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# Monitoring and Evaluation of Hydraulic Off-Takes Sensitivity in Left Main Canal Scheme in Chiang Rai Province

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## Abstract

The study aims at monitoring and evaluation the sensitivity of hydraulic off-takes and improving implementation program of selected hydraulic off-take in the Left Main Canal scheme (LMC scheme) to help manage the Mae Lao irrigation scheme (MLIS), Chiang Rai province in the dry season. Water scarcity is always a serious problem in the dry season due to over cultivated area, investigating irrigation water supply along the main canal level in terms of equity of water distribution is necessary to the monitoring and evaluation. 13 selected hydraulic off-takes structures along the LMC are measured by the off-take sensitivity indicator for identifying low, medium and high values of off-takes sensitivity. All results found that the upstream-end section has low sensitivity values (less than 1), while the middle and downstream-end sections have high sensitivity values (greater than 2). According to these study results, the recommendation for implementation program of selected off-takes along to the LMC are such that 1. For the low off-take sensitivity values covers the upstream-end section only require intermittent gate adjustments 2. For the medium off-take sensitivity values includes some parts of the upstream-end only require moderate adjustment and frequency maintenance program 3. While the high sensitivity, including almost all structures located from the middle to the downstream-end section, would require frequent adjustments, calibrations, and maintenance program before the beginning of wet and dry seasons.

**Keywords:** Off-takes sensitivity; Monitoring and Evaluation; Irrigation scheduling

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## 1. Introduction

The Left Main Canal scheme (LMC scheme) is one sub irrigation district area, under the Mae Lao Irrigation Scheme (MLIS). The LMC scheme supply irrigation water for the 1,920 ha of paddy (rice growing) area in the dry season. Over-cultivation and poor performance of hydraulic structures [15] lead to extreme water scarcity during dry season. Over cultivation necessitates more irrigation supply; while poor performance of hydraulic structures adversely affects water distribution equity, particularly, from main canal level to secondary canal level. Therefore, monitoring and evaluation of hydraulic off-take sensitivity during the dry season (March to the end of April) is fundamental to improve cost-effectiveness of ensuring water distribution equity along the main canal level.

Hydraulic off-take sensitivity is the approach to assess flow variation of hydraulic control structures for irrigation. This approach was developed by [4], [6] studied the sensitivity of hydraulic structures. By applying this approach at the canal level, and then [10] developed the concept of sensitivity for conveyance system levels in order to investigate the overall levels of the system and the effects of water perturbation for irrigation water distribution.

Sensitivity study of irrigation water conveyance covers all levels of conveyance system. MASSCOTE approach [7] was developed by FAO in year 2007 to investigate hydraulic off-takes sensitivity from subsystem of irrigation conveyance to overall conveyance system. Moreover, there have been many studies relevant to hydraulic sensitivity. For example, [5] studied hydraulic sensitivity indicators to assess canal operations at irrigation canal networks in Iran. [14] studied the influence of cross-regulator settings on off-takes through hydraulic structure sensitivities in the Doroodzan irrigation network in Iran. In Thailand, [8] studied the sensitivity of main hydraulic structures to monitor water distribution plans and operate hydraulic structures within irrigation canal networks managed by the Royal Irrigation Department (RID).The study

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has two main objectives : 1. to investigate the sensitivity of off-takes on the main canal level during dry season in the LMC scheme 2. to improve implementation program of hydraulic off-take structures on the main canal level.

### *1.1. Study Area*

In the Figure 1., the LMC is one of four major sub-irrigation schemes under the MLIS, which is the large irrigation scheme in the northern of Thailand. The LMC scheme is located in Amphur Mae Lao, Chiang Rai province. It is one of two irrigation districts (the Right Main Canal scheme and the Left Main Canal scheme) belonging to the larger MILS scheme. Generally, the LMC scheme supplies irrigation water for rice paddies in the irrigation service area. The LMC scheme is divided into five irrigation zones. During the dry season, irrigation service area can supply irrigation water in Zone 2 (43 ha), Zone 3 (450 ha), Zone 4 (890 ha), and Zone 5 (537 ha) respectively.

