WES Activity No. N-W-PS-2

Capacity building/trainings with pilot farmers' associations and relevant communities on optimal irrigation management and practices

Management and analysis of the performance of collective irrigation networks

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I'm…

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A Ph D in ***collective irrigation systems*** design and performance analysis (Italy) with background in ***rural engineering*** (Lebanon)

A post doc in ***combined effects of water and salinity stress on crop production*** (USA)

and interest in ***decision analysis***, ***PIM***, and ***science policy***.

A **Senior Researcher/International Officer** at CIHEAM – Bari

I've been told that…

you're coming from different regions…

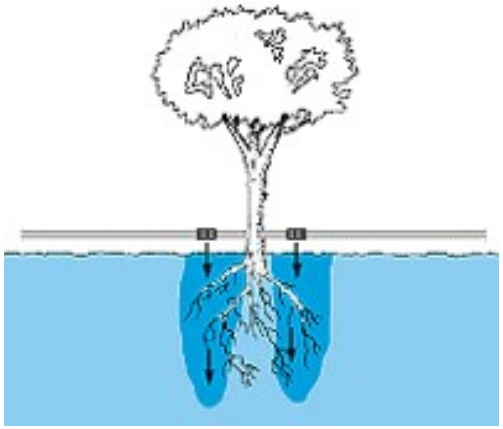
From different public and private institutions…

WHAT ELSE?…NEED TO KNOW MORE

IRRIGATION SCHEDULING

GENERALITIES
A GOOD START

What is irrigation ?



Irrigation is an agronomic practice that relates to the artificial supply of water to soil and plants.

It is a **fundamental** mean to cultivate arid areas and to **optimize** crop production in cultivated areas

Essential conditions for irrigation of new areas

1. Availability of a water source

2. Ability of soils to receive water

3. Real irrigation need (unsufficient rainfall, poorly distributed rainfall along the year, possibility of development of alternative cropping patterns within the irrigated area)
4. Socio-economic conditions (roads, markets, processing plants etc.)

Rainfall Distribution in the Mediterranan Countries

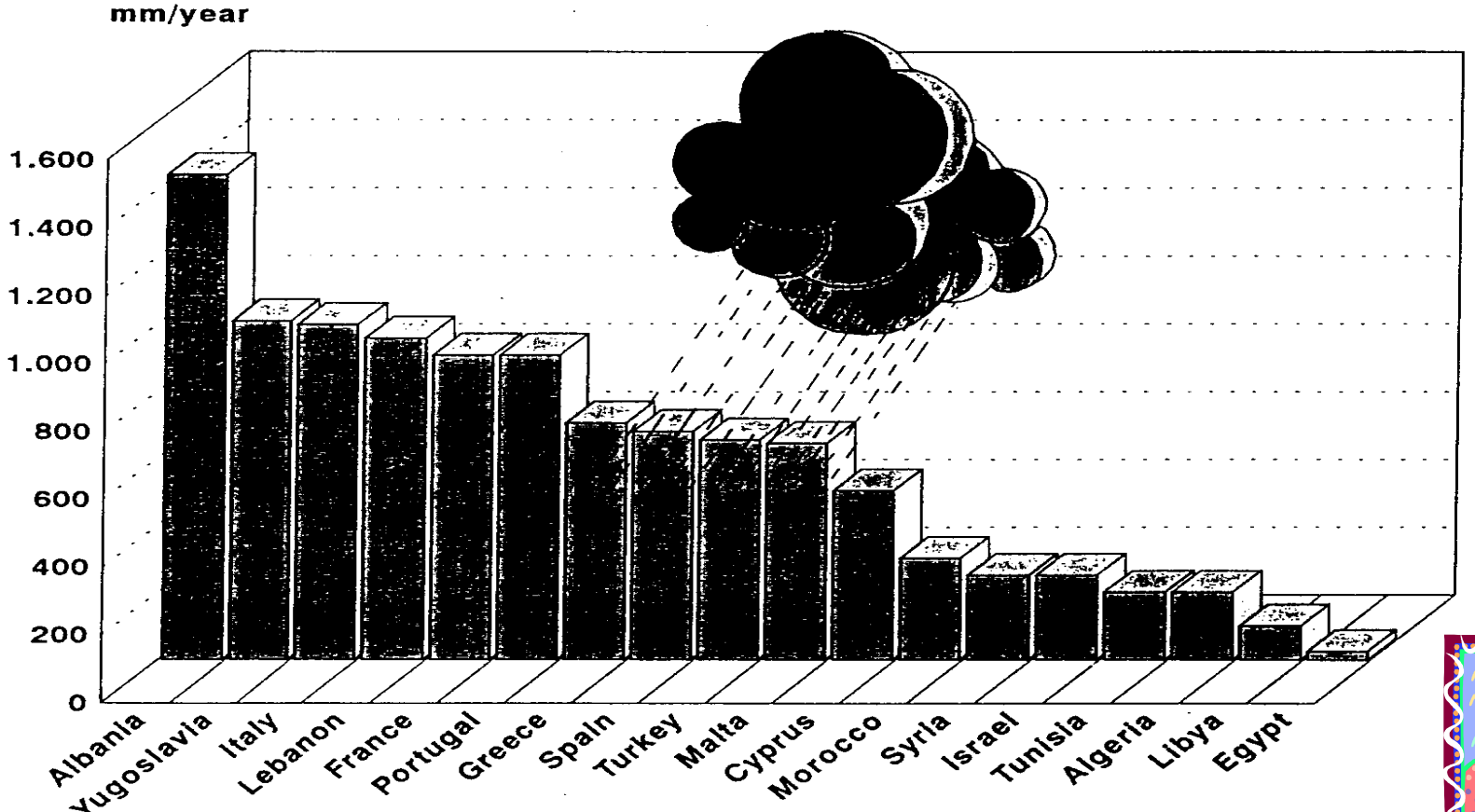


Fig.2 Rainfall Distribution in the Mediterranean Countries

Different purposes of irrigation

- **Wetting** irrigation aims at supplying water to soil and plants for their production (most commonly utilized).
- **Fertigation** is carried out to supply nutrients to plants through irrigation water.
- **Thermic irrigation** aims at modifying soil and plants temperature (irrigation to prevent plant **freezing** in California/Australia)
- **Leaching irrigation** is used to remove salts from top-layers of soils (if drainage is available. Australia).
- **Corrective irrigation** aims at modifying soil reaction **(pH)** (ex. acid soil sommersion – rice production)

Wetting irrigation

Objectives:

- Supply water to plants and provide nutrients necessary for their growth and production.

- Leaching and diluting salts stored into the soil, without loosing nutrients by deep percolation and runoff.

Irrigation variables

- **Seasonal irrigation volume** (m^3/ha) is the total amount of water to be supplied to a crop in order to satisfy its water needs for the whole irrigation season.

- **Watering volume** (m^3) is the amount of water that is supplied at each irrigation.

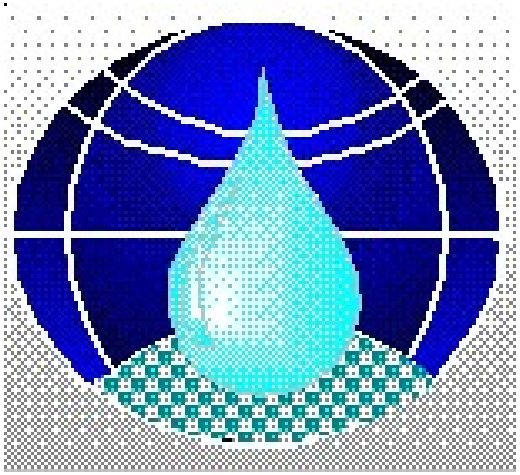
- **Irrigation interval** (days) is the time interval between two subsequent irrigations.

Irrigation variables

- **Irrigation time** (hours) is the time duration of every irrigation.

- **Water stream** (l/s) is the amount of water distributed to the field for any time unit.

WATER IN THE SOIL



Water availability in the soil

- **Field Capacity** (θ_F) is the maximum amount of water (measured in mm/m) that the soil can **keep**
- **Wilting Point** (θ_{WP}) is the amount of water (measured in mm/m) below which plants suffers a permanent water stress.
- **Available holding capacity** (θ_A) is the water (measured in mm/m) held in the soil between field capacity (θ_F) and the permanent Wilting Point (θ_{WP}).

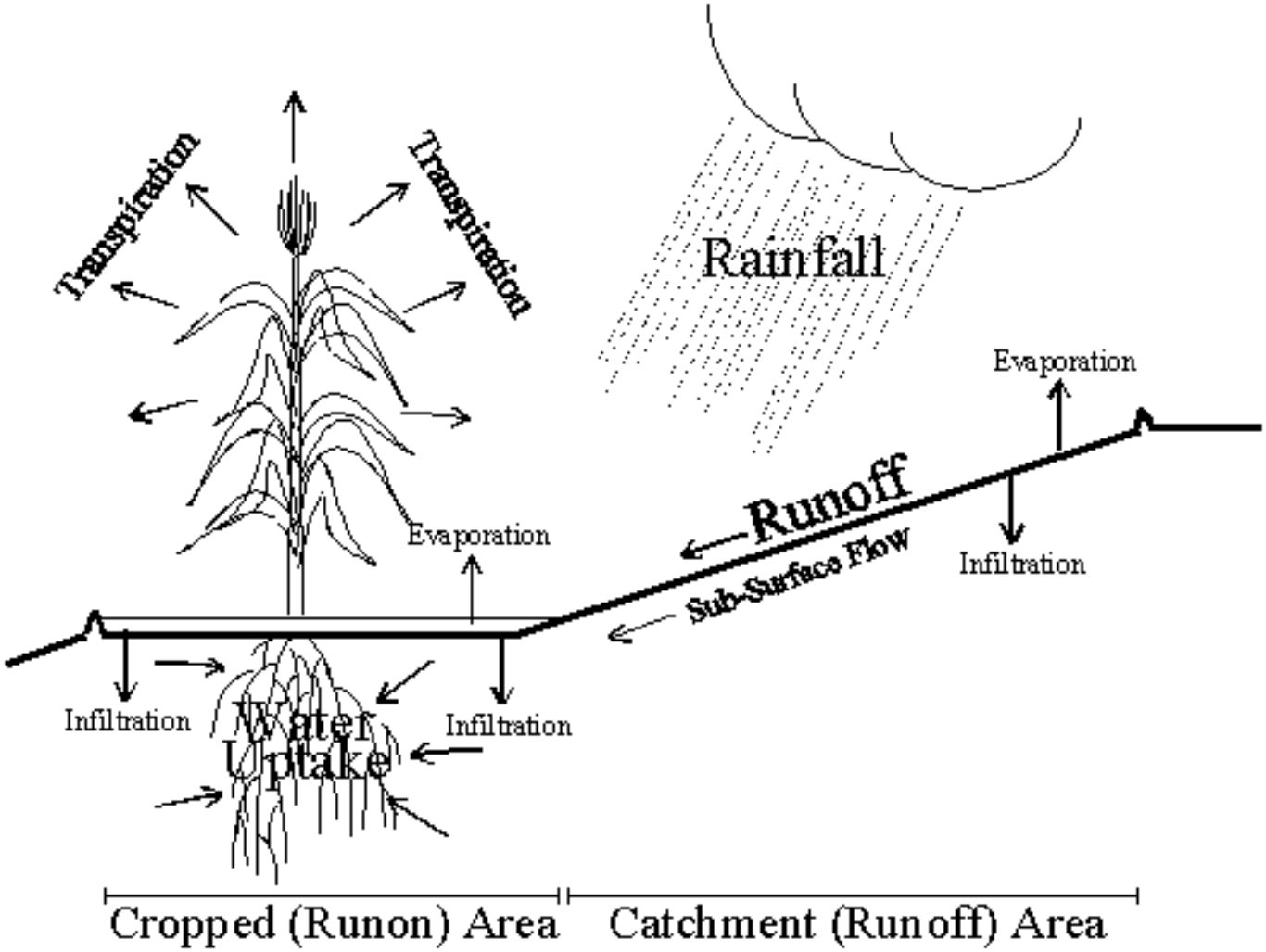
Water availability in the soil

- Please note that **(θ_A), (θ_F) and** (θ_{WP}) are water holding capacities and to determine the FC, AW and PWP content in mm for a known depth of soil, the capacities are * by the soil depth.

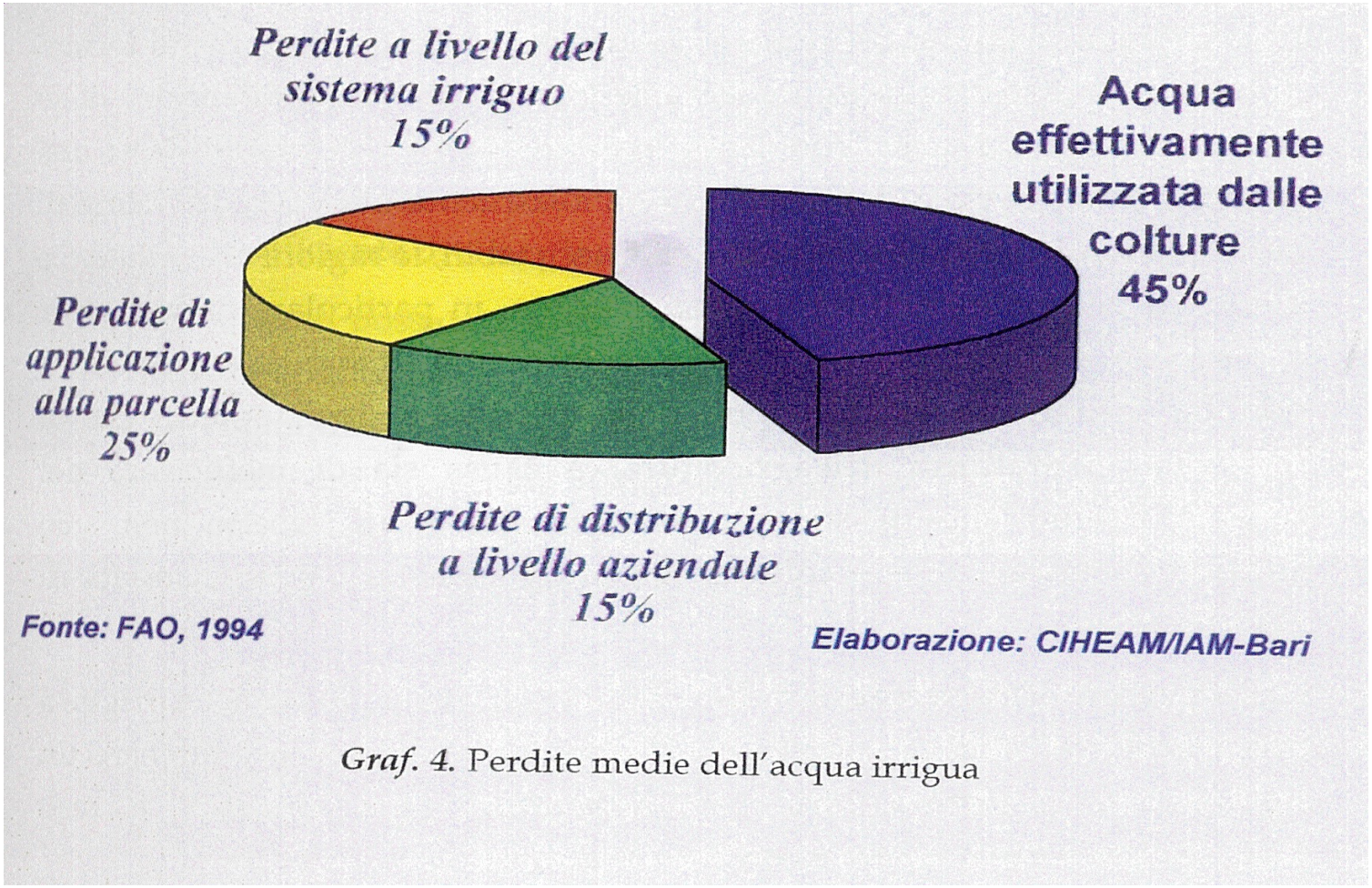
- **Yield Threshold Depletion (YTD)**

The water content where a crop is expected to start experiencing yield reducing water stress is called the yield threshold (YT) and the difference between FC and YT is called the yield threshold depletion and is often defined in terms of the Allowable Depletion (AD) which is the percentage of plant available water corresponding to the YTD.

Irrigation efficiency



Water losses normally occurring in agriculture



Graf. 4. Perdite medie dell'acqua irrigua

•**<u>Application efficiency</u> (AE)**
is a measure of how much of the water applied contributes to Crop Evapotranspiration Et_c

•**<u>Distribution Uniformity</u> (DU)**
is a measure of how evently water soaks in the field

•*For a well-drained field, if there is no runoff and if the Gross Application (GA) is equal to NA divided by the DU then AE is ± equal to the DU. The goals in good irrigation management are to apply and maintain the system with the highest DU possible.*

- **Runtime (RT)**

is the time needed to apply the GA and is found by dividing GA by the Application Rate (AR) .
The AR is equal to the Medium overall flow rate from the system evaluation converted to mm.

- **Management Allowable Depletion (MAD)**

is the soil water depletion value that is used to time irrigation events. The MAD is selected to fit with other management constraints, but it should always be smaller than the YTD to avoid yield reducing water stress

WATER BALANCE: ESTIMATING SOIL WATER CONTENT

The water content in the effective root zone is estimated by using the water balance equation :

$$WC_t = WC_{t-1} + IRR + RAIN - AET - DP$$

Where:

WC_t = Soil water content today (mm)

WC_{t-1} = Soil water content yesterday (mm)

IRR = Irrigation depth since yesterday (mm)

RAIN = Rain since yesterday (mm)

AET = Actual ET (mm) and

DP = Deep Percolation

Main issues for irrigation systems design

- Design of irrigation systems starts from two technical points:

1) Availability of water

2) Gross Irrigation Requirements (including water losses)

The **availability of water** compared to the **gross irrigation requirements** allows to determine the **area which is possible to irrigate**.

