Planning Procedure for a Paddy Irrigation System Consisting of a Regulating Pond and Pipelines

Shin-ichi HIROSE

Section of Agricultural Engineering, Department of Agricultural Technology, College of Technology

This report offers a sketch of the planning procedure for a pond-regulated pipeline irrigation system, with a special focus on a practically feasible way of determining the capacity of a regulating pond. This system was developed in order to fill temporal gaps between supply and demand in paddy irrigation and has been introduced in many sloping areas on alluvial fans.

As of the irrigation season of 1997, there are twelve of these systems in operation in Tonami Plain of Toyama, a typical alluvial fan, and one in Niigata, and four more of them are being planned in Toyama. The Shogawa regulating pond project, the first of this type, was undertaken back in 1974 by the Toyama prefectural government[1]. Ever since then, the present author has been monitoring the water balances of several regulating ponds, the adaptability of field inlet valves and other aspects of this system, and has compiled quantities of basic data with a view to obtaining optimal criteria for designing this system[2)~12)]. The planning procedure proposed below is based on the analyses of these data.

Key Words : regulating pond, supply and demand, planning procedure, pipeline irrigation, field inlet valve

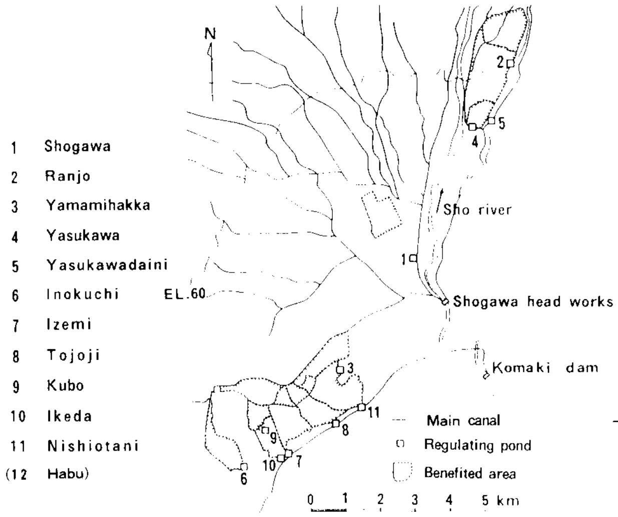


Fig. 1 Location of pond-regulated pipeline irrigation systems

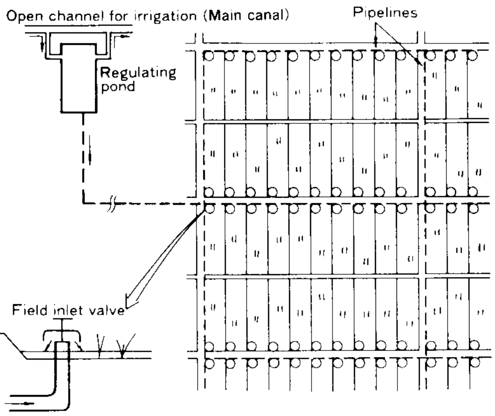


Fig. 2 Bird's-eye view of a pond-regulated pipeline irrigation system

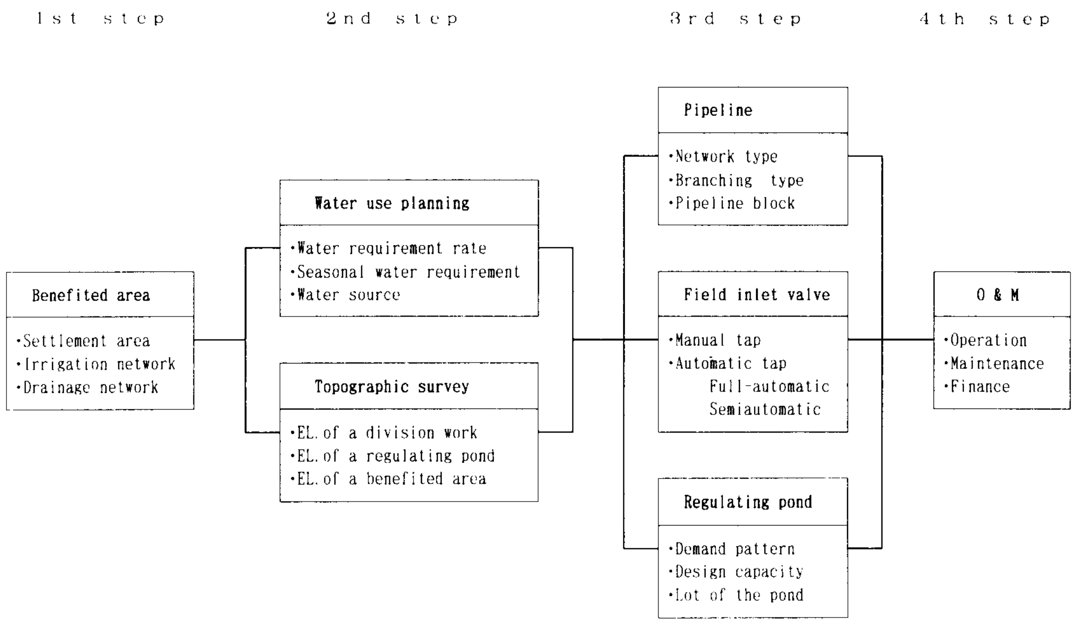


Fig. 3 Planning procedure for a pond-regulated pipeline irrigation system

Introduction

Underlying this innovation in irrigation technology are the following three needs:

1) the need for a regulating pond so designed as to close the discrepancies between supply-side-based constant flow in main and branch canals and demand-side-based flow fluctuation in tertiaries, due mainly to concentration of demand at particular hours of a day;
2) the need for a well-coordinated combinations of a regulating pond, pipelines and field inlet valves so designed as to allow farmers to take water into their paddy lots when they need to, not when they are obliged to, and thus to secure maximal degrees of freedom in irrigation; and
3) the need for utilization of slope-derived gravity energy and water pressure for off-farm water conveyance and on-farm intake.

In every step of the planning of this system, all these needs or design constraints should be given due consideration.

The planning procedure for this system comprises the four steps shown in the flow diagram in Fig. 3. The first step is to decide the target area (i. e. the area to be benefited by the system); the second to calculate water requirements for different rice growth stages and to conduct a topographic survey, essential for facility planning in general; the third to prepare an outline design of the pipelines and the field inlet valves and to determine the capacity of the regulating pond; and the last to formulate plans for O & M of the system. Needless to say, as is generally the case in system planning, the results of these four steps should be fed back each to the other before a well-coordinated and coherent plan can be finalized.

