Expert System for Strategic Evaluation of Wastewater Technologies and Sewer Networks **WaMEX**

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UNESCO-IHE
Institute for Water Education

Institute for Postgraduate Education, Training and Capacity Building in Water, Environment and Infrastructure

UNESCO-IHE

1955 Origins - Her Excellency Begum Ra'ana Liaquat Ali Khan, Bangladesh Ambassador to the Netherlands requests transfer of Dutch expertise in Hydraulic Engineering to Bangladesh

1957 Birth - IHE established as an International Education Institute

1991 Transformation - IHE Delft becomes an independent Foundation

2003 Operational - UNESCO-IHE Institute for Water Education becomes operational

Staff and Outputs

160 Staff (80 Academic, 80 Support)

300 Guest Faculty

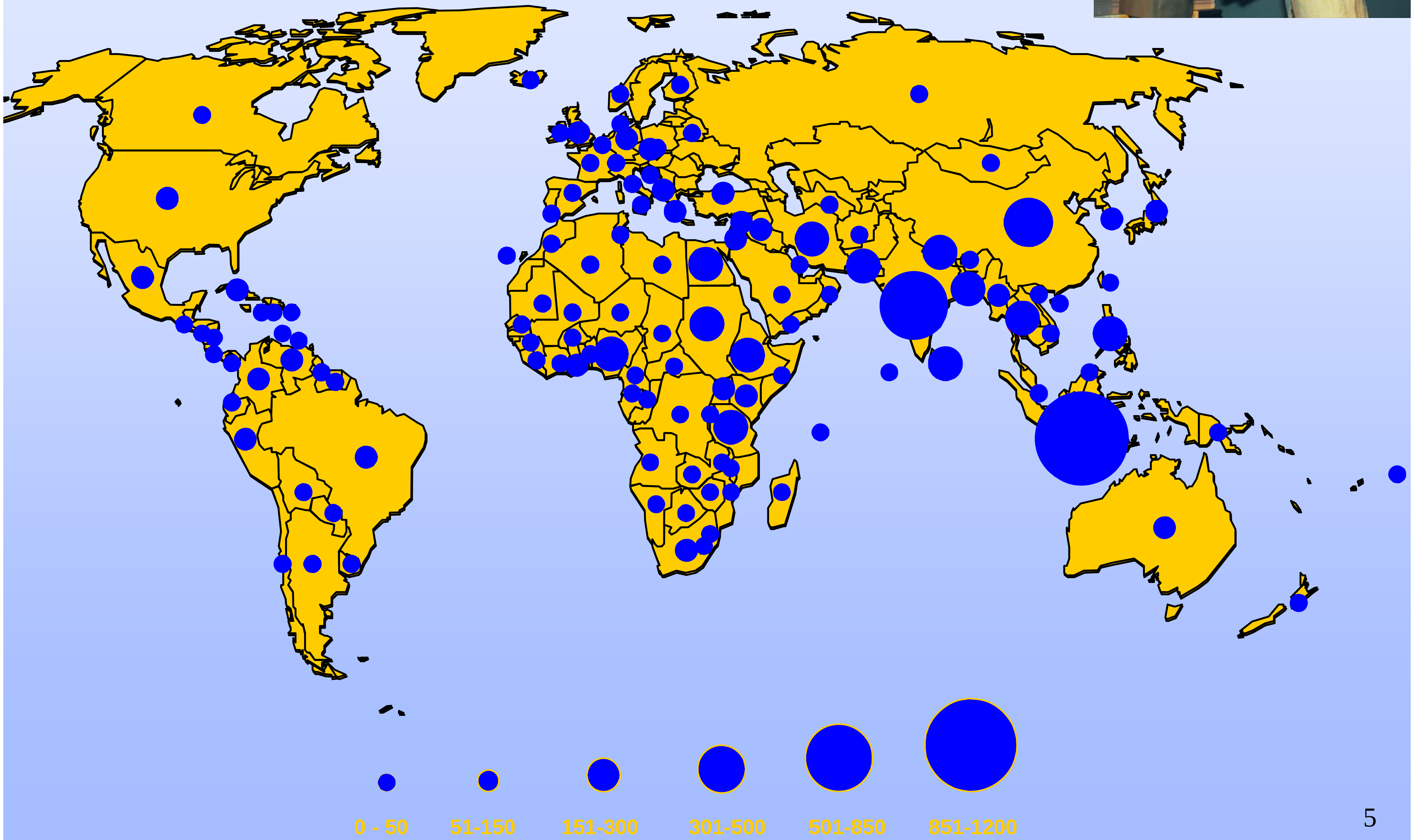
4 Water and Environment Academic Programmes:

- 222 MEng participants)
- 92 MSc participants) From about 80 countries
- 53 PhD fellows)
- 250 Short Course Participants

R&D: 170 Publications / year

200 Projects 2012 (Capacity Building, research, tailor made training, advisory services)

Connecting the Community of 14,000 Alumni



Outline

- Introduction
- Development to date
  - Treatment technologies
- Further work
  - Scenario assessment
  - Integrated assessment

Introduction – Project Background

- ADB-DMC Sanitation Dialog 3-5 March 2009 identified the following focus points:
  - institutions and policies,
  - technology options,
  - financing options,
  - information,
  - education and communication, and
  - economics of sanitation
- As one of the knowledge products, the need for an Expert System has emerged with the aim to assist in the evaluation of wastewater management options
- UNESCO-IHE teamed up with an Asian/Australian partners to undertake the above work.

Objectives of the development work

- To develop a tool that enable decision makers to carry out "what-if-scenario" at a higher planning (or scoping) level:
  - Evaluation in relation to effluent and influent characteristics;
  - Preliminary cost estimates of WWT technologies and sewer reticulation works

- To develop two separate modules:
  - Wastewater technologies evaluation module;
  - Sewer network evaluation module;

Work to date

- Some real-world tests have confirmed that the tool is useful but further refinements (i.e., technologies, costs, standards, correction factors for local conditions, functionalities, scenario builder) are ongoing;

- Developments are planned through 3 phases (2nd phase is nearly complete);

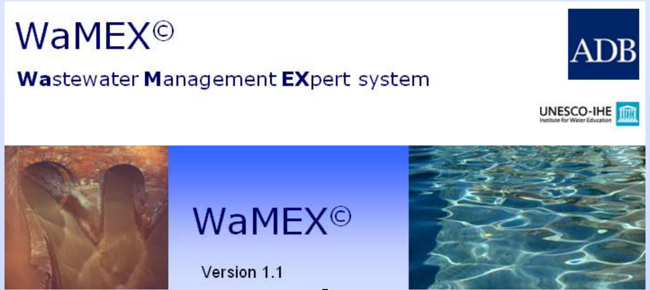
- Important points:
  - The tool is not meant for detailed engineering design purposes!
  - Current technologies are sewer-based with minor septage;
  - No tool can produce estimates that anticipate all possibilities of unplanned events and unanticipated local factors that every real-world job entails (strengths vs. limitations)!

The team and external inputs

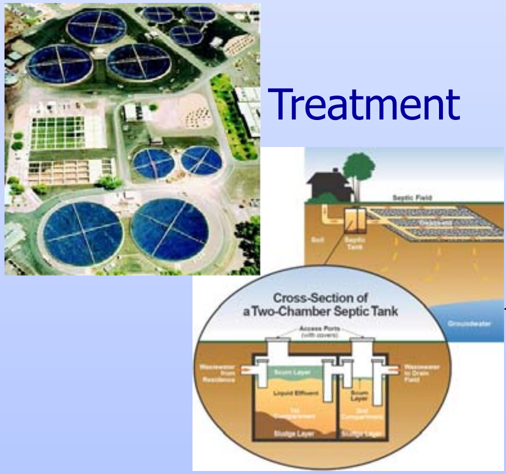
- UNESCCO-IHE's HI & Sanitation core teamed up with Beijing Richway Tech & Development Co. Ltd and Worley Parsons Ltd.

- Throughout the project comments were received from ADB, World Bank, IWA and other international experts in the field.

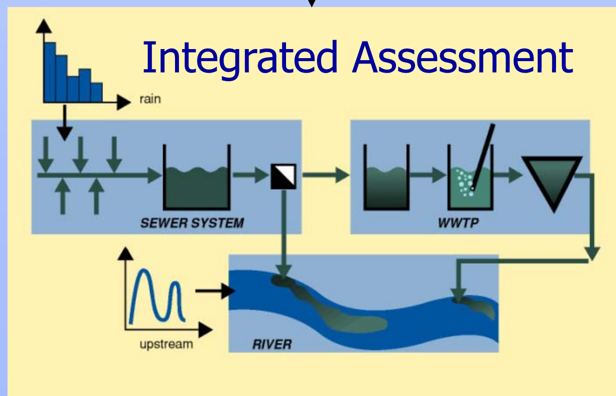
DSS/ES functional illustration
Code Name: WaMEX

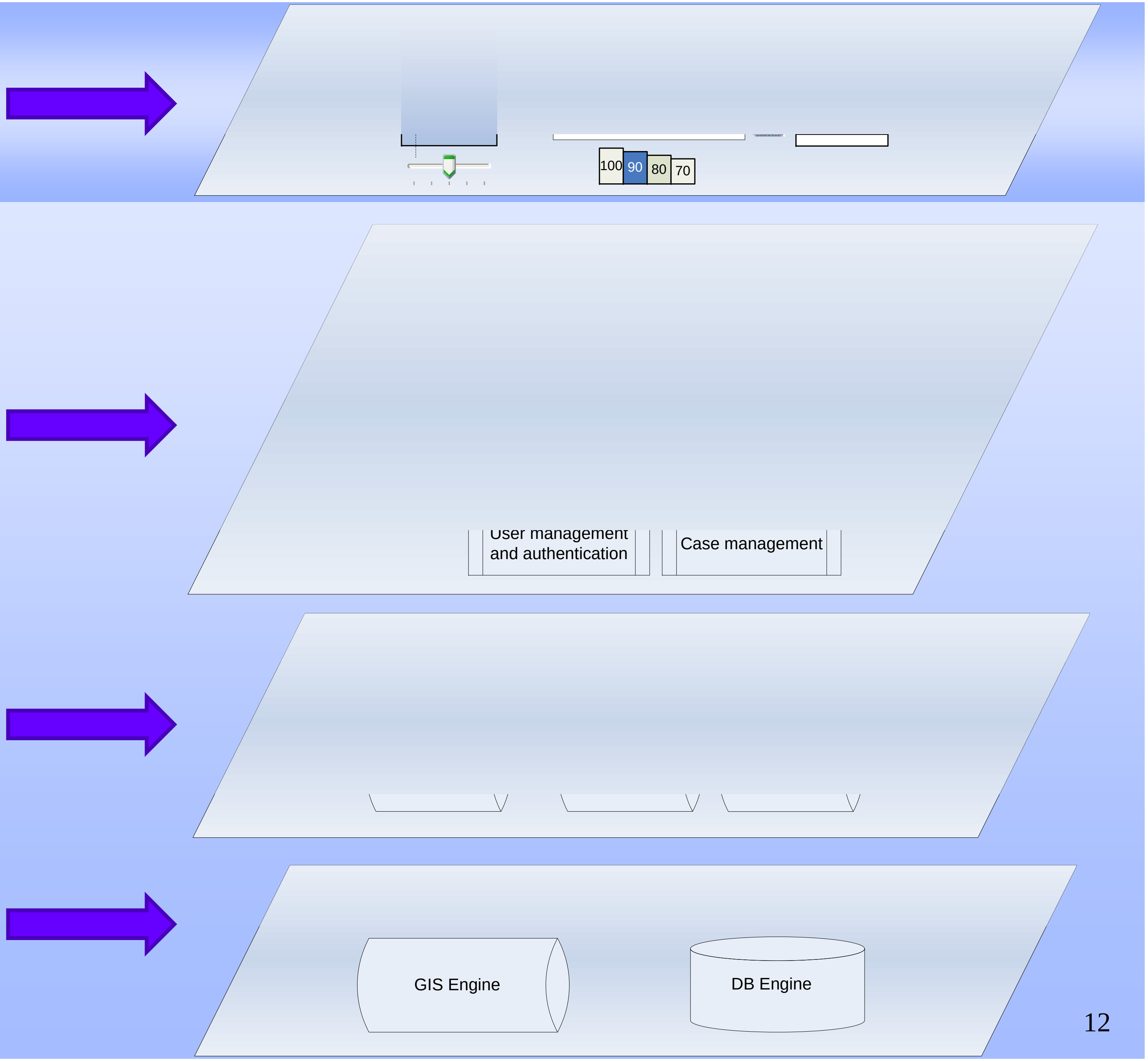


Treatment



Sewers




100
90
80
70
User management and authentication
Case management
GIS Engine
DB Engine

TECHNOLOGY SELECTION MODULE

Wastewater treatment technologies

- Pollutants
- Treatment methods
- Technology selection criteria
- Von Sperling's book and other references
- Demonstration of the module

MAIN MECHANISMS FOR THE REMOVAL OF POLLUTANTS IN WASTEWATER TREATMENT

Solids

Coarse
- *screening*

Suspended
- *sedimentation*

Dissolved
- *adsorption*

Organic matter

Particulate
- *sedimentation*
- *adsorption*
- *hydrolysis*
- *stabilization*

Soluble
- *adsorption*
- *stabilization*

Nitrogen

Organic
- *ammonification*

Ammonia
- *nitrification*
- *bacterial assimilation*
- *stripping*
- *break-point chlorination*

Nitrate
- *denitrification*

Phosphorus

Phosphate
- *bacterial assimilation*
- *precipitation*
- *filtration*

Pathogens

Protozoa/eggs
- *sedimentation*
- *filtration*

Bacteria/viruses
- *adverse env. cond*
- *UV radiation*
- *disinfection*

Logarithmic scale

1st Level: SCREENING

TREATMENT OPERATIONS, PROCESSES AND SYSTEMS FREQUENTLY USED FOR THE REMOVAL OF POLLUTANTS FROM DOMESTIC SEWAGE

Solids	Organic matter	Nitrogen	Phosphorus	Pathogens
• Screening • Grit removal • Sedimentation • Land disposal • Membrane filtration	• Stabilization ponds • Land disposal • Anaerobic reactors • Activated sludge • Aerobic biofilm systems	• Nitrification/ denitrifictaion • Maturation/ high-rate ponds • Land disposal • Physical-chemical p.	• EBPR • Maturation/ high-rate ponds • Physical-chemical p.	• Maturation ponds • Land disposal • Disinfection • Membranes

Wastewater treatment technologies

Currently: only technologies for sewer-based systems with minor contribution from septage
Phase 3: additional technologies for fecal sludge management (septage)

PRIMARY TREATMENT
- Primary treatment (septic tanks)
- Conventional primary treatment
- Advanced primary treatment (chemically enhanced)

STABILIZATION POND SYSTEMS
- Facultative pond
- Anaerobic pond + facultative pond
- Facultative aerated lagoon
- Complete mixed aerated lagoon + sedimentation pond
- Anaerobic pond + facultative pond + maturation pond
- Anaerobic pond + facultative pond + high rate pond
- Anaerobic pond + facultative pond + algae removal

AEROBIC BIOFILM REACTORS
- Low rate trickling filter
- High rate trickling filter
- Submerged aerated biofilter with nitrification
- Submerged aerated biofilter with biological N removal
- Rotating biological contactors

ACTIVATED SLUDGE SYSTEMS
- Conventional activated sludge
- Activated sludge + extended aeration
- Sequencing batch reactor (extended aeration)
- Conventional activated sludge with N removal
- Conventional activated sludge with P/N removal
- Conventional activated sludge + tertiary filtration

LAND DISPOSAL SYSTEMS
- Slow rate treatment
- Rapid infiltration
- Overland flow
- Constructed wetlands

ANAEROBIC REACTORS
- Septic tank + anaerobic filter
- Septic tank + infiltration
- UASB reactor
- UASB reactor + activated sludge
- UASB reactor +submerged aerated biofilter
- UASB reactor + anaerobic filter
- UASB reactor + high rate trickling filter
- UASB reactor + dissolved air flotation
- UASB reactor + maturation ponds
- UASB reactor + facultative aerated ponds
- UASB reactor + facul. aerated lagoon + sediment pond
- UASB + overland flow

TECHNOLOGY SELECTION METHODS

2nd Level: RANKING

- **descriptive documents**
- **checklists**
- **selection matrices**
- **algorithms**
- **models**

EXAMPLE SELECTION MATRIX: MCA

Selection criteria

Weights

Range 0-10

6	8	1	2	4	9	3	5	7	8	9	1	2	0	5

Technologies

Scores

Range 0-5

3	3	0	1	2	4	5	4	3	2	1	0	4	3	2
5	4	2	2	2	1	1	1	4	4	4	3	3	5	2
3	3	2	4	5	1	3	5	5	3	2	1	5	2	3
2	4	5	1	1	1	5	4	2	2	2	1	1	1	4
1	1	5	4	2	2	2	1	5	4	2	2	2	1	5
2	4	5	2	4	5	2	4	5	2	4	5	1	1	1

weights x scores

total
256
307
188
399
300
229

Criteria for wastewater technology selection

Local conditions
- Climate
- Hydrology
- Footprint size
- Land availability

Processes
- Process applicability
- Removal efficiency
- Resistance/robustness
- Sludge generation
- Sludge handling/processing
- Water efficiency/losses

Environment
- Soil pollution
- Air pollution
- Water resources pollution
- Devaluation of area
- Inconvenience

Health and Safety
- Odour
- Noise
- Aerosols
- Insects & worms
- Occupational safety

Economics
- Construction costs
- Chemicals
- Energy
- Personnel
- Land costs
- Other resources

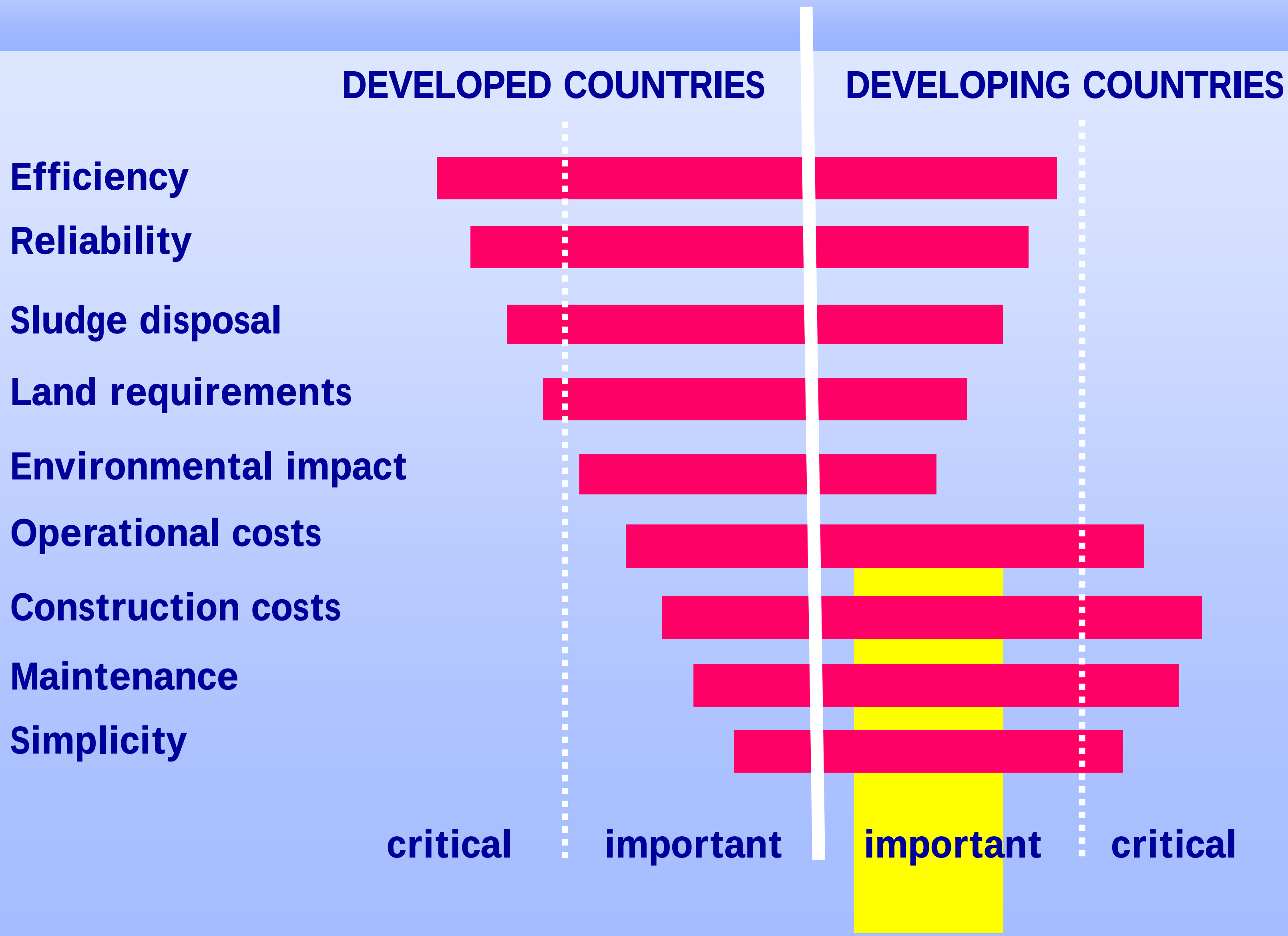
Operation & Maintenance
- Operational attention
- Reliability
- Complexity/Simplicity
- Compatibility