Determination of irrigation requirements

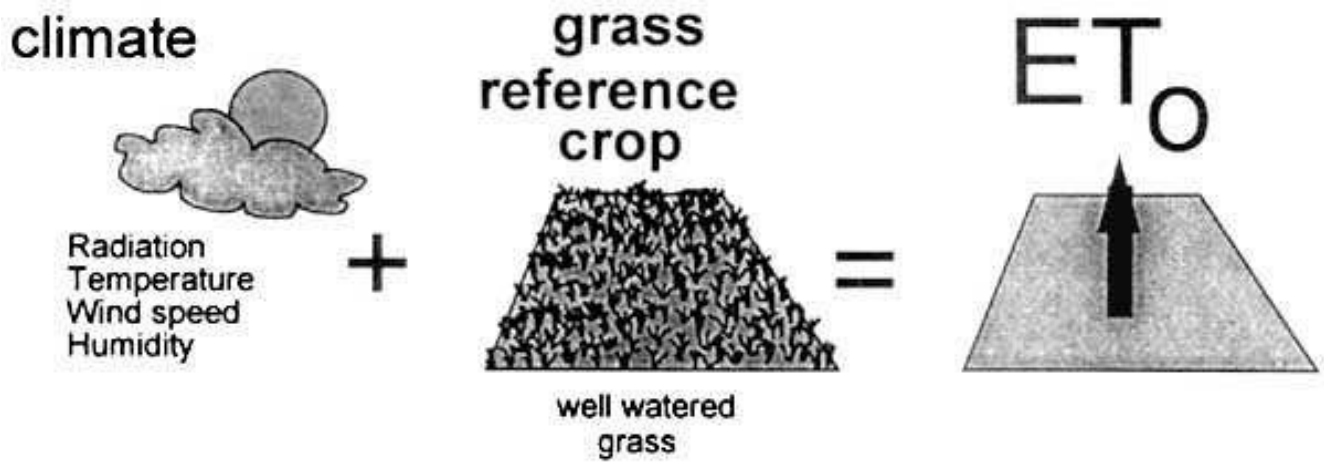
1) Hypothesis of a cropping pattern in the irrigation scheme based on the potential of the area :

- Climatic charactersitics
- Soils characteristics
- Topografic situation
- How is the area connected for commercial purposes??
- Socio-economic reality

2) Determination of crop water requirements

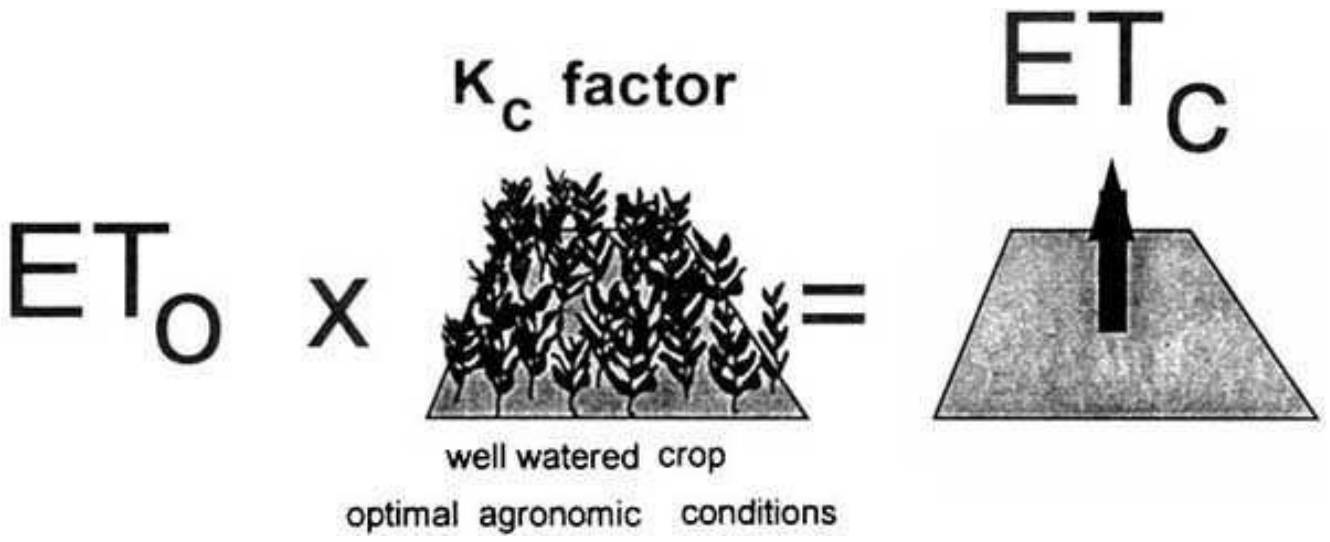
Potential Evapotranspiration (ET_O)

is the overall water lost from the soil due to the transpiration of the crop and to the direct evaporation from the soil <u>completely covered and well wetted.</u>



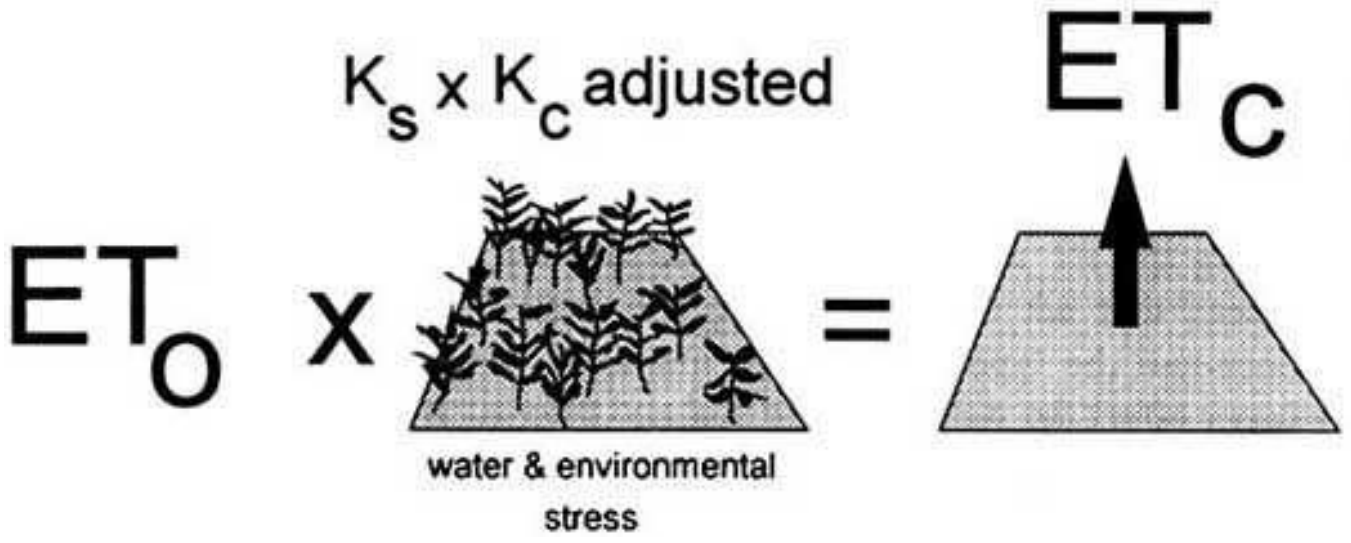
Crop Evapotranspiration (ET_c) in Standard Conditions

- Real water losses from the soil in Real Conditions, depending on the conditions of soil humidity, of the development stage of the crops, etc.



Crop Evapotranspiration (ETc adj) In Non-Standard Conditions

- Effective Water Losses from the soil occuring in <u>real conditions</u> and under <u>stress conditions</u>, depending on water stress (Ks) or on other factors (low nutrients availability etc.)



ETc is expressed in mm/d

1 mm = 10 m^3/ha

Irrigation Requirements in the peak period are considered for Project purposes (mm/d x number of days).

Computation of the specific continuous flow

- An evaluation of the Daily Net Irrigation Requirements allows the definition of the peak month. In the south of Italy it's usually July.

  Ex.) Net.Irr.Req Peak (July) = 8000 m^3/ha

  (Irr.Req - Effective Rainfall)

- This value should be affected by an efficiency coefficient (GWR) and converted in l/sec/ha
- **This value will be used for the irrigation network design**

Dimensioning of the irrigation scheme

- On the basis of this minimum availability of water the designer dimensions the irrigation scheme

$$Irrigated\ \ Area\ (ha) = \frac{Minimum\ water\ availability\ (l/\sec)}{Gross\ Irrigation\ \mathrm{Re}quirements\ (l/\sec/ha)}$$

Aspects to consider

- Once the position of the hydrants is established, a couple ***Q, P*** for each hydrant must be fixed. This is done on the basis of the irrigation method used at on-farm level. For a microflow :

$\boldsymbol{Q} = 5$ l/s

$\boldsymbol{P} = 25$ m

Determination of the flows

- In theory the flow of a section is

$$Q = N \, x \, d$$

where:

***N*:** number of hydrants served at the section

***d*:** flow of each single hydrant

Determination of the diameters
(from downstream to upstream)

- The diameters of eache single section are calculated considering a medium velocity of 1 m/s

$$D = \sqrt{\frac{4 \times Q}{Vm \times \pi}}$$

Verifications

- Verification of the velocity with the established diameters.

$$V = \frac{Q}{Sez} = \frac{4 \times Q}{\Pi \times D^2}$$

$$0.5 < V < 2 \text{ m/s}$$

If the velocity doesn't fit, the calculations must be repeated.

Calculation of Head Losses along the sections

- Unitary Head losses (J)

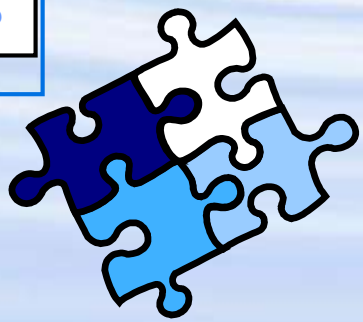
$$J\ (m/m) = \frac{10.7 \times Q^{1,852}}{Chw^{1.852} \times D^{4.87}}$$

- Chw di Hazen-Williams coefficient : it's an adimensional number equals to 150 for PVC and 120 for the concrete.
- Total Head Losses : **H*(m)* = J x L**

Large scale irrigation systems Design/Performance Analysis

ENVIRONMENTAL PARAMETERS

- CLIMATIC CONDITIONS
- PEDOLOGIC CONDITIONS
- WATER RESOURCES
- FARMERS CONDITIONS



DECISION PARAMETERS

- CHOICE OF THE CROPPING PATTERN
- COMPUTATION OF THE CROP WATER REQUIREMENTS
- DECISION ON THE TOTAL OR PARTIAL SATISFASCTION OF THE CROP WATER REQUIREMENTS
- CHOICE OF ON FARM METHOD
- MODULE OF THE HYDRANT
- NUMBER OF FARMERS PER HYDRANT
- AREA SERVED BY EACH HYDRANT
- DELIVERY SCHEDULE

Different types of irrigation

- **Autonomous** Irrigation: the farm has its own private water source

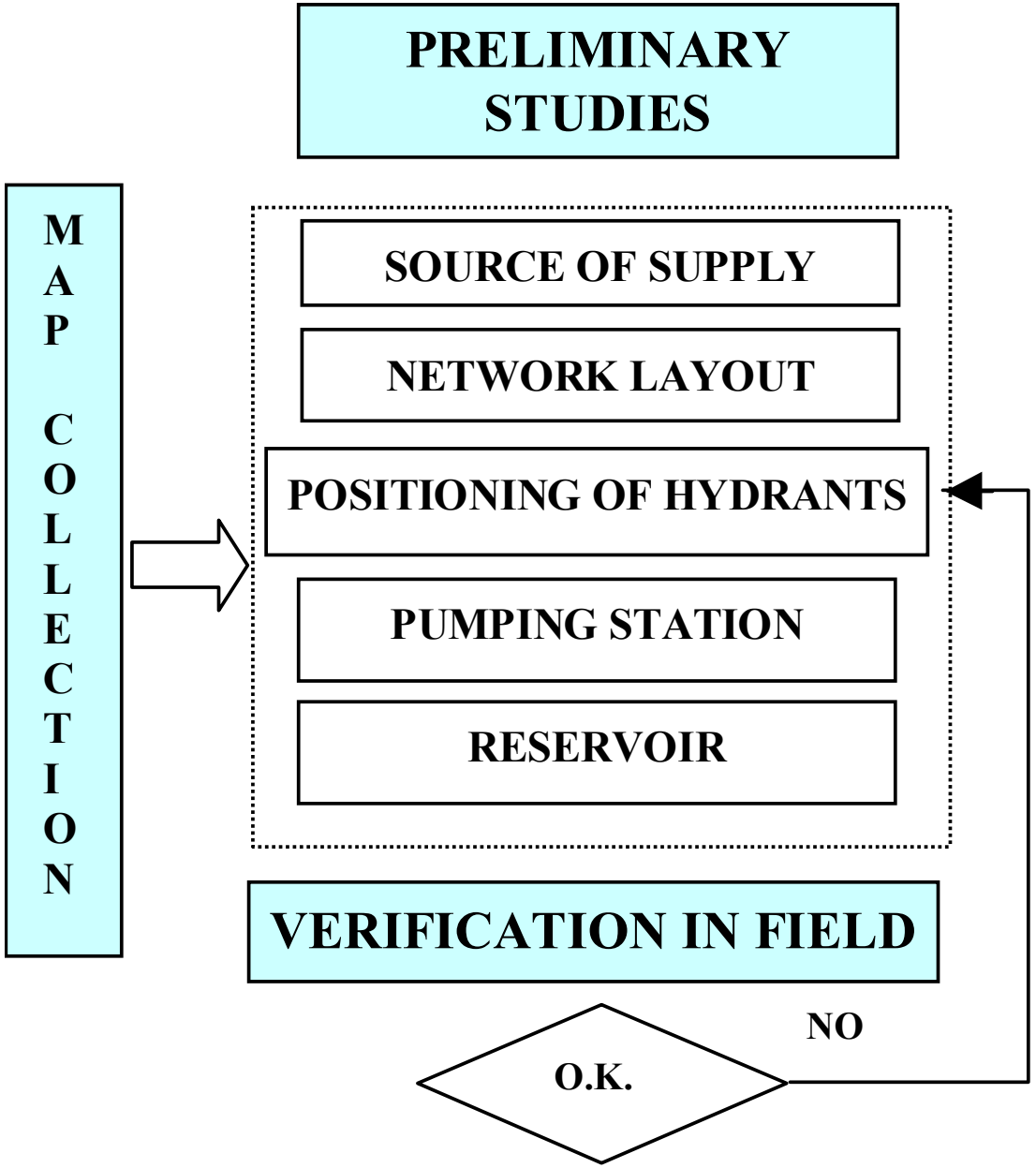
- **Collective** Irrigation: An organism manages water sources and distributes water to the different farms

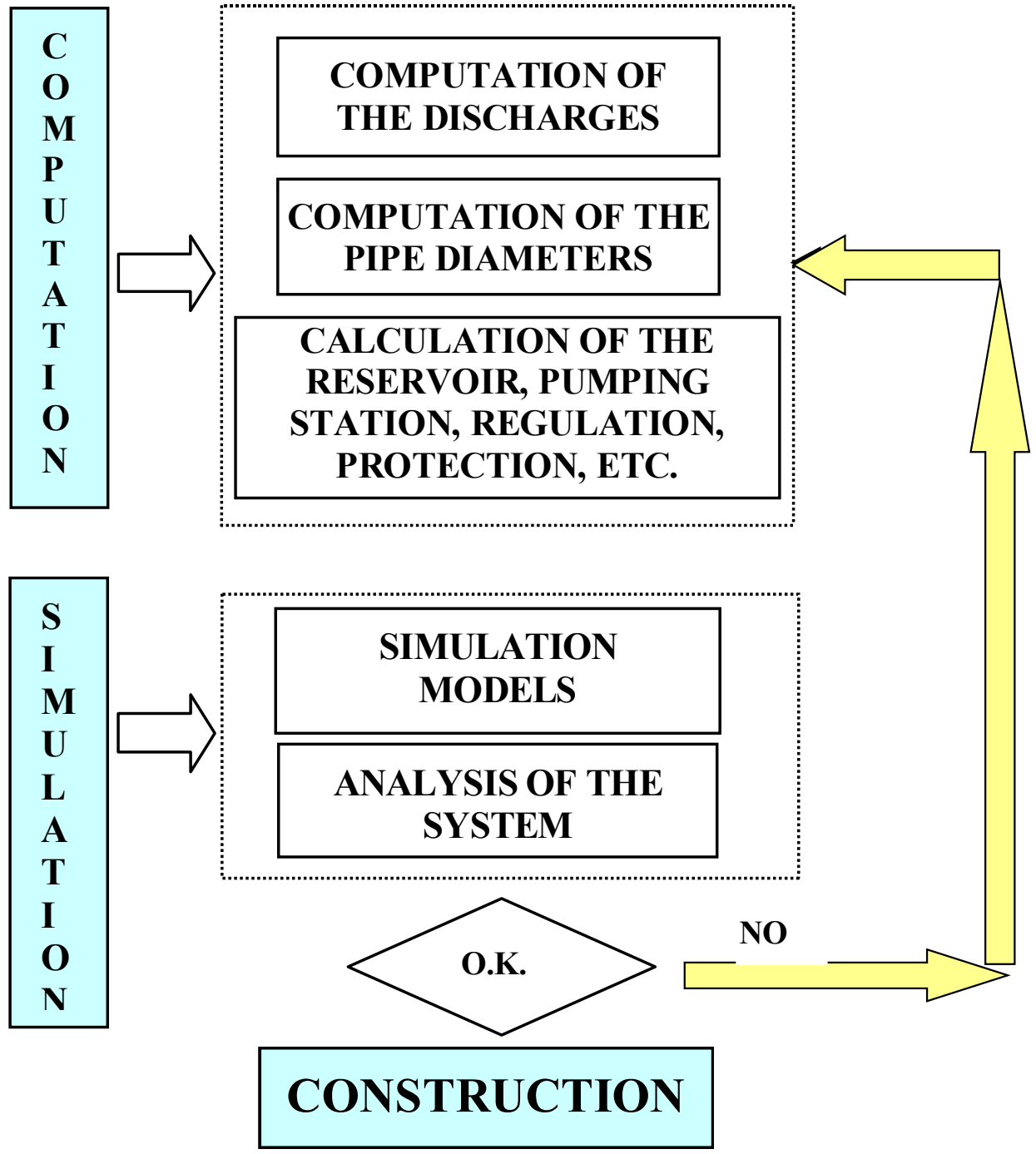
Types of Collective Irrigation

- **Rotation:** the organism in concern distributes water according to turns and quantities pre-established (according to the crop type, soil type, available discharge)
- **On-demand:** water distribution occurs under pressure and the farmer is free to use it whenever he wants. Volumes and discharges withdrawn are free.

