ENGINEERING OF WATER DISTRIBUTION NETWORKS

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CIHEAM - IAMB

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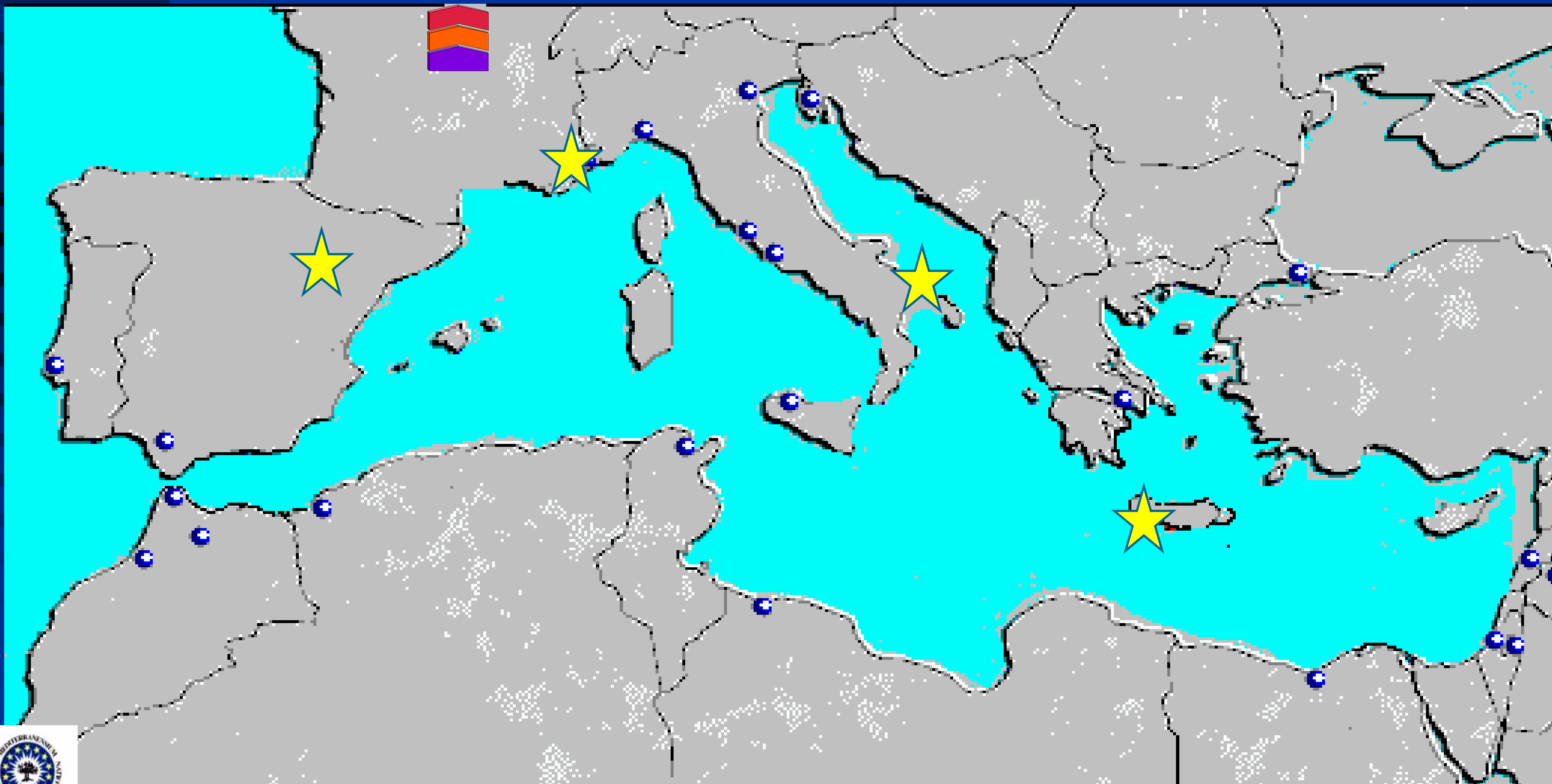
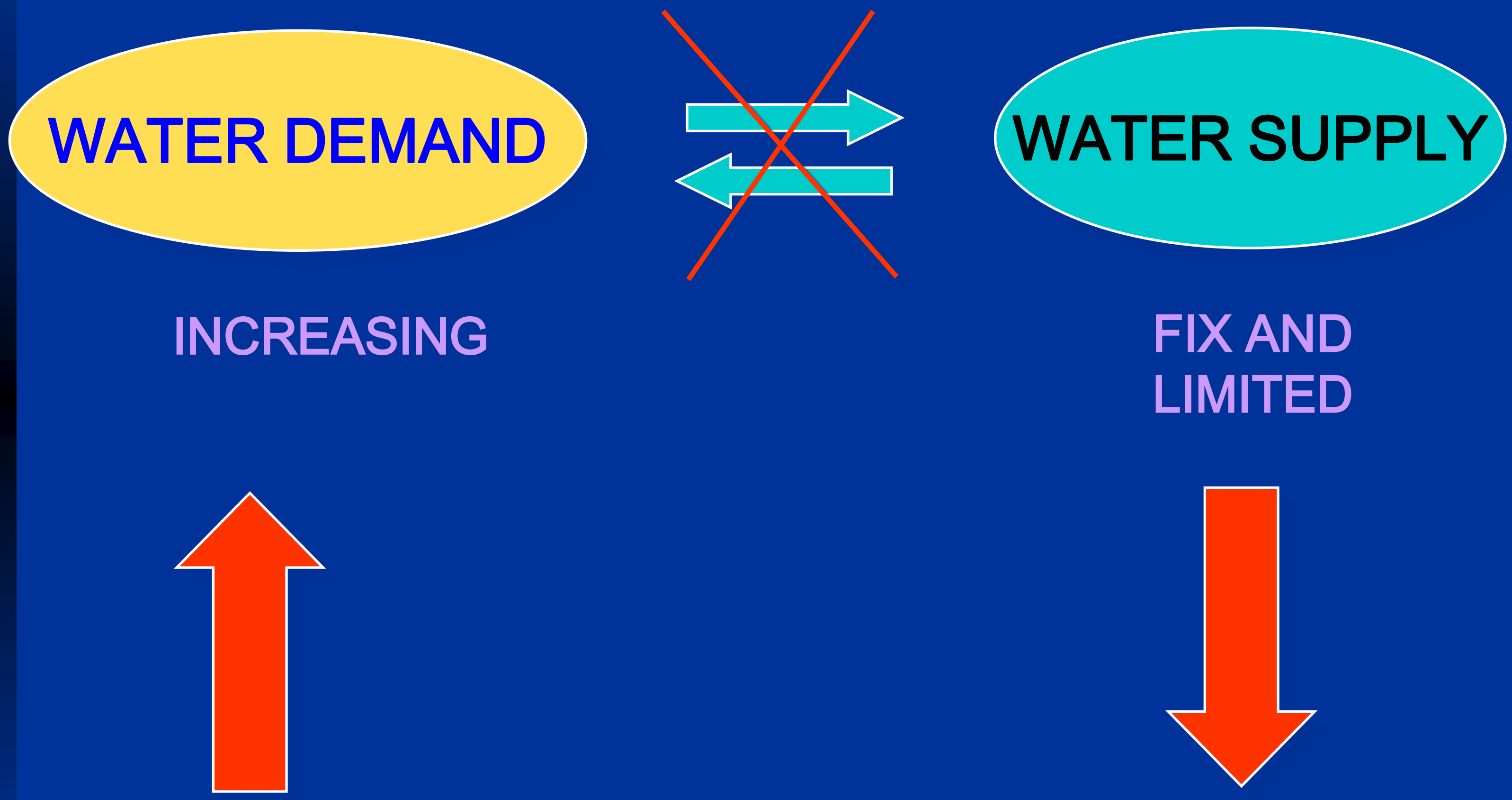


