Improvement of Management Performance Efficiency of Irrigation by Application of Flow Control Systems at Irrigation Networks in West Java

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Abstract

Water use for irrigated agriculture is very high compare with other uses. In West Java Province, approximately around 20 billion m^3 per year water is applied for irrigation, and only around 1.5 billion m^3 per year is applied for domestic porposes. If irrigation efficiency can be improve 1% only, hence around 200 million m^3 per year water could be saved and used for other porposes. This volume of water can fulfill demand for domestic of about 4.5 million people per year.

This paper studies implementation concept of irrigation management through application of flow control systems technique, in other to improve water use efficiency either in level of farmer, network level, and even in the basin level. The objective of development is to support agriculture sector to reach the optimal food production. Management of irrigation must give service causing yields optimal production.

Optimal service is obtained when network can serve system on-demand, which hydraulically needs flow control method type down-stream control. In the basin area, result of analysis shows that correct flow control systems as according to condition of field and hydrology can increase water use efficiency as a whole basin.

***Key Word**: flow control system, upstream control, downstream control, efficiency, on-demand.*

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1. Introduction

In West Java Province, until 2009 there are around 6,954 number of irrigation schemes has been constructed to irrigate around 973,000 ha of rice field. These schemes consisted of 503 number of government irrigation schemes to irrigate around 590,300 ha, and 6,449 number of rural irrigation schemes to irrigate around 382,700 ha, see figure 1.

Irrigation extensification in West Java is economically marginal. Area of technical irrigation for agriculture is no longer possible to be developed. The potential exists to increase production is through increased efficiency.

The aim of irrigation network development basically meant to give additional water to agriculture area mainly during drought periods (*not enough rainfalls*). The objective is to support agriculture sector to reach the optimal food production. Around 20 Billion m^3 per year, water in West Java Privince is used for irrigation.

Problems that are often faced in operational of irrigation networks especially in West Java Province in general includes:

- Inefficient of the existing irrigation network, especially in the main system, so at the drought period, the downstream area cannot be supplied enough water.
- Operation of the main system is inappropriate of water allocation procedure and rule of hydraulic network. This cause water use conflicts.
- Inadequate of operation and maintenance activities, so that the network function quickly declines.
- Wasteful water consumption at conventional system.

All problems need to be solved with integrated solution, as the production of paddy is still pledge for policy of National Food Security. But on the other hand, because of government policy which majoring arrangement of authority rather than arrangement of substantial conservation of resource, there are lot of land use change that is in general from agricultural land to non agriculture of like settlement and industry. It needs arrangement approach to manage the competitive use of water and its potential impacts by establishing policy of water use and water allocation.

To minimize problems arising from conflicting interests between these different uses and user, coordination of water use and water allocation is required. Addressing these problems often also requires establishing new rules or changing the existing rules for water use (Malano and Hofwegen, 1999).

For the purpose, irrigation network performance which more efficient become more importance, because of water demand continueslly increases and competitives. There are 3 (three) activities that are supporting improvement of irrigation network efficiency:

1) Improvement of network function, by means of rehabilitation or upgrading of canals and related structures.

2) Improvement of hydraulic function, such as the modernization of irrigation system by improving the flow control systems.
3) Control of demand, such as diversifying crops with crops that have high economic value and not much need water.

In this paper, the discussion is more emphasis on the increase of hydraulic functions in order to optimize water use efficiency through the application of flow control systems and methods of operational management. With increased efficiency in network and system control settings in each irrigation area, it is expected that an increasing in water use efficiency in the overall basin can be reached.

2. Irrigation Management

It need to be realized that management of irrigation is not merely post construction problem, but should have been drawn up starts since phase planning, design, and construction of an irrigation network development project. Allocation system, distribution method, and flow control systems are the real tightly factors in the irrigation management.

Malano and Hofwegen (1999) classify that the irrigation and drainage system management activities consist of three main catagories, as follow:

- The activities centred on water deal with the tasks of acquiring, allocating and distributing water for supply and disposing excess water.
- The activities centred on structures deal with the tools required to perform the water related activities.
- The activities centred on organization deal with the development and management of the infrastructure to provide the irrigation and drainage service.

The objective of the irrigation management in general is to optimize the irrigation network function in orther to get optimal agriculture production. In more detail, the aim of irrigation management as established by Uphoff (1991), as follows:

- Improvement of production, reached through improvement of cropping pattern and cropping intensity.
- Improvement of water distribution system, fairly and equitable, reliability and good predictability, and on time.
- No conflict of interest between water users.
- Sustainable in the availability of resources, such as: land, water, material or human resources for the sustainability of optimal production.
- Mobilization of resources.

System of water allocation to the tertiary network, and method of water distribution on the main network in irrigation management is basically a policy in determining the allocation of water to the area of agriculture. Who is determine the amount of water at the tertiary units, depend on the systems or operational procedures of water delivery which is supported by the condition of the regulator structures on the irrigation network. Water allocation policy can be determined by the Government (*O & M Agency*), or by farmers or jointly by the government and farmers.

The decision-making on water allocation to the tertiary unit can be follow three different procedures (Ankum, 1995):

- **On-Demand Allocation**: Under this procedure, irrigation water is supplied to the tertiary unit when it is requested by farmers (*Water User Association*). The decision-making of water deliveries to all tertiary units is decided by Water User Association. Farmers can use water directly at any time as much as they need. The consequences of this procedure, water should be available in the main systems at any time and as much as possible.

- **Semi-Demand Allocation**: Under this procedure, the decision-making of water deliveries to tertiary units is decided by government (*O&M Agency*), based on advance requests from the Water Users Association. Firstly, farmers request an application to be supplied water to the tertiary units. All applications afterward are evaluated and compared with water availability. When the accumulated requests from the tertiary units exceed the water availability, the decision is to share the water shortage proportional over all tertiary units in an equitable way. A decision must be made on the period of irrigation cycle.
- **Imposed**: Imposed allocation is an allocation system that is most widely used in West Java Province. Under the imposed system, water allocation is determined by the government or O&M Agency without consultation with the farmers (WUA). The decision of water allocation to tertiary units can be based on the expected water need of crop (*demand-based or crop-based*) or on the actual water availability at the headworks (*supply-based*).

Selection of water distribution method through the main system must refer to water allocation method to the tertiary units. Basically, irrigation water can be allocated to a tertiery unit in three methods (Ankum, 1995):

- Splitted flow, i.e. the discharge from the main system is diverted into a fix ratio. It needs an ungated diversor at the tertiary offtake.
- Intermitten flow, i.e. "on/off" flow at the peak discharge. It needs an on/off gate at tertiary offtake to divert this intermitten flow.
- Adjustable flow, i.e. continues-but-adjustable discharge from the main system. It needs adjustable discharge regulator and a discharge measurement structure at the tertiary offtake.

In West Java, there are two types of irrigation management, i.e. *Farmer-Management* and *Dual-Management*. Farmer-management generally applied to manage rural irrigation schemes.

With the available recourse, group of farmers has been able to manage rural irrigation schemes as well. All management activities like water allocation, conflict solving, and maintenance of irrigation network can be implemented as well. Water distribution method for rural irrigation generally is splited flow, where the discharge from the main system is diverted proportional according to the area of tertiary unit.

Dual-management is applied to manage large schemes, where government and farmers together manage the irrigation network. Generally in the implementation, main system is managed by the Government, and tertiary system is managed by farmers.

3. Flow Control System in Irrigation Networks

Flow control system is required in the irrigation network in order to regulate water flows and water levels in the canal. The discharge and water level in the irrigation canals is subject to variation mainly due to variation of river discharge or changes introduced during operation to meet water delivery requirement (Malano and Hofwegen, 1999). The objective of regulation is to provide discharge to the plants conducted in accordance with the expected water need of crop.

In the irrigation network operation, the parameters which are controlled to fulfill demand according to service agreement, includes: discharge, duration of water delivery, beginning of water delivery, and irrigation interval. Control parameter is done through setting of water level or discharge at each division structure or offtake structure where the distribution of water is required.

Flow control methods can be classified on basis of the use of setpoints in water level (Ankum 1995): (i) the setpoint in water level is *absent*; (ii) the setpoint is located *at the regulator*, either at the *upstream* or at *downstream* side; (iii) the setpoint is located *at the distant*, either at the *upstream* or at *downstream* direction.

Flow control methods discussed in this paper is only type of method where exists in West Java, that is:

a. ***Proportional control:*** without any setpoint in water level (see figure 2a). Control structures in principle do not function as a regulator of water level, but only serves as a regulator of discharge. Proportional control requires only structures that split the flow proportional into fixed ratio. Irrigation system under proportional control, providing equitable service to farmers according to the proportions established under a fixed ratio. Generally, this control method mostly occurred on rural irrigation; high operational losses so low network efficiency.

b. ***Upstream control:*** Water level as *a set point* is located at the upstream side of the regulator structures (see figure 2b). The regulator structure can be either: fixed regulator; manual regulator; or automatic regulator. Upstream control method mostly occurred at government irrigation schemes in West Java. The discharge in the channel must be regulated centrally started from the weir site continueslly to the downstream. Changes of demand should be reported to Water Operation Centre (WOC), so that water supply is accomodated.

c. ***Downstream control***: Water level as *a set point* is located at the downstream side of the regulator structures (see figure 2c). The type of structure is automatic regulator, so that the human function of water level control is taken over by hydraulic device. The irrigation system under downstream controls can serve demand every time needed and as much as required. On-demand system is applicable under the method. The main irigatin network can automatically serve the demand (*Self management*). Downstream control fails if water resource at the headwork is not sufficient to serve all the demand.

4. Improvement of management performance efficiency

a) Conceptual approach

The aims of improvement of management performance at the irrigation network are expected to: i) improve efficiency, ii) deliver water to the farmers on right quantity and right time, iii) make ease operation and reduce cost of Operation and Maintenance (O&M).

Efficiency of irrigation management performance in this case includes at least three aspects: technical, social, and economic aspects. Generally, efficient management performance is where with the available water resources, management can increase production to be optimal in order to improve the welfare of society.

Winpenny (1997) defines *"efficiency" is primarily a matter of ensuring that as much as possible of the available water is actually applied to beneficial use*. Within the irrigation management operations, there are three possible loss of water: (i) at farm level, (ii) at the network level (the scheme), and (iii) at the watershed level (basin).

At the farmer level, the efficiency associated with the amount of water applied to the agriculture area to be used by crops. Management concerned to improve efficiency at farm level has three options: (i) improve cropping patterns plan referring to the water availability and distribution; (ii) crop type selection referring to the level of productivity and economic values, and (iii) the procedures for water allocation to the tertiary network referring to the *service agreement*.

At the network level, the efficiency associated with the amount of water delivered from the source (reservoirs, rivers, likes) to the area of agriculture. The activities for improving efficiency is minimizing canal losses with linning, and improving network functions with flow control systems to reduce losses in both physical and operational losses.

Althouht the cost of construction and maintenance is an important criterion in the selection of control structures, the ease operation which a discharge can be regulated and measured is frequently more important since this will reduce cost of operation. Ease of operation is labour saving and ensures a more efficient distribution of water over the irrigated area (Bos, *et al*, 1984).

The water use efficiency at the basin level is how far the potential availability of water in the river basin could be used for production purposes, rather than castaway to the sea. Improving efficiency at the level of river basin is more focused on the concept of ***reuse water***. Water which castaway in upstream area of the basin can be diverted by other downstream irrigatin scheme, even water which infiltrate in upstream area also can be exploited in downstream area.

Farmers interested in the development of irrigation, in order to meet basic food needs and to improve income and living standard. Equally is to increase production. The water allocation procedures should meet service agreement and should be sufficient, reliable, and on schedule to optimize agriculture productions.

The ideal system of water allocation is ***On-Demand***, where water must be available at all times necessary. Farmers are free to choose cropping pattern and type of plant, and it is safe to use water whenever and whatever is needed according to crop needs. The consequence is that farmers should participate actively, especially in the activity of O & M. Government more accountable in both technical and management guidance, and helps prepare the facilities for marketing and price controls.

b). Improvement of Irrigation Performance Strategy

In analysis of improvement of irrigation network performance, irrigation in West Java Province in general will be classified in 3 (three) groups, there are: i) rural irrigation, ii) irrigation without reservoir, and iii) irrigation with reservoir.

Rural Irrigation:

Rural irrigation in West Java Province, generally located at the upstream part of river basin. There are 6,449 numbers of schemes to irrigate the total area of around 382,700 ha. Water resource of each scheme is supplied from the river tributaries through a simple fixed weir. In each tributary sometimes there are more than one irrigation schemes with small area lest than 500 ha.

Technically, rural irrigation is a simple irrigation scheme, which is fully managed by farmers (*Farmer-managed schemes*). Water distribution method through the main system and water allocation procedure to tertiary unit are determined by Water User Association (*WUA*). Basically, in accordance with their respective social environment, at present the management of farmers has been running well.

At the farm level, efficiency is low. Water discharge to the tertiary units without measuring structure cannot be controlled. The method of flow control is generally proportional system equipped by simple structure. At the network level, efficiency is also low, as a proportional control system causes high operational losses. But at the basin level, it has not much effect on overall efficiency, because:

- The individual irrigation areas are relatively small; main channel is relatively short and small dimensions, and the average channel slope is steep, so the time-lag will not be a problem.
- Location of rural Irrigations are generally in the upper part of river basin, so that water losses due to operations will return to the river and will be used at downstream (*reused water*).

Allen. RG, *et al*, 1997 defines reused water as *reusable fraction represents the fraction of the diverted water that returns to the water resource for subsequent reuse by others.* It is estimated that 46% of water diverted for irrigation in USA returns to a water resource for future reuse (Soil Conservation Service, 1981; Sollyet al, 1988; in Allen. RG, *et al*, 1997).

In West Java Province, this is estimated that 35% of water diverted for rural irrigation returns to the river below the scheme, and are diverted by other downstream irrigatin scheme. So in the overall basin area, water usage efficiency is quite high. Flow control system for rural irrigation schemes does not need to be improved. Improvements in rural irrigation strategy should be more inclined towards management training.

Irrigation without Reservoir:

Irrigation without reservoir is defined as a government irrigation network where the water resource is diverted from a natural river (*unregulated river*) by means of either fixed or movable weir. Water resources are sometimes fluctuative, and flow control methods are generally upstream control. **Rentang** irrigation scheme is an example of scheme in West Java Province. Water resource is diverted from Cimanuk River through movable weir to irrigate the area of about 90,000 ha. The existing water allocation procedure is imposed, and the existing cropping pattern which determined by government is padi-padi-palawija.

There are several problems occur in the management of large irrigation scheme under upstream control method: (i) It requires technically and financially more resources to manage the scheme successfully; (ii) The implementation of network operations will be more complex and impractical; (iii) extend the respond times (*time-lag*), and high operational losses. So the overall networks efficiency is low.

Imposed allocation procedure needs an accurate estimation of water availability and water requirement for crops. Cropping Pattern and schedule of water delivery which have been determined by government sometimes does not meet farmer's expectation. It causes conflict between water users.

To improve the efficiency of irrigation management performance, there are two alternative solutions:

1. ***Through a combination of upstream control method with field reservoirs***: This concept of principle has been running at the time of the Dutch Government in Indonesia. At that time, field reservoirs, because its function is called *Night Reservoir*. Field reservoir is filled at night and used to irrigate areal in the daytime (Angoedi, 1984). Minimum depth of reservoir is 3 m.

   With the field reservoir, the response time becomes shorter because the farmers can use water from the reservoir before the flow from the headwork reachs downstream area. Typically, the concept can be developed as follows (see figure 3):

   Flow control method in the main system downstream of the reservoirs can be upgraded from *upstream control* to *downstream control* (e.i. upstream control in the primary canals and downstream control in the secondary canals). Downstream control method in secondary canals, can serve on-demand allocation procedure to the tertiary units. The advantages of this concept are: (i) in term of water allocation to tertiary units, on-demand allocation is the most flexible system, and very likely system from the water user point of view; (ii) in term of operation efficiency in the main system, it is more efficient because high operation losses and time lag in the primary canal can be balanced with high efficiency in the secondary canal; (iii) the effective use of rainfall can be high, even for High Yielding Variety crops which need a pricise water management (Ankum, 1995).

The disadvantages of this concept are: (i) it needs high cost of investment to build field reservoirs and to improve the existing flow control structures; (ii) it falls when the water demand exceeds the water supply from the headworks; (iii) the distribution efficiency within tertiary unit may become very low, when water users have no incentives for efficient water use (Ankum, 1995).

2. ***Through composit control structures:***

   Composite control structure is a kind of flow control structure that can serve combination procedure between upstream and downstream control systems on one canal reach. With its structure, the canal reach has doble functions as a conveyance and as a storeage (*in-canal storage*). Composite control can be applied well in run-of river systems with very fluctuating discharge, when the sediment can be kept out of the canal system. Explanation in more detail about this structure has been studied and published by Ankum, 1995. See figure 4.

   The hydraulic control section of the gate consists of three components: (i) a downstream compartment, (ii) an upstream compartment and (iii) a small upstream cistern. The downstream compartment is in open connection with the downstream canal via tube K, and the upstream cistern is also in open connection with the upstream canal via tube A. See figure 5 (Ankum, 1995).

Gate operation: When water level in the upstream canal reach is low, the gate is operated under upstream control to fill dead storage. Water elevation in the two compartments is in balance, the gate is closed. If water level in the upstream canal reach continually rises, water flows to fill the compartments through upstream cistern. When water level in the downstream compartment is high enough, the gate is operated under downstream control to save water as a canal storsge. Finally if water level in the upstream canal reach is continually rised, the gate is again operated under upstream control, so water does not spill over the dike.

Irrigation with Reservoir.

Irrigation with reservoir is defined as a government irrigation scheme where the water resource is diverted from a reservoir. On irrigation with reservoir, there would be no problem of water shortages. **Jatiluhur** irrigation scheme is an example of scheme in West Java Province. Water resource is diverted from Jatiluhur Dam through movable weir downstream of the dam to irrigate the area of about 240,000 ha. The existing flow control method is upstream control, and water allocation procedure to tertiary unit is semi-demand.

The main existing problems dealing with efficiency of the management performance, is that usually high respond time (*time-lag*) and operational losses problems that cannot be avoided. Semi-demand allocation procedure needs a frequent communication with the Water Users Association (WUA), and needs more operators to maintain water level at all regulation structures at a certain specification. These problems need high cost of operation and maintenance.

The solution to improve management performance in Jatiluhur irrigation scheme is: (i) improve flow control method to be downstream control. The main irrigation system with downstream control can serve on-demand allocation procedure to the tertiary units. (ii) Improve the efficiency of conveyance structure with rehabilitation of existing system. The irrigation system under downstream control as has been discussed above:

- No operational losses, no time-lag, and water distribution runs automatically.
- Theoretically, there should be no Water Operations Centre, the water users can be free to take water whenever and whatever, On-demand allocation system can be serviced by the downstream control. The management is self management.
- Types of plants can vary; the farmer can choose their own desired type of plant in accordance with market conditions.
- If the layout of the secondary canals is too steep (lot of drop structures), downstream control requires more structures since this will increase investment cost. In this case, then it can be planned in such a combination system with the Downstream Control at primary canal, and upstream control at the secondary canal.

5. Conclusions and Recomendations

Conclusion:

a. ***Rural irrigation*** schemes managed by farmers, although at the network levels are inefficient deal with flow control system; there do not need to be improved, since the water losses can be used for other porposes downstream as *reuse water*. Water allocation system under demand oriented is basically in accordance with the socio-cultural conditions of the society in West Java Province. This was proven with the farmer management since several centuries ago without interference from the government.

b. The irrigation scheme under upstream control system in some places according to the topography condition, basically could be improved become downstream control or combination of both upstream and downstream control. This strategy will improve efficiency of management performance.

c. ***Irrigation without reservoir*** could be improved with combination of upstream control in primary channels, and downstream control in secondary channels. Since the water resource in the river is generally fluctuative, this strategy needs water storage which basically can be as field reservoir or canal strorage. Water can actually be stored either in irrigation channels or in drainage channels or even in river itself as the canal storage. With canal strorage, besides improving dependeble discharge, also can responds the varieous water demands.

d. ***Irrigation with reservoir*** which is operated under upstream control (Jatilihur scheme) could be improved with downstream control in other to serve on-demand allocation procedure. In some cases if there are any problems dealing with existing steeps slope of secondary channel, the improvement of flow control system could be combined between downstream control in the primary channel and upstream control in the secondary channels.

Recommendation

To support the industrial development, agricultural development in West Java towards Agro-Industry, should have been considered. To support food self-sufficiency, the cropping pattern can be determined as follows:

- Paddy-paddy-palawija for all rural irrigation schemes. It is reasonable since dependable flow at the tributeries is relatively sufficient to irrigate two crops padi with one crop palawija. Farmers are freedom to plant crops of palawija which high economic value. Organic farming with SRI methods can increase productivity of rice up to 10 tonnes / ha.
- Paddy-palawija-palawija for other irrigation schemes. It means that in first crop (rainy season) all area are cultivated paddy to support government policy of National Food

Security. Otherwise to increase farmer’s income, the other two crops can be cultivated by crop type which high economic value.

- Selection of appropriate technologies for the improvement of irrigation system performance in different conditions both physical and social-economic, are very complex. Since further research include the physical and managerial conditions, should first be done.

References

- Ankum, P: Flow Control in Irrigation and Drainage, Report no. 65, Faculty of Civil Engineering, TU DeIf, June 1995.
- Abdullah Angoedi, Ir: Sejarah Irigasi di Indonesia, ICID, Bandung, 1984.
- Bos, M. G. ed. : Discharge Measurement Structures, ILR publication 20, The Netherlands, 1989.
- Bos, M. G, John A. Replogle, and Albert J. Clemmens, : Flow Measuring Flumes for Open Channel System; John Wiley & Sons, 1984.
- Hofwegen, P.J.M, : Principles Of Irrigation Management; Lecture Notes, HE Delf, The Netherlands, April 1992.
- Plusquellec, H, : Improving the Operation of Canal Irrigation Systems. Economic Development Institute of the World Bank, Washington D.C. 20433, March 1988.
- Richard G. Allen, et al,: Water Use Definitions And Their Use For Assessing the Impacts of Water Conservation, Oxford, U.K., Kay, M., Franks, T., and Smith, L., Editors, E & FN Spon, 1997.
- Simon, A.L. Hydraulics, ; John Wiley & Sons, 1986.
- Suardi, N. : Sisitem Kontrol Aliran Pada Jaringan Irigasi, Catatan kuliah, Bandung, Juni 1997.
- Winpenny. JT, : Demand Management For Efficient and Aquitable Use,, dalam *Water: Economics, Management and Demand,* Oxford, U.K., Kay, M., Franks, T., and Smith, L., Editors, E & FN Spon, 1997.

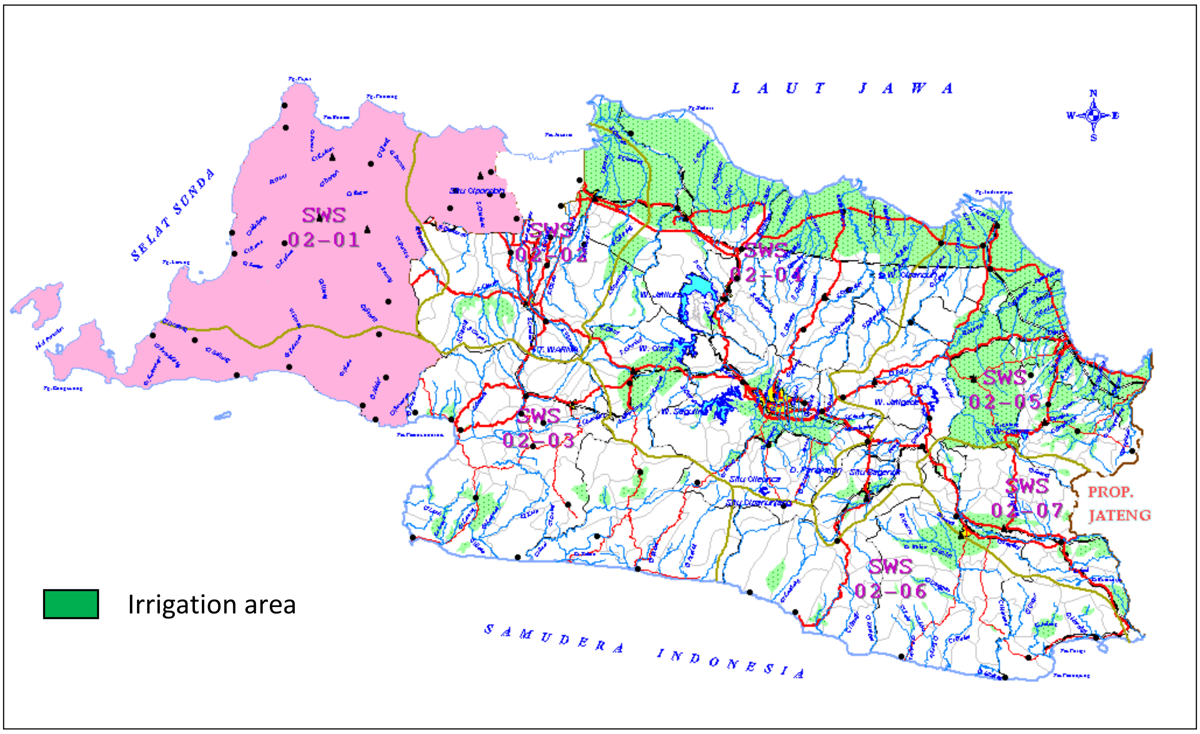

Figure 1: Irrigation Area in West Java Province

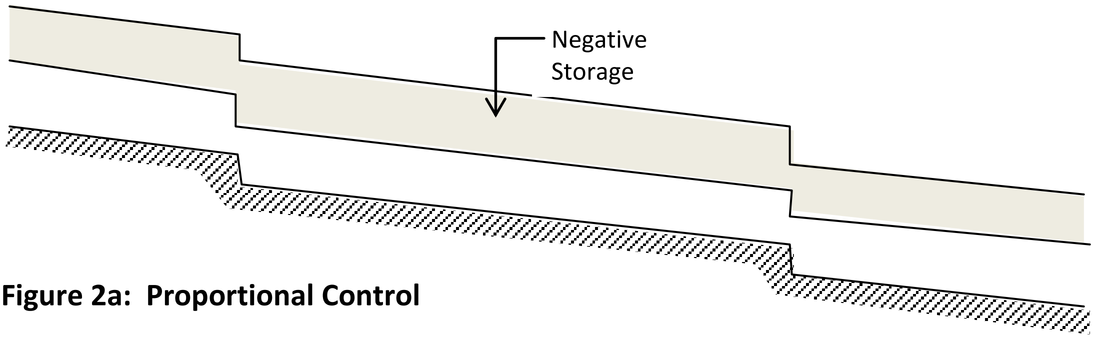

Figure 2a: Proportional Control

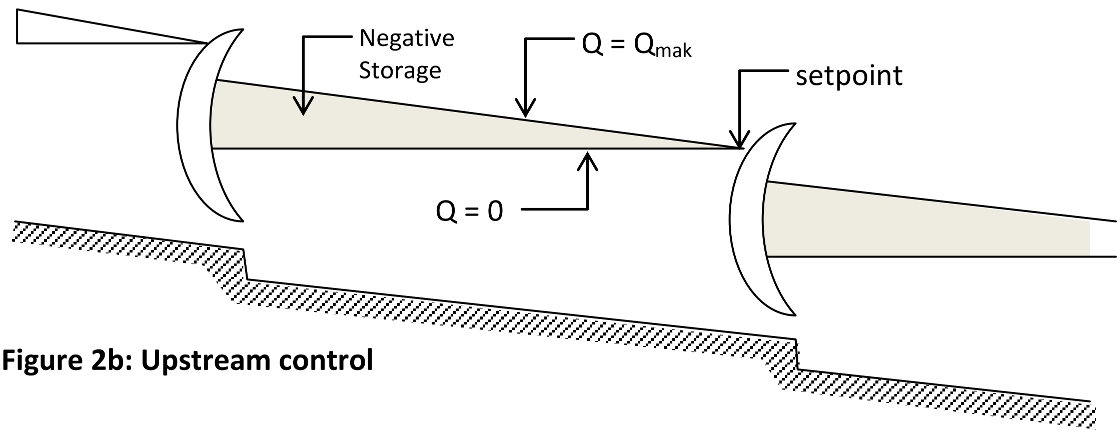

Figure 2b: Upstream control

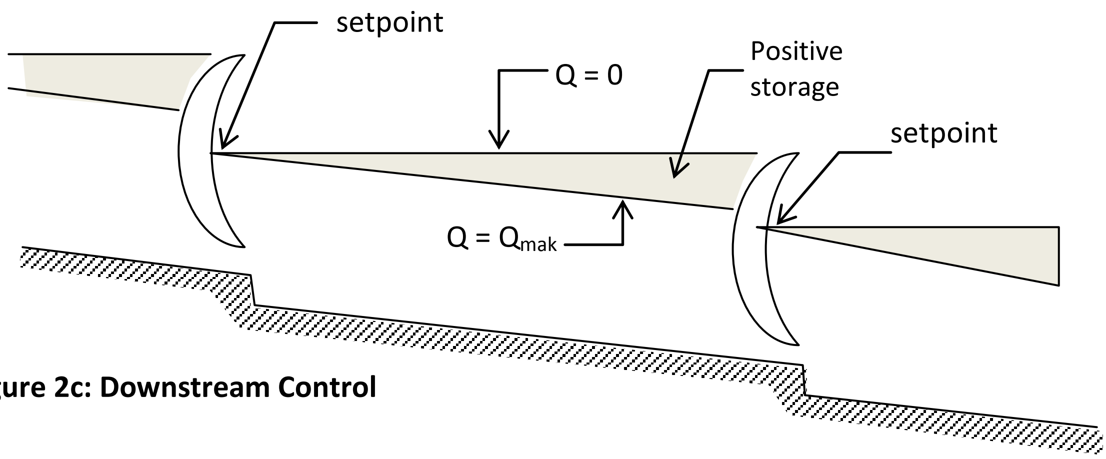

Figure 2c: Downstream Control

Figure 2: Flow Control System

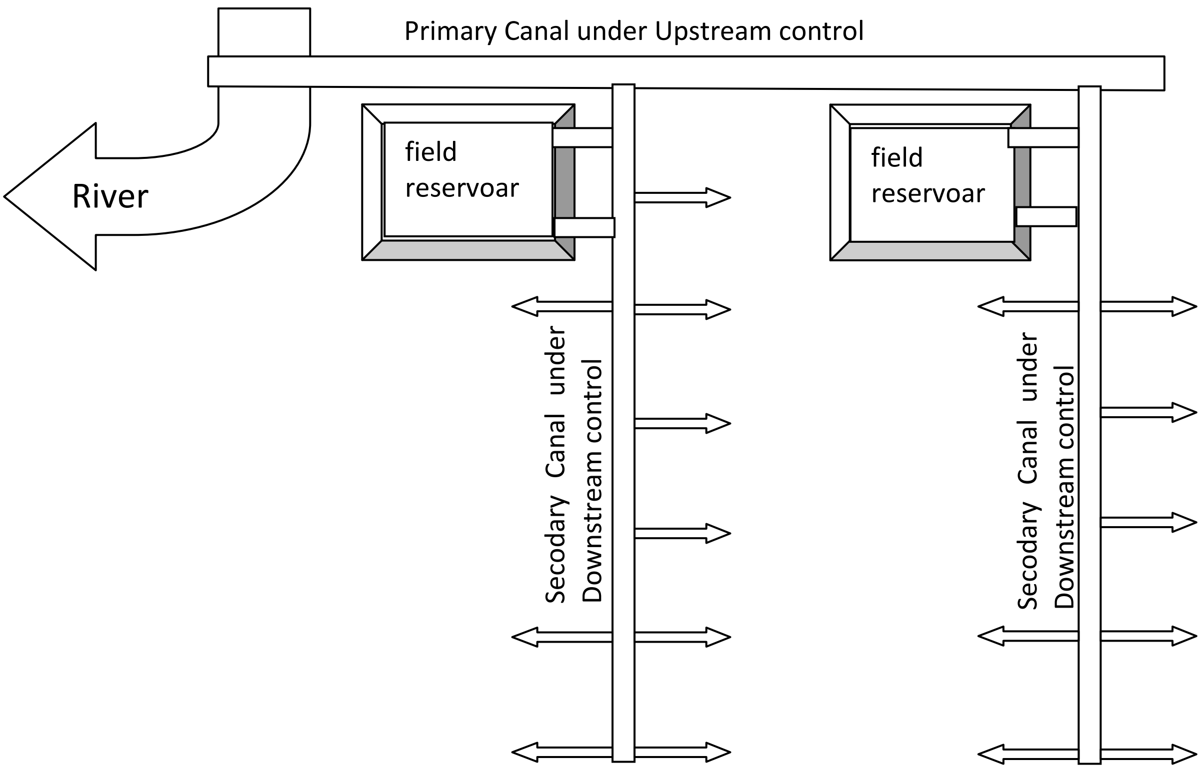

Figure 3: The combination of Upstream and Downstream Control

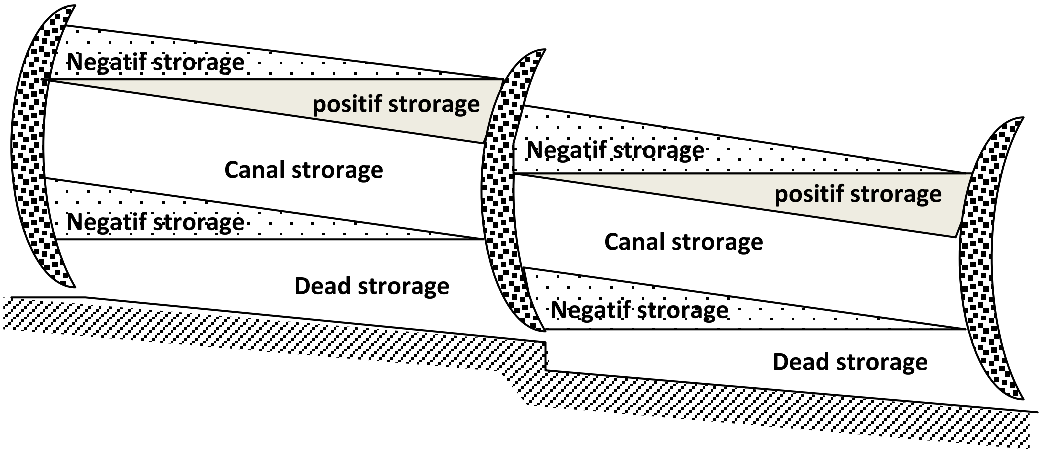

Figure 4: Flow characteristic under Composite Control System

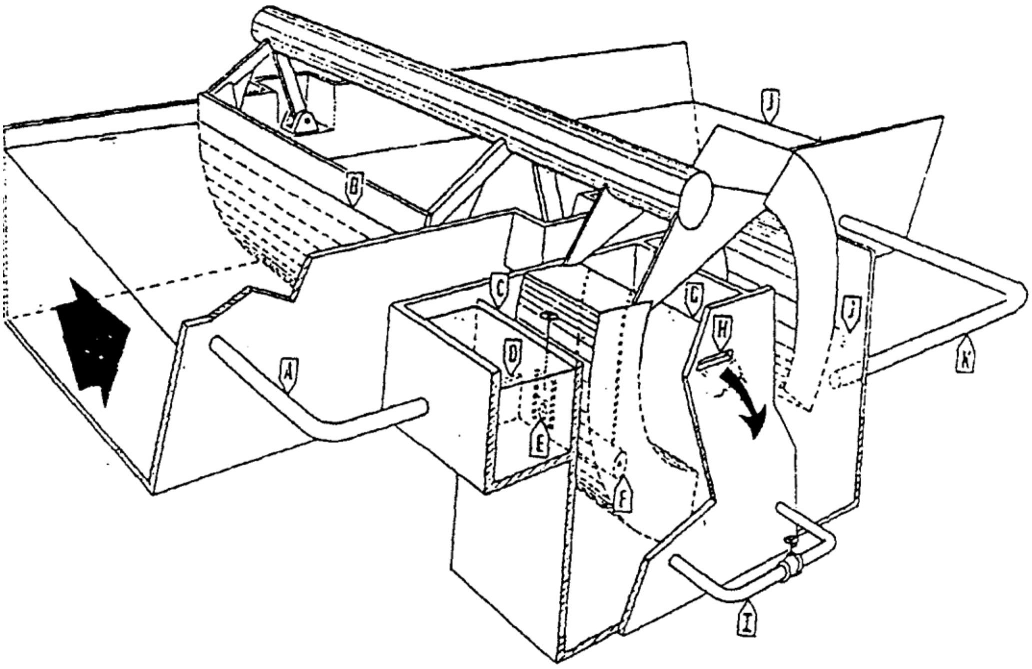

Figure 5: Composite gates (Alsthom in Ankum, 1995)