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# Rural Water Supply from the Irrigation Reservoir

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**Abstract**□Irrigation water has been mainly used for paddy rice. Irrigated paddy land tends to be recently converted to land for green house, farm house, and rural-industrial complex. Consequently, demand of water for crops, domestic & industrial, rural recreations, small-scaled hydropower, livestocks, and environment in the rural area, so called rural water, is rapidly increasing. In order to supply rural water, water in the existing irrigation reservoir could be enlarged by repairment of irrigation canal and reinforcement of irrigation reservoir, and be saved by the operation rule curve, utilization of dead water, and balanced storage management.

**Keywords**□Rural water, irrigation reservoir, operation rule curve, balanced storage management.

## I. Introduction

The traditional role of agriculture will be transferred from food-supply for the people and employment of rural labor to shock-absorbing for food crisis and maintenance of regional society in 21st century. New role of agriculture will be to conserve the nature such as water, soil, and air, and to keep the rural society and supply the recreation space for the people.

The policy on the farm land and water development is being changed from hardwareward to softwareward concept through the projects for the improvement of agricultural structure in 1990s.

Effective storage capacity of irrigation reservoir is normally designed safe from the drought of irrigation season once in 10 years. In other words, water in the irrigation reservoir may be sufficient during other 9 years. In this sense, once if supply of irrigation water can be ensured in the irrigation season and the drought year, surplus water in the irrigation reservoir might be utilized for the rural water.

Water in the existing irrigation reservoir could be enlarged by the repairment of irrigation canal and reinforcement of irrigation reservoir, and be saved by the operation rule curve, utilization of dead water, and balanced storage management.

## II. Present Status of Farm Land and Water Development

Main problems we are facing in the farm are the lack of farm labor, small farming size, income gap between farmers and urban workers, decrease of food self-sufficiency ratio, and low competitive power of agricultural products in the world market.

We had paid most efforts to the construction of irrigation facilities for paddy rice and finally achieved the self-sufficiency of rice in 1980s. Even with 73% of irrigated paddy land and poor function of irrigation facilities, we have already faced the over-production of rice. But, as far as irrigation for crops of field, fruit, vegetable, and forage are concerned, almost nothing is available. Afterwards, we have to pay more attentions to irrigation for crops.

Land consolidation is the most important factor to save labour power and make farm mechanization. The criterion for land consolidation has been loosened, because of necessity of farm mechanization. The 600,000 ha of paddy has been consolidated and 400,000 ha would be consolidated by 2001.

## III. Expanding Water Supply from the Irrigation Reservoir

Available countermeasures to expand water supply are supposed to be the reinforcement of irrigation reservoirs, the repairment of irrigation canal, the effective management by operation rule curves, the utilization of dead water, and balanced storage management.

### 1. Reinforcement of Irrigation Reservoirs

Saving the effective storage volume by reinforcement of irrigation reservoir is important for the multi-use of irrigation water. It was surveyed that there are 140 irrigation reserviors managed by FLIA(Farm Land Improvement Association) which have potential to be utilized as the multi-use reservoir through the reinforcement.

**A. Heightening the Dam**

Effective storage volume can be enlarged by heightening the dam, where the area of watershed of dam is enough.

**B. Changing the Structure of Spillway**

Effective storage capacity can be enlarged by changing the type of spillway from overflow to gate type, where freeboard of dam and area of water-surface is big enough.

**C. Dredging the Sediment Deposit**

Storage capacity of reservoir can be expanded by dredging the sediment deposit.

### 2. Repairment of Irrigation Canal

Repairment of irrigation canal is urgent to save the irrigation water. Irrigation canal of 84% is unlined earth canal. The rate of water loss in the unlined earth irrigation canal is supposed to be 30 to 40%. If this rate can be reduced to 5 to 10% by replacing all the earth-canal with concrete-canal, about 800 MCM($10^6 m^3$) of extra water

**Table 1. Effective storage volume of irrigation resevoirs managed by FLIA**

| Managed by | No. of reservoir | Benefit area | Water-surface area | Effective storage capacity | Mean | | |
|---|---|---|---|---|---|---|---|
| | | | | | Benefit | Surface | Eff. sto. |
| | ea. | ha. | ha. | ha-m | ha. | ha. | ha-m |
| FLIA | 2,831 | 373,408 | 41,130 | 197,500 | 132 | 14.5 | 70 |

which is useful to overcome the drought can be ensured from the irrigation reservoirs managed by FLIA.

