National Technical University of Athens
Faculty of Water Resources, Hydraulics & Maritime Engineering

Infiltration- Inflow into Sewer Systems

Zalachori Ioanna

Supervisor: D. Koutsogiannis

Co-supervision: **A. Andreadakis**

Infiltration-Inflow:

Infiltration (ground water):

Sources of infiltration:

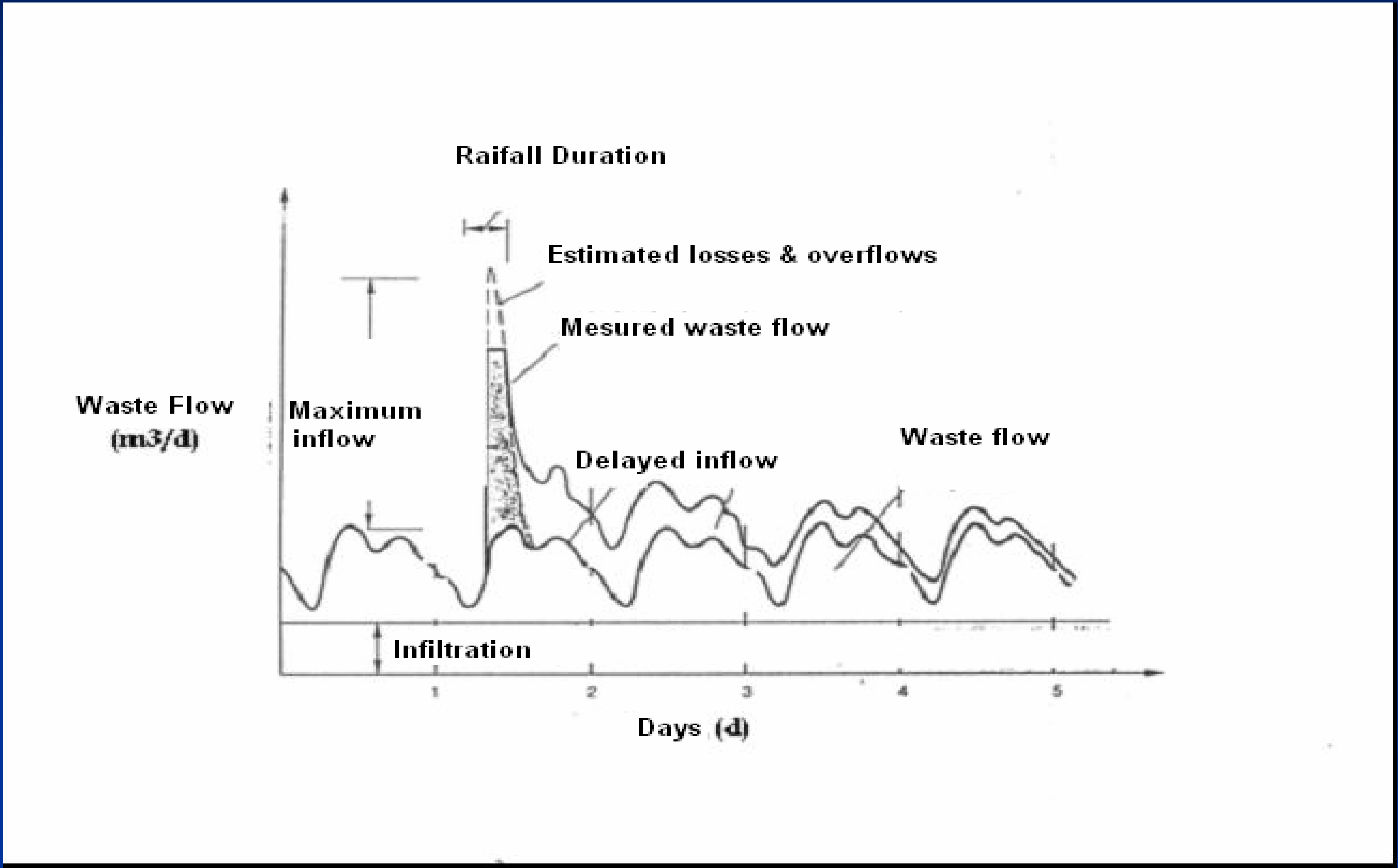
- Through cracks inside the pipes
- Through defects in the construction and the water-tightness of manholes,
- Through defects in the connections of pipes

Inflow (surface water):

Sources of inflow:

- Through the covers of manholes (fast runoff component)
- Through illegal connections of the drainage from yards, roofs (fast runoff component), and foundations (slow runoff component) into the sewer system.
- Through the storm sewer systems (slow runoff component)

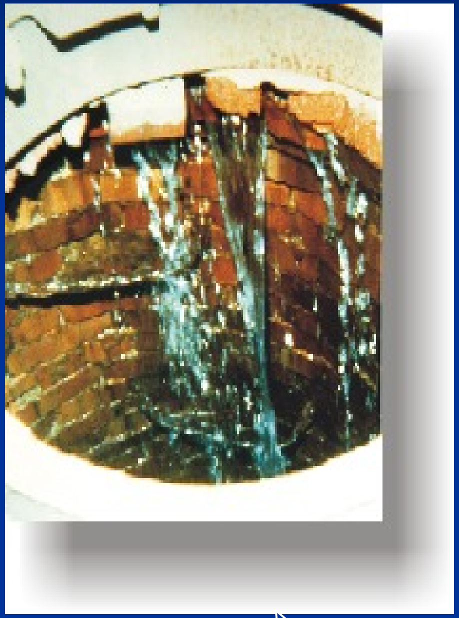
Components of Infiltration - Inflow:



Source: Metcalf & Eddy, 1981

Sources of I/I

Illegal connection roof drainage into sewer system



Manhole improperly covered

Eroded sewer pipe

Crack inside sewer pipe

Problems caused by I/I:

- Sewer System

  Overloaded pipes

  Overflow in pipes

  Increase in the functional cost of collection

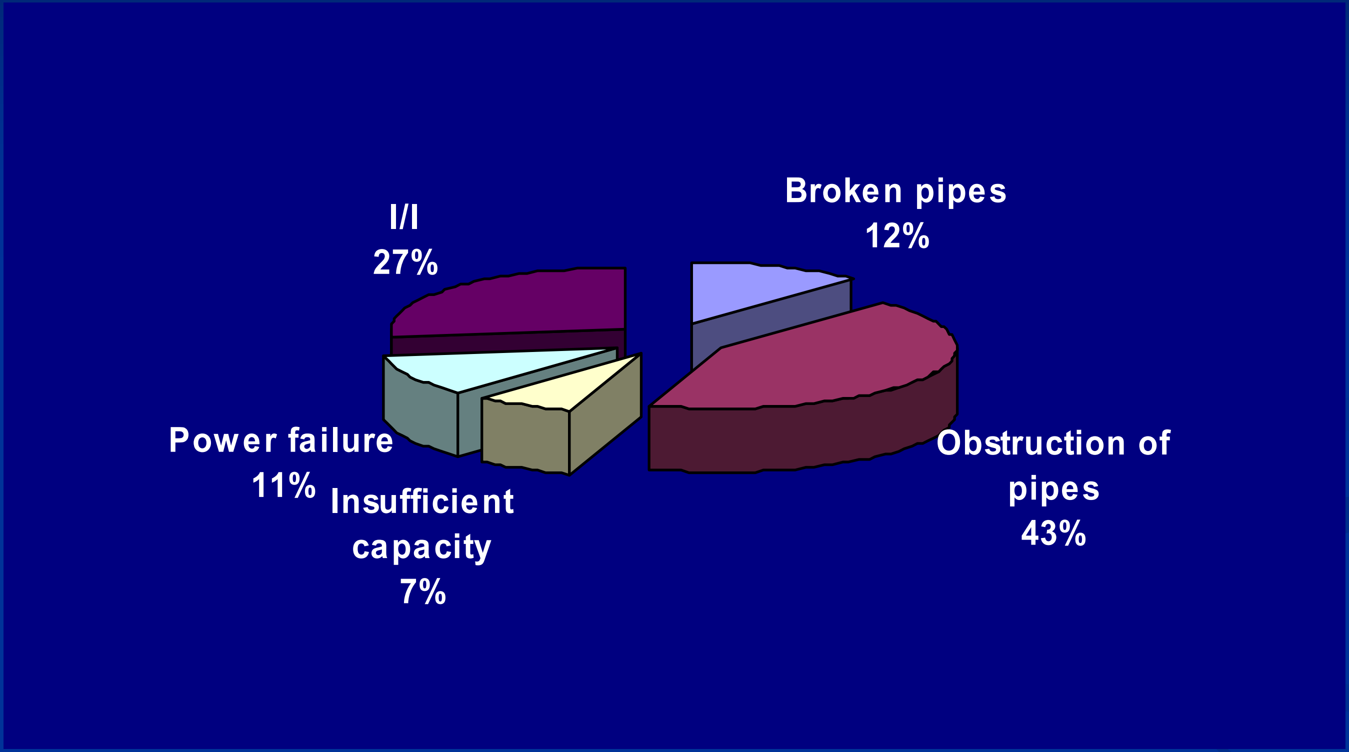
- Waste Treatment Plan

  Insufficient treatment of waste

  Increase in the functional cost of the facility

  Deterioration in the quality of the final receiver.

Extent of the problem:



Reasons for overflow in pipes

Source: USEPA, 1996 (sample of 6 sewer systems in the USA)

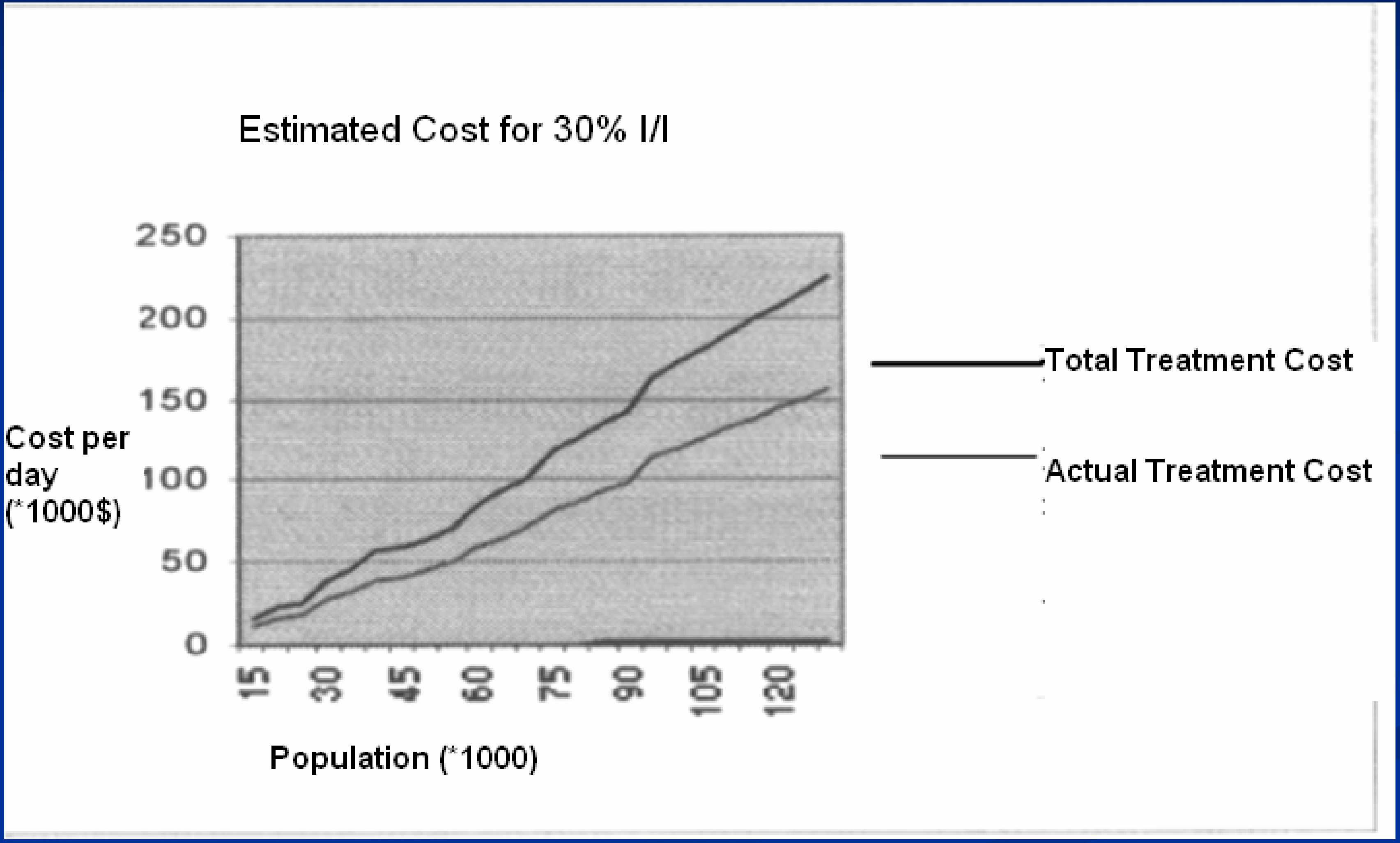
Extent of the problem (2):

- 100 % total waste discharge (Petroff 1996)

- Increase in waste discharge from 3.5 to 20 times during dry weather and minimum ground water level. (USEPA 1990, sample of 10 cities)

- Increase in the waste discharge up to 30 times during dry weather and minimum ground water level in rare cases. (Jeng et al. 1996, Houston Texas)

Estimated Cost for 30% I/I:



Source: Liu & Vipulanandan, 2003

Regulations:

USA

Identifying and limiting I/I :

- Inflow ≥ 275 gpcd
- Infiltration ≥ 120 gpcd

(Modification according to state laws)

Europe

Insufficient regulations

Designing advises (Martz 1970)

Regulations:

Greece:

Building Regulations (Decision 3046/304/1988, ΦΕΚ 59 Δ΄/ 1989 Άρθρο 26)

§ 3.7. Connections of wastewater facilities in the storm water system are prohibited, except in case of combined sewer system.