Social aspects
- …

Institutional aspects
- …

Political aspects …
- …

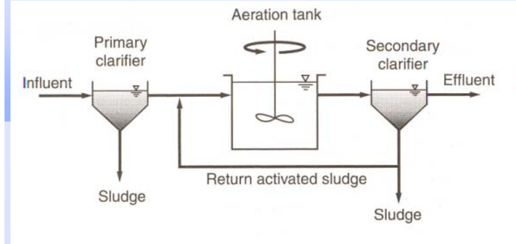
IMPORTANCE OF CRITERIA FOR TECHNOLOGY SELECTION:
Perspective of developed and developing countries



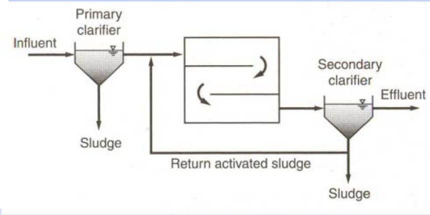
COD removal - nitrification plants

3rd Level: Selection at the individual technology level
Not In the SCOPE

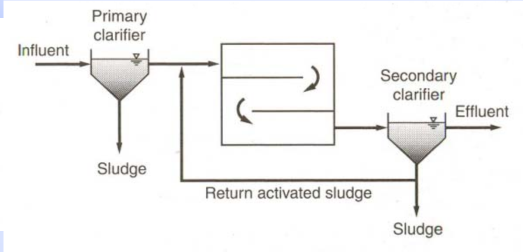
(a) Complete-mix activated sludge - CMAS



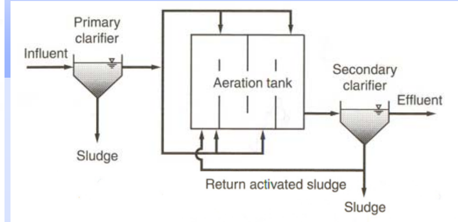
(b) Conventional plug-flow



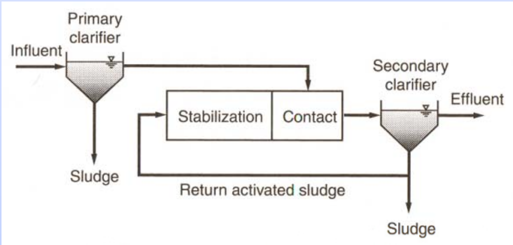
(c) High-rate aeration



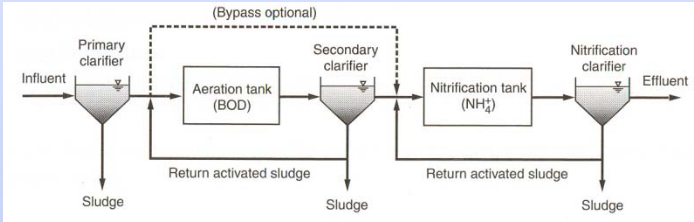
(d) Step feed



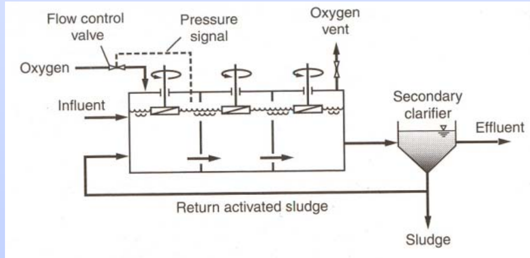
(e) Contact stabilization



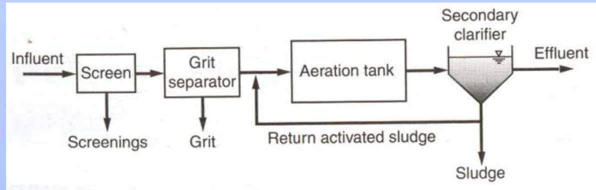
(f) Two-sludge



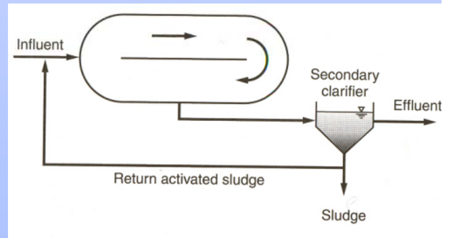
(g) High-purity oxygen



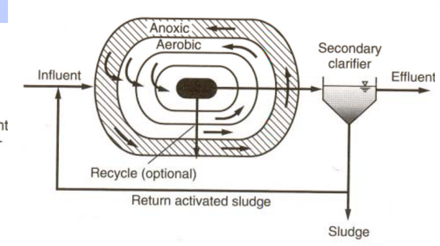
(h) Conventional extended aeration



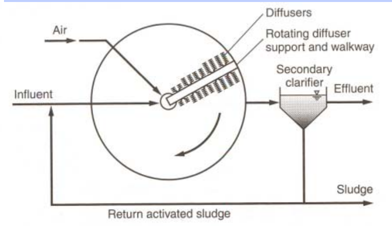
(i) Oxidation ditch



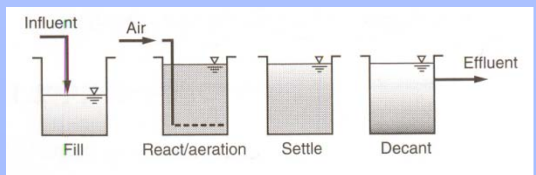
(j) Orbal



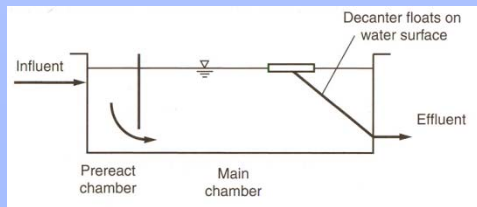
(k) Countercurrent aeration system



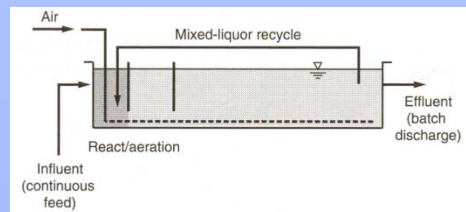
(l) Sequencing batch reactor - SBR



(m) Intermittent cycle extended aeration system

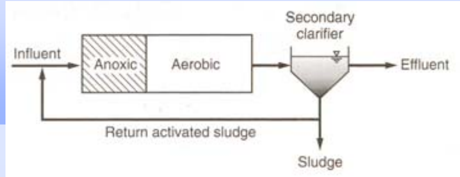


(n) Cyclic activated sludge system - CAAS

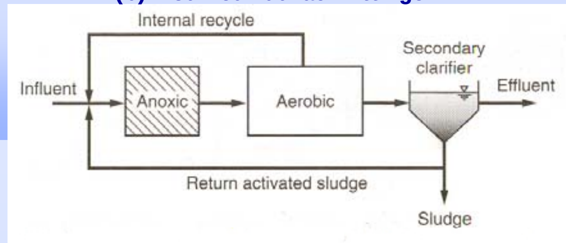


COD and N removal plants – nitrification and denifitrication plants

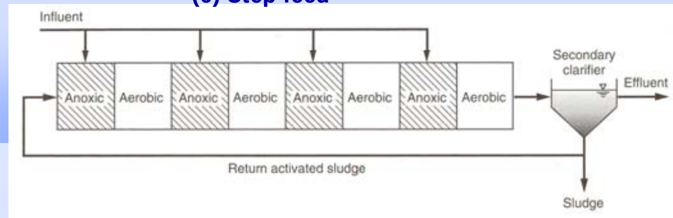
(a) Ludzack-Ettinger



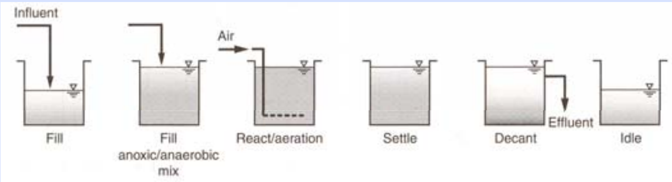
(b) Modified Ludzack-Ettinger



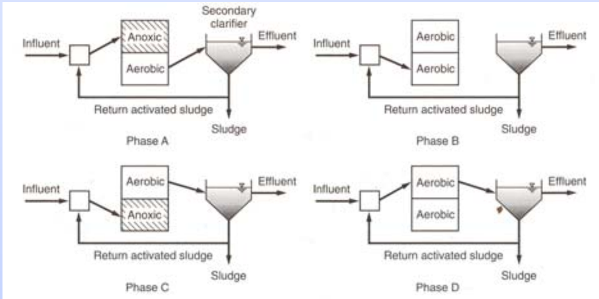
(c) Step feed



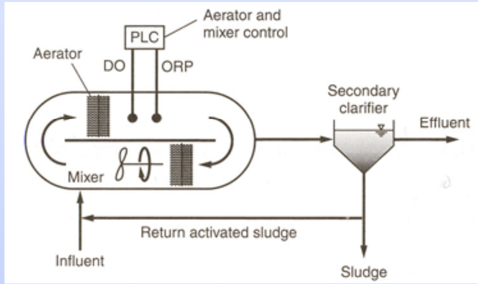
(d) Sequencing batch reactor - SBR



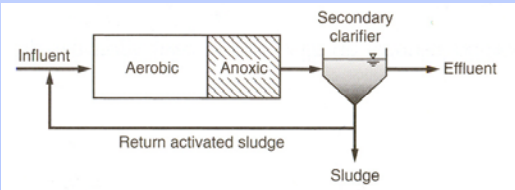
(e) Bio-denitro



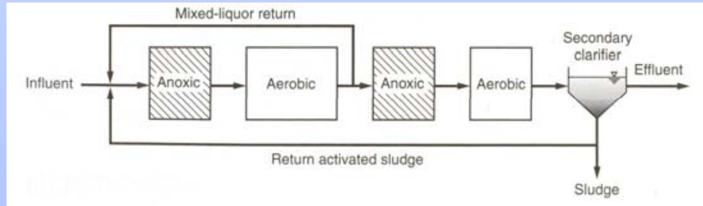
(f) Nitrox



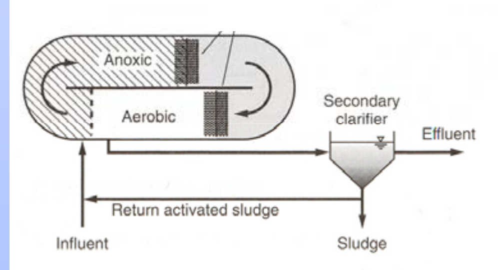
(g) Single-sludge



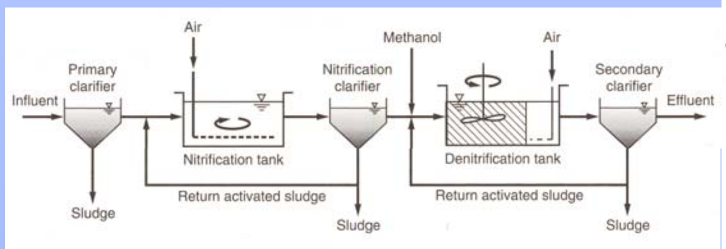
(h) Bardenpho (4 stage)



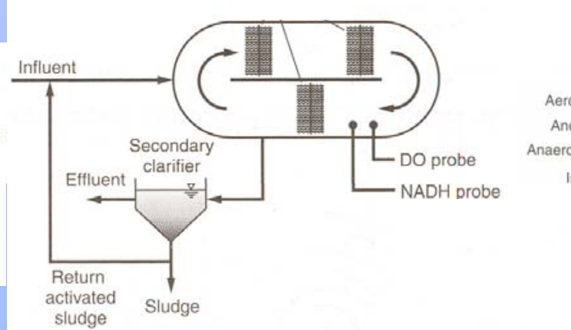
(i) Oxidation ditch



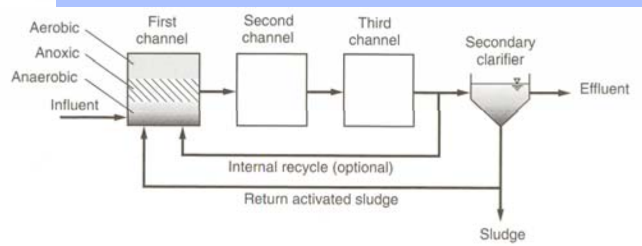
(j) Two-sludge



(k) Low DO oxidation ditch

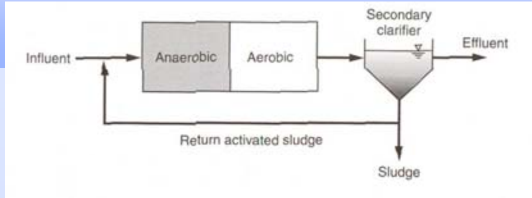


(l) Orbal

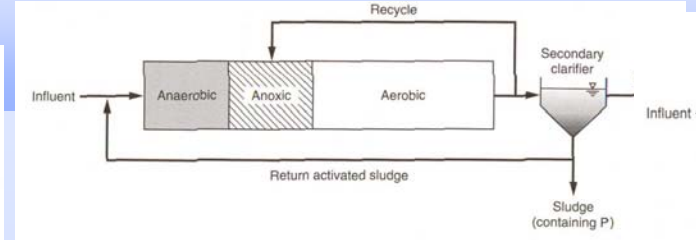


COD, N and P removal plants - nitrification and denifitrication and phosphorus removal plants

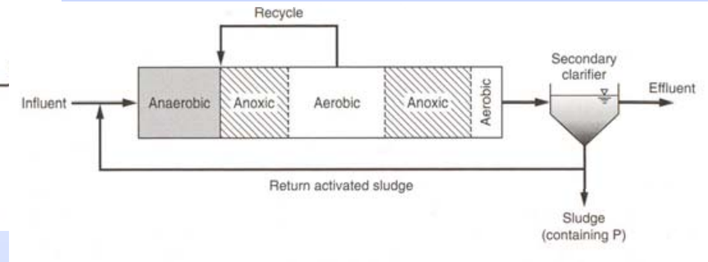
(a) Phoredox (A/O)



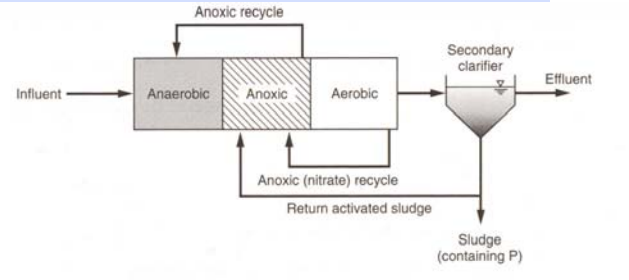
(b) A2/O



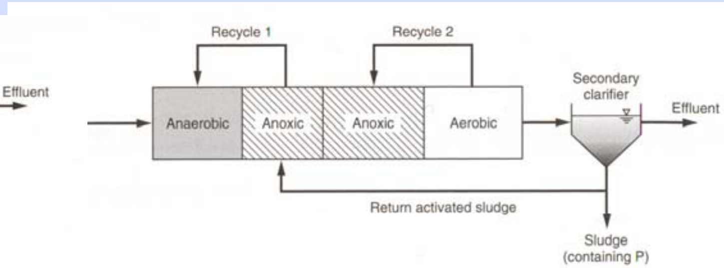
(c) Modified Bardenpho (5 stage)



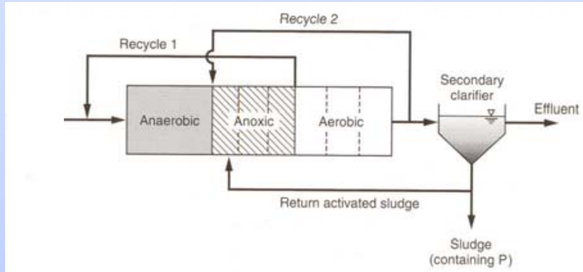
(d) UCT



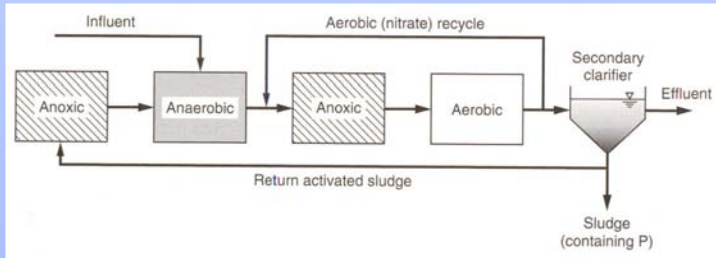
(e) Modified UCT



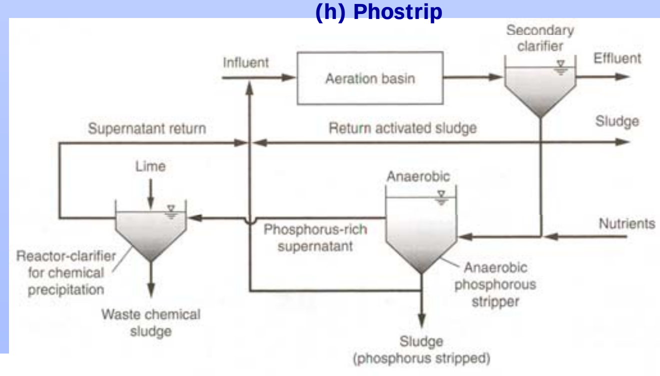
(f) VIP



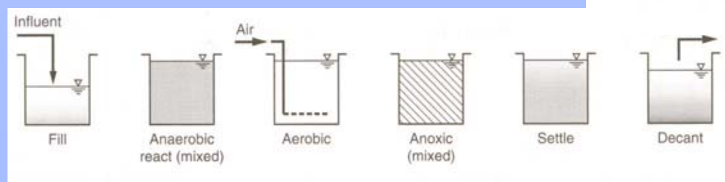
(g) Johanesburg



(h) Phostrip



(i) SBR



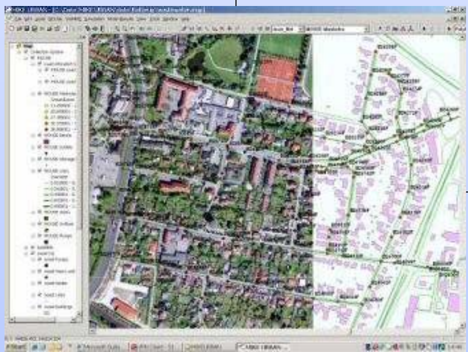
TECHNOLOGY SELECTION MODULE - DEMO

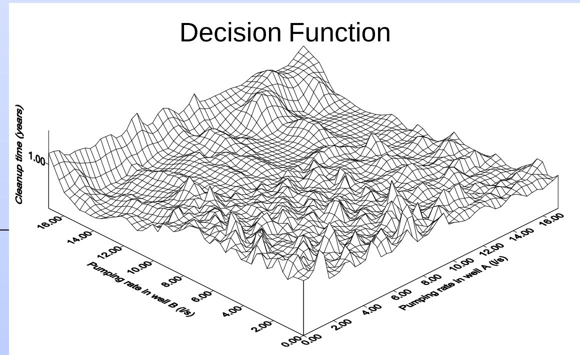
Selection of technologies in relation to:

- Different Effluent Standards
- Different Wastewater Characteristics

WaMEX functional illustration – Reticulation

<u>Sewers</u>



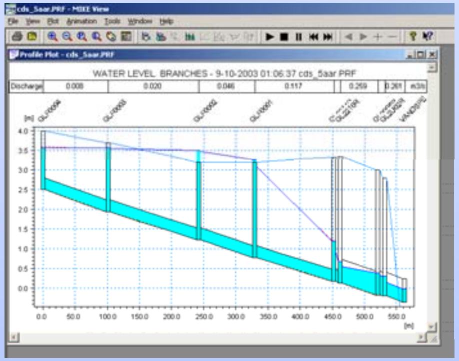


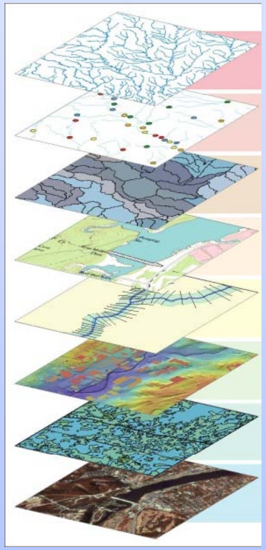
Optimal Solution

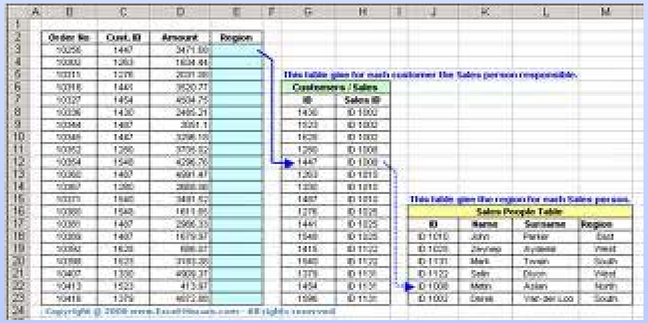
Two approaches to sewer analysis

- Simplified (a library of model runs and the lookup table),

Off line - dynamic simulations with optimisation



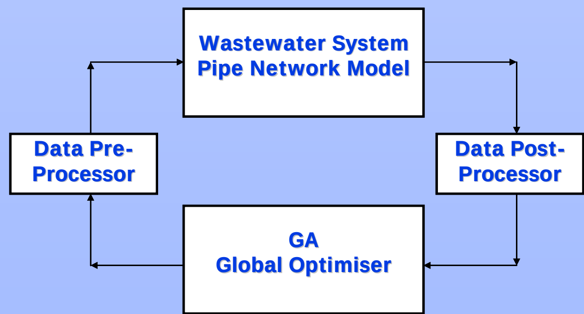




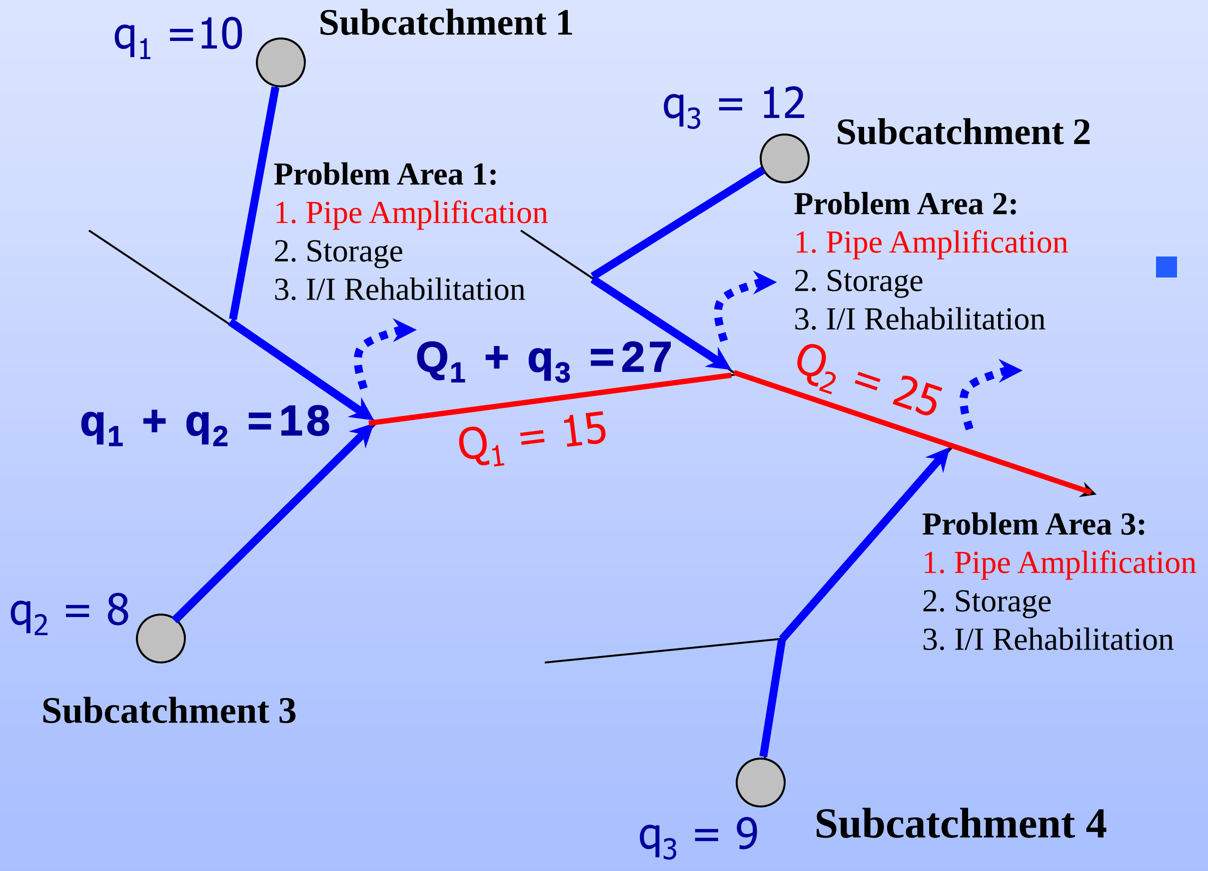
- Complex (real time computations)

On line - dynamic simulations

with optimisation

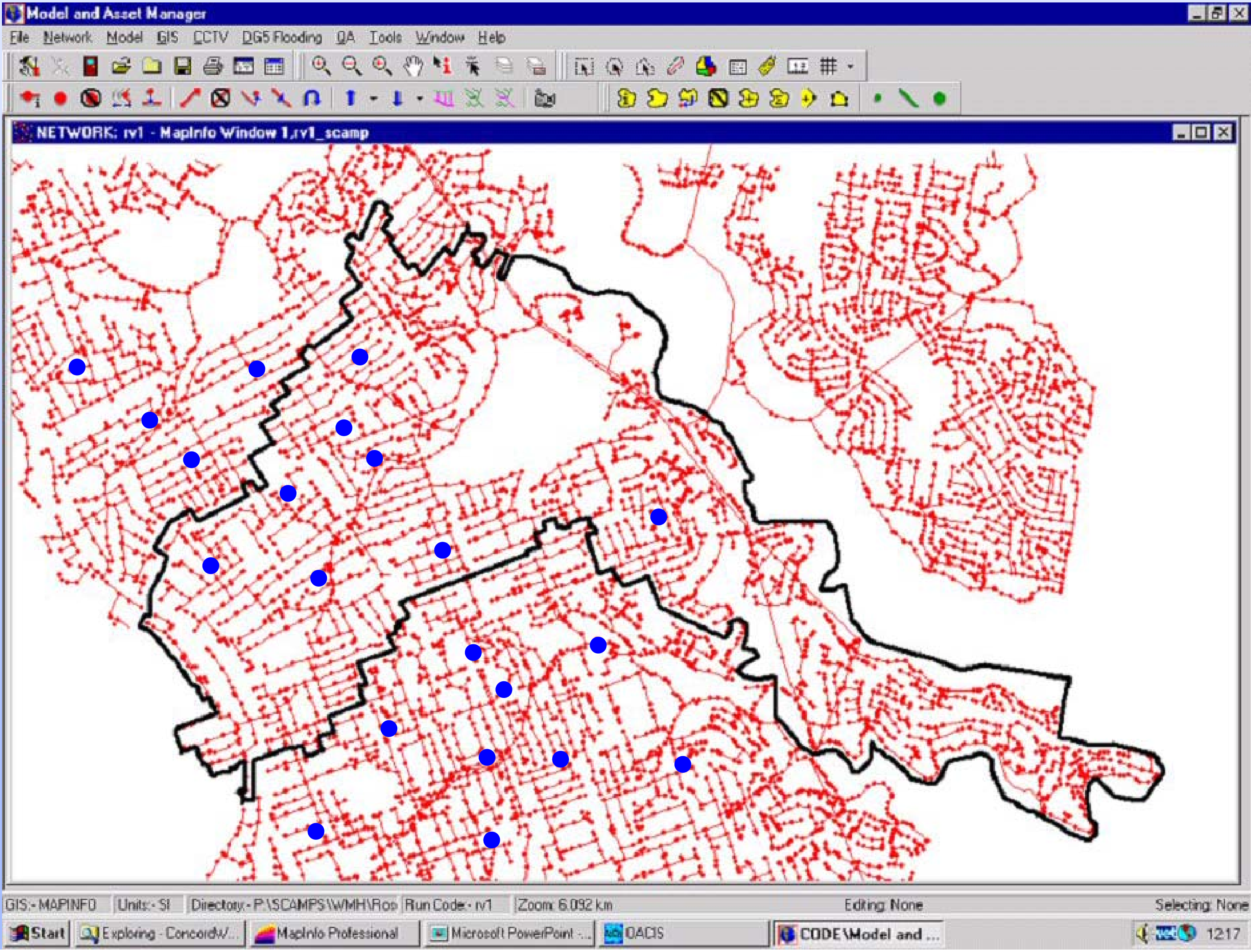


Sewer Rehabilitation/Design Problem - Illustration



- Single-criterion setting of an optimisation problem:
  - total cost of remedial works
- Multi-criterial setting of an optimisation problem:
  - total cost of remedial works
  - total system surcharge/overflow volume, etc.
  - Pipe condition

A real-life problem – hundreds/thousands of pipes!!



Two approaches to sewer analysis

- Steady state analysis approach (kinematic wave or other simplified calculation)
- Dynamic analysis approach (full dynamic wave computation)

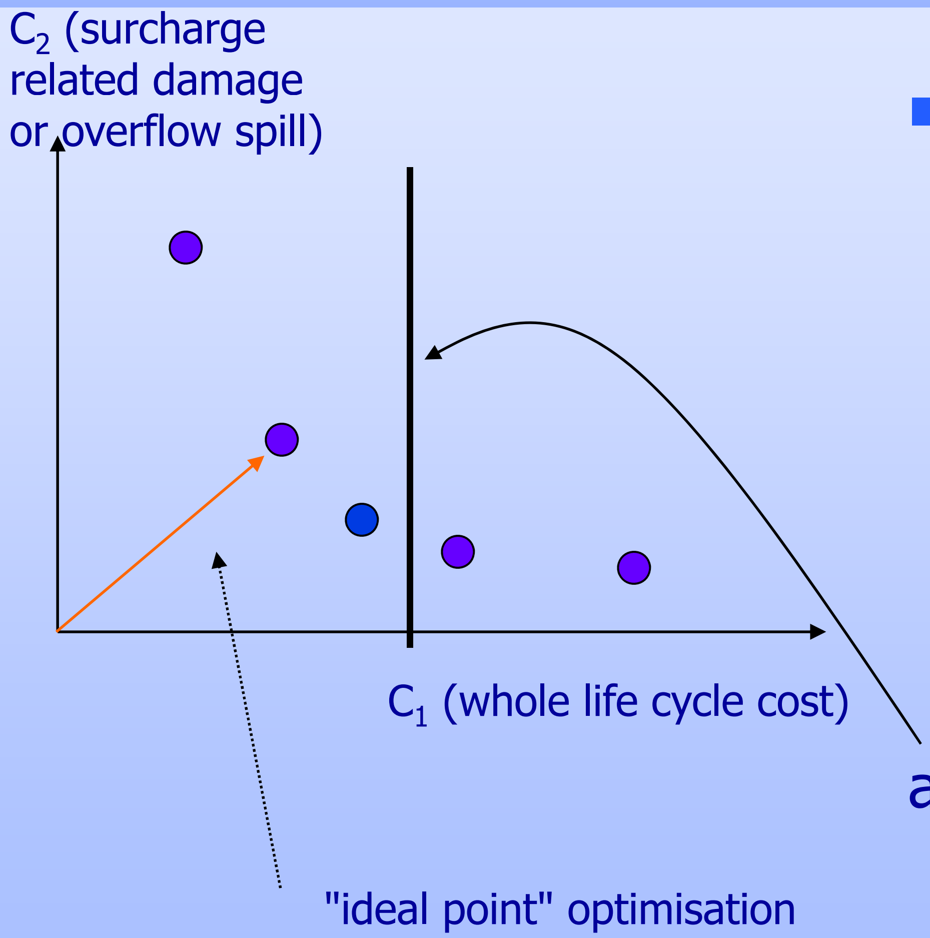
Optimisation in Sewer System Rehabilitation/Design

- System dynamics
- Multi-objective
- Objective functions are hard to express analytically – they are computed by a modelling system
- Complex constraints
- Infinity of solutions - optimisation requires location of a global minimum

Global optimisation techniques

- Set (space) covering techniques;
- Random search methods, including evolutionary and genetic algorithms
- Methods based on multiple local searches (multistart) using clustering;
- Other methods (simulated annealing, trajectory techniques, tunneling approach, analysis methods based on a stochastic model of the objective function, etc.).

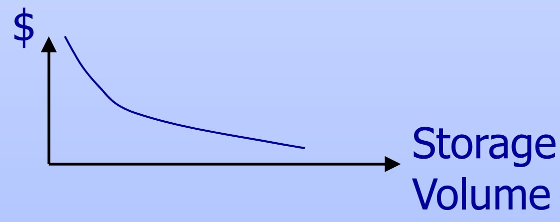
Random search method: Genetic Algorithms



- Cost to minimise:

$$C_a = \sum_{i=1}^{n} c(D_i) L_i$$

  - D=pipe diameter, L=pipe length



an option is to use "constraint method":

if costs are below certain level, minimise flood damage

Single-criteria optimisation

- Criterion: combined cost and surcharge/overflow spill

Multi-criterial optimisation

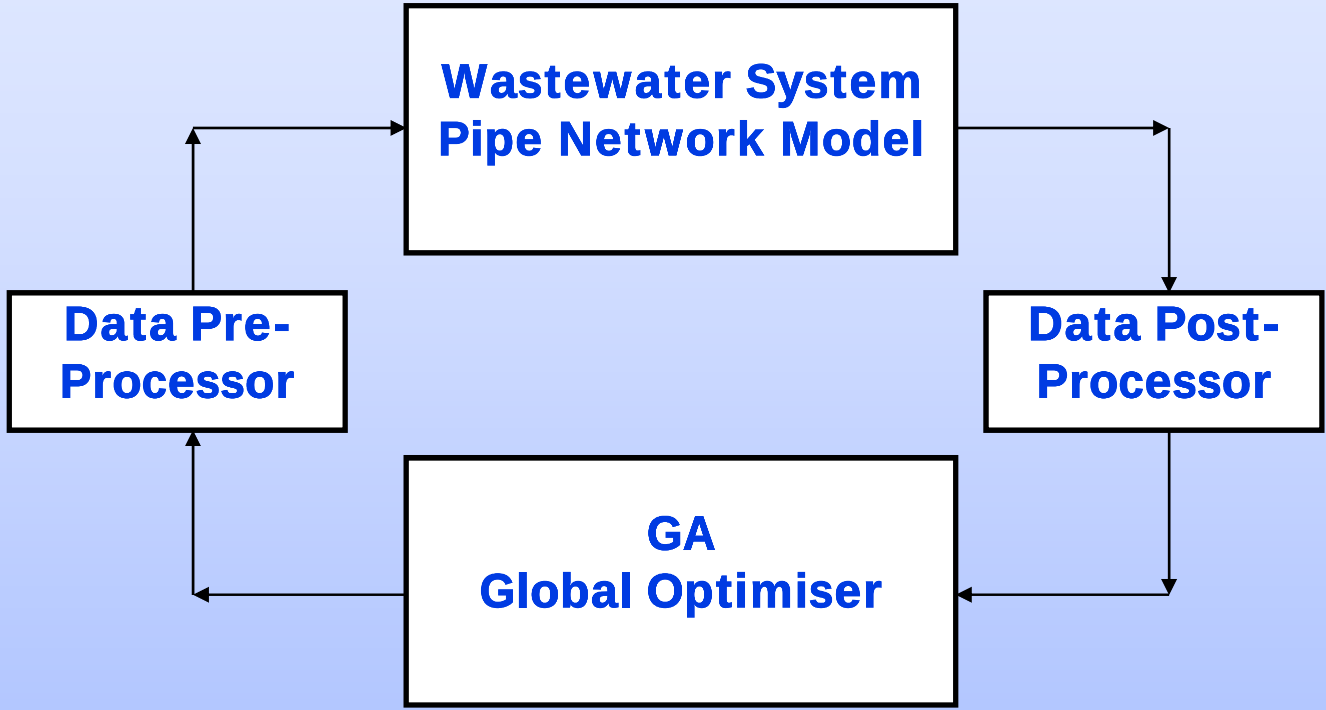
- Two criteria considered:
  - C1_nor = costs (normalised)
  - C2_nor = surcharge/overflow-related damage (normalised)

Genetic algorithm (GA)

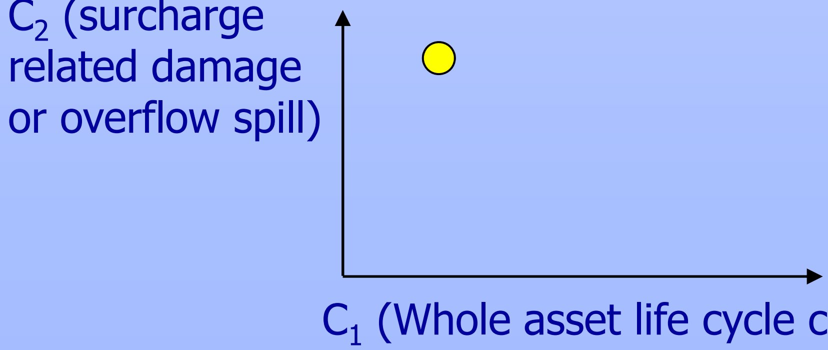
- Main idea: try to emulate the natural evolution
- Terminology is borrowed from natural genetics
- Genetic operators:
  - recombination (to combine good points),
  - mutation (to generate new points),
  - selection (to select points for the next population)
- Evolution:
  - iterative generation of organisms (points) and
  - death (removal) of the unfit ones (with low function value)

- Non-dominated Sorting Genetic Algorithm (NSGA-II)

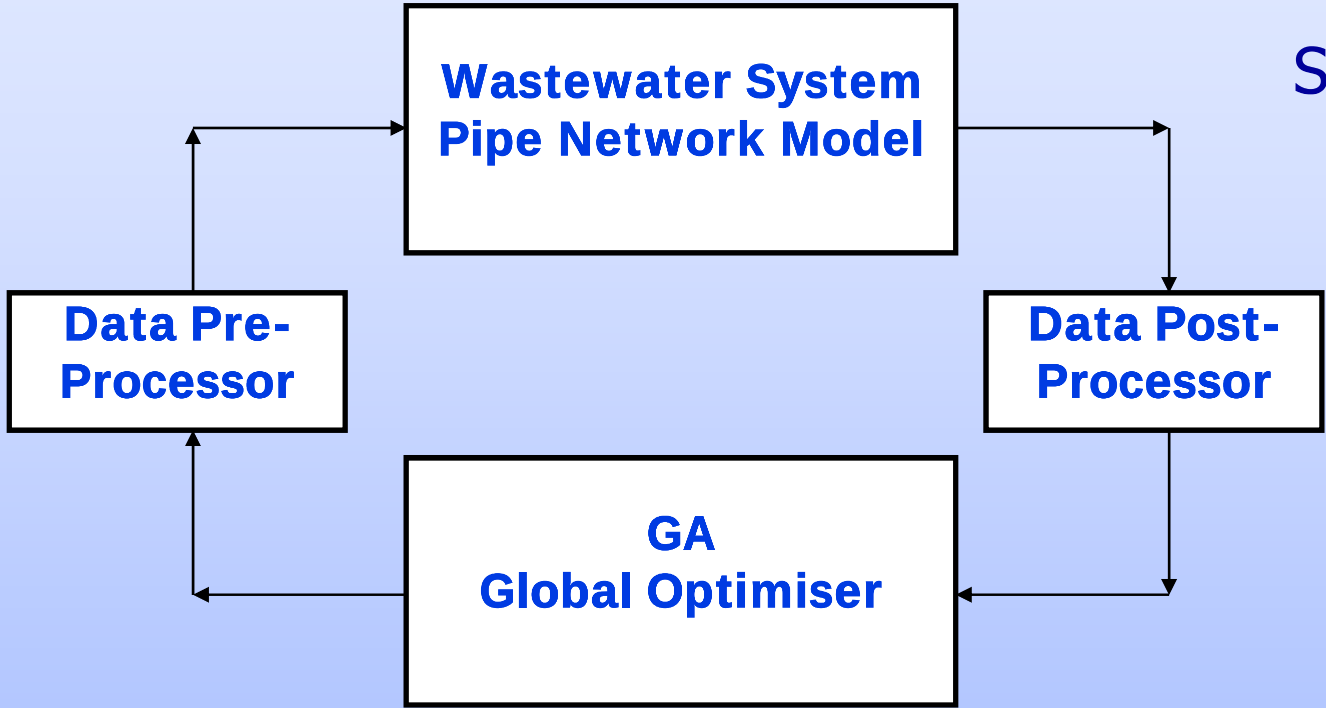
Dynamic analysis approach: Tools used



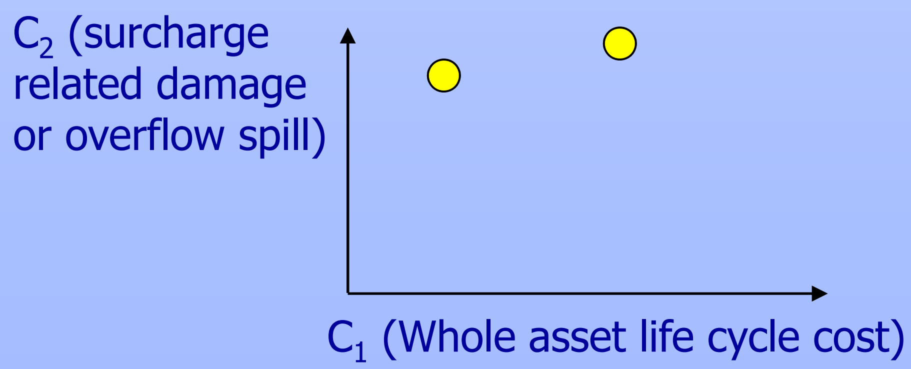
First Iteration!