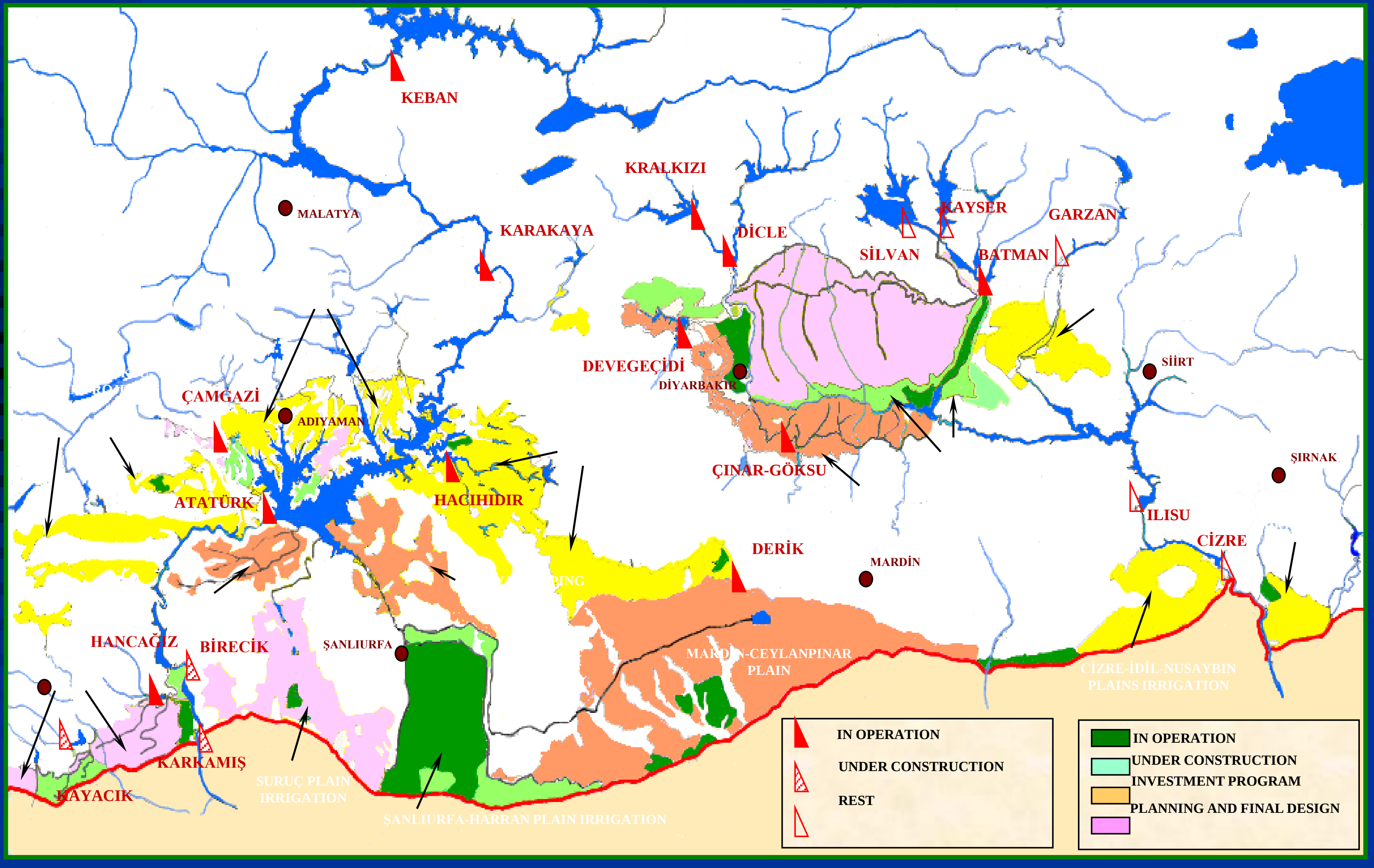
PROBLEM OF WATER RESOURCES



PAST STRATEGY

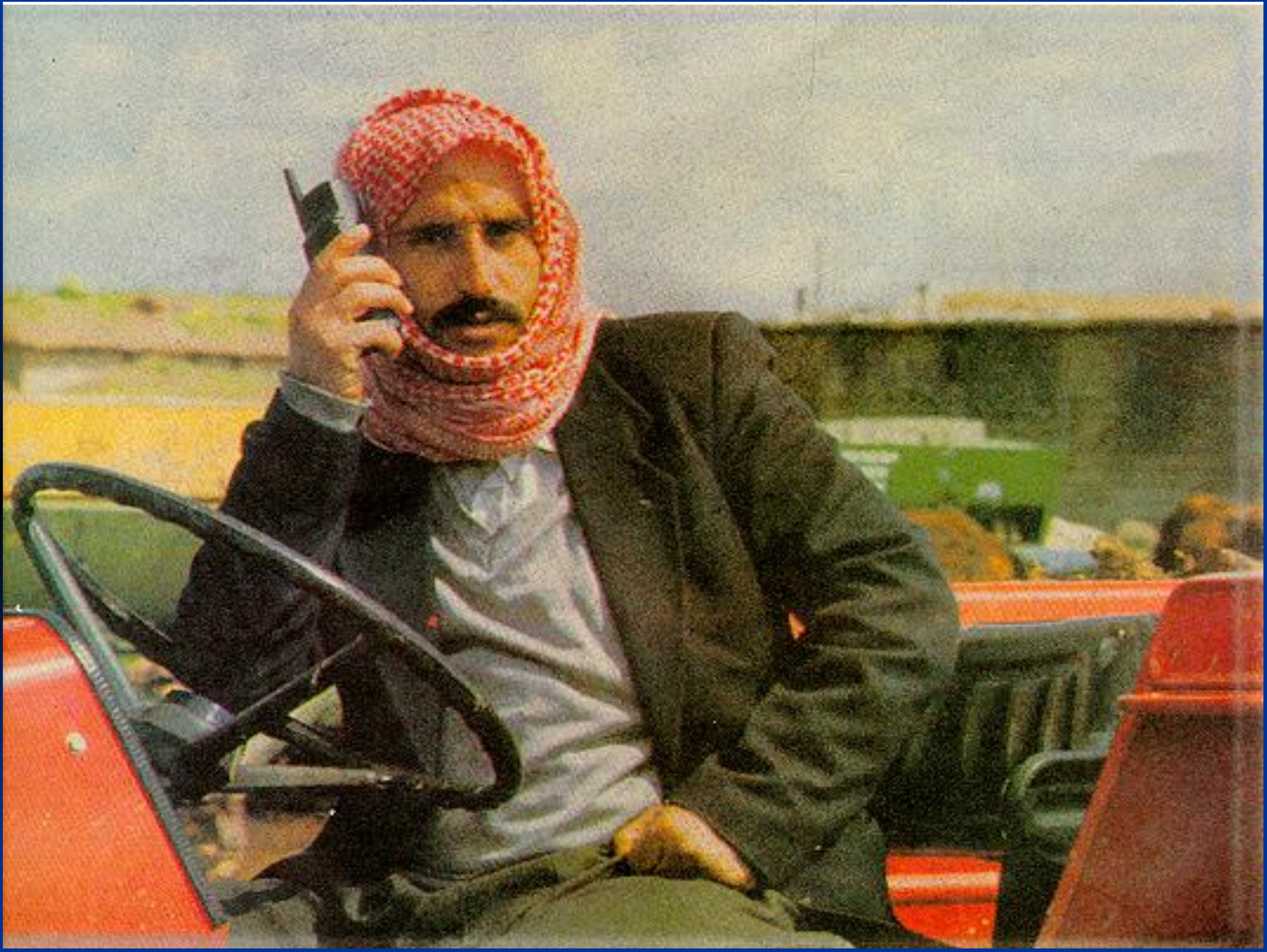
- In the last 40 years the policy choices privileged the big hydraulic infrastructures in irrigation giving priorities to the quantitative aspect rather than the qualitative (Supply Management).

Turkey (project GAP)
Water Distribution plan



ATATÜRK DAM – Completed in 1990



Kabur river - 1975

Kabur river - 2006

Kebrit spring - 1999

Kebrit spring - 2006

Kebrit spring - 2007

PRESENT STRATEGIES

- The current policy choices highlighted the importance of Operation, Maintenance and Management activities (DEMAND MANAGEMENT)
  - Technical approaches (improving WUE at the whole chain of the system, use of new technologies,..)
  - Institutional approaches (PIM, Capacity Building,…)

TECHNICAL APPROACHES

CHAIN OF EFFICIENCIES

Storage Efficiency

Distribution Efficiency

Farm Efficiency

Application Efficiency

0.90 x 0.85 x 0.72 x 0.75 = 0.413

$$\frac{W_{reservoir\ \ out}}{W_{reservoir\ \ in}} \times \frac{W_{farm\ gate}}{W_{reservoir\ \ out}} \times \frac{W_{field}}{W_{farm\ gate}} \times \frac{W_{root\ \ zone}}{W_{field}} = \frac{W_{root\ \ zone}}{W_{reservoir\ \ in}}$$

From: T. Hsiao - 2006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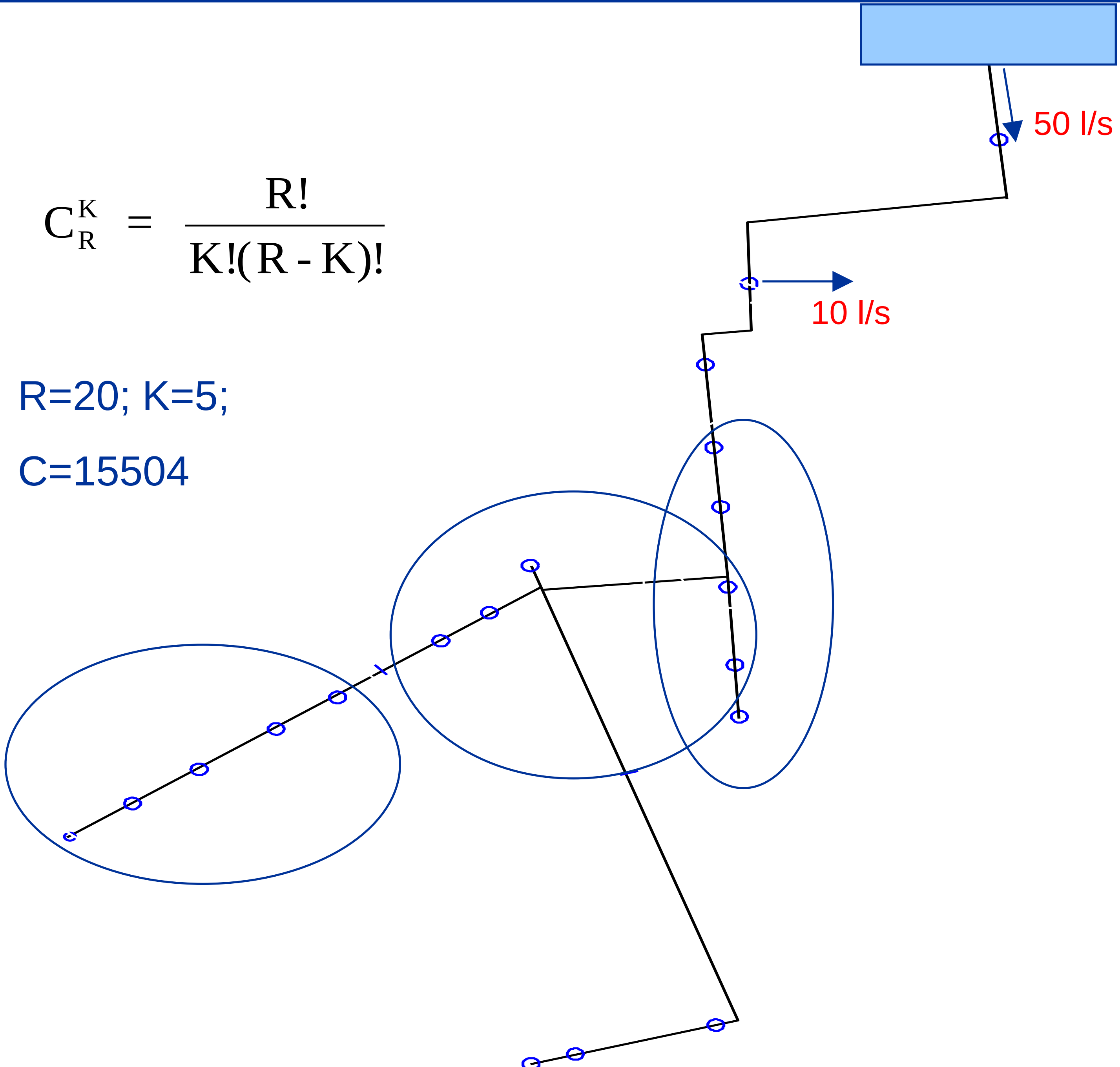
DESIGN OPTIONS

