Analysis of hydraulic sluice gate Sapon – intake in Progo river Special Region of Yogyakarta

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Abstract. Progo River is water source from one of the harvests to irrigate Special Region of Yogyakarta irrigation network. Sapon, which has an area of 2250 Ha, received the water from Progo through Sapon intake. To fulfill the water requirement for Sapon irrigation area according to the demand of water debit based on the water needs of System Planning (August - Jul planting pattern) and Alternative water supply (Oct - Sep), it is necessary to operate the technique on the door Sapon intake by analyze the Sapon intake watergate in terms of hydraulics. The method used was field observation by conducting interviews and hydraulic analysis of watergate by analyzing water door height (ha). From the analysis, the results has shown, four door openings are not necessary because one, two and three door openings meet the requirements for operational intake doors with high door openings <h (height of intake holes). The operation of intake doors based on the water demand system planning (August - Jul planting pattern) is more efficient than the intake door operation based on alternative water demand (Oct - Sep). From the results can be concluded that Sapon intake capable of flowing water following the required discharge.

1. Introduction
Water is the source of life for living things. Almost all life activities of living things are using the water. Water can be obtained from various sources, and one of the sources is the river. River water is used as a water source for household, industrial, and irrigation activities for rice fields and plantations. The number of living things increases proportionally to the amount of water needed. To maintain the sustainability of water availability, the use of water will be more efficient by using management. To increase the utilization can be done by making flood control dams or good irrigation systems [1].

Progo River downstream, where it is the source of water to irrigate Special Region of Yogyakarta irrigation network. Sapon, an area where Progo river is located, covers an area of 2.250 Ha, by tapping water from Progo river through the intake Sapon according to the required water discharge. The water discharge requirements are based on the Water System Planning (pattern planting Augst - Jul) and alternative water discharge requirements (pattern planting Oct - Sep). The existing network irrigation on Sapon, Special Region of Yogyakarta consists of intake structure (decision), building complementary (tapping, bridge, gutters, culverts, etc.), channel carrier, and channel waster.

The intake building is equipped with four sluice gates, which are operated simultaneously or alternately to drain water according to the required discharge. The operation of the sluice openings is done mechanically. If the operation is not done regularly, there will be excess water that causes flooding.
in the irrigation area or vice versa. During the dry season, the amount of water that enters is less, so that the water does not flow into the irrigation area and will have an impact due to an imbalance of water availability.

The operation of sliding door openings in the irrigation channel aims to measure the distribution of water carefully to the channels served. The sliding door also functions to adjust the discharge and water level according to the required needs (Irawan, 2016) [2].

Based on the above issues then the author tries to reanalyze the ability of the building Sapon intake from hydraulics analysis by adjusting the height of the sluice opening and the number of sluice gates that are opened so that the operation of the sluice gate is more optimal. It is expected that the results of this study can be used as a reference to the merits of managing the Sapon Intake sluice in the Kulon Progo River.

2. Materials and methods

Primary data collection were obtained from the observations directly to the field at the Sapon Intake location. The observation aims was to invent the existing condition of the Sapon intake. In addition to completing the data obtained from the field, interviews were conducted with the Sapon intake door interpreter. For secondary data were taken from relevant agencies in the form of data such as the following: Sapon Intake Technical Data (Irrigation area of Sapon area, number of doors retrieval (intake), door width of intake (intake), intake hole height), Debit of water requirement every half month (Final Project Analysis of Water Needs and Evaluation of Sapon Irrigation Area Planting Patterns), and Map of Sapon Intake Locations.

This study were conducted in several stages, which can be seen in the research flow chart, as shown in Figure 1.