### 3. Effective Management by Operation Rule Curves

Operation rule curves with reference storage curve and restricted release curve can be made from the practical operation data of irrigation reservoir. Through the operation rule curve, management of irrigation water can be effectively achieved and emptying in the irrigation reservoir may be avoided until the end of irrigation season. From the operation rule curve, the amount of water supply for irrigation could be determined in a daily basis depending on the water level and growing stage.

As shown in Fig. 1, water supply for irrigation on May 6 in 1981 in Yedang reservoir should be resrtricted by 10% to prevent the reservoir from emptying at the end of irrigation season when the ratio of storage was down to 88%.

When the drought continued and the ratio of storage on June 3 dropped down to 39%, water supply for irrigation might be restricted to 30~50 % until July 1. The storage volume of reservoir was fully recovered by heavy rain on July 2 and the water supply was free from the restricted release.

As shown in the Table 2, the ratio of effective release of water was 149% in Yedang irrigation reservoir. On the other hand, it was 325% in Daechung multi-purposed dam. It means that if the

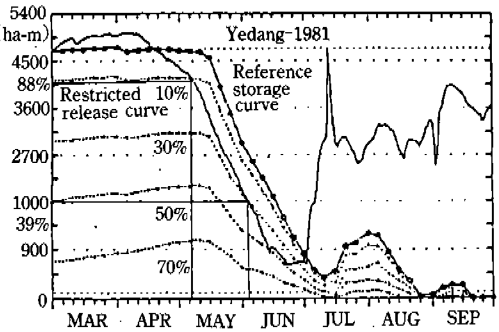


**Fig. 1. Operation rule curve for Yedang reservoir**

**Table 2. Operation record of Yedang reservoir(FLIA, 1978~87)**

| Year | Rainfall | Inflow | R/I ratio | Irrigation water | Non. eff. release | Release ratio | Storage ratio | E. R ratio |
|---|---|---|---|---|---|---|---|---|
| Unit | mm | MCM | % | MCM | MCM | % | % | % |
| 1978 | 1079.7 | 208 | 51.6 | 66 | 125 | 32 | 22 | 143 |
| 1979 | 1136.6 | 213 | 50.3 | 70 | 120 | 33 | 22 | 152 |
| 1980 | 1307.4 | 273 | 55.8 | 66 | 189 | 24 | 17 | 143 |
| 1981 | 1048.3 | 192 | 48.9 | 76 | 96 | 40 | 24 | 165 |
| 1982 | 893.5 | 105 | 31.6 | 83 | 11 | 79 | 44 | 180 |
| 1983 | 1081.4 | 200 | 49.4 | 62 | 111 | 31 | 23 | 135 |
| 1984 | 1097.0 | 180 | 43.9 | 71 | 83 | 39 | 26 | 154 |
| 1985 | 1342.3 | 259 | 51.7 | 74 | 174 | 29 | 18 | 161 |
| 1986 | 1196.6 | 225 | 50.2 | 64 | 139 | 28 | 20 | 139 |
| 1987 | 1604.1 | 367 | 61.3 | 53 | 287 | 14 | 13 | 115 |
| Mean | 1178.7 | 222 | 49.5 | 69 | 147 | 35 | 23 | 149 |

Release ratio=Irrigation/Inflow, Storage ratio=Effective storage/inflow
Effective release ratio=Irrigation/Effective storage

ratio of effective release assumed to be raised from 149% to 325%, approximately 3,480 MCM of extra water can be saved from the irrigation reservoirs managed by FLIA.