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

R=20; K=5;

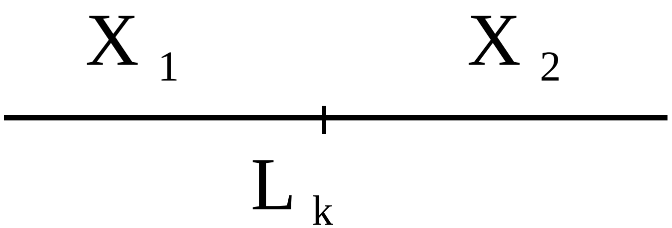
C=15504

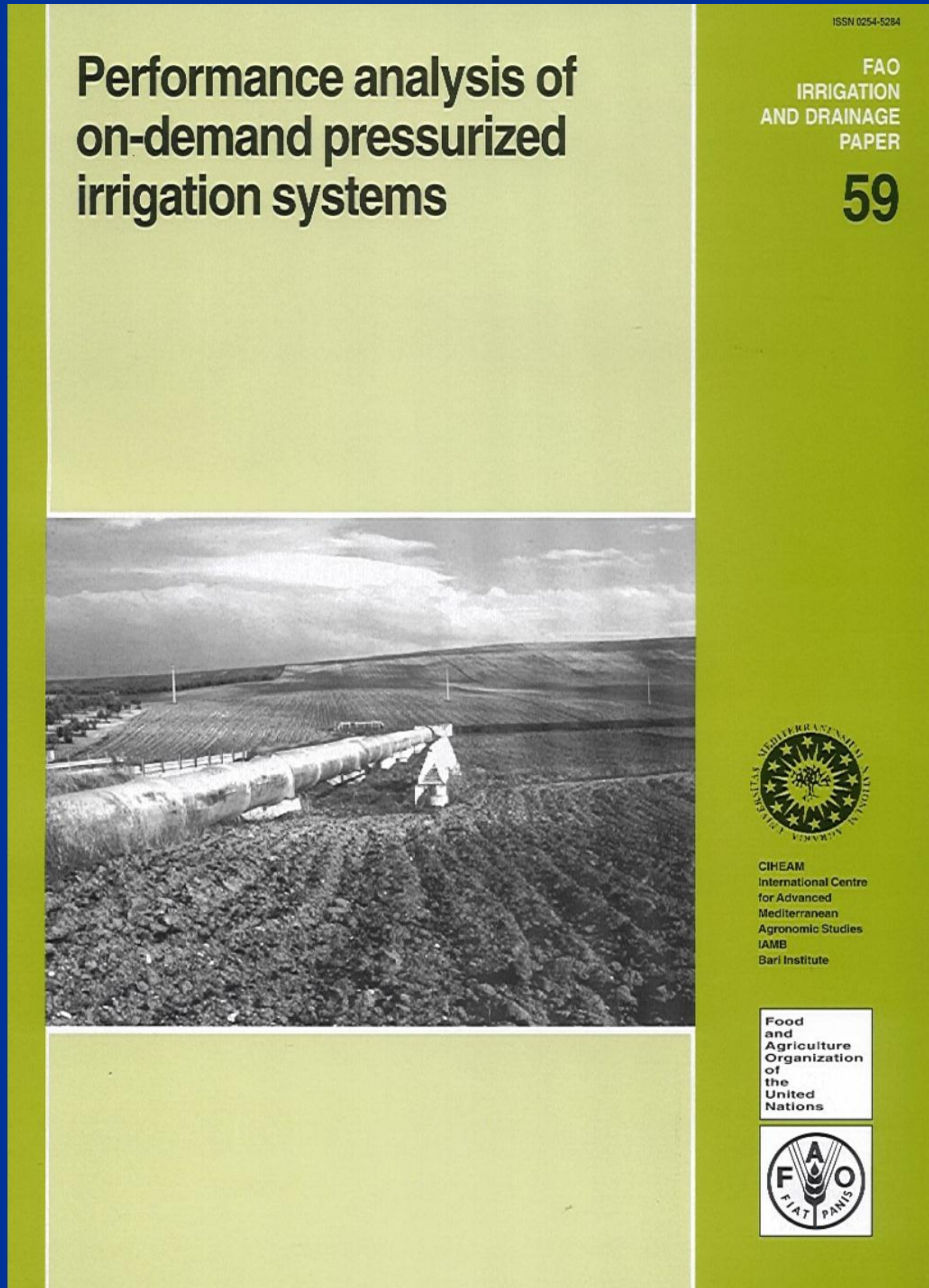


COMPUTATION OF DIAMETERS

$$\text{Min}\; C_{NET} = \sum_{K=1}^{NTR} C_K L_K$$

$$\begin{cases} H_i = Z_{UP} - \sum J_K L_K \geq H_{min} \\ Y_k = J_K L_K = \sum J_i X_i \\ L_k = \sum X_i \\ X_i \geq 0 \end{cases}$$

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RELIABILITY

RELIABILITY IS DEFINED AS HOW OFTEN A SYSTEM FAILS

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

X_t = The random variable denoting the state of the system at a time t

S = The set of all satisfactory outputs

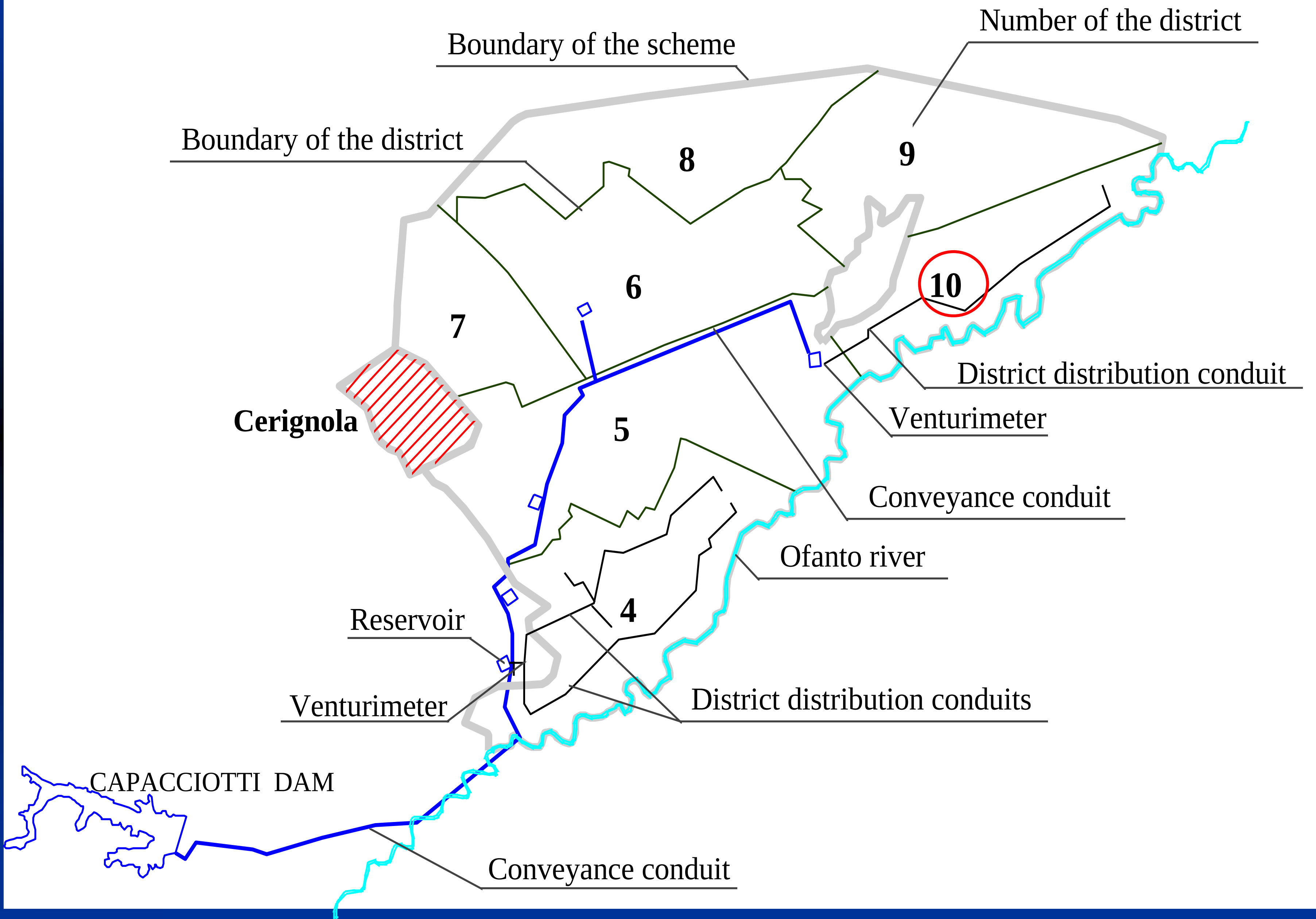
$$\alpha_j = \frac{\sum_{r=1}^{C} Ih_{j,r}\, Ip_{j,r}}{\sum_{r=1}^{C} Ih_{j,r}}$$

$Ih = 1$ → ***Open hydrant***

$Ih = 0$ → ***Close hydrant***

$Ip = 1$ → $H \geq H_{min}$

$Ip = 0$ → $H < H_{min}$



Number of the district
Boundary of the scheme
Boundary of the district
8
9
6
10
7
District distribution conduit
Cerignola
5
Venturimeter
Conveyance conduit
Ofanto river
Reservoir
4
Venturimeter
District distribution conduits
CAPACCIOTTI DAM
Conveyance conduit