![Figure 1. Flow chart for sapon intake research methods](image-url)
The research were adopted several formulae, the equation that uses in hydraulic analyze, i.e. Discharge plan [3]:

\[ Q_r = \mu \cdot b \cdot h \cdot a \cdot \sqrt{2 \cdot g \cdot z} \]

High door openings (done by trial and error), loss of high energy at opening:

\[ z = 0.15 - 0.30 \text{ (KP-02)} \]

Debit per unit width (q):

\[ q = \frac{Q_r}{b} \]

h critic [4]:

\[ h_{cr} = \sqrt{\frac{\alpha \cdot q^2}{g}} \]

Initial speed [5]:

\[ h_{cr} = \sqrt{\frac{\alpha \cdot q^2}{g}} \]

Froude number [5]:

\[ F1 = \frac{v_1}{\sqrt{gha}} \]

Downstream water depth (h2) [5]:

\[ h_2 = \frac{1}{2} \cdot ha \left( \sqrt{1 + 8 \cdot F_1^2} - 1 \right) \]

Final speed [5]:

\[ v_2 = \frac{q}{h_2} \]

The specific energy size for each appearance [6]:

\[ ES1 = ha + \alpha \cdot \frac{v_1^2}{2 \cdot g} \]

\[ ES2 = h_2 + \alpha \cdot \frac{v_2^2}{2 \cdot g} \]

3. Results and discussion

The Progo River is located in the area of Kulon Progo Regency, which is part of the Special Region of Yogyakarta Indonesia. Geographically located between 7° 38' 42" - 7° 59' 3" South Latitude and 110° 1' 37" - 110° 16' 26" East Longitude. The area is 58,627.5 km2 covering 12 subdistricts and 88 villages (Figure 2).
Special Region of Yogyakarta irrigation network *intake* building. Sapon, located in Kulon Progo DIY district in 1970, was covered with sand, resulting in reduced channel capacity. The removal is moved 100 m downstream located on the outer corner of the right cliff of the Progo River and approximately 8.7 km from the river mouth. In 1979 the building was *free*. This Sapon *intake* was built by the Kali Progo Irrigation Project and completed in 1984 with four sluice gates with three pillars.

To review the *intake* ability, the analysis is seen from four conditions to get the discharge plan (Qr) with the varying height of the door opening (ha). The first assumption is, that of the four existing retrieval doors opened only one. The second only two doors are opened. The third is, of the four retrieval doors that are opened three. The fourth is that all four doors are opened. From the secondary data obtained from the Yogyakarta Mainstay Irrigation Project data, the following data are obtained for the primary channel:[7]

- Irrigation network area (A): 2250 Ha.
- The number of retrieval gates: 4 pieces.
- Pick up channel width (b): 1 meter.
- Intake height (h): 1.4 meter.

Discharge of water requirements [8] (can be seen in Table 1 and 2).

**Table 1.** Discharge of water requirements for *System Planning* (August Planting Pattern - Jul)

| Month   | AGUST | SEPT | OKT | NOV | DES | JAN |
|---------|-------|------|-----|-----|-----|-----|
|         | I     | II   | I   | II  | I   | II  |
| Discharge Requirement of Water (m³/sec) | 1.71  | 3.63 | 4.79| 4.54| 4.42| 4.50|
|         | I     | II   | I   | II  | I   | II  |
|         | 3.69  | 2.53 | 2.22| 3.57| 3.53| 3.10|
|         |       |      |     |     |     |     |

| Month   | FEB | MAR | APR | MAY | JUN | JUL |
|---------|-----|-----|-----|-----|-----|-----|
|         | I   | II  | I   | II  | I   | II  |
| Discharge Requirement of Water (m³/sec) | 3.16 | 3.33 | 3.48 | 2.33 | 1.83 | 1.80 |
|         | I   | II  | I   | II  | I   | II  |
|         | 1.45 | 1.24 | 1.55 | 1.79 | 1.78 | 1.29|

(Source: Fajarhati MA, 2006)
Table 2. Discharge of Alternative Water Needs (Planting Pattern Oct - Sep)

| Month | OKT | NOP | DES | JAN | FEB | MAR |
|-------|-----|-----|-----|-----|-----|-----|
|       | I   | II  | I   | II  | I   | II  |
| Discharge Requirement of Water (m$^3$/sec) | 1.73 | 3.67 | 4.25 | 3.90 | 3.80 | 3.93 |
|       | I   | II  | I   | II  | I   | II  |
|       | 3.12 | 2.19 | 2.06 | 3.26 | 4.00 | 3.62 |
|       | APR | MAY | JUN | JUL | AGUST | SEPT |
|       | I   | II  | I   | II  | I   | II  |
| Discharge Requirement of Water (m$^3$/sec) | 4.33 | 4.43 | 3.85 | 2.59 | 1.71 | 1.81 |
|       | I   | II  | I   | II  | I   | II  |
|       | 1.40 | 1.15 | 1.88 | 2.16 | 2.33 | 1.68 |

(Source: Fajarhati MA, 2006)

An important character of the flow through the sluice is the flow condition. That is, *free flow* or *submerged flow* (Figure. 3). To find out, whether the flow is free or submerged depends on the depth of the water downstream, which is alternately determined by the slope and roughness of the channel downstream of the door.