### 4. Utilization of Dead Water in the Drought Year

Once if there is possibility that dead water in the irrigation reservoir can be effectively used in the drought year, the availability of water can be widely expanded in the non-drought year. Dead water can be effectively used by releasing down to the stream and/or pumping up to the benefit area.

Especially, the ratio of dead water to total storage volume is 20 to 50% in the fresh water lakes. Dead water of 235 MCM from the 6 fresh water lakes is potentially available in the drought year.

### 5. Release with Balanced Storage

Irrigation water can be saved by the management of balanced storage volume in the reservoir group located within the system. The systems of management of equivalent storage volume are parallel, tandem(or series), and combined reservoirs.

Inflow to and outflow from reservoir may be combined into a continuity equation.

$$S = PS + QI + LF - QO + D \quad (1)$$

where, S : Storage within the zone at the end of the current period
PS : Present storage
QI : Upstream inflow for period
LF : Local flow for period
QO: Outflow for period
D : Diversion for the period (−), or a returnflow to stream (+)

**A. Parallel Reservoirs**

When parallel reservoirs are being considered the downstream demand may be satisfied by any combination of $QO_1$ and $QO_2$ which adds up to the proper demand of QT.

$$QT = QO_1 + QO_2 \quad (2)$$

In order to keep reservoirs balanced, the two index level must be the same.

$$S_1/TS_1 = S_2/TS_2 \quad (3)$$

where, $TS_{1,2}$ : Storage volume of reservoirs 1 and 2, respectively
$S_{1,2}$ : Present volume of reservoirs 1 and 2, respectively

From Eq. (2),

$$QO_2 = QT - QO_1 \quad (4)$$

Since all the terms on the right hand side of Eq. (5) are known, the amount of release from the reservoir 1 can be calculated directly and the

**Table 3. Storage volume of dead water**

| Name of dam | Total sto. $\times 10^4 m^3$ | Dead sto. $\times 10^4 m^3$ | Ratio % | Name of lake | Total sto. $\times 10^4 m^3$ | Dead sto. $\times 10^4 m^3$ | Ratio % |
|---|---|---|---|---|---|---|---|
| Yedang | 4,700 | 103 | 2.2 | Asan | 12,300 | 4,300 | 35.0 |
| Tapjung | 3,161 | 60 | 1.9 | Namyang | 3,100 | 1,300 | 42.0 |
| Dukdong | 3,270 | 344 | 10.5 | Sapkyo | 8,426 | 2,147 | 25.0 |
| Bangdong | 337 | 31 | 9.2 | Yongsan | 25,320 | 7,220 | 29.0 |
| Daeduk | 270 | 37 | 13.6 | Daeho | 12,200 | 6,882 | 56.0 |
| | | | | Kumgang | 13,900 | 1,700 | 12.0 |

amount of release from the reservoir 2 can be obtained from Eq. (4).

$$QO_1 = \frac{TS_2(PS_1+QI_1+LF_1+D_1) - TS_1(PS_2+QI_2+LF_2-QT+D_2)}{TS_1+TS_2} \quad (5)$$

As an example, Asan and Sapkyo lake can be managed as parallel reservoirs to meet the water demand in the region.

**B. Tandem Reservoir**

For tandem reservoirs, the downstream demand QT must be satisfied by the release from downstream reservoir, and the release of upstream reservoir is equal to upstream inflow to downstream reservoir.

$$QT = QO_2 \quad (6)$$

$$QI_2 = QO_1 \quad (7)$$

Since Eqs. (1) and (3) hold for tandem reservoir, Eq.(8) can be derived from Eqs.(6) and (7).

$$QO_1 = \frac{TS_2(PS_1+QI_1+LF_1-D_1) - TS_1(PS_2+LF_2-QT-D_2)}{TS_1+TS_2} \quad (8)$$

All the terms on the right hand side of eq. 8 are known, the amount of release from upstream reservoir can be calculated directly.