Intermediate Distribution Modes

- **Demand with limited flow:** the withdrawn discharge is fixed by the managing organism using flow limiters. The farmer decides when and for how long to use water.
- **Demand with restricted frequency:** the managing organism establishes when the farmer could withdraw water and the maximum flow. Once the withdrawal started, the farmer decides for how long to irrigate and so the volume to withdraw.


PRELIMINARY STUDIES
MAP COLLECTION
SOURCE OF SUPPLY
NETWORK LAYOUT
POSITIONING OF HYDRANTS
PUMPING STATION
RESERVOIR
VERIFICATION IN FIELD
O.K.
NO


COMPUTATION
COMPUTATION OF THE DISCHARGES
COMPUTATION OF THE PIPE DIAMETERS
CALCULATION OF THE RESERVOIR, PUMPING STATION, REGULATION, PROTECTION, ETC.
SIMULATION
SIMULATION MODELS
ANALYSIS OF THE SYSTEM
O.K.
NO
CONSTRUCTION

LARGE-SCALE

SOUND WATER RESOURCE MANAGEMENT BY AVOIDING THE UNCONTROLLED WITHDRAWALS FROM THE SOURCE

PARTICIPATORY MANAGEMENT

PRESSURIZED

BETTER SERVICES

ESTABLISHMENT OF WATER FEES BASED ON VOLUMES CONSUMED

SERVING HILLY AREAS

INCREASE OF IRRIGATED AREA

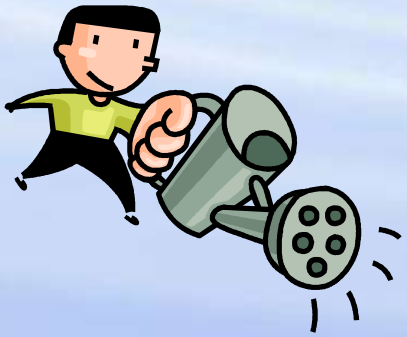
ON-DEMAND

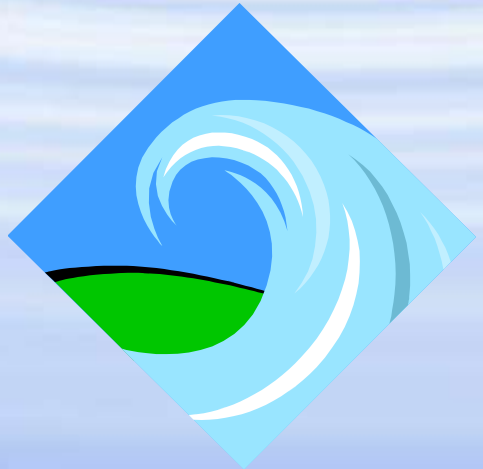
FLEXIBILITY

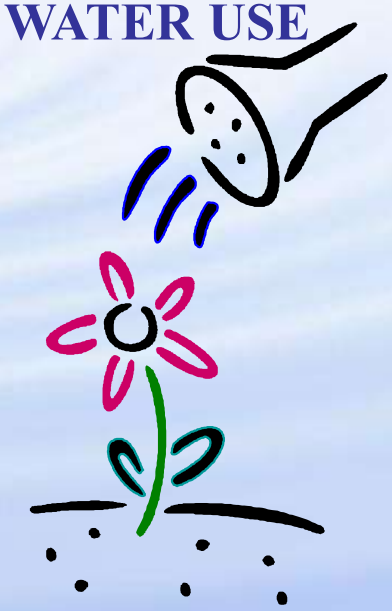
IRRIGATION ACCORDING TO REAL CROPS NEEDS

OFFERS A CONSIDERABLE POTENTIAL FOR EFFICIENT WATER USE

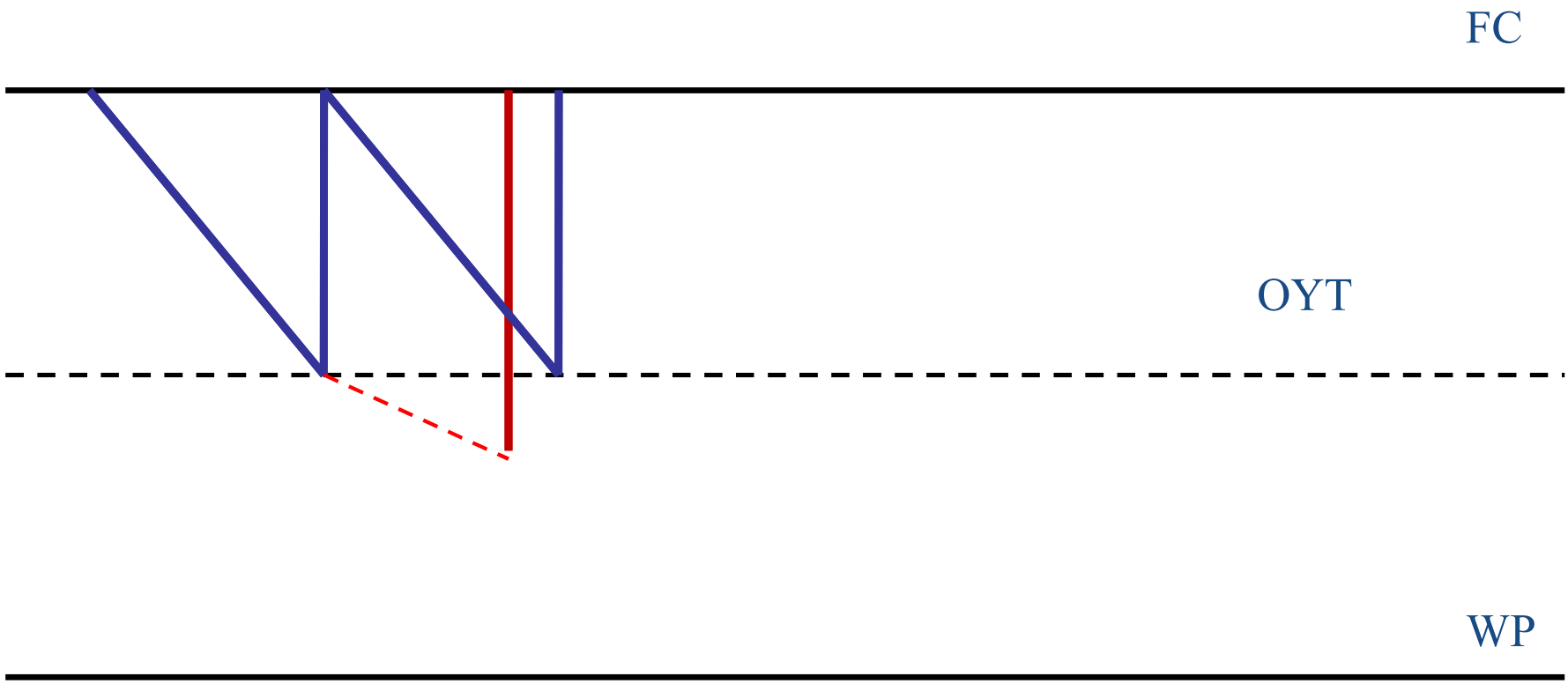
REDUCES DISPUTES AMONG FARMERS



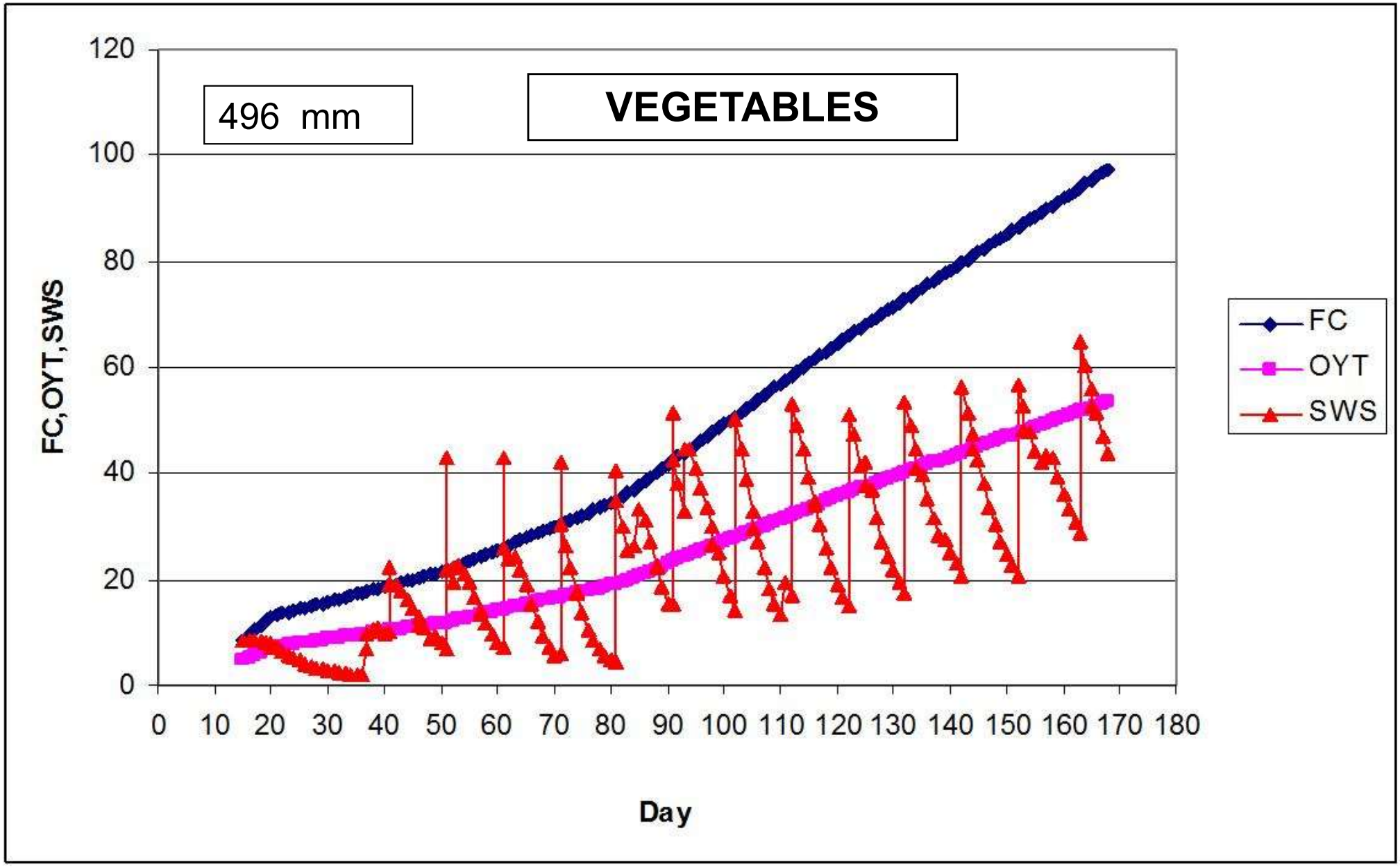




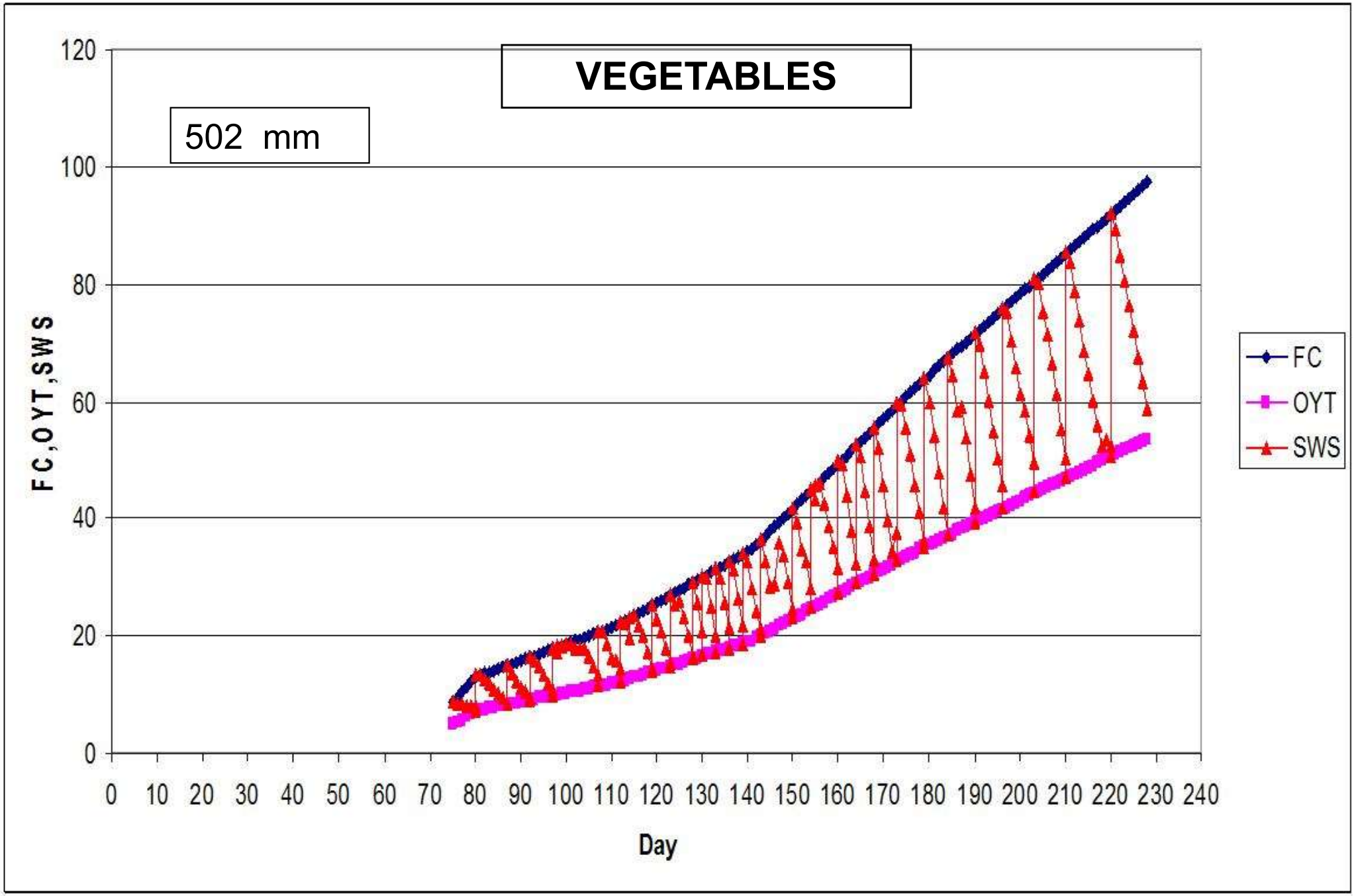
SOIL-WATER BALANCE



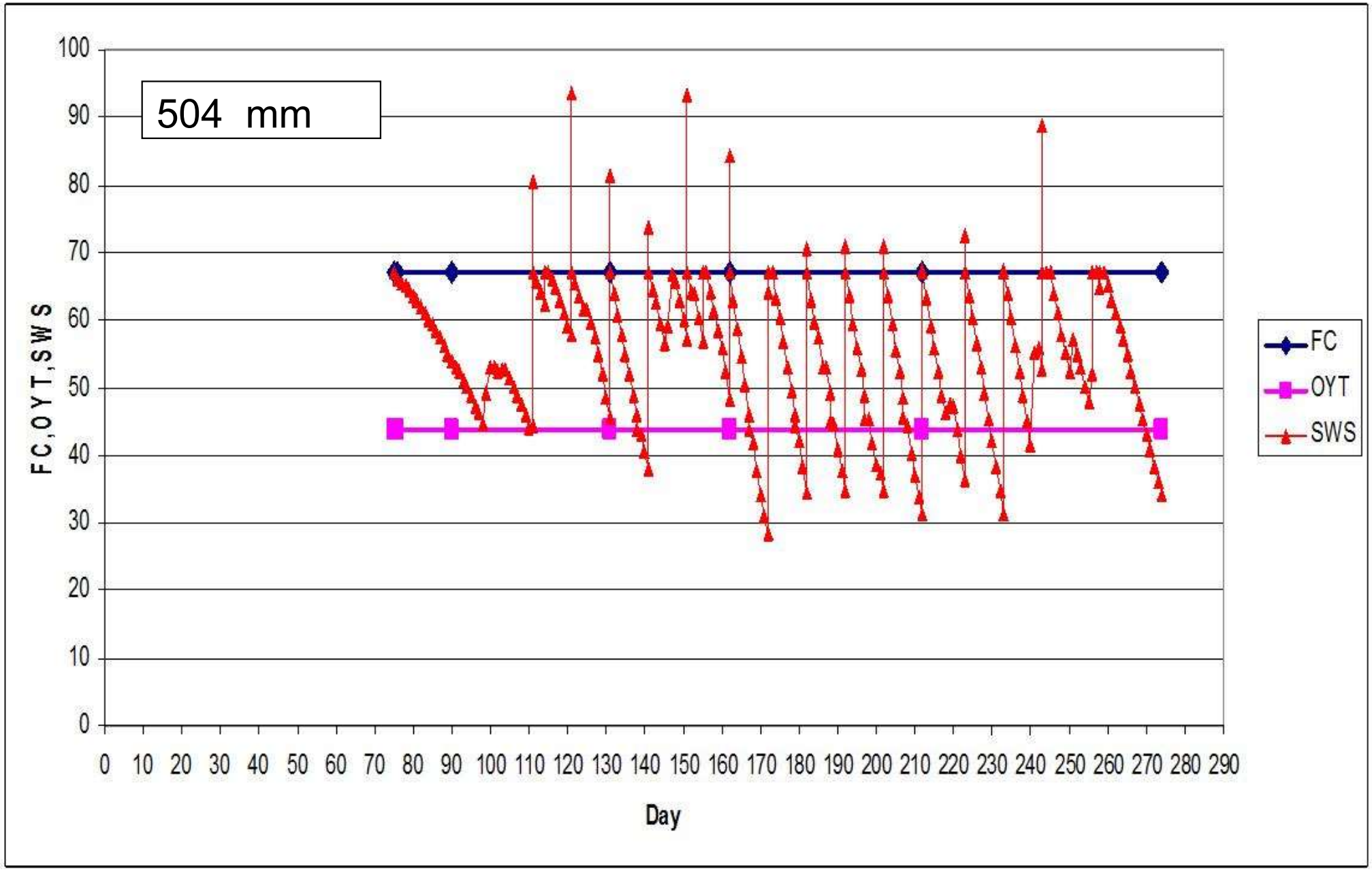
Simulated soil-water balance for VEGETABLES according to the rotational delivery schedule conducted by the Water Users Association