1 Determination of the acreage of the target area[6)]

The determination of the acreage of the area to be benefited is a primary step in planning, which affects the scale of the system and the success of the whole project. The acreage is determined by taking into account the boundaries of the villages concerned, the irrigation and drainage networks available and the contour of the landform of the area. A regulating pond is usually installed within the district concerned near a division work of a main or branch canal. The target area, therefore, should be determined in such a way that the whole of it is located at levels far enough below the regulating pond so that the system can generate an effective head difference for off-farm water conveyance and an effective water pressure for on-farm intake operation of field inlet valves. Another point to bear in mind is that the size of the target area should not exceed the extent within which mutual cooperation among the beneficiaries on the O and M of the system is easily available. Past data on the existing systems have proved that a benefited area of 50～150 ha is generally more or less appropriate in this respect.

2 Water use planning

Water requirements for the area to be benefited are formulated based on a water requirement survey, water use customs and water rights. This step of the procedure is much the same as in an ordinary irrigation project or in a farm land consolidation project. Water supply is investigated at a division work of a main canal. Before determining the capacity of the regulating pond, it is of particular importance to check whether or not water supply at the division work is sufficient for the future benefited area, and to investigate the interrelationship of the available supply at the division and those utilized at other divisions upstream and / or downstream.

3 Topographic survery

In planning any type of irrigation system, in order to find the most effective route for delivering water, scrutiny of a landform map of the target area is indispensable. This is even more important for the present system. Since it entirely depends on the sloping landform of the area for gravity energy and water pressure, as a basis for the optimal installation of the pipelines, it is essential to obtain correct data on the relative elevations of the division work, the regulating pond and major points of the target area.

4 Pipelines[6)]

There are two types of pipelines—network pipelines and branching pipelines. A comparative evaluation of these types should be conducted in terms of cost effectiveness, also taking into account the contour and the slope of the benefited area. A network type is often adopted when the contour of a benefited area is nearly square and its slope is not so steep. When water supply is inadequate or unstable, rotational irrigation is resorted to, with the pipeline system divided into several irrigation blocks. In this case, obviously a branching type is preferable.