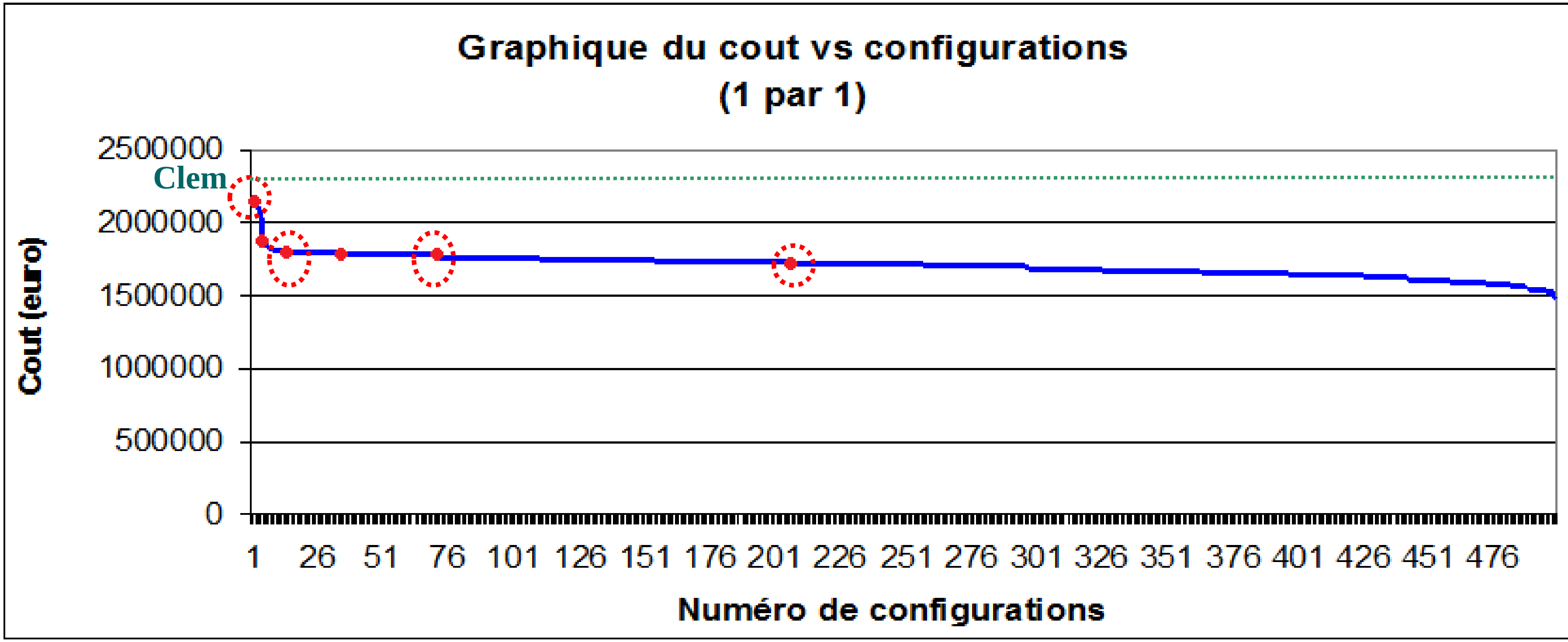
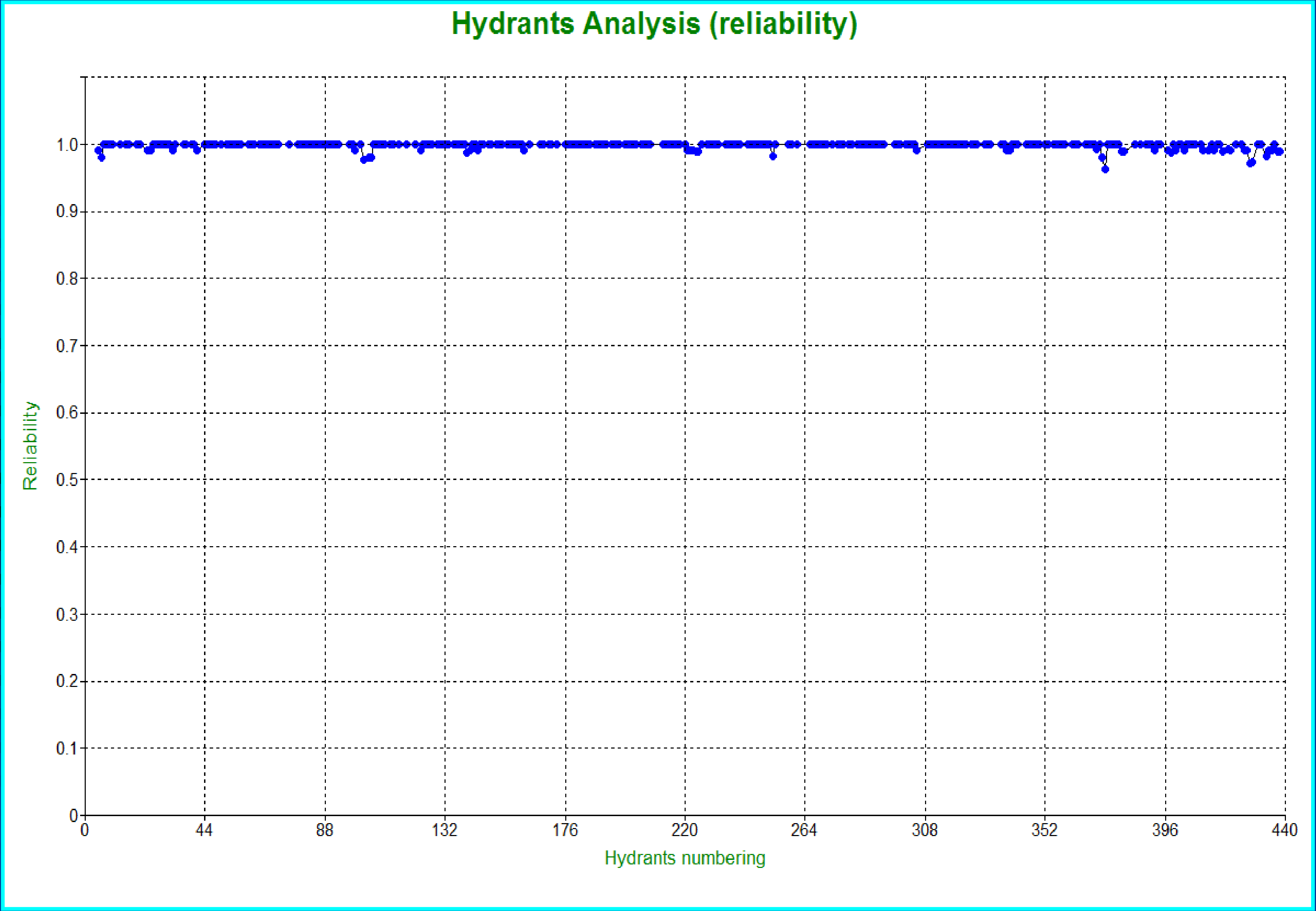
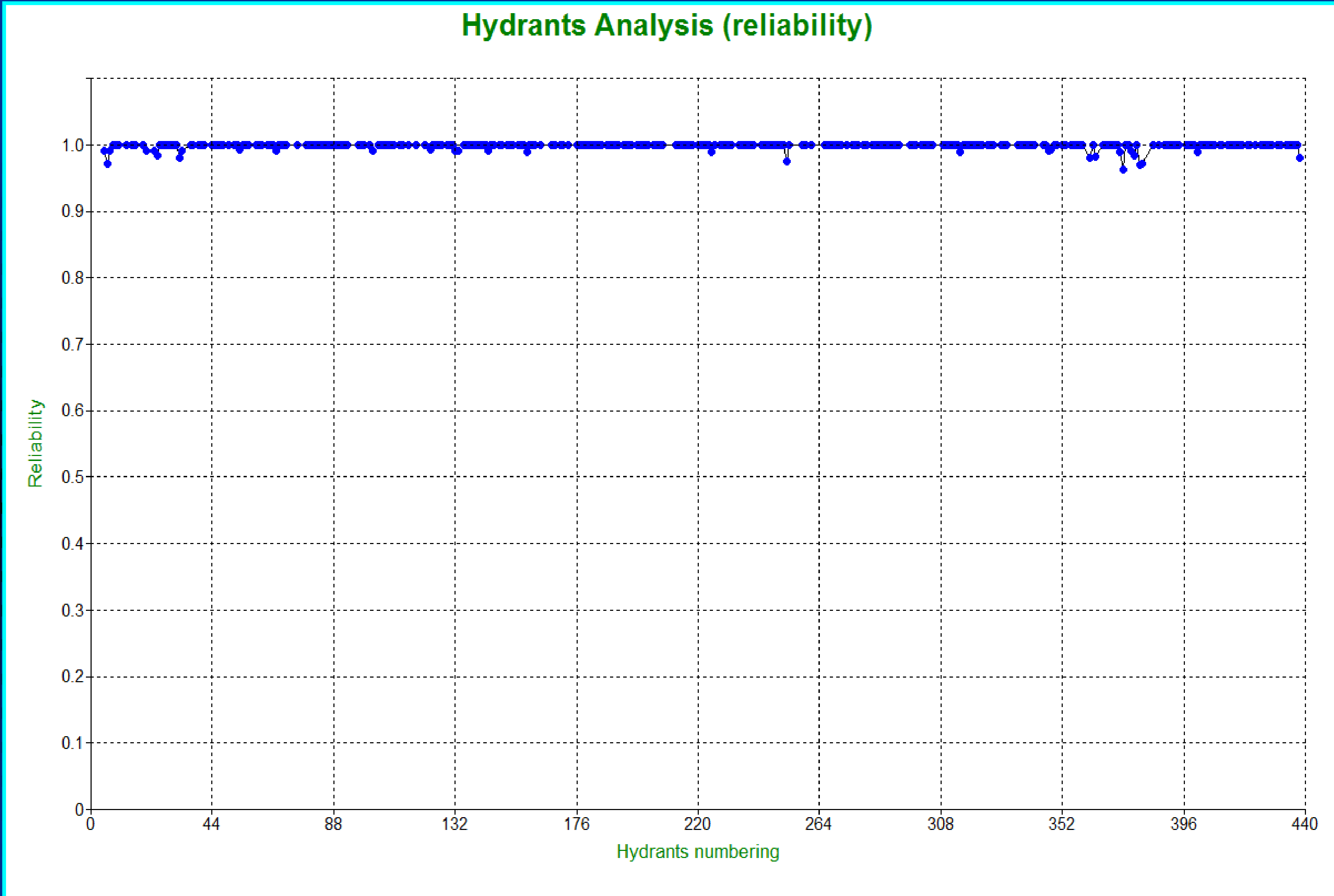


Figure 8 : Relationship cost vs configuration

Which is the optimal network ??