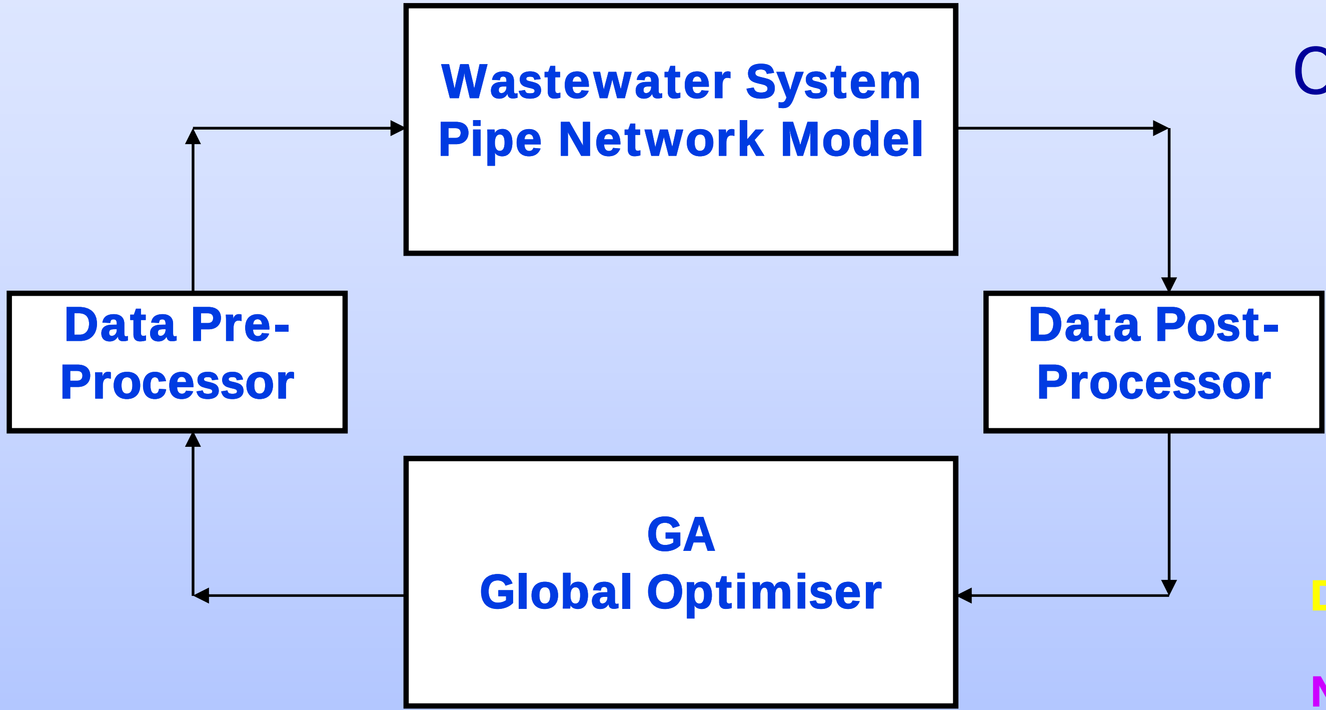
Dynamic analysis approach: Tools used



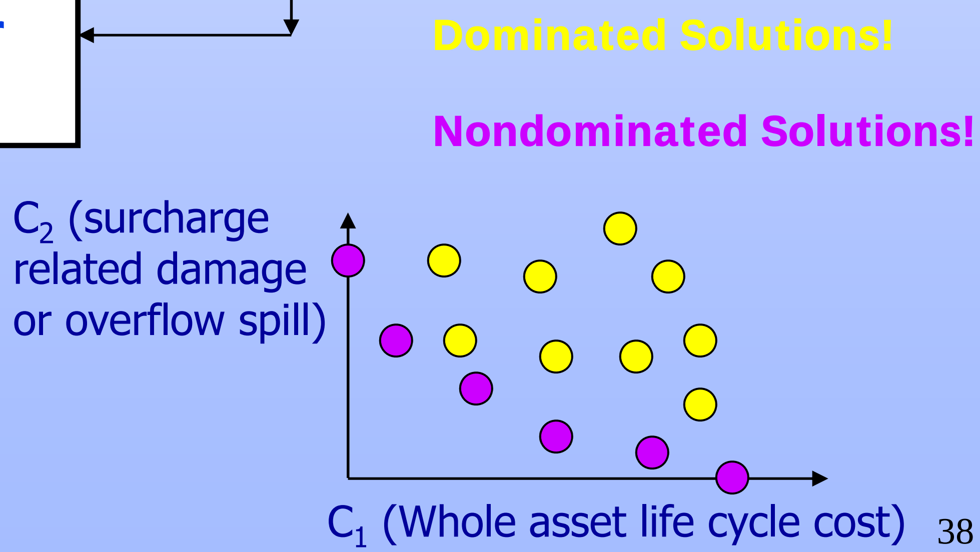
Second Iteration!



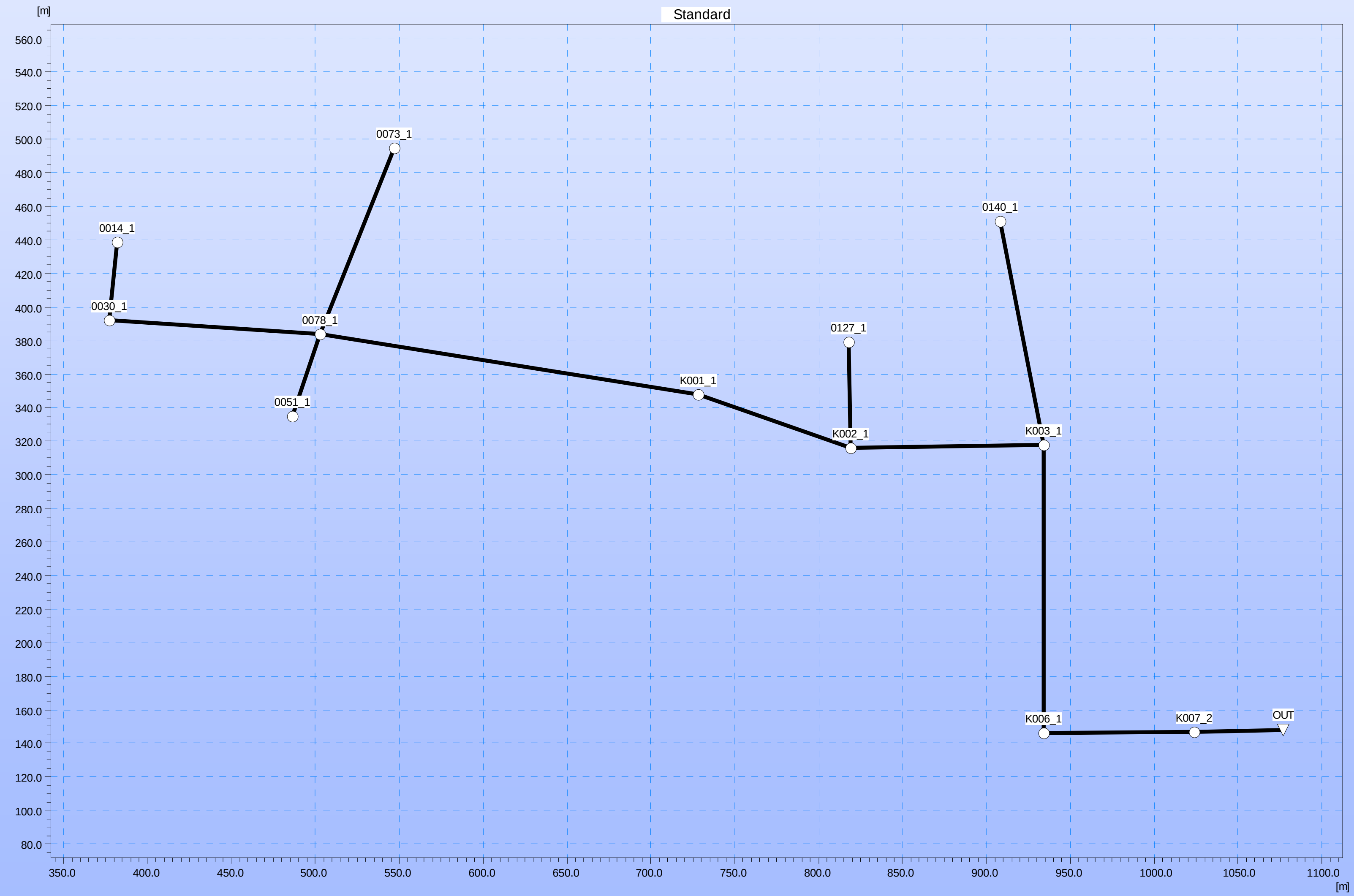
Dynamic analysis approach: Tools used



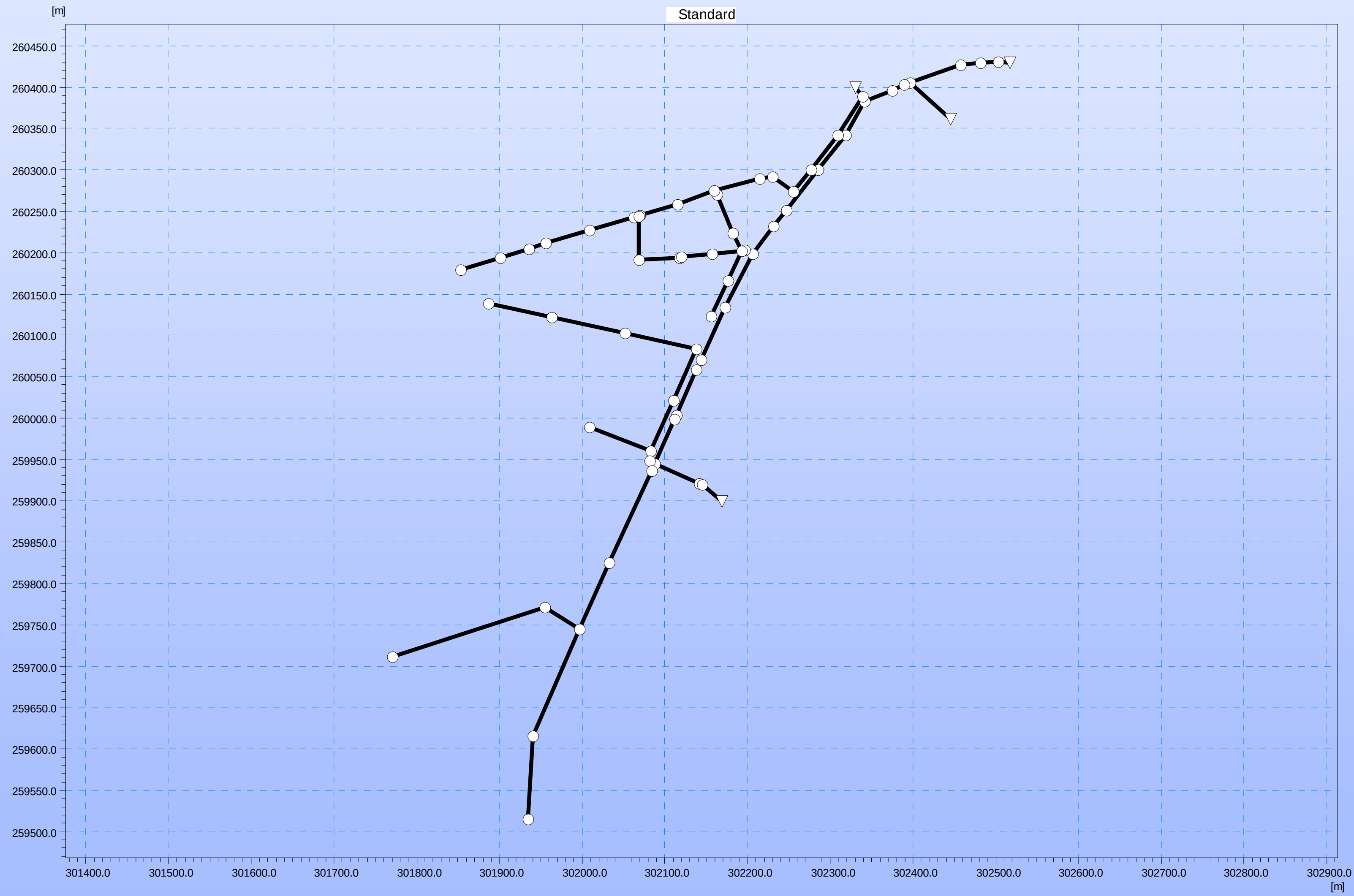
Other Iterations!



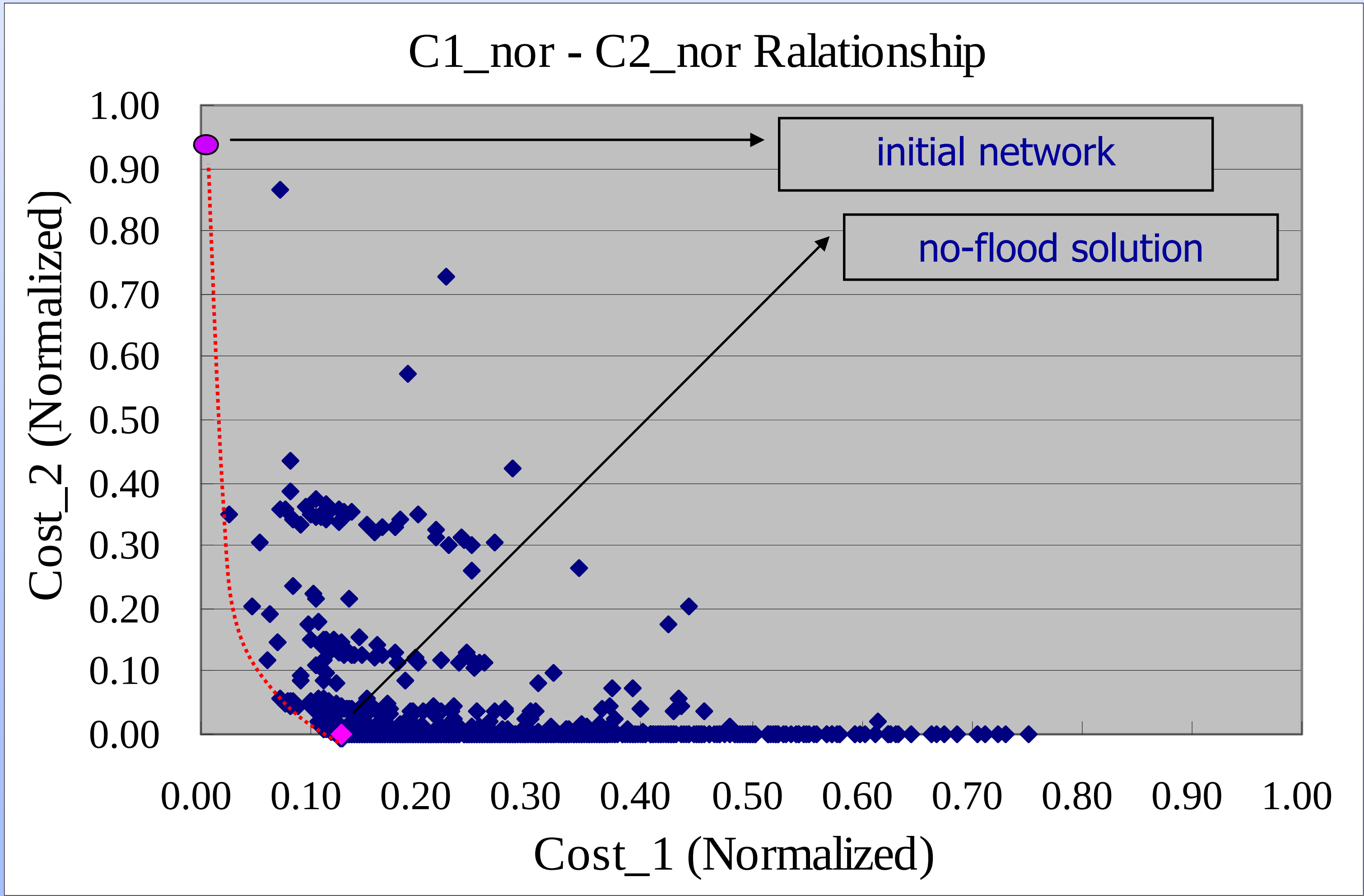
Case study results – a network of 12 pipes



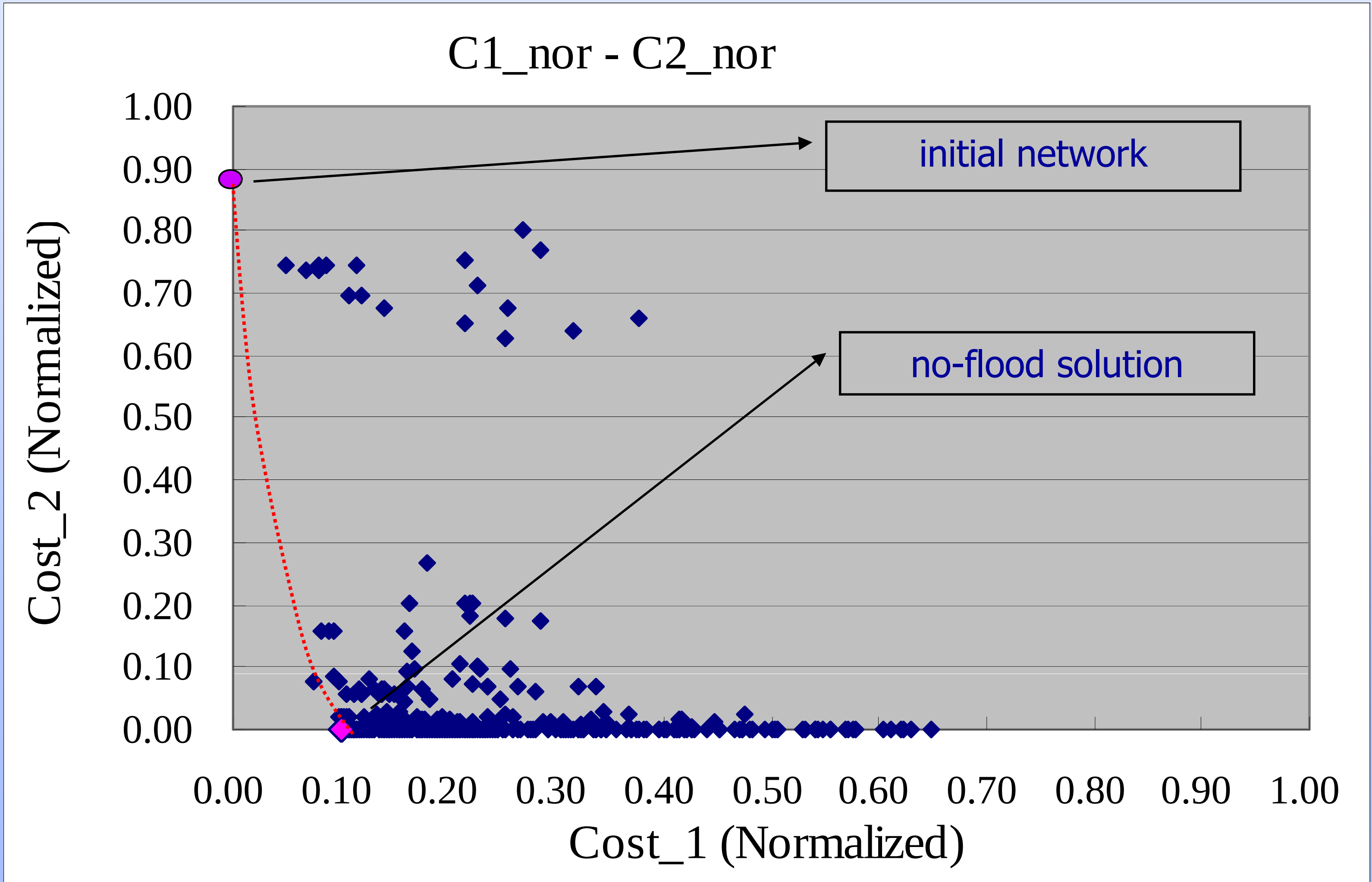
Case study results – a network of 63 pipes



