2. Investments in Irrigation Infrastructure

Losses of Water in Irrigation Systems.
Efficiency of an Irrigation System

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Strengthening of master curricula in water resources management for the Western Balkans HEIs and stakeholders

Project number: 597888-EPP-1-2018-1-RS-EPPKA2-CBHE-JP

1. Investments in Irrigation Infrastructure

- Investments in irrigation infrastructure have multiple goals, depending on the level of the investments:
  - Farm Level
    - ✓ To decrease the labour use
    - ✓ To increase the water use efficiency (to decrease losses)
    - ✓ To increase and/or to make the yields sustainable
    - ✓ To improve the energy efficiency
  - Water User Association Level (Irrigation Field Level)
    - ✓ To increase the water use efficiency (to decrease losses)
    - ✓ To improve the energy efficiency
    - ✓ To decrease the water price

1. Investments in Irrigation Infrastructure

- Investments in irrigation infrastructure - goals:
  - Irrigation System Level
    - ✓ To increase the water use efficiency (to decrease losses)
    - ✓ To improve the energy efficiency
    - ✓ To facilitate the IS management
    - ✓ To improve the service quality (delivery of irrigation water)
    - ✓ To decrease the water price
- The investments in irrigation infrastructure in Bulgaria are supported mainly by *European Agricultural Fund for Rural Development*
  - There are also several other EU funds
    - ✓ e.g. Programme for Vines and Grapes

1. Investments in Irrigation Infrastructure

- The *Rural Development Programme* of EU developed requirements for support of the investments in irrigation
  - ➢ The requirements for the period 2014-2021 are described in the document

Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005

  - ➢ The Article 46 is dedicated to requirements in irrigation infrastructure

2. Requirements of EU

- According to Article 46 – Investments in irrigation
  - ➢ The investments are eligible for funding, if the following requirements are fulfilled

1. **A River Basin Management Plan** for the entire area in which the investment is to take place **is approved**
   a. The River Basin Management Plan is required by the Water Framework Directive of EU
   b. The measures under the River Basin Management Plan related to the agricultural sector have to be already specified.
2. **Water metering** enabling measurement of water use at the level of the supported investment **has be in place** or **has to be put in place as part of the investment**

2. Requirements of EU

- According to Article 46 – Investments in irrigation
  3. The investment for improvement of an existing IS, part of IS or irrigation installation (i.e. the investment, which *does not lead to net increase of irrigated area*) is eligible only if it offers **potential water savings (PWS)** of a minimum of between 5% and 25%, according to the technical parameters of the existing infrastructure.
  4. If the investment affects bodies of ground- or surface water whose status has been identified as less than good for reasons related to water quantity:
     a. the investment has to ensure an **effective reduction in water use** of at least **50%** of the **PWS**, estimated at the level of the investment;
     b. in the case of an investment in a single farm, it has to result in a reduction to the farm's total water use amounting to at least **50%** of the **PWS**

2. Requirements of EU

- According to Article 46 – Investments in irrigation
  5. None of the conditions in paragraph 4 shall apply to an investment in an existing installation which:
     a. affects only energy efficiency or
     b. is for creation of a reservoir or
     c. is for use of recycled water, which does not affect a body of ground or surface water.
  6. An investment resulting in a *net increase of the irrigated area* affecting a given body of ground or surface water *is eligible only if*:
     a. the status of the water body is not *less than good* for *reasons related to water quantity*; and
     b. an environmental analysis shows that there will be no significant negative environmental impact from the investment

2. Requirements of EU

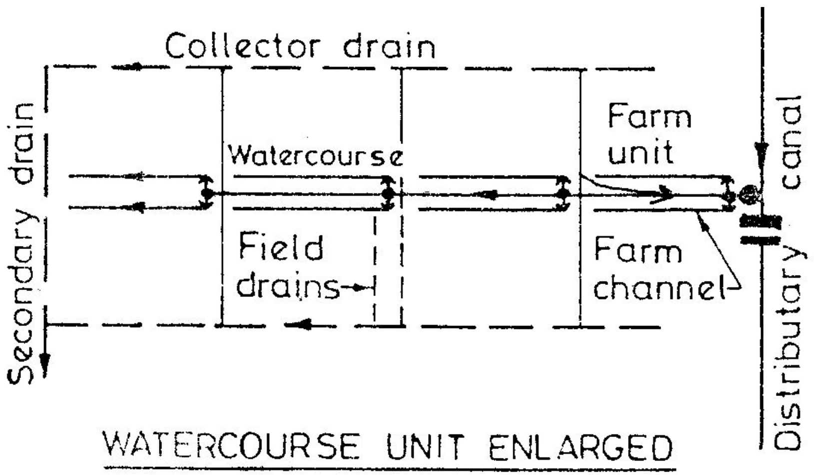
- According to Article 46 – Investments in irrigation
  7. Areas which are not irrigated but in which an irrigation has been done in the recent past, may be considered as irrigated areas for the purpose of determining the net increase of the irrigated area.
  8. The investments resulting in a *net increase of the irrigated area*, according to paragraph 6, may still be eligible if:
     a. they are combined with an investment in an existing irrigation installation or element of irrigation infrastructure, which offers **PWS** of a minimum **5% to 25%,** according to the technical parameters of the existing infrastructure and
     b. the investment ensures an ***effective reduction in water*** use, at the level of the investment, amounting to at least **50%** of the **PWS** made possible by the investment in the existing irrigation infrastructure.

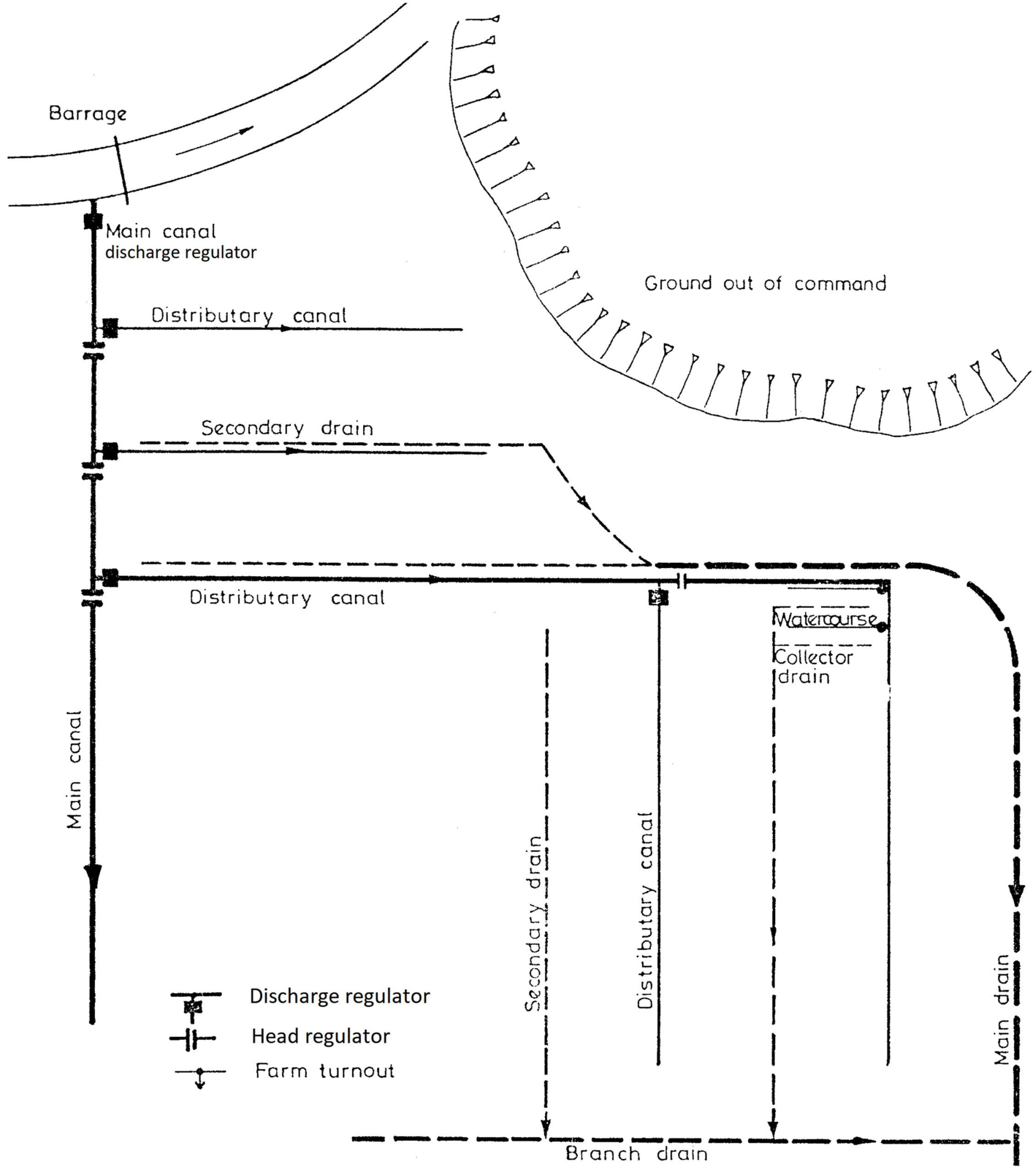
2. Requirements of EU

- According to Article 46 – Investments in irrigation
  9. As an exception in case of a *net increase of irrigated area*, the investments are eligible if a new irrigation installation is provided and it is *supplied* with water *from an existing reservoir*, and if the following conditions are met:
     a. the reservoir is identified in the River Basin Management Plan and is subject to the control requirements set out in the Water Framework Directive;
     b. there is in force either a maximum limit on total abstractions from the reservoir or a minimum required water discharge downstream of the reservoir;
     c. the investment in question does not result in abstractions beyond the maximum limit or result in a reduction of the water discharge downstream of the reservoir

3. Improvement of Flow Control

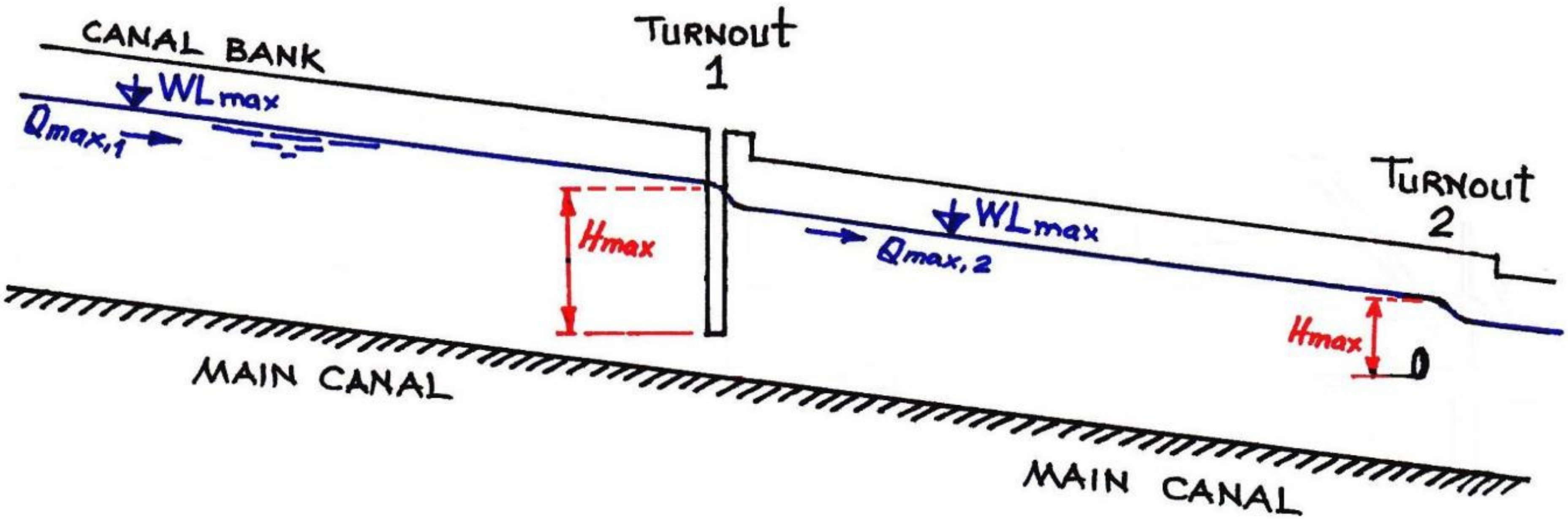
- Canals in IS
  - Main canal
  - Secondary canals
    - ✓ also called Distributary canal (Distributor – in BG)
  - Tertiary networks
    - ✓ Watercourses
    - ✓ Farm canals





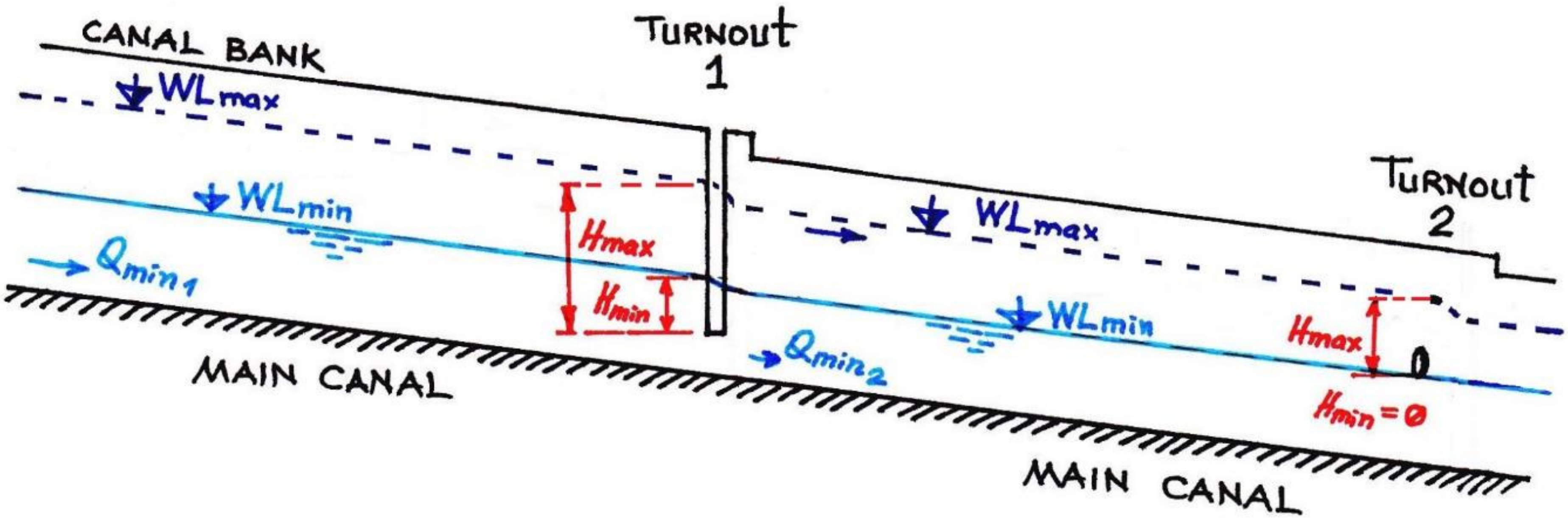
3. Improvement of Flow Control

- All delivery network is designed for maximal discharge, i.e. for maximum water level
- The position of the turnouts (and division boxes) is chosen according local conditions
- The maximum discharge through turnouts should be assured when the water level in major canal is minimal, i.e. head is *min*.