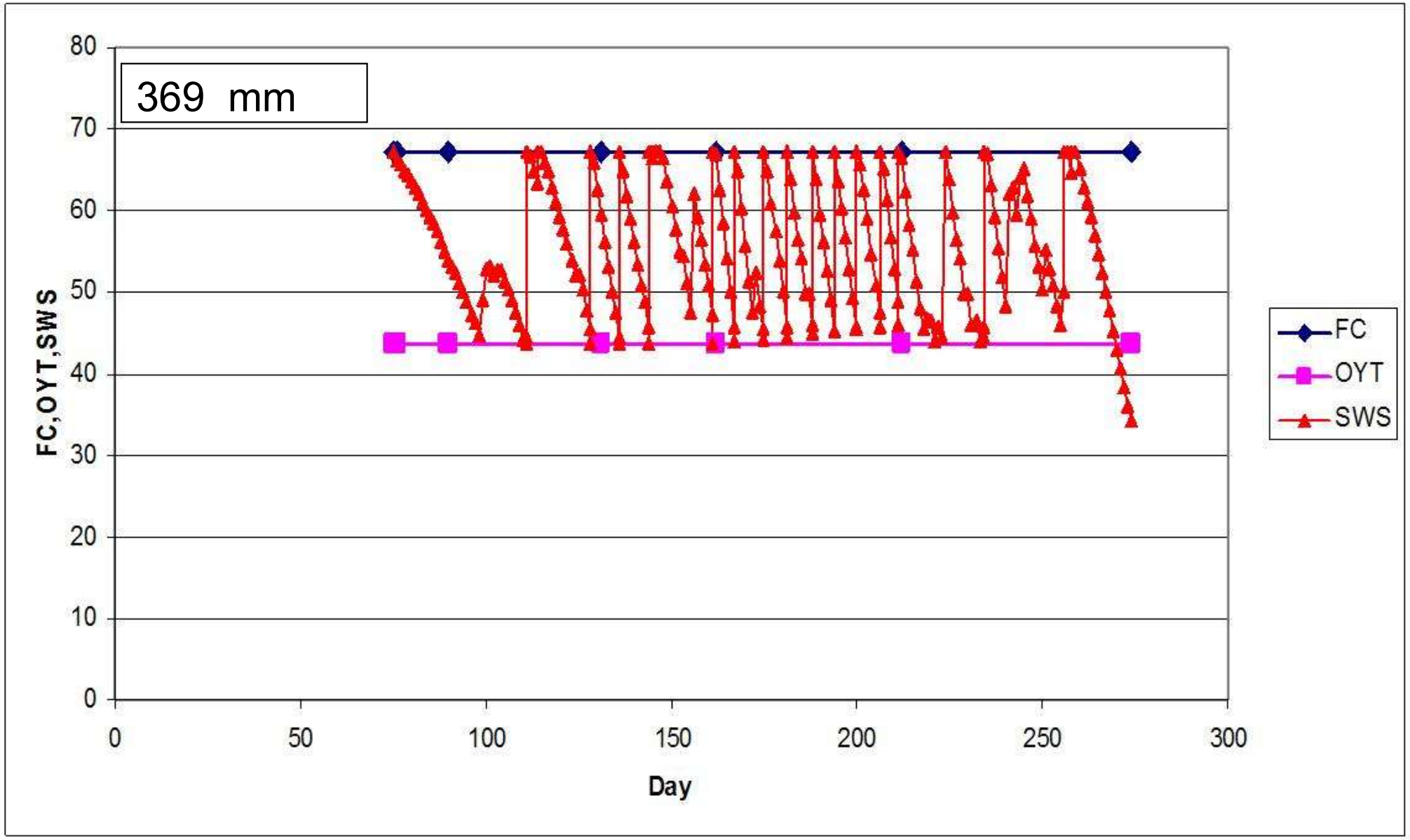
Simulated soil-water balance for VEGETABLES
according to the on-demand delivery schedule



Simulated soil-water balance for TABLE GRAPES according to the rotational delivery schedule conducted by the Water Users Association



Simulated soil-water balance for Table grapes according to the on-demand delivery schedule



THE CONDITION

SATISFYING HYDRAULIC PERFORMANCE

Discharge and Pressure head

- In fact, the discharge of a section is dimensioned for a smaller number of hydrants. In other terms, the dimensioning is done for the number of hydrants (K) with a high probability to be opened at the same time

$$K < N$$

- K is determined following a probabilistic approach (Clément model).
- Once K is determined, the discharge Q is given by: $Q = K \times d$

where d = Hydrant discharge

Teaching Unit 1

OFRM: Statistical Model - OVERVIEW

OVERVIEW

One Flow Regime Models

In on-demand irrigation systems, the nominal discharge of the hydrants d is selected much higher than the duty, D. It allows farmers to irrigate for a duration lower than 24 hours. This condition implies that the event to find all the hydrants simultaneously operating has very low probability. Thus, it is not reasonable to calculate the irrigation network by adding the discharges delivered at all the hydrants simultaneously.

Probablistic approaches for computing the discharges into the sections of an on-demand collective network have been widely used in the past and are still used actually.

Clément (1966) proposed **two formulas to compute the design flows:**

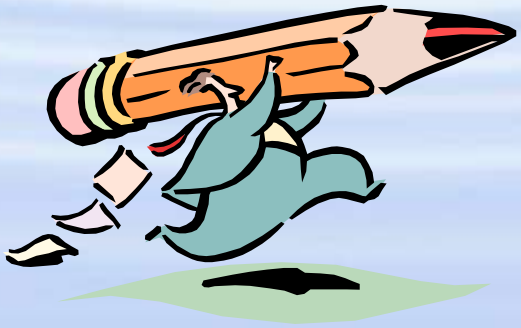
- **The first** is based on a probabilistic approach.
- **The second** is based on simulating the irrigation process as a birth and death process.

TEACHING UNIT 1: ONE FLOW REGIME MODEL – STATISTICAL MODEL

The first Clément formula is based on a probabilistic approach where, **within a population of R hydrants, the number of hydrants being open simultaneously is considered to follow a binomial distribution**.

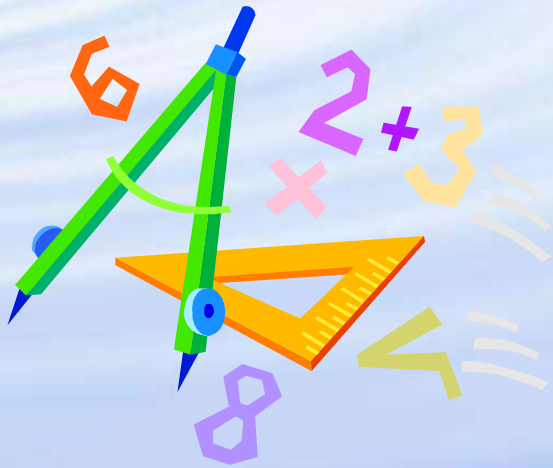
The second is based on simulating **the irrigation process** as **a birth and death process** in which, at a given state j (j hydrants open), the average rate of birth is proportional to (R-j) and the average rate of death is proportional to j.

Only the first demand formula has been widely used thanks to its simplicity and will be reported hereafter, applying it to an irrigation network.



Teaching Unit 2

OFRM: Statistical Model – First Clément Formula



TEACHING UNIT 2: FIRST CLÉMENT FORMULA

HYDRANT DISCHARGE CALCULATION

The discharge attributed to each hydrant is defined according to the size, crop water requirements of the plot, the on-farm system and its efficiency. It is always greater than the duty (the duty is the flow based on peak demand period water requirement on a 24-hour basis) so as to give the farmer a certain degree of freedom in the management of the irrigation. The ratio between the discharge attributed to each hydrant and the duty is a measure of the **"degree of freedom"** which a farmer has, to manage irrigation.

Since the maximum flow at hydrants is fixed by flow regulators it is usual to opt for a standard range of flows. Such ranges vary from country to country. In Italy the range of hydrants corresponds to the following discharges (tab. 1):

Class of hydrant	0	1	2	3	4	5
Discharge (l s^{-1})	2.5	5	10	15	20	25

Table 1. Range of hydrants and corresponding discharges-Italian standards

TEACHING UNIT 2: FIRST CLÉMENT FORMULA

HYDRANT DISCHARGE CALCULATION - AN APPLICATION

Simplistic approach[1]

q_s	specific continuous discharge (24/24 hours)	= 0.6 l s^{-1} ha^{-1}
A_p	area of the plot to be irrigated	= 2 ha
D	Duty (i.e., continuous discharge required by the plot)	= 0.6 x 2 = 1.2 l s^{-1}

****

By selecting a hydrant having nominal discharge d = 5 l s^{-1}, we obtain

e_h = elasticity of the hydrant = d/D = 5/1.2 = 4.17

It means that the duration of the irrigation, T, will be

T = 24/4.17 = 5.76 hours

The volume supplied to the plot (2 ha) is

V_p = d x T = 5 x 5.76 x 3600/1000 = 103.68 m^3

It corresponds to the unitary volume and thus the application rate

v = V_p/A_p = 103.68/2 = 51.84 m^3 ha^{-1} = 5.18 mm

AR = Application Rate = v/T = 5.18/5.76 = 0.9 mm/h

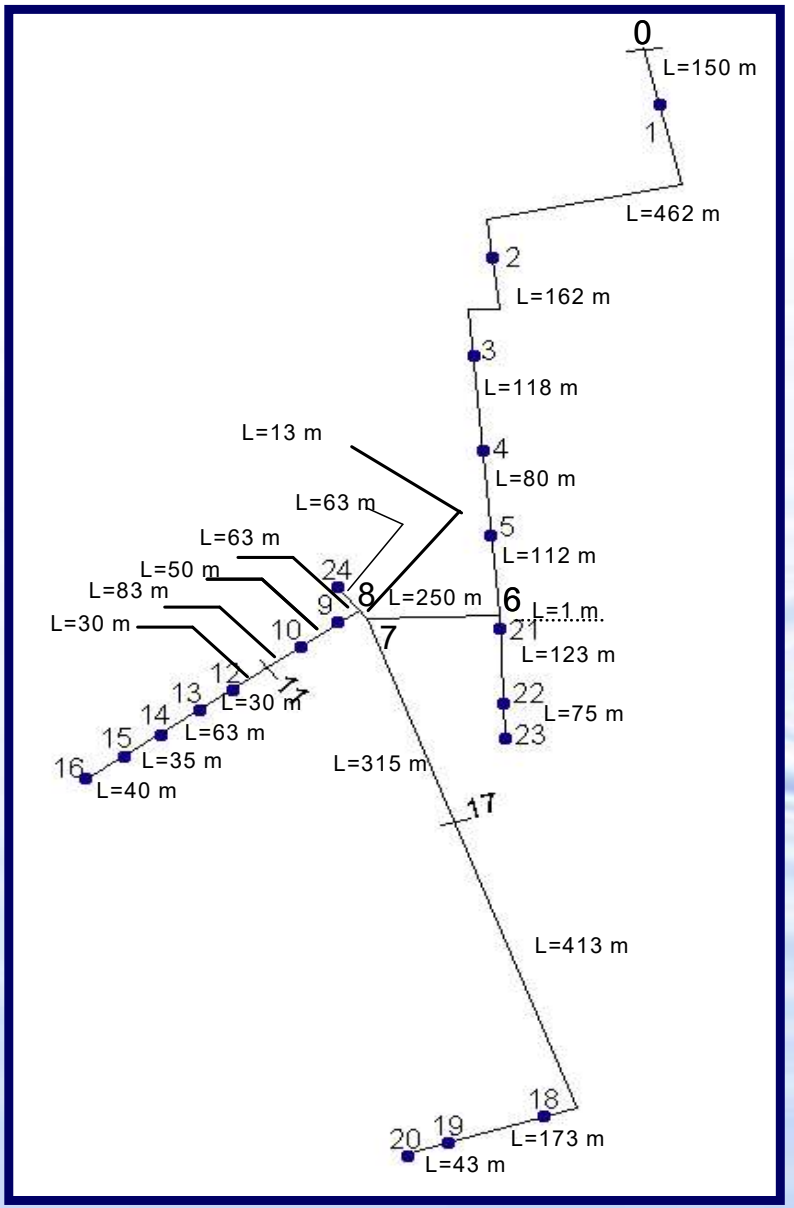
The application rate, AR, should be applied by the on-farm network and this value should be lower than the infiltration rate in order to avoid runoff.

[1] For a detailed and a sounder approach see Clément and Galand (1979)

TEACHING UNIT 2: FIRST CLÉMENT FORMULA

After calculating the hydrant discharge, we will calculate the upstream discharge using the first Clément formula.

TEACHING UNIT 2: FIRST CLÉMENT FORMULA



Irrigation network under study

Data: PEAK PERIOD

q_s = specific continuous discharge (24/24 hours) = 0.327 l s^{-1} ha^{-1}

A_p = area of the plot to be irrigated = 3 ha

R = total number of hydrants = 19

A = total irrigable area = 3 · 19 = 57 ha

d = nominal discharge of the hydrants = 10 l s^{-1}

P_q = cumulative probability for having a maximum of x hydrants simultaneously operating = 95%

$U(P_q)$ = **standard normal variable** = operation quality = 1.645

r = **use coefficient** = 16h/24h = 0.667

Nba = minimum number of hydrants in simultaneous operation = 4

The numbers are referred to the number of each node

L= Length of the section in meters

TEACHING UNIT 2: FIRST CLÉMENT FORMULA

p = elementary probability = operation probability of a hydrant = $\frac{q_s A}{r R d} = \frac{0.327 \cdot 57}{0.667 \cdot 19 \cdot 10} = 0.147$

1) Number of hydrants simultaneously operating downstream the section 0-1:

$N_{0-1} = Rp + U(P_q)\sqrt{Rp(1-p)} = 19 \cdot 0.147 + 1.645\sqrt{19 \cdot 0.147 \cdot (1-0.147)} = 5.33$

We assume $N_{0-1} = 6$ [2] and thus the design discharge downstream the section 0-1 is:

$Q_{0-1} = N_{0-1} \cdot d = 6 \cdot 10 = 60\ l\ s^{-1}$

2) Number of hydrants in simultaneous operation downstream the section 1-2:

$N_{1-2} = R_{1-2}p + U(P_q)\sqrt{R_{1-2}p(1-p)} = 18 \cdot 0.147 + 1.645\sqrt{18 \cdot 0.147 \cdot (1-0.147)} = 6.11$

We assume $N_{1-2} = 6$ and thus the design discharge downstream the section 1-2 is:

$Q_{1-2} = N_{1-2} \cdot d = 6 \cdot 10 = 60\ l\ s^{-1}$

3) Number of hydrants in simultaneous operation downstream the section 2-3:

$N_{2-3} = R_{2-3}p + U(P_q)\sqrt{R_{2-3}p(1-p)} = 17 \cdot 0.147 + 1.645\sqrt{17 \cdot 0.147 \cdot (1-0.147)} = 4.90$

We assume $N_{2-3} = 5$ and thus the design discharge downstream the section 2-3 is:

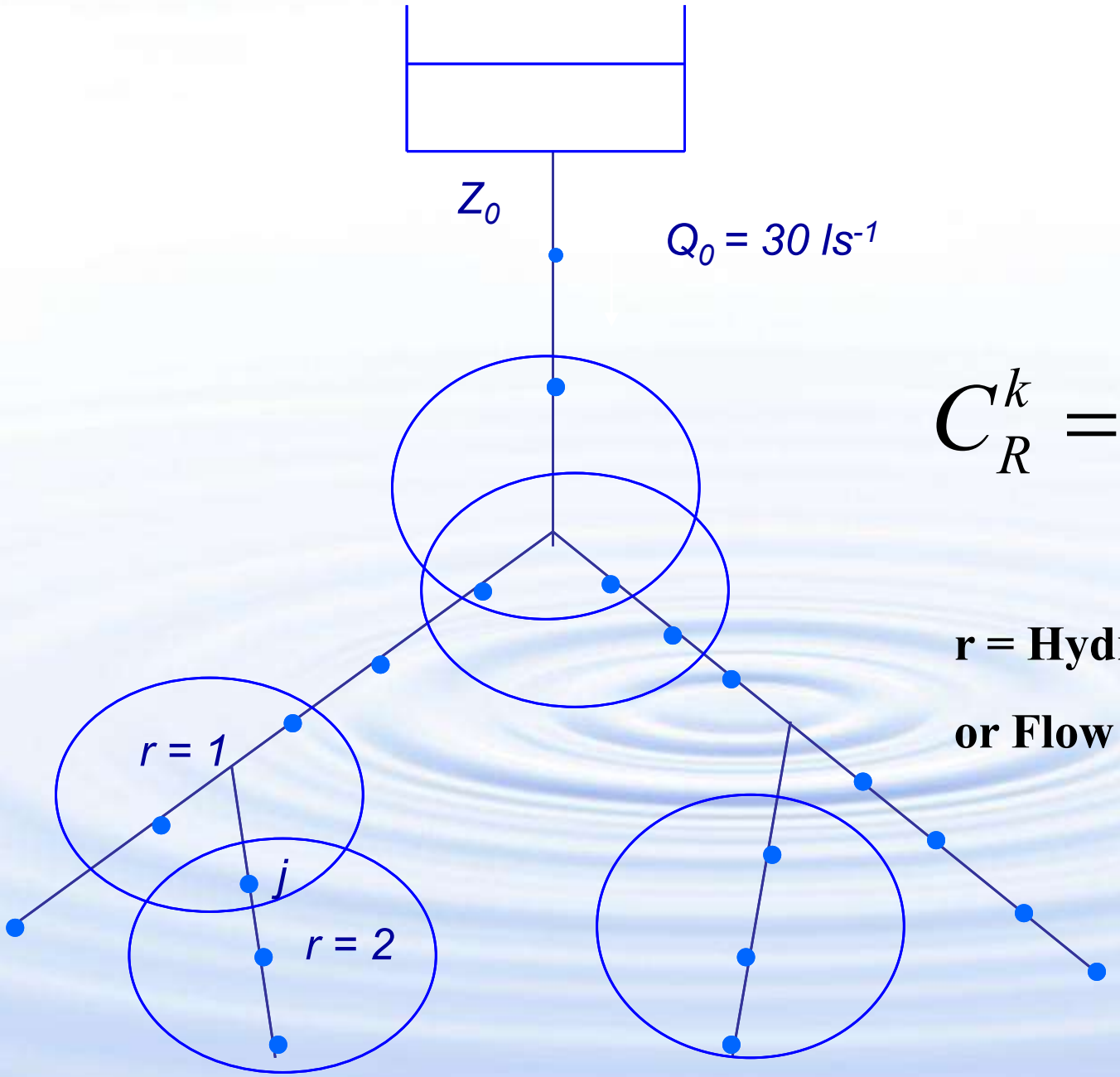
$Q_{2-3} = N_{2-3} \cdot d = 5 \cdot 10 = 50\ l\ s^{-1}$

and so on for the calculation of the discharges in the other sections.

