HV-Consult ApS

Wastewater-Talk
Sulfide Balance in Drainage Systems

Jes Vollertsen, Professor of Environmental Engineering, Aalborg University
Owner of HV-Consult (Denmark) and shareholder of The WATS Guys (USA)

Nobody (but us) loves her sewers

The public doesn't want to

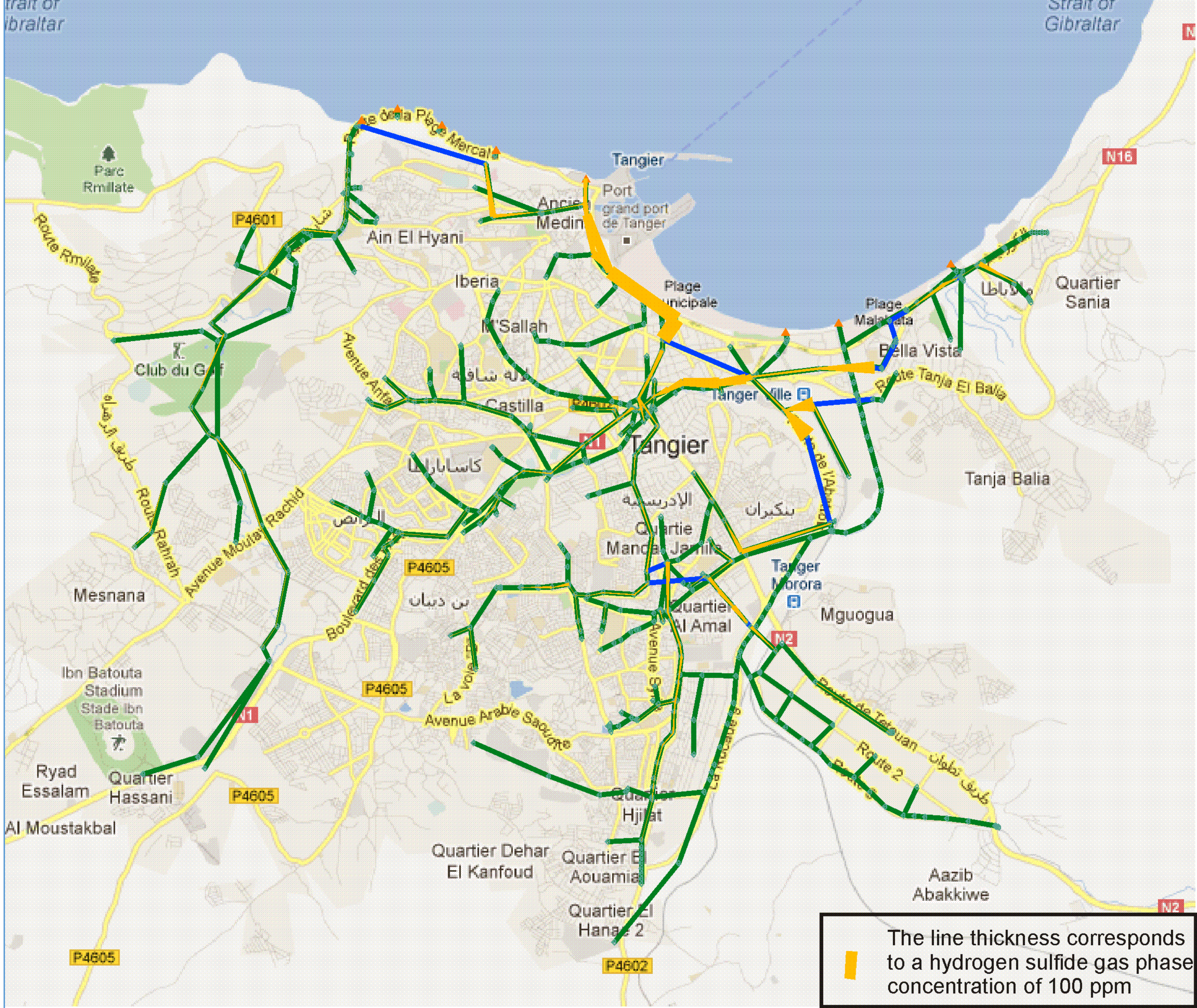
- Know about them
- See them (or the wastewater)
- Smell them
- The public simply wants to ignore their existence

BUT: The public wants their service,
without interruption and fuss

Foto: www.sewerhistory.org

That’s why there are no ice cream stands, coffee shops, and people at the beach !!!

Sewer process modelling shows where and why we have the problem

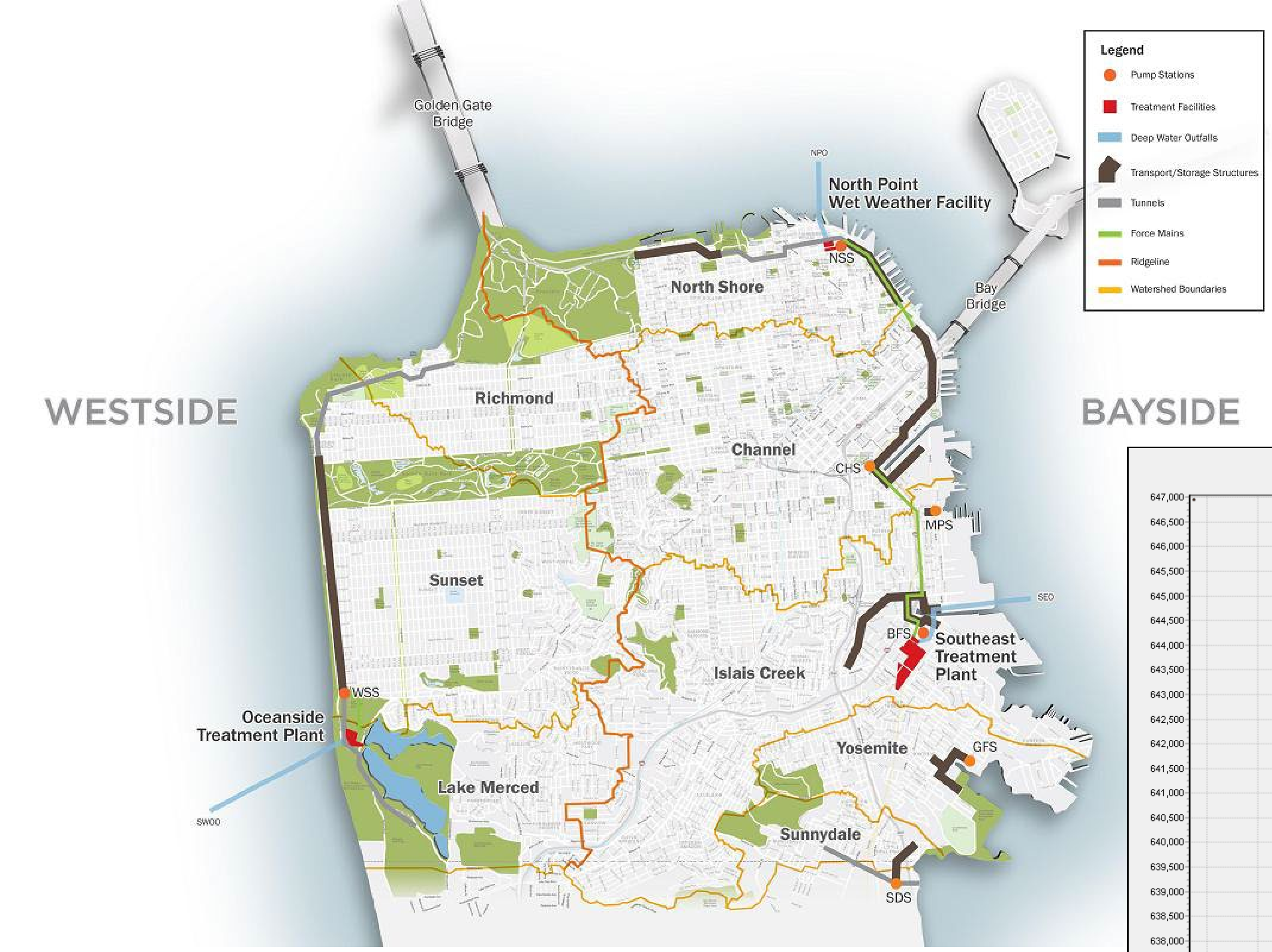


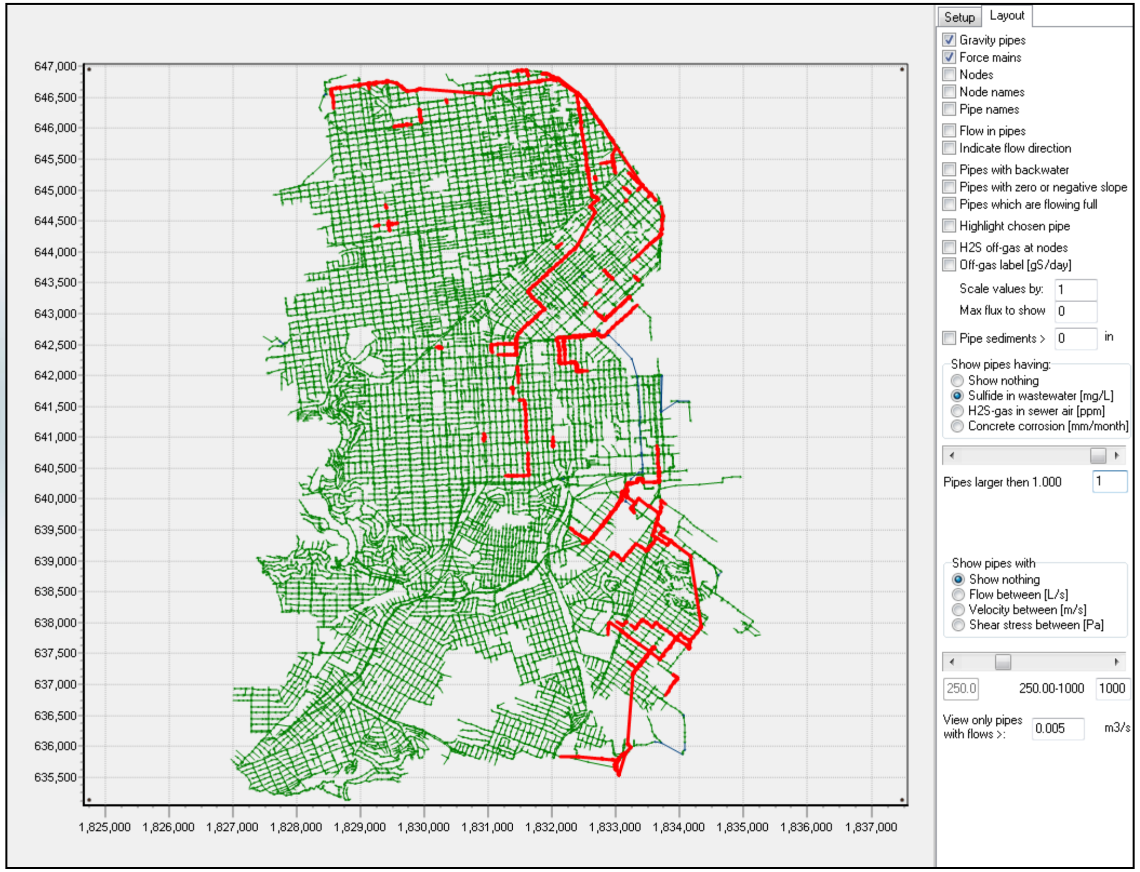
THE WALL STREET JOURNAL

Residents Turn Up Noses at Sewer Stink Cure

Most San Franciscans have learned to live with foul sewer smells that come and go along the city's waterfront, Mission Bay and some other neighborhoods. But some residents are finding a growing effort by the city to combat the odors too objectionable to ignore.

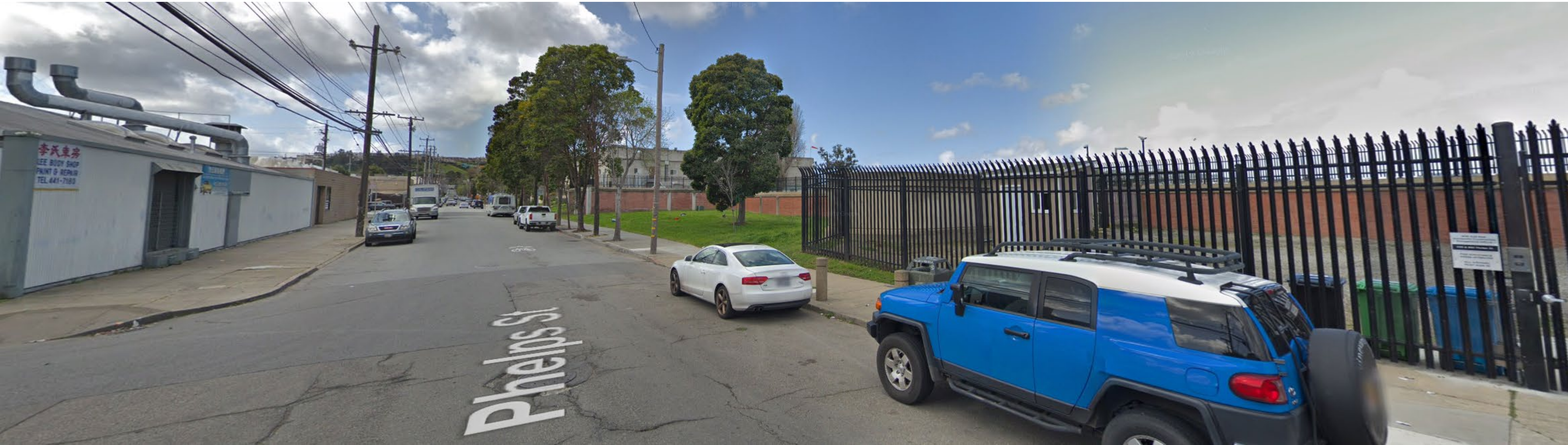
Sewer process modelling helps finding solutions





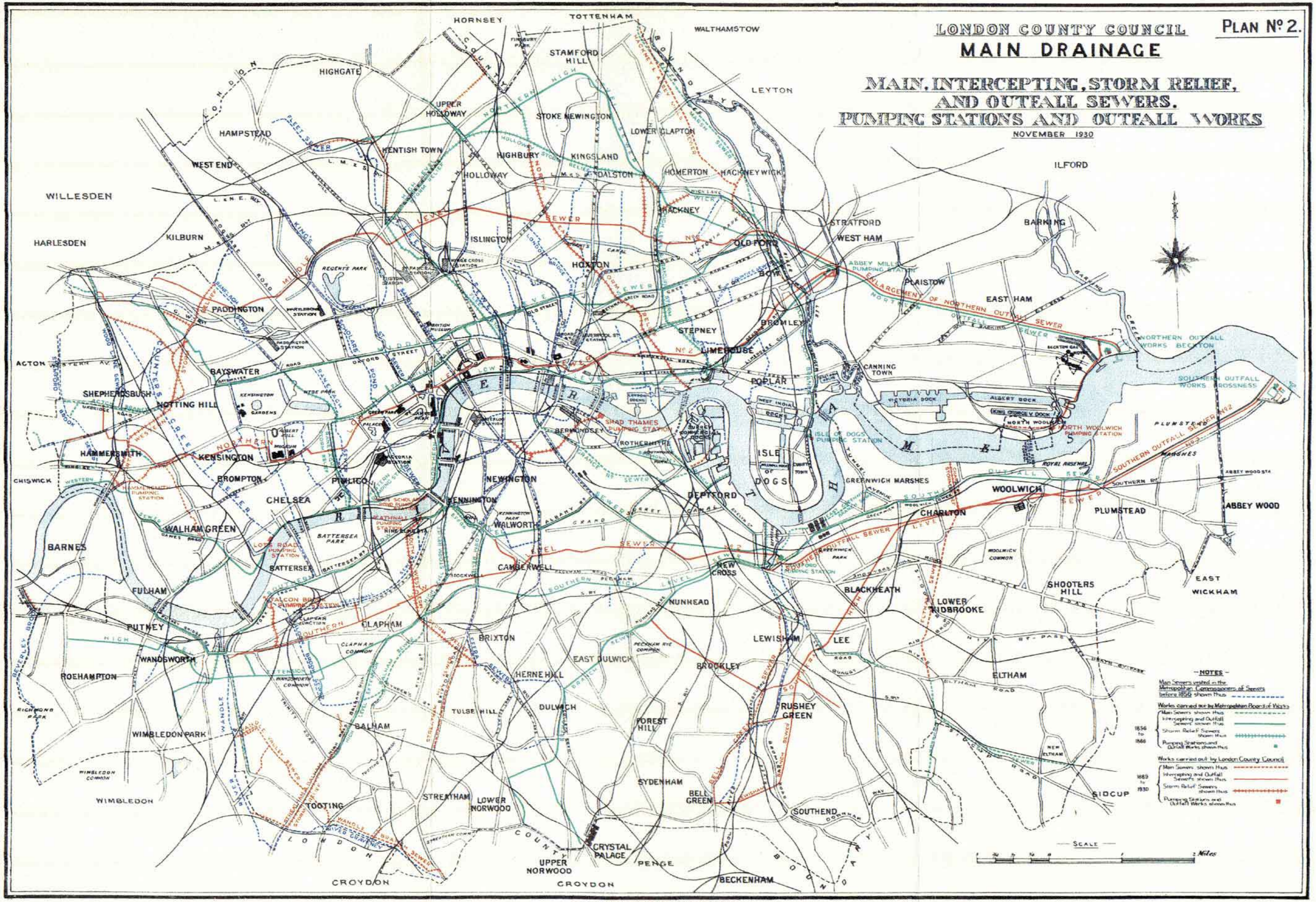
Whether odor is an issue or not, depends on the quality of the neighborhood

(no taxi driver wants to pick you up where the San Francisco treatment plant is located …)



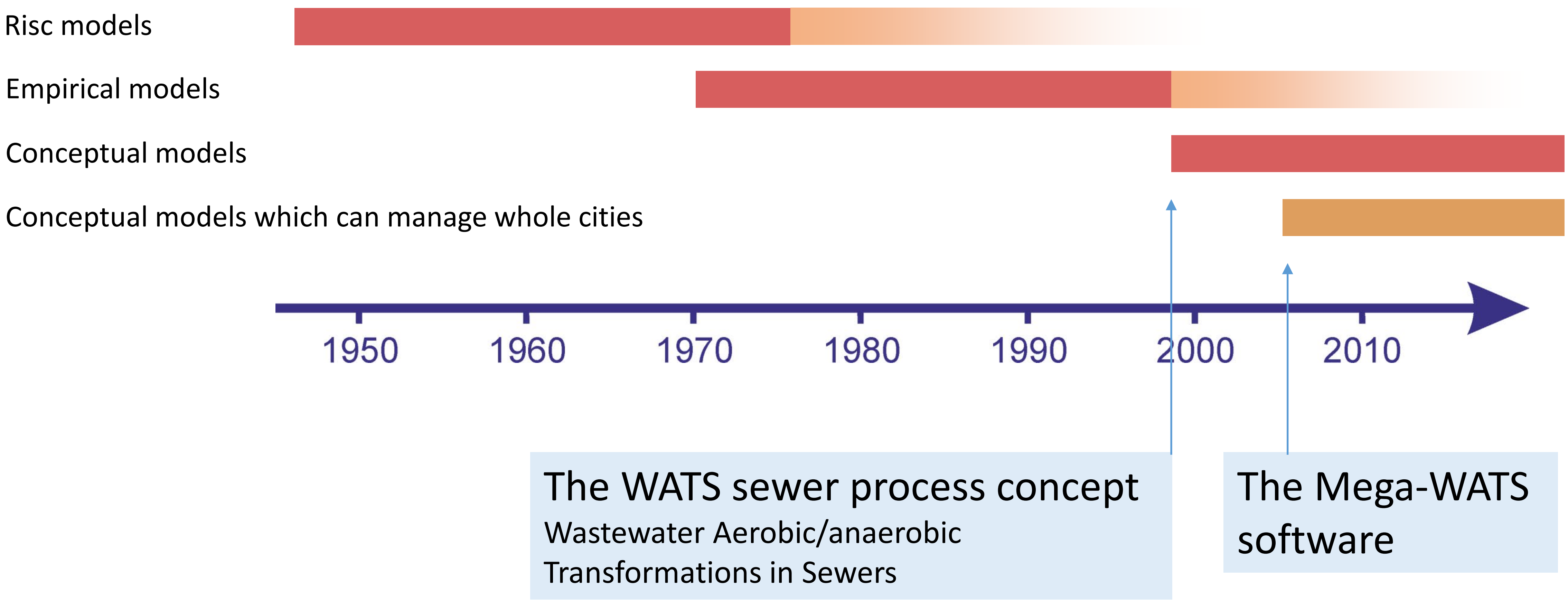
Sewers are quite complex systems

How to keep track of the chemical, physical, and biological processes within them?



Modelling helps keeping track of complex systems

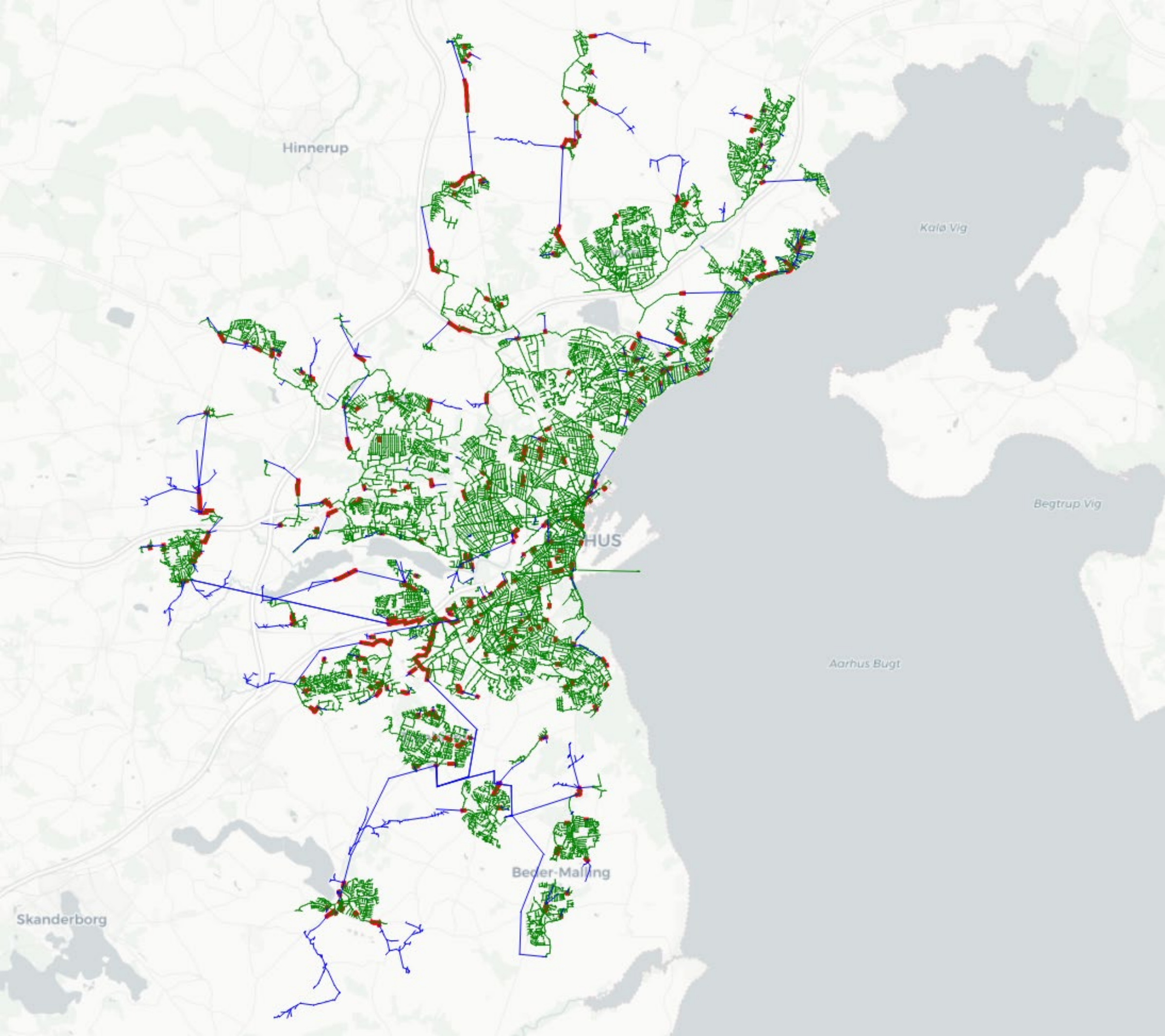
The history of sewer process modelling:



Mega-WATS simulates whole cities for odour, corrosion, and more

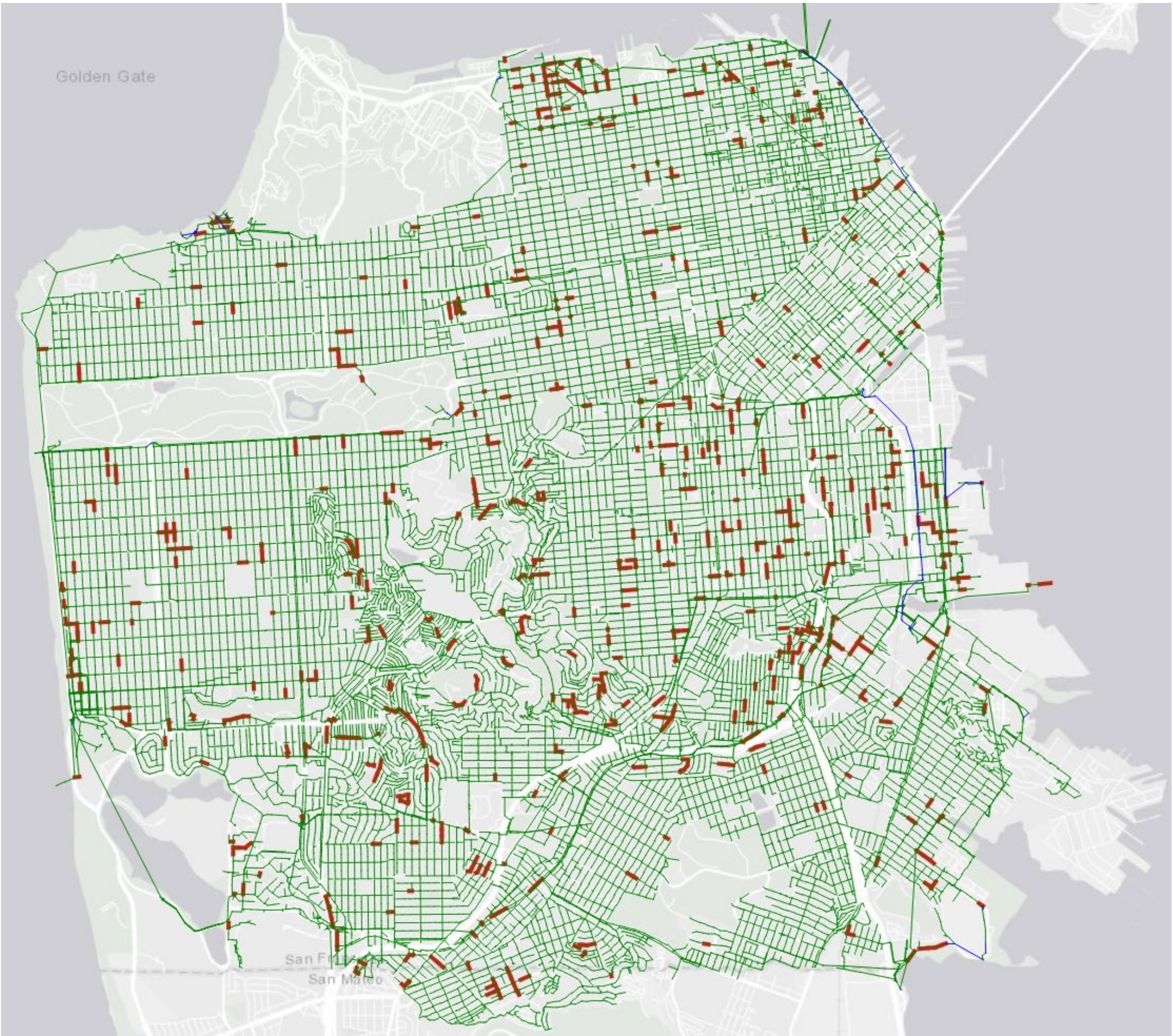
Aarhus, Denmark

Sewer air H_2S >1 ppm