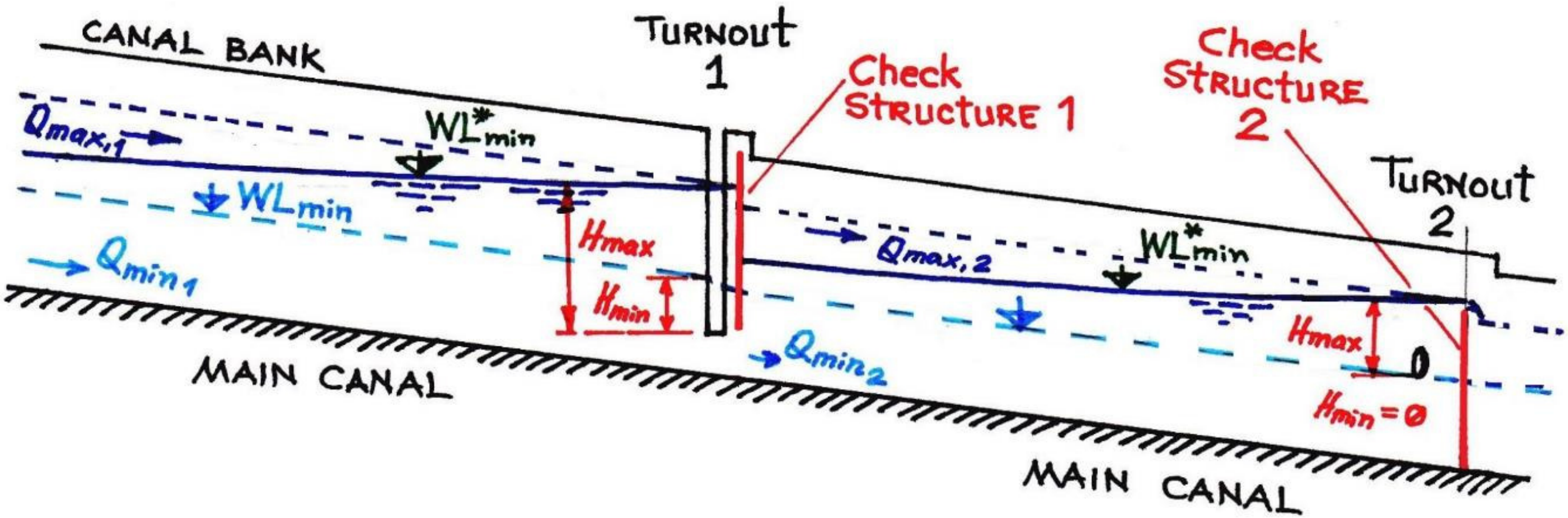
3. Improvement of Flow Control

- At minimum discharge in Main canal the water level drops
  - Some turnout entrances may occur above the water level
  - Head at turnouts varies significantly
  - Any change in discharge in Main canal causes change in water level, i.e. change in head at turnouts, thus the discharge of the turnouts is also changed. A lot of adjustments are needed at turnouts



3. Improvement of Flow Control

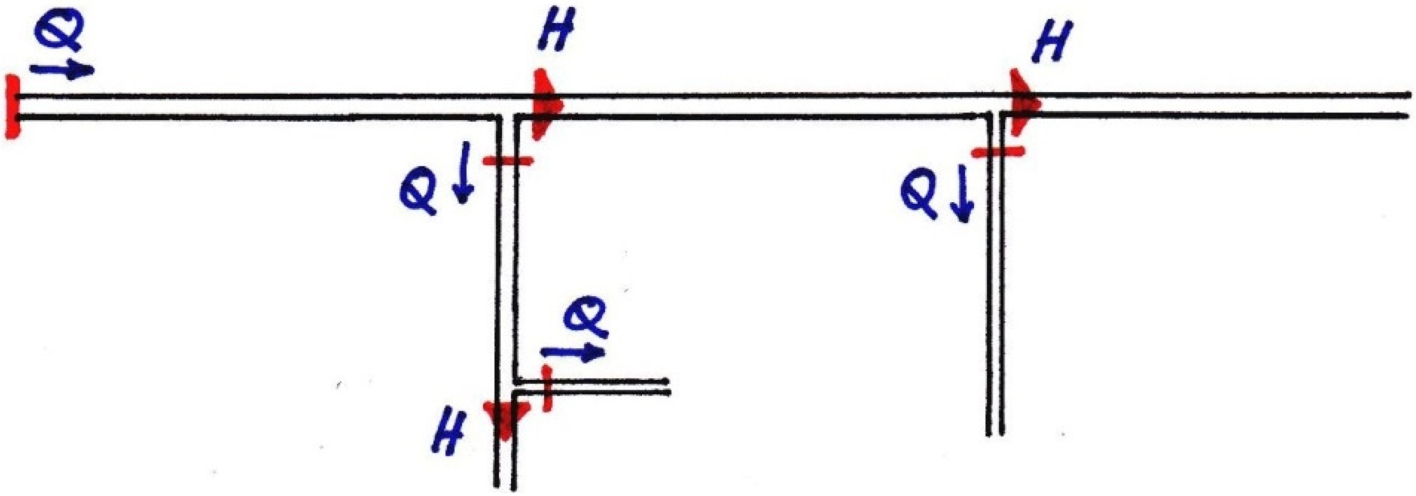
- Check structures are used for Flow Control
- Check structures at Main canal are needed keep constant head
  - ➢ To avoid frequent discharge adjustments at turnouts,
  - ➢ To decrease discharge variation
  - ➢ To facilitate flow measurement
  - ➢ To make flow measurement more accurate



3. Improvement of Flow Control

Basic Principles of Flow Control

- Flow control is used for both main flow parameters – discharge Q and head H (water level)
  - At turnouts the water level (head *H*) is regulated to be approximately constant.
  - At the head of each canal the discharge *Q* is adjusted (controlled)
- These 2 principles are used for water control in each level of the Delivery Network



4. Flow Control Systems and Structures

- **Upstream Control Systems**

Designed and operated for Scheduled Distribution in IS

- ➢ Head (Water Level) Control Structures
  - ✓ Long Crested Weir (overshot structure)
  - ✓ AMIL gates (undershot structure)
  - ✓ Leaf gates / Rubicon FlumeGate (overshot structure)

- **Downstream Control Systems**

Designed and operated for On-demand Distribution in IS

- ➢ Head (Water Level) Control Structures
  - ✓ AVIS regulators (undershot structures)
  - ✓ AVIO regulators (orifice structures)

4. Flow Control Systems and Structures

- <u>Discharge Regulators</u>

Some of them can be used also as flow measurement structures

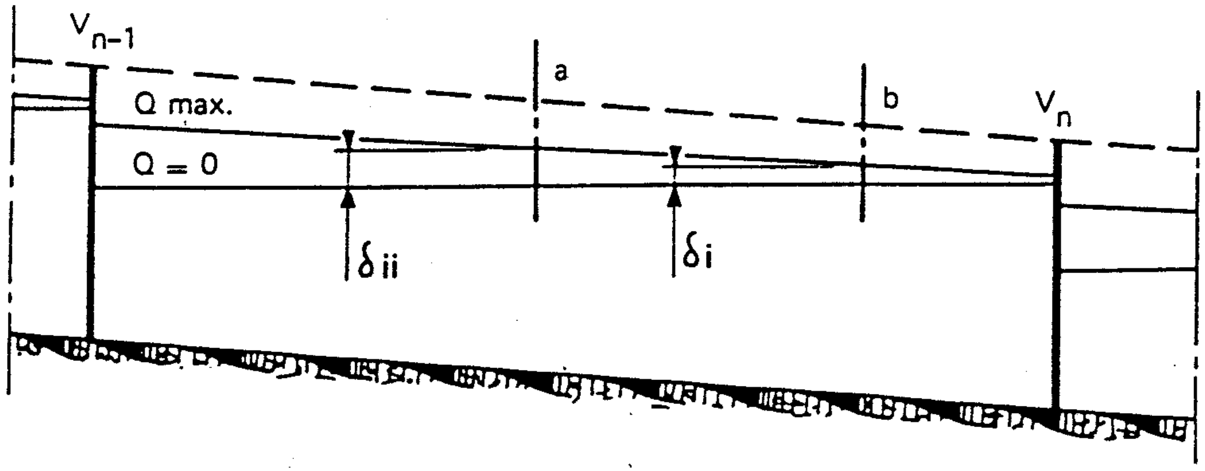
  - ✓ Baffle Distributors (undershot structure)
  - ✓ Khamadov Distributor (undershot structure)
  - ✓ Metergate (orifice/undershot structure)

- <u>Flow measurement Structures</u>
  - ✓ Flumes (Parshall flume, Venturi)
  - ✓ Weirs (Broad crested weirs, Sharp crested weirs)

N.B. There are other structures for discharge regulation and for flow measurement.

5. Upstream Control Systems

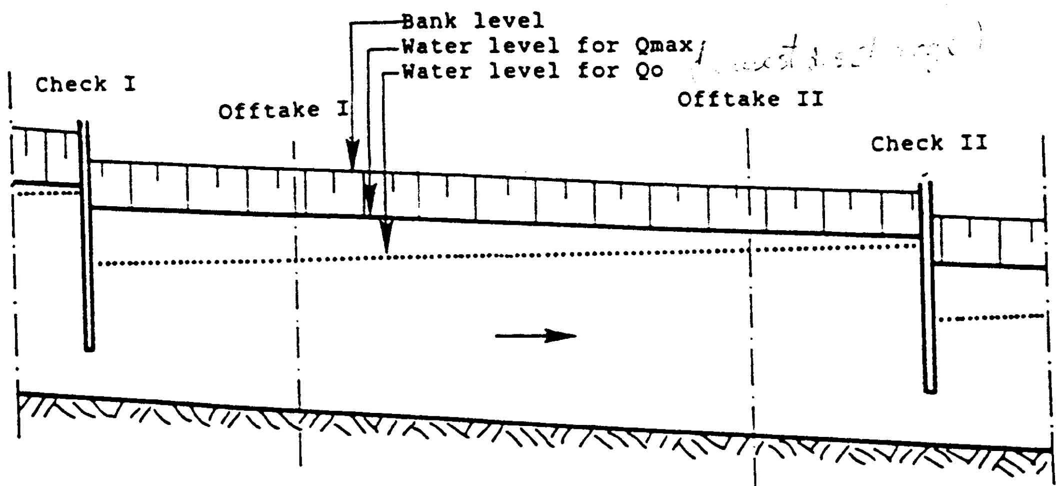
- Operation principle
  - The upstream water level at canal regulators located at Main and Secondary Canals is maintained fairly constant
  - The water is released from the headworks on the basis of pre-set schedule, which is done after the consumers send their requests
  - Gate operators adjust the discharges of tertiary unit turnouts according to requests, sent in advance, and according to the preset schedule



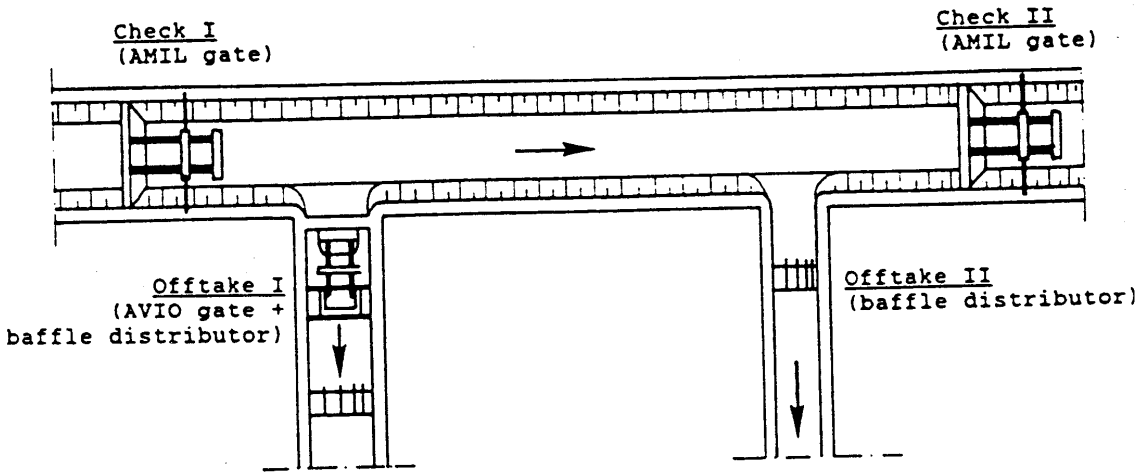
LONGITUDINAL SECTION OF CANAL REACH

5. Upstream Control Systems

- **Canal reaches**
  - Automated and non-automated systems have the same canal reach specifics.
  - The water level @ Q_{max} is approx. parallel to canal bed
  - The water level @ Q = 0 is horizontal
  - Canal bank – parallel to canal bed
  - The canal slope should be less than critical.
  - It is preferable that the turnouts are situated just upstream of the regulator, where the water level is maintained fairly constant.