2 Different opinions occur on this type of approximation. Some authors consider the normal mathematical approximation (i.e.: 5.5=6 and/or 5.4=5). We believe that, physically, any decimal number means another hydrant operating. In fact, in the complete output of the network in this example, the discharges in each section was computed with this last criteria.

PERFORMANCE = SYSTEM REQUIREMENTS NECESSARY TO MEET DESIGN STANDARDS FOR PRESSURE AND/OR DISCHARGE

IRRIGATION SYSTEMS ANALYSIS IS THE PROCESS OF USING A COMPUTER SIMULATION MODEL TO ANALYZE PERFORMANCE CAPABILITIES



$$C_R^k = \frac{R!}{k!(R-k)!}$$

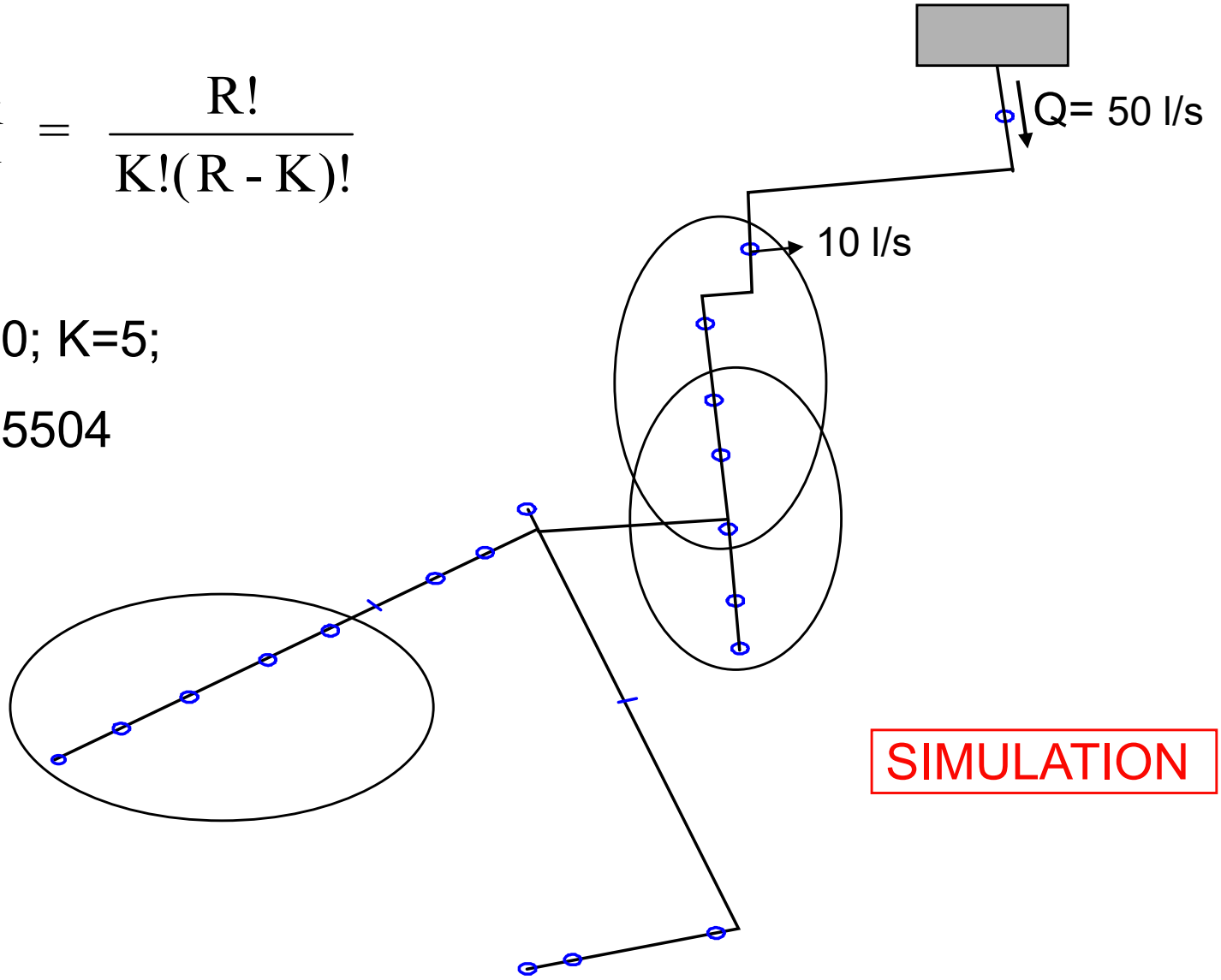
r = Hydrants Configuration

or Flow Regime

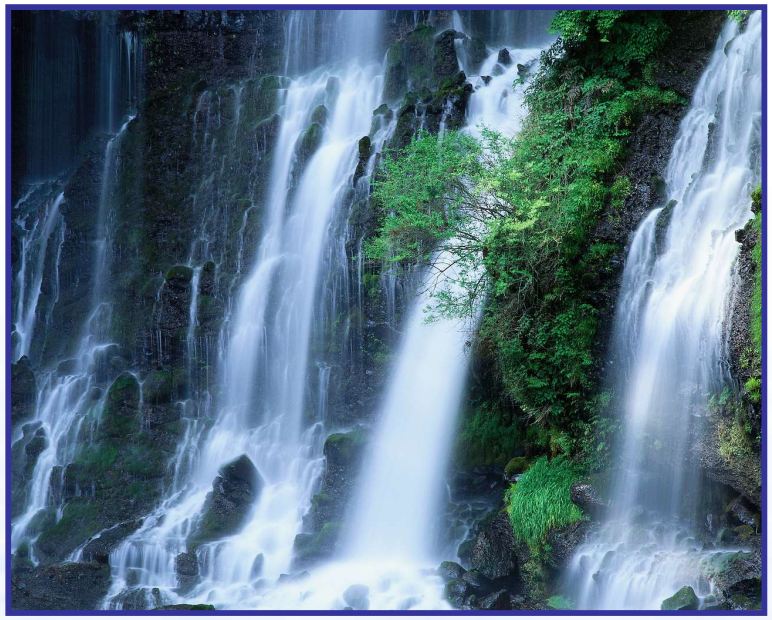
$$C_R^K = \frac{R!}{K!(R-K)!}$$

R=20; K=5;

C=15504



SIMULATION



Teaching Unit 1 :

Indexed Characteristic Curves Model Background

ABOUT THE CONFIGURATION

Under the hypothesis that any operating hydrant may deliver the **nominal discharge** d [l s^{-1}] even when the pressure head changes[1] (Figure 1), let's redefine **"configuration"** r as a group of operating **hydrants** j corresponding to a fixed value of the **nominal discharge**, Q [l s^{-1}], at the upstream end of the network.

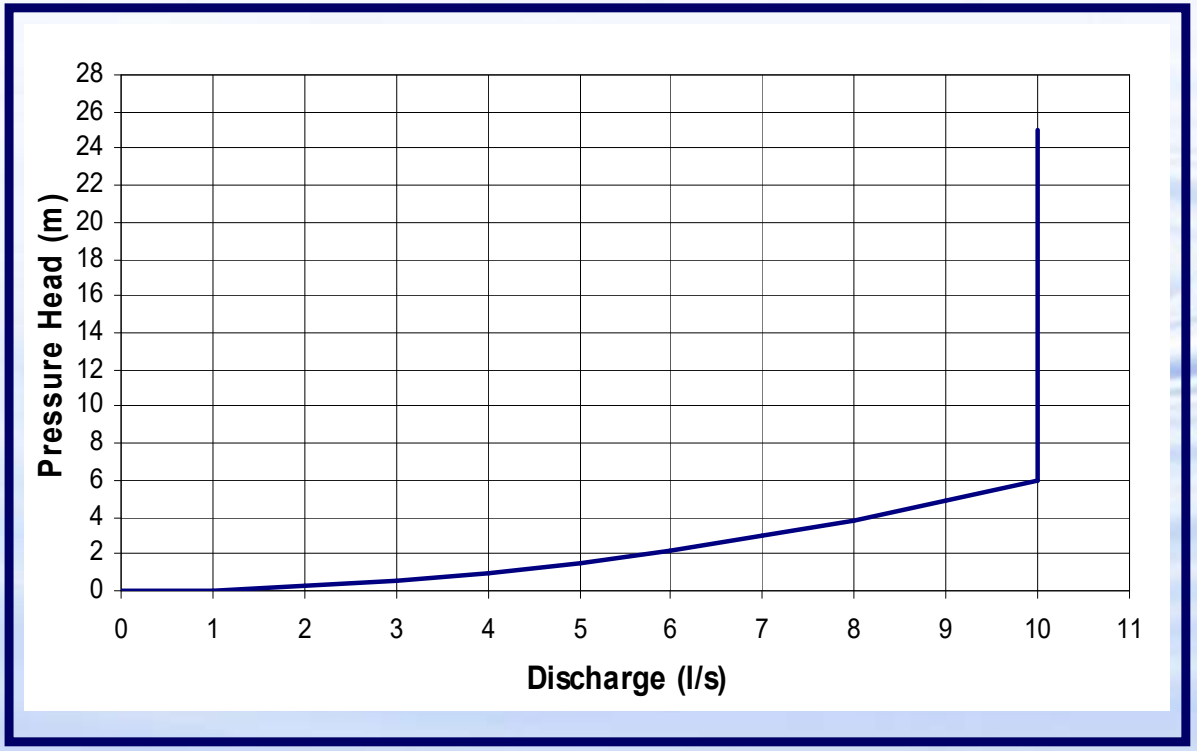


Figure 1: Characteristic curve of a hydrant

[1] Usually this is true when the hydrants incorporate a proper flow limiter

A configuration is said **satisfied** when for **all the operating hydrants** of the configuration the following relationship is respected:

$$(Hj)r \geq Hmin \quad (1)$$

(Hj)r [m] represents the **hydraulic head** of the hydrant j within the configuration **r** and
Hmin [m] represents the **minimum required head** for appropriate operation of the on-farm system.

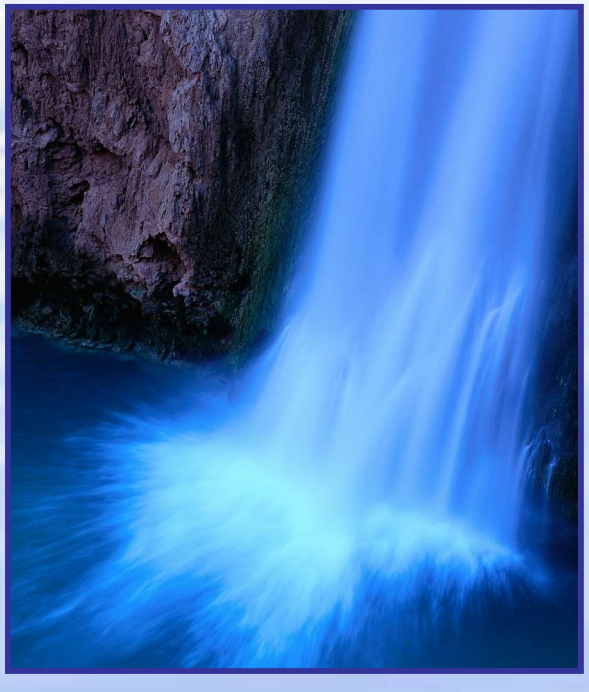
For each configuration, the satisfaction of the above condition depends on the plano-altimetric location of the operating hydrants.

In general, the network is able to satisfy only a percentage of the possible configurations

Teaching Unit 1 :

AKLA Model

Background



WHAT IS THE AKLA MODEL?

AKLA allows the analysis of the pressure head at each hydrant under different operating conditions.

This pressure head is compared with the minimum pressure required for an appropriate on-farm irrigation.

A measure of the hydraulic performance for each hydrant is obtained through the computation of the relative pressure deficit defined hereafter.

WHEN THE MODEL IS APPLICABLE?

The model is applicable under the hypothesis that the hydrant may deliver a constant discharge for a wide range of operating pressure heads. This condition is appropriate for a wide range of commercial delivery equipment.

AKLA [1] is based on the multiple generation of a pre-fixed number of Configurations using a random number generator having a uniform distribution function.

[1] This model has been developed by Ait Kadi and Lamaddalena. The first version of the computer program has been available since 1991. It has been utilized for the analysis of several irrigation schemes and reported in M. Sc. Thesis at the C.I.H.E.A.M., Institute of Bari (Italy) under the supervision of Prof. Ait Kadi and/or Lamaddalena (Abdelwahab, 1992; El Aallouni, 1993; El Yacoubi, 1994; Ben Abdellah, 1995; Nerilli, 1996; Zaccaria, 1998; Khadra, 1999).

WHEN THE MODEL IS APPLICABLE?

Within each generated configuration r, a hydrant j is considered satisfied when the following relationship is verified:

$$H_{j,r} \geq H_{min}$$

where $H_{j,r}$ [m] represents the head of the hydrant j within the configuration r, and H_{min} [m] represents the minimum required head for the appropriate operation of the on-farm systems.

DESCRIPTION

The relative pressure deficit at each hydrant is defined as:

$$\Delta H_{j,r} = \frac{H_{j,r} - H_{min}}{H_{min}}$$

AKLA computes within each configuration this relative pressure deficit at each hydrant and determines the percentage of unsatisfied hydrants.
The head losses, Y [m], are computed by the Darcy's equation:

$$Y = 0.000857\,(1 + 2\ \gamma / \sqrt{D})^2\ \frac{Q^2}{D^5} L = uQ^2 L$$

where γ is the roughness parameter of Bazin, expressed in $m^{0.5}$, Q [$m^3\ s^{-1}$] is the discharge flowing in the pipe and u [$m^{-1}\ s^2$] is the dimensional coefficient of resistance.

TEACHING UNIT 1 : AIT KADI – LAMADDALENA (AKLA) MODEL BACKGROUND

Assuming that each hydrant may withdraw the nominal discharge d [l s^{-1}] also when its head is lower than the minimum required [H_{min}], and for a discharge at the upstream end of the network Q_r [l s^{-1}], the number of hydrants simultaneously operating K_r is [2] :

$$K_r = Q_r / d$$

Once the available piezometric elevation at the upstream end of the network Z_0 [m a.s.l.] is established, the set of discharges to be tested Q_r and the number of configurations C to be investigated for each discharge have to be selected.

Later, by using the RGM, the K_r hydrants simultaneously operating are randomly drawn.

This procedure is repeated C times for each discharge Q_r.

---

[1] In the case of different hydrant discharges, the same procedure reported in the previous section is applied. Random drawing will be performed to satisfy the relationship:

$| Q_{tir} - Q_i | < \varepsilon$

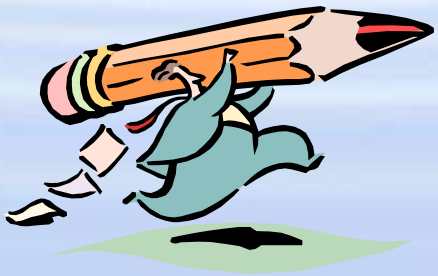
where Q_{tir} is the discharge corresponding to K hydrants drawn at random [l s-1] and ε is the accepted tolerance. In general, ε is assumed as equal to the value of the lowest hydrant discharge.

CONFIGURATIONS INVESTIGATION

According to the results obtained by analyzing a large number of irrigation systems, it is possible to state that:

- the number of configurations C to be tested should be higher than the number of hydrants of the network R (C>R) when R<200

- the number of configurations C to be tested can be smaller than the number of hydrants of the network R (C<R) when R>600.