(max cost = 2.295×10^3 euro)



5% of configurations; C_{net} = 1.782 x 10^3 euro

$$Re_{NET\ n} = \left(\sum_{K=1}^{Nidr} Re_K / N_{idr} \right)$$

Re_{NET} : Reliability of the network
Re_k : Reliability of the hydrant k
N_{idr} : Number of hydrants

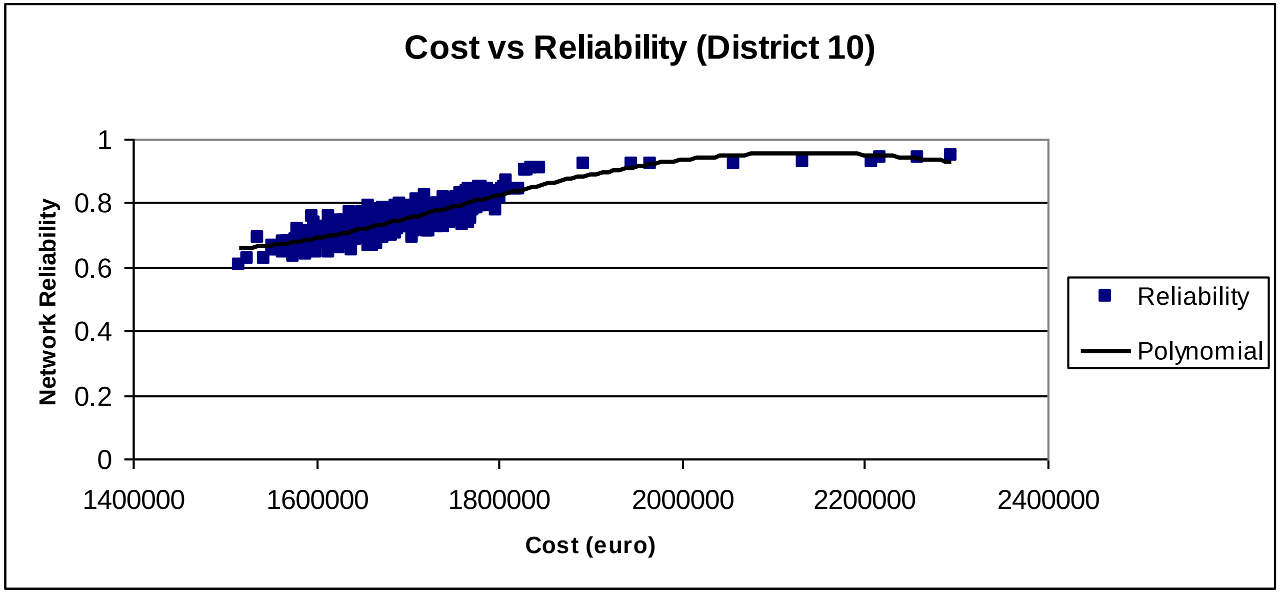


Figure 9 : Reliability vs Cost (District 10)

PERFORMANCE INDICATOR

$$\beta_1 = \frac{R}{C}$$

R = Reliability of the network
C = Cost of the network

OBJECTIVE FUNCTION

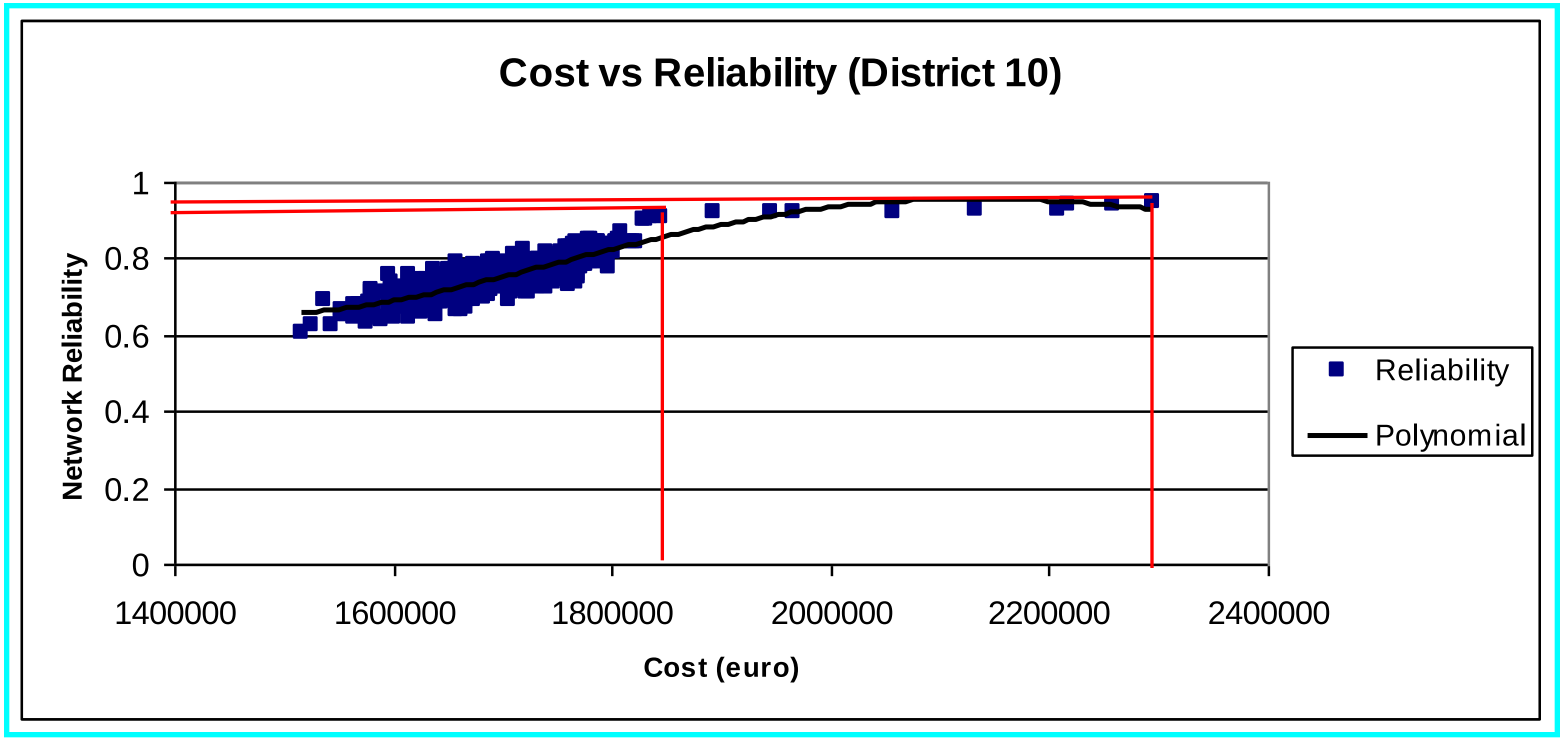
$$Max\beta_1 = \frac{R}{C}$$

$Max\beta_1$ → (Max R, Min C)

District 10

500 discharge configurations were generated:

- the maximum cost of the network is **2.295×10^3** euro.
- Reliability = **0.97 .**



- The <u>optimal network</u> ($\beta_{1,max}$) costs **1.837×10^3 euro** with Reliability = **0.94**
- Around 20% may be saved

MANAGEMENT OPTIONS

RELATIVE PRESSURE DEFICIT

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

j = number of the hydrant

r = number of the configuration

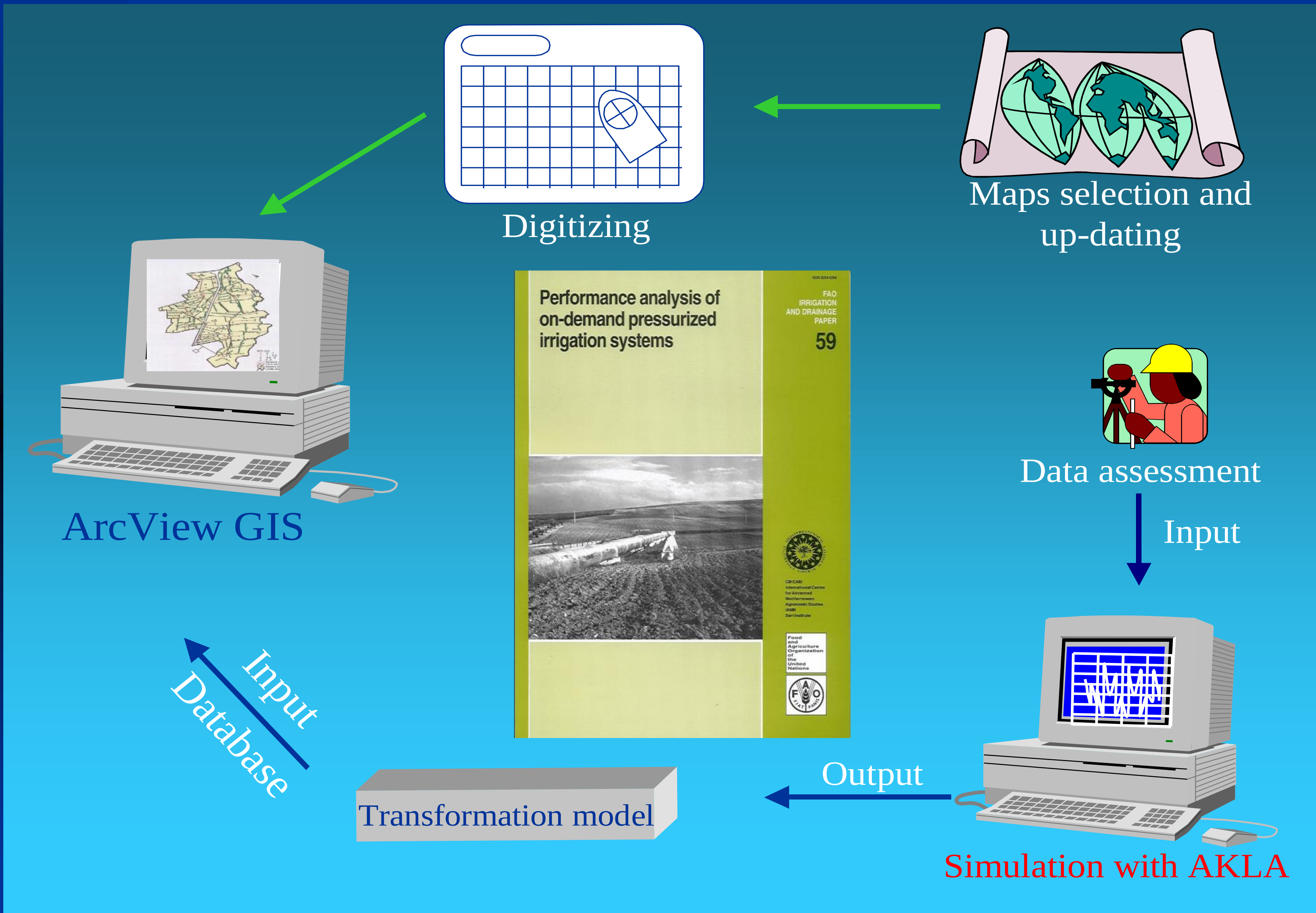
H_{min} = Pressure head required at the hydrant for an appropriate on-farm irrigation