LONGITUDINAL PROFILE UPSTREAM CONTROL



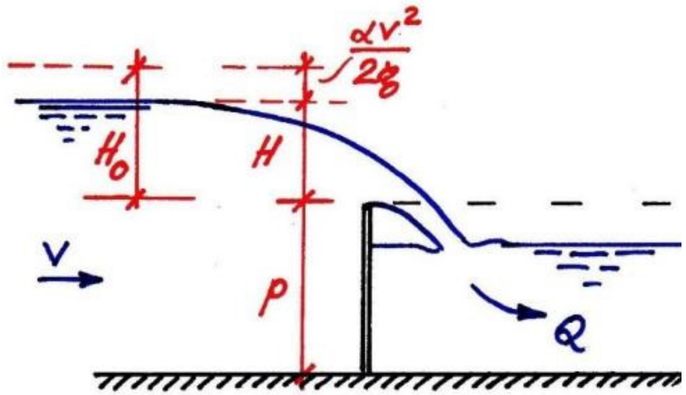
SCHEMATIC SITUATION OF REACH FOR UPSTREAM CONTROL

5. Upstream Control Systems

- **Water Level Regulators**
  - **Long Crested Weirs**
    - ✓ The weir should be in free flow conditions, i.e. the weir should not be submerged

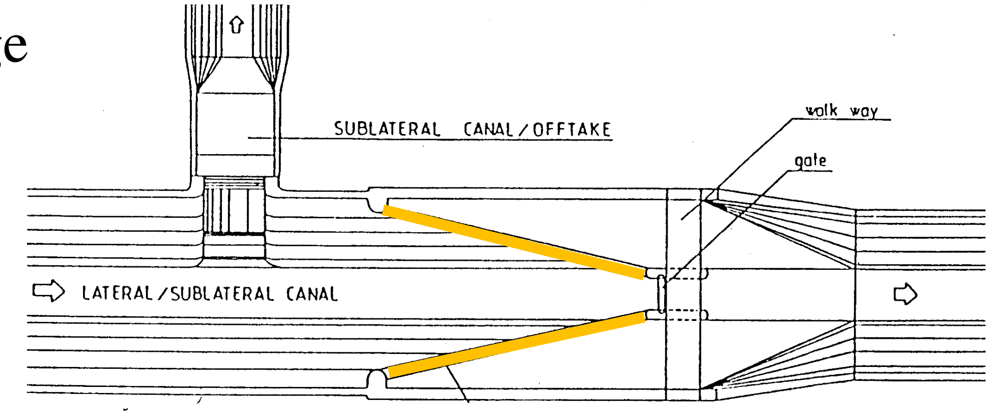
– when the crest length b is great a small change in head H leads to great change in discharge Q.

– in the opposite – big change in discharge Q leads to small change in head H – thus, the water level can be kept in practically constant



$$Q = mb\sqrt{2gH_0^3}$$

$$m = f(H/p)$$



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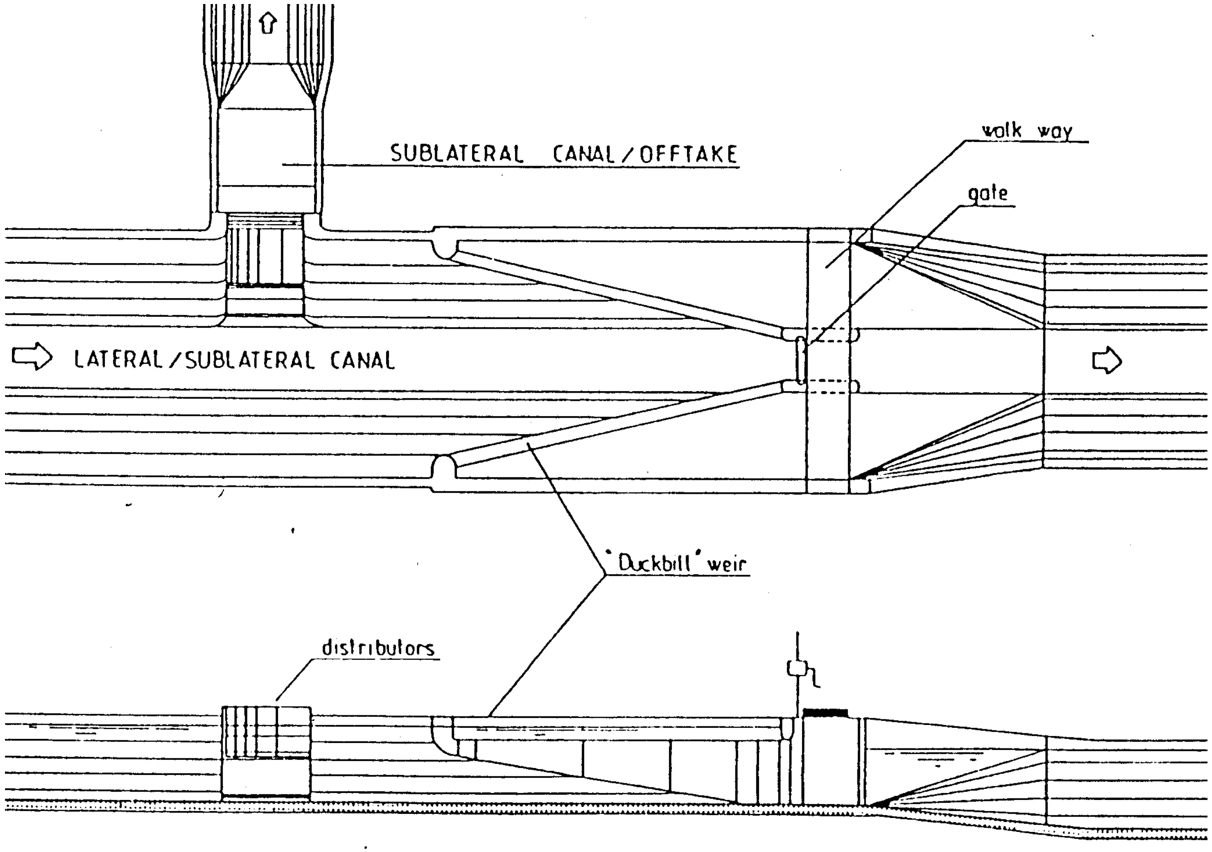
5. Upstream Control Systems

- **Water Level Regulators**
  - **Long Crested weirs**
    - ✓ Permanent structures
    - ✓ Needs canal widening just downstream of the structure to prevent the submergence



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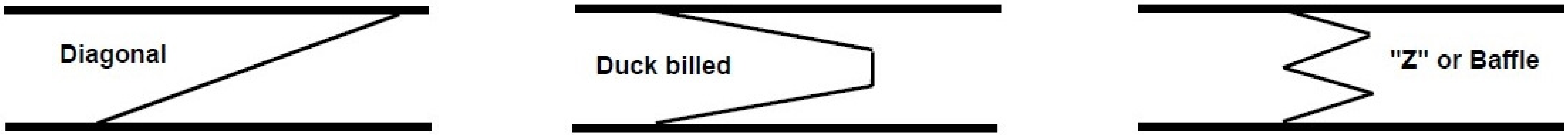
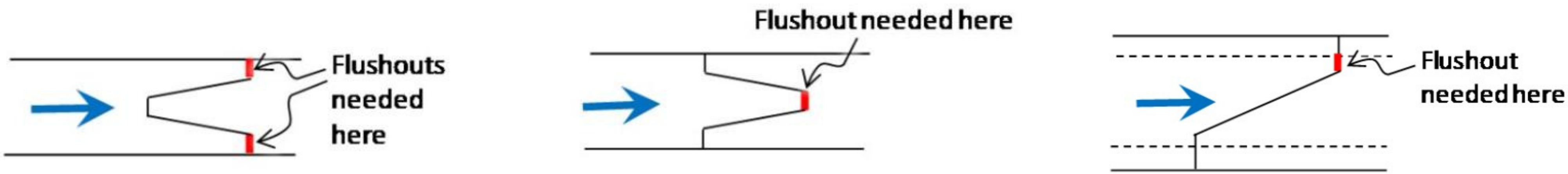
5. Upstream Control Systems

- **Water Level Regulators**
  - **Long Crested weirs**
    - ✓ There are several types of constructions

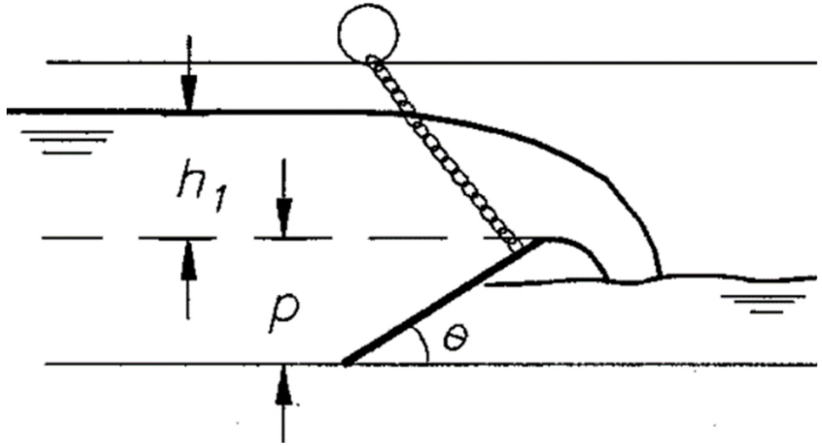




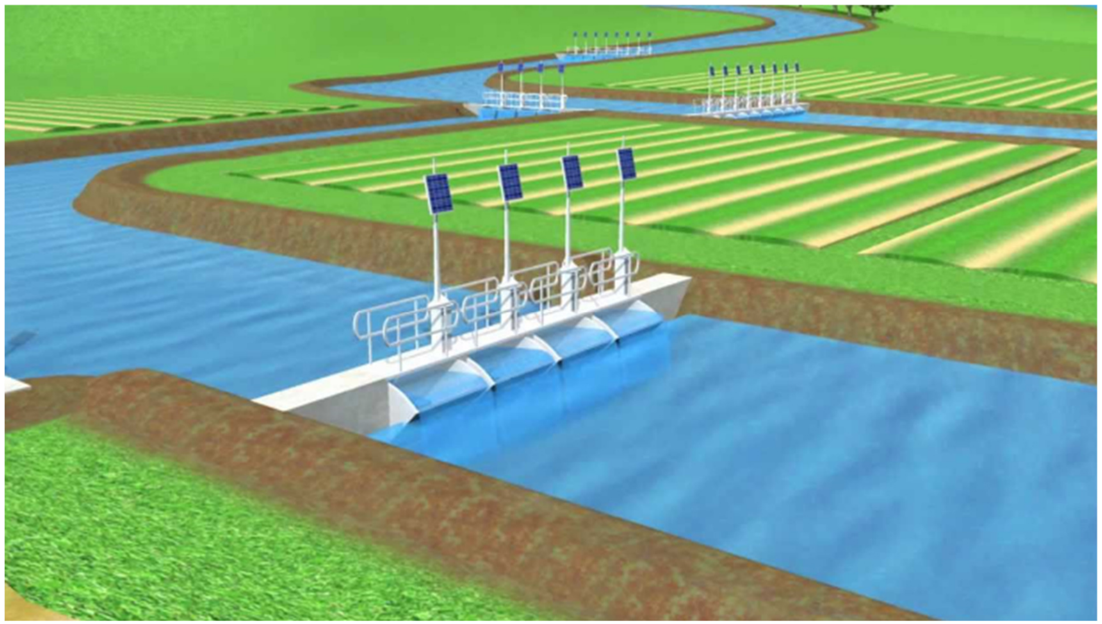
✓ It needs openings at the tip of the weir (flushouts), made with sliding gates, to allow flushing out of the sediments, caught by the structure

5. Upstream Control Systems

- **Water Level Regulators**
  - **Overshot Gates**
    - ✓ Weirs with adjustable crest hight
    - ✓ By adjusting the angle of the gate θ, the weir crest level is changed, thus the head h_1 is changed and also discharge Q.

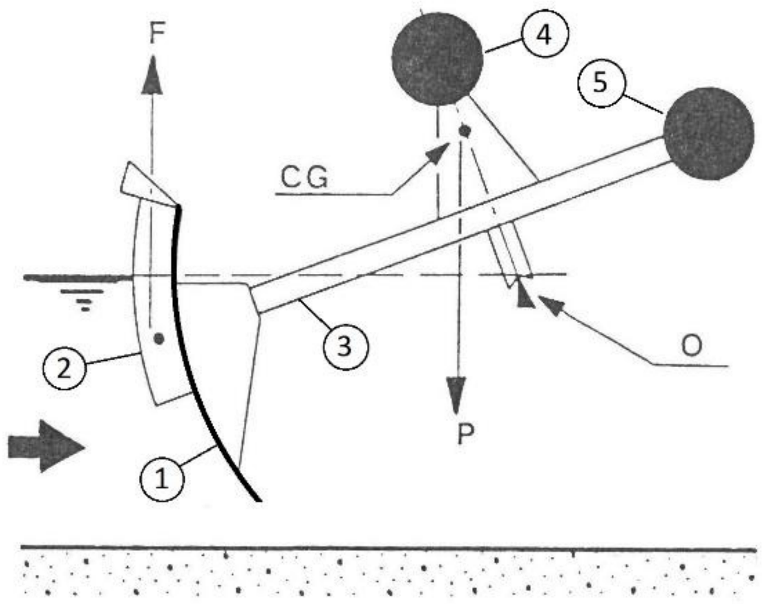


Rubicon Flume Gate
Adjustments are made using electric motors powered by solar panels



5. Upstream Control Systems

- **Water Level Regulators**
  - **AMIL Gates**
    - ✓ French construction (and patent until 1990's)
    - ✓ The construction parts are:
      - gate leaf ① - cylindrical, with center point O;
      - float ②, welded to ①
      - frame ③
      - counterweights ④ and ⑤.

