Method for Determining Design Discharge of Main Drainage Canal : Design and Management of Large Scale Irrigation System (II)

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Abstract

This paper describes the following two problems; (1) The case of the drainage area boundary being determined by operating the irrigation facilities and as defined in lower part, agricultural area, within a natural catchment area, and (2) how to determine the design discharge of a primary canal in such the defined area. For the second, an attempt was made to calculate the discharge of a primary canal by estimating the conveyance capacity of a lower order canal network of unimproved dual-purpose canal. That method was applied and evaluated based on the results investigated at Harumich-ichinomoto district where "the special drainage improvement project" being carried out by Nara Prefecture.

Introduction

"The special drainage improvement project"[1], a prefecture-operated project, is one of the drainage improvement projects to promote the crop diversification in paddies. A main drainage system, such as outlet sluice gates, a pumping station and a primary canal, is improved by this project (in which irrigation and drainage systems, paddy plots, agricultural roads are not improved). The areas served by a main drainage system usually range from a few dozen up to several hundred hectares. This project seems to be carried out especially in a suburban area in recent years, because the improved drainage system also performs to receive an increased run-off peak from a rapidly urbanized area.

The function of a main drainage system is, generally speaking, to convey following water to the outlet point; (1) water from field drainage system, (2) natural darainage flow from upper parts of a basin, (3) discharge from urban drainage system and (4) excess water directly from the fields themselves[2]. There is, however, a case that a check structure lets in base flow from upper parts of a basin downward for irrigation water resource but lets out flood flow derectly into a natural river through a flood way. In this case, a design discharge of a primary canal is determined by estimating the drainage discharge from lower parts of a basin without the upper inner parts of a basin.

This paper reports on the estimation of the design discharge of a primary canal to be improved by "the special drainage improvement project" and discussion of the results of a field invcestigation.

Situation of Drainage System

The situation shown in Fig. 1 is typical of the layout and functioning of a drainage

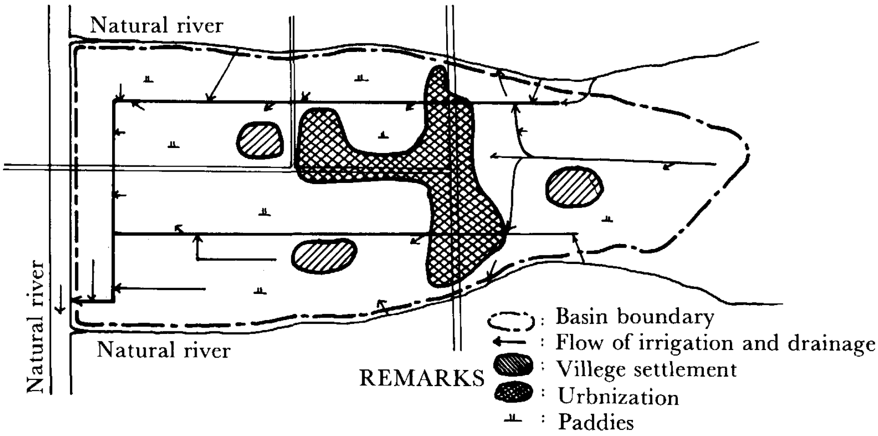


Fig. 1 Schematic diagram of a Main Drainage System

system. The figure is shown illustratively based on the situation of an investigated area described section III. The area encompassed is about 450 ha of farmland which includes an urban area. The layout of the system is based mostly on the geography and topography of the area, although historical and infrastructual developments have also had an obvious considerable influence. The latter is, for example, apparent in the interrelationships between road and canal systems and in the division between the two parts, an upper part and a lower part, formed by the main road crossing the area.

Paddies in the lower part are drained internally by the field drainage systems. the paddy plots are normally bounded on one or more sides by a lower order drainage canal (tertiary canal or farm ditch) into which the field system discharges. The drainage canal network is composed hierarchically to combine with small lower order drains into higher order canals in the process of centralization of the flow and convergence toward the outlet. However, most of these canals are not yet improved systematically by such as the land consolidation project. Therefore, they are left as unlined dual-purpose canals for irrigation and drainage with many checks of stop-logs at almost every plot, and allowed to become obstructed by weed growth and sediment deposits.

