundation occurs just upstream of the roads. The roads are constructed on the embankment that is higher than the ground level along the road. Consequently, once inundation occurs, the road dams up the floodwaters and thus increasing the inundation depth. The flood will have various flow directions between the drainage channels and inundation area. At the same time, the flood water dammed up by the road will have a flow direction toward downstream either over the road or through the culvert as illustrated above. In order to express the above flood channel flow and inundation conditions, the trunk drain and its surrounding flood inundation area are divided into the following blocks:



(1) Channel Block : The drainage channel is longitudinally divided into several blocks in accordance with the sub-basin boundaries.

(2) Inundation Block : The possible maximum inundation area is assumed based on the topographic map and the detailed field reconnaissance. The possible maximum flood inundation area is further divided into several blocks in due consideration of the above division of the channel blocks and the roads across the trunk drains.

The simulation model assumes both of the channel block and the inundation block as a tank, connecting lengthwise and breathe-wise with each other, as shown in the following illustration.



The model estimates the movement of discharge from a tank to its next tank based on the water level estimated at the preceding time (t - Δ t). Then, the storage volume as well as its corresponding water level is estimated based on the movement of discharge. Thus, the simulation is made one after another on the movement of discharge from a tank to the next tank and the water level at the tank. The movement volume of discharge from a tank to the next tank within the calculation time interval (Δ t) is controlled by the equation of motion, while the storage volume of the tank is by the equation of continuity. In this simulation, the following equations of motion and continuity are applied:

(1) Equation of Motion

The movement of discharge from a tank to the next tank is assumed as the unsteady flow and expressed by the following formula when the boundary neither form an embankment nor culvert:

$$\delta H/\delta x + n \cdot v \cdot |v| \,/\, R^{2/3} + 1/g \cdot \delta v / \delta t + 1/2g \cdot \delta v^2 / \delta x = 0 \quad \text{(Eq. 3.5)}$$

$$Q = A \cdot v \quad \text{(Eq. 3.6)}$$

Where	H	:	Water level
	n	:	Roughness Coefficient
	v	:	Flow velocity
	R	:	Hydraulic radius
	A	:	Cross-sectional area of flow

When the embankment (such as road and dike) or the culvert forms the boundary, the movement of discharge within a unit calculation time (Δ t) is decided by the following formula for overflow discharge.

Embankment:

$Q = C \cdot B \cdot h_1 \cdot (2gh_1)^{1/2}$ ($h_2/h_1 \leq 2/3$) .... (Eq. 3.1)

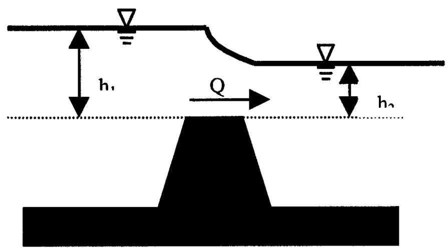
$Q = C \cdot B \cdot h_2 \cdot \{2g(h_1 - h_2)\}^{1/2}$ ($h_2/h_1 > 2/3$) .... (Eq. 3.2)

Where Q : Overflow discharge

C : Coefficient (assumed as 0.9)

B : Width of the Embankment (overflow width)

h_1, h_2 : The water level of blocks



Culvert:

$Q = -C \cdot A \cdot \{2g(h_1 - h_2)\}^{1/2}$ ($h_1 > h_2$) .... (Eq. 3.3)

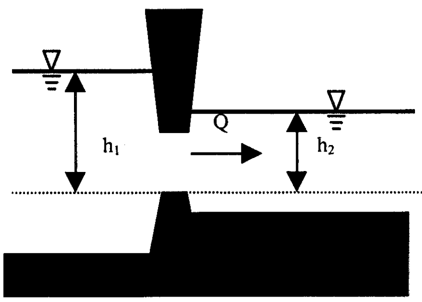
$Q = +C \cdot A \cdot \{2g(h_2 - h_1)\}^{1/2}$ ($h_1 \leq h_2$) .... (Eq. 3.4)

Where Q : Flow discharge through the culvert

C : Coefficient

A : Cross-sectional area of the culvert

h_1, h_2 : The water levels of the upstream and downstream blocks



(2) Equation of Continuity

The following equations are given to the inundation block and the channel block respectively:

Channel Block

The channel flow area varies with the channel flow discharge, therefore, the following equation is applied:

$\delta A/\delta t + \delta Q/\delta x = -q$ .... (Eq. 3.8)

Where A : Cross-sectional area of flow

Q : Channel flow discharge

q : Inflow discharge from the inundation block to the channel block

Inundation Block

The storage volume is estimated by the following equation, and its corresponding water level is estimated through the relation curve of the water level - the storage volume. The relation curve is developed from the topographic map newly surveyed in this study.

$$\sum Qin - \sum Qout = dV/dt \qquad \text{(Eq. 3.7)}$$

Where	Qin	:	Inflow discharge to the block
	Qout	:	Outflow discharge from the block
	V	:	Flood storage volume in the tank

3.2.3 Results of Channel Flow and Flood Inundation Simulation

As the results of the aforesaid basin runoff and channel flow simulations, it is confirmed that the probable flood runoff discharge could cause expansion of the inundation, as shown in Table 3-2 and Fig. 3-1. Due to the inundation, the channel flow discharge is hardly propagated from the upstream to the downstream, and the peak discharge is reduced in appearance. Should the drainage channel improvement be implemented to eliminate the flood inundation, the flood runoff discharge concentrates into the channels and increases the peak channel flow discharge, as shown in Table 3-3.