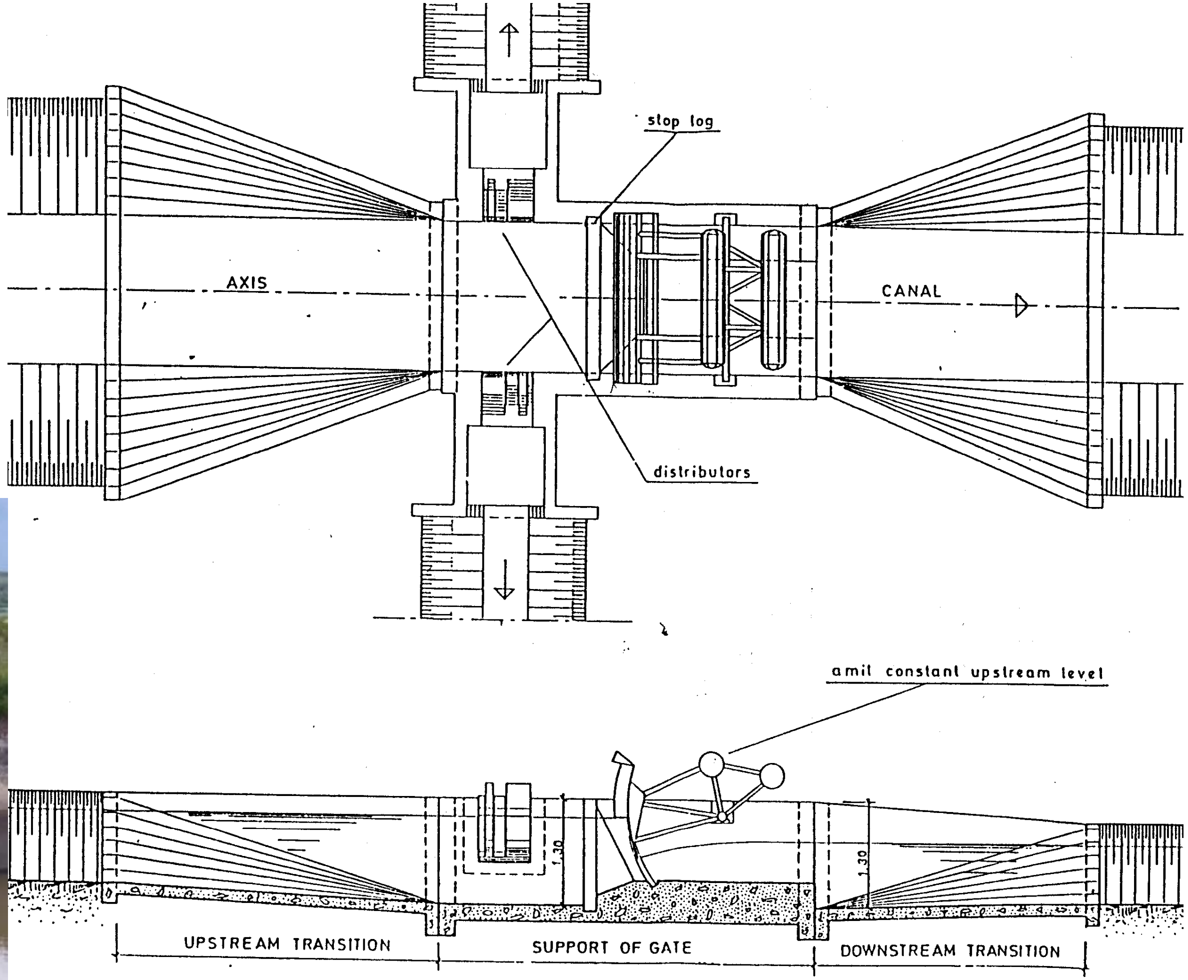


CG = center of gravity
O = axis
P = weight of the gate and counterweights
F = buoyance of the float

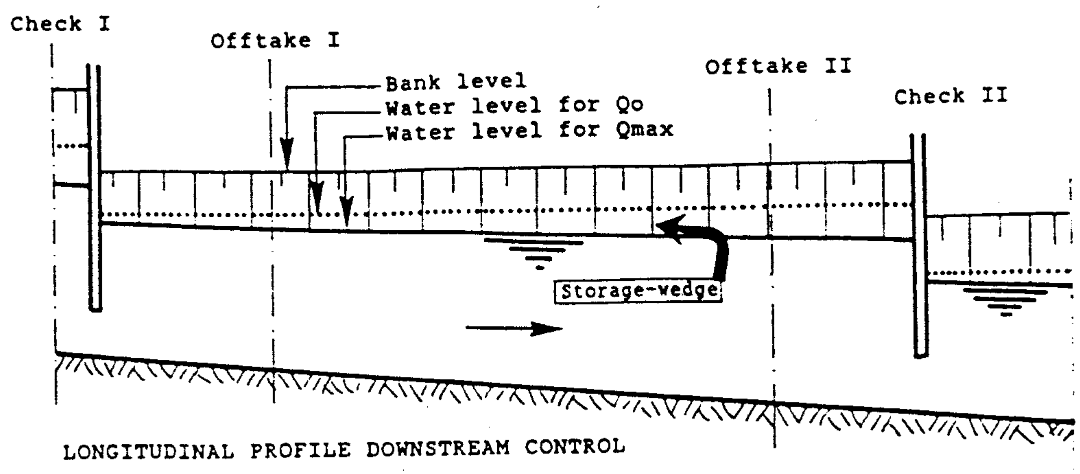
- ✓ When the discharge Q increases, the upstream water level rises, which causes the rising of the float, and thus opening of the gate leaf. The discharge Q_{AMIL} through the gate also increases.
- ✓ When the discharge Q decreases, the upstream water level decreases $\Rightarrow$ the float and the gate leaf move down $\Rightarrow$ Q_{AMIL} also decreases.

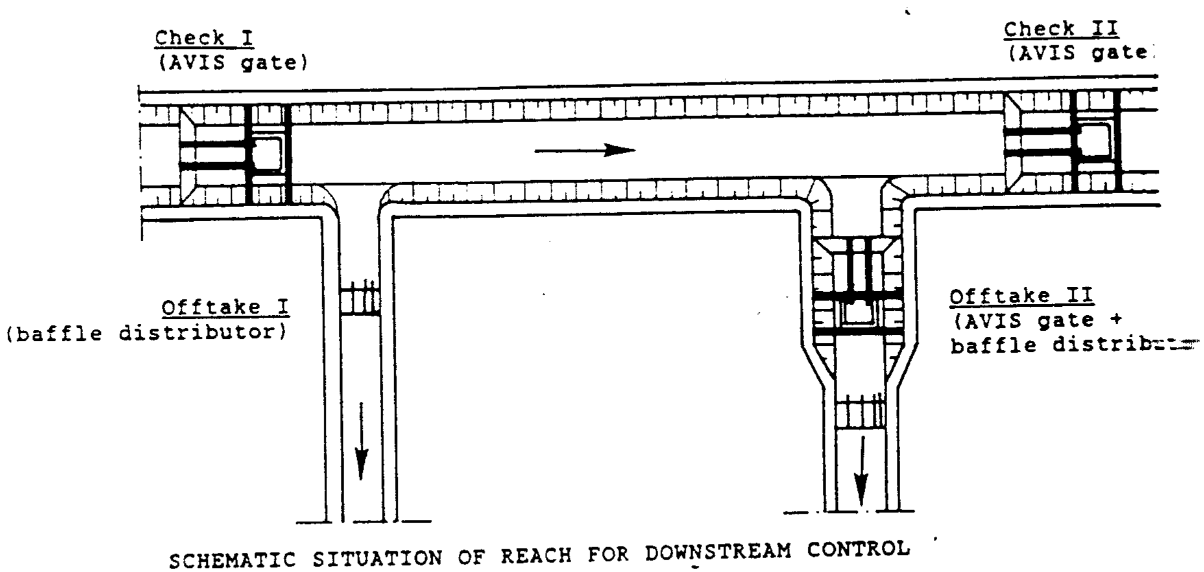
5. Upstream Control Systems

- **Water Level Regulators**
  - **AMIL Gates**
    - The canal cross section at the gate should have very steep walls



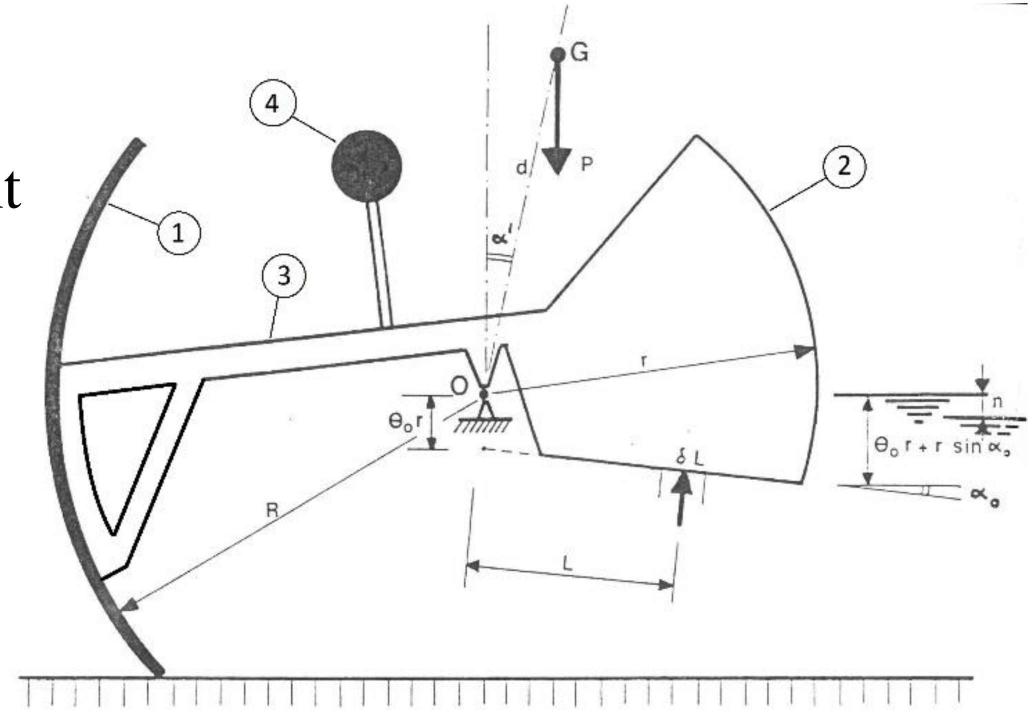
- **Canal reaches**
  - When hydraulically operated regulators are used (such as AVIS gates), ***the distance between regulators must be thoroughly determined***.
  - Because of the lag time the volume between water levels @ Q = 0 and Q_{max} must be enough to store the volume of water released through upstream regulator for the period of time between closing of the downstream regulator and closing of the upstream regulator.





6. Downstream Control Systems

- **Water Level Regulators**
  - **AVIS Gates**
    - ✓ French construction (and patent until 1990’s)
    - ✓ The construction parts are:
      - gate leaf ① - cylindrical, with center point O;
      - float ②,
      - frame ③
      - counterweight ④.

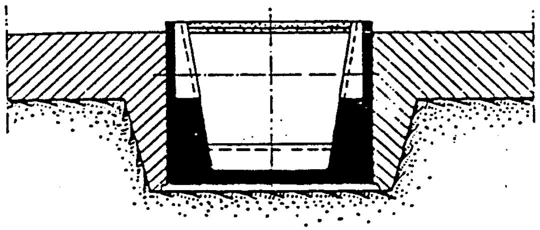


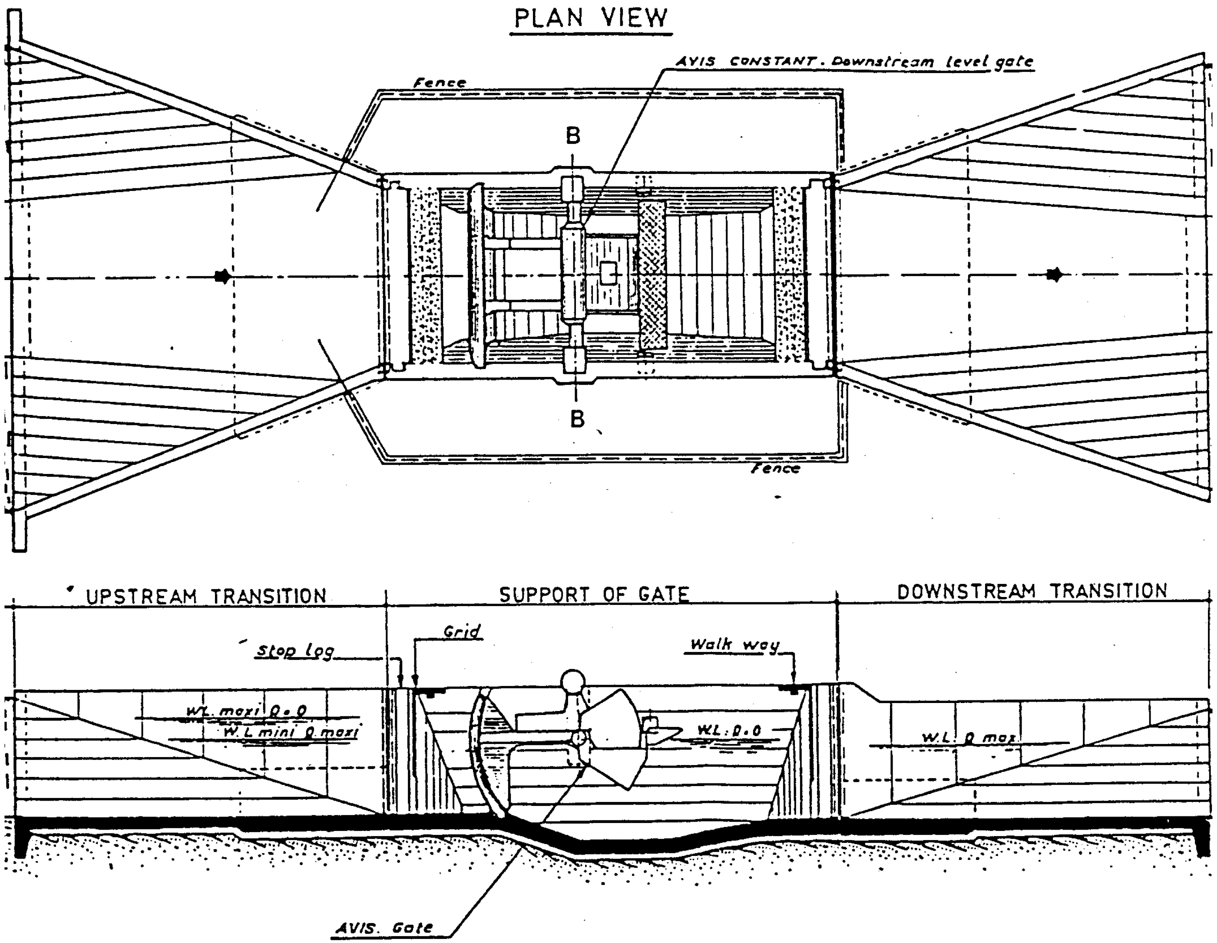
- ✓ The operation principle is the same as for AMIL gates – the float ② causes rotation of the gate leaf ①.
- ✓ When the downstream discharge *Q* increases, the downstream water level drops, which causes the opening of the gate.
- ✓ In contrast, when nobody uses water the water level increases, this the gate closes.

