EXPLORING THE FUTURE WATER INFRASTRUCTURE OF CITIES

Eng. Arlex Sanchez Torres
PhD. R.K. Price
PhD. Z. Vojinovic

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Background

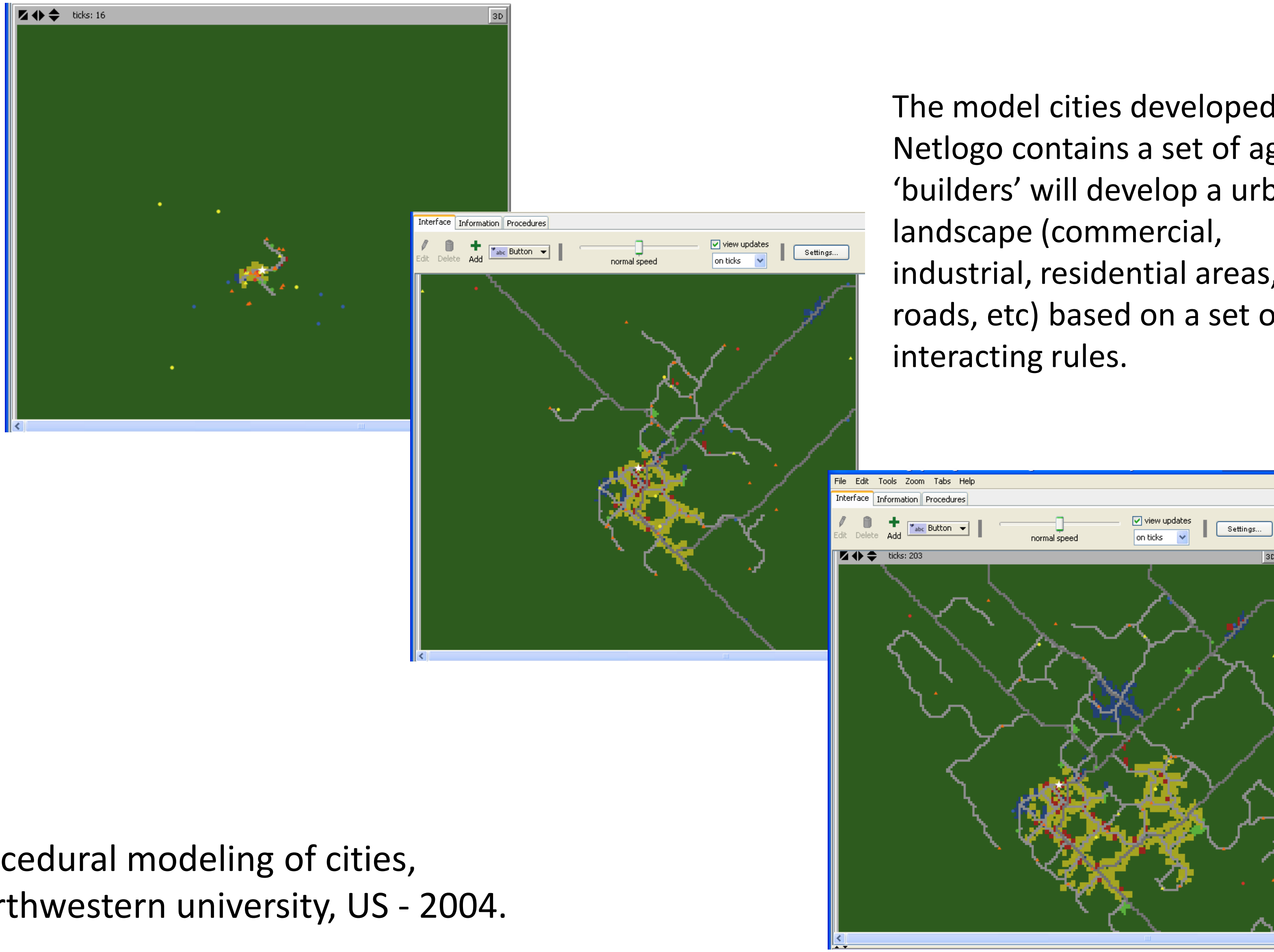
- Urbanization growth, on one hand is considered as a symbol of economical development, brings out on the other hand more complexity and stress to the natural systems and resources.

- There is a call for innovative thinking and redesign of the urban water cycle to achieve environmental sustainability. SWITCH, 2006.

- Integrated modeling and decision support systems are accepted tools to manage data, information and enhance the decision making process.

- Agent-based models and cellular automata have been successfully applied to explore emergence phenomena like the growth of urban areas and land use modeling.