![Figure 3. Scheme of a gate operating under free (a) and submerged (b) flow condition [9]](image)

According to the Irrigation Planning Standard, the KP-02 Main Building part planning criteria, the Ministry of Public Works for the planned discharge at the *intake* or pickup capacity must be at least 120% or 1.2 of the retrieval requirement (*dimension requirement*) in order to increase flexibility and to meet the needs which is higher during the project life.

\[
\text{Debit plan (Qr) } = 1.2 \times Qh = 1.2 \times 4.43 = 5.32 \text{ m}^3/\text{sec}
\]

Energy loss at the intake (z) door are between 0.15-0.30 m, with Eqs.(1). According to Binilang [10], the local phenomenon of flow of hydraulic jump can occur on the downstream intake door, which is a condition of flow due to the transition of subcritical flow to critic or subcritic flow. The transition process resulted in a considerable loss of energy.

To find the value of the door opening height (ha) is done by *trial and error* until the value of the door opening height (ha) that occurs in the equation above gets the discharge value as planned. High energy loss value (z) is used as a benchmark or comparison that the water can still flow when the door is opened. For retrieval doors on two, three, and four-door openings, in principle, the steps are the same as in one door opening.
Table 3 and Figure 4 represent the graph of the relationship between ha and z for one door opening with a measure of energy loss at the take-up door (z) of 0.15-0.30 m, the high value of the door opening that occurs in the range of 2.74 - 3.87 m.

**Table 3. Relationship between ha and z for one door opening**

| Qr  | µ   | b  | Ha | z  |
|-----|-----|----|----|----|
| 5.32| 0.80| 1.00 | 2.74 | 0.30 |
| 5.32| 0.80| 1.00 | 2.79 | 0.29 |
| 5.32| 0.80| 1.00 | 2.84 | 0.28 |
| 5.32| 0.80| 1.00 | 2.89 | 0.27 |
| 5.32| 0.80| 1.00 | 2.94 | 0.26 |
| 5.32| 0.80| 1.00 | 3.00 | 0.25 |
| 5.32| 0.80| 1.00 | 3.06 | 0.24 |
| 5.32| 0.80| 1.00 | 3.13 | 0.23 |
| 5.32| 0.80| 1.00 | 3.20 | 0.22 |
| 5.32| 0.80| 1.00 | 3.28 | 0.21 |
| 5.32| 0.80| 1.00 | 3.36 | 0.20 |
| 5.32| 0.80| 1.00 | 3.44 | 0.19 |
| 5.32| 0.80| 1.00 | 3.54 | 0.18 |
| 5.32| 0.80| 1.00 | 3.64 | 0.17 |
| 5.32| 0.80| 1.00 | 3.75 | 0.16 |
| 5.32| 0.80| 1.00 | 3.87 | 0.15 |

**Figure 4.** Graph of the relationship between ha and z at one door opening

From the analysis carried out, there were three types of flow at the **intake** door, namely: Subcritical Flow and Free Flow with the Froude number is F1 < 1 and ha > h2, criticism and Flow Free Flow with the Froude number value F1 = 1 and ha = h2, and Supercritical Flow and Submerged Flow, Choppy Jump with the Froude number value F1 > 1 → Springboard choppy and ha < h2. Figure 5.
Hydraulics analysis result that using Eqs. (1)-(9) based on the Debit of Water Requirement System Planning (August Planting Pattern - Jul) are shown in Table 4 and used as a benchmark for the operational height of the intake door openings every half monthly shown in Table 5. While the alternative water requirements (cropping patterns Oct - Sep) shown in Table 6–7.

**Table 4. Hydraulics Analysis Results That can be applied in the field based on the Discharge of Water Requirement System Planning (August Plant Pattern - Jul)**

| Month    | AUGUST | SEPT  | OKT  | NOV  | DES  | JAN  | FEB  | MAR  | APR  | MAY  | JUN  | JUL  |
|----------|--------|-------|------|------|------|------|------|------|------|------|------|------|
| I        | I      | I     | I    | I    | I    | I    | I    | I    | I    | I    | I    | I    |
| Qr (m³/s) | 2.05   | 2.18  | 1.92 | 1.82 | 1.77 | 1.78 | 2.03 | 2.12 | 1.33 | 2.09 | 1.90 | 2.00 |
| ha Max (m) | 1.06   | 1.12  | 0.99 | 0.94 | 0.91 | 0.93 | 1.14 | 0.78 | 0.69 | 1.10 | 0.96 | 0.98 |
| ha Min (m) | 1.50   | 1.59  | 1.40 | 1.32 | 1.29 | 1.31 | 1.61 | 1.11 | 0.97 | 1.56 | 1.54 | 1.36 |
| ha Average | 1.28   | 1.32  | 1.19 | 1.13 | 1.10 | 1.12 | 1.32 | 0.94 | 0.83 | 1.33 | 1.32 | 1.16 |
| v1 (m²/sec) | 0.76   | 0.79  | 0.72 | 0.70 | 0.66 | 0.69 | 0.79 | 0.62 | 0.56 | 0.78 | 0.77 | 0.71 |
| v2 (m²/sec) | 5.13   | 5.74  | 4.83 | 4.64 | 4.54 | 4.61 | 5.47 | 4.80 | 3.63 | 5.26 | 4.75 | 4.80 |
| L1 (m)  | 5.27   | 5.65  | 4.75 | 4.26 | 4.38 | 5.82 | 3.56 | 2.81 | 5.55 | 5.50 | 6.14 | 4.73 |
| E11 (m) | 1.41   | 1.46  | 1.26 | 1.25 | 1.23 | 1.37 | 1.07 | 0.94 | 1.46 | 1.45 | 1.32 | 1.27 |
| E12 (m) | 1.78   | 1.35  | 1.49 | 1.44 | 1.47 | 1.93 | 1.20 | 1.56 | 1.83 | 1.81 | 1.81 | 1.54 |
| AEF (m) | -0.33  | -0.38 | 0.26 | 0.23 | 0.21 | 0.22 | 0.42 | 0.12 | 0.08 | 0.37 | 0.36 | 0.25 |

**Table 5. Operational Door Intakes based on Discharge Water Needs System Planning (August Plant Pattern - Jul)**

| Month    | AUGUST | SEPT  | OKT  | NOV  | DES  | JAN  | FEB  | MAR  | APR  | MAY  | JUN  | JUL  |
|----------|--------|-------|------|------|------|------|------|------|------|------|------|------|
| I        | I      | I     | I    | I    | I    | I    | I    | I    | I    | I    | I    | I    |
| ha 1 Door Opening | 2.72   | 3.77  | 3.58 | 3.20 | 3.36 | 3.26 | 3.75 | 1.89 | 1.61 | 2.47 | 2.74 | 2.73 |
| ha 2 Door Openings | 0.64   | 0.94  | 0.90 | 0.86 | 0.80 | 0.83 | 1.35 | 1.32 | 1.16 | 1.28 | 1.35 | 1.28 |
| ha 3 Door Openings | 0.43   | 0.69  | 0.77 | 0.77 | 0.73 | 0.77 | 0.78 | 0.85 | 0.97 | 0.98 | 0.95 | 0.97 |
| ha 4 Door Openings | 0.32   | 0.48  | 0.31 | 0.35 | 0.47 | 0.47 | 0.67 | 0.66 | 0.58 | 0.62 | 0.65 | 0.65 |

Subcritical Flow and Free Flow

Criticality and Flow Free Flow

SuperCritical Flow and Submerged Flow, Choppy Jump

Figure 5. Types of flow at the intake door
Table 6. Hydraulics Analysis Results That can be applied in the field based on Alternative Water Needs (Planting Patterns Oct - Sep)

| Month   | OKT | NOP | DES | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEPT |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| h= 1 Door Opening |     |     |     |     |     |     |     |     |     |     |     |     |
| 1.28   | 2.74 | 3.17 | 2.91 | 2.83 | 2.93 | 2.32 | 1.64 | 1.54 | 2.45 | 2.06 | 2.7 | 3.23 |
| 2.31   | 2.38 | 3.31 | 2.87 | 1.95 | 1.28 | 1.35 | 1.64 | 0.66 | 1.4 | 1.61 | 1.7 | 1.79 |
| h= 2 Door Opening |     |     |     |     |     |     |     |     |     |     |     |     |
| 0.84   | 1.87 | 1.96 | 1.46 | 1.42 | 1.47 | 1.36 | 0.82 | 0.77 | 1.22 | 1.49 | 1.35 | 1.65 |
| 1.44   | 0.97 | 0.64 | 0.67 | 0.52 | 1.33 | 1.29 | 1.22 | 1.77 | 1.11 | 1.06 | 0.86 | 0.82 |
| h= 3 Door Opening |     |     |     |     |     |     |     |     |     |     |     |     |
| 0.43   | 0.01 | 1.06 | 0.97 | 0.94 | 0.99 | 0.87 | 0.55 | 0.51 | 0.61 | 0.9 | 1.08 | 1.1 |
| 0.11   | 0.96 | 0.64 | 0.63 | 0.51 | 1.05 | 1.03 | 1.03 | 1.57 | 1.48 | 1.35 | 1.06 | 0.92 |
| h= 4 Door Opening |     |     |     |     |     |     |     |     |     |     |     |     |
| 0.32   | 0.08 | 0.79 | 0.73 | 0.71 | 0.73 | 0.58 | 0.49 | 0.41 | 0.38 | 0.61 | 0.75 | 0.81 |
| 0.81   | 0.34 | 0.52 | 0.43 | 0.34 | 0.43 | 0.32 | 0.24 | 0.22 | 0.33 | 0.34 | 0.35 | 0.37 |

4. Conclusion
From the analysis, the results has shown that one until three doors opening more efficient to get the water requirement the intake operational system based on the water demand system planning (planting pattern Agust - Jul) to be more efficient, four-door openings are not necessary because one, two or three-door openings meet the requirements for operational intake doors with high door openings -h (height of intake holes). The operation of intake doors based on the water demand system planning (August - Jul planting pattern) is more efficient than the intake door operation based on alternative water demand (Oct – Sep). There were three types of flow occured on the intake door, i.e. a subcritical flow and free flow, critical flow and free flow, supercritical flow and submerged flow, choppy jump. Finally, the results of the analysis can be concluded that Sapon intake capable of flowing water following the required discharge.

References
[1] Triatmodjo, Bambang, 1993. Hydraulics Volume 1. Beta offset. Yogyakarta
[2] Irawan, RO, 2016. Study of Sluice Openings and Flow Efficiency in Irrigation Areas. Thesis. Makasar
[3] Ministry of Public Works, 2004. Irrigation Planning Standard, the KP-02 Main Building part planning criteria. Yogyakarta
[4] Ranga Raju, KG, 1986. Flow through Tebile channel. Jakarta. Erlangga Publisher
[5] Chow, VT, 1997. Open Channel Hydraulics. Jakarta, Erlangga Publisher
[6] Henderson, FM, 1966. Open Channel Flow. New York. MacMillan Publishing Co.Inc
[7] Ministry of General Affairs Ministry. 2004. Brief Description of Sapon Weir Development in the Kulon Progo River. Yogyakarta.
[8] Fajarhati MA, 2004. Analysis of Water Needs and Evaluation of Sapon Irrigation Area Planting Patterns. Final Project. Graduate Program. Gadjah Mada University. Yogyakarta.
[9] Oskuyi, Navid Nasehi., Salsami, Farzin, 2012. Vertical Sluice Gate Discharge Coefficient.
Journal of Civil Engineering and Urbanism Vol. 2 Issue 3 (108-114) 2012

[10] Binilang, A. (2014). Behaviour of the relationship between the hydraulic parameters of the water jumping through the sliding door on the open. *Scientific Journal of Engineering Media, 4*(1), 41-44