$\Delta H \geq 0$ ⟶ O.k

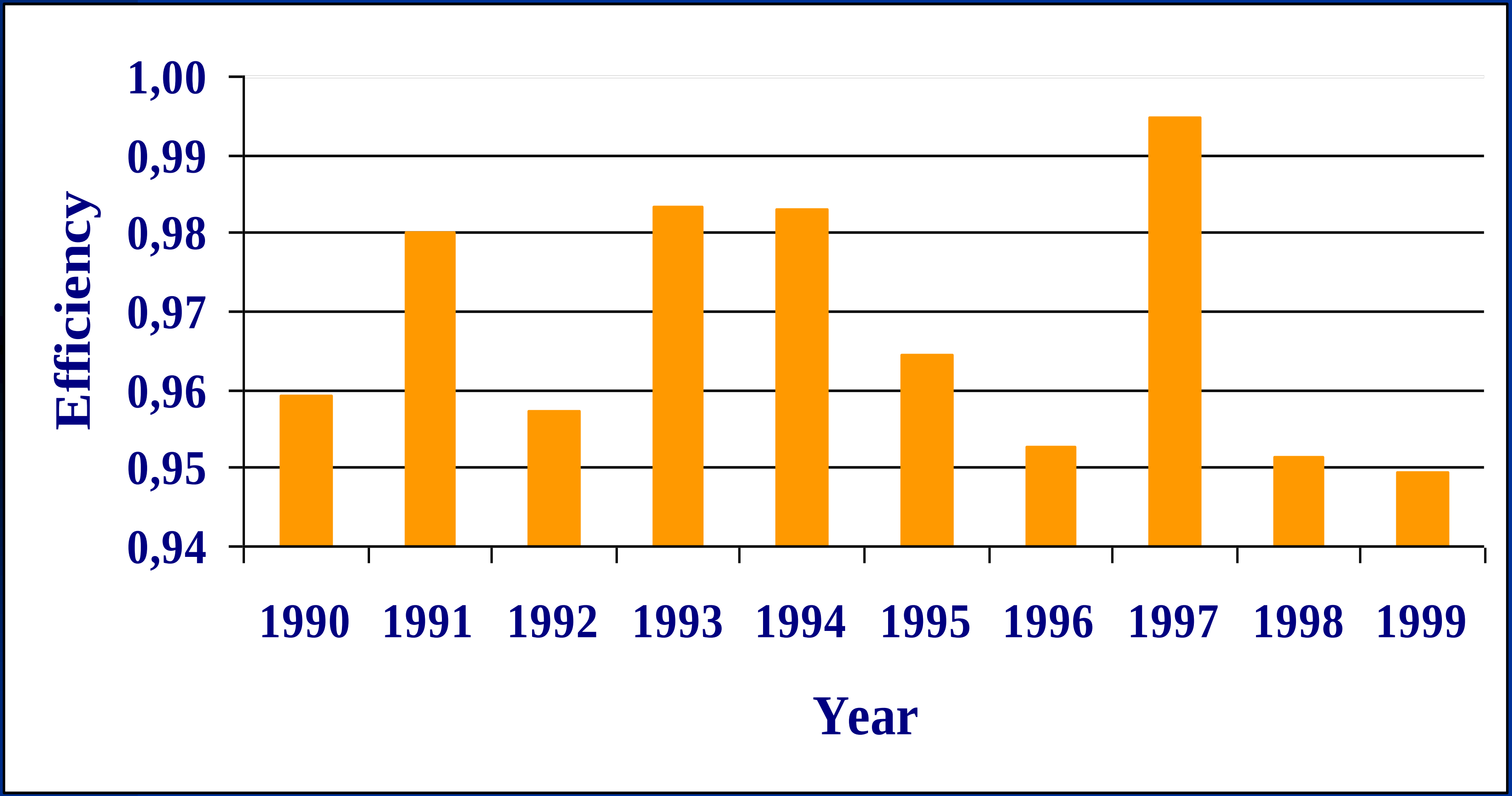
$-1 < \Delta H < 0$ ⟶ Failure

$\Delta H < -1$ ⟶ Danger (negative pressure at the hydrant)