6. Downstream Control Systems

- **Water Level Regulators**
  - **AVIS Gates**
    - ✓ The canal cross section at the gate should have very steep walls
    - ✓ The bottom below the float is slightly deeper.
    - ✓ The float is located in the middle of the canal cross section

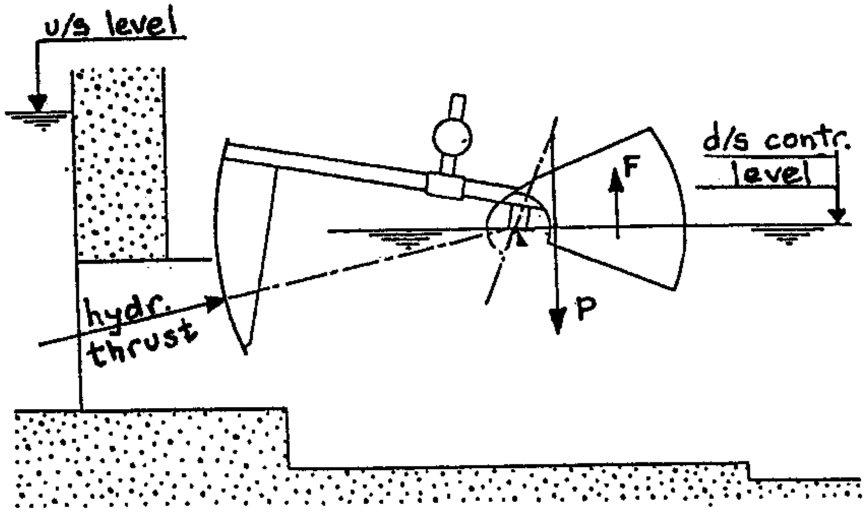
SECTION B.B

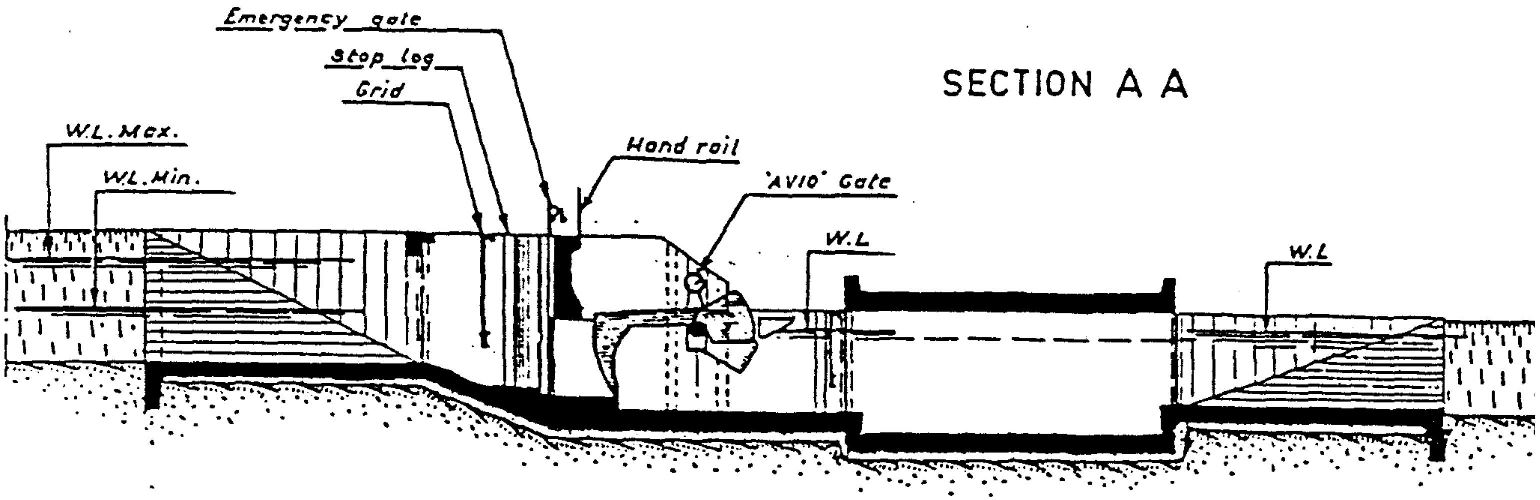




6. Downstream Control Systems

- **Water Level Regulators**
  - **AVIO Gates**
    - ✓ Designed for intakes from large and deep canals
    - ✓ The leaf is set against an orifice
    - ✓ The leaf decreases the incoming flow, when the downstream water level increases





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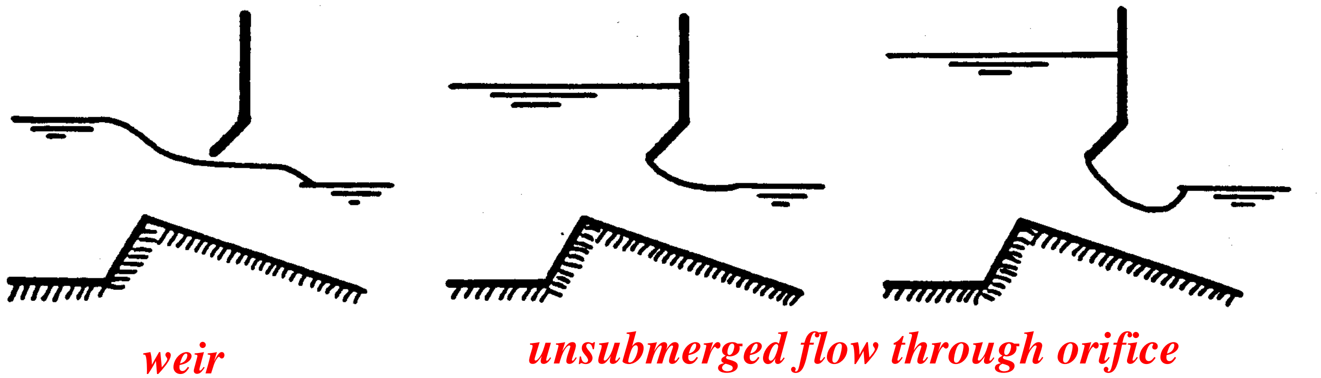
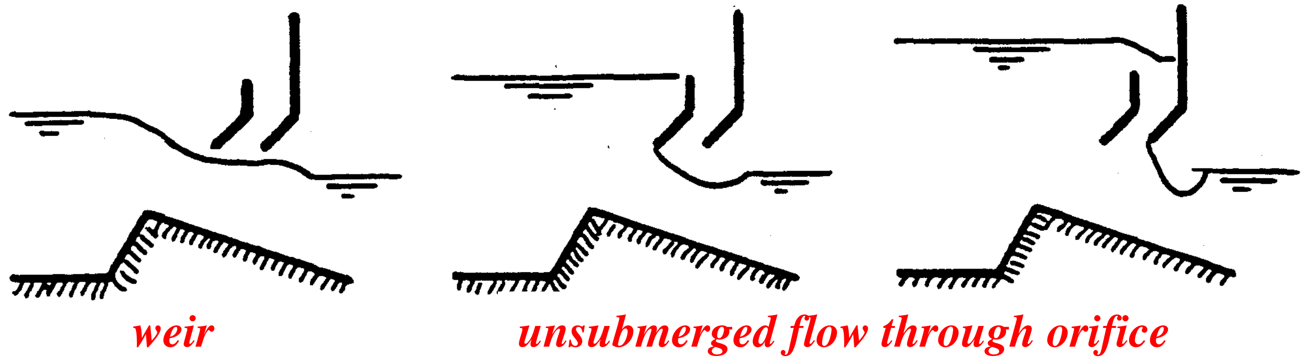
7. Discharge Regulators

- **Baffle Distributors**
  - ➢ French design
    - ✓There are 2 types - single baffle and double baffle regulators

Single baffle



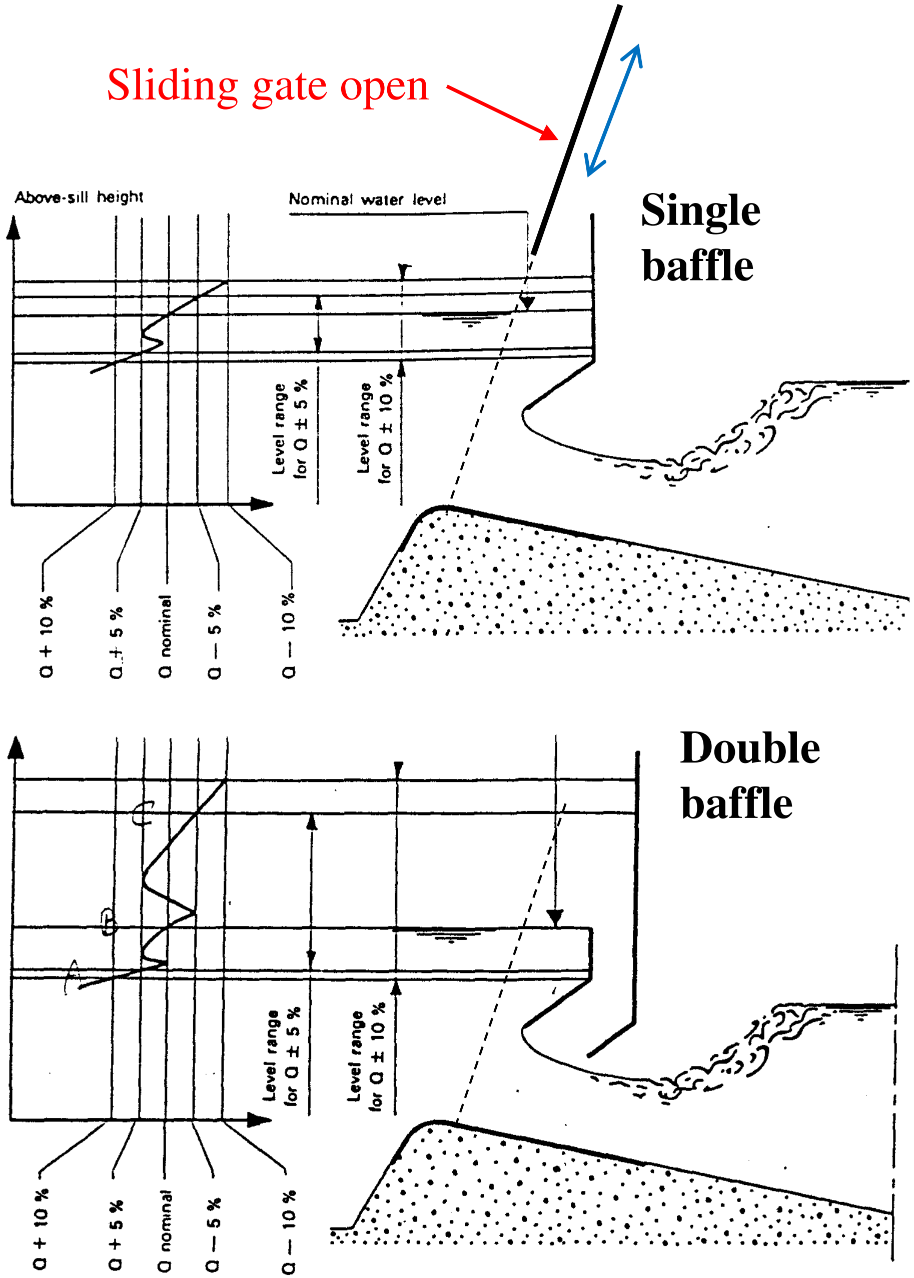
Double baffle



- ✓ The baffles are fixed
- ✓ The regulator operates in two modes – as a weir (unsubmerged) and as undershot structure - orifice (unsubmerged flow)

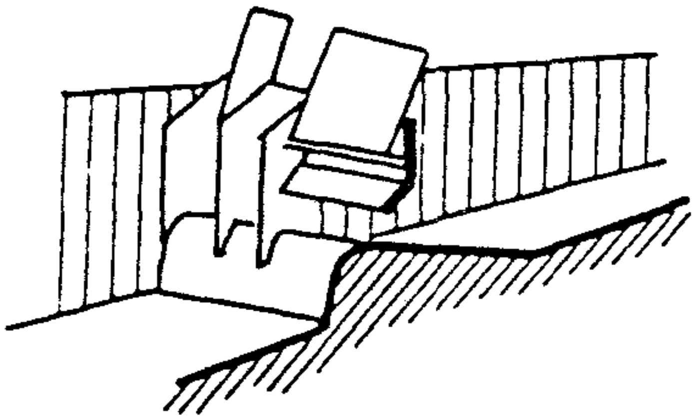
7. Discharge Regulators

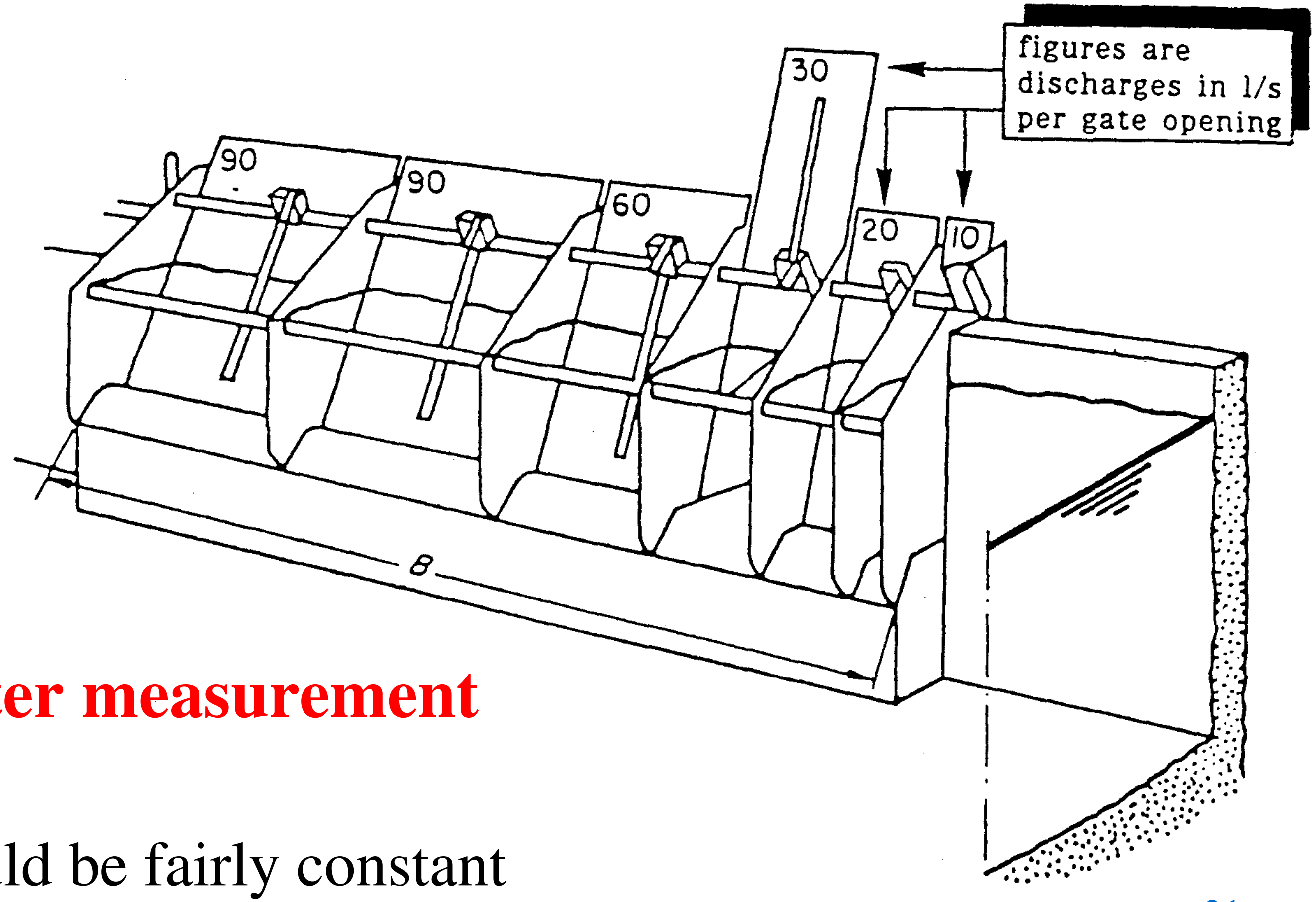
- **Baffle Distributors**
  - ✓ A sliding gate is used to open or close one baffle section
  - ✓ The sliding gate is not used for regulation
  - ✓ At relatively high change in upstream head *H* (±10%), the discharge *Q* is maintained within ±5% of design flow.
  - ✓ The baffles are made of metal
  - ✓ They are placed over a concrete structure