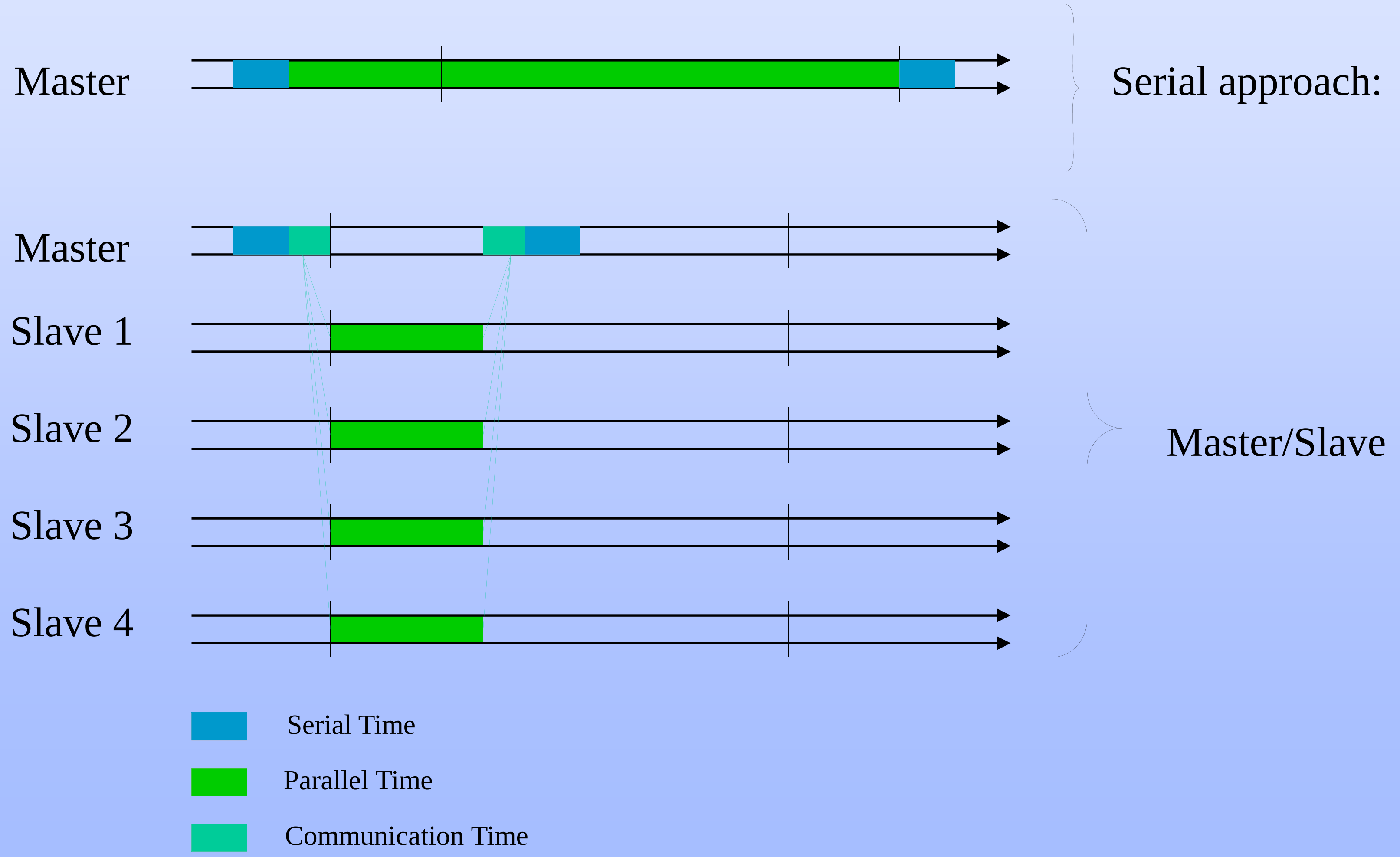
Two-criteria optimisation with ACCO and GA C1=costs, C2=surcharge/overflow-related damage, 12 pipes



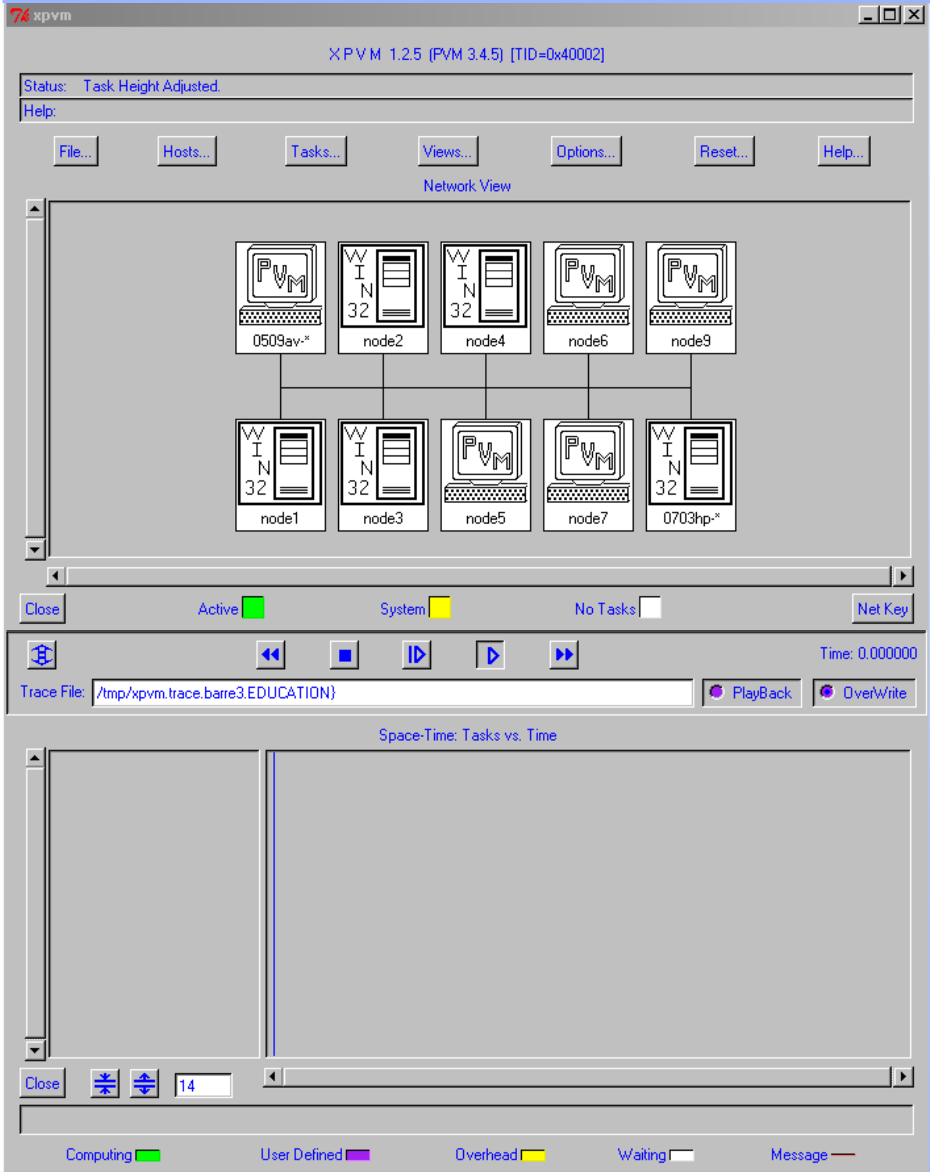
Two-criteria optimisation with ACCO and GA
C1=costs, C2=surchage-related damage, 63 pipes

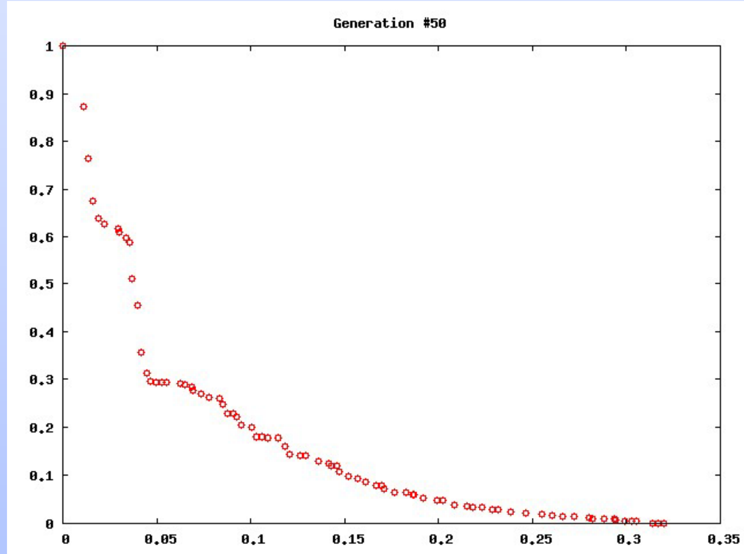


A parallel computing platform has been developed for larger networks



A parallel computing platform has been developed for larger networks





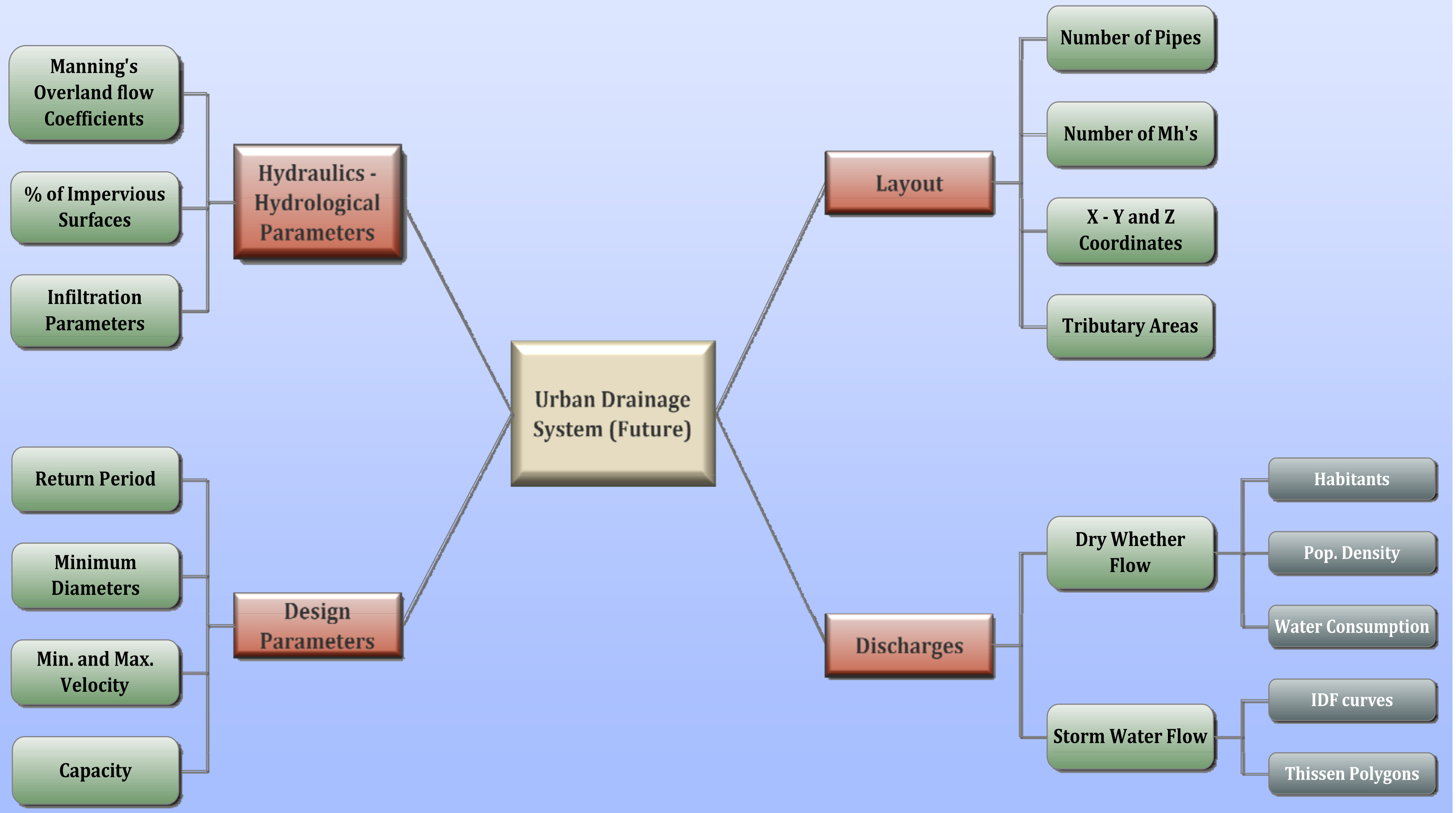
Implementation

- Conventional: separate and combined
- Simplified

Implementation

- Known cases: details from several cases available
- Unknown cases: details determined using specialised tools

Design Parameters for Sewer Reticulation



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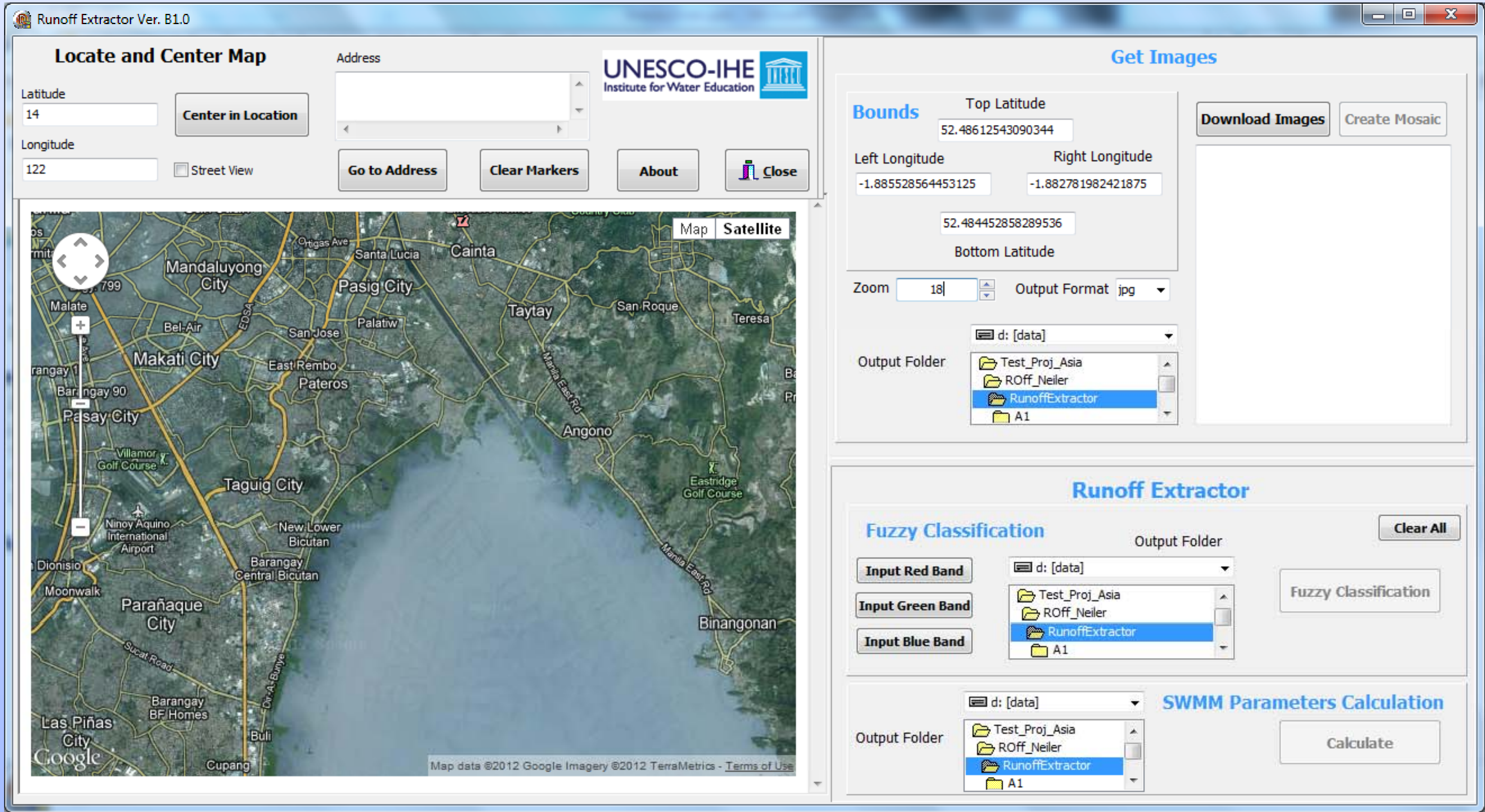
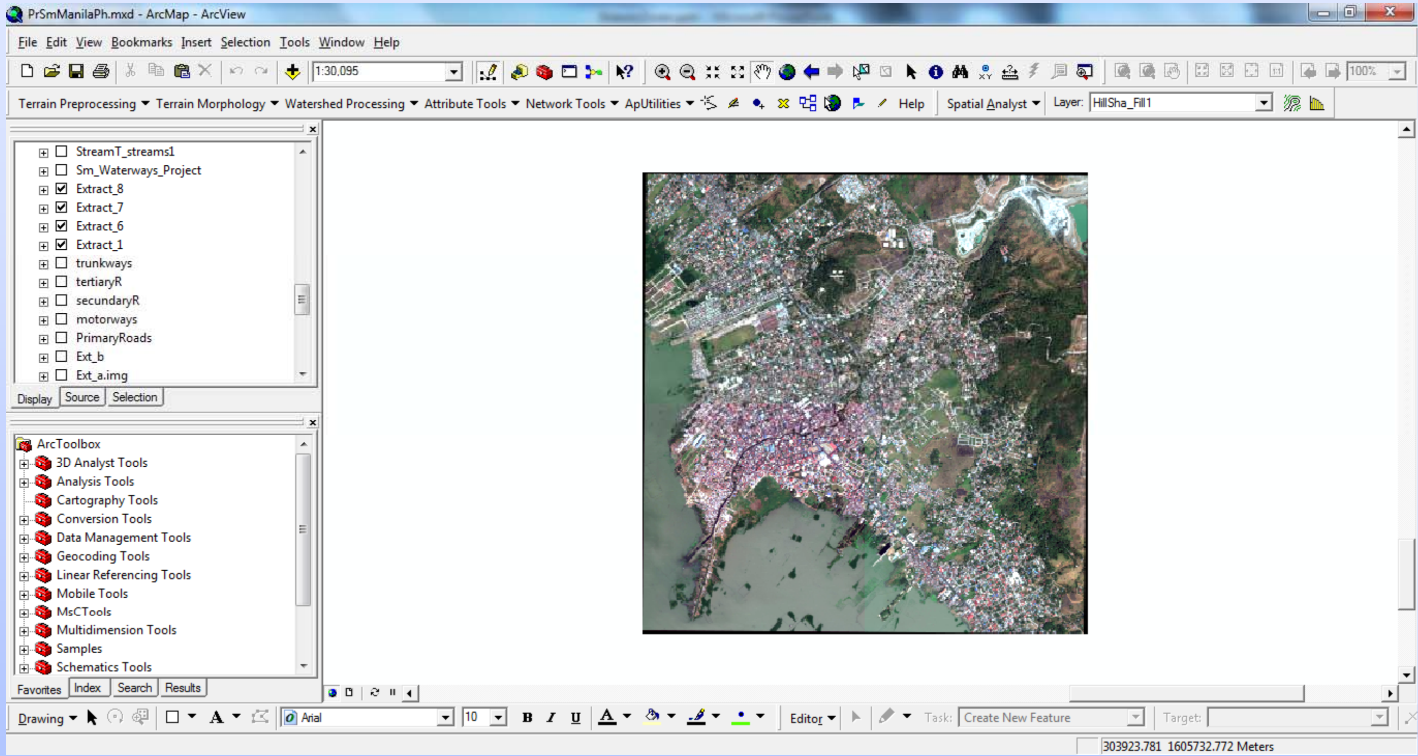
Hydrologic / Hydraulic Parameters



Hydrologic / Hydraulic Parameters …cont



Select the area of interest and download the images with the desired level of zoom.