TECHNICAL SOLUTIONS

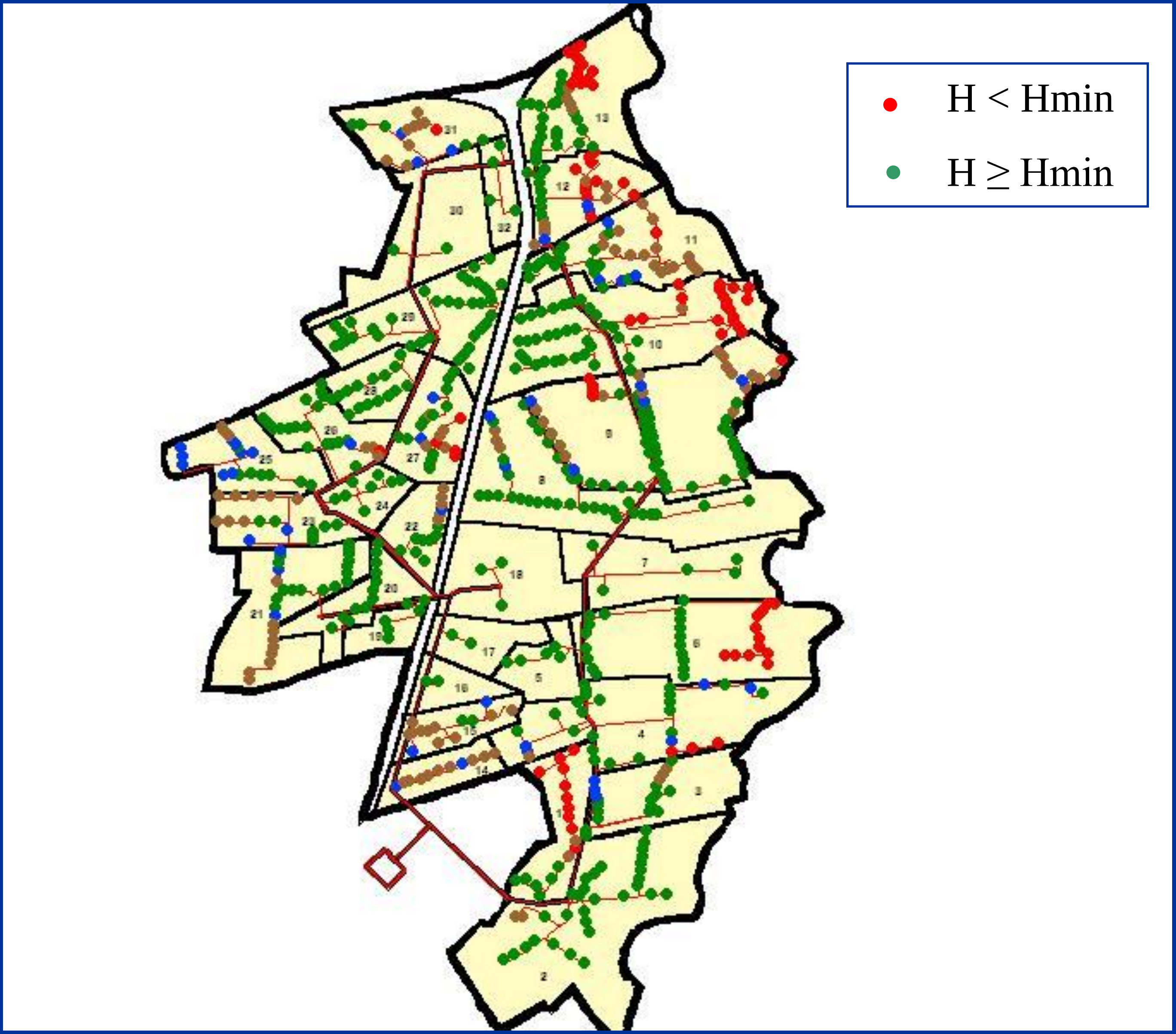


DISTRIBUTION NETWORK EFFICIENCY

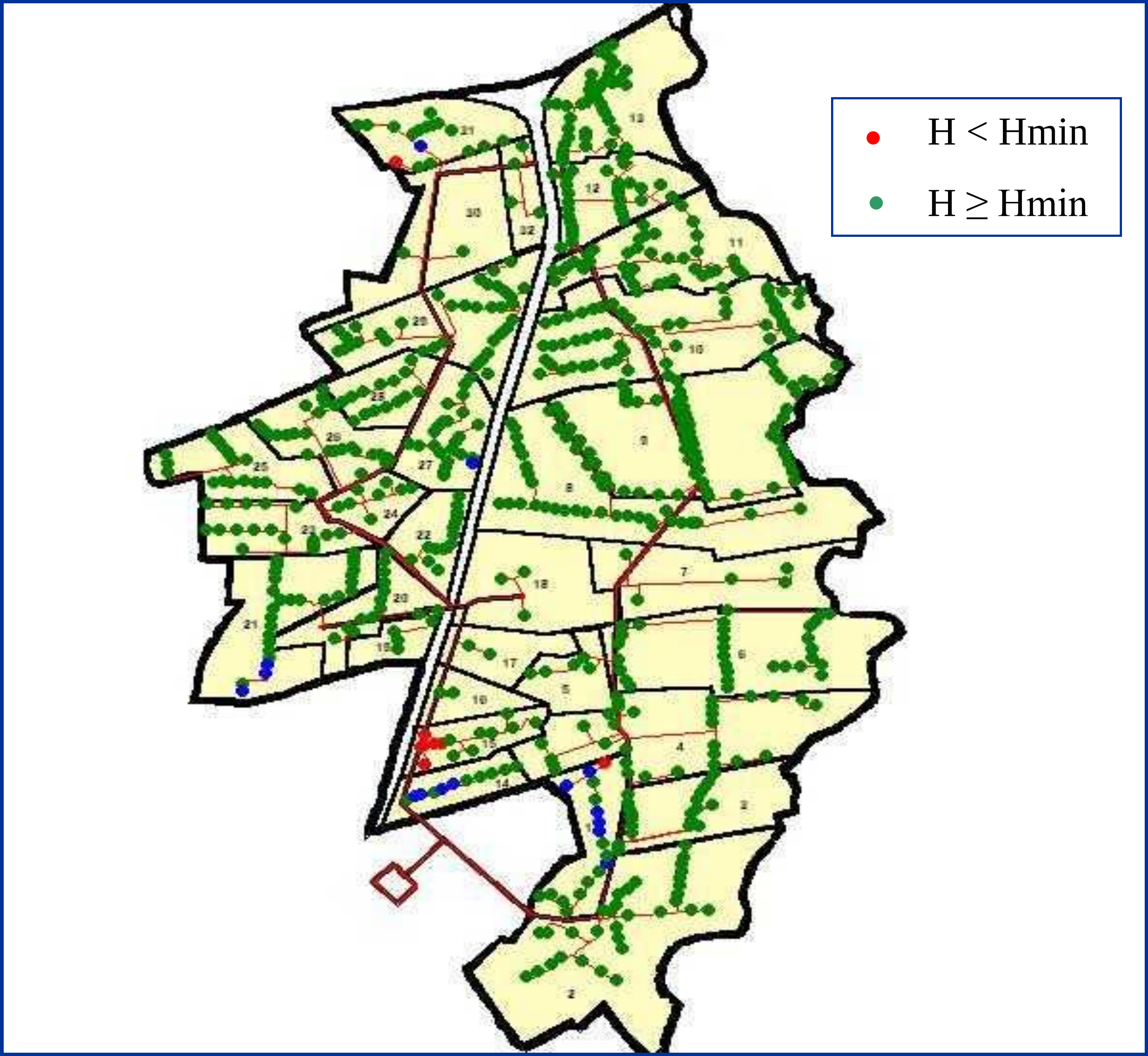


Discharge (l/s)
1500
1200
900
600
300
0
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Time (h)

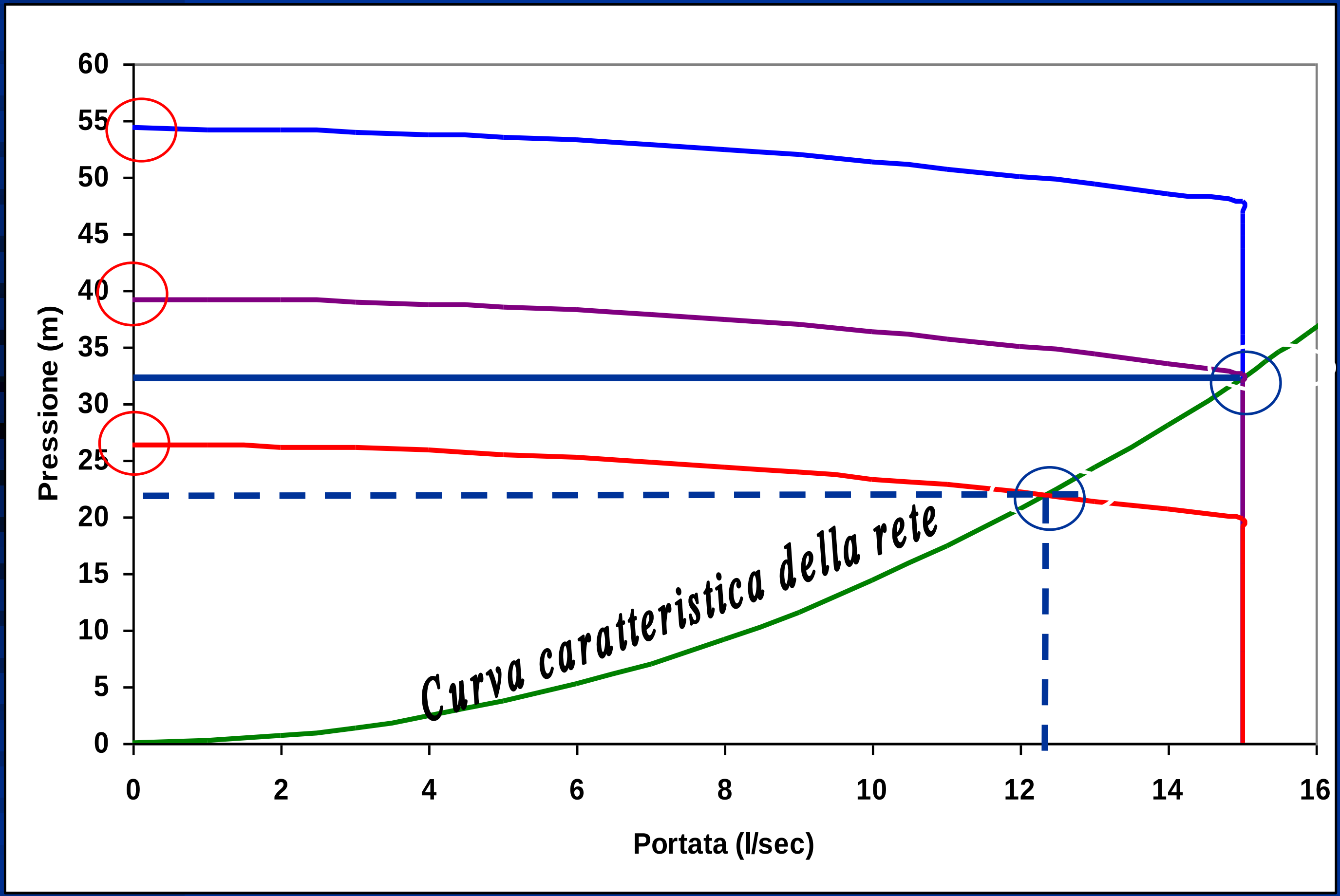
DEFICIT DE PRESSION (H-Hmin)/Hmin – Q=1200 l/s



DEFICIT DE PRESSION (H-Hmin)/Hmin - Q= 700 l/s



Working parameters of the on-farm network



Hmax=54 m
Hmin =26 m

H=33 m
Q=15.31 l/sec

H=21 m
Q=12.84 l/sec

INDICATORS USED TO EVALUATE THE ON-FARM NETWORK PERFORMANCE

Uniformity Coefficient

$$CU = 100\left(1 - \frac{\sum |Z - m|}{\sum Z}\right)$$

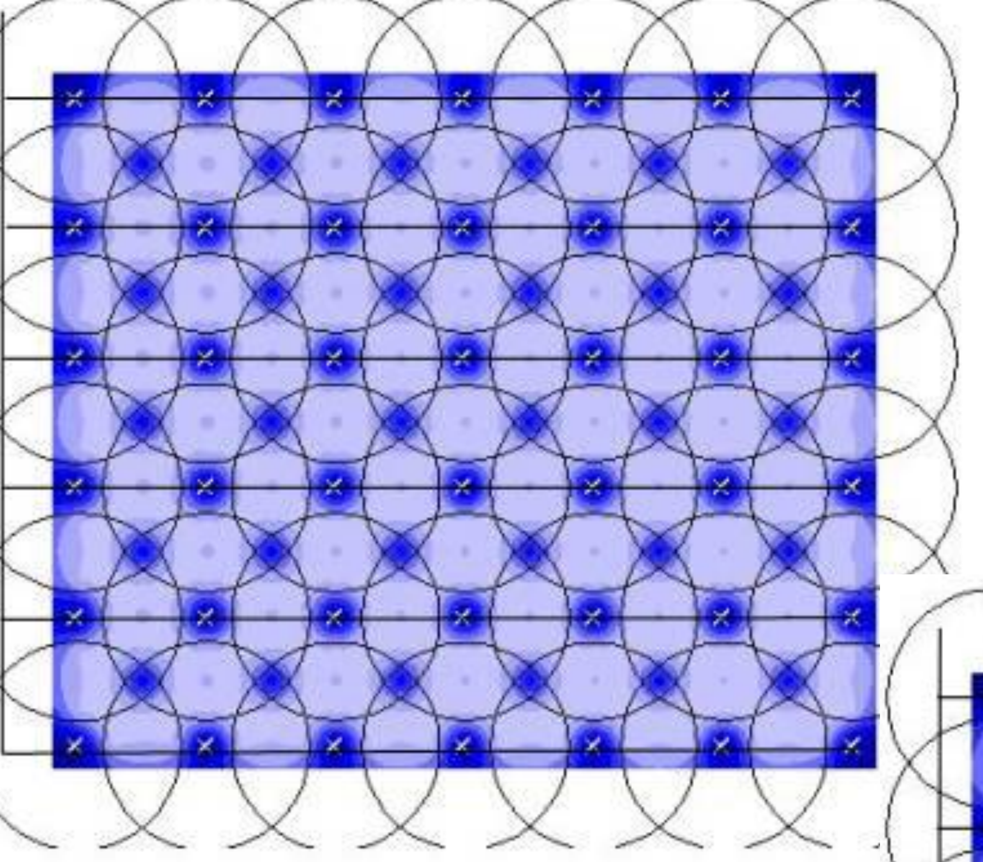
Distribution Uniformity

$$DU = 100 * \frac{Z_{lq}}{Z_{av}}$$

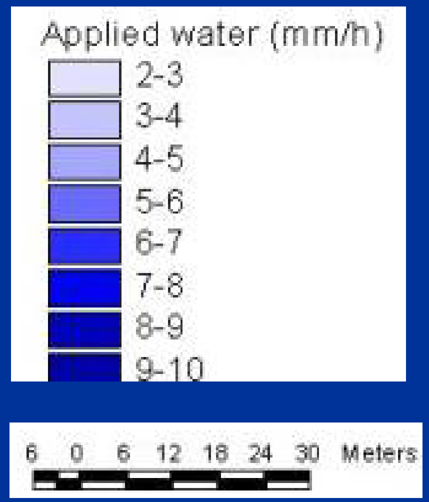
m= :mean depth of observations (mm)
Z= individual depth of catch observations(mm)
Z_{lq} = average low ¼ of the measured value (mm)
Z_{av}= average infiltrated depth in the entire field (mm)