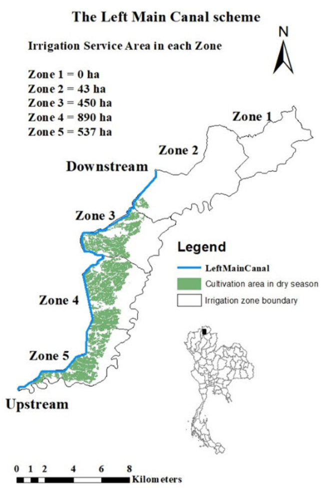


**Figure 1**: The Left Main Canal (LMC) scheme

### *1.2. Off-takes in the main canal system*

In the LMC scheme, the main canal length is 24.7 km. 13 hydraulic from the total of 17 off-take structures were selected for this study. Selected hydraulic off-takes and all position along the leftside of main canal in each structure were shown in the Table 1.(*).

### *1.3. Irrigation scheduling*

Generally, irrigation scheduling during dry season starts on January and finishes by May every year. The scheduling controls irrigation supply along with the main canal level by rotational flow pattern from zones 5 to zone 2. In Table 2., the scheduling starts from zone 5 (2 days), zone 4 (2 days), zone 3 (3 days) tozone 2 (3 days). In this study, selected days for measuring hydraulic off-take sensitivity started from $17^t h$ March to $21^s t$ April for 36 days.

### *1.4. Theory*

#### *1.4.1. Flow description of hydraulic off-takes*

Concept of off-takes sensitivity was originally published by the FAO report no. 63 in year 2007 [3]. In the Figure 2., flowing description through hydraulic off-takes with different downstream conditions (free-flow or submerged conditions).

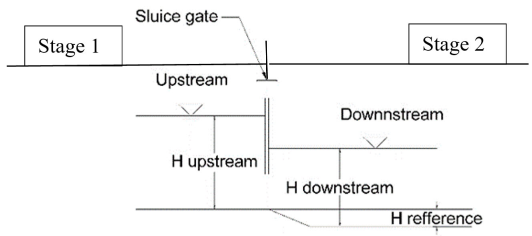


**Figure 2**: Flowing description through hydraulicoff-takes with different downstream

According to Figure 2., general governing equations of flow through hydraulic off-takes are:

$$q = aA\,(H_{us} - H_{ds})^{\alpha} \quad \text{(Stage 1)} \qquad (1)$$

$$q = a'b\left(H_{ds} - H_{ref}\right)^{\beta} \quad \text{(Stage 2)} \qquad (2)$$

Where, $A$ is flow section parameter through the structure ($A$ is area through the orifice for an undershot flow, and $A$ is the crest length for an overshot flow);a is discharge coefficient equal to $c(2g)^{0.5}$;c is flow coefficient function of the shape of the flow (c 0.5 for an orifice);a' and b are hydraulic parameters of the stage 2;a, b are exponent equal to 1/2 for undershot flow, to 3/2 for overshot, and about to 1.6 for normal flow;$H_{us}$ is water level upstream of the structure;$H_{ds}$ is water level downstream of the structure;$H_{ref}$ is areference level depending on the downstream flow conditions;q is discharge through the structure.

$H_{ref}$ is a constant reference level taken at: (1) the crest level of the weir where there is ameasurement weir; or (2) a reference level (bottom bed or a crest level) further downconditioning the flow at the structure. It is assumed that $dH_{ref}$ equals 0.

#### *1.4.2. Conditions of flow through hydraulic off-takes*

Free-flow conditionsat the offtake, equation in stage 2 is irrelevant and itreduces to one equation as equation in stage 1. Then, Hds is taken either as the crest level of the weirin the case of overshot, or as the orifice axis in the case of undershot. Moreover, flow parameters characteristics ($\alpha$ and $\beta$) are affected by flow conditions in the Table 3.