The images are decomposed in the RGB bands and a fuzzy classification method is used to estimate land classes and the Parameters %pervious, %impervious, n-pervious, n-impervious.

Design Parameters

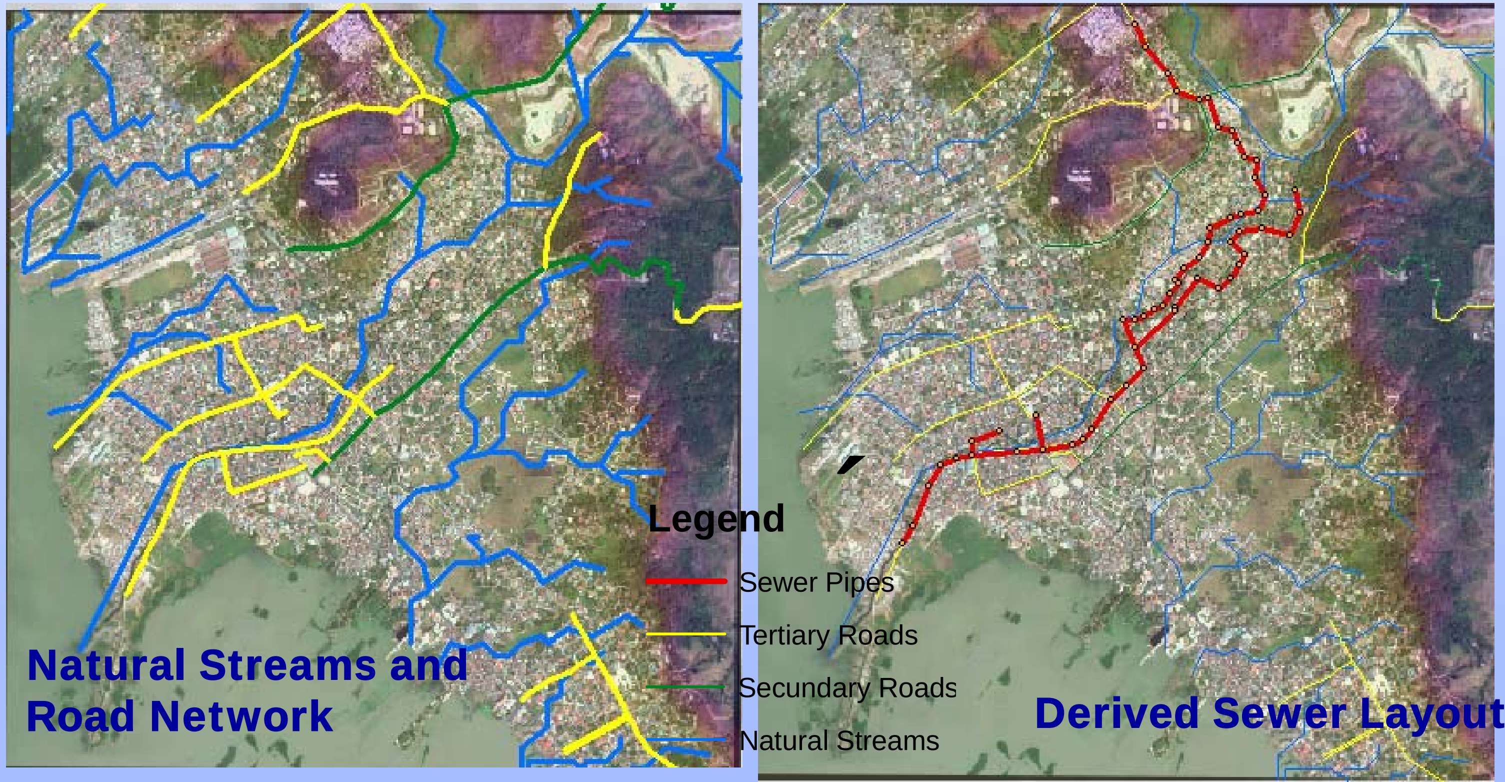
Depend on local conditions and regulations

- Return Period (The level of risk that is managed)
- Design Period (The quality of the civil works)
- Minimum Diameter (Security Factors)
- Minimum/Maximum Velocity (Self cleaning, water quality considerations, Hazardous gases (security), maintenance, etc).

Layout of the System

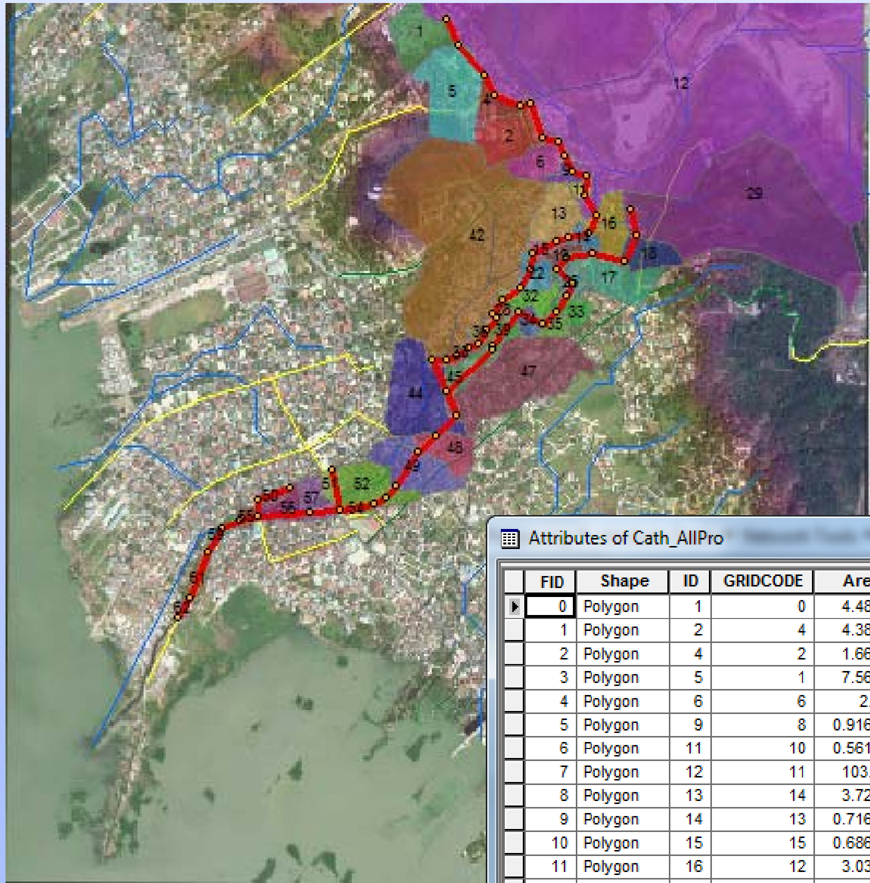
Based on the local topography. The RASTER DTM (30 m) for the previously selected area is downloaded and processed (hydrologically corrected).

The road network is considered to lay down the main trunks or drains. (Information was locally acquired or from internet i.e. Google maps, Open street maps, Derived from the fuzzy classification algorithm)



Catchment Delineation

ArcHydro Tools are used to process the catchment delineation. Based on the layout and flow direction. The areas are processed and the required parameters extracted to the attribute table.



Attributes of Cath_AllPro

FID	Shape	ID	GRIDCODE	Area	Outlet	MEAN	MEAN_1	MEAN_12	MEAN_12_13	Width	WT
0	Polygon	1	0	4.48629	1	0.243066	0.004437	0.491212	0.350259	915.065	230
1	Polygon	2	4	4.38313	5	0.35407	0.002489	0.648076	0.19613	943.78302	220
2	Polygon	4	2	1.66138	7	0.345237	0.003388	0.630674	0.264649	677.82703	98.041496
3	Polygon	5	1	7.56983	3	0.373198	0.001885	0.685351	0.150087	1165.59	259.77701
4	Polygon	6	6	2.794	9	0.367707	0.001843	0.677127	0.147692	807.70801	138.367
5	Polygon	9	8	0.916558	10	0.326267	0.002746	0.625661	0.21969	510.10001	120
6	Polygon	11	10	0.561479	12	0.294822	0.003348	0.591339	0.269786	343.72101	80
7	Polygon	12	11	103.283	13	0.363016	0.002172	0.671569	0.172132	5578.5698	1500
8	Polygon	13	14	3.72711	16	0.313216	0.003113	0.606589	0.24861	763.64502	195.22701
9	Polygon	14	13	0.716836	33	0.358625	0.002002	0.671489	0.160653	450.43301	63.657501
10	Polygon	15	15	0.686862	17	0.386194	0.001609	0.702382	0.127332	403.09698	68.158501
11	Polygon	16	12	3.03583	14	0.365782	0.001872	0.67948	0.149649	788.57599	170
12	Polygon	17	31	4.59911	34	0.374345	0.001821	0.684519	0.145346	1121.33	164.05901
13	Polygon	18	32	0.18716	32	0.473754	0.000381	0.807896	0.030629	687.13599	110
14	Polygon	19	33	0.842219	35	0.37117	0.001623	0.688597	0.130995	527.26599	63.893299
15	Polygon	22	17	1.68444	19	0.319903	0.002827	0.613472	0.225535	588.44702	140

Record: 1 Show: All Selected Records (0 out of 42 Selected) Options

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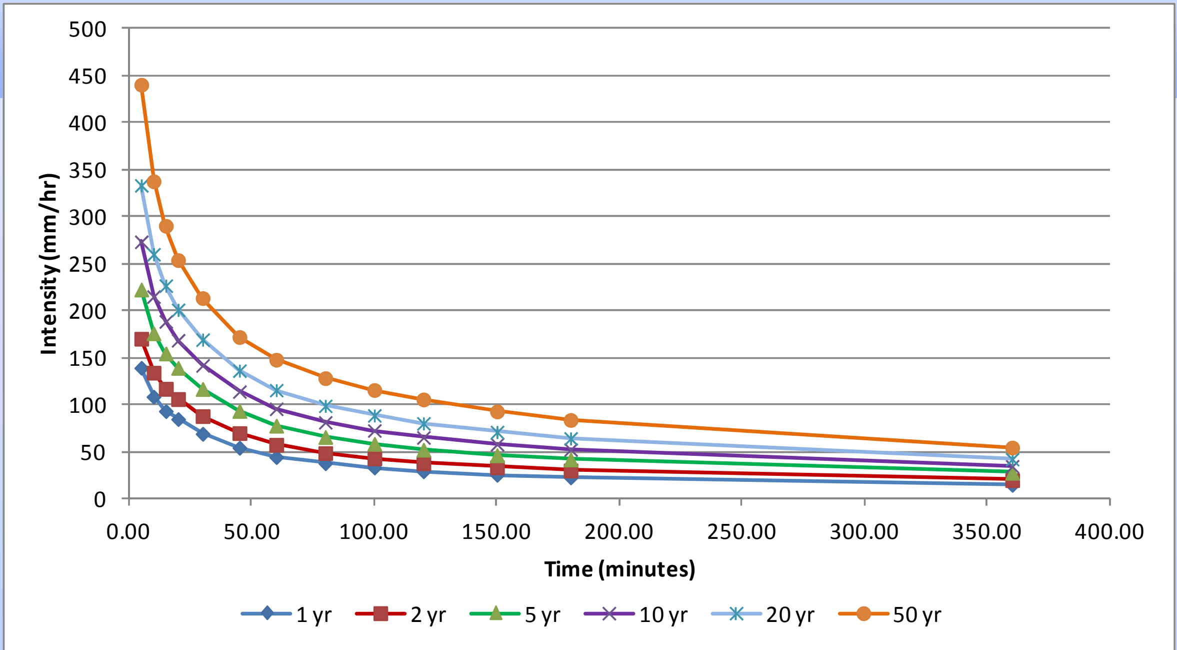
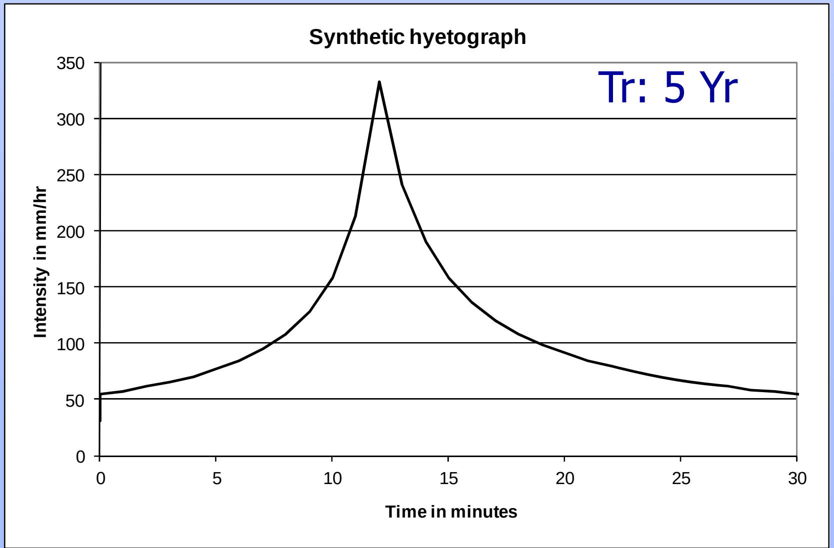
Discharges

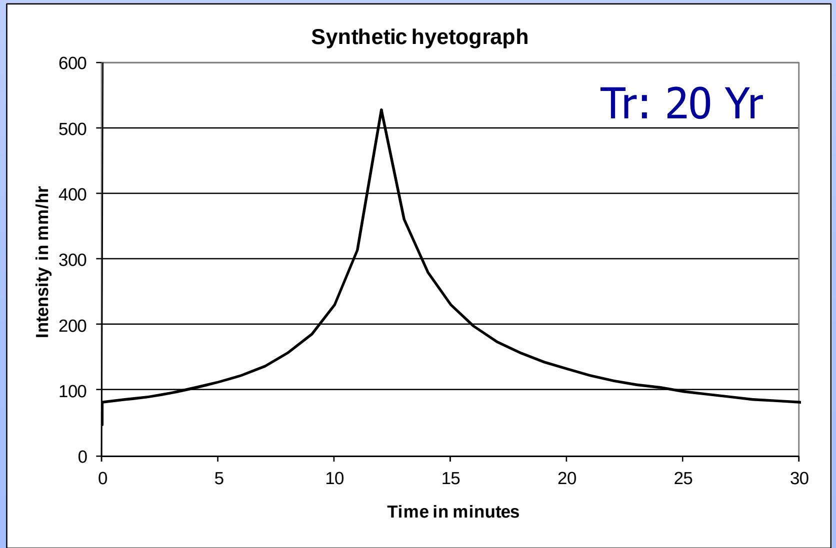
Dry Wheatear Flow: Is computed based on the population density (150, 500 and 1700 inh/Ha) and the catchment area. A per capita consumption of 150 l/inh/day is assumed. The average flows per catchment are computed and used as an input for the model.

Wet Weather Flow is computed using the information from a nearby weather station. For the case study illustrated, the Naia Station (Airport) data is used. The station is located approx 12.5 Km from the catchment in Manila. IDF curves for this station are extracted from the FRIEND report, UNESCO-IHP 2008.

IDF Curves for Naia Station - Manila







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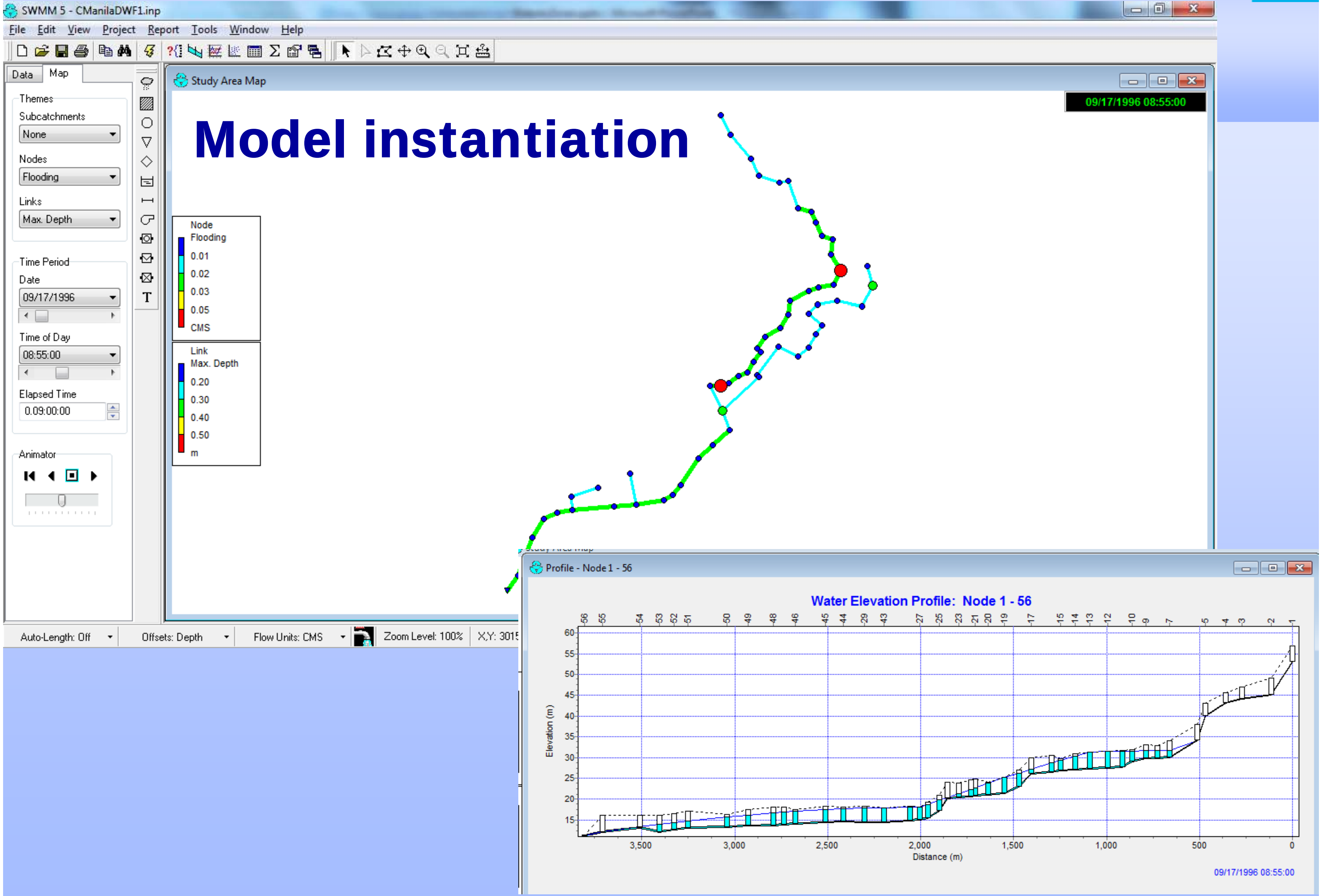
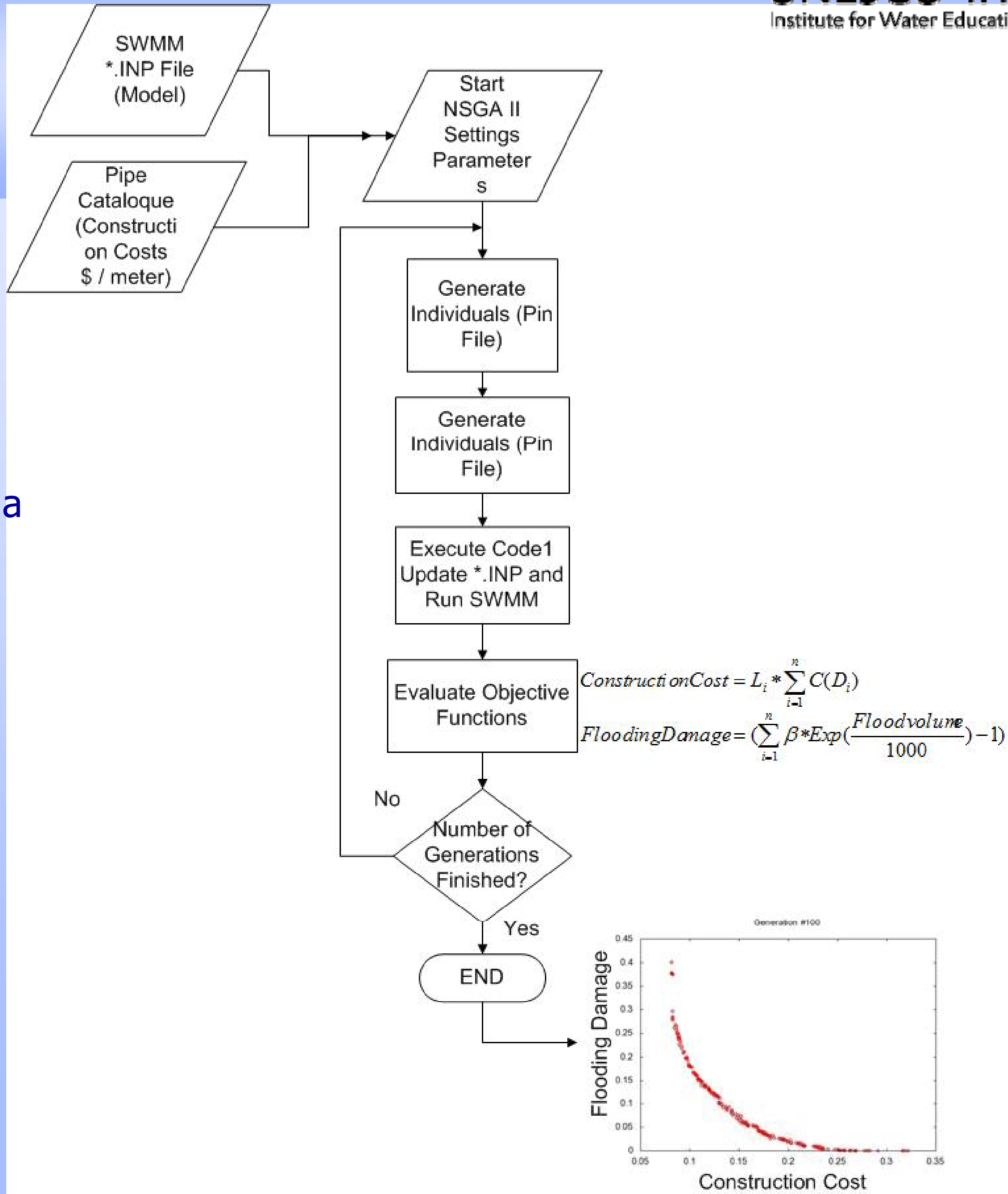
Model instantiation