Distribution Efficiency

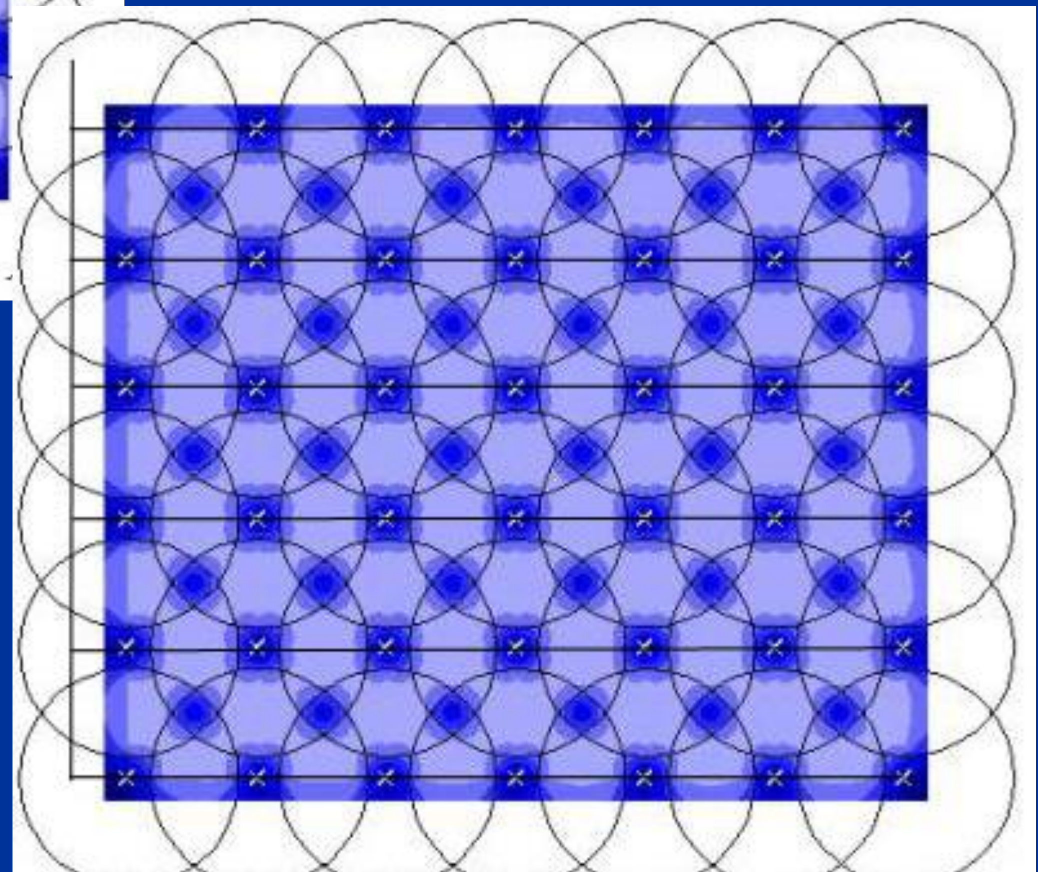
$$DE_{pa} = \frac{Minimum\ \ net\ \ depth\ \ received\ by\ \ wettest\ \ pa\%\ \ of\ area}{Average\ \ net\ \ depth\ \ received\ \ over\ \ entire\ \ area}$$



H= 26 m
CU = 63%
DU = 67%
DE_{90}= 62%



H >= 39 m
CU = 74%
DU = 80%
DE_{90}= 80%



OVERALL EFFICIENCY

CASE 1:

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

CASE 2:

$$E_{O,1} = 0.95 \times 0.62 = 0.57$$

$$\Delta E = (0.57 - 0.76)/0.76 = -0.25 = -25\%$$

Conclusions (1)

- It is important to set up new methodologies for a better design if distribution systems taking into account different operating conditions (design for management)
- It is important to develop models and related user-friendly software packages
- It is important to collect reliable field data in order to test and validate models and plan appropriate modernization programs
- It is important to know the hydraulic characteristics of the hydraulic devices and their effect on irrigations systems

Conclusions (2)

- It is important to take into account the interactions among the different steps of the distribution chain
- The concept of efficiency is strictly link to the concept of performance
- Exists a time dimension of the concept of efficiency
- The technical options need to be combined with institutional options
- The use of new technologies may help in improving operation and management of distribution systems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INSTITUTIONAL APPROACHES

WHAT IS PARTICIPATORY IRRIGATION MANAGEMENT (PIM)

- Involvement of irrigation users in all aspects and at all levels of irrigation management.
- Transfer of irrigation systems from public organizations (Gov'ts) to WUAs.

TARIFF RULES

BUDGET

COST OF MAINTENANCE
(on the base of the previous Year Budget)

FIXED RATE
(€/ha)

$$\frac{\text{Cost of manteinance}}{\text{Irrigable Area}} = 15 \text{ €/ha}$$

OTHER COSTS
(on the base of the previous Year Budget)

VARIABLE RATE
(€/m^3)

$$\frac{\text{Other Costs}}{\text{Available Water Volume}} = \text{Water Tarif - P (€/m}^3\text{)}$$

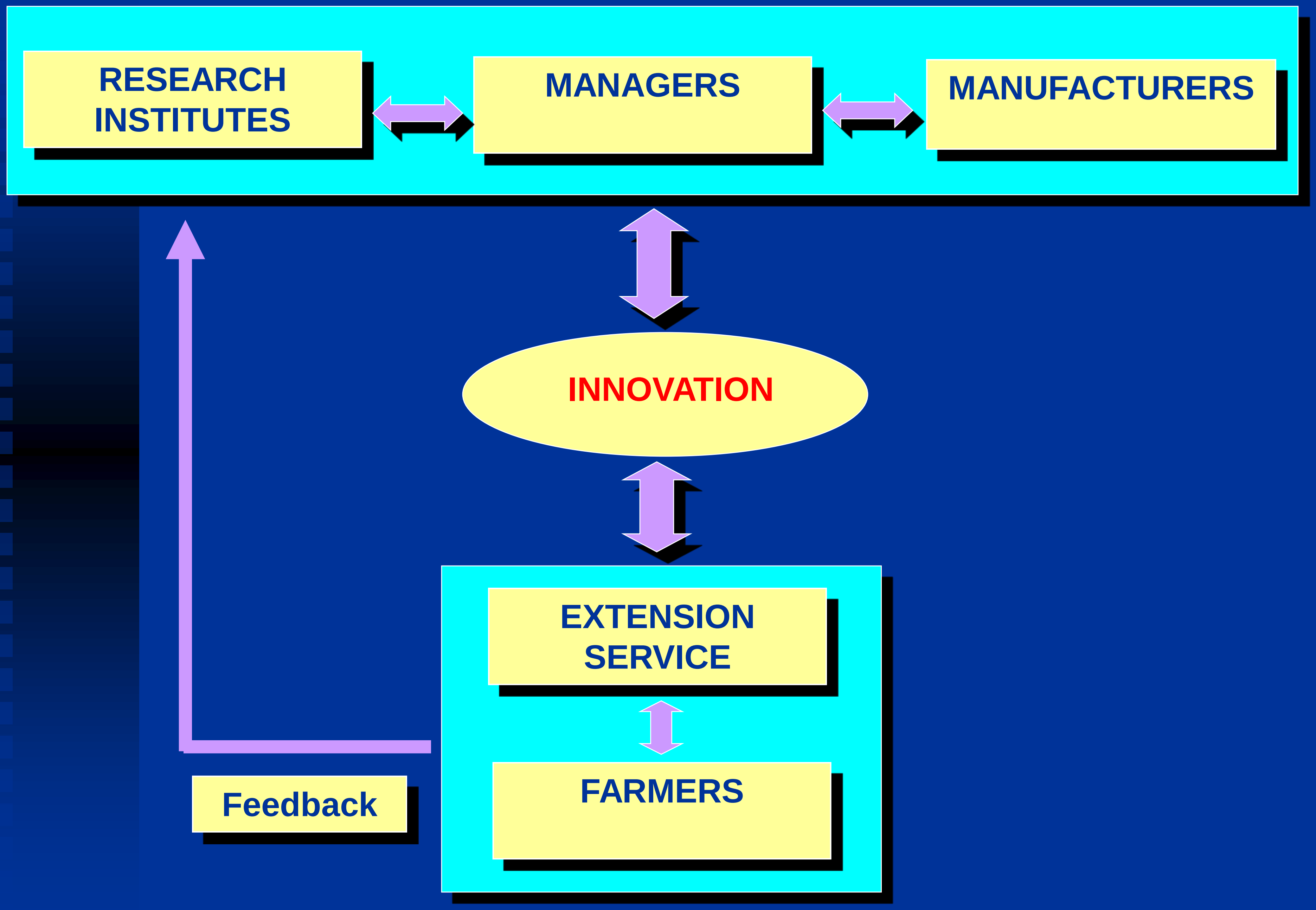
WATER AVAILABILITY

$$\frac{\text{Available water volume}}{\text{Irrigable Area}} = 2000 \text{ m}^3\text{/ha}$$

- 0.10 €/m^3 0 - 2000 m^3/ha
- 0.18 €/m^3 2000 - 2500 "
- 0.28 €/m^3 2500 - 3000 "
- 0.38 €/m^3 > 3000 "

IMPORTANCE OF THE TRAINING: FROM THE CLASSROOM TO THE FIELD

EXTENSION SERVICE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