§ 4.3. In case of inexistence of proper storm sewer pipes, the roof and the yard drainage will be lead into the gutter of the pavement. In case this alternative isn't possible, then roof, yard, and foundation drainage is led into an absorptive trench.

EYDAP (1985) designing advises:

I/I is considered as 30% of wastewater flow in regions with high ground water level.

I/I is considered as 20% of wastewater flow in regions with low ground water level.

Limiting I/I during design & construction:

- Identifying local characteristics
- Increase design discharge
- Include modern construction techniques
- Proper construction

Limiting I/I during function:

Identifying problem (approximately)

- Waste flow comparison during high groundwater level or/ and during rainfall.
- Comparison of waste discharge – water consumption
- Comparative analysis of functional characteristics during high ground water or/ and during rainfall.
- Correlation of hourly waste discharge data – rainfall during the early morning hours.

Limiting I/I during function:

Identifying (accurately)

- Field checking (during rainfall)
- Flow meters/ Continual measuring devices especially in vulnerable positions
- Smoke test
- Dying water test
- TV inspection
- Checking pipes and conjunctions by using pressure

Identifying methods:

(α)
TV inspection

(β)
Smoke Test

Limiting I/I during function:

- **Sewer system evaluation survey**
- **Repair sewer system**

(modern techniques vs traditional techniques)

repairing local/ extensive defects

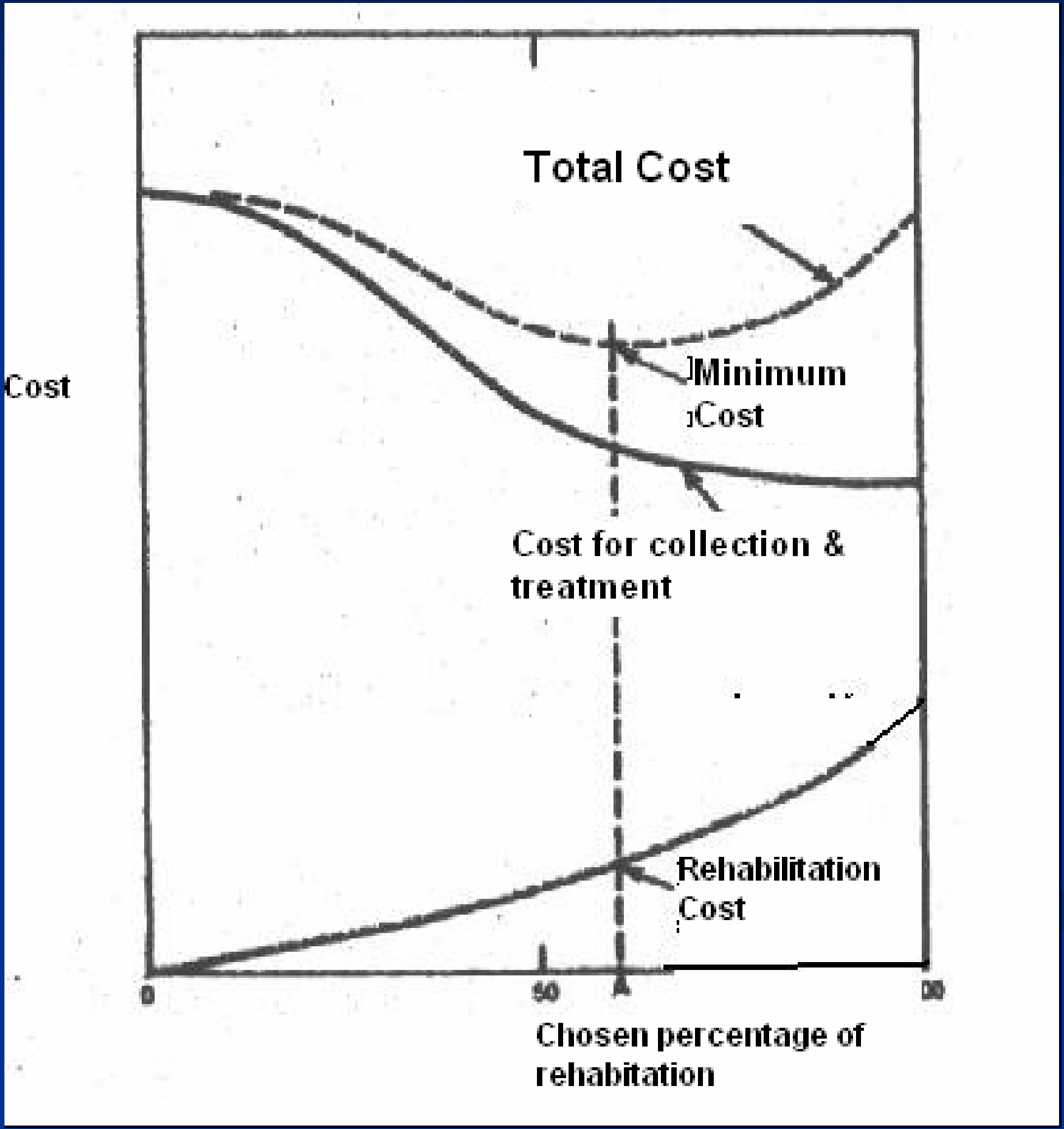
sealing manholes/ conjunctions

disconnect illegal connections

replace pipe sections

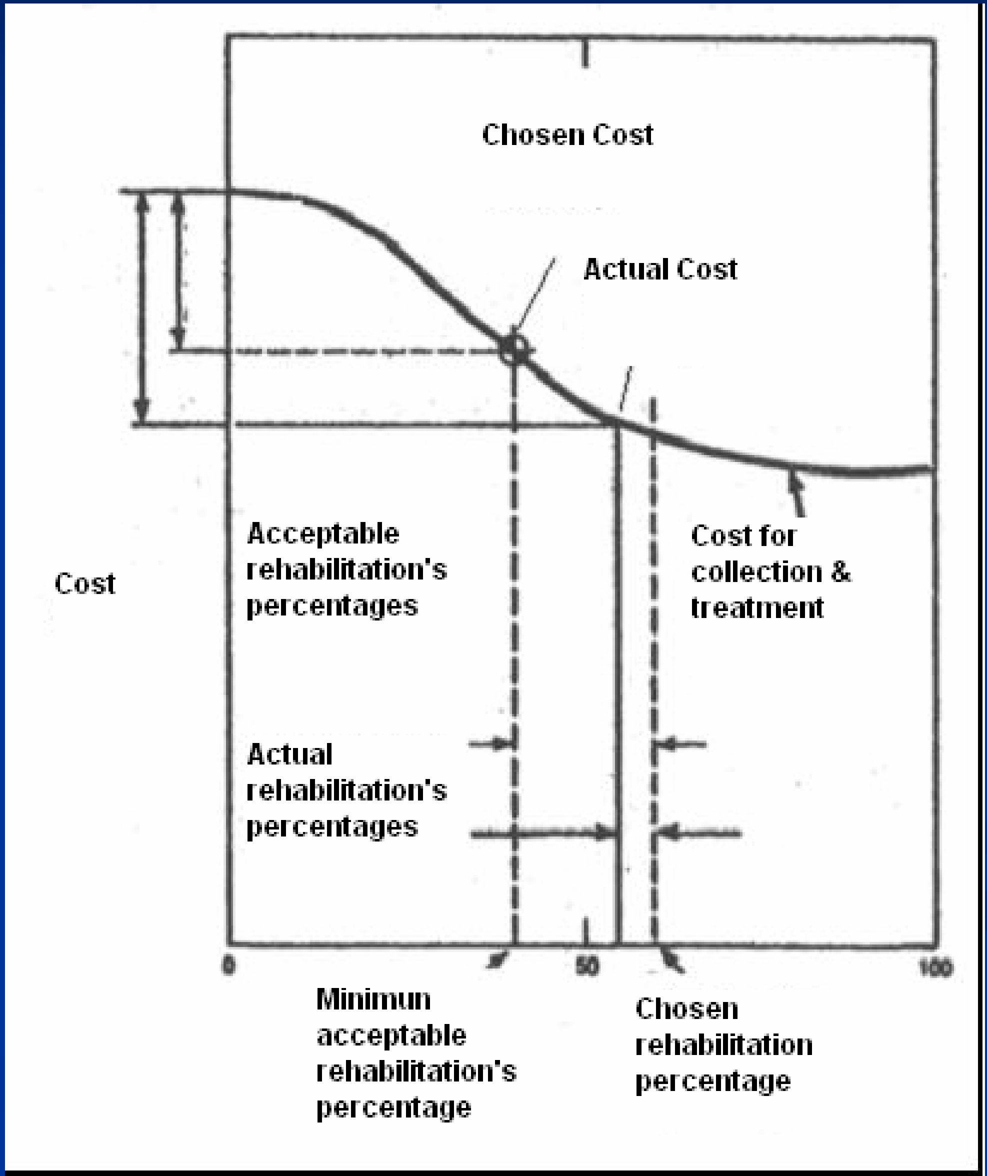
- **Extension or replacement of wastewater treatment plan**

Sewer System Evaluation Survey (1):



Source: USEPA, 1985

Sewer System Evaluation Survey (2):



Source: USEPA 1985

Examples of I/I limitation of cities & counties:

- Alexandria, Virginia USA
- St Lawrence, Pensylvania
- Austin, Texas USA
- Johnstown, Pennsylvania USA
- Broward County, Florida USA
- Honolulu, Hawaii USA
- Lower Paxton, Pennsylvania USA
- Countywide, Kentucky USA
- Plant City, Florida USA
- Boston, Massachusetts, USA
- Tulsa, Oklahoma USA
- Springfield, Pensylvania USA
- Skagit County, Washington USA
- Eaton Rapids City, USA
- Louisiana, USA
- Allegheny County, USA
- Ottawa, Canada
- Indianapolis, Indiana USA
- Alaska, USA

Research –Pilot Projects in Europe:

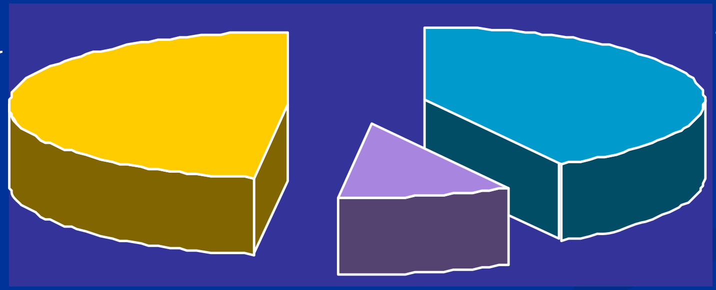
- **Sweden**

  MouseNAM model with case studies in Prague, Zagreb, Ljublijana, Goteborg Rya, Helsingborg, Sydney & Auckland.
- **Bouguenais, France**

  Estimation of ground water entering the system
- **ETH, Switzerland**

  Estimation of ground water entering the system with case studies in many European cities.