7. Discharge Regulators

- **Baffle distributors**
  - ✓ The baffle distributors contain several sections
  - ✓ Each section is designed for a standard discharge





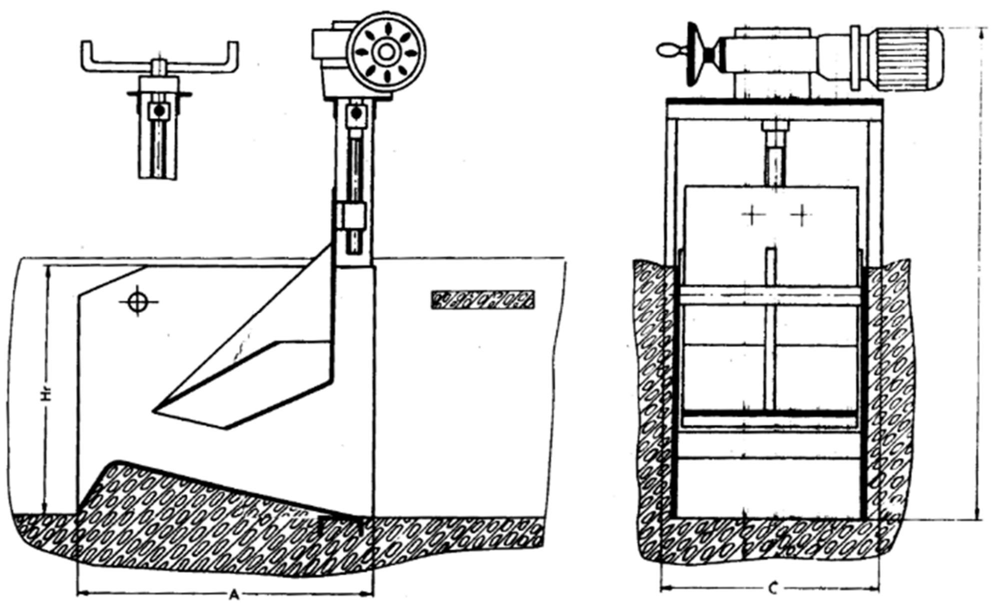
➢ **Can be used as water measurement structure**

- ✓ Head at inlet should be fairly constant

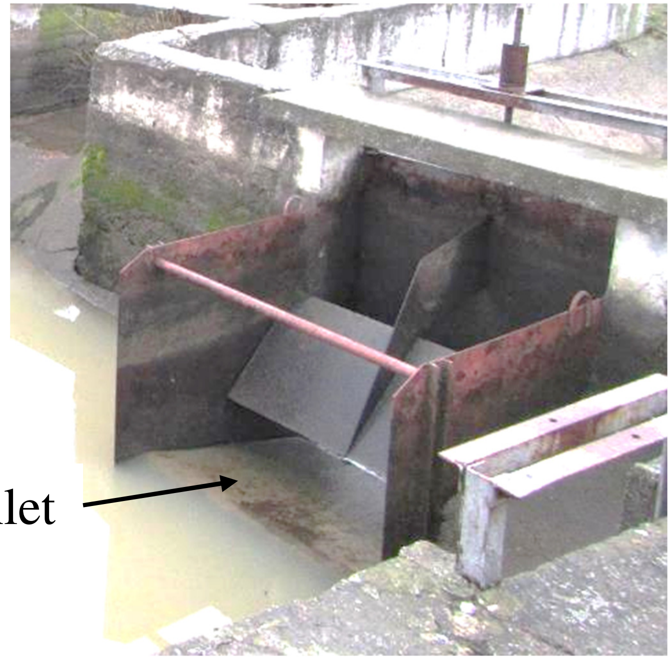
7. Discharge Regulators

- **Khamadov Distributor**
  - ✓ Designed in USSR
  - ✓ Operate using the same principles as Baffle distributors
  - ✓ Difference – the baffles are welded on a sliding gate
  - ✓ The discharge is adjusted by gate opening.
  - ✓ There is no need of sections – the structure is very compact

Khamadov Distributor (Дозатор „Хамадов“)

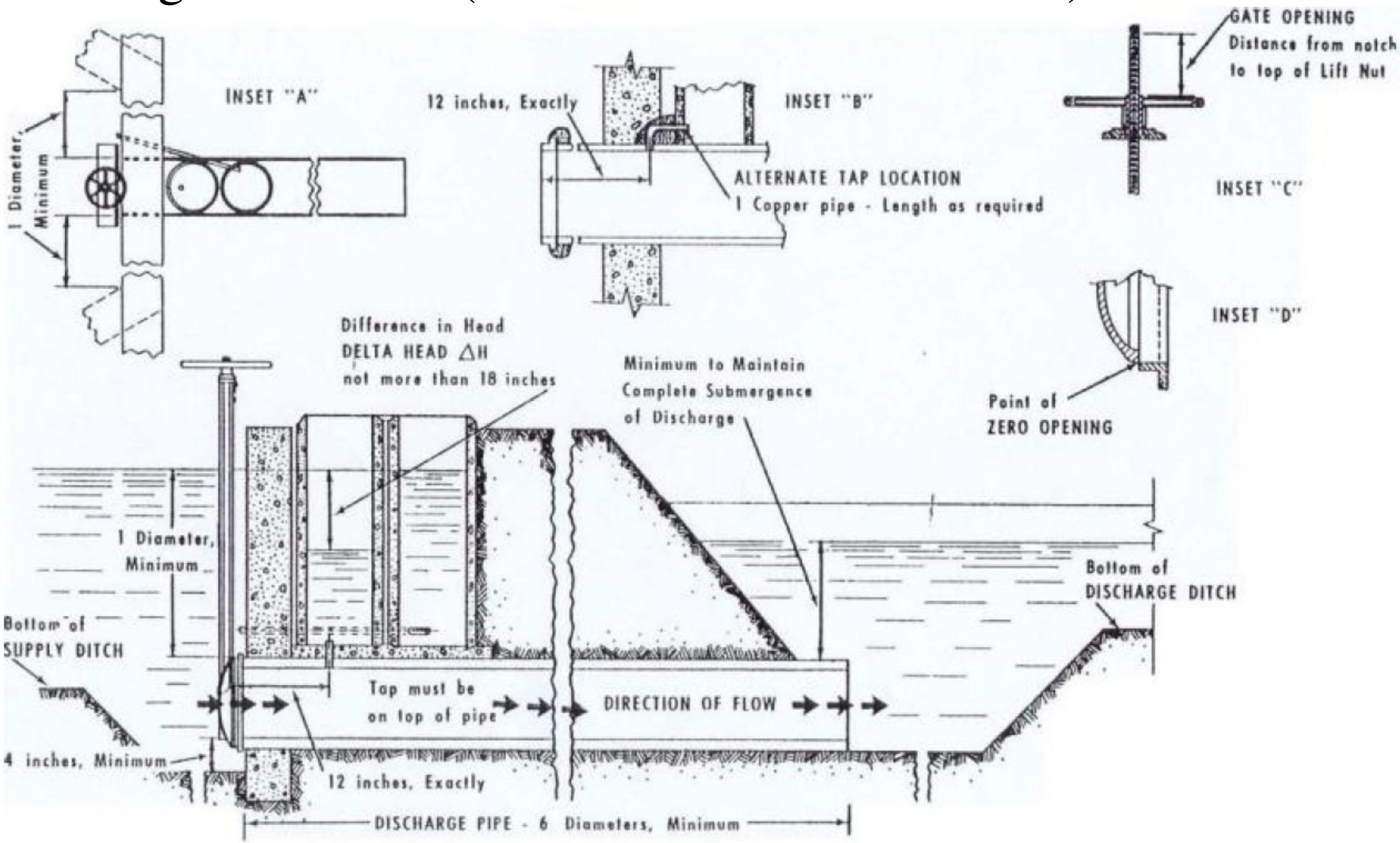


Inlet



7. Discharge Regulators

- **Metergates**
  - Designed in USA (US Bureau of Reclamation)



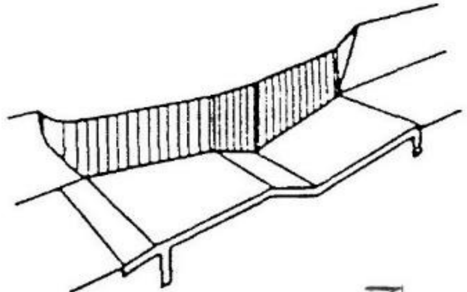
7. Discharge Regulators

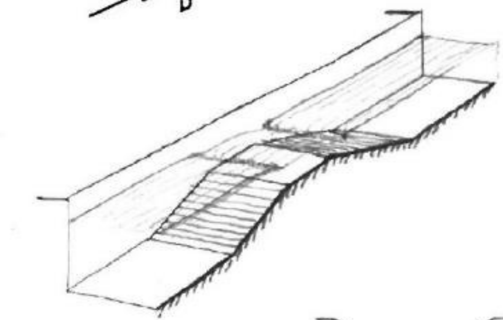
- **Metergates**
  - ➢ The inlet and outlet parts may be prefabricated
  - ➢ **Can be used as water measurement structure**
    - ✓ Head at inlet should be fairly constant

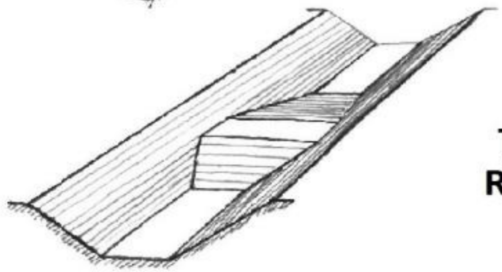
Pictures provided by prof. C.M. Burt from ITRC at CalPoly (USA) for Strategy for management and development of hydro-melioration in Bulgaria

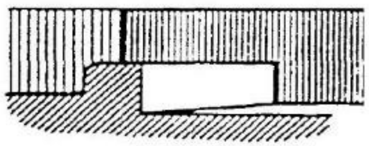
8. Discharge Measurement Structures

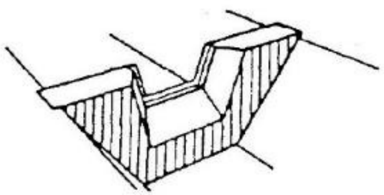
- **Measurement of Transit Flows**
  - Flumes
    - ✓ **Parshall flume**
    - ✓ Venturi flumes
      (Long Throated flumes)
  - Weirs
    - ✓ Broad crested weirs
      - **Trapezoidal**
      - **Replogle Flume**
      - Classic
    - ✓ Sharp crested weirs
      - Cipoletti


Parshall Flume
ISO 9826


Trapezoidal Weirs
ISO 4362

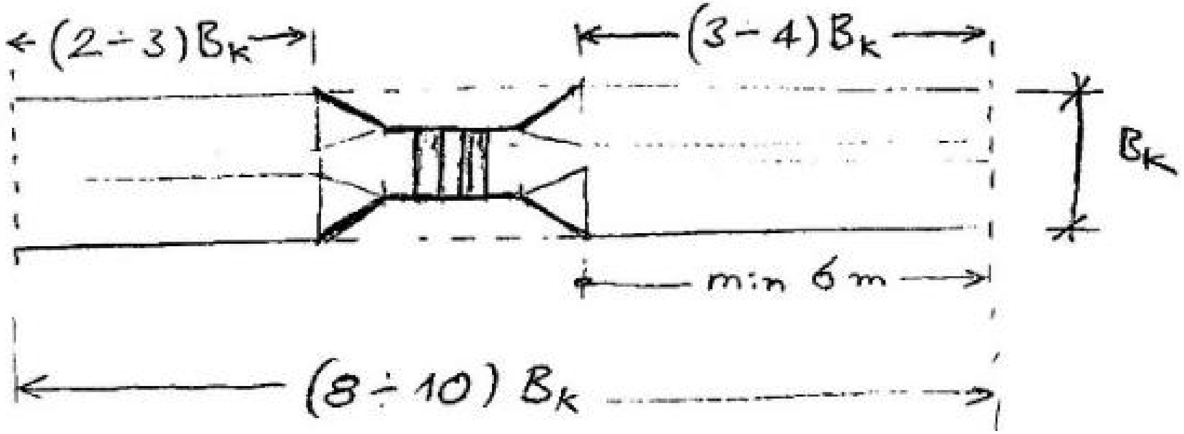

Trapezoidal Weir
Replogle Flume (ASCE)