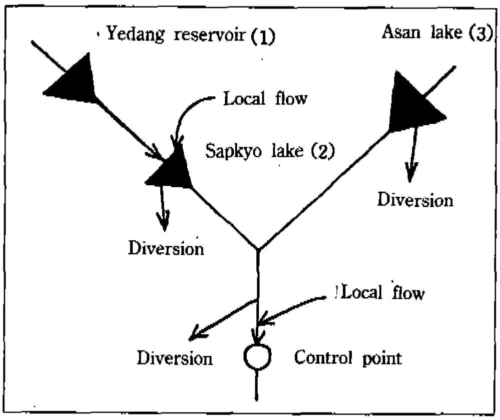


**Fig. 2. System of combined reservoirs**

As an example, Yongdam dam and Daechung dam located in the Kum river can be managed as tandem reservoirs to meet water demand in the region.

**C. Combined Reservoirs**

In the system of combined reservoirs, the amount of release from reservoir 2 and 3 in Fig. 2 can be calculated from Eqs. (9) and (10).

$$QO_2 = \frac{TS_3(PS_1+PS_2+QI_1+LF_2-D_2) - (TS_1+TS_2)(PS_3+QI_3-QT-D_3)}{TS_1+TS_2+TS_3} \quad (9)$$

$$QO_3 = QT - QO_2 \quad (10)$$

As an example, Sapkyo lake and Yedang reservoir which can be managed as tandem reservoirs may form the system of combined reservoirs with Asan lake.

## IV. Rural Water Supply from the Irrigation Reservoir

Water in the irrigation reservoir could be used in respect of nature conservation and public service. Water for domestic & industry, rural recreations, maintenance of stream, flood control, and multi-use of irrigation reservoir can be supplied by the saved water, mentioned in the previous section. FLIA can make business with the irrigation reservoir under the permission of MAFF(Ministry of Agriculture, Forestry, and Fisheries) minister, and it mobilises the function of FLIA.

### 1. Water Supply for Domestic and Industry

When water for domestic and industry is supplied from the irrigation reservoir, it may produce

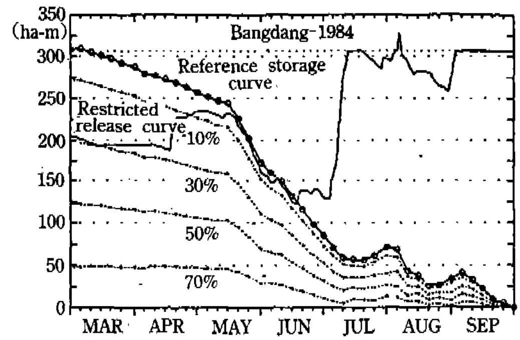


**Fig. 3. Operation rule curve in Bangdong reservoir**

great influence on the existing irrigation management system. Water level may not be fully recovered at the beginning of irrigation season, because of water supply during non-irrigation season. The influence should be carefully studied in advance for the safe irrigation management.

For an example, Bangdong reservoir originally built for irrigation supplies industrial water of 10,000m$^3$/day. In case of 1984, water storage volume was only 70% at the beginning of irrigation season due to the drought in winter and water supply during non-irrigation season.

## 2. Water Supply for Rural Recreations

Rural recreations in the irrigation reservoir are boating, motor-boating, fishing, skating, restaurant, garden, shops for agricultural products, camping site, and athletic facilities, etc.. Reallocation is needed to meet contradictory objectives of irrigation and rural recreations.

First is how to keep the proper water level in the reservoir. While water should be freely released for irrigation, water level should be kept as high as possible in respect of rural recreations.

Second is water quality. Water quality in the reservoir can be getting worse because of wastes. Especially, when the water level is low and temperature of water is high in summer, water can be deteoriorating due to the multiplication of algae and planktons.

## 3. Water Supply for Maintenance of Stream

It is favourable to provide "Space with water" to urban people from irrigation water, as far as there is no problem on the supply of irrigation water. Water supply for maintenance of urban stream is recently planned to enhance the scienary of space and the emotion of people, such as U-i stream in Seoul and Hanbat dam in Taejon.