**Table 1.** Weights of dimensions and indicators

| Zone | Position(km + m) | Hydraulic structure |
|---|---|---|
| 5 | 3+756 | Off-take 1* |
| | 5+023 | Off-take 2* |
| | 5+600 | Off-take 3* |
| 4 | 7+455 | Off-take 3.1* |
| | 8+123 | Off-take 4* |
| | 8+848 | Off-take 5* |
| | 9+862 | Off-take 6* |
| | 10+621 | Off-take 7* |
| | 11+672 | Off-take 8* |
| | 12+976 | Off-take 9* |
| 3 | 16+006 | Off-take 10* |
| | 17+468 | Off-take 11* |
| | 18+429 | Off-take 11.1* |

* Selected hydraulic structure off-takes for study

**Table 2.** Irrigation scheduling for the LMC scheme during the dry season (2020)

| Month | Zone 5 | Zone 4 | Zone 3 | Zone 2 | Zone 1 |
|---|---|---|---|---|---|
| **March** | **17,18** | **19,20** | **21,22,23** | **24,25,26** | **27,28,29** |
| | **30,31** | | | | |
| **April** | | **1,2** | **3,4,5** | **6,7,8** | **9,10,11** |
| | **12,13** | **14,15** | **16,17,18** | **19,20,21** | 22,23,24 |

Bold numbers are selected days for study

## 2. Methodology

The methodology of study has been adapted from [1], which was developed as a tool to improve irrigation project by monitoring and evaluation. The procedure was summarized by steps as below.

1. *Identification target of hydraulic off-takes in the main canal level*, selected to study for 13 hydraulic off-take structures, was measured the water level at upstream and downstream in each structure (see in Table 1.).

2. *Setting objectives that two objectives of this study* (to investigate the sensitivity of off-takes on the main canal level during the dry season and to improve implementation program of hydraulic off-take structures in the study area) were set in the study through measurement of hydraulic off-takes sensitivity as the indicator.

3. *Defining hydraulic off-takes measurement* that the measurement of water depth (upstream and downstream) was measured by two operation gate staffs during selected time periods for 36 days (see in Table 2.).

4. *Analysis outputs* that two outputs (sensitivity of hydraulic off-takes and implemented program operation of hydraulic off-takes), was analyzed by the hydraulic off-takes sensitivity indicator and then all indicators were analyzed for searching low, medium and high sensitivity values in each structures along to the main canal for improving implementation program of hydraulic off-takes in the main canal level.

### 2.1. Data collection

To investigate the variation of irrigation supply of the main canal level in the dry season, data was collected during March to April (see in Table 2.) in year 2021and 13 hydraulic structures will be selected to measure the water at upstream and downstream in each structure at the LMC scheme. For investigation of characteristics of main canal level, semi-structure interview will be held on the office before the irrigation supply season began by irrigation staffs using a Participatory Rural Appraisal (PRA) technique [2].

### 2.2. Analysis

The analysis of this study consisted of two steps according to two study objectives. Off-takes sensitivity analysis and implementation program of hydraulic off-take structures analysis were analyzed through relevant information in data collection procedure.

#### 2.2.1. Off-takes sensitivity analysis

The off-takes sensitivity is defined as a ratio of the relative variation of outputs (downstream water level) to the variation of the inputs (upstream water level) of controlled gate of water distribution. This is shown in equation (3).

$$Sensitivity = \frac{Variation of outputs}{Variation of inputs} \quad (3)$$

The sensitivity of off-takes and the cross regulators are shown in equations (2) and (3).

$$S off-take = \frac{Dq/q}{DH} \, (m^{-1}) \quad (4)$$

Where S off-take is the sensitivity of off-takes, Dq/q is the ratio of relative discharge of the hydraulic struc-

**Table 3.** Conditions of flow and reference to be considered in calculations

| Specific conditions | HREF | Stage 2. equation | $\alpha$ | $\beta$ |
|---|---|---|---|---|
| Undershot free flow | Orifice axis | Not needed | 0.5 | no |
| Overshot free flow | Crest level of the weir | Not need | 1.5 | no |
| Undershot submerged by a downstream measurement weir | H crest of the measurement weir | Need | 0.5 | 1.5 |
| Undershot submerged normal uniform flow | H bed bottom of the downstream canal section | Need | 0.5 | 1.66 |

ture and DH is the water differential depth upstream and downstream (m).