Teaching Unit 2 :

AKLA MODEL

HYDRANT ANALYSIS – PRESSURE DEFICIT

The discharges flowing in each section of the network for each discharge Q_r are obtained by aggregating from downstream to upstream the discharges delivered by the selected K_r hydrants. Starting from the upstream piezometric elevation Z_0, Darcy's equation is used for the calculation of the head losses[1] and, consequently, for the calculation of the head available at each hydrant in each confiuration.

[1] Local head losses have been neglected in the computations. Usually they are very small respect to the linear head losses, anyway they may be taken into account when the upstream piezometric elevation is analyzed.

The last representation provides for an immediate and complementary comparison with the ICCM. Through the HYDRANT ANALYSIS of both models, the number of fully satisfied configurations as well as the PUH can be identified with the variation of Z_0.

It is possible to identify for each configuration the range of variation of the head at each hydrant.
The relative pressure deficit $\Delta H_{j,r}$ may be represented in a plane (Hydrants numbering, ΔH).

The hydrants which may be most subject to insufficient pressure head, and hence the critical zones of the network, may be clearly identified (Figure 6).

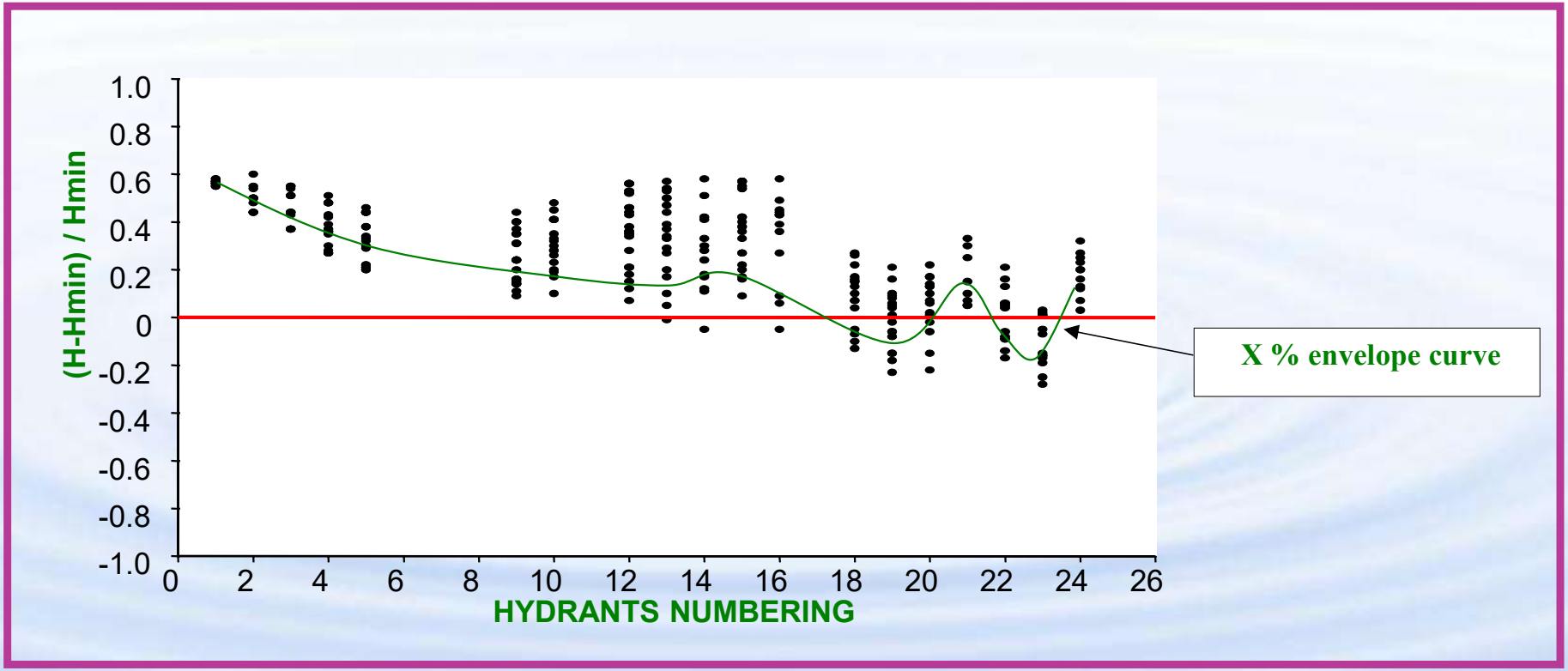


Figure 62: Relative pressure deficits for every hydrant in the network

HYDRANT ANALYSIS – RELIABILITY

The operational status of a water resource system can be described as either satisfactory or unsatisfactory.

The occurrence of unsatisfactory conditions is defined as failure.

A failure in a pressurized irrigation system corresponds to a drop in pressure head (and/or discharge) at the hydrant below the minimum required for an appropriate on-farm irrigation.

The reliability performance indicator for identifying an irrigation system failure, especially during peak periods, can be utilized for improving both design and HYDRANT ANALYSIS of irrigation systems.

The system reliability describes how often the system fails.

(Hashimoto, 1980; Hashimoto et al., 1982).

The reliability of a system can be described by the probability α that the system is in a satisfactory state:

$$\alpha = \text{Prob}\,[X_t \in S]$$

In the case of pressurized irrigation systems, the reliability of each hydrant was defined and computed from the results obtained by the AKLA model.

TEACHING UNIT 2 : AKLA MODEL

From the definition of reliability the following relationship may be obtained:

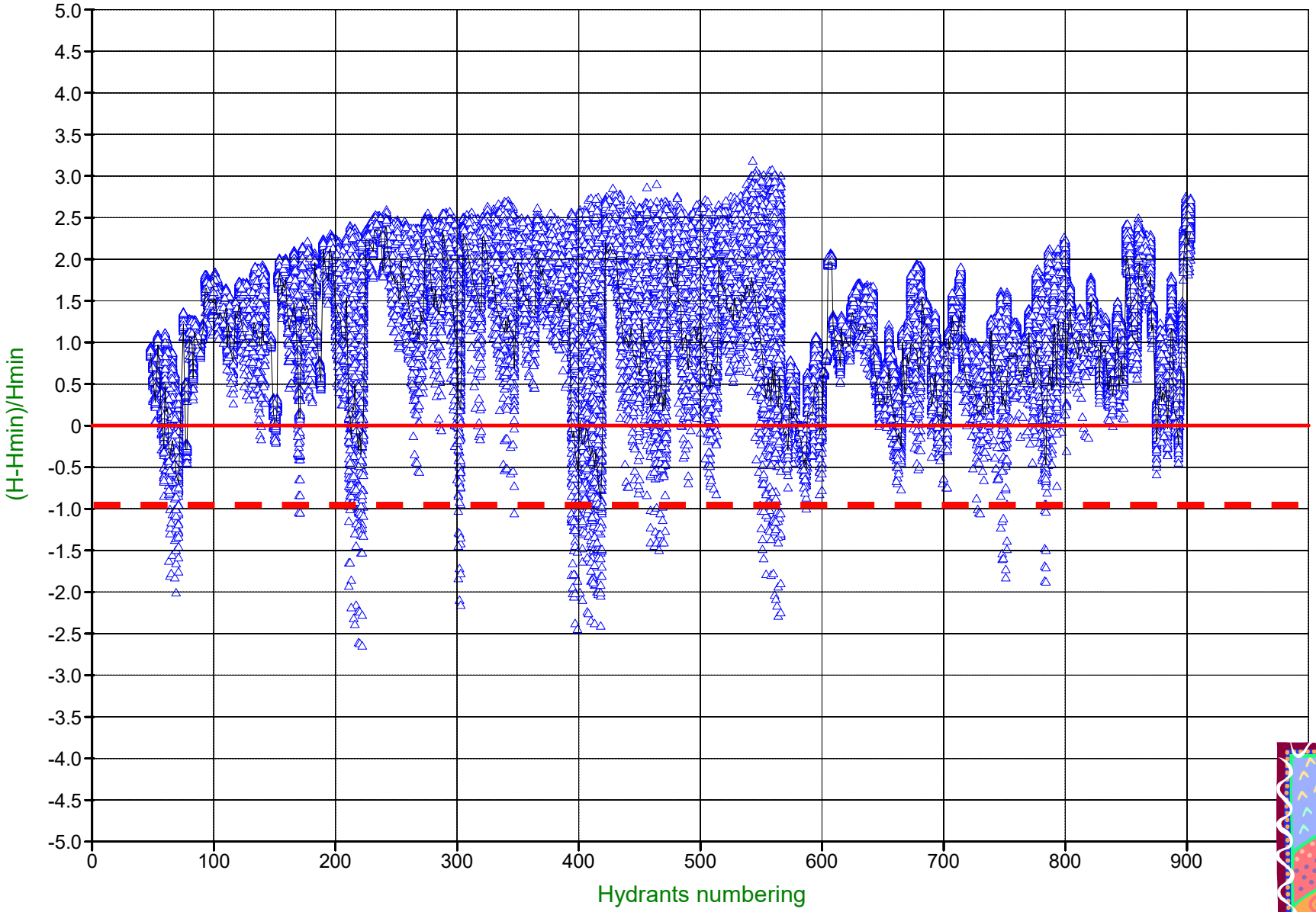
$$\alpha_j = \frac{\sum_{r=1}^{C} Ih_{j,r}\, Ip_{j,r}}{\sum_{r=1}^{C} Ih_{j,r}}$$

where:

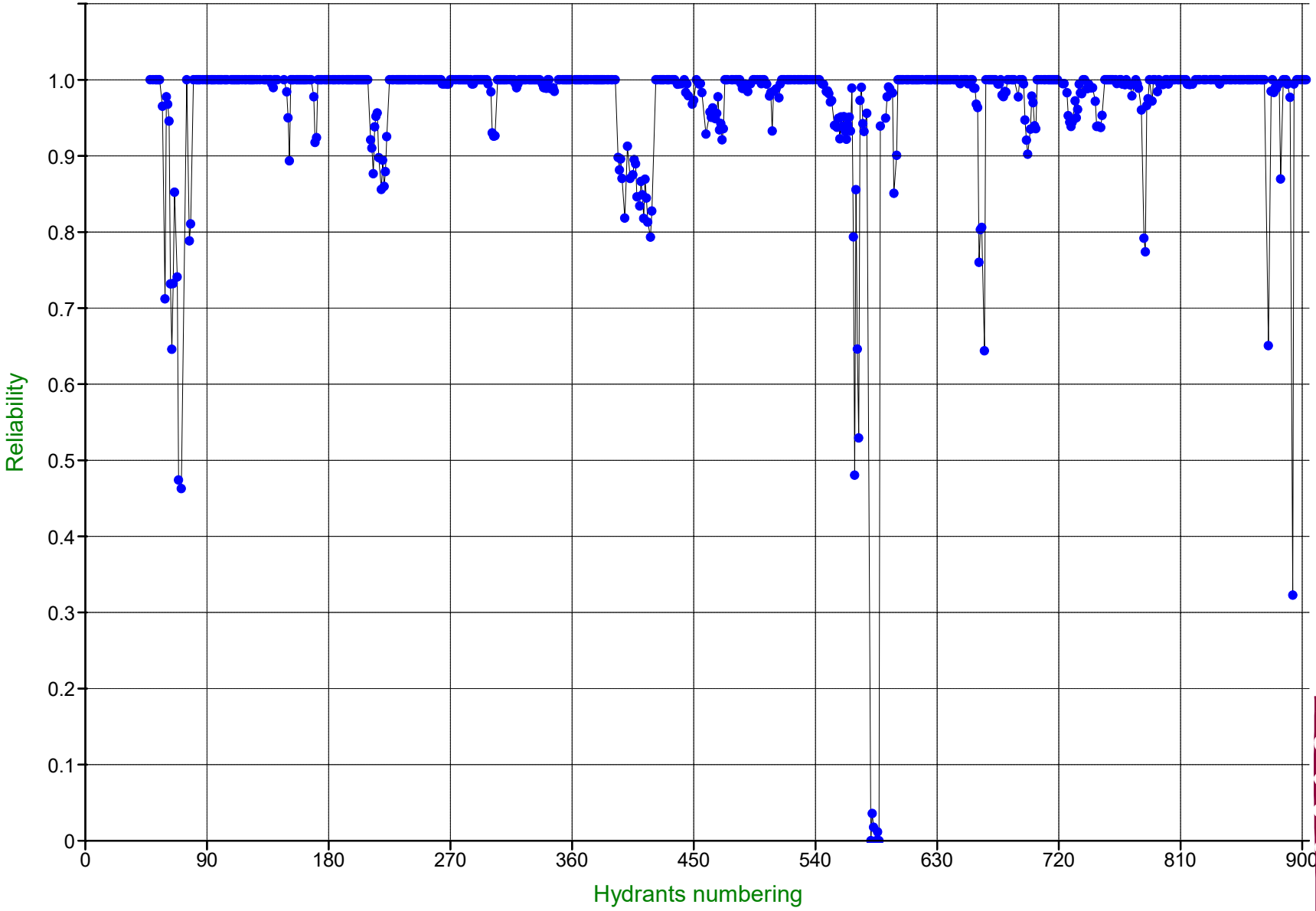
α_j = **reliability** of the hydrant j
$Ih_{j,r}$ = 1 if the hydrant j is **open** in the configuration r
$Ih_{j,r}$ = 0 if the hydrant j is **closed** in the configuration r
$Ip_{j,r}$ = 1 if the **pressure head** at the hydrant j open in the configuration r is **higher** than the minimum pressure head
$Ip_{j,r}$ = 0, if the **pressure head** at the hydrant j open in the configuration r is **lower** than the minimum pressure head
C = total number of the generated configurations.

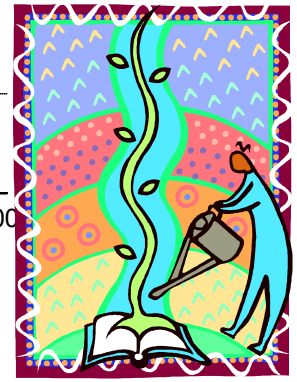
For **each discharge configuration** the **HYDRANT ANALYSIS** performed with the model **AKLA** gives the **available head [m]** at each **operating hydrant**. Therefore, the indexes $Ih_{j,r}$ and $Ip_{j,r}$ may be easily calculated and the relationship may be solved.