Components of waste flow (MouseNAM):



Source: 3rd DHI Software Conference, Sweden 1999

I/I problems in Greece (2):

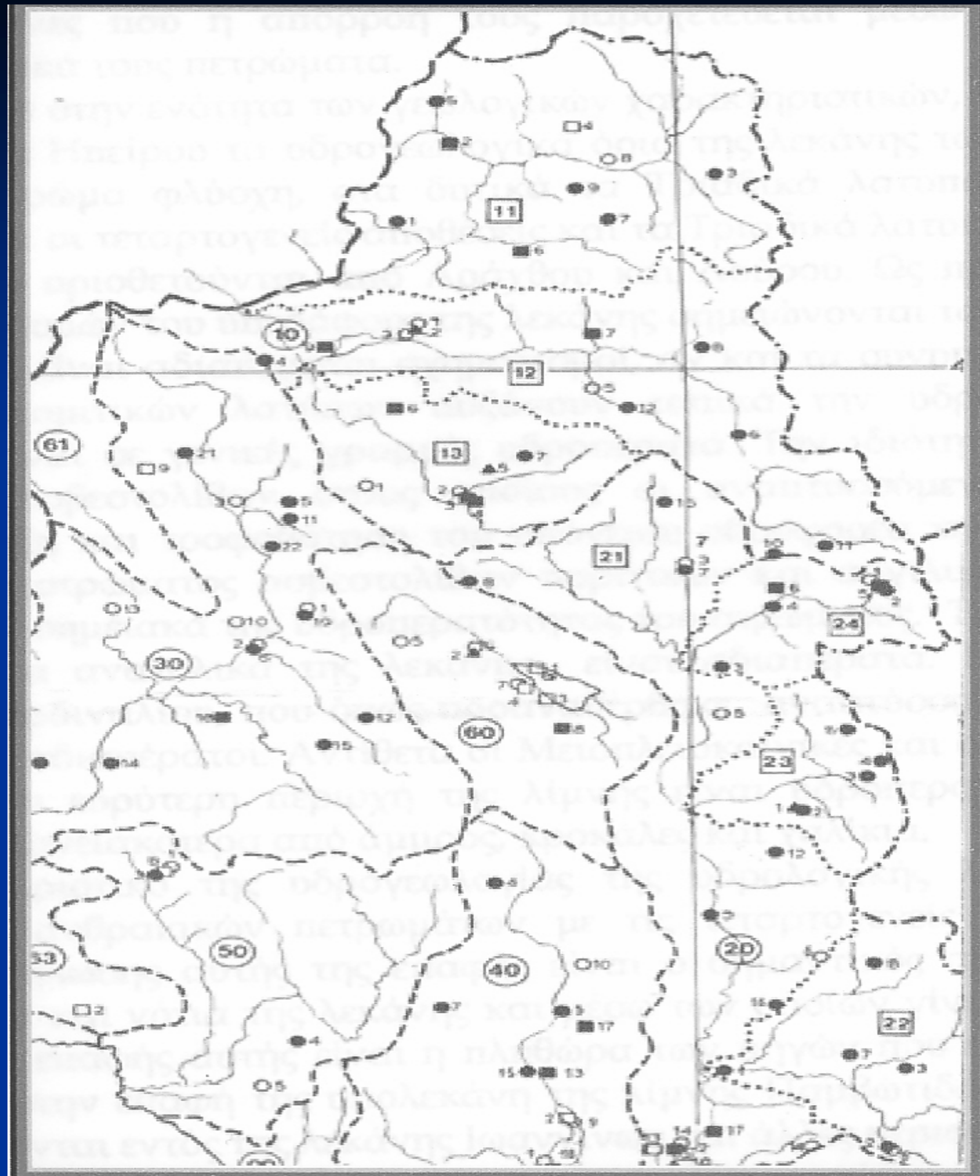
- Underestimating problem
- Incomplete data series for sewer systems
- Insufficient research
- Lack of field inspection by local authorities
- Lack of information in the designer community
- Lack of information in the local society

Base 800032 (A01424) 5-84

Ioannina Sewer System:

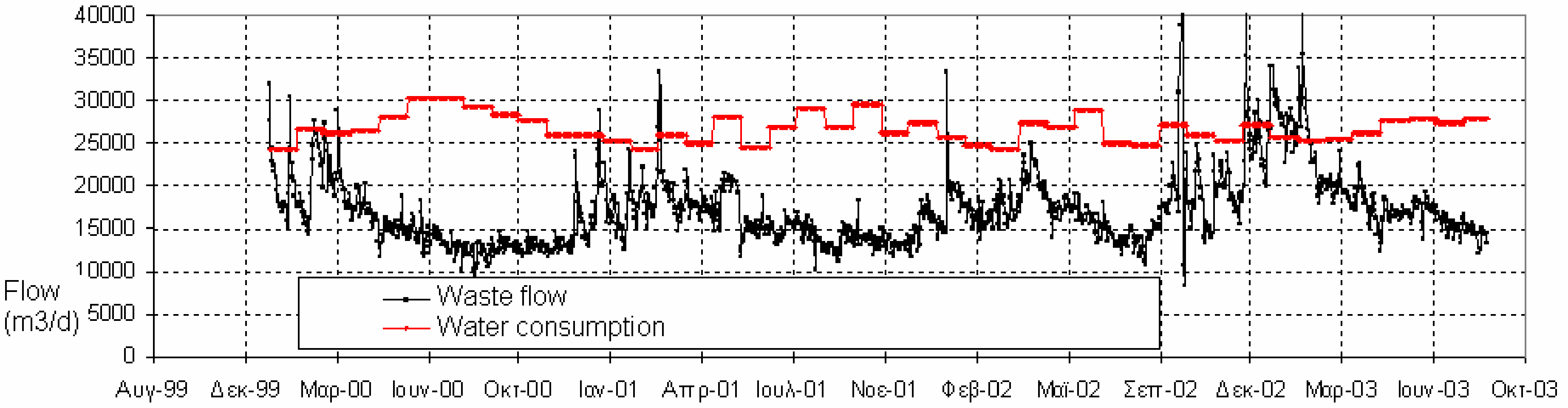
- Serves 130.000 habitants
- Separate sewer system
- Constructed during 1985 - 2000
- Pipes of PVC, cement & amiantocement
- Watertight conjunction rings
- 5 main pumps leading to pipes under pressure
- Main sewer length 3,5km out of PVC Φ1200.
- Extension waste water treatment plan 2003.

Source: Ioannina local authorities / Population Census 2001



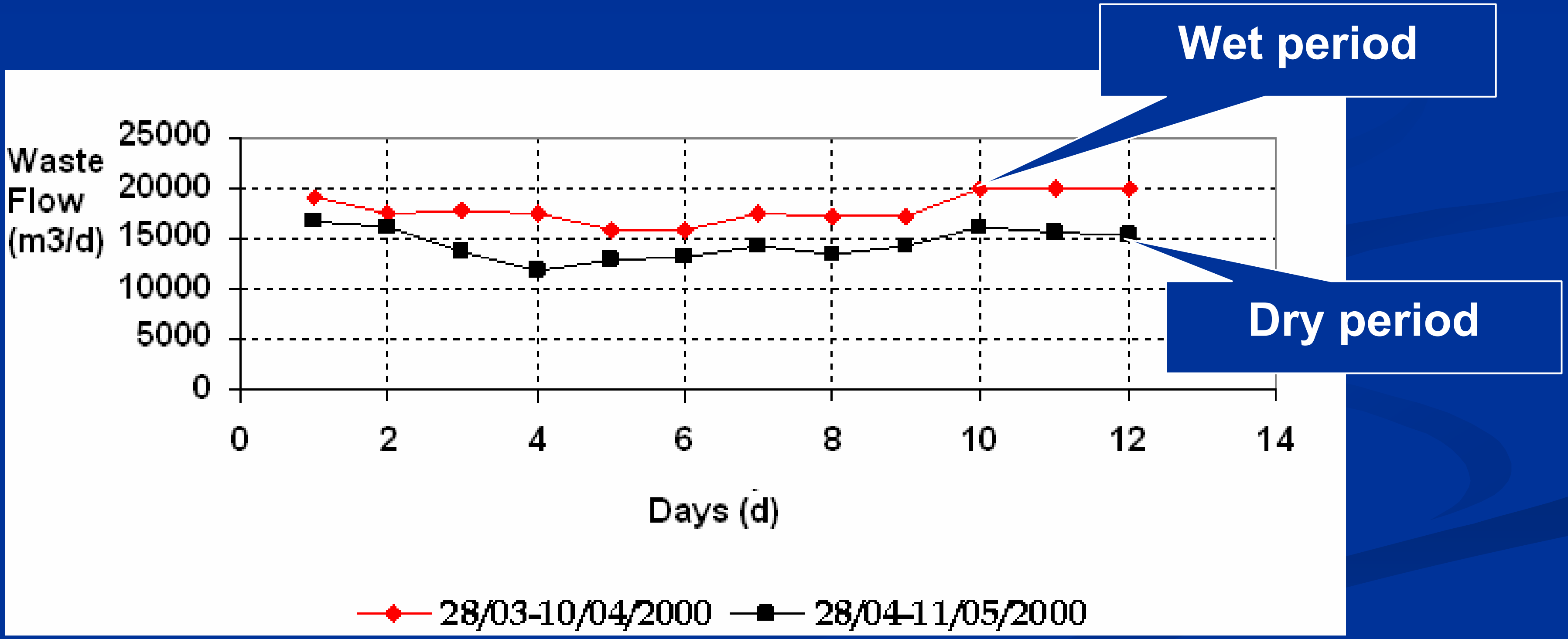
Source: Ministry of Energy & Development

Comparison waste flow – water consumption:



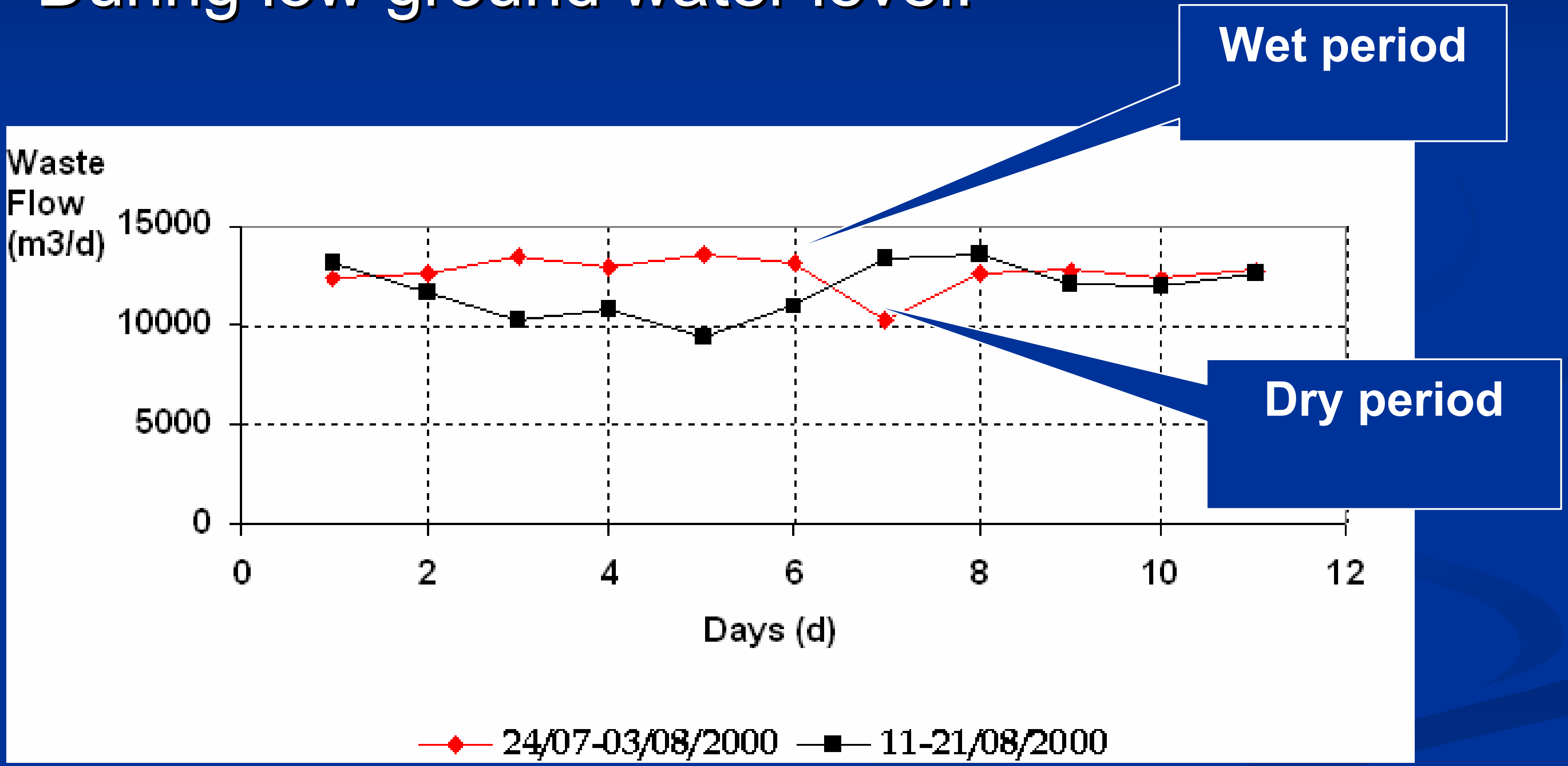
Identification (approximately) (1):

During high ground water level:



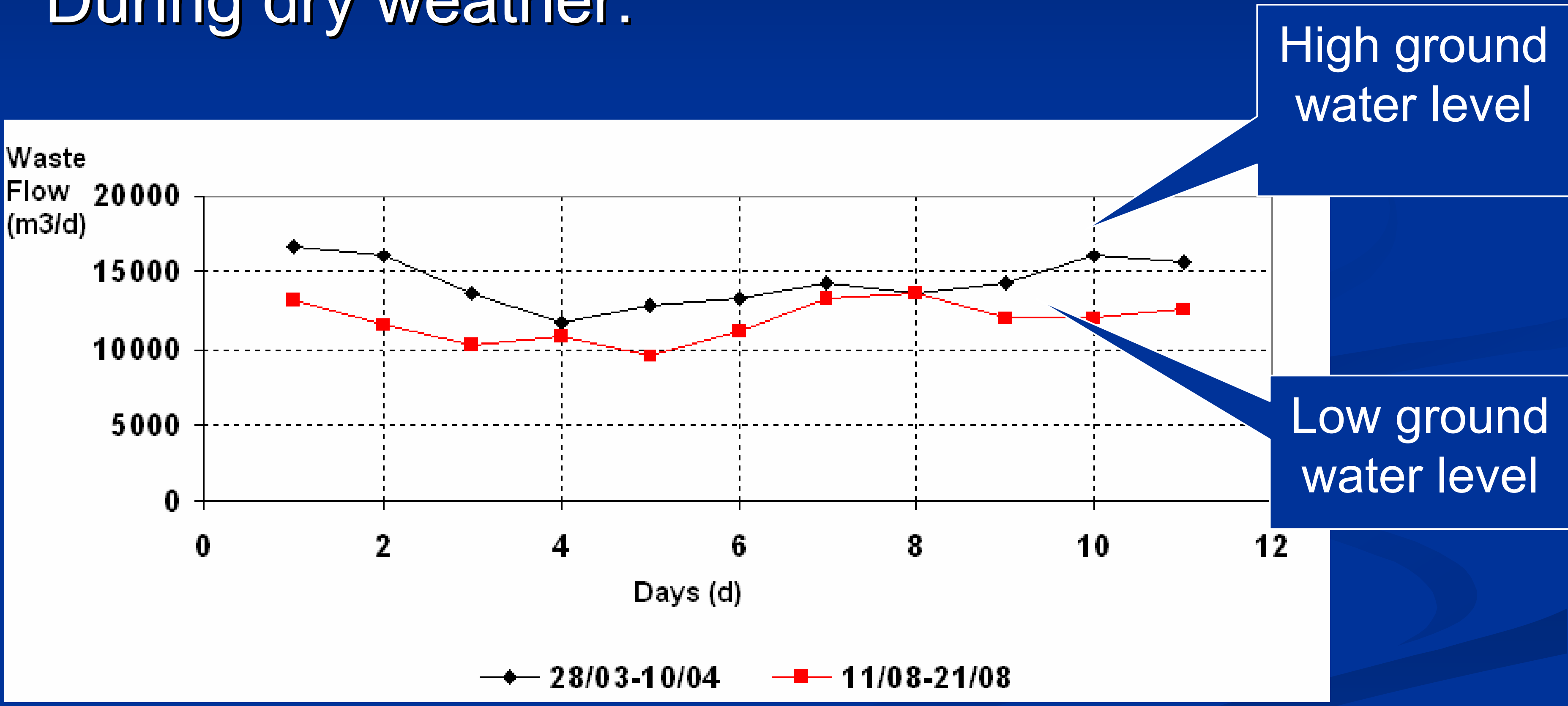
Identification (approximately) (2):