In equation (5), head equivalent (HE) is developed to reduce the equation term(q. DH) in equation (4). It represents to the characteristics of flow condition (undershot or overshot flow) as shown in the Figure 2.It can be shown in the equation (5).

$$HE = (Hup - Hds)/[(\alpha/\beta)(Hds - Href)](m) \quad (5)$$

In this study, assumption of flow conditions is defined as the undershot free flow, so, the head equivalent (HE)is equal to different depth between H up and H ds due to irrelevant equation of stage 2 ( is not consideration) in the Table3.

According to the equation (4), the term of differential equation (Dq/q) is represented by the exponential value as constant term ()of hydraulic off-takes and DH is represented by HE. So, the hydraulic off-takes sensitivity equation is newly developed in the equation (6).

$$Soff - take = \frac{\alpha}{HE}\,(m^{-1}) \quad (6)$$

The meaning of hydraulic off-takes sensitivity can be defined as follows: low sensitivity (less than 1), medium sensitivity (between 1 and 2), and high sensitivity values (over 2).

### 2.2.2. *Implementation program of hydraulic off-take structures analysis*

All sensitivity of hydraulic off-takes was mapped in the table for searching low, medium and high values of sensitivity index of each structure along the main canal of the study area.If any structures were high sensitivity values, it will be required to increase frequency of operation maintenance and calibration in the implementation programs, referred by the Thai Royal Irrigation Management manual[11], [12] and [13].

## 3. Results

### 3.1. *Hydraulic off-takes sensitivity in the main canal level*

Measurement of water level sites began fromzone 5 to zone 2 respectively. However, in real situation, the measurement could not be measured in zones 2 due to no irrigationwater supply in this zone. General characteristics of hydraulic control structures on the main canal level during measurement the water depth can be described that:

o Cross-regulators in the main canal are not fully opened or some structures are closed. Both overshot flows and submerged flow conditions can be occurred along in the canal. o The cross regulator and hydraulic off-takes on the secondary canal level were fully open.

An average hydraulic off-takes sensitivity on the main canal level was shown intheFigure 2.,It concluded that in the upstream-end section, the off-take sensitivity values of zone 5, from 3+756 km to 5+600 km, demonstrated low sensitivity values (less than 1), except for off-take 1, had a medium sensitivity value (1.14). Next, in the middle-end section, the off-takes sensitivity in zone 4 (7+455 km to 8+976 km) showed higher sensitivity values (over 2), except for off-take 4, had a medium sensitivity value (1 - 2). And the downstream-end section in Zone 3, 16+006 km to 18+429 km was a high sensitivity value.

For the weekly averages of off-takes sensitivities along the main canal level in the Table 4, zones 5 increased from weeks 1 to 3 and decreased from weeks 3 to 4., zone 4 slowly increased from week 1 to week 2, sharply increased in week 3, and then decreased form weeks 3 to week 4. And the sensitivity values for zone 3 increased from week 1 to week 2; however,both weeks 3 and 4 could not be measured due to no irrigation water supply in this area.

### 3.2. *Improving implementation program of hydraulic off-takes on the main canal level*

Final results of this during selected time period provided helpful information to improveimplementation program through operation and maintenance program in the main canal level of the study area. It can be described as below.