"The special drainage improvement project" is carried out to improve only a primary drainage canal in the irrigation and drainage canal network. Then there are the following two problems; how to determine (1) divides (drainage area boundaries) served by the primary canal and (2) conveyance capacity of it (design discharge, inflow rates from secondary canals).

Drainage area boundary

For the determination of drainage area boundaries, it is necessary to consider a paddy irrigation system, especially in dual-purpose canal network for irrigation and drainage. It is a popular paddy irrigation system that the water diverted from a natural river is delivered to all canals and to all the paddy plots in a specified command area simultaneously and continuously[3]. Then the base flow from the upper parts of an inner basin is added of course to the canals (this stream usually reaches the primary canal in the lower part). Such on-farm water management and operation are performed by a local irrigation association or rural community.

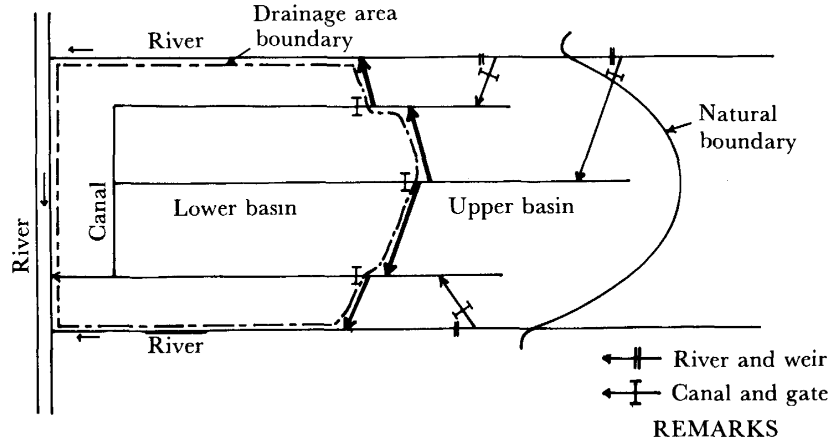
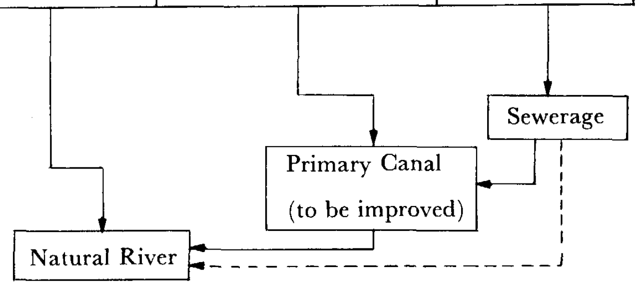


Fig. 2 Natural Basin Boundary and Drainage Area Boundary

Table 1 Categorization of Water Flow on Irrigation, Drainage and Run-off in Upper (Mountainous) Basin and Lower Basin (Agricultural Area), and Components Discharged into a Primary Drainage Canal to be improved.

Basin		Upper Basin	Lower Basin	
			Fields	Habitation
Water Use		→	Irrigation	Water supply
Drainage	Ordinary	Base flow	Ordinary dranage	Waste water
	Rainstorm	Flood flow	Rainstorm drainage	Rain water



During a rainstorm, however, the intake gates at diversion weirs in a natural river are closed and flood flow from the inner basin is turned away from a stream (reaches a canal downstream) and into a natural river as shown in Fig. 2. These operations to exclude water-inflow into the basin prevent inundation damage in the lower basin. Consequently, the darainage area is defined in the lower basin as the area from which flood drainage finally discharges itself into the primary canal through many small lower order canals.

Flows of water may be categorized as shown in Table 1 on irrigation and drainage in two basins into which a natural basin is divided. Though sewerage system is rightfully charged with waste water and rain water from habitation (in rural settlement and urbanized areas), an agricultural drainage system takes charge of them where there is no planning to install the sewerage. They discharge themselves into the primary canal to be improved by "the special drainage improvement project."