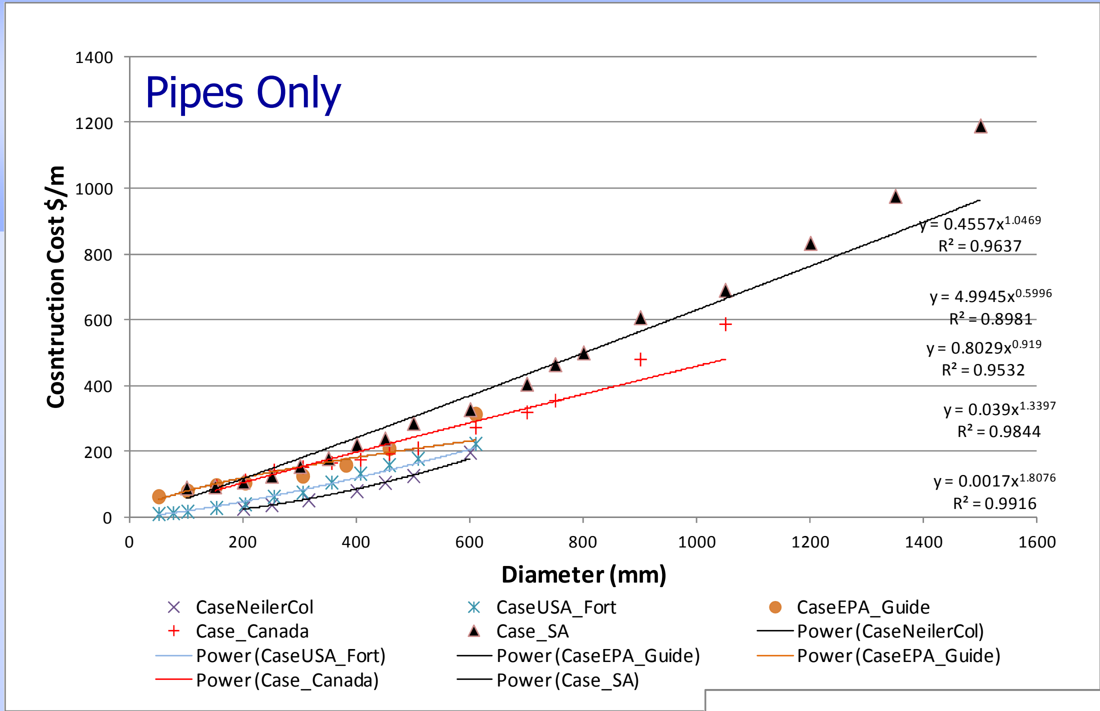
Optimization Loop



The Methodology produce a set of optimal solutions (Pareto Set).

For design the cheapest solutions that do not generate flooding in the systems is selected.

Construction Costs Catalogue (from cases found in literature)

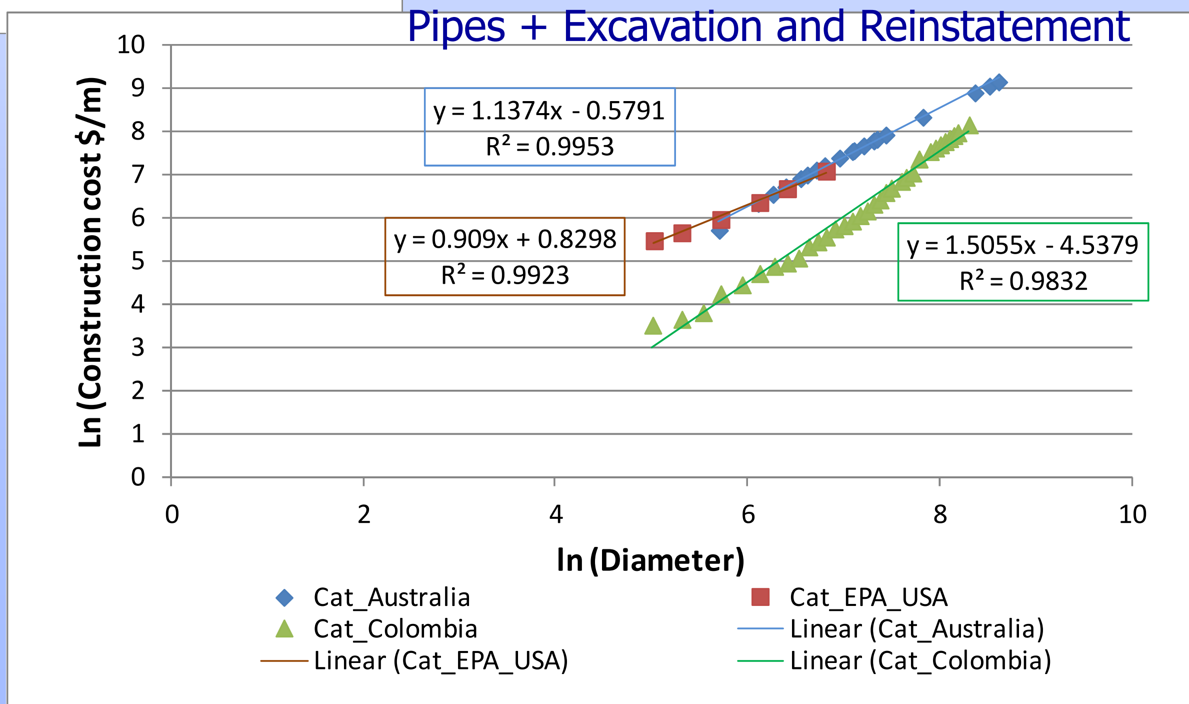


- Up to 1m dia: PVC, Hobas (larger than 1m)
- Larger than 1m dia: usually concrete

General form

$$C_p = \sum_{i=1}^{n} \beta * D_i * L_i$$

β is a parameter to represent local conditions



Summary Table for each model

Combination	Design Criteria							Input Data									OutPut Data						
	Minimum Diamete	Minimum Depth (m)	Velocity Min (m/s)	Velocity Max (m/s)	Per Capita Consum	Design Period (years)	Design Rainfall (yr)	AREA = 50 Ha									Total Flow (Q) (m3/s)	Pipe Distribution (km)			Costs		
								Density 1: 150 inh/Ha			density 2: 500 inh/Ha			Density 3: 1700 inh/Ha									
								S1	S2	S3	s1	s2	s3	s1	s2	s3		< 500 mm	500-1000	>1000 mm	CI	O&M	Total (NPV
10	225	2	0.75	10	150	20	5	< 3%									2.903	17.5	2.5	0.1	40.00	6.00	46.00
11	225	2	0.75	10	150	20	5		3-10%								3.313	17.5	2.5	0.1	37.60	5.64	43.24
12	225	2	0.75	10	150	20	5			> 10%							3.713	17.5	2.5	0.1	36.00	5.40	41.40
13	225	2	0.75	10	150	20	5				< 3%						4.173	17.5	2.5	0.1	52.00	7.80	59.80
14	225	2	0.75	10	150	20	5					3-10%					4.583	17.5	2.5	0.1	48.88	7.33	56.21
15	225	2	0.75	10	150	20	5						> 10%				4.993	17.5	2.5	0.1	46.80	7.02	53.82
16	225	2	0.75	10	150	20	5							< 3%			5.928	17.5	2.5	0.1	70.00	10.50	80.50
17	225	2	0.75	10	150	20	5								3-10%		6.338	17.5	2.5	0.1	65.80	9.87	75.67
18	225	2	0.75	10	150	20	5									> 10%	6.748	17.5	2.5	0.1	63.00	9.45	72.45
Combination	Design Criteria							Input Data									OutPut Data						
	Minimum Diamete	Minimum Depth (m)	Velocity Min (m/s)	Velocity Max (m/s)	Per Capita Consum	Design Period (years)	Design Rainfall (yr)	AREA = 100 Ha									Total Flow (Q) (m3/s)	Pipe Distribution (km)			Costs		
								Density 1: 150 inh/Ha			density 2: 500 inh/Ha			Density 3: 1700 inh/Ha									
								S1	S2	S3	s1	s2	s3	s1	s2	s3		< 500 mm	500-1000	>1000 mm	CI	O&M	Total (NPV
19	225	2	0.75	10	150	20	5	< 3%									5.816	30	1.6	1.04	75.00	11.25	86.25
20	225	2	0.75	10	150	20	5		3-10%								6.636	30	1.6	1.04	70.50	10.58	81.08
21	225	2	0.75	10	150	20	5			> 10%							7.466	30	1.6	1.04	67.50	10.13	77.63
22	225	2	0.75	10	150	20	5				< 3%						8.347	30	1.6	1.04	90.00	13.50	103.50
23	225	2	0.75	10	150	20	5					3-10%					9.177	30	1.6	1.04	84.60	12.69	97.29
24	225	2	0.75	10	150	20	5						> 10%				10.007	30	1.6	1.04	81.00	12.15	93.15
25	225	2	0.75	10	150	20	5							< 3%			11.865	30	1.6	1.04	110.00	16.50	126.50
26	225	2	0.75	10	150	20	5								3-10%		12.685	30	1.6	1.04	103.40	15.51	118.91
27	225	2	0.75	10	150	20	5									> 10%	13.515	30	1.6	1.04	99.00	14.85	113.85

Estimation of Costs for Pumps

$$C_{Pumps} = \sum_{i=1}^{n} a_i * Q_i^{b_i}$$

The cost depends on the flow or capacity required

The number of pumps required in the system can be estimated according with the topography and the slope. Earle et al, 1999.
http://www.wateronline.com/doc.mvc/Estimating-Sewer-Costs-A-Mathematical-Model-0001

Flat Terrain (<3%): 1 Pump of 12 l/s per 1.6 Km and 2 Pumps of 6 l/s per 1.6 Km.
Rolling Terrain (3-10%) : 1 Pump of 6 l/s per 1.6 Km
Steep Terrain (>10%): 2 Pumps of 12 l/s per 1.6 Km and 2 Pumps of 6 l/s per 1.6 Km

References:
Farrell, R.P., 1992, Two decades of experience with pressure sewer systems, *Journal of the New England Water Pollution Control Association.*
R.S. Means Co., 1996, Site Work and Landscape Cost Data, 16th Kingston, Massachusetts.
Environment One Corporation, 1995, Low-pressure sewer systems using environment one grinder pumps, Schenectady, New York.

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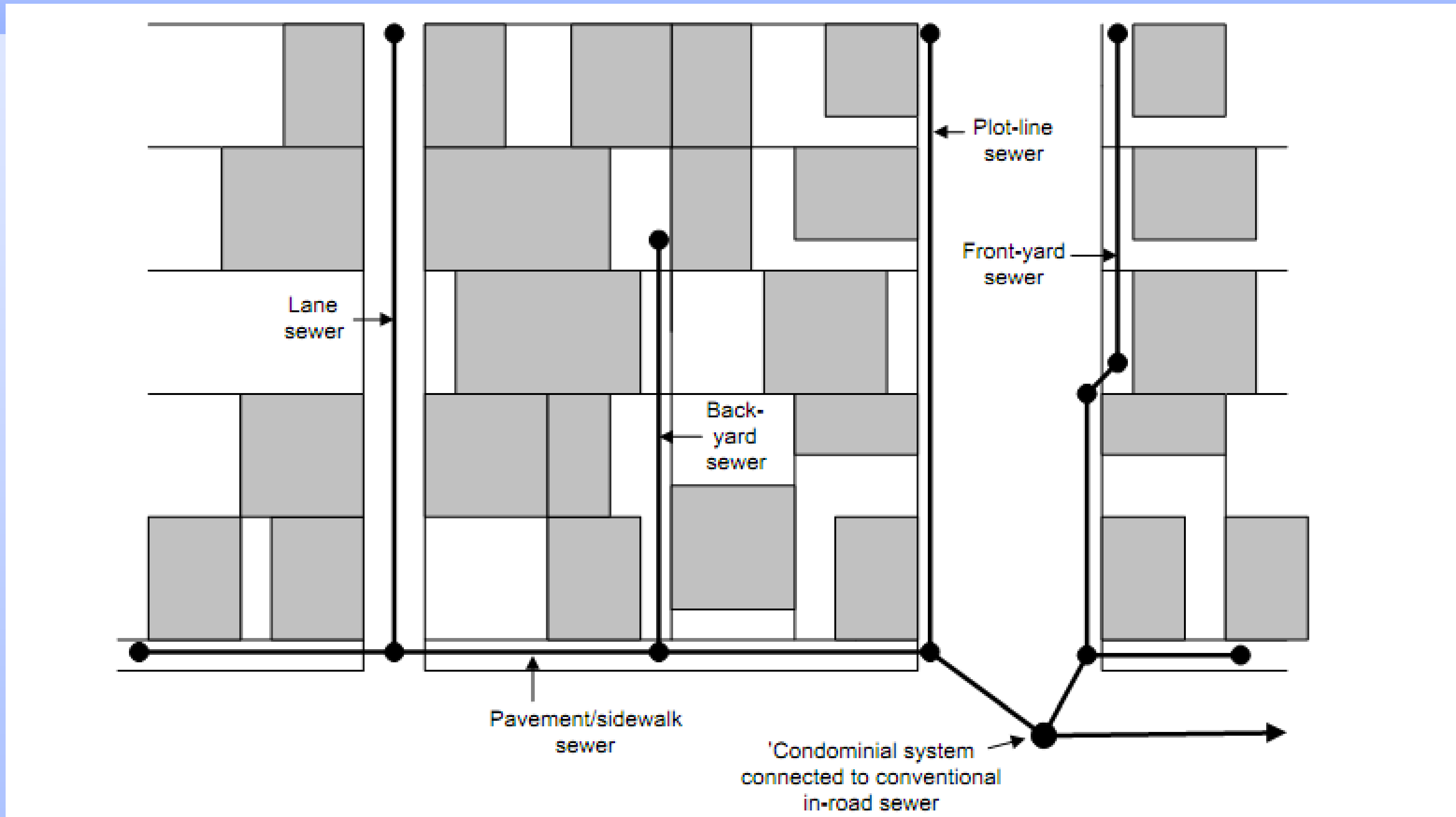
Simplified Sewerage or Condominial Sewerage

Simplified sewerage is an off-site sanitation technology that removes all wastewater from the household environment. Conceptually it is the same as conventional sewerage, but with conscious efforts made to eliminate unnecessarily conservative design features and to match design standards to the local situation. Mara et all, 2000.

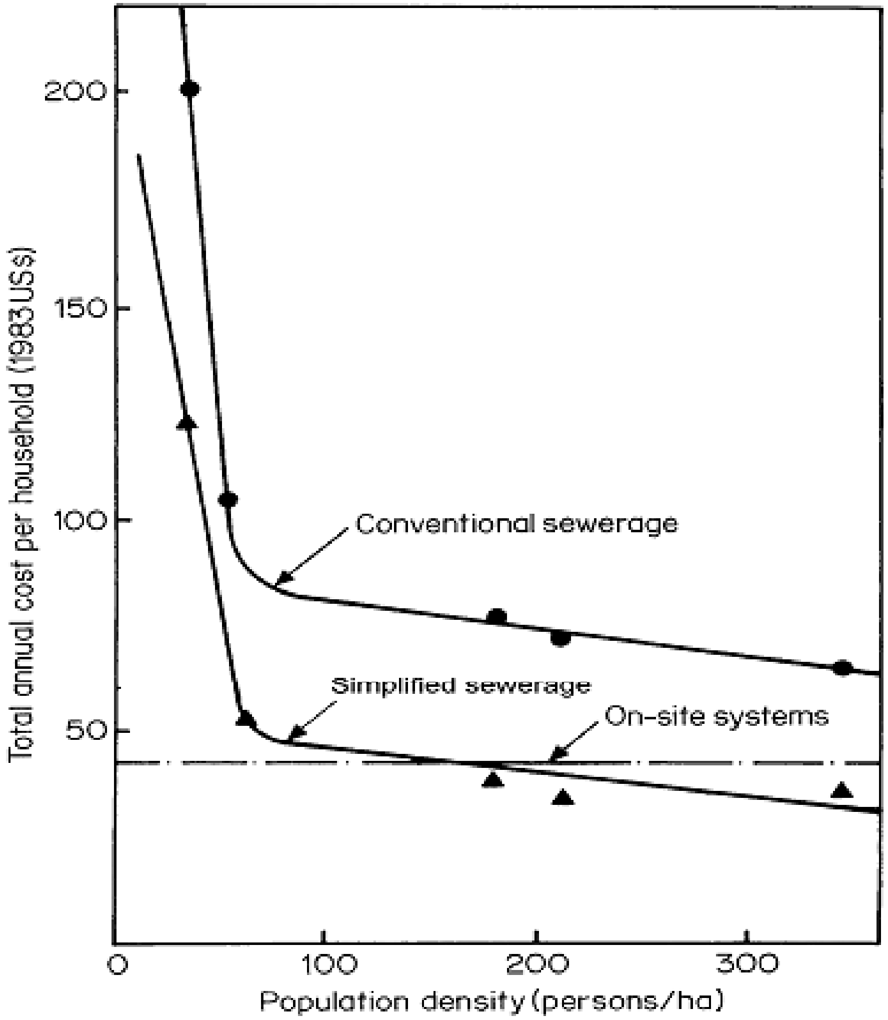
Key Features

Layout: to reduce costs, simplified sewerage are developed as an in-block system , rather than as with conventional sewerage an in-road system. The key feature of an in-block system is that sewers are routed in private land, through either back or front yards.