In the Table5., almost hydraulic off-take structures were generally high off-takes sensitivity (over 2). These structures had highly variation of irrigation supply, so adjustment, calibration, and maintenance programs of hydraulic control should be strictly monitored(more than 2 times per year).In this study, there are three groups of off-take structures of sensitivity values (low, medium, or high). Groups with low

**Table 4.** Average hydraulic off-takes sensitivity per week in the main canal system

| Zone | Position | Hydraulic structure | Average sensitivity of off-take in each week($m^{-1}$) | | | |
|---|---|---|---|---|---|---|
| | | | **Week 1 (March)** | **Week 2 (April)** | **Week 3 (April)** | **Week 4 (April)** |
| 5 | 3+756 | Off-take 1 | 0.98±.02 | 1.06±.02 | 1.34±.05 | 1.17±.30 |
| 5 | 5+023 | Off-take 2 | 0.71±.01 | 0.94±.06 | 0.83±.03 | 0.76±.05 |
| 5 | 5+600 | Off-take 3 | 0.67±.07 | 0.65±.02 | 0.70±.06 | 0.49±.04 |
| | | | **Week 1 (March)** | **Week 2 (April)** | **Week 3 (April)** | **Week 4 (April-May)** |
| 4 | 7+455 | Off-take 3.1 | 1.41±.06 | 1.67±.00 | 4.01±.16 | 1.55±.30 |
| 4 | 8+123 | Off-take 4 | 1.30±.21 | 1.88±.21 | 1.93±.07 | 0.66±.12 |
| 4 | 8+848 | Off-take 5 | 3.94±.61 | 3.33±.00 | 6.70±.45 | 2.56±1.61 |
| 4 | 9+862 | Off-take 6 | 4.01±.16 | 3.75±.42 | 5.63±.63 | 3.84±0.71 |
| 4 | 10+621 | Off-take 7 | 2.19±.19 | 6.25±2.08 | 1.97±.81 | 2.86±0.47 |
| 4 | 11+672 | Off-take 8 | 3.35±.22 | 1.19±.19 | 1.66±.34 | 4.82±3.51 |
| 4 | 12+976 | Off-take 9 | 3.06±.79 | 2.50±.00 | 1.34±.58 | 1.20±.47 |
| | | | **Week 1 (March)** | **Week 2 (April)** | **Week 3 (April)** | |
| 3 | 16+006 | Off-take 10 | 3.30±1.14 | 2.15±.29 | NA | |
| 3 | 17+468 | Off-take 11 | 3.69±.51 | 3.20±.96 | NA | |
| 3 | 18+429 | Off-take 11.1 | 2.83±.04 | 4.79±1.73 | NA | |

**Remark**: the value less than 1 = low sensitivity, the value between 1 to 2 = medium sensitivity
**Remark**: and the value more than 2 = high sensitivity, NA = Not available