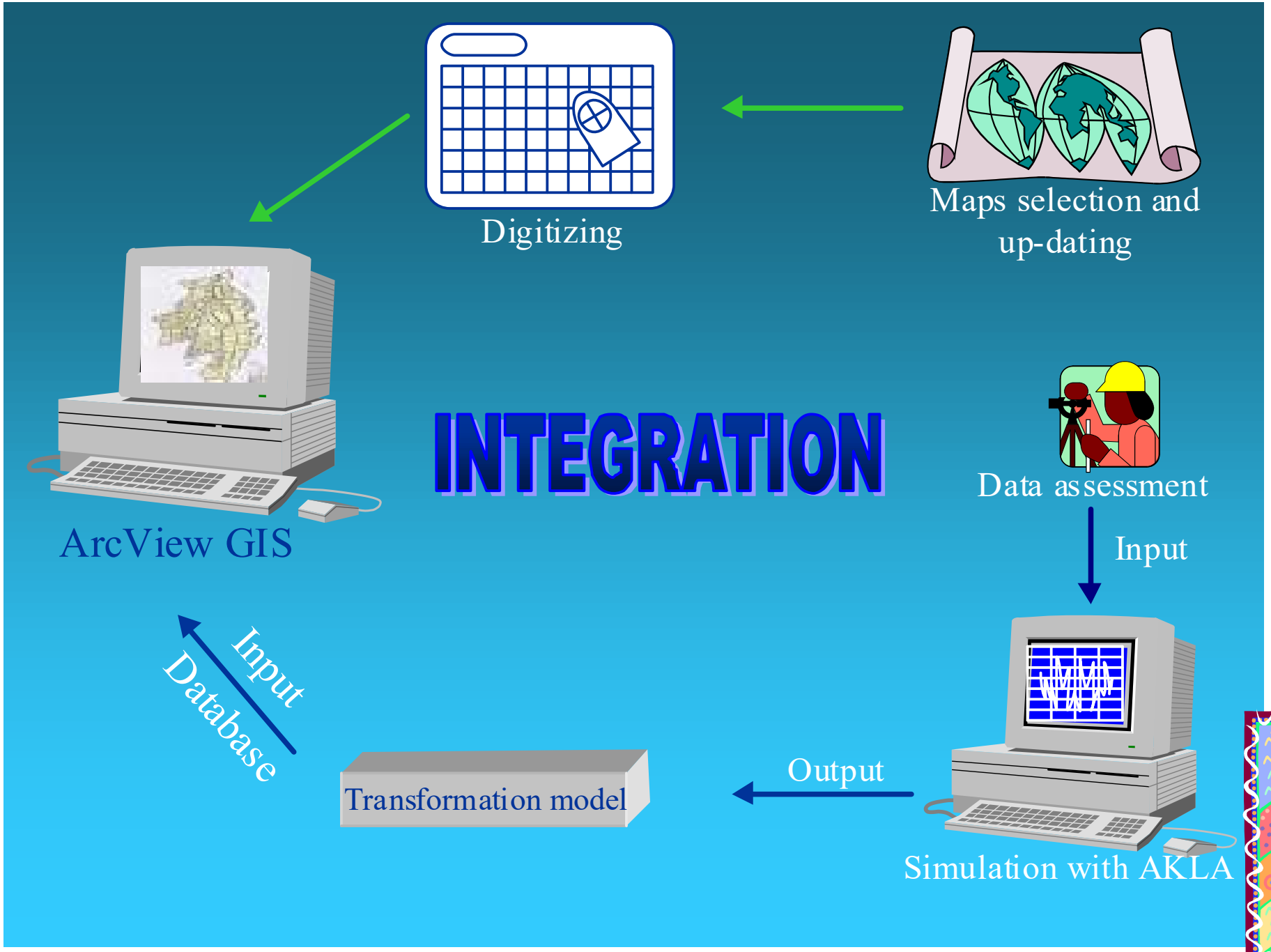
Hydrants Analysis



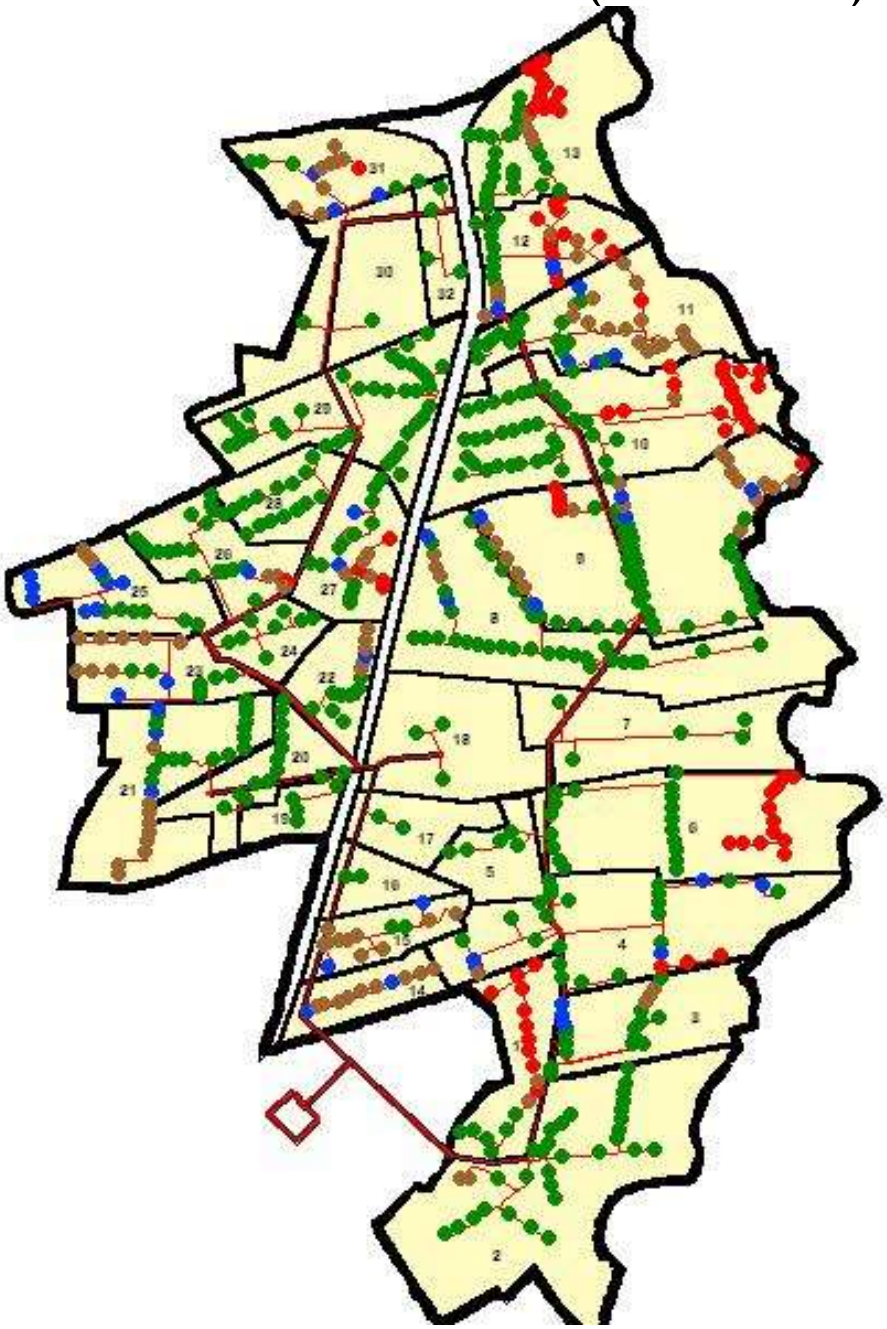
Hydrants Analysis (reliability)



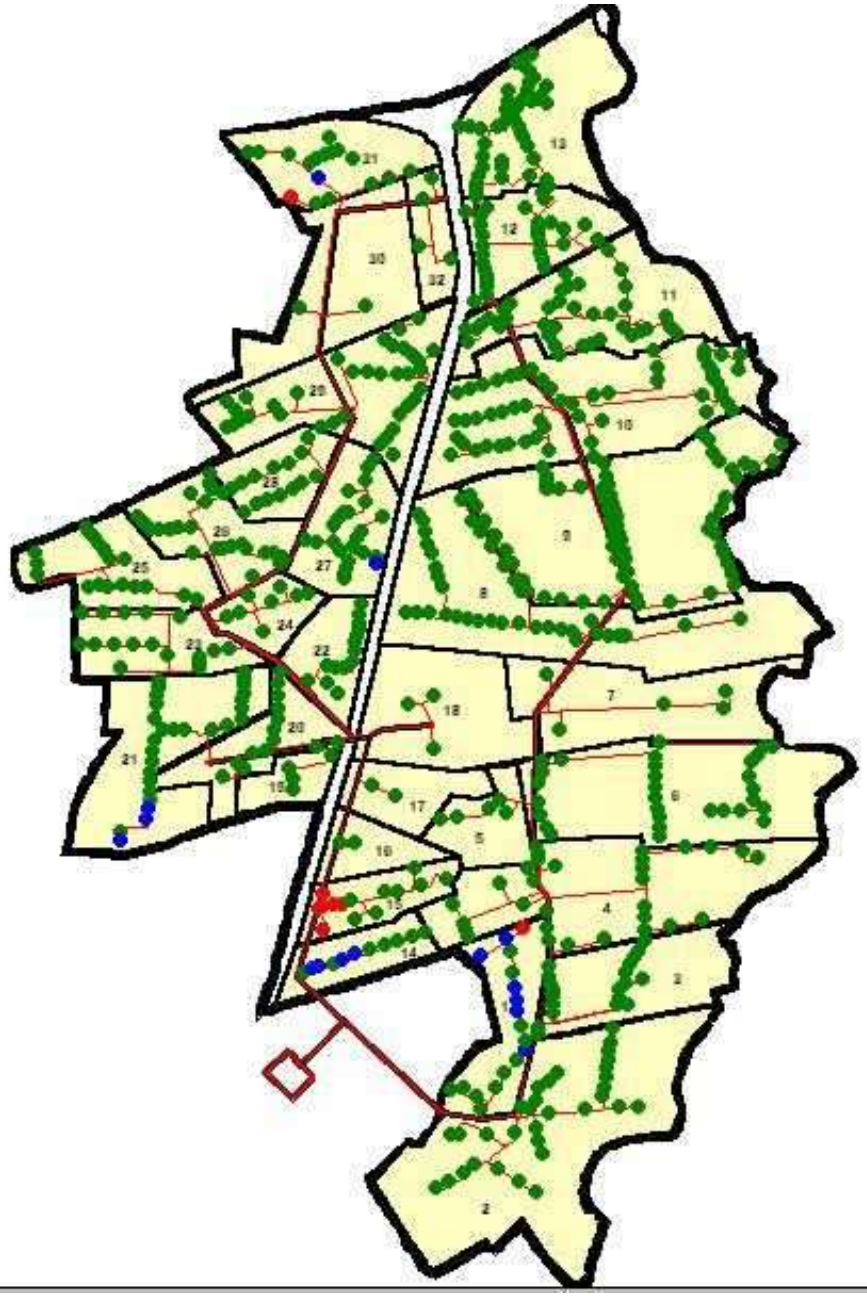



Digitizing
Maps selection and up-dating
ArcView GIS
INTEGRATION
Data assessment
Input
Input Database
Transformation model
Output
Simulation with AKLA