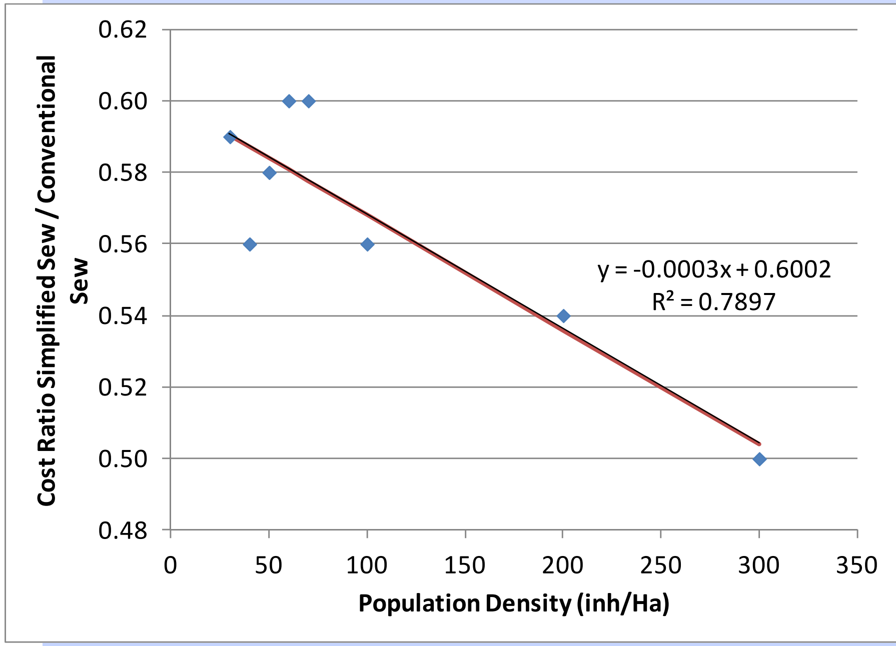
Depth and diameter: simplified sewers are laid at shallow depths, often with covers of 0.4 m. or less. The minimum allowable sewer diameter is 100 mm, rather than the 150 mm or more that is normally required for conventional sewerage. The relatively shallow depth allows small access chambers to be used rather than large expensive.



Example of Alternatives routes for simplifies sewers, Mara et al, 2000



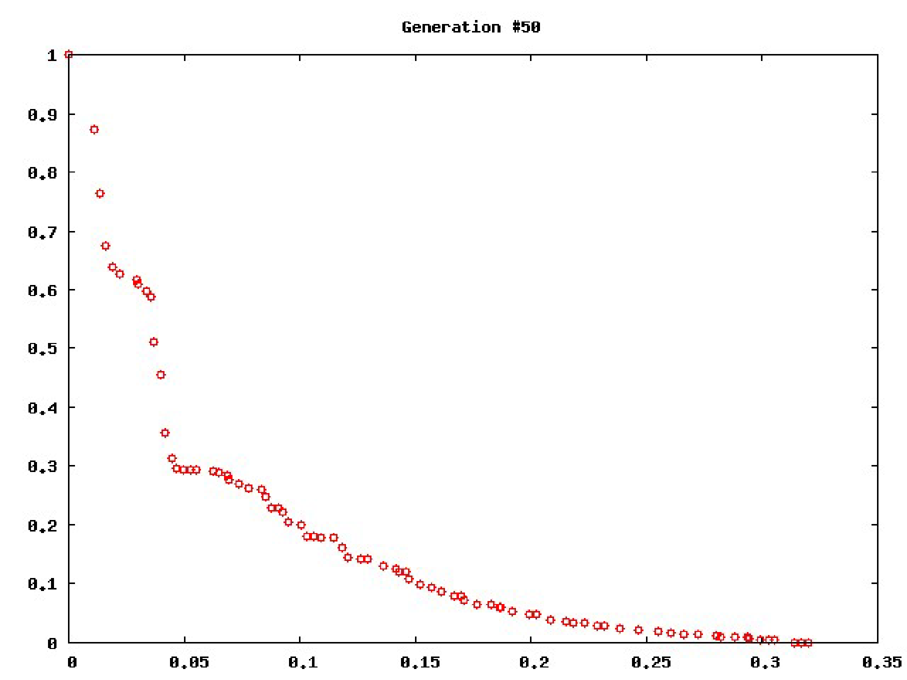
Costs of conventional and simplified sewerage and on-site sanitation in Natal in northeast Brazil in 1983. Source: Sinnatamby, 1983

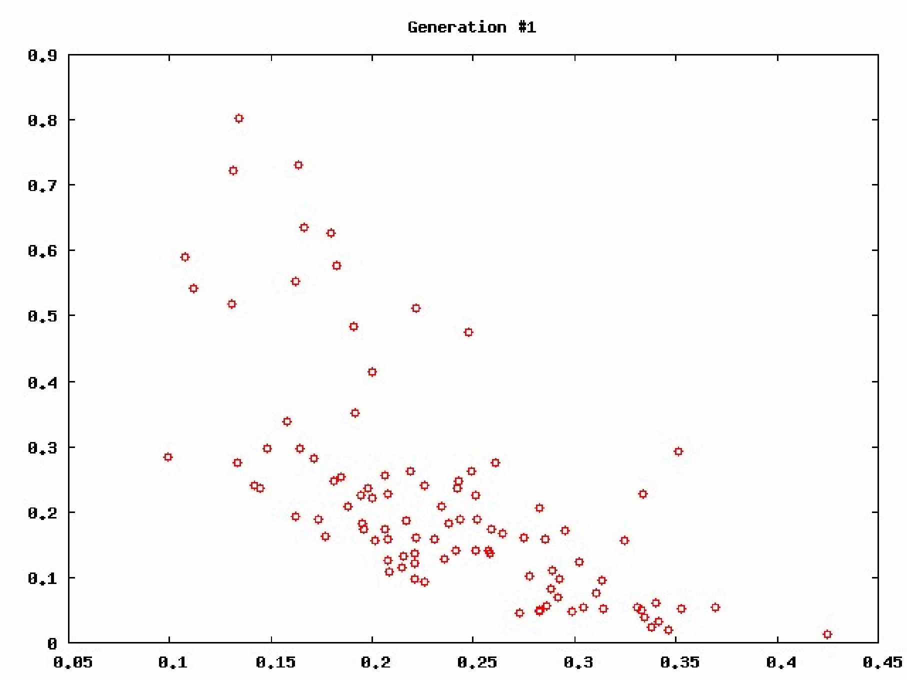


Based on the Brazil Experience. The simplified sewerage alternative is between 40% to 50% cheaper than conventional sanitary sewers.

Parallel Computing

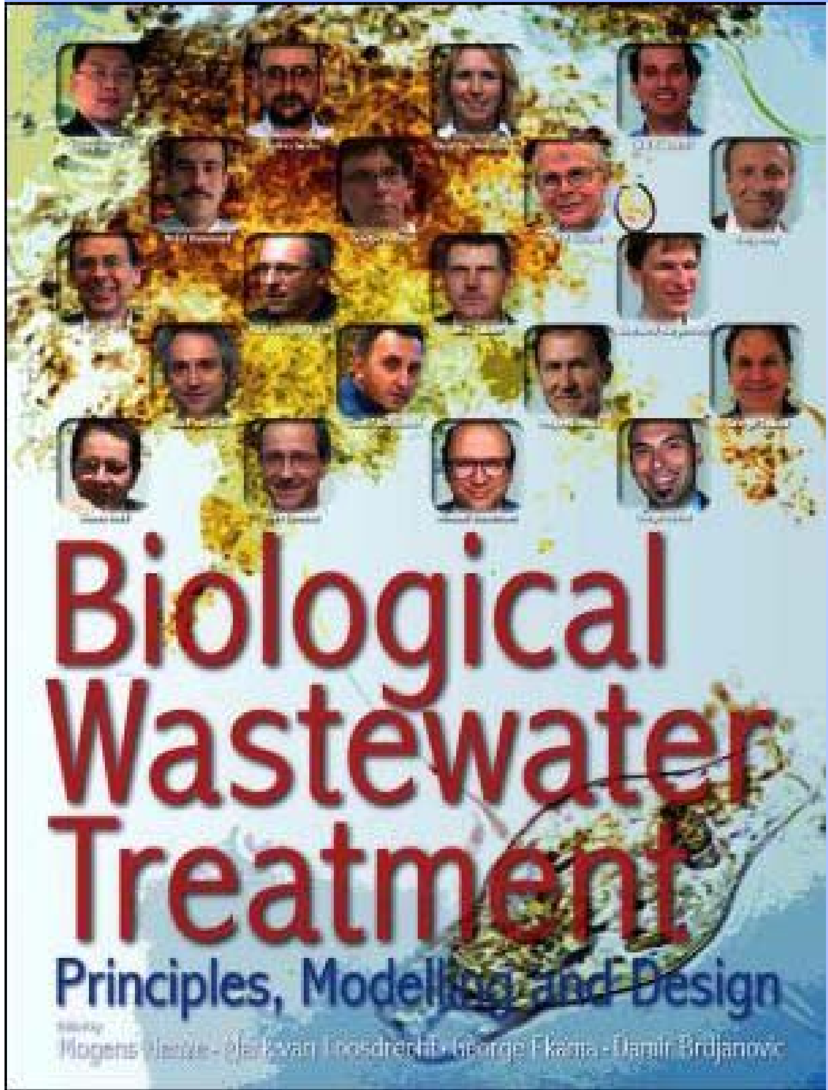
- Study Case and Results: Pareto Front

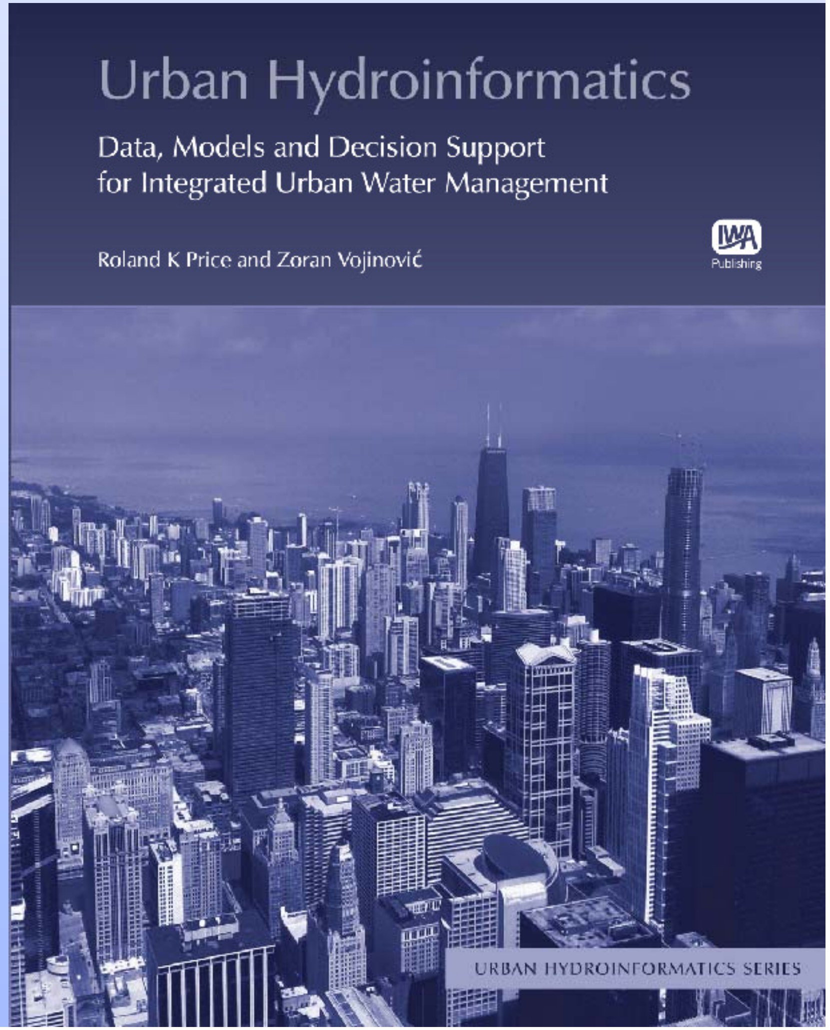




References

z.vojinovic@unesco-ihe.org





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Thank you for your attention!

DEMONSTRATION

RETICULATION SELECTION MODULE - DEMO

Selection of sewer reticulation network in relation to:

- Different Population Density
- Slope of Terrain

EXERCISE: Wastewater Technology Selection Module

Step 1

Urban area in Malaysia (KL): 30 Hectares
Wastewater production per person per day:
Group a) 100 liters/person/day
Group b) 150 liters/person/day
Group c) 200 liters/person/day

Wastewater source: Group a) Grey water (non-sewer);
Group b) Sanitary Sewage;
Group c) Combined Sewage;

Design Horizon: 20 years;
O&M as % of CI: 3%;
Discount Rate: 5%
Factors for Consideration: Efficiency, Shock Resistance, Economy;

EXERCISE: Wastewater Technologies Selection Module

Typical Values

BOD5:	**54 (15 – 80)**
COD:	**100 (25 - 200)**
TotP:	**2 (1-3)**
TotN:	**5 (2 – 15)**
TSS:	**10**
Vol/C:	**200 (100 – 300)**

EXERCISE: Wastewater Technology Selection Module

Step 2

Government is considering to change to Singaporean Stds

What are the implications?

EXERCISE: Wastewater Technology Selection Module

Step 3

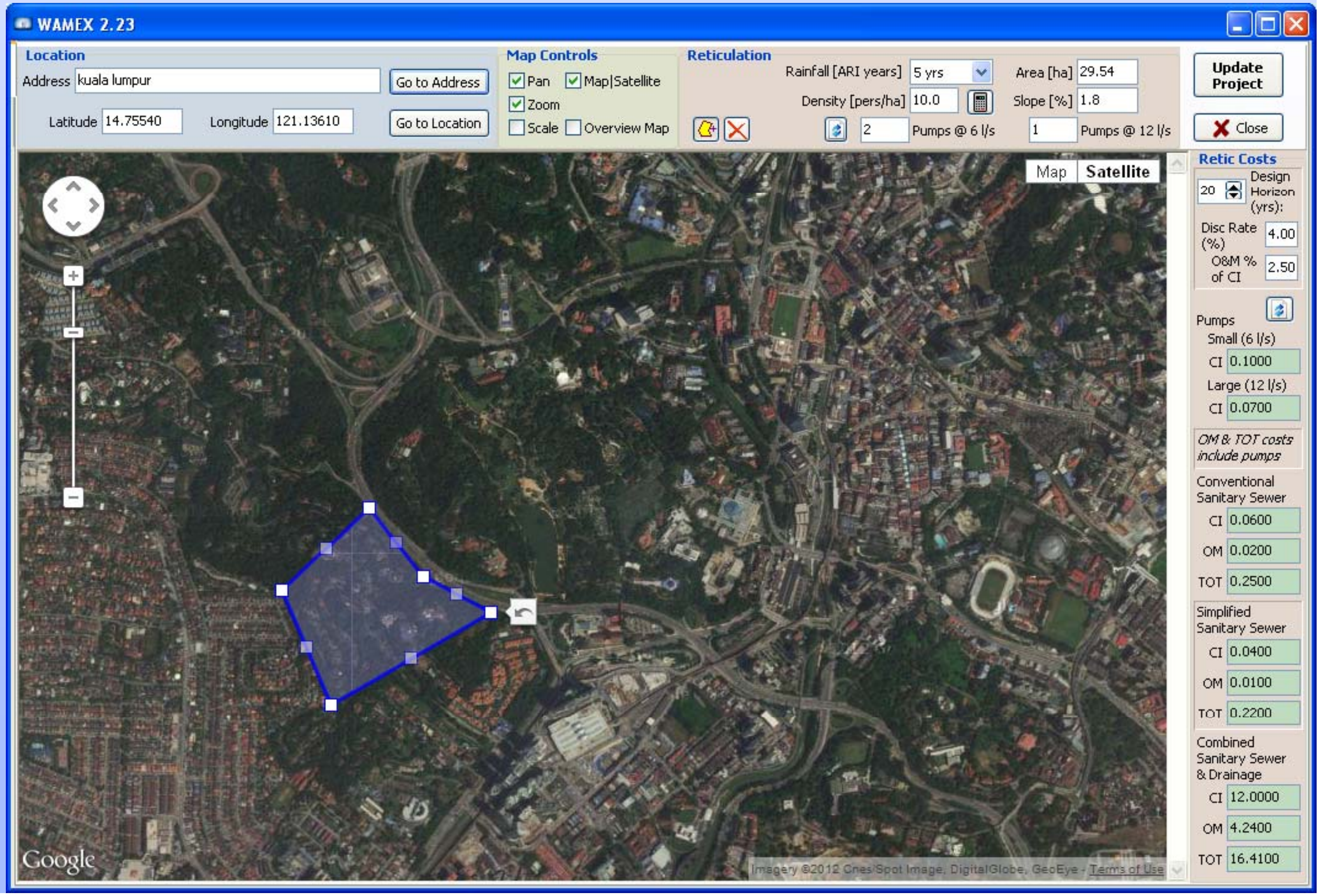
Government is considering to change to European Stds

What are the implications?

EXERCISE: Reticulation Selection Module

Urban area in Malaysia (KL) needs to be sewered:

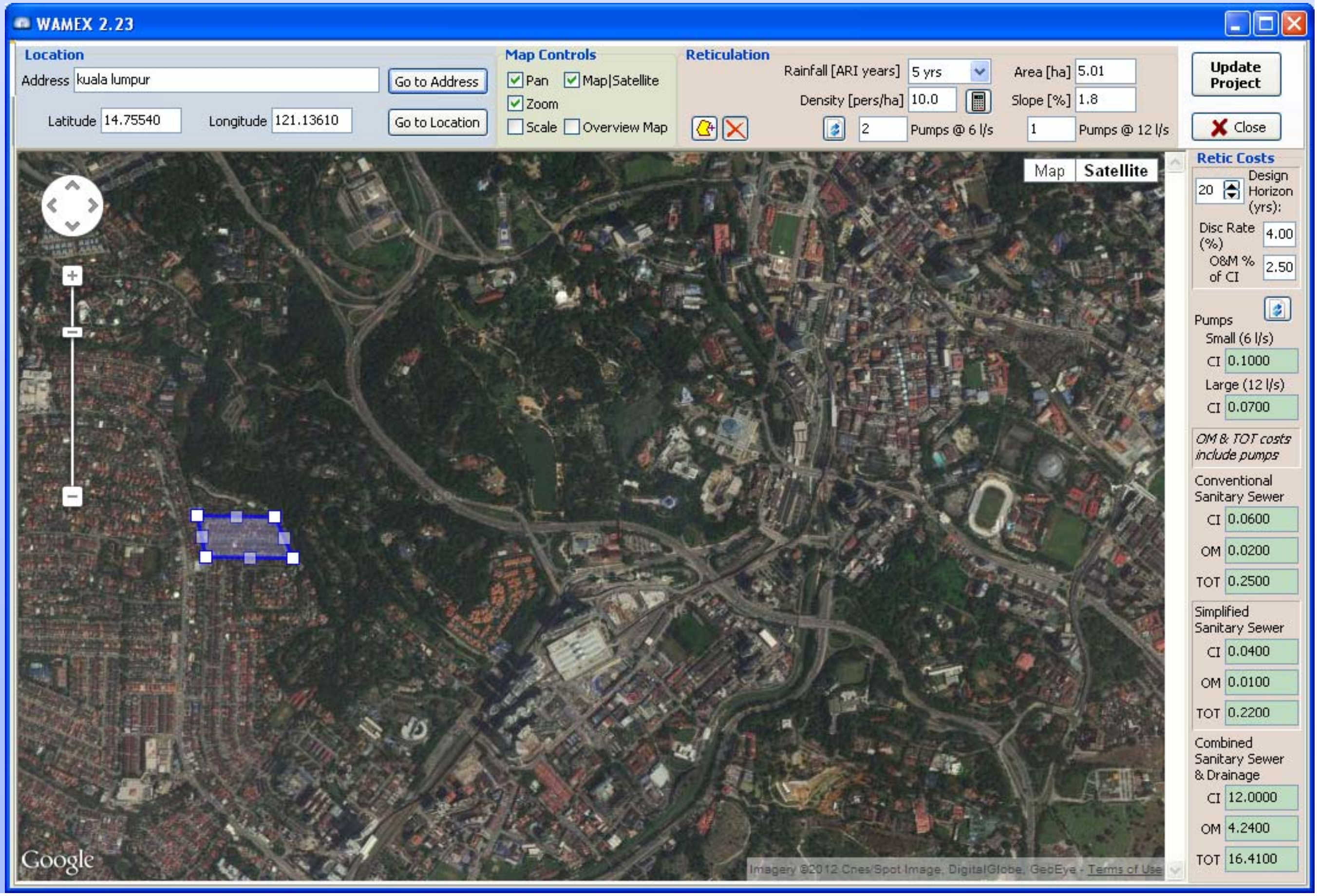
Step 1: Measurements



EXERCISE: Reticulation Selection Module

Approximate development density:

Step 2: Measurements



EXERCISE: Reticulation Selection Module

Terrain slope: 1%
Design Horizon: 50 years;
O&M as % of CI: 2%;
Discount Rate: 5%

Calculate the costs of the following:

- Pumps/pumping stations
- Conventional sanitary sewer
- Simplified sanitary sewer
- Combined Sanitary Sewer and Drainage

Discuss the findings within your group and present the conclusions!