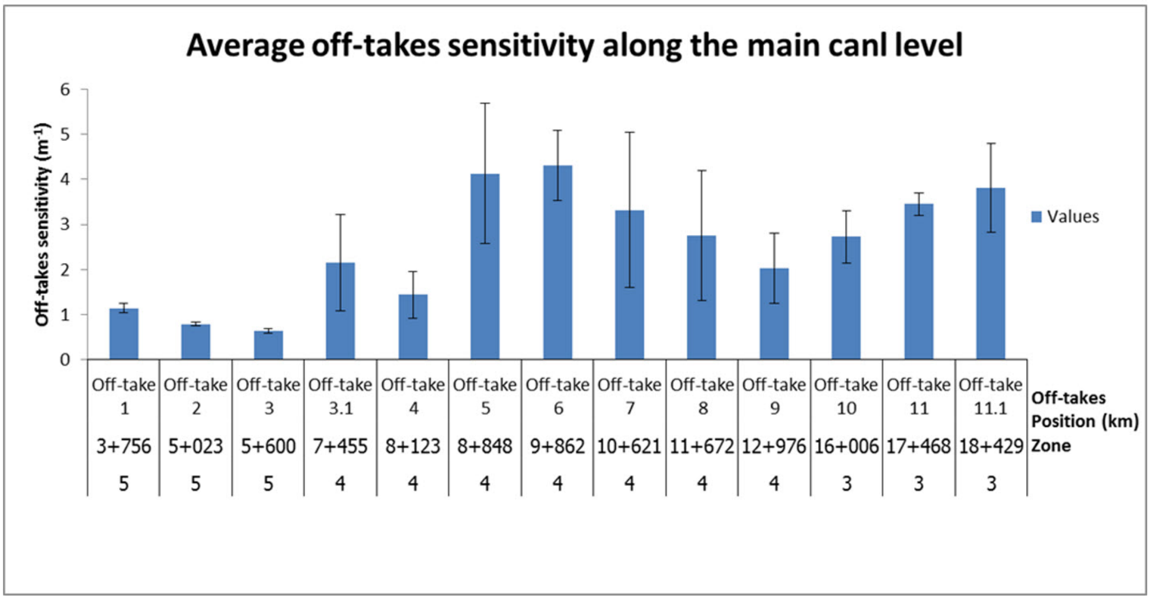


**Figure 3**: Average off-takes sensitivity along with main canal level.

off-take sensitivity (off-takes 2 and 3) should be required only low-frequency gate adjustments program (1 time per year), groups with medium off-take sensitivity should be requiredmoderate frequency adjustments and maintenance program(both wet and dry season starting). And the last group (high sensitivity) should be requiredmost frequent operation, adjustments, calibration, and maintenance program(more than 2 times per year).

The implementation procedure; operation, adjustment, calibrate and maintenance program are referenced by the RID manual.

## 4. Discussion and conclusion

### *4.1. Discussion*

According to thesestudy objectives, to make improvements or modifications of irrigation supply management on the main canal level, relevant factors affect to achieve the goal of monitoring and evaluation in this study can be described as below.

o Experienced staff capable for measuring water levels and high-quality measurement tools is necessary to measure water level data accuracy because more accuracy data of H us and H ds needed to require a skillful for using staff gauge and read all water depth values.

o For the assumption of the study, the undershot free flow condition was chosen to considerate because two

**Table 5.** Improvements of implementation process on the main canal level

| Off-take structures | Off-take sensitivity | Adjustment/ improvement of the implementation process |
|---|---|---|
| Off-takes 2 and 3 | Low | Low frequency of adjustment(1 time per year) |
| Off-takes 1 and 4 | Medium | Average frequency of adjustment and maintenance(both wet and dry season starting) maintenance(both wet and dry season starting) |
| Off-takes 3,3.1,5,6,7, 8, 9, 10, 11 and 11.1 | High | Most frequent adjustments, operation, calibration, and maintenance(more than 2 times per year) |

major reasons that (1) reduction a complexed equation in flow condition (stage 2.) in order to simplified to get water depth information and (2) smoothly flow of water in the main canal during the most water scarcity period in the dry season. So, the flow assumption will be a concept according to [10].

o Although, the irrigation scheduling was set by the rotational flow, started from zone 5 (2 days), zone 4 (2 days), zone 3 (3 days) tozone 2 (3 days), in the real situation of irrigation supply, it was a continuous flow (not a rotational flow). The irrigation scheduling cannot control to supply irrigation water from zone 5 to zone 2 because the water user group of upstream-end section open hydraulic off-takes. So, the water user groups among middle and downstream- end section were not enough received the irrigation supply. This why the reason that almost hydraulic off-takes (middle and downstream- end sections) were high off-take sensitivity because these areas had low water depth level in each hydraulic off-takes. So, almost flow condition in these sections were not undershot flow condition, this cause affected to variation of sensitivity of off-takes.

o Operation and maintenance program including, monitoring the water level and calibrating of hydraulic infrastructures, i.e., off-takes, cross-regulator on the main canal level should be implemented appropriately according to RID manuals. All of actions should be strongly support relevant equipment, people and budget by the irrigation management budget (by the RID and by the local irrigation budget) according to the participatory irrigation management concept, have been promoted by the RID.

o The water user group necessary to join the monitoring waterlevel in the main canal level. Two main reasons of importance of water user groups were (1) strength of water user groups through the strict rule of water usage for control to open and close all off-takes along to the LMC needed to handle a tailed-end problem in irrigation supply topic and (2) participatory irrigation management from hydraulic off-takes network distribution to field irrigation distribution needed to operate and maintenance by them according to the participatory irrigation management concept because only government sector could not possibly to operate and maintain all irrigation network distribution in the LMC scheme.

### *4.2. Conclusion*

Study results point to conclusion that almost all hydraulic sensitivity in upstream-end section show slow sensitivity values (less than 1), the middle and downstream end sections show high sensitivity values (over than 2). And for the implementation program of hydraulic off-takes on the main canal level, the recommendation focuses on frequency of calibration, operation and maintenance program of these structures that the low off-take sensitivity (off-takes 2 and 3), is on the upstream- end section, only required low-frequency adjustments, the groups of medium off-take sensitivity, including some parts of the upstream- end section, require moderate frequency adjustments and maintenance. While most of the high sensitivity structures located from the middle to the downstream- end of the canal, require frequent adjustments, operation, calibration, and maintenance program.

## References

[1] M.A Burton, Irrigation Management: Principles and Practices, Wallingford: CABI, UK, 2010.

[2] L. Cavestro, Participatory Rural Appraisal (PRA): Concepts Methodologies and Techniques, UniversitaDegliStudi Di Padova Facolta' Di Agraria, Italy, 2003.

[3] FAO., Modernizing Irrigation Management: The MASSCOTE Approach Mapping System and Services for Canal Operation Techniques, Irrigation and Drainage Paper No. 63, Food and Agriculture Organization of United Nations, Rome, 2007.

[4] L. Horst, Irrigation Systems. International Report. Agricultural University, Wageningen, Netherlands, 1983.

[5] S. Kouchakzadeh and A. Montazar, Hydraulic Sensitivity Indicators for Canal Operation Assessment. Irrigation and. Drainage Engineering,(2005)54 (4).

[6] S.I. Mahbub and N.D. Gulati, Irrigation Outlets. Atma Ram, Delhi, India, 1951.

[7] M. S. Seyedjavad, M. Mashaal, and A. Montazar, Evaluation of Hydraulic Sensitivity Indicators for Baffle Modules (Case Study: Varamin Irrigation and Drainage Network), Journal of HydraulicStructures, 1(2) (2014) 33—43.

[8] Y. Prayoon, Analysis of main infrastructures of hydraulic control in 13th Office of irrigation. The Royal Irrigation Project report. Thailand.www.kmcenter.rid.go.th/kmc13/km/send/vijai-2012-3.pdf, 2010, (Accessed date: 3 Aug 2018).

[9] D. Renault, Aggregated Sensitivity indicators of irrigation systems hydraulic behavior, Agricultural Water Management, 43(2) (2000) 151–157.

[10] D. Renault and H.M. Hemakumara, Irrigation Off-takes Sensitivity, Journal of Irrigation Drainage Engineering, 125:3 (1999) 131.

[11] RID., Monitoring and Evaluation of Water distribution Plan in Weekly Manual. Working Manual No. 10. Royal Irrigation Department. Thailand, 2010.

[12] RID., Flow Rate Calculation Manual. Working Manual No. 13, Royal Irrigation Department. Thailand, 2010.

[13] RID., Water Level and Hydraulic Structure Manual. Working Manual No. 14. Royal Irrigation Department. Thailand, 2010.

[14] M. Shahrokhnia, A.M. Javan and M. Shahrokhnia. , Influence of lateral canal water depth on off-take and cross regulator discharge. Irrigation and Drainage, 58(5): (2009) 561–568.

[15] U. Wongtragoon , N.Kubo and H. Tanji, Performance diagnosis of Mae Lao Irrigation Scheme in Thailand. (I) Development of unsteady irrigation water distribution and consumption model. Paddy Water Environ, 8(1) (2009) 1-–13.