5 Field inlet valves[5)]

There are two types of field inlet valves—an automatic tap and a manual tap. The choice between the two depends on the needs of beneficiaries. In Toyama, manual taps were adopted in earlier nine systems. In recent four systems, automatic taps have been adopted. Table 1 shows the result of an investigation on the operations of the two types in several paddies during a two-year period. Semiautomatic operations of automatic taps were less than two thirds of those of manual taps. Full-automatic operations of automatic taps were less than one third of those of manual taps. If all beneficiaries were to operate their respective automatic taps full-automatically, the demand for irrigation water in individual paddy lots would occur at random and thus the total demand at each hour of a day in the project area would be just as constant as that in round-the-clock irrigation, and the required capacity of the regulating pond would not have to be large. But a personal interview survey shows that the beneficiaries prefer to handle automatic taps semiautomatically. The reason is that the average farmer usually makes a tour of his paddy lots in early morning to check the condition of the rice growth and the ponding in the paddy lots, and, if needed, he manually opens the taps for intake and then sets the upper limit of the water level on the gage at which water will automatically stop flowing in.

Photo 1 An automatic tap in operation

Table 1 Number of the operations of the field inlet

Type of the field inlet	Target paddy lot	Number of the operations 1988	1989	Mean	Specification
Automatic tap	K. T. 91	11	—	11.0	Full-automatic
	T. T. 50	20	20	20.0	Semiautomatic
Manual tap	K. J. 5	56	33	36.3	Mean, ignoring 56
	K. M. 123	39	—		
	K. T. 91	—	37		
Farm ditch	J. K.	50	51	50.5	
Precipitation		473mm	552mm		

6 Design of a regulating pond[7), 8)]

A major step in the planning procedure of this system is to determine the approximate

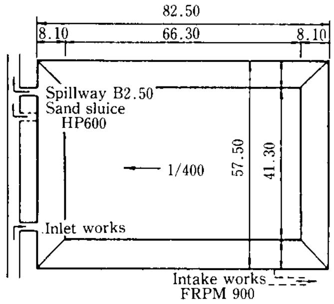
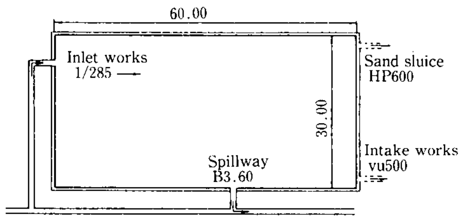
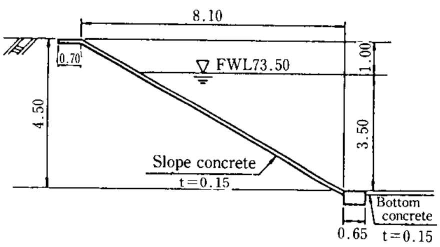
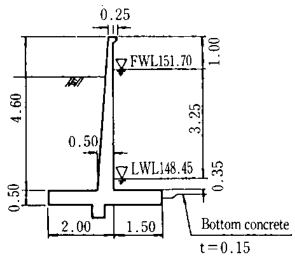
<table>
<tr><th>District</th><th>Yasukawa</th><th>Izemi</th></tr>
<tr><td>Benefited area
Design capacity</td><td>123. 3ha
12, 140m³</td><td>77. 5ha
5, 850m³</td></tr>
<tr><td>Type
Shape</td><td>Concrete lining
Prismoid</td><td>Inversed retaining wall
Rectangular parallelepiped</td></tr>
<tr><td>Plan</td><td>
</td><td>
</td></tr>
<tr><td>Section</td><td>
</td><td>
</td></tr>
</table>

Fig. 4 Structures of the regulating ponds

Photo 2 Izemi regulating pond with a capacity of 5,850m³

Table 2 Specifications of the regulating ponds

No.	①	②	③	④	⑤
District	Shogawa	Ranjo	Yamami	Yasukawa	Yasukawa 2
Start of the operation	1989	1980	1981	1983	1984
Benefited area : A(ha)	86.7	83.6	198.3	123.3	23.9
Required capacity : B(m³)	7,711	7,625	14,424	11,966	1,965
Design capacity : C(m³)	7,730	7,680	14,450	12,140	2,130
Construction cost : D(1,000yen)	60,000	85,600	212,600	117,500	56,800
B/A (m³/ha)	88.9	91.2	72.7	97.0	82.2
D/A (1,000 yen/ha)	692.0	1,023.9	1,072.1	953.0	2,376.6
D/C (1,000 yen/m³)	7.8	11.1	14.7	9.7	26.7

No.	⑥	⑦	⑧	⑨	⑩
District	Inokuchi	Izemi	Tojoji	Kubo	Ikeda
Start of operation	1985	1987	1989	1990	1991
Benefited area : A(ha)	63.1	77.3	70.2	46.1	85.7
Required capacity : B(m³)	4,385	5,789	5,400	2,873	4,406
Design capacity : C(m³)	4,540	5,850	5,410	3,100	4,550
Construction cost : D(1,000 yen)	87,700	113,000	95,075	67,900	77,100
B/A (m³/ha)	69.5	74.9	76.9	62.3	51.4
D/A (1,000 yen/ha)	1,389.9	1,461.8	1,354.3	1,472.9	899.6
D/C (1,000 yen/m³)	19.3	19.3	17.6	21.9	16.9