During low ground water level:

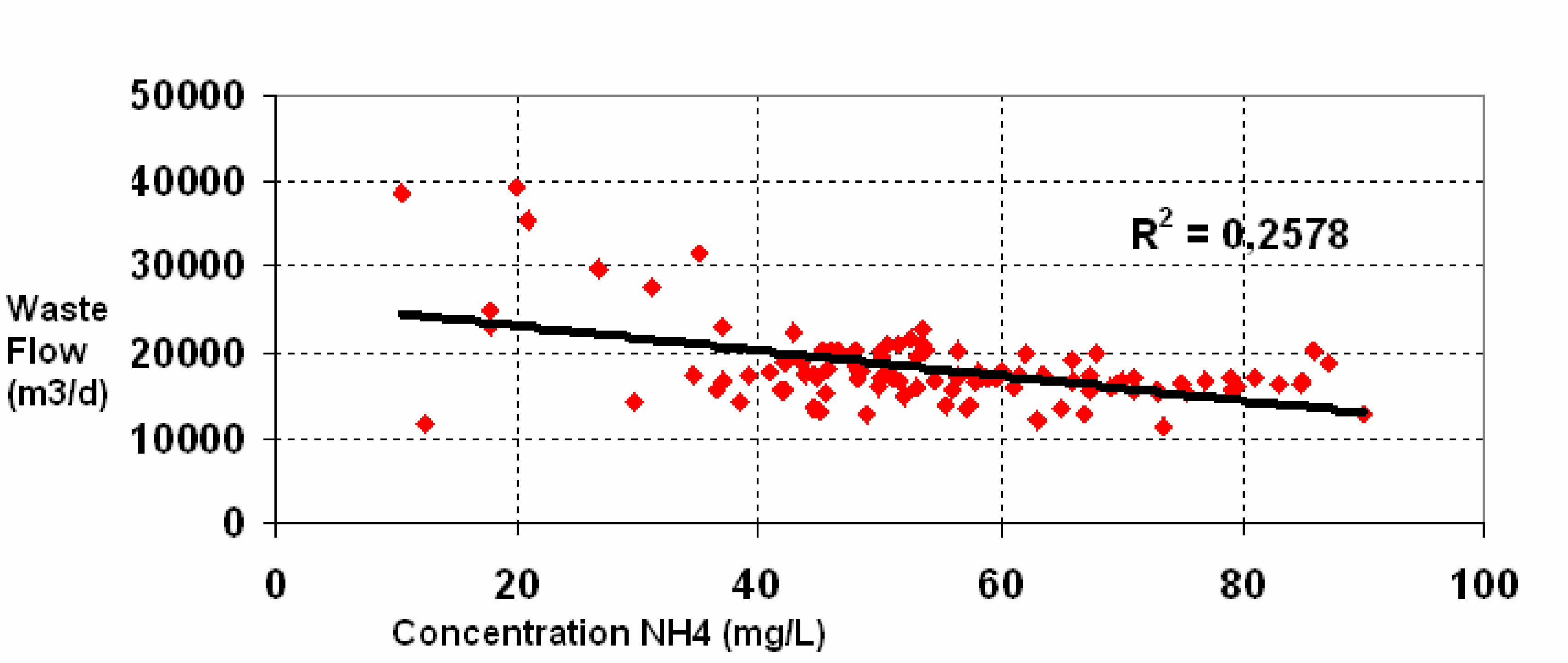


Identification (approximately) (3):

During dry weather:

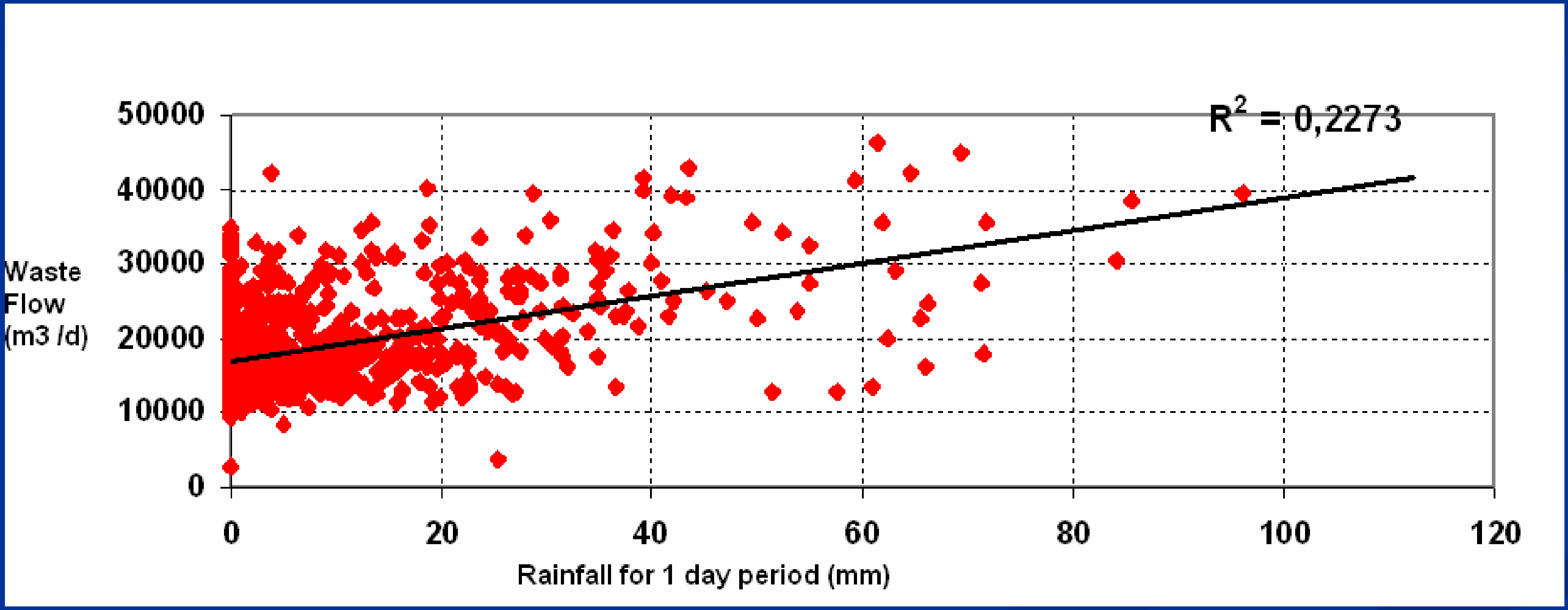


Correlation of waste flow & functional characteristics:



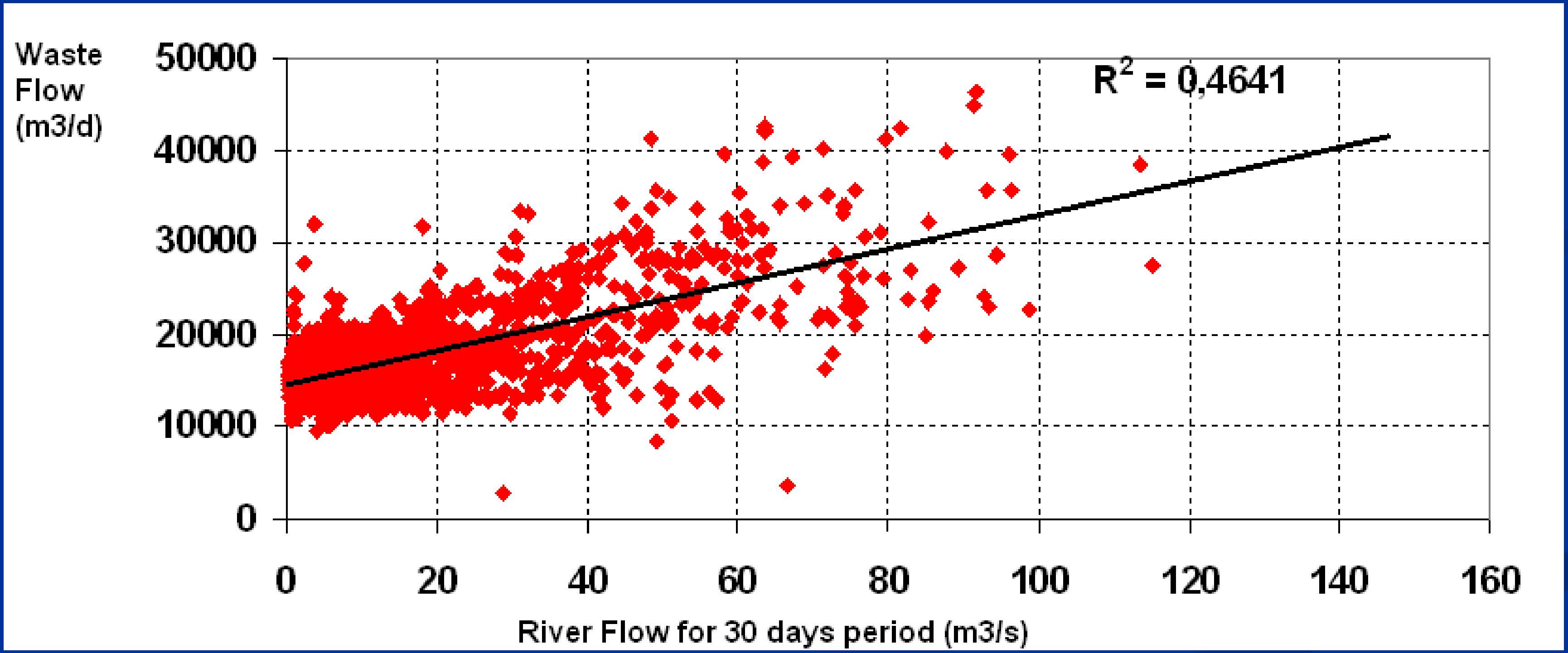
Correlation waste flow & rainfall (1):

Correlation for 1 day period (today & day before)



Correlation waste flow & rainfall (2):

Correlation for 30 days period (today & 30 days before)



Conclusions:

Time period:

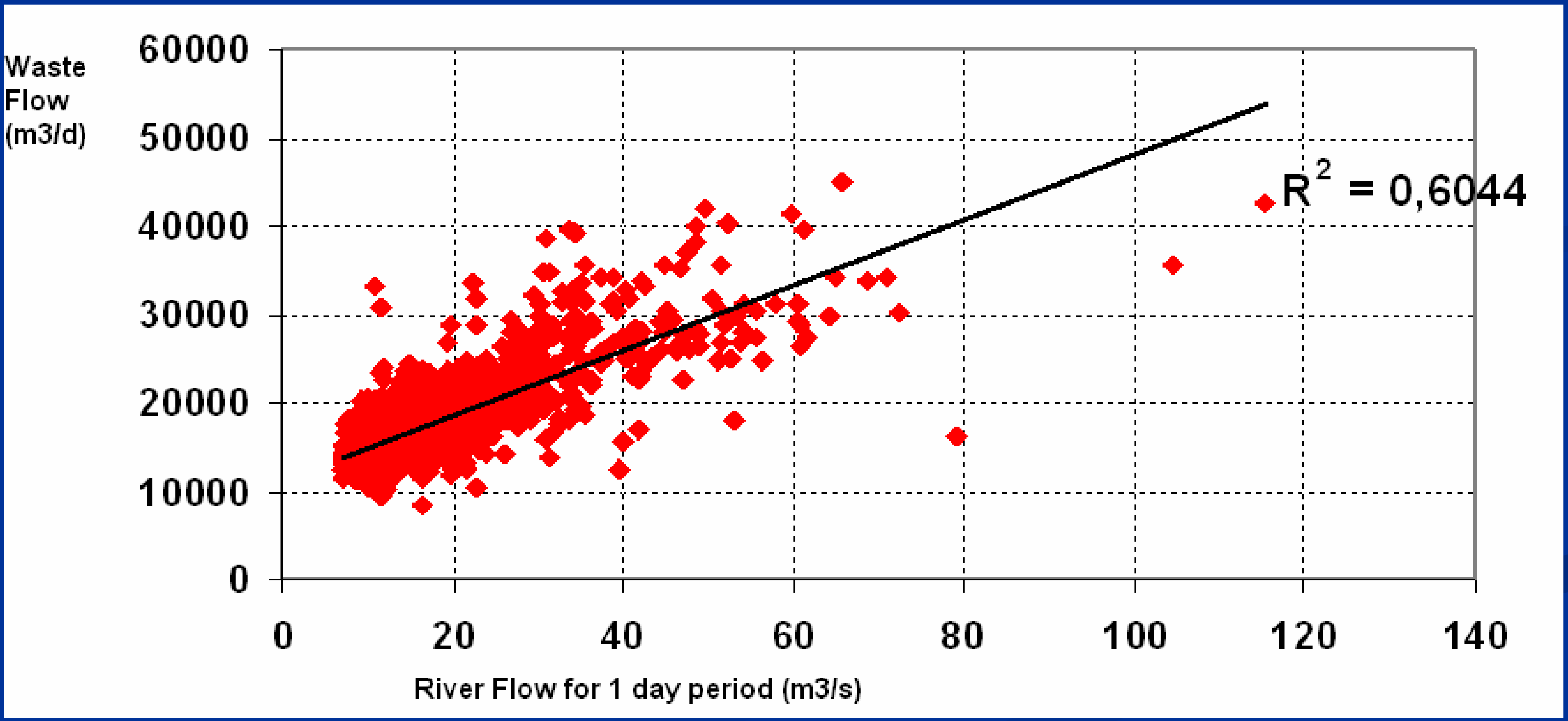
1 day → 23% explained correlation

30 days → 46% explained correlation

- Great ground water contribution
- Minor infiltration contribution
- No data for ground water level
- Use of river flow as an index of ground water behavior

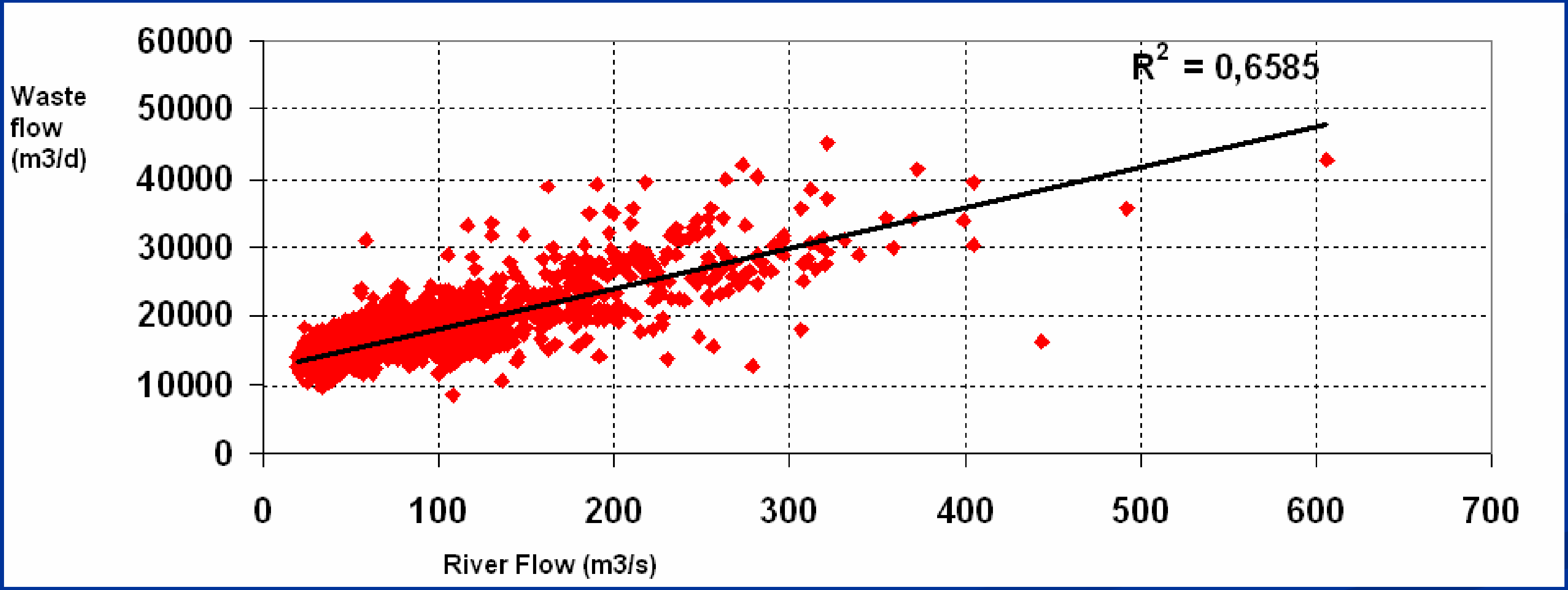
Correlation waste flow & river flow (1):

Correlation for 1 day period



Correlation waste flow & river flow (2):

Correlation for 30 day period



Pilot Model:

Model equation :

$$Q = a + f\,Y^{h} + b\,\Pi^{c} + d\,B^{e} + E$$

, where:

Q: weighted waste flow

Y: weighted water consumption

Π: weighted river flow

B: weighted rainfall

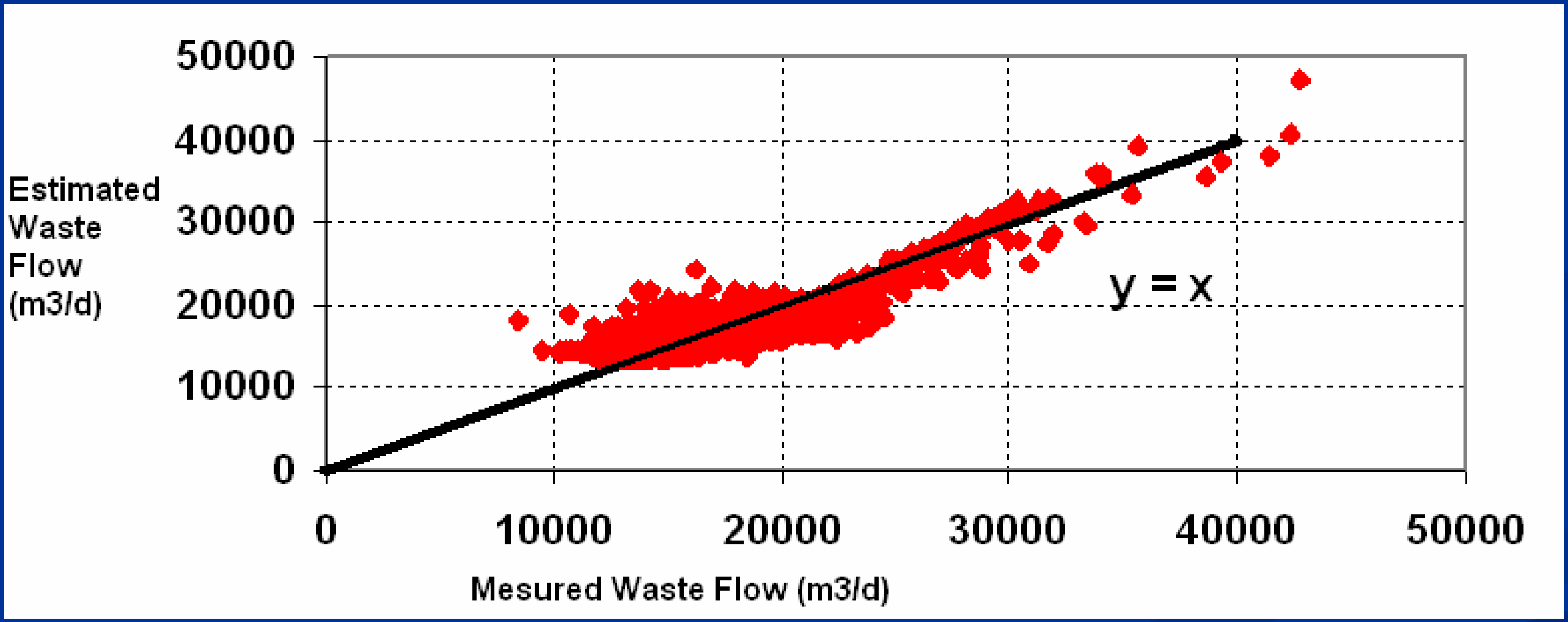
E: additional rainfall (resulted from filtering the picks of rainfall data series)

a, b, c, e, h: model parameters

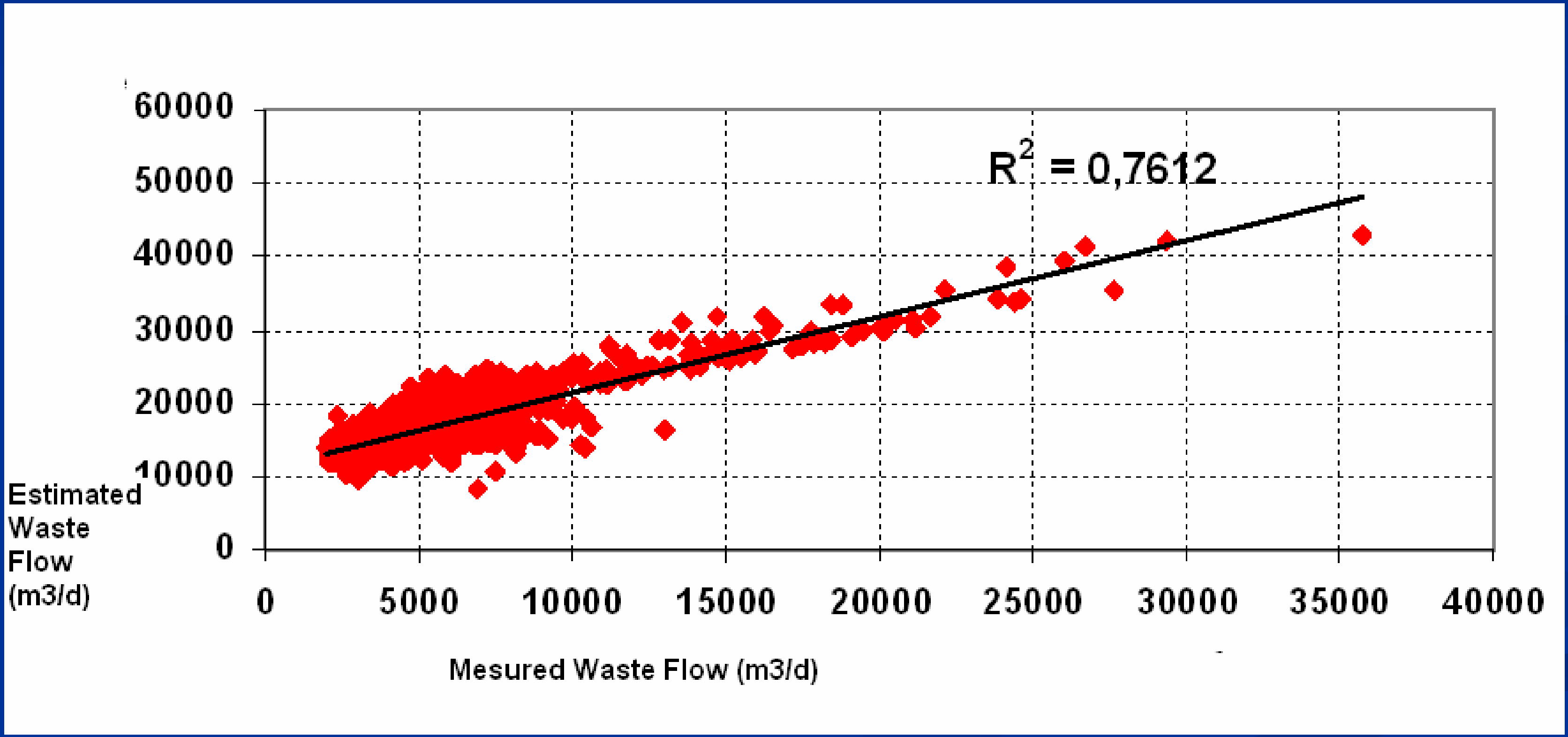
Model components:

- $a + f\,Y^h$: Waste flow
- $b\,\Pi^c$: infiltration
- $d\,B^e + E$: inflow

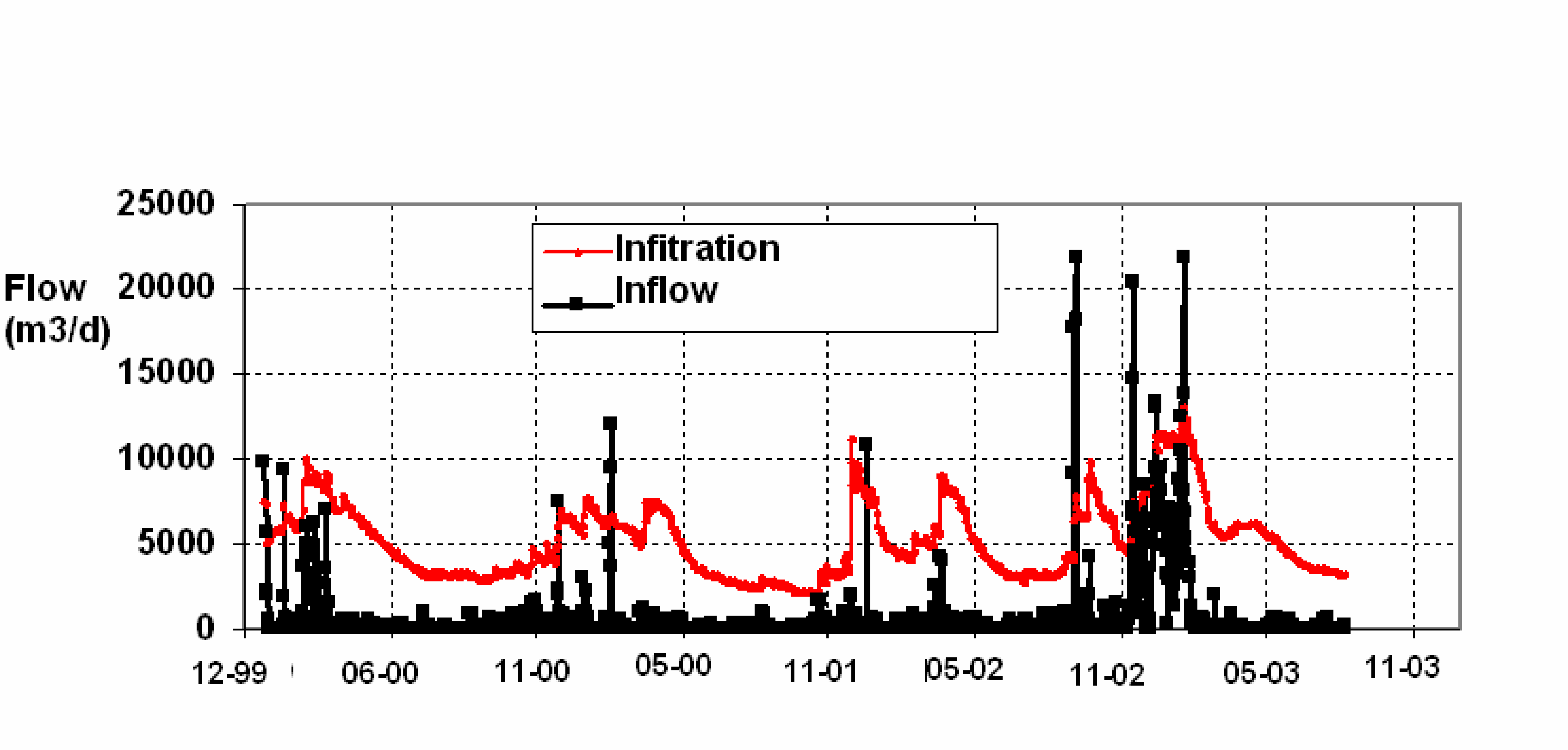
Checking the pilot model (1):



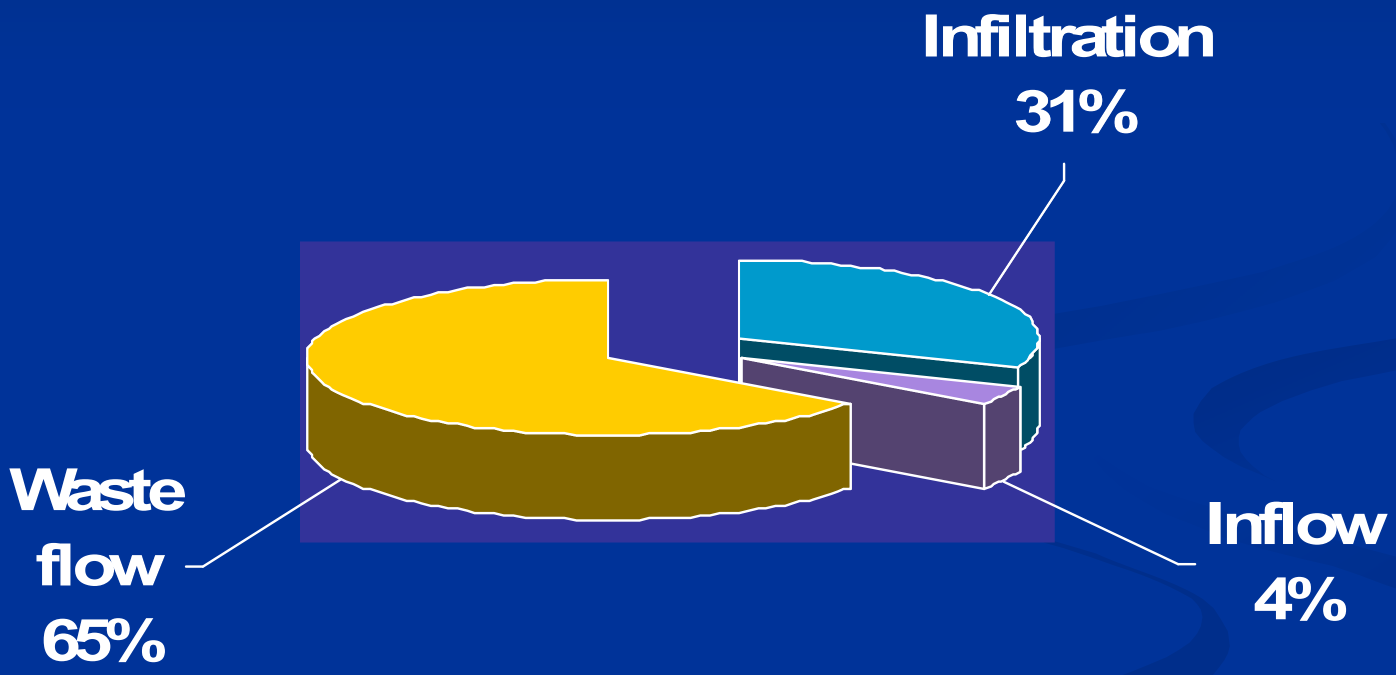
Checking the pilot model (2):



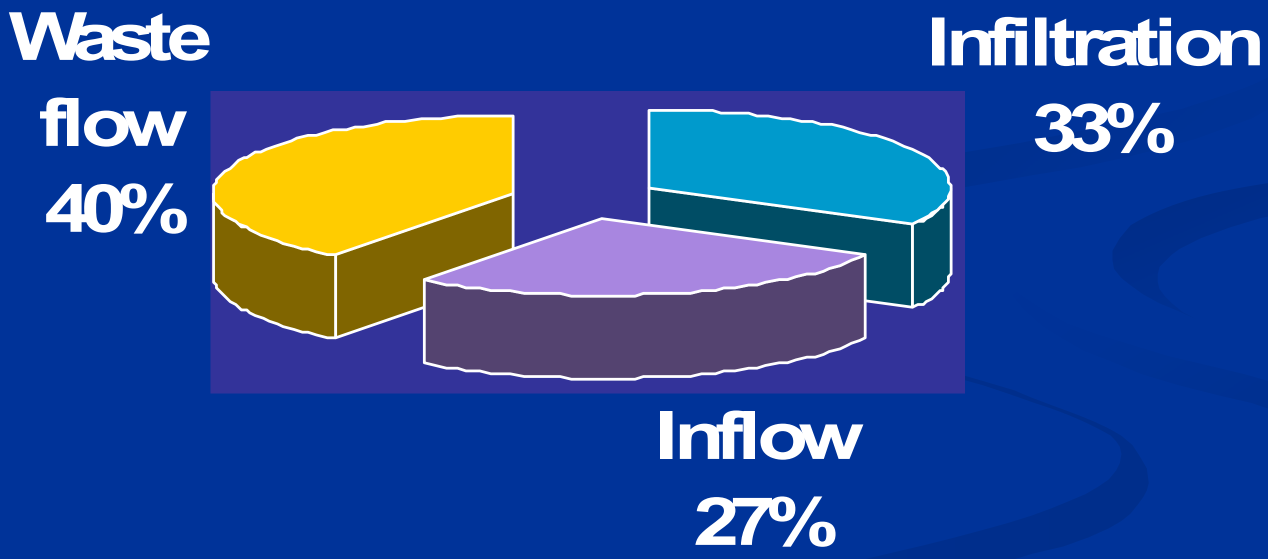
I/I distribution:



Waste flow components for the average annual values



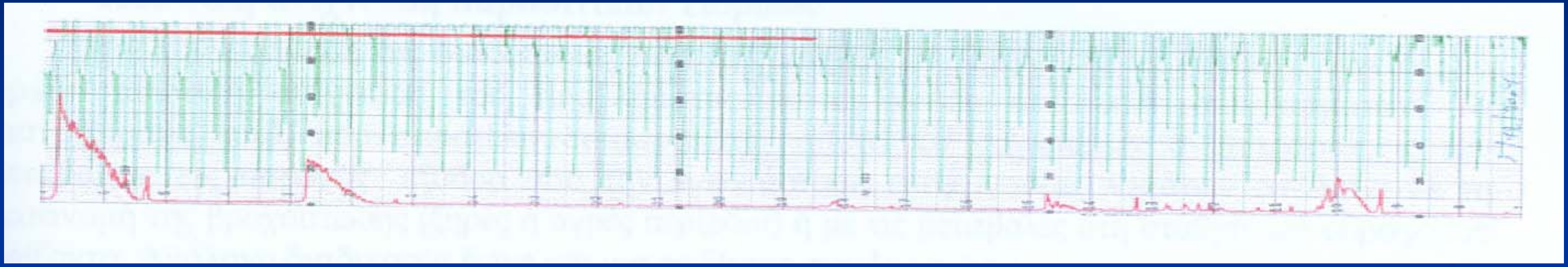
Waste flow components for the maximum 5 % of annual values :

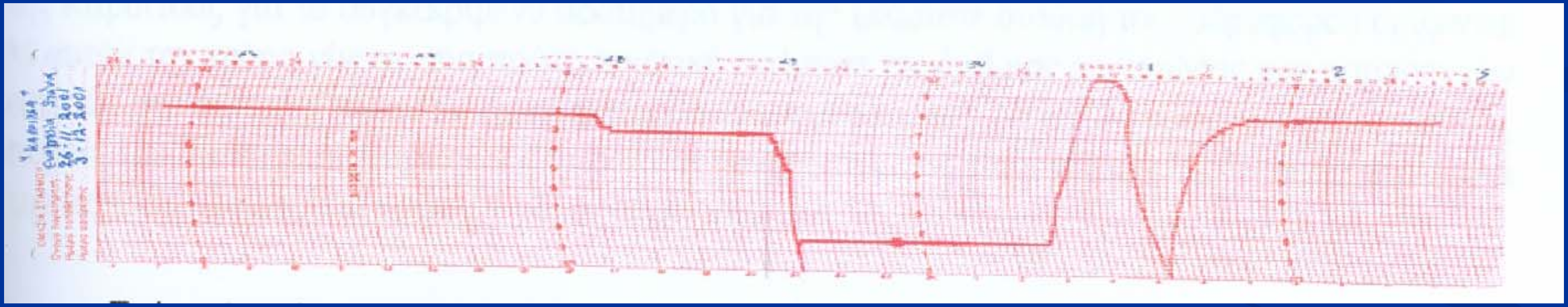


Karditsa:

- Total served population 35.000
- Separate sewer system
- Constructed 1980 – 2000
- Pipes of PVC & amiantocement
- Waste water treatment plan completed in 1989
- 2 construction periods according to population data: 2005 & 2025
- Lack of daily waste flow data