Design Discharge

1. Flow in dual-purpose canal

During a rainstorm, the flow in a farm ditch is illustrated conceptually as follows. At first, the cross-sectional shapes of farm ditches, earthen dual-purpose canals, are much shallower and rather wider than the concrete-lined canals. Their conveyance capacity is usually less than that of the lined drainage canals set independently of irrigtion performance because the permissible flow velocities are less and besides many check structures to distribute water to paddy plots are installed. Therefore, the farm ditches convey the drained water downstream (from paddies) of their own capacity at every cross-section, flooding or being charged with the rest of the water beyond, or within the capacity respectively, and finally, discharge the conveyed water to full capacity into the higher order canals.

Thus, the design discharge for improving the primary canal is determined by summing the inflow rates from all the secondary canals (and by summing drained water directly

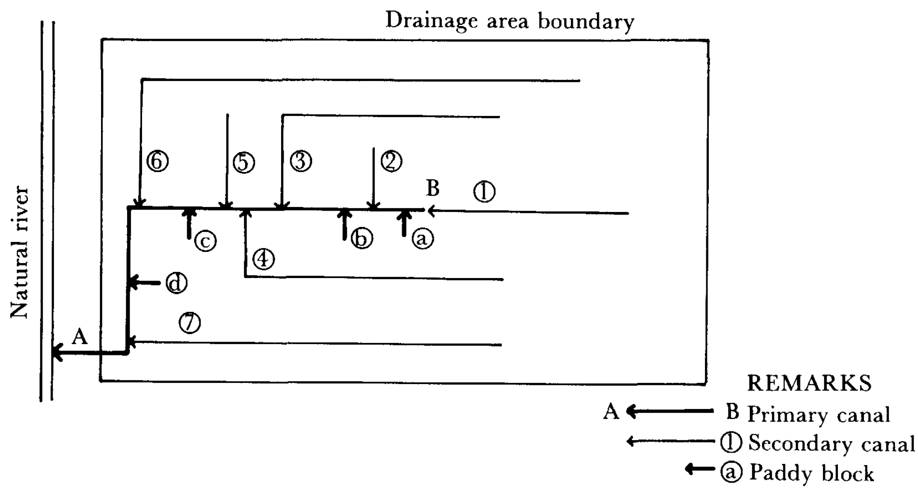


Fig. 3 Example of Main Drainage System Layout.

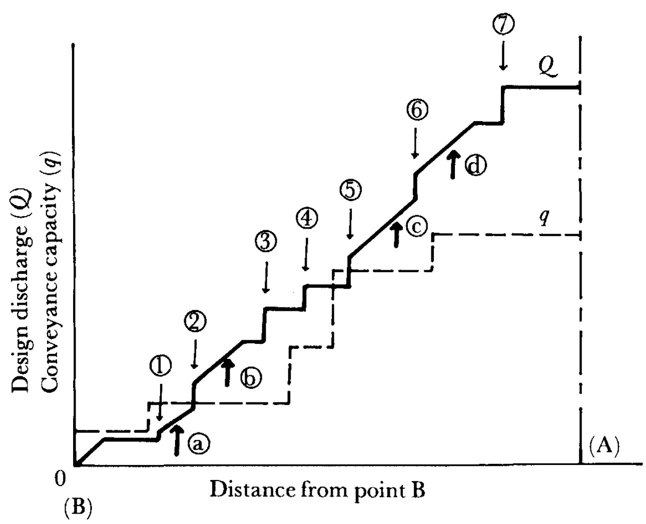


Fig. 4 Conveyance Capacity (q) and Newly Calculated Design Discharge (Q) at Distance from Point B, Upper End of Primary Canal to Be Imroved.

from paddis). These procedures are shown in Fig. 3 and 4[4].

2. Inflow rate from seconfary to primary canal

The inflow rate (q_c in m^3/s) from secondary canal into the primary canal is calculated from:

$$q_c = Av \qquad (1)$$

$$v = F(gh)^{1/2} \qquad (2)$$

where A = cross-sectional area of a secondary canal in m^2 (maximal flow area), v = average flow velocity in m/s, F = Froude number (0.5), g = Acceleration of gravity, and h = canal depth in m. Froude number 0.5 is assumed by estimating canal depth of an earthen secondary canal at 0.5 m and a permissible flow velocity for clayey soil at 1 m/s[5].

If the depths and average widths of the secondary canals are observed at every critical point near each confluence with the primary canal, the inflow rates can be calculated.