Examples : The Cities Model

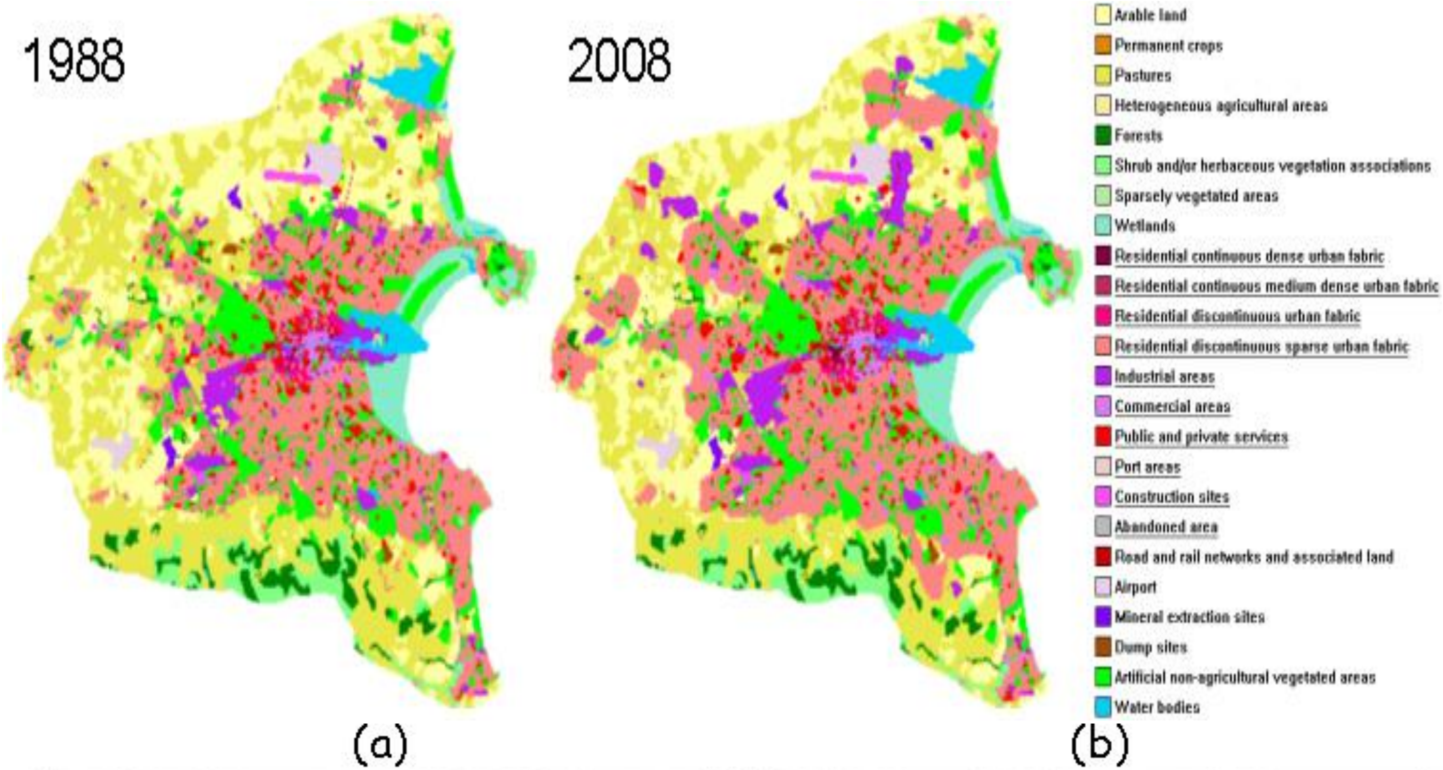


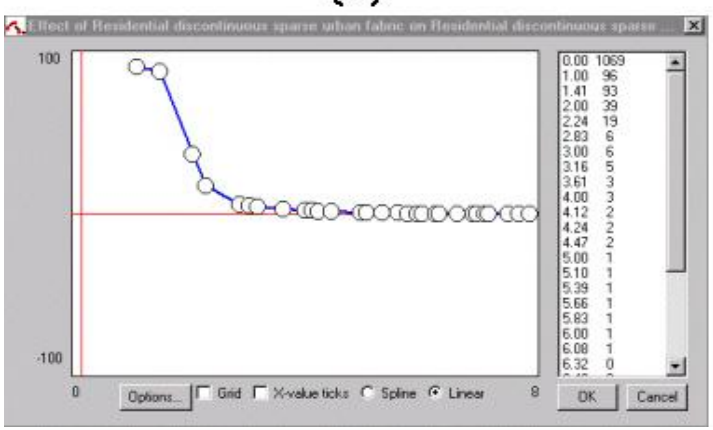
The model cities developed in Netlogo contains a set of agents ‘builders’ will develop a urban landscape (commercial, industrial, residential areas, roads, etc) based on a set of interacting rules.

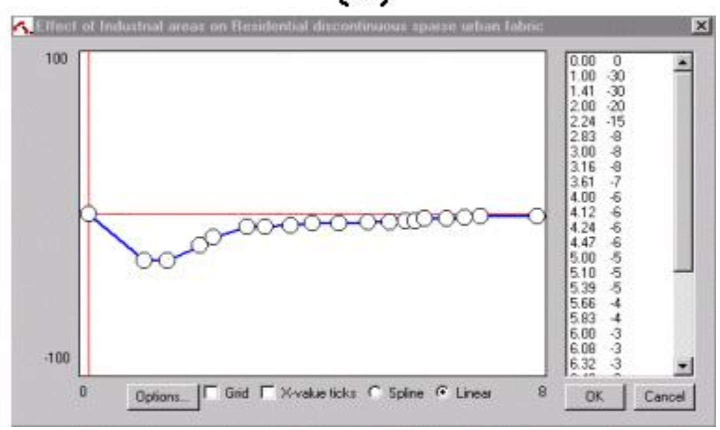
Procedural modeling of cities, Northwestern university, US - 2004.

Examples: The Great Dublin Area – EU Project

Source: Barredo et al, 2003





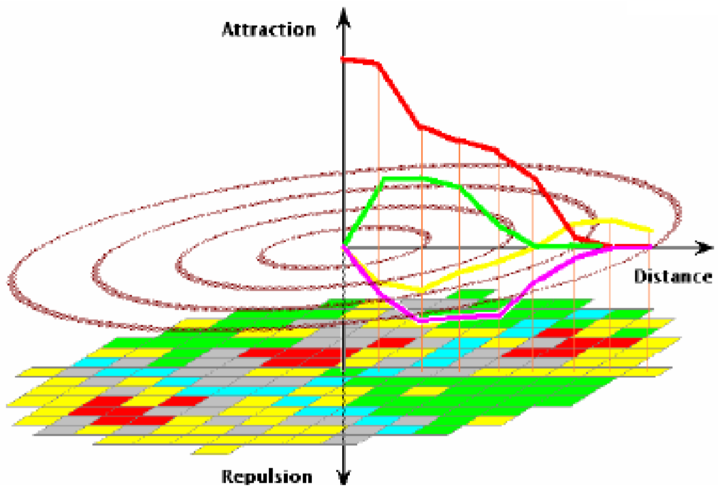


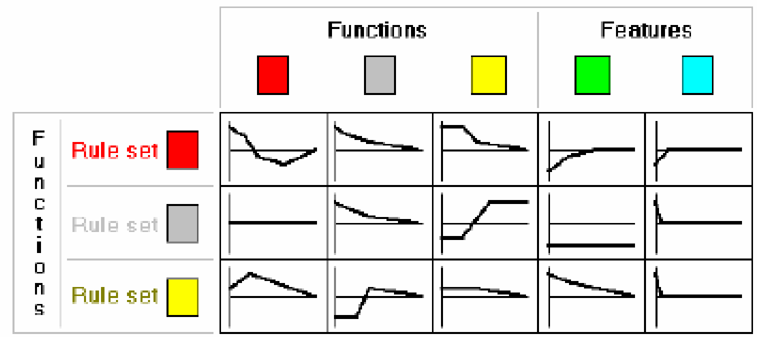
The Metronamica Model, RIKS, 2007

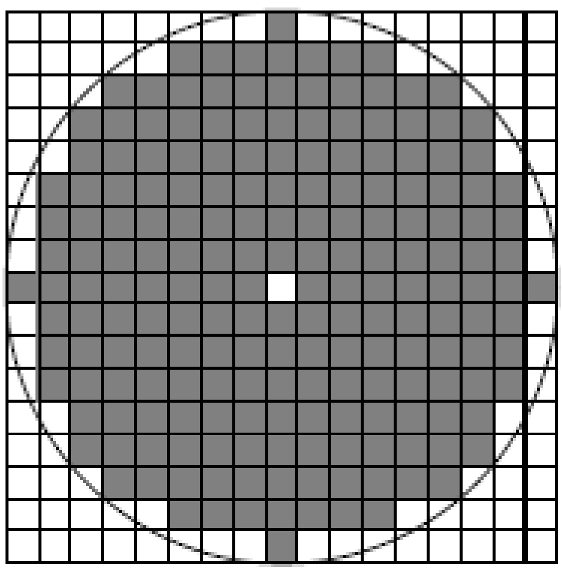
Source: RIKS, 2009

Neighborhood and Rules

$$TP_{x,i} = c_{l(i),x} \cdot Z_{x,i} \cdot S_{x,i} \cdot A_{x,i} \cdot f\left(N_{x,i} + E_{x,i} + \varepsilon\right)$$

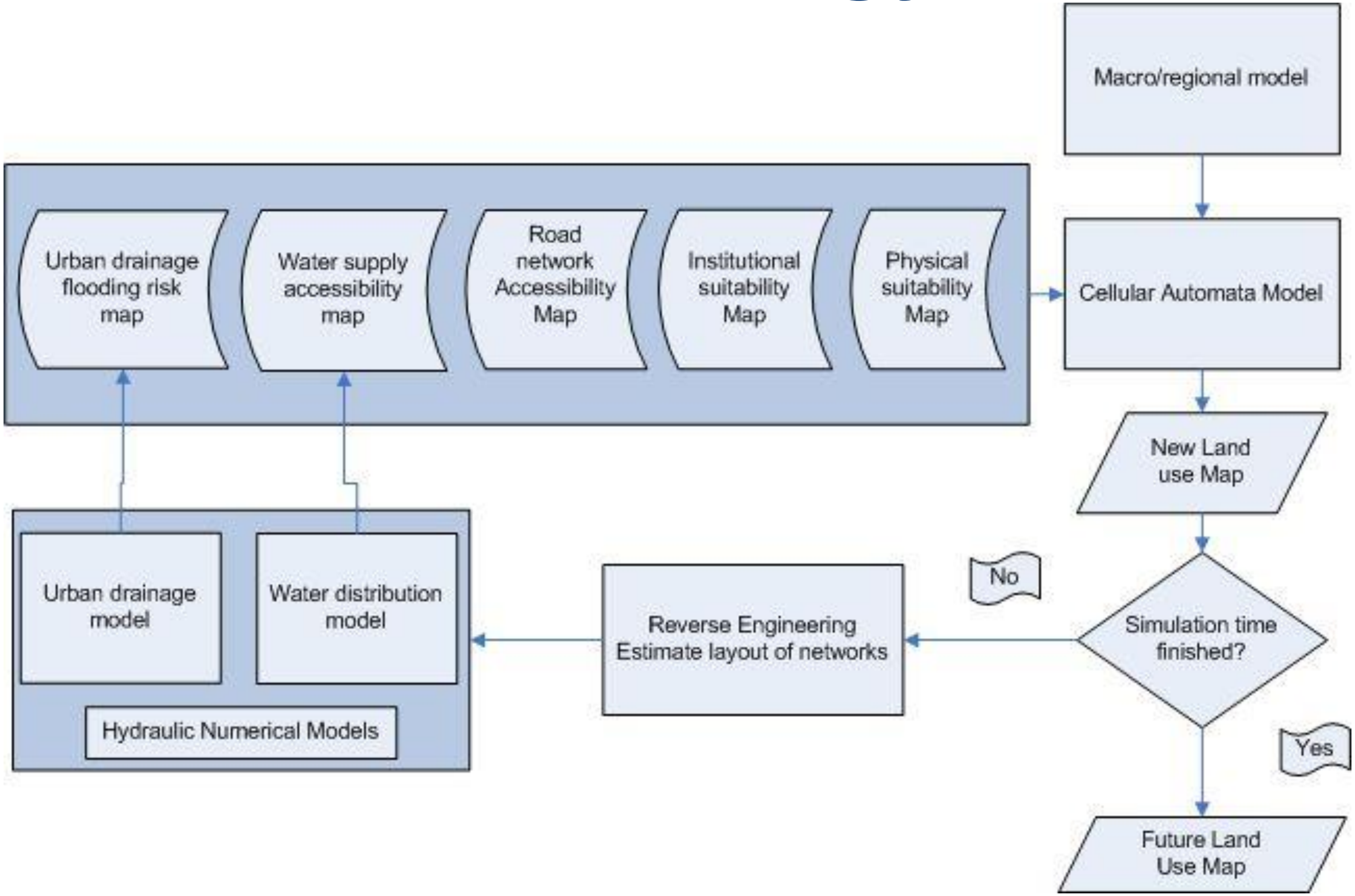






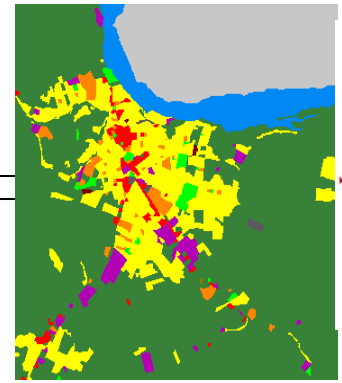
Distance functions	Meaning of the distance function in socio-economic and geographical terms
Effect at distance = 0 of the function on itself	
	Inertia: expressing the strength with which the existing land use will 'stick' to its present location.
Effect at distance = 0 of any other function on the function	
	Ease of re-conversion: the ease with which a new land use will take over from the existing land use (in blue: easy re-conversion, such as in-fill and in red: difficult re-conversion for example re-conversion of brownfields)
Effects at distance > 0	
	No interaction
	Attraction: positive agglomeration benefits diminishing with distance.
	Repulsion: negative agglomeration benefits diminishing with distance
	Changing interaction with distance: from attraction to repulsion or/and vice versa.
	Strong interaction with far neighbours, abruptly falling
	Gradual distance decay,
	Strong interaction with immediate neighbours, gradually falling
	Sphere of influence: *short tail*: the interaction is limited to short distances; *long tail*: the interaction effect works over longer distances.

Methodology



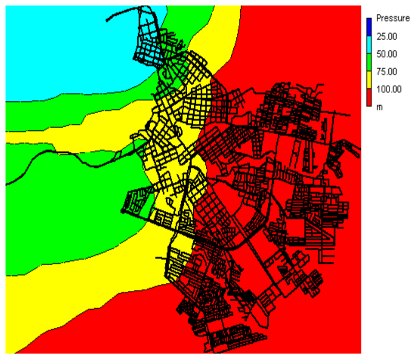
The Modeling Framework

Input : Urban land use map and numerical models of urban water systems



Suitability maps

Considering, elevation, existing infrastructure, water bodies, water quality, water availability.

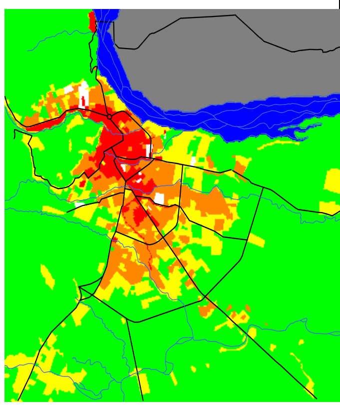


Feedback sub-model

New developments (transitional potential)

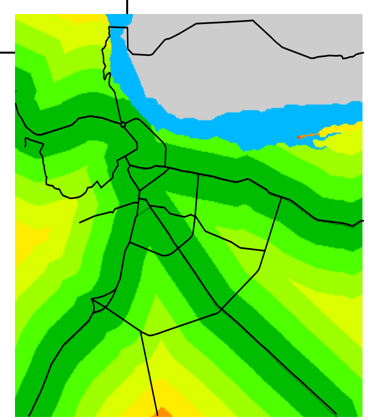
Regional model

Socio-economics, regulations, master plans, legislation.

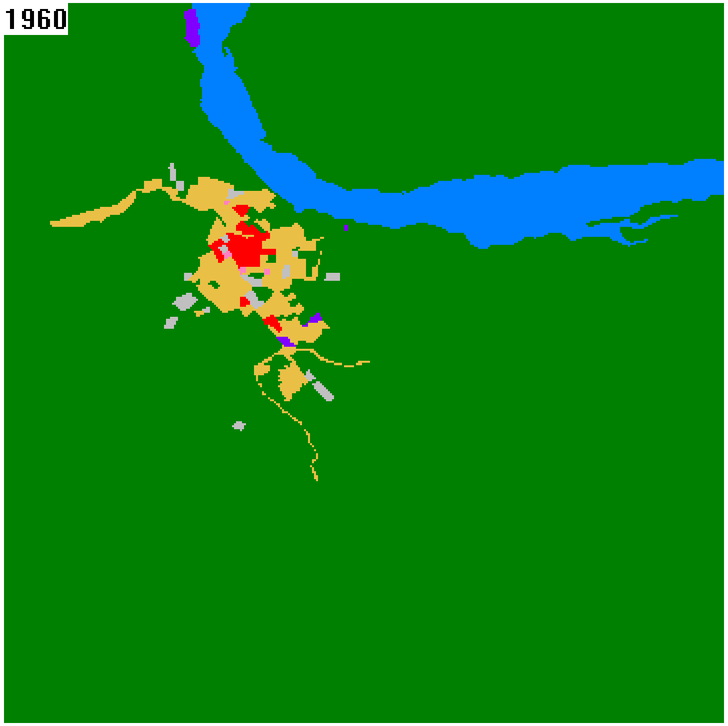


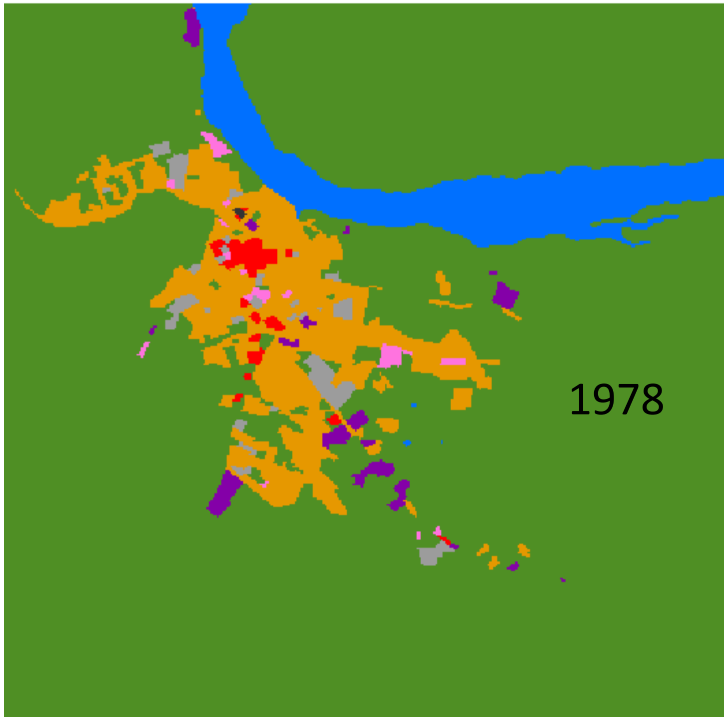
Accessibility map

Road network, Pipe networks, State natural streams.

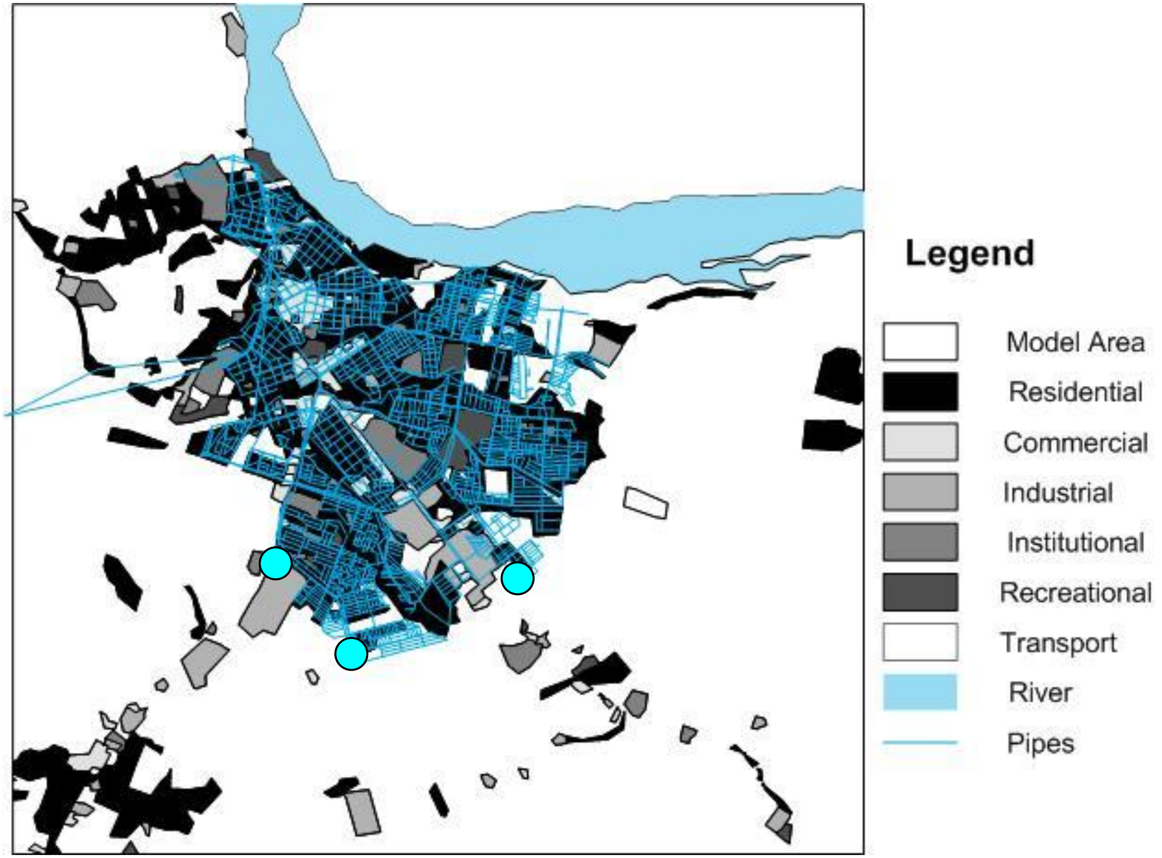


Case Study : The city of Villavicencio located in the south-east part of Colombia with an approximate population of 400.000 inhabitants. Data sets of the land use classification were available for different years. Digital terrain model, main roads and a model for the water distribution system of the city were also available. The water distribution model was build in Epanet 2.0 and consisted of 4100 pipes and 2800 nodes.





Land use changes and expansion of the water distribution network

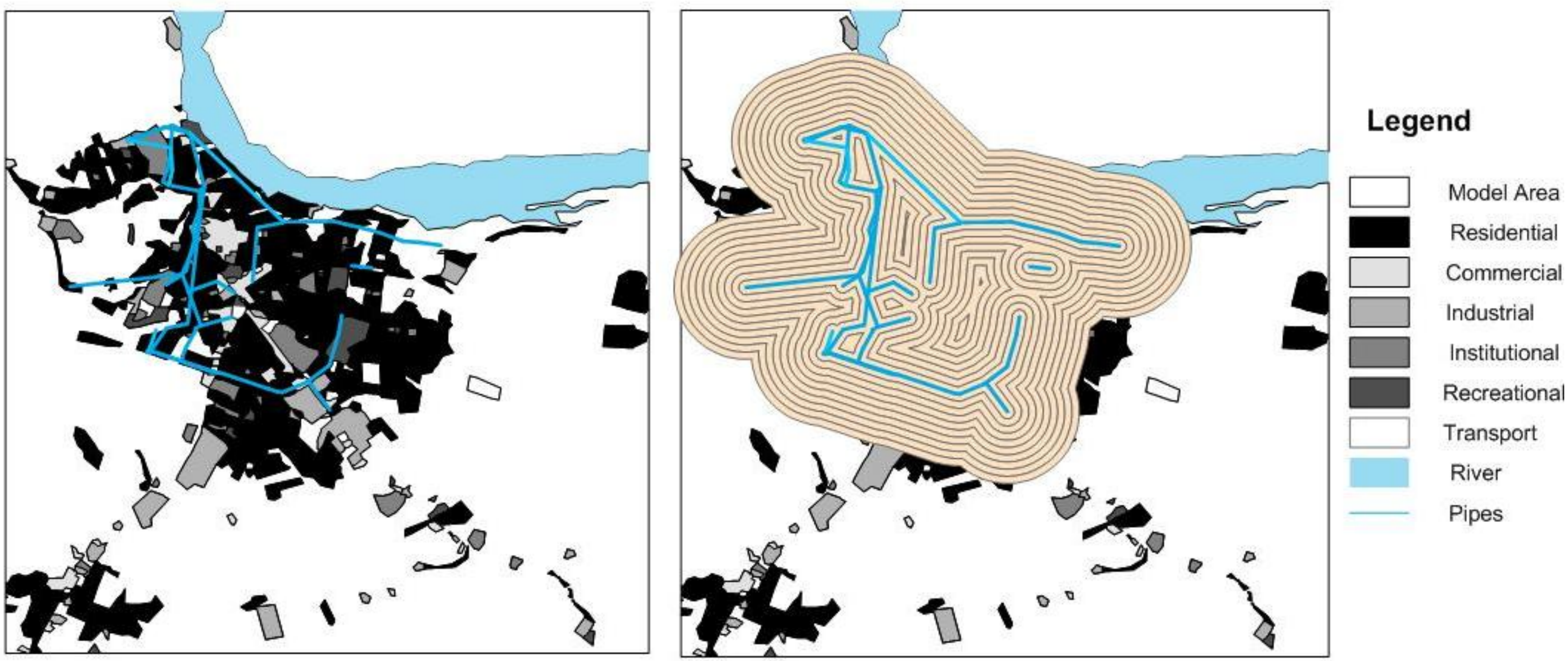


How to connect the new developments predicted by the CA with the existing network infrastructure?

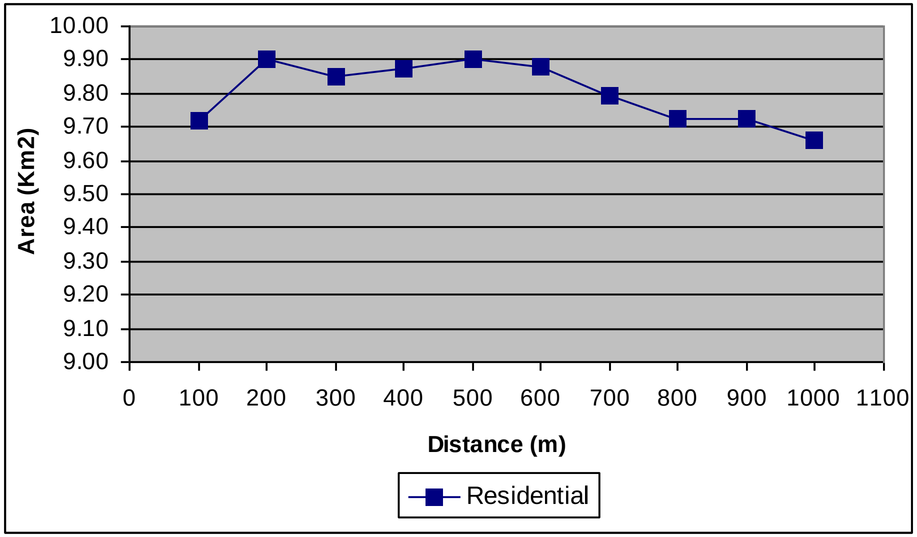
Corridor Analysis

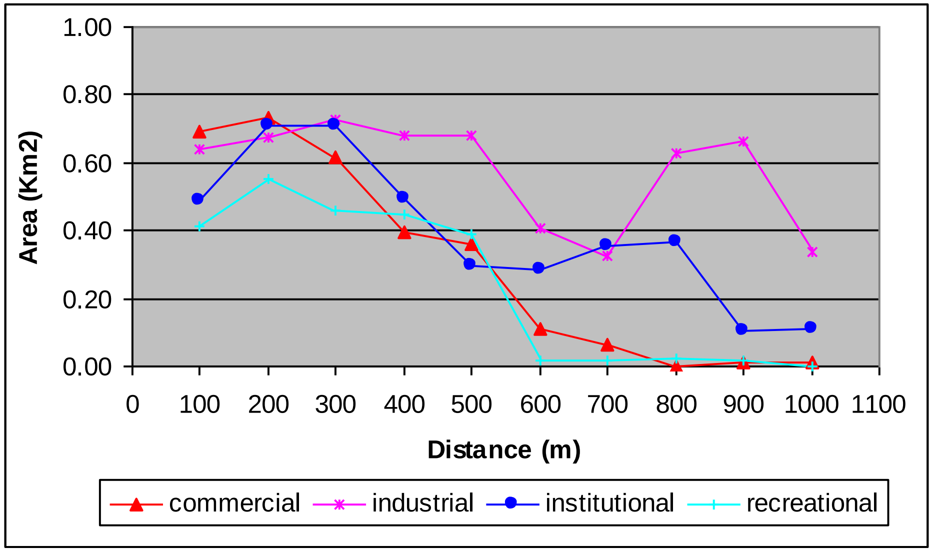
Main ring of the system – Select pipes above certain threshold

Create corridors every 100 m. meters till 1000 m. to cover the existing system



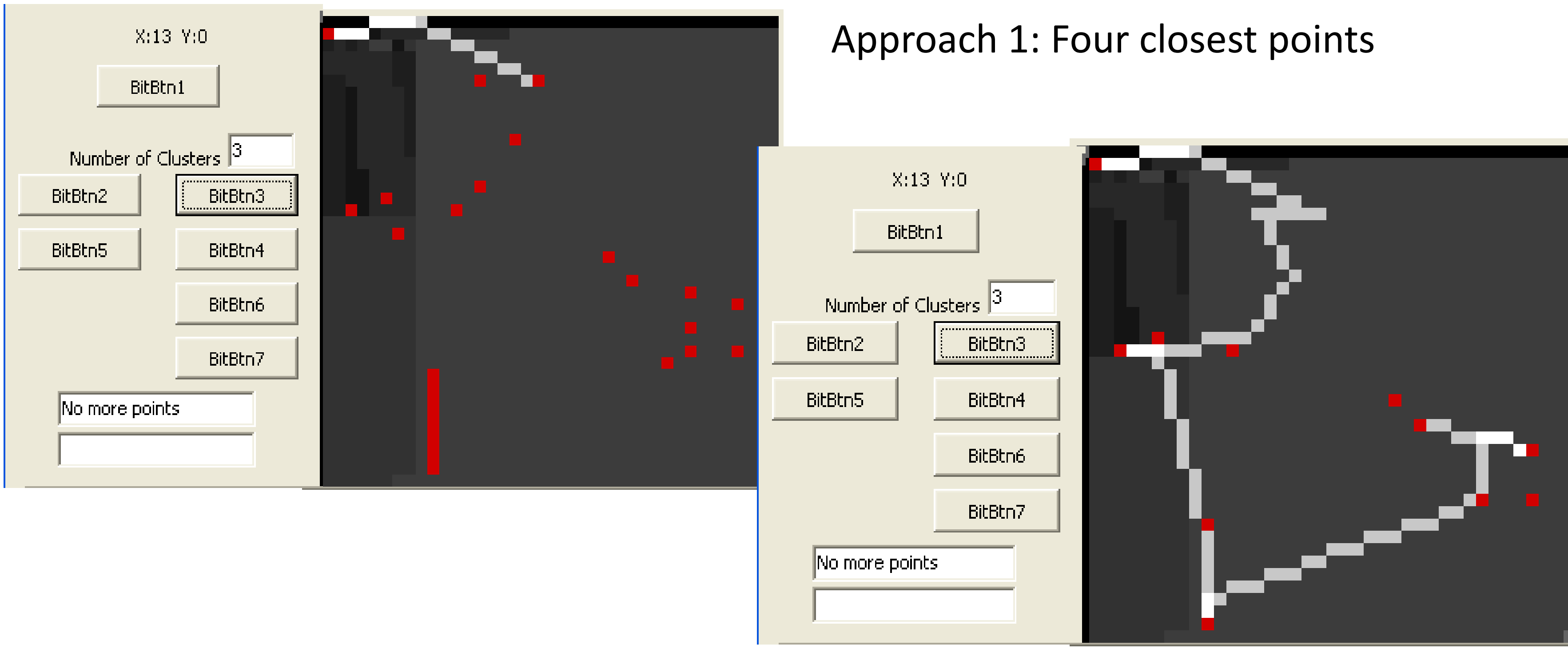
Distribution of intercepted area per land use categories



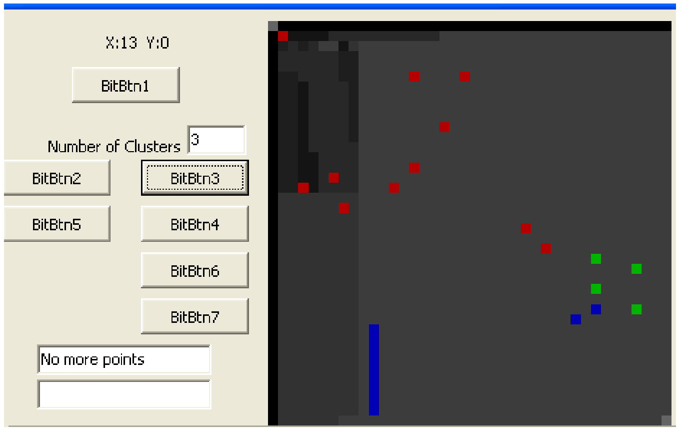


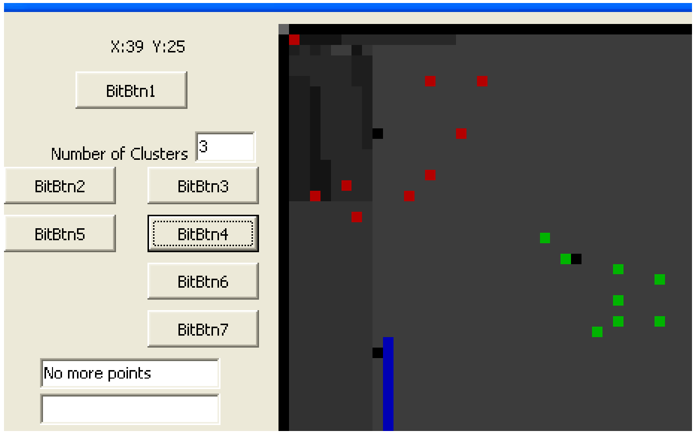
Extending the Network

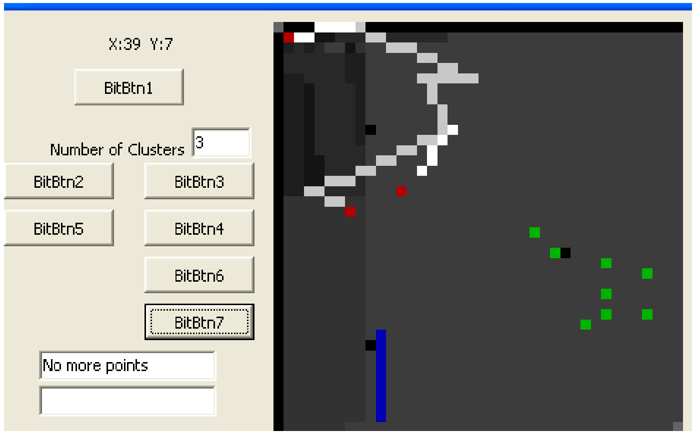
Approach 1: Four closest points

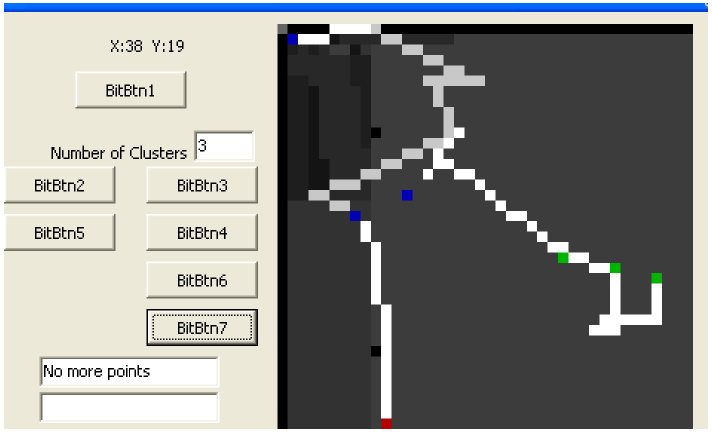


Approach 2: Clustering and Four closest points









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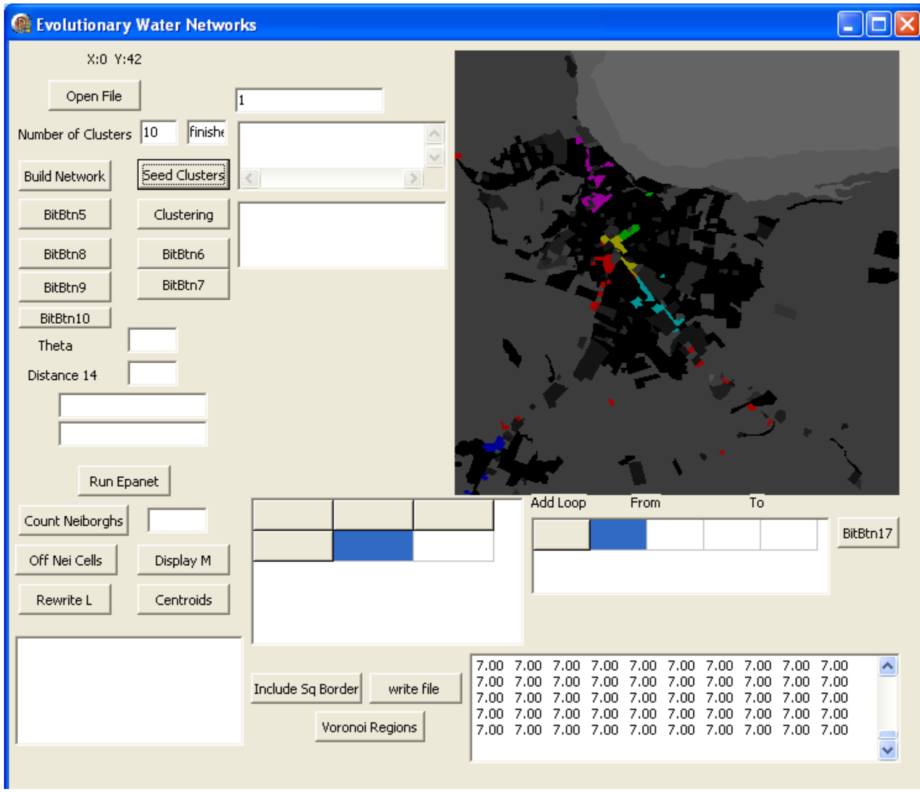
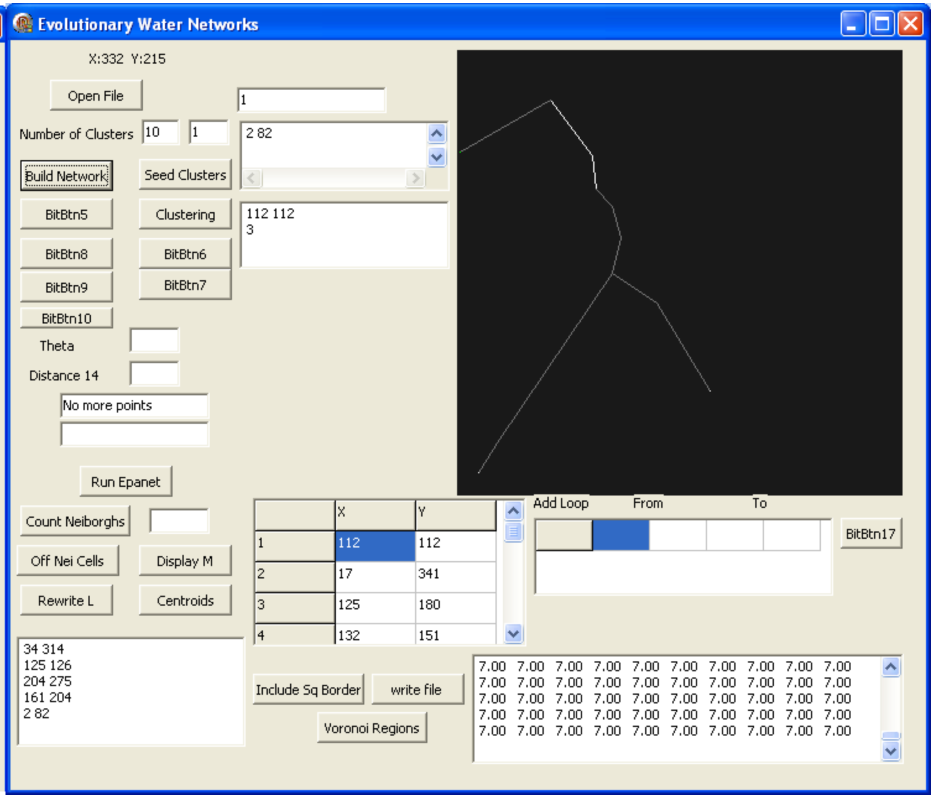
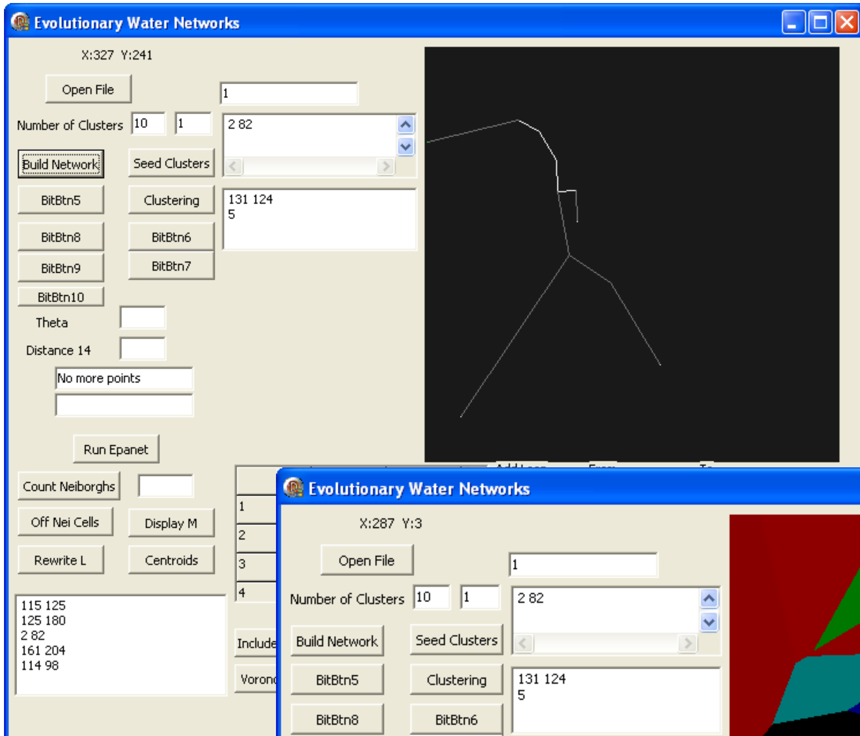
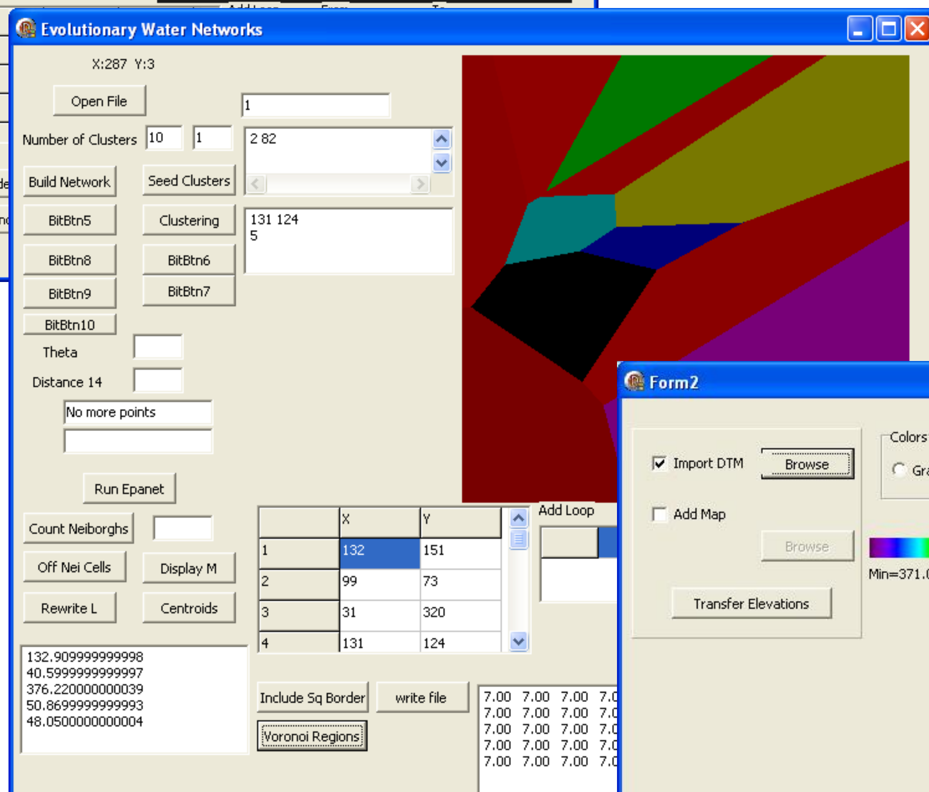
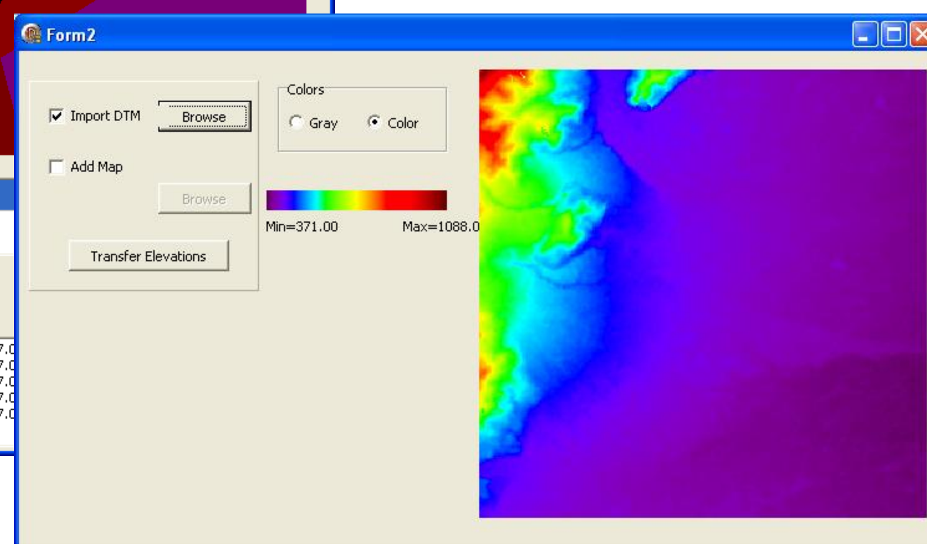




Approach 2: Distributing Demands and preparing the Epanet input file



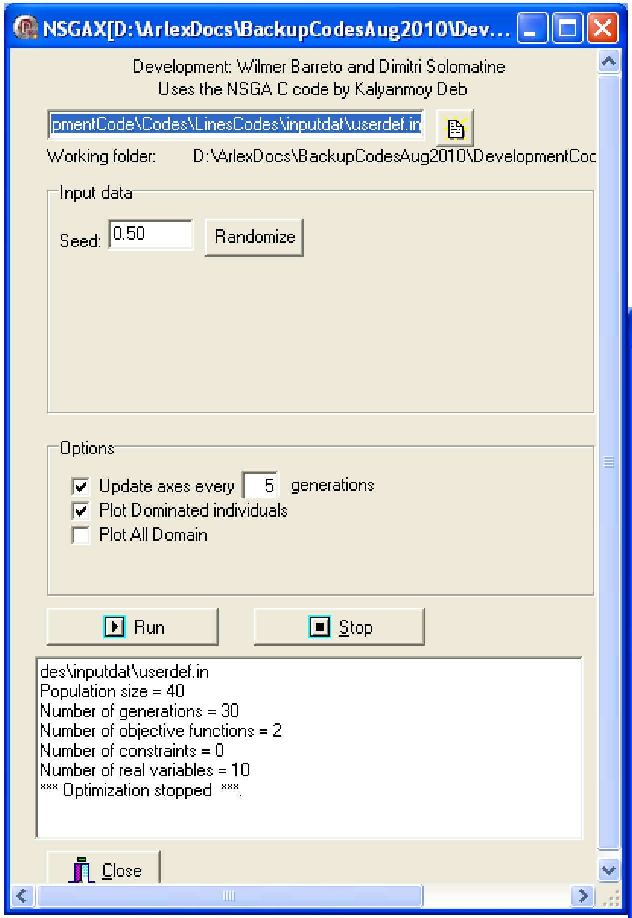


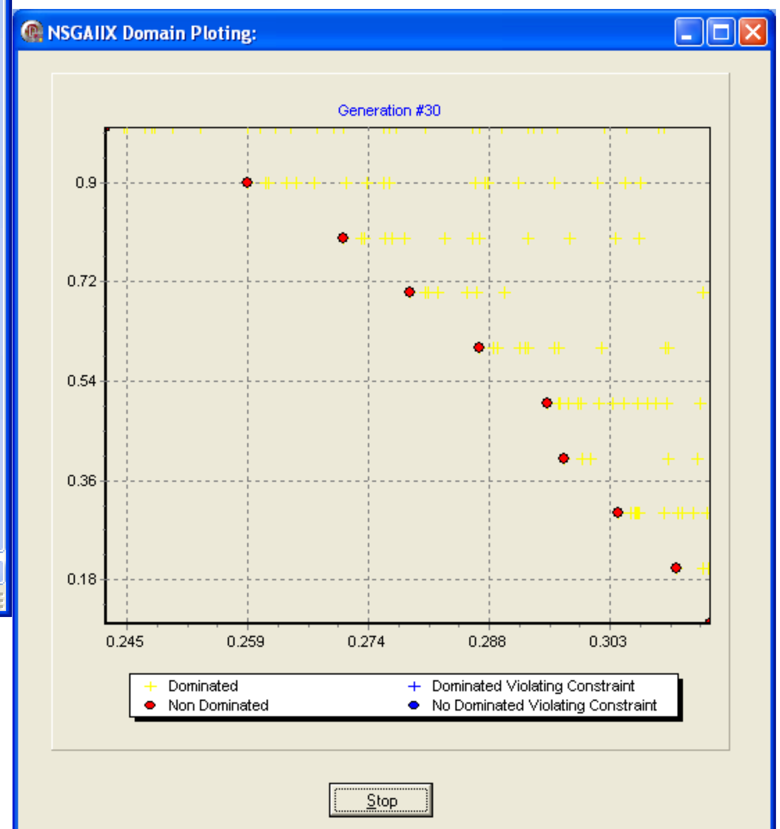


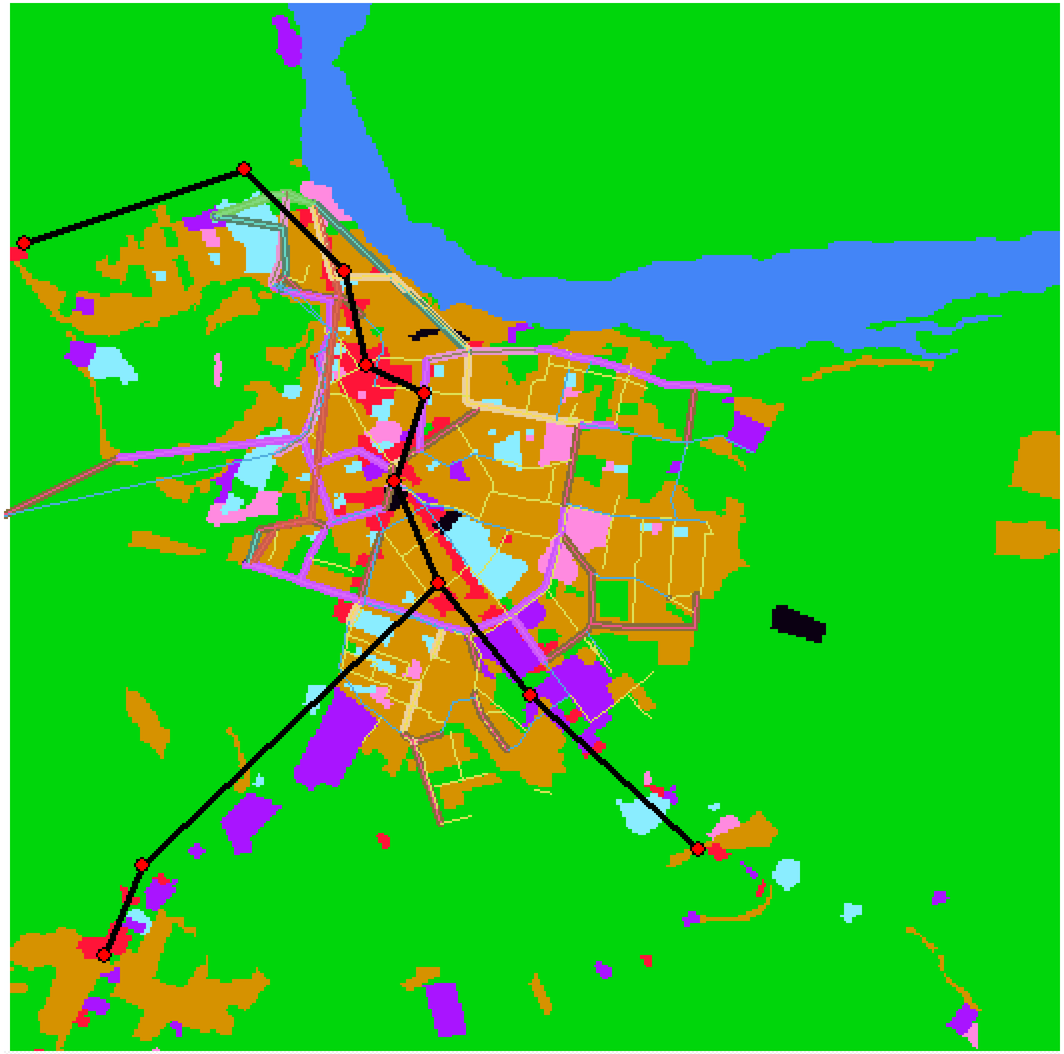
Sizing the Network layout

Optimization using NSGA II

2 Objective functions: Cost and pressure above 15 m







One of the Best Solutions (Pin)

The general layout of the main trunks looks good.

The Diameters are in the same interval (350-800 mm)

CONCLUSIONS

The analysis done with the corridors along the main pipes and the distribution of land use can be used to find some of the rules to setup the reverse engineering algorithm. The reverse engineering algorithm can draw an updated layout of the network that can be used to derive a new performance of the system that plays in the following time steps of the cellular automata urban growth model.

The development of this approach is an on going task. Some of the steps that are currently under evaluation are:
Sizing the system
Determine fine network layout (with costs)
Rehabilitation of existing network (impact on existing infrastructure)

The urban drainage component can be done in a similar way. We are expecting that topography and the existing road network will have a stronger influence in the layout of the drainage network.