No.	⑪	⑫			⑬
District	Nishiotani	Habu			Shomen
Start of operation	1993	1995			1995
Benefited area : A(ha)	105.3	27.8	Total	991.3	109.3
Required capacity : B(m³)	7,992	1,944	Total	76,480	4,385
Design capacity : C(m³)	8,120	2,250	Total	77,950	4,400
Construction cost : D(1,000 yen)	151,100	62,500	Total	1,186,875	110,000
B/A (m³/ha)	75.9	69.9	Mean	76.1	40.1
D/A (1,000 yen/ha)	1,434.9	2,248.2	Mean	1364.9	1,006.4
D/C (1,000 yen/m³)	18.6	27.8	Mean	17.6	25.0

* Cost is shown as the 1994 equivalent value.
* ①~⑫ are in Toyama. ⑬ is in Niigata.

capacity of the regulating pond (V) and then make a rough design for it and acquire a site of an appropriate size. But obviously we cannot hope to correctly predict a possible pattern of hour-to-hour demand fluctuation generated by concentrated irrigation, nor does it make much sense to make such an attempt. We should realize that water demand is inherently indeterminate, since it is affected not only by individual farmers' needs but also by other factors such as rice growth stages and meteorological changes. All this calls for the choice of a more realistic and practicable approach to our present task. What I have tried to do in a series of relevant studies is to devise appropriate calculation formulas based on the analyses of the accumulated data on the actual operations of several existing systems. My first recommendation is to adopt Equation (1):

$$V = 3{,}600 \times Tpo \cdot avrQfi \cdots\cdots\cdots (1)$$

The symbol *'avrQfi'* stands for the average of hourly out-of-pond discharges over a 24-hour interval—*Tpo*, an abbreviation for 'pond storage represented by time'—denotes 'perday discharge excess over the discharge average calculated in terms of the discharge average multiplied by *n* hours.' However, there is another thing to take into account : the consumption of pond-stored water peaks between the latter half of July and August, a period corresponding to the booting, heading and flowering stages of rice plants and the water requirement during this period approximates 'q' — ' the maximum gross water requirement for the ordinary irrigation period.' This suggests that it would be more realistic to substitute '*avrQfi*' with 'q.' Moreover, the actual data on the operations of the existing systems of this type indicate that the values of *Tpo* range from 3 to 6 h, that these values tend to be smaller if automatic irrigation is adopted or the scale of the system is comparatively large and that if the water source is unstable, they tend to be comparatively large. These facts suggest that Equation (1) should actually be replaced with the variant form of Equation (2) :

$$V = 3{,}6000 \times Tpo \cdot q \cdots\cdots\cdots\cdots (2)$$

V : required capacity of the regulating pond (m^3)
Tpo : pond storage represented by time (3～6h)
q : maximum gross water requirement for the ordinary irrigation period (m^3/s)

The step following the design of a regulating pond is to prepare its site. As mentioned earlier, a regulating pond should be located sufficiently far above the target area so that the system can generate an effective head difference and an effective water pressure over the length and breadth of its coverage. Therefore, the site for a regulating pond sometimes has to be acquired in a different district upstream from the area to be benefited. In such a case, efforts should be made in the earlier stages of the project to gain the understading of the inhabitants of the district to be affected.

7 Operation and maintenance[6)]

For most beneficiary farmers with plentiful experience concerning the O & M of open channels, the O & M of a pipeline irrigation system must be their first experience. However, the existing pond-regulated pipeline systems are maintained and operated so smoothly that their O & M cost is less than that of ordinary open-channel systems,. The O & M of this system consists of the following :

1) ordinary O & M : elimination of trash from the inlet works of the regulating pond, control and recording of the water levels of the regulating pond, valve operation involved in conventional drainage regulation in the benefited area ;
2) seasonal O & M : weeding and elimination of sludge along the link canal leading up to the regulating pond, weeding around the regulating pond, elimination of sludge from the regulating pond ;
3) countermeasure against emergency : safeguard against people falling into the regulating pond, provision against mud flow caused by the burst of water out of destroyed pipelines ;
4) maintenance of facilities : maintenace of location maps of irrigation structures

and underground pipelines, operating procedure for repair and rehabilitation of facilities, preparation of materials for repair work ;

5) financing : financing O & M, repair and rehabilitation.

Particular attention should be paid to the maintenance of location maps of underground pipelines. In this age of part-time farming, even farmers who saw the pipelines installed can hardly be expected to remember their precise locations, still less can later generations. This makes it all the more important to securely keep location maps of underground pipelines readily available in the event of an emergency.

Concluding remark

Of the four planning steps, the third step, especially the determination of the capacity of the regulating pond, is the most vital part of the procedure. To use Eq.(2), maximal data should be collected concerning the local water demand. In this connection, it would be of particular use to refer to my recent report[10], in which the required capacity of a regulating pond was estimated based on a demand curve that was extrapolated from the results of a questionnaire survey on user demand.

The foremost advantage of this system is its ability to close the gaps between supply and demand in such a way as to allow flexible and efficient use of any required amount of irrigation water whenever and only when it is needed. Moreover, this system can be constructed at no undue cost and can easily be adjusted to the peculiar conditions and needs of a locality. There is no doubt that the adoption of this system will drastically improve irrigation in paddy field farming irrespective of its scale.

References

1) Hirose, S. (1978) : *Example of a Regulating Pond in Tonami Alluvial Fan of Toyama,* Jour. JSIDRE., No. 46, Vol. 1, pp. 8—12.
2) Hirose, S. (1980) : *Improvement of Irrigation in a Typical Alluvial Fan in Japan,* Proc. 3rd A-A Regional Conference of ICID, Vol. IV, pp. 97—111. (in English)
3) Hirose, S. (1987) : *On the Structure and the Use of Regulating Ponds in Tonami Plain,* Jour JSIDRE., No. 55, Vol. 11, pp. 29—34.
4) Hirose, S. (1990) : *An Evaluation of a Paddy Field Irrigation System Based on Questionnaire Results,* Trans. JSIDRE., No. 146, pp. 109—118.
5) Hirose, S. (1991) : *An Investigation of Two Different Types of Inlets for Paddy Fields,* Trans. JSIDRE., No. 155, pp. 19—25.
6) Hirose, S. (1994) : *An Evaluation on the Use of Pond-and-Pipeline-regulated Paddy Irrigation Systems in Tonami Plain,* Jour. JSIDRE., No. 62, Vol. 6, pp. 7—12.
7) Hirose, S. (1995) : *Characteristic of the Water Balances of Regulating Ponds,* Trans. JSIDRE., No. 175, pp. 29—36.
8) Hirose, S. (1995) : *Determination of the Capacity of a Regulating Pond in terms of the Discharge Average Multiplied by n Hours,* Trans. JSIDRE., No. 175, pp. 37—46.
9) Hirose, S. (1995) : *Determination of the Capacity of Regulating Ponds in Irrigation Systems,* Trans. JSIDRE., No. 175, pp. 109—118.
10) Hirose, S. (1995) : *Realistic Determination of the Capacity of a Regulating Pond in a Pond-regulated Pipeline Irrigation System,* Trans. JASIDRE., No. 103, pp. 86—93.

11) Hirose, S. (1996) : *Determination of the Design Capacity of a Regulating Pond through a Questionnaire Survey of the Types of the Farmers' Valve Operation*, Jour. JSIDRE., No. 64, Vol. 8, pp. 53—59.
12) Hirose, S. (1997) : *Determination of the Capacity of A Regulating Pond in a Pipeline Irigation System*, REE of JSIDRE., No. 33, pp. 66—78. (in English)

調整池潅漑システムの計画手順について

広瀬　慎一
(短期大学部農業技術学科農業土木専攻)

「調整池潅漑システム」は、「調整池とパイプラインによる水田潅漑システム」を短く表現したものである。その目的は、①調整池により、幹・支線用水路の24時間通水と、末端圃場の短時間潅漑に基ずく集中的水需要の間の調整を行う。②調整池とパイプラインと圃場給水栓の三者の組み合わせにより、必要なときに容易に潅漑ができる、いわゆる自由度の高い潅漑を目指す。③地形勾配により生ずる、調整池と受益圃場との間の落差により、ポンプを用いない自然圧パイプライン潅漑を行うことである。調整池潅漑システムの計画は、４段階を経て行われる。第１段階として、受益面積を確定する。第２段階として、用水計画を策定して、施設計画の基礎となる地形調査を実施する。第３段階として、パイプラインと圃場給水栓の施設計画を行い、総合的かつ最終的に調整池の容量を決定する。第４段階として、日常、定期及び非常時の維持管理規定を根幹とした、維持管理計画を策定する。
本論では、調整池潅漑システムの必要性と、その計画の４段階について詳述する。

キーワード：調整池、需要の集中、計画手順、パイプライン潅漑、圃場給水弁