Broad Crested Weir


Sharp Crested Weir
Cipoletti

8. Discharge Measurement Structures

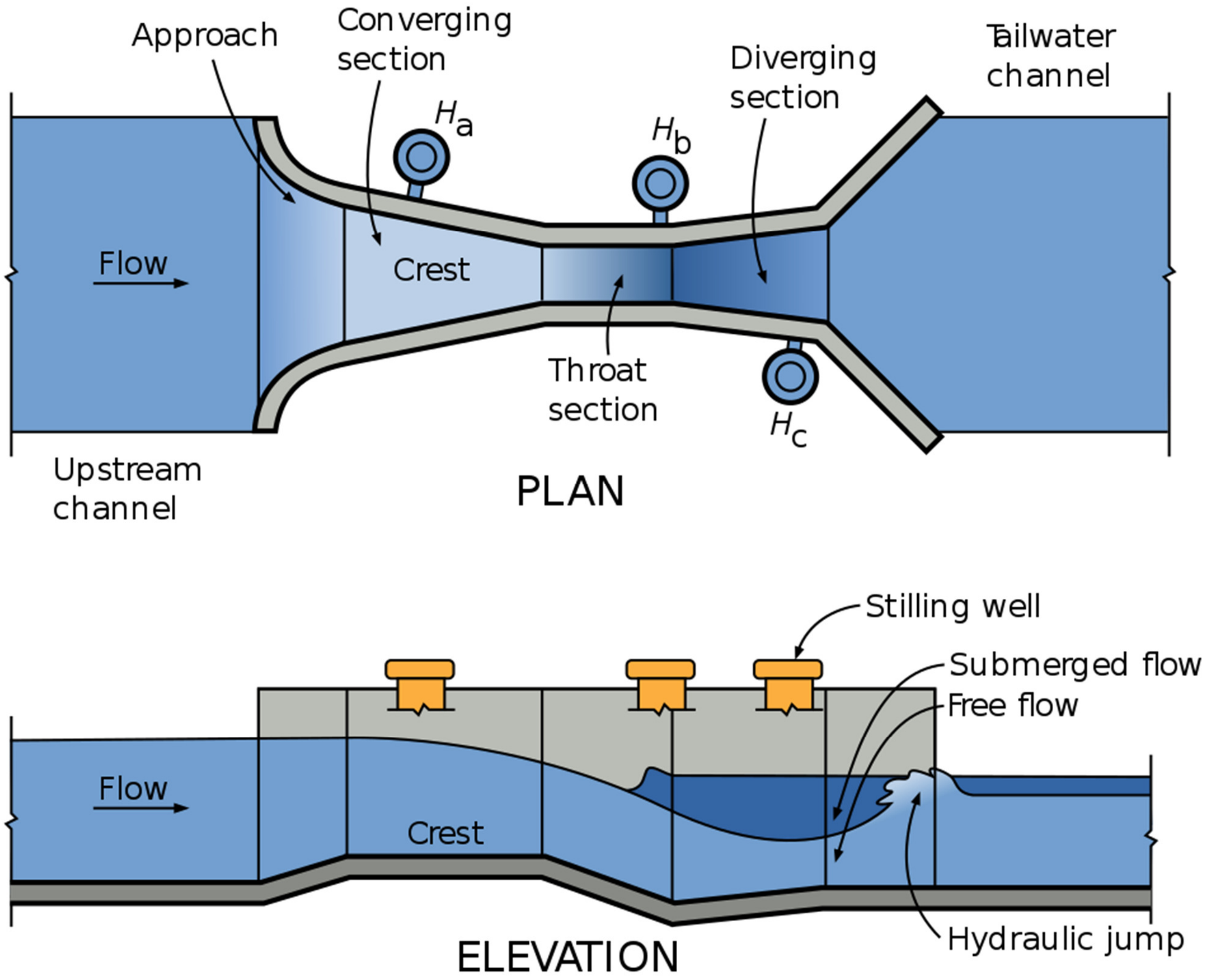
- General requirements
  - ➢ Canal cross section and longitudinal slope – constant
    - ✓ Cross section – symmetrical about the axis
  - ➢ Canal axis to coincide with the axis of the structure
  - ➢ Straight canal section – L ~ 10 time the water surface width B_κ
    - ✓ $(2 \div 3)B_\kappa$ upstream and $(3 \div 4)B_\kappa$ downstream of structure



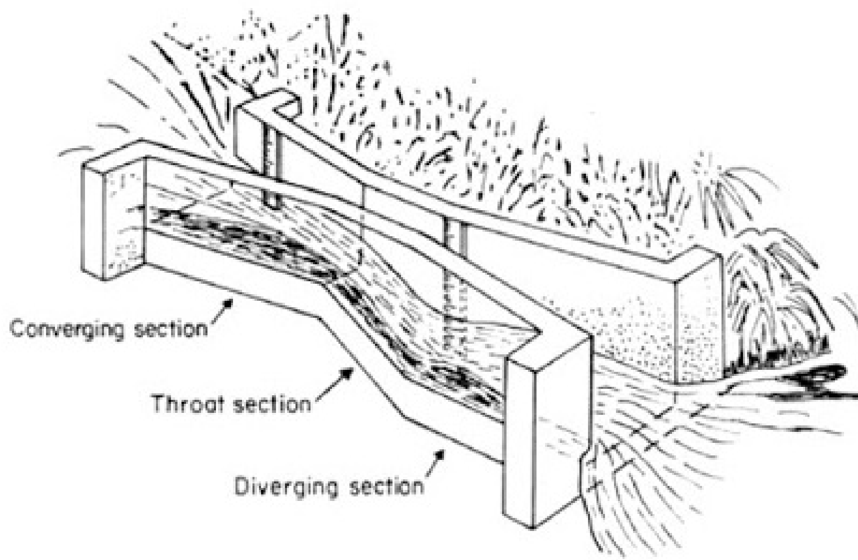
  - ➢ The throat width b of the measurement structure should be less than B_κ – e.g. $b = (1/2 \div 1/3)B_\kappa$.

8. Discharge Measurement Structures

- **Flumes**
  - ➢ **Parshall Flume**

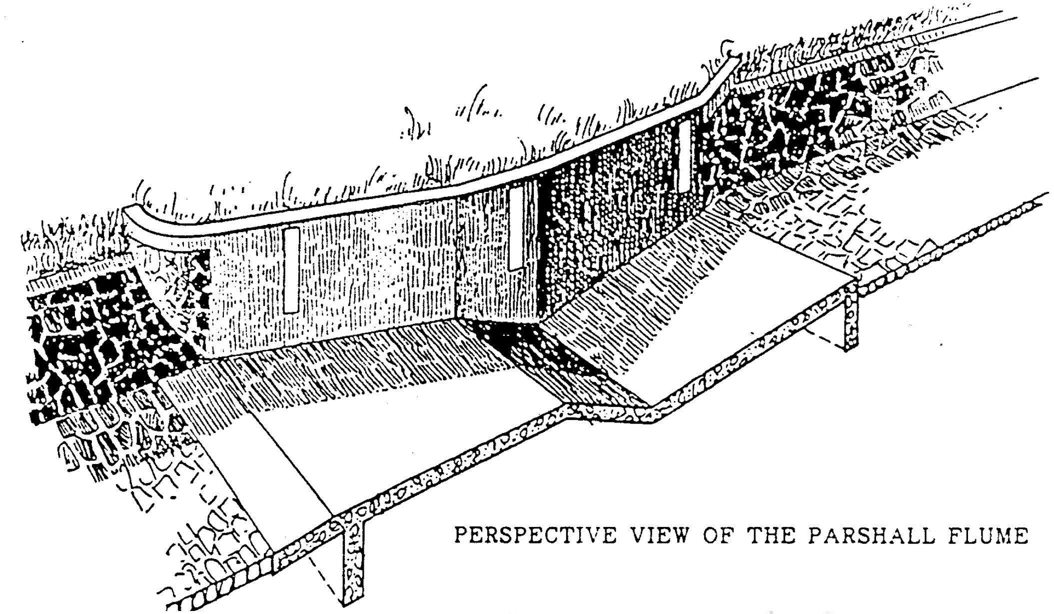


- The flume has standardized dimensions, i.e. standard sizes.
- ✓ According to ISO 9826.
- Discharge $Q_{max} = 0{,}4 \div 4{,}0\ m^3/s$
- There are non-standard flumes – for discharges $Q_{max} \leq 90\ m^3/s$.

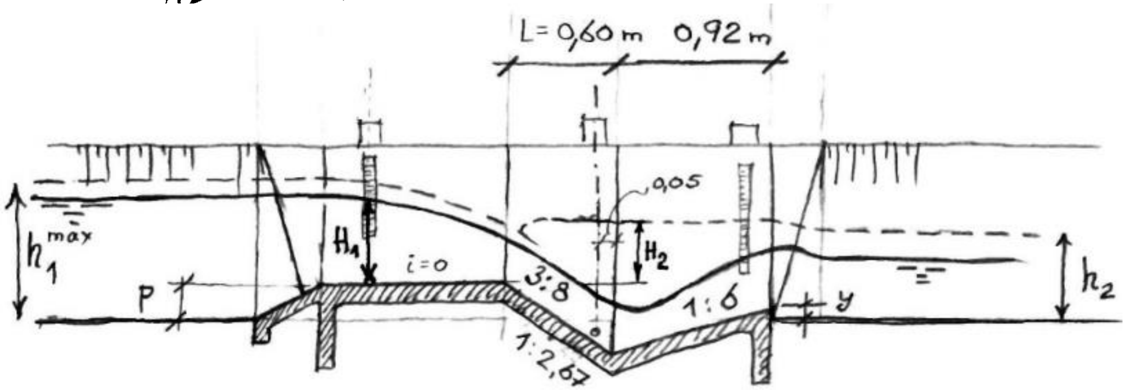


8. Discharge Measurement Structures

- **Flumes**
  - ➢ **Parshall Flume**



PERSPECTIVE VIEW OF THE PARSHALL FLUME



- Operates at free flow conditions, as well as submerged when $H_2/H_1 \leq 0{,}95$
- Large operating range – $Q_{min} = (1{,}5\% \div 2{,}5\%)Q_{max}$.

Accuracy:

- ➢ **± 2% at free flow conditions**
- ➢ **± 5% at submerged flow**

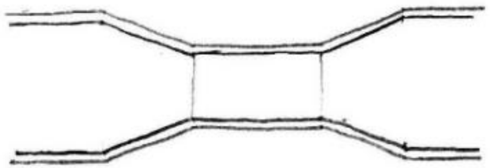
- <u>Advantages:</u>
  - ➢ Relatively small head losses;
  - ➢ Operates both at free and submerged flow
  - ➢ Conveys floating debris and bed load
  - ➢ May be installed in existing canals

<u>Disadvantages:</u>

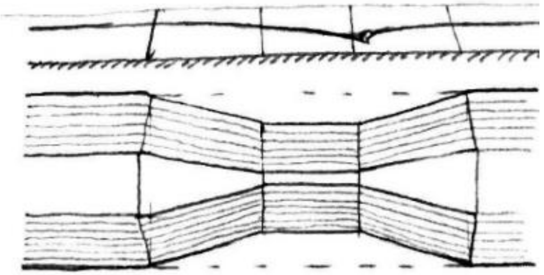
- ➢ High requirements for accuracy of construction – lengths, slopes, etc.
- ➢ Relatively expensive

8. Discharge Measurement Structures

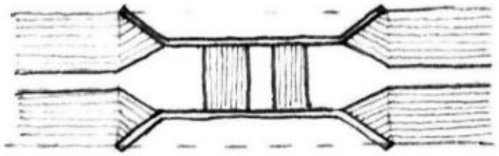
- **Flumes**
  - **Venturi Flumes**
    - ✓ Operating principle – to create *vena contracta*, i.e. flow contraction
    - ✓ Contraction can be
      - – Horizontal
      - – Horizontal and vertical
    - ✓ The cross section can be
      - – Rectangular
      - – Trapezoidal
      - – Triangular
    - ✓ The water depth is measured at the converging section (inlet section)
    - ✓ Suitable for installation in exiting canals, due to small head losses, i.e. small backwater effect.
    - ✓ Individual design to meet requirements



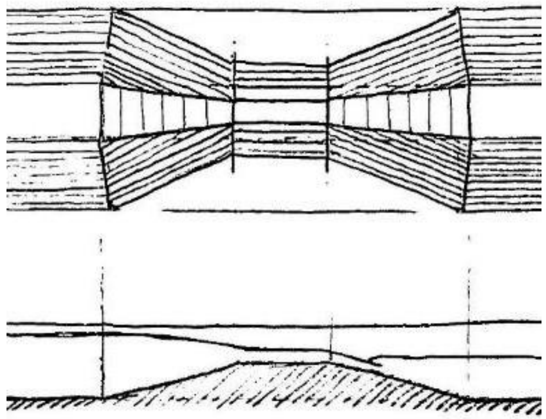
Horizontal contraction, rectangular cross section



Horizontal contraction, trapezoidal cross section



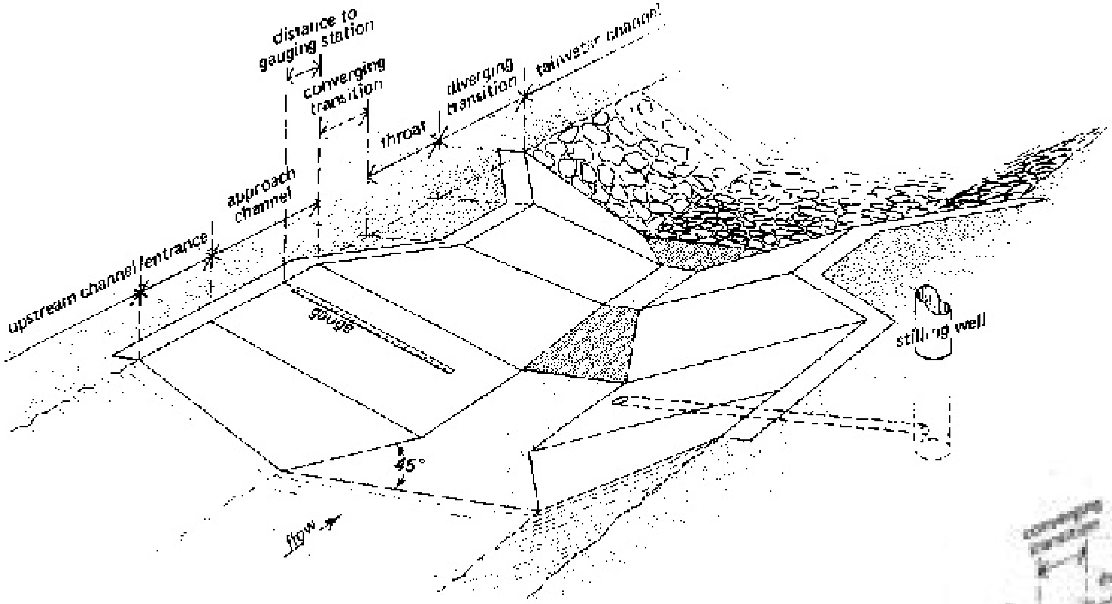
Horizontal and vertical contraction, rectangular cross section