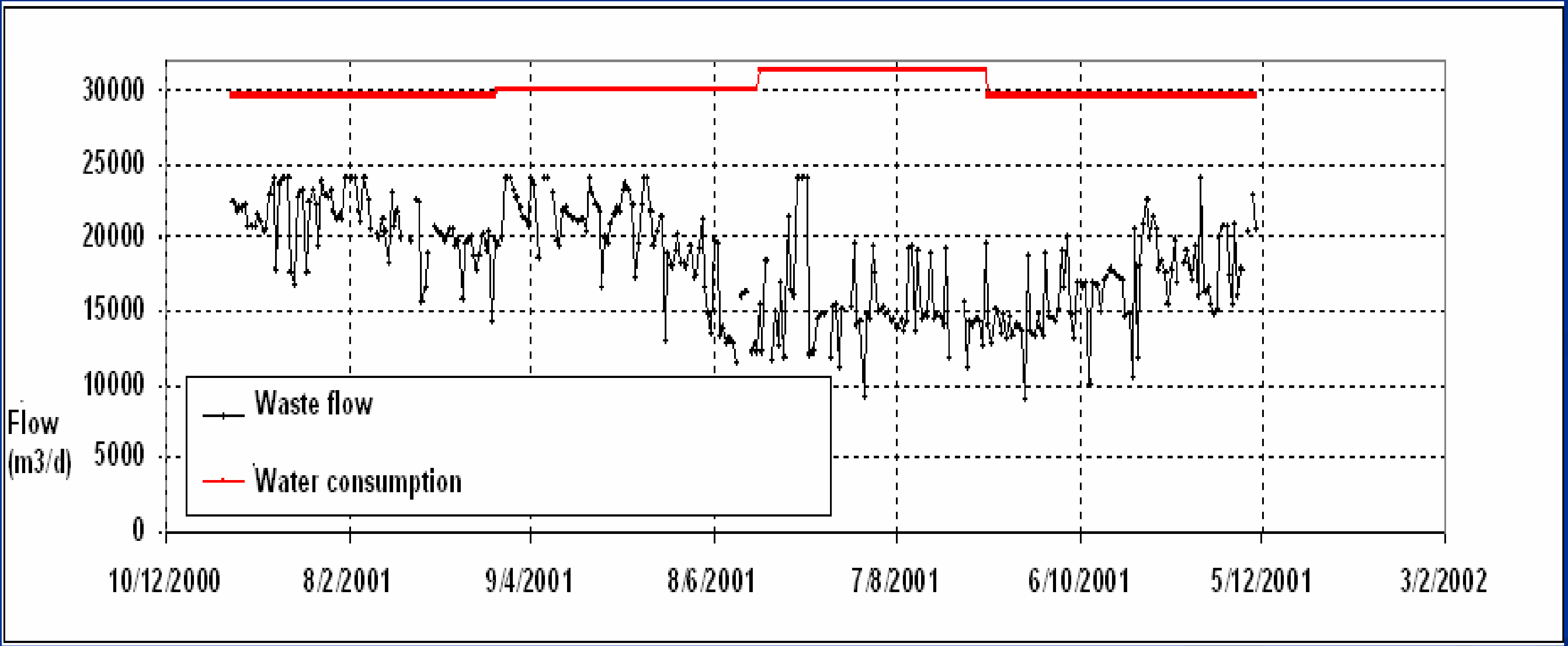
Measuring Input Data



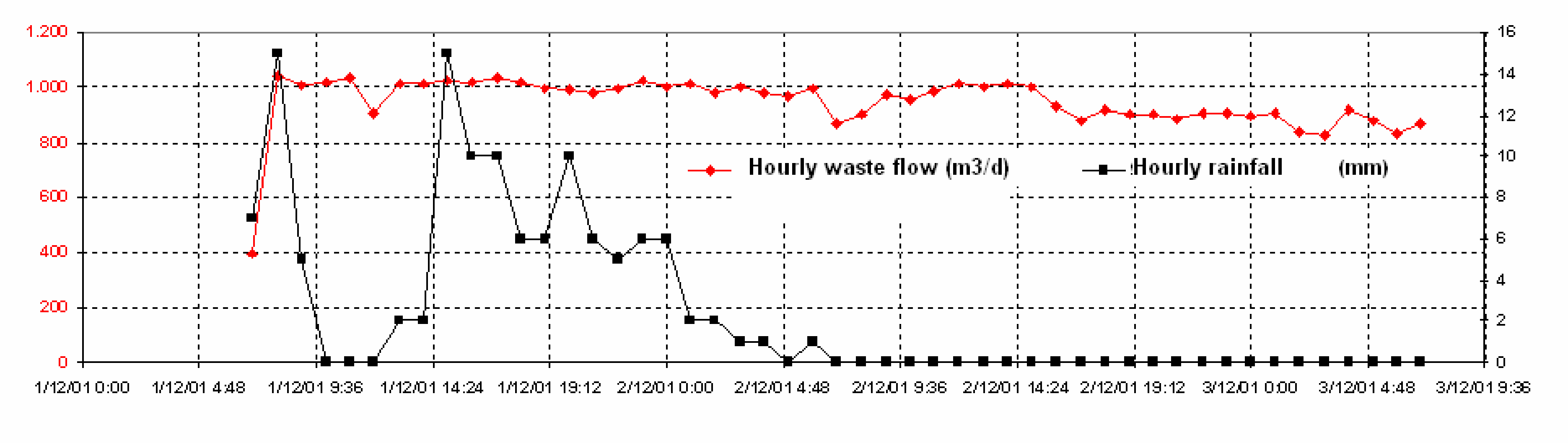


Above: Waste Discharge (continuous measurement)
Below: Rainfall Data (continuous measurement)

Comparison of waste flow & water consumption:

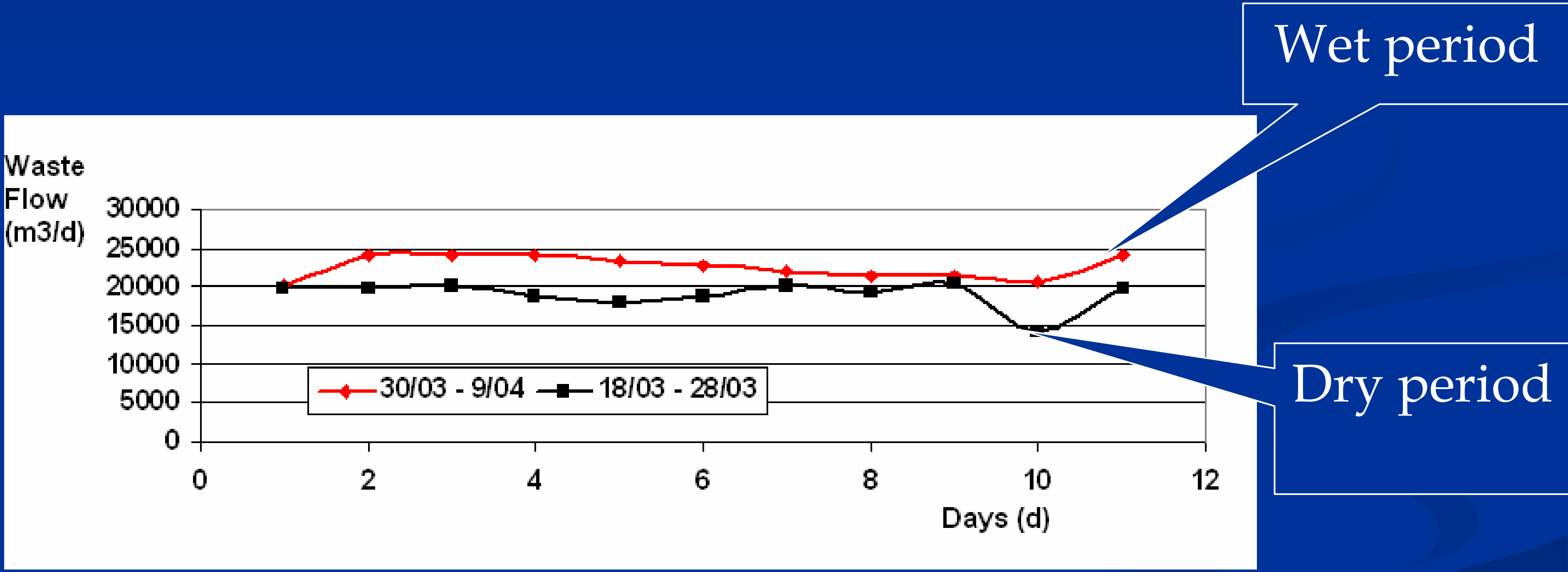


Hourly distribution of waste flow & rainfall:



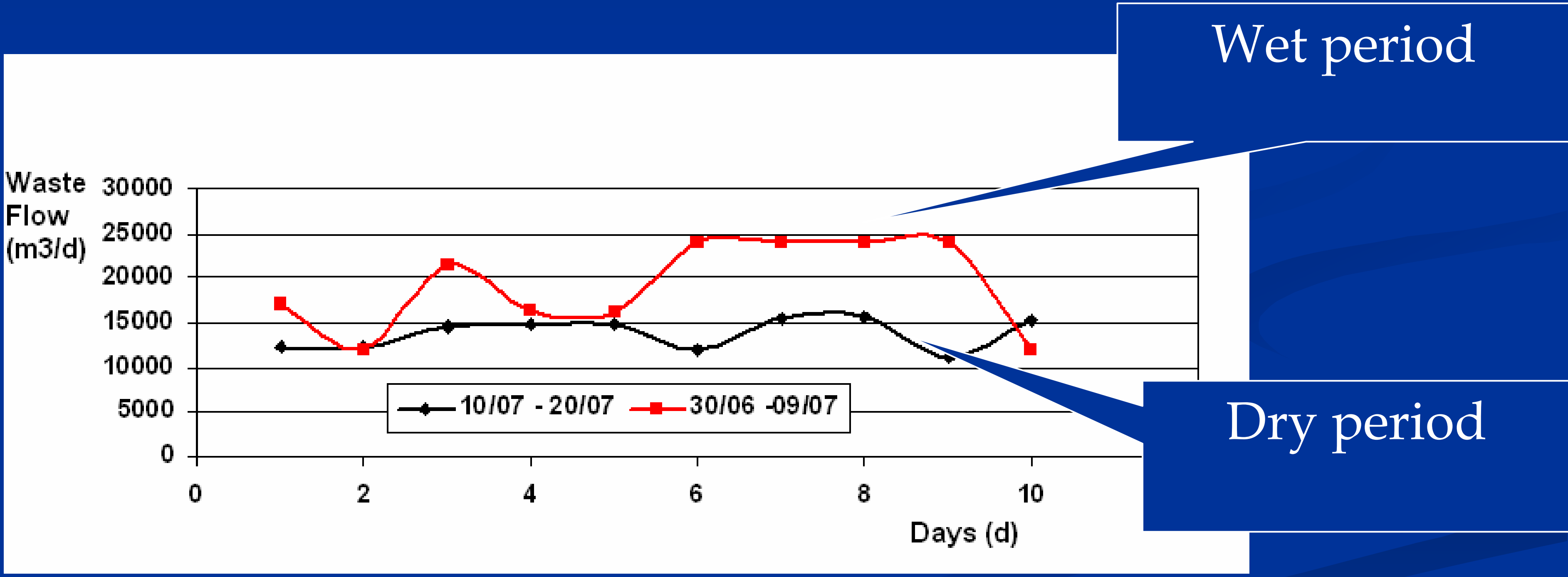
Identification (approximately) (1):

During high ground water level:



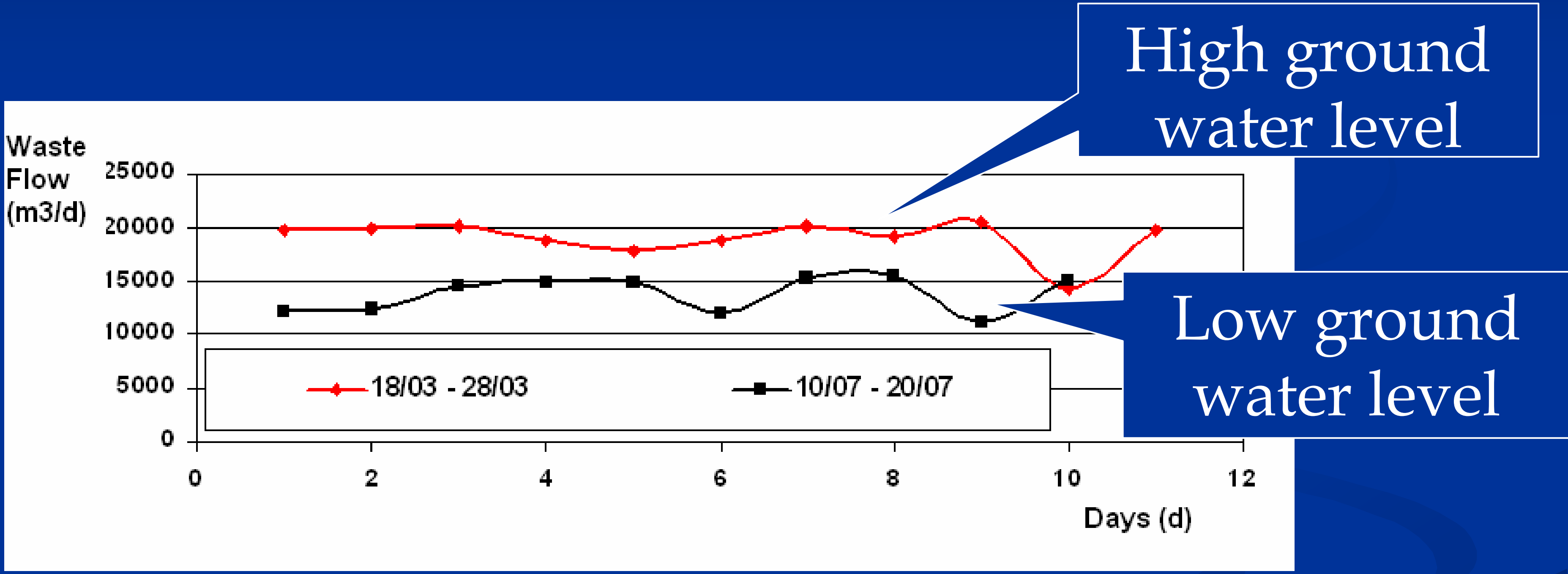
Identification (approximately) (2):

During low ground water level:

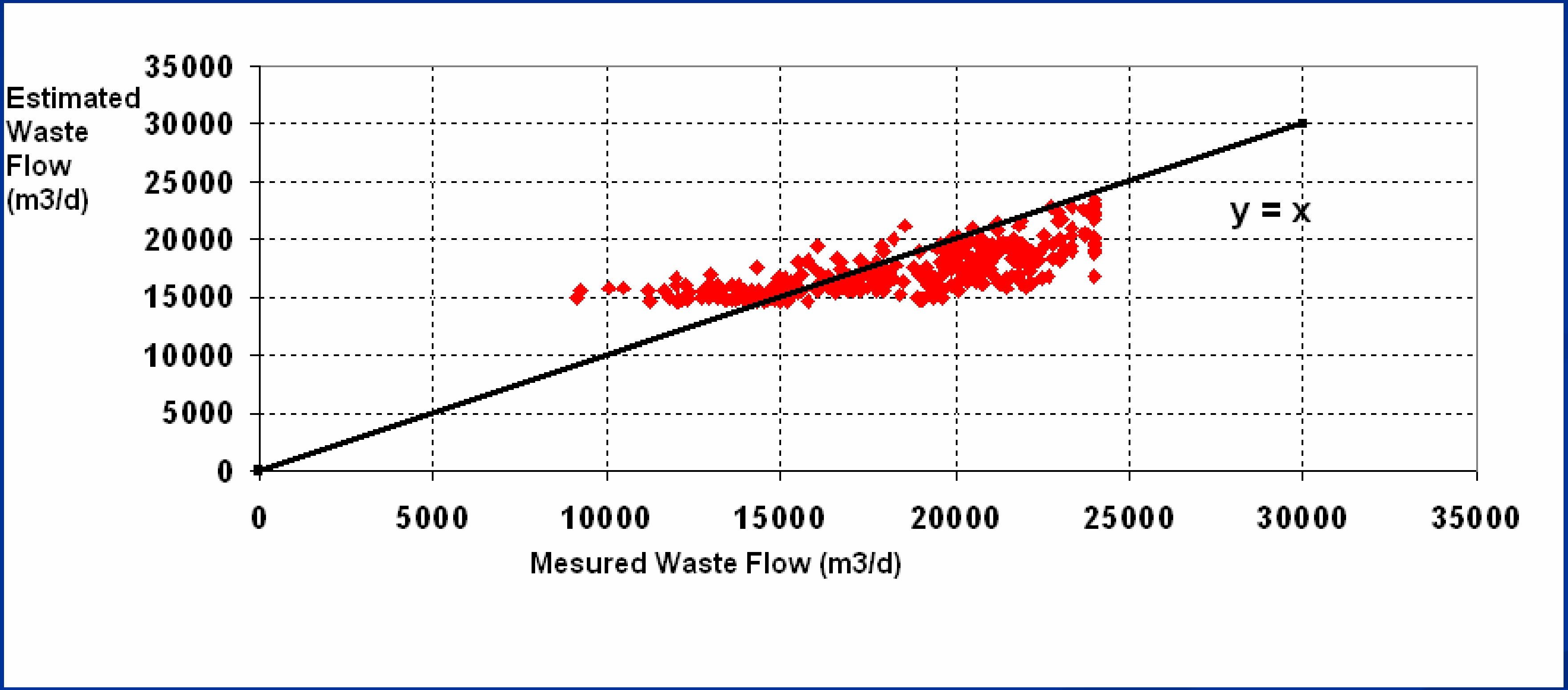


Identification (approximately) (3):

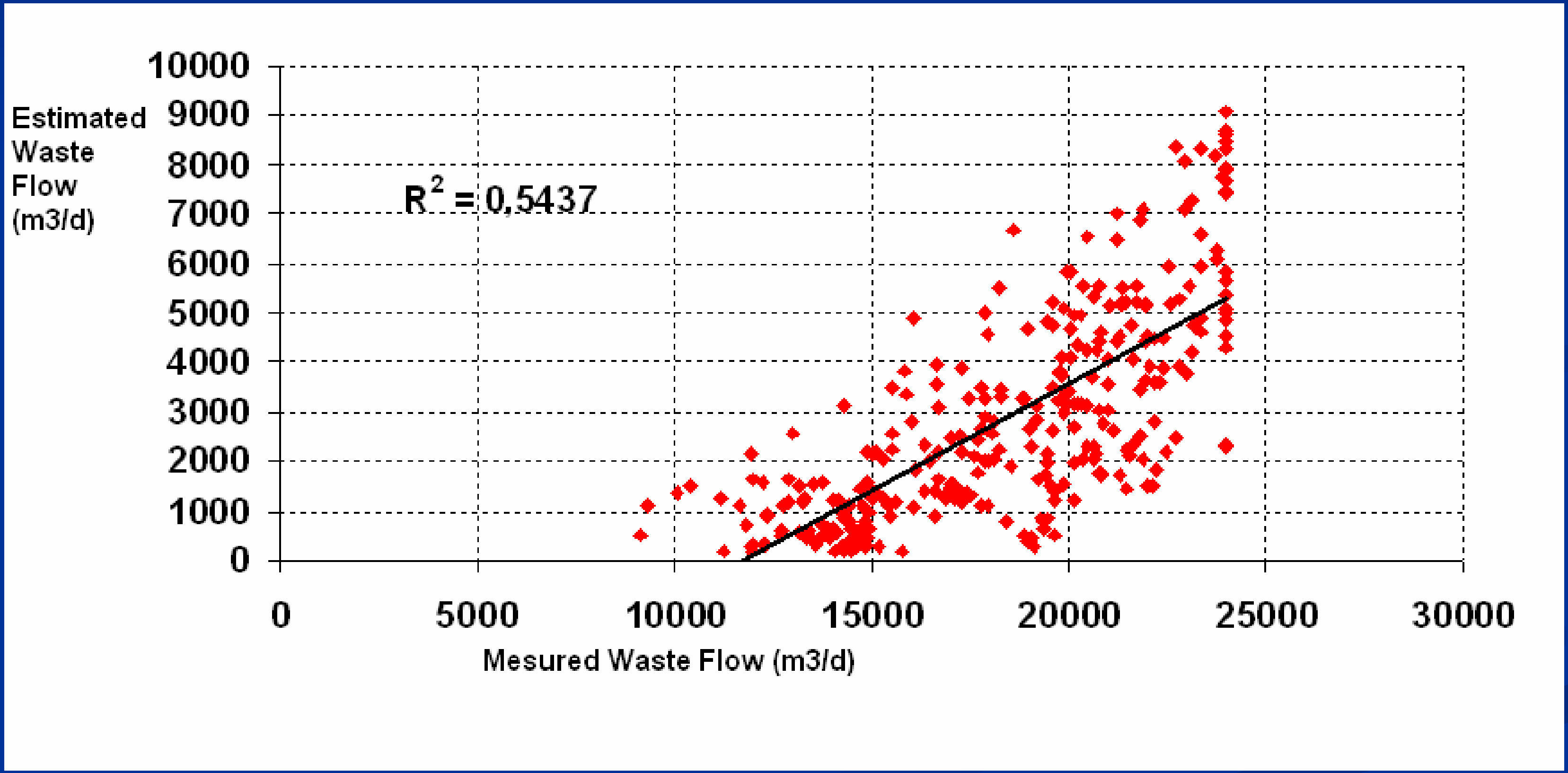
During dry weather:



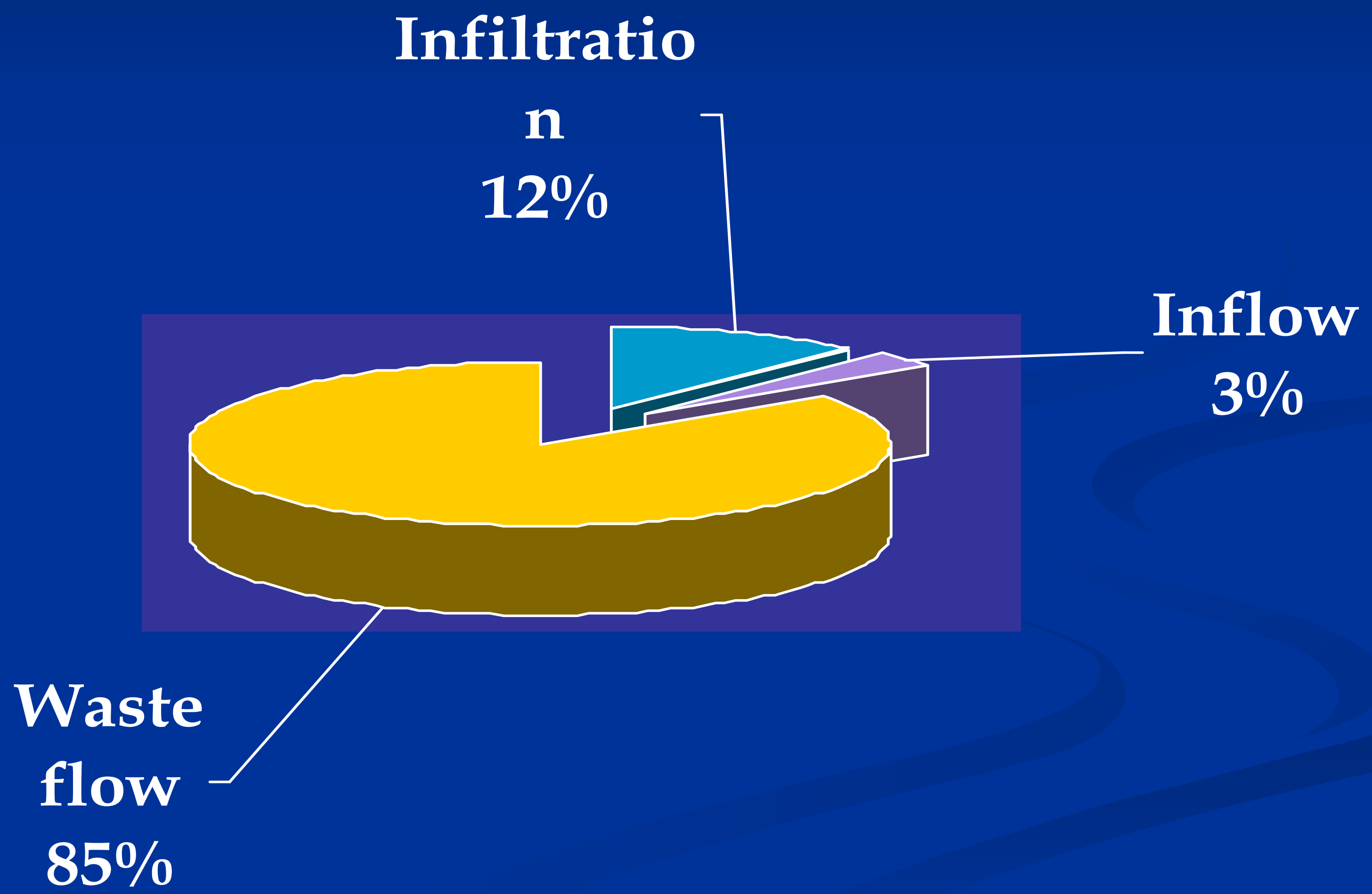
Checking the pilot model:



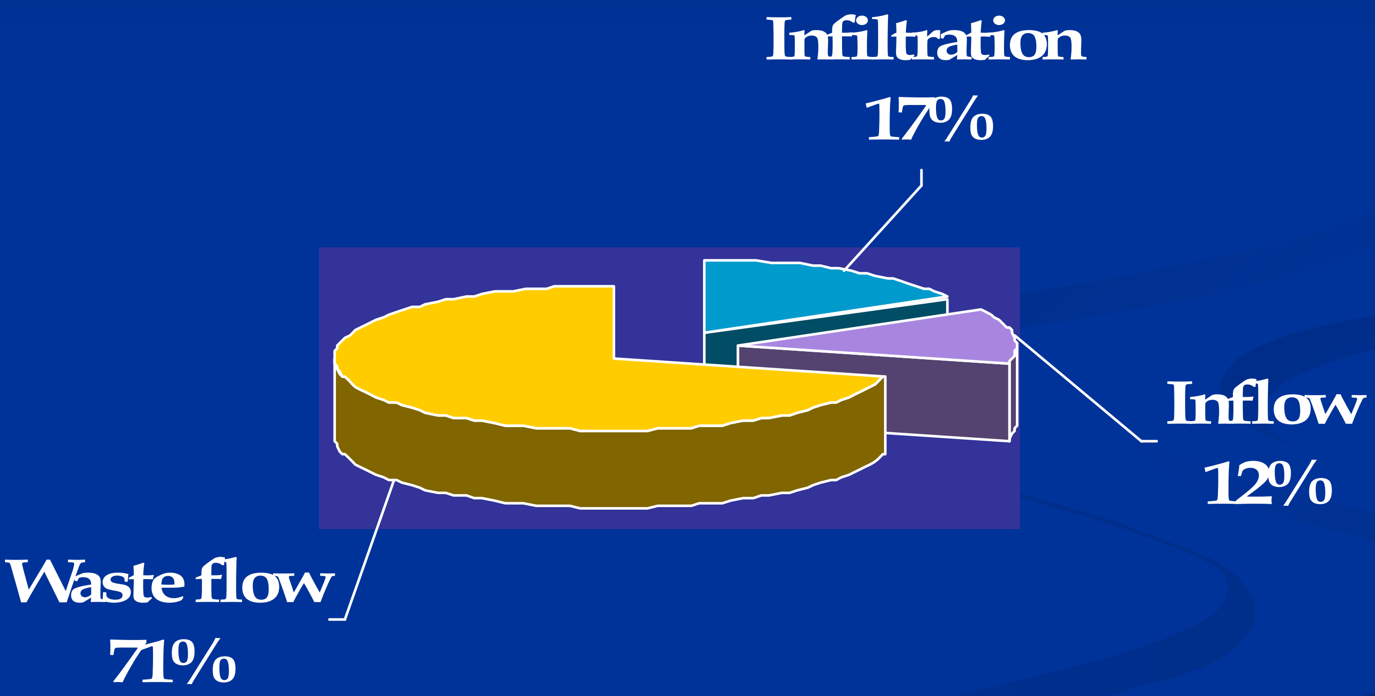
Checking the pilot model (2):



Waste flow components for the average annual values:



Waste flow components for the maximum 5 % of annual values :



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