Duty of water for maintenance of stream is about 9ℓ/sec per width of stream and minimum discharge can be obtained from Eq. (11).

$$Q = 0.0117 \times A^{0.318} \cdot I^{-0.5}, \ (m^3/sec) \qquad (11)$$

where, A : Area of watershed(km$^2$), I : Slope of channel(m/m)

## 4. Function of Flood Control

Flood control in the irrigation reservoir is made from late June to early July. Optimal flood control volume in the irrigation reservoir should be deter-

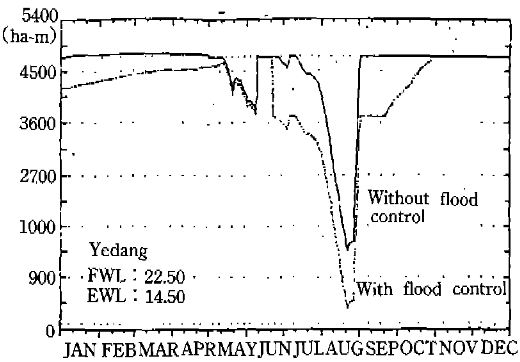


**Fig. 4. Water level with and without flood control in Yedang reservoir**

mined such that benefit by flood control is greater than the damage by restricted release of irrigation water.

Water level of reservoir(Solid line in Fig. 4) was dropped near the bottom in the middle of August due to the flood control in the middle of June. But, if there was no flood control in the middle of June, water level of reservoir(Dashed line in Fig. 4) could be maintained to a safe water level in the middle of August. We have to compare the benefit of flood control to the damage of restricted water supply.

Flood damage per $m^3$/sec×flood control volume>Drought damage per $m^3$×restricted release water (12)

Flood control volume in the irrigation reservoir is generally determined by simulating the variation of water level in the reference drought year once in 10 year frequency. But, this method is not so proper, because of the randomness of rainfall pattern. It is more desirable to analyse the data as long as possible to overcome the randomness of rainfall pattern, and simulation of water balance is carried out to determine optimal flood control volume in the irrigation reservoir throughout this period.

### 5. Multi-use of Irrigation Water

Irrigated paddy land is partly converted to green house, farm house, and rural-industrial complex due to the construction of well-being farm village and urbanization. Consequently, if there is a surplus of irrigation water, it should be converted to rural water such as domestic and industrial water.

For an example, irrigation reservoir called A with effective storage of 46 MCM has benefit area of 8,700ha and flood control volume of 10 MCM.

**Table 4. Conversion of irrigation water to rural water in reservoir A**

| Items | Unit | Present | Converted | Remark |
|---|---|---|---|---|
| Irrigated area | ha | 8,700 | 6,500 | |
| Domestic | $m^3$/day | – | ? | 35,000 |
| Industrial | $m^3$/day | – | 10,000 | |
| Flood control | MCM | 10 | 10 | |

If benefit area is reduced to 6,500ha and water demand for industry increases to 10,000$m^3$/day because of urbanization, how much domestic water can be supplied from reservoir A ? It is 35,000$m^3$/day.

## V. Conclusions

Someone has to live in the rural area and save the farming in order to keep the social, industrial, ecological, and environmental balance of our country. Farmers are seriously worrying about the openning of agricultural products to the world market according to Uruguay Round and the complete collapse of infrastructure of agriculture. We, agricultural engineers, believe that rural development could be achieved by new policy which includes the modernization of irrigation facilities, the supporting program for professional farmers, and the planning of well-being farm village.

800 MCM of extra water which is useful to overcome the drought can be ensured from the irrigation reservoirs managed by FLIA, if all the earth-canal is replaced with concrete-canal.

3,480 MCM of extra water can be saved from the irrigation reservoirs managed by FLIA, if the ratio of effective release can be raised from 149% to 325%.

Dead water of 235 MCM from the 6 fresh water lakes is potentially available in the drought year.

Irrigation water can be saved by the operation rule curve and by the management of balanced storage volume in the reservoir group within the system.

Rural water supply from the irrigation reservoir mentioned here is one of the alternatives to accomplish the improvement of agricultural structure.

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