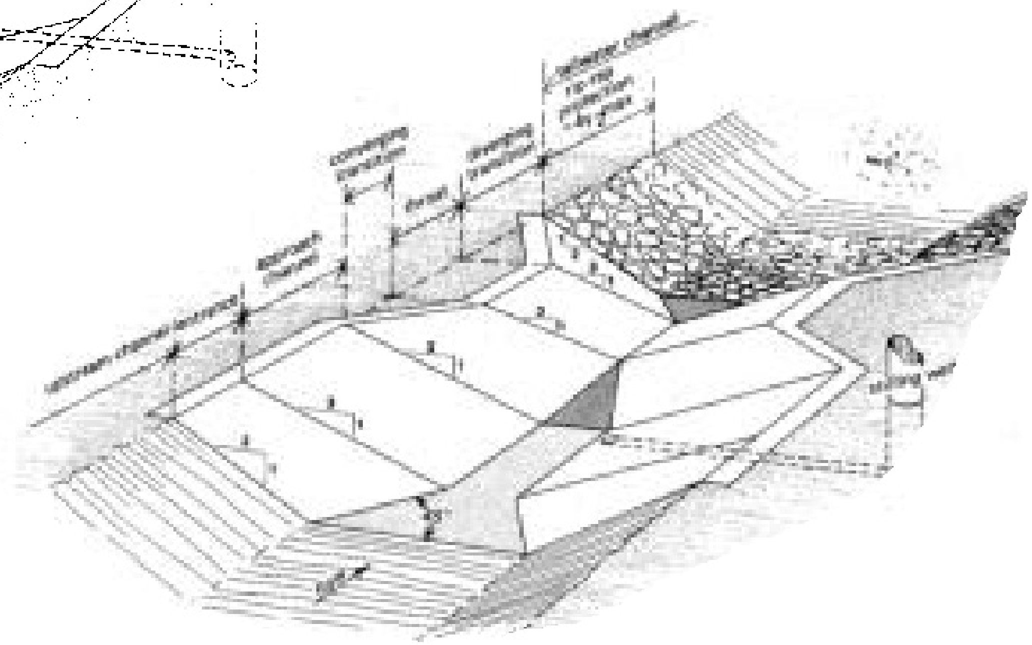


Horizontal and vertical contraction, trapezoidal cross section

8. Discharge Measurement Structures

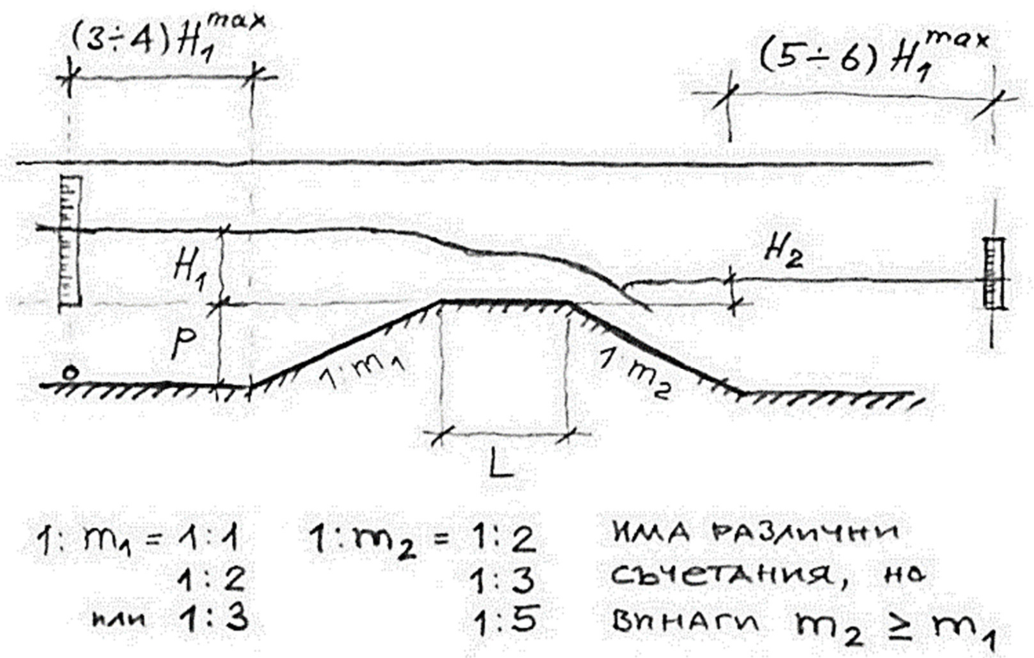
- **Flumes**
  - ➢ **Venturi Flumes (Long Throated Flumes)**

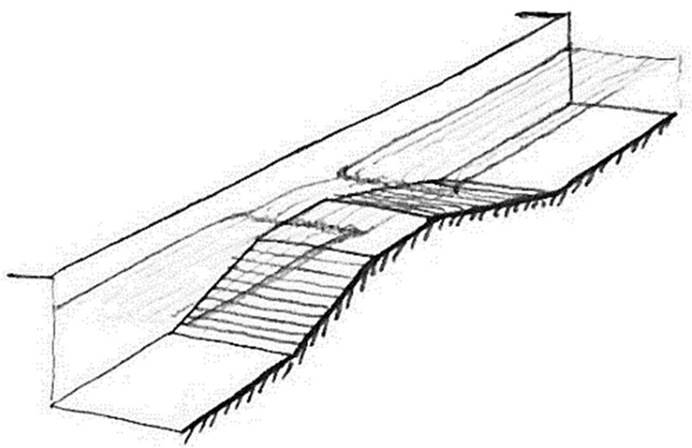




8. Discharge Measurement Structures

- **Weirs**
  - ➢ Trapezoidal weirs (ISO 4362)





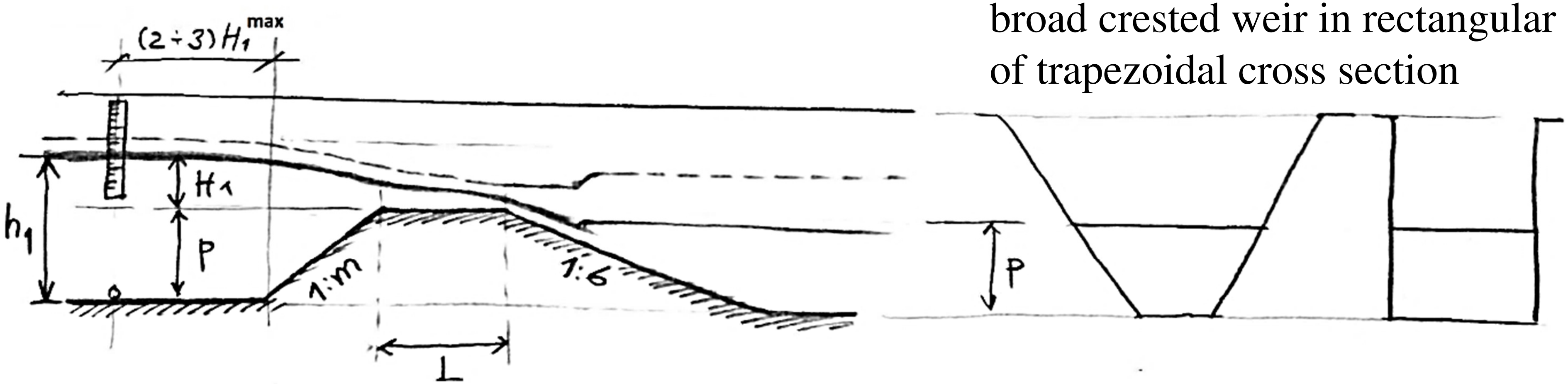
Intermediate case between venturi flumes and broad crested weirs

- For **rectangular cross sections**
- The structure can be designed to fit into any canal
- Discharges $Q_{max} = 0{,}1 \div 10{,}0\ m^3/s$
- Wide range of measured flows
- Operates at free and submerged flow
- According to the combination of H_1 and L can be either broad crested, or nappe-shaped weir
- **Accuracy:**
  - ➢ **± 4% at free flow conditions**
  - ➢ **± 6% at submerged flow**

8. Discharge Measurement Structures

- **Weirs**
  - **Replogle Flume** - Trapezoidal weir / flume

broad crested weir in rectangular of trapezoidal cross section



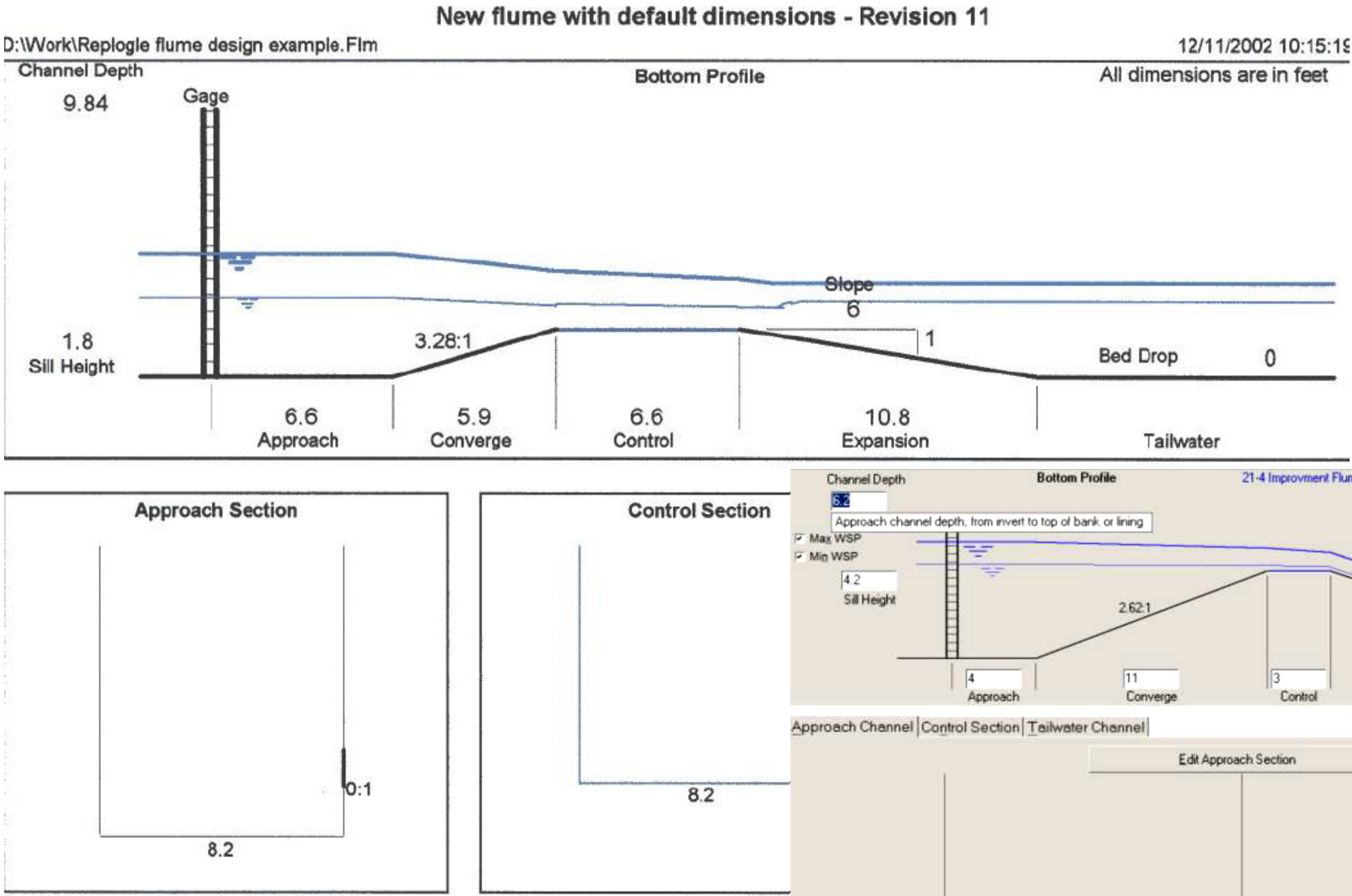
- ✓ In case of rectangular cross section – it may have horizontal contraction in addition to vertical
- ✓ The structure can be designed to fit into any canal
- ✓ Discharges Q_{max} = 0,5 ÷ 15,0 m^3/s
- ✓ Wide range of measured flows
- ✓ **Suitable for existing canals**
- ✓ Operates at free and submerged flow

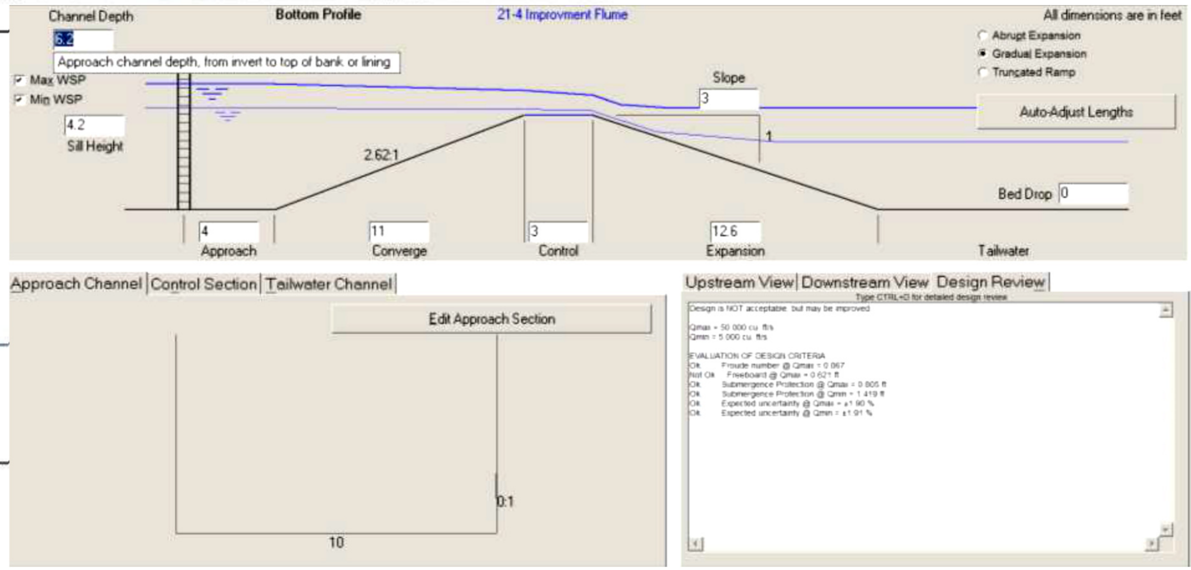
Accuracy:
- ✓ **4% at free flow**
- ✓ **6% at submerged flow**

Co-funded by the Erasmus+ Programme of the European Union

8. Discharge Measurement Structures

- **Weirs**
  - **Replogle Flume**





- Special software for design – **Win Flume** (freeware) – made by *ITRC* at CalPoly (USA)

Source: ITRC (Irrigation Training and Research Center)

8. Discharge Measurement Structures

- **Weirs**
  - ➢ **Replogle Flume**

Source: ITRC (Irrigation Training and Research Center)