PRESSURE DEFICIT (H-Hmin)/Hmin



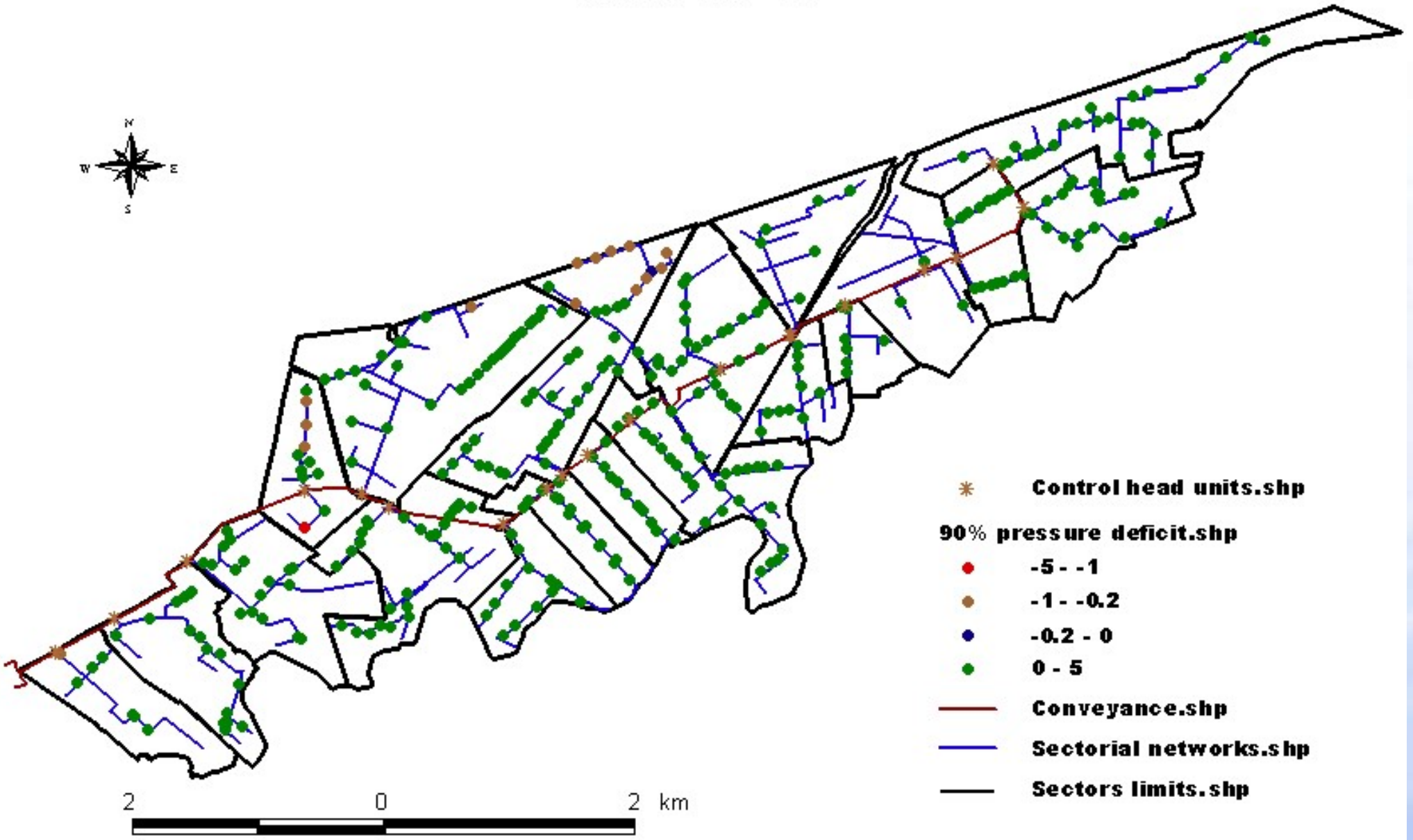
RELIABILITY



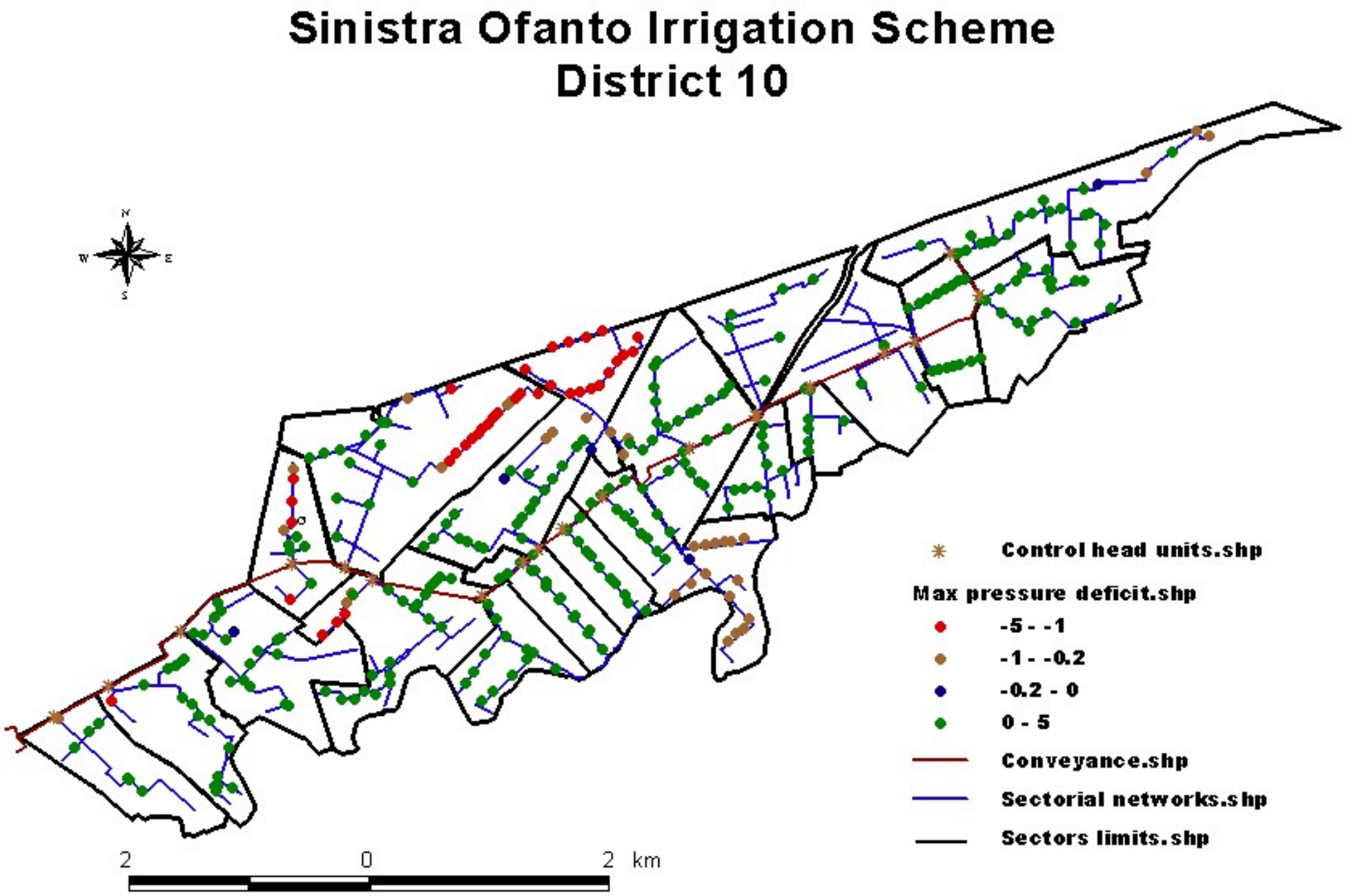
90 % RELATIVE PRESSURE DEFICIT

Sinistra Ofanto Irrigation Scheme

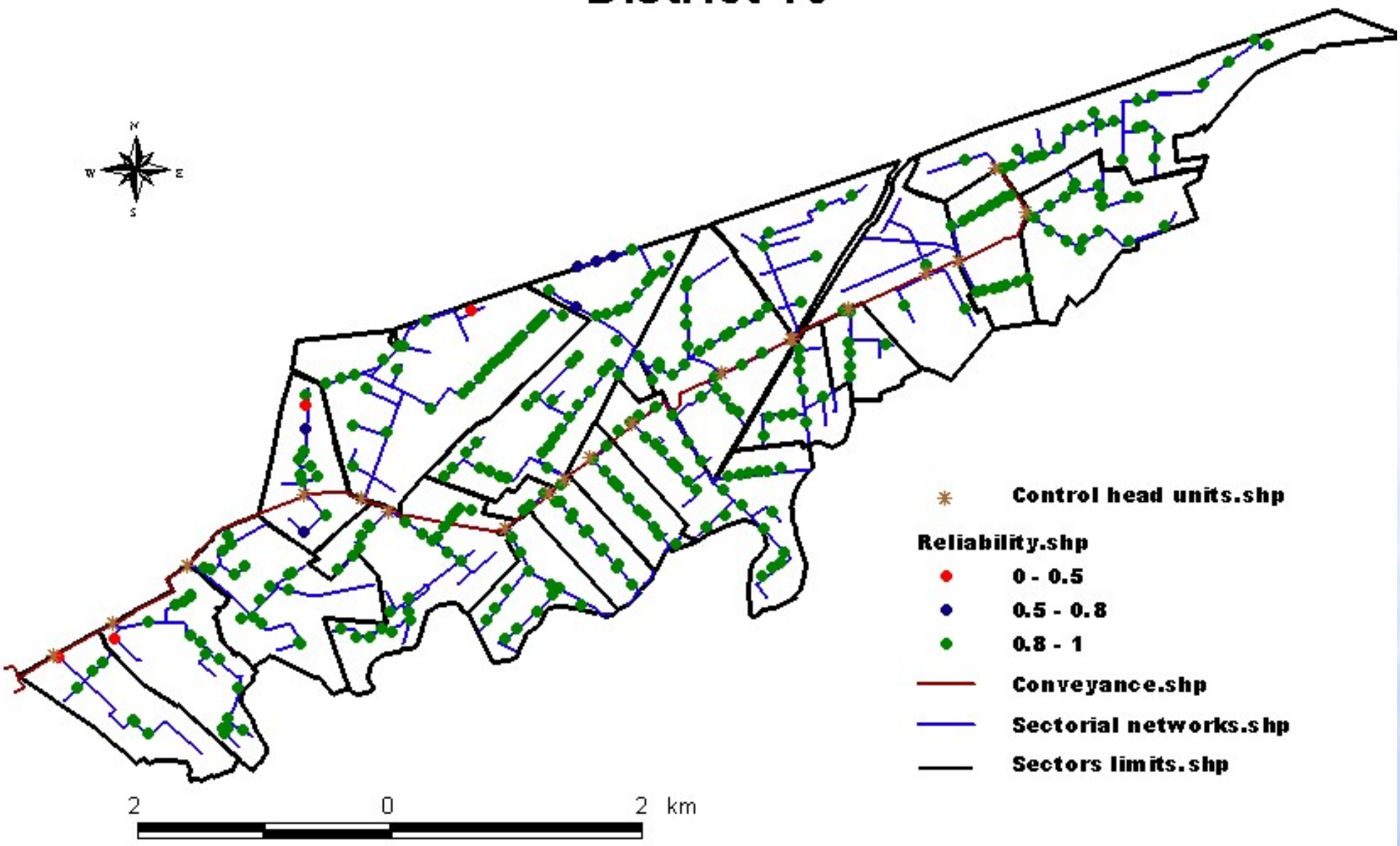
District 10

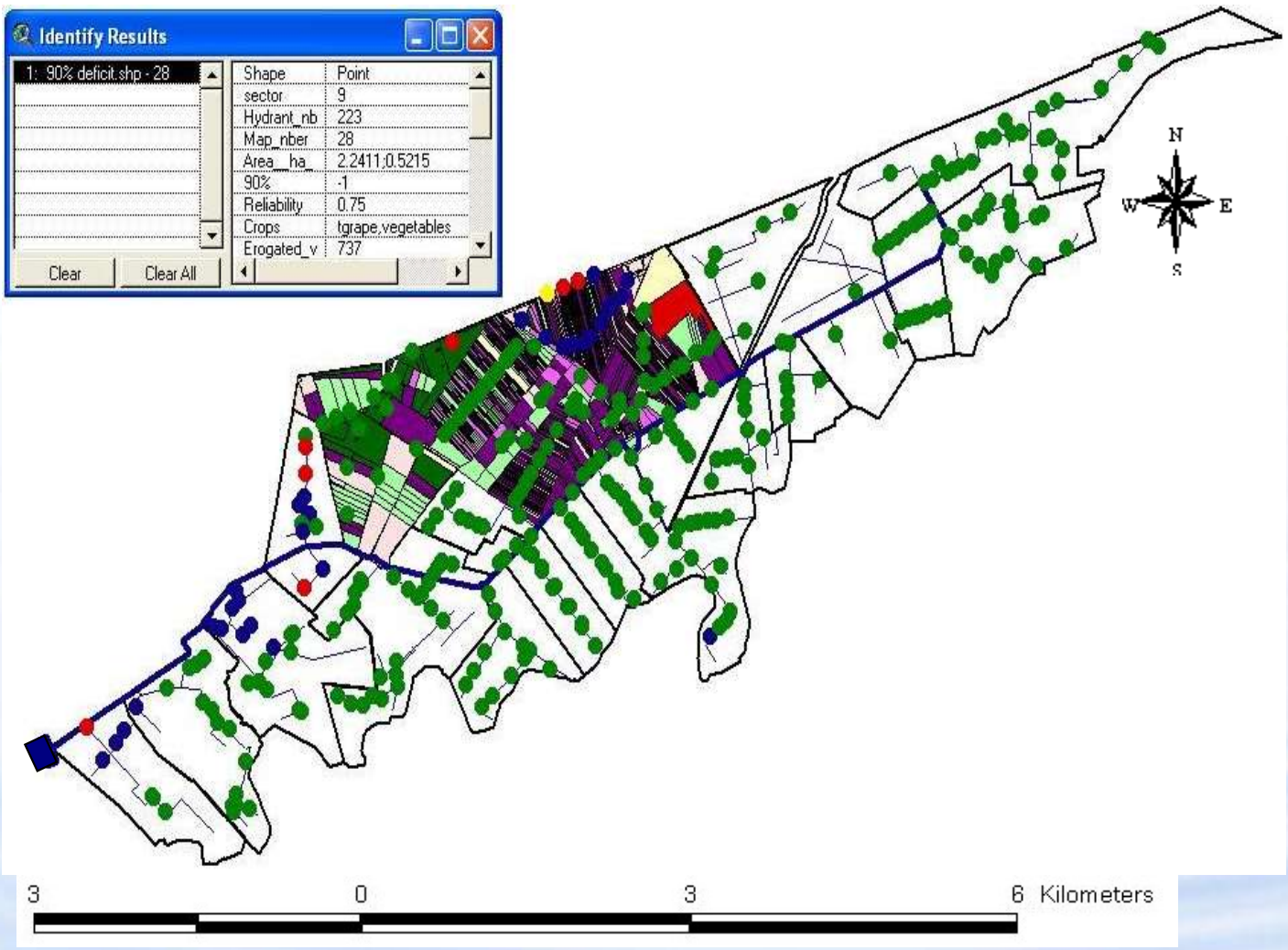


MAX PRESSURE DEFICIT



RELIABILITY

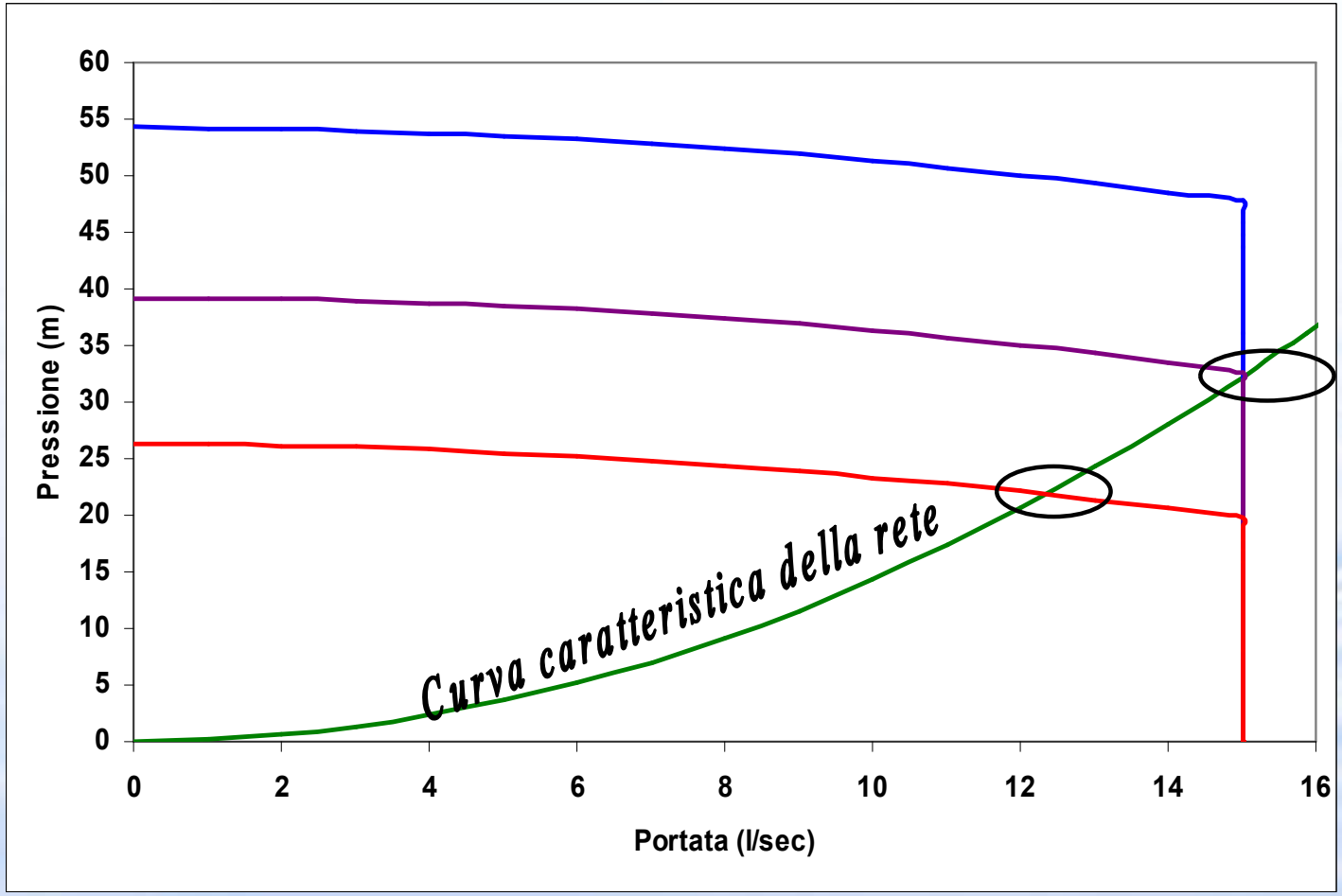




Overlaying the scenario of the relative pressure deficit with crops and identifying the detailed records of one hydrant

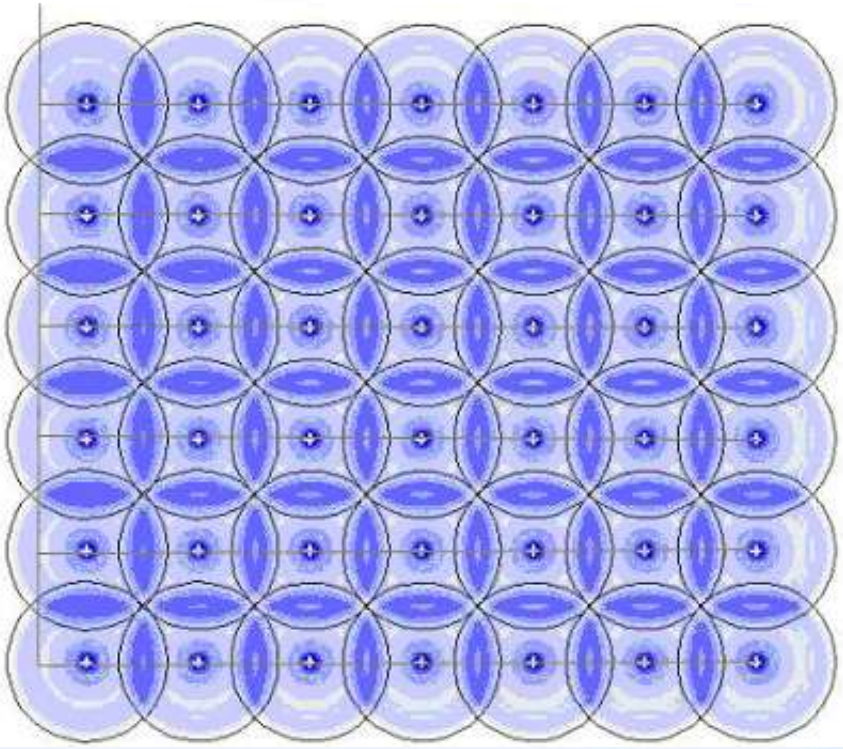
Working parameters of the on-farm network

H_{max}=54 m
H_{min} =26 m

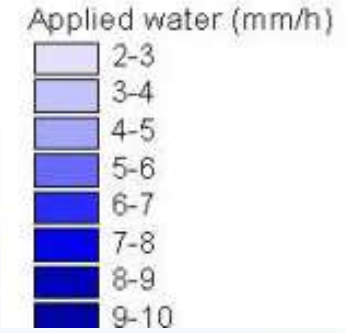


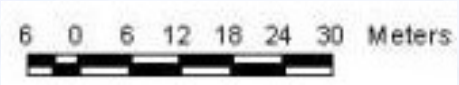
H=33 m
Q=15.31 l/s

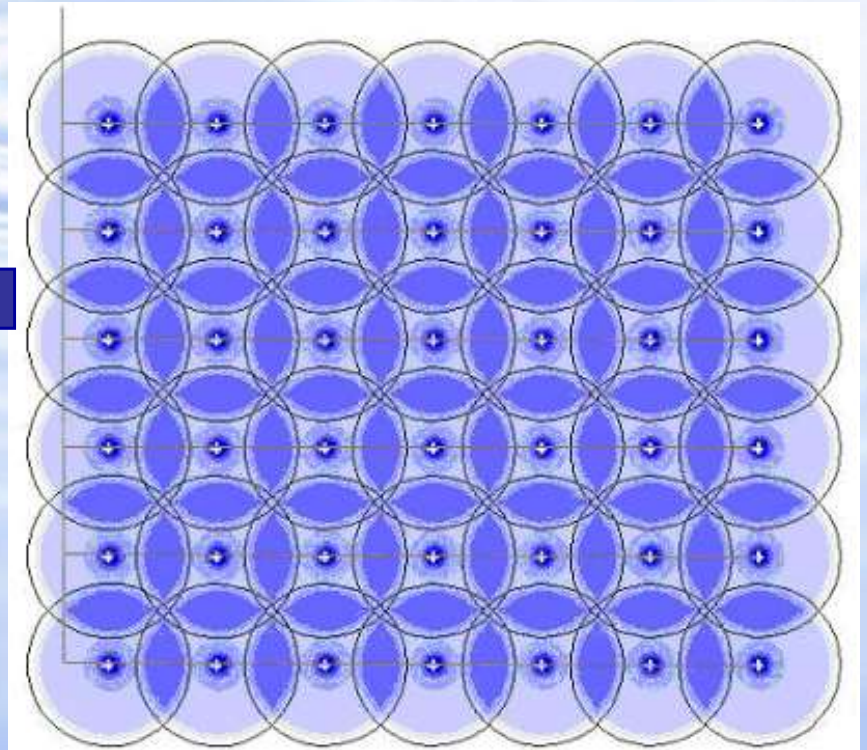
H=21 m
Q=12.84 l/s



H = 21 m
CU = 63%
DU = 67%
DE_{90} = 60%
Dn_{90} = 3mm/h







H = 33 m
CU = 74%
DU = 80%
DE_{90} = 80%
Dn_{90} = 4.5mm/h

SIMPLE CALCULATION

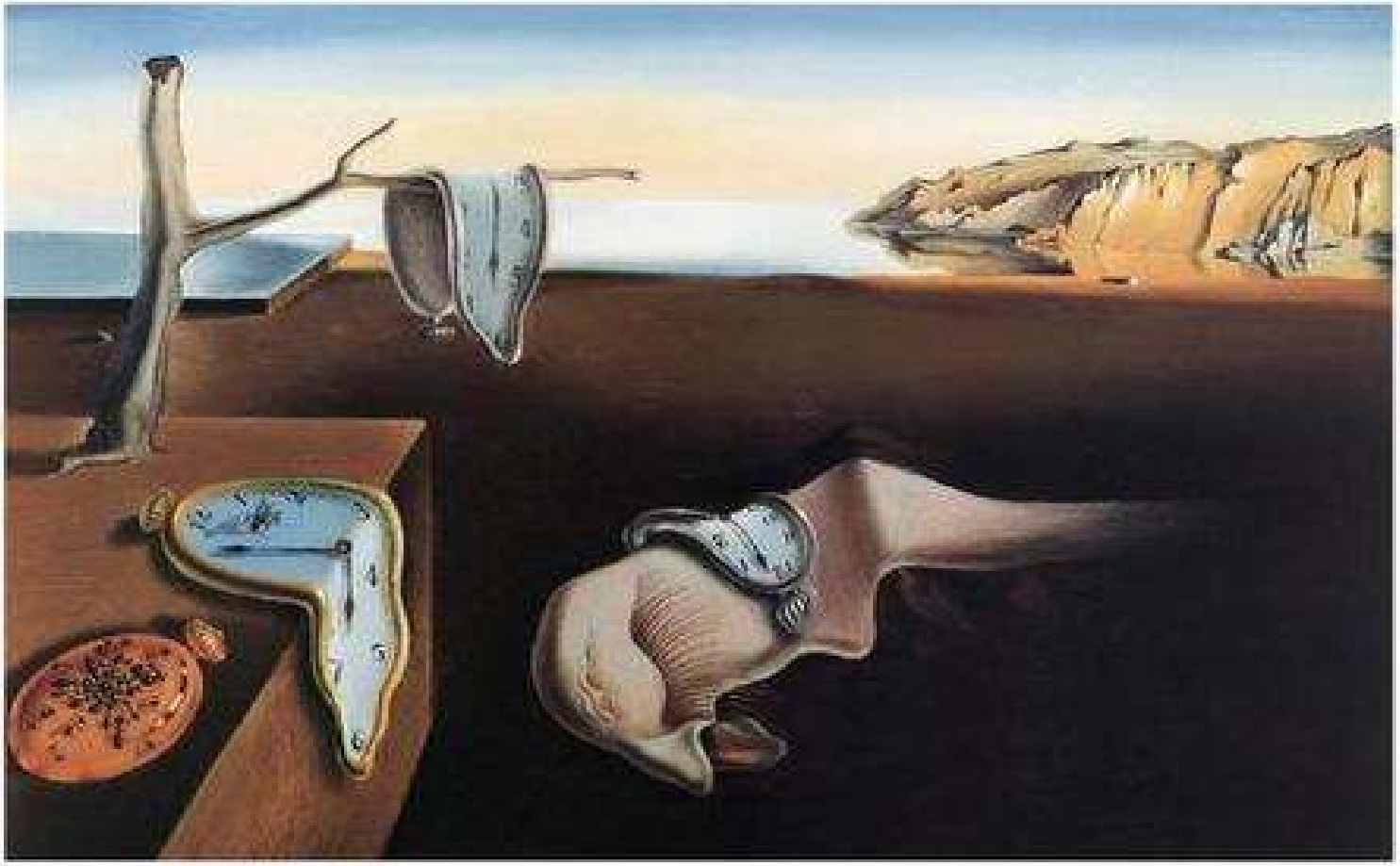
CASE 1:

$E_{G,1} = 0.95 \times 0.60 = 0.57$

CASE 2:

$E_{G,2} = 0.95 \times 0.80 = 0.76$

$$DE = (0.76 - 0.57)/0.57 = 0.33 = +33\%$$



SALVADOR DALI

Persistence of Memory