3. Drainage rate directly from paddy plot

The drainage rate from paddy plots (through spill ways) is reported in the ranges from 2.8 $m^3/s/km^2$ to 1.4 $m^3/s/km^2$. Here, it was calculated by applying the formula of full width weir[6] for a spill way. As a result, the discharge of 3.1 l/s per plot and 2.1$m^3/s/km^2$ per unit paddy area were obtained. If every area of a block of paddies located along the primary canal is given on a map and multiplied by the unit drainage rate, each drainage rate can be obtained.

4. Design discharge of primary canal

Through the procedures of calculating inflow rates and drainage rates, the design discharge in the primary canal is determined by summing every inflow and drainage rate at each confluence with secondary canal and spill way. Figure 4 shows schematically the summation of the inflow rates and the drainage rates downward in a section of the primary canal to be improved. Thus, this method follows the existing and old drainage canal

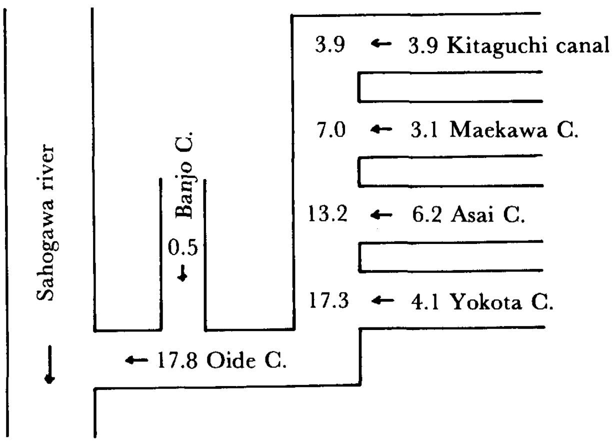


Fig. 5 Design Discharge (m^3/s) of Main Canals at Harumich-Ichinomoto district in Nara Prefecture.

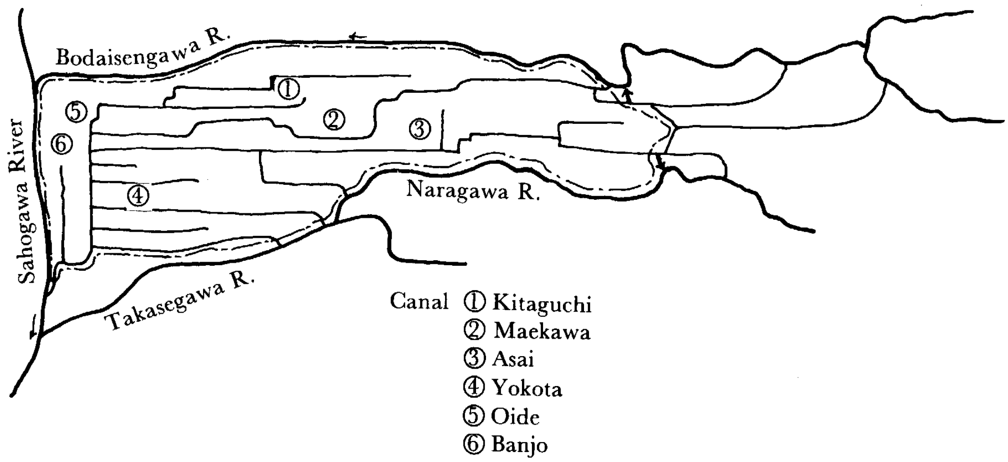


Fig. 6 Layout of Main Canals at Harumichi-Ichinomoto District in Yamatogawa Basin.

network more systematically than the rational formula method which is used popularly in drainage improvement projects.

Figure 5 shows the design discharge obtained through the field investigation at Harumichi-Ichinomoto district, located in northeast of Yamatogawa River basin, where Nara Prefecture is carrying out "the special drainage improvement project" as shown in Fig. 6. The Kitaguchi canal, the Asai canal and the Oide canal in Fig. 6 are improved. The drainage area seved by these canals is defined as shown with a broken line.

The disign discharges were calculated from 10 secondary canals and 25 ha of paddy, directly drainage, for Kitaguchi canal, from 12 secondary canals and 40 ha of paddy for Asai canal, 9 canals including Kitaguchi and Asai canals without any paddy for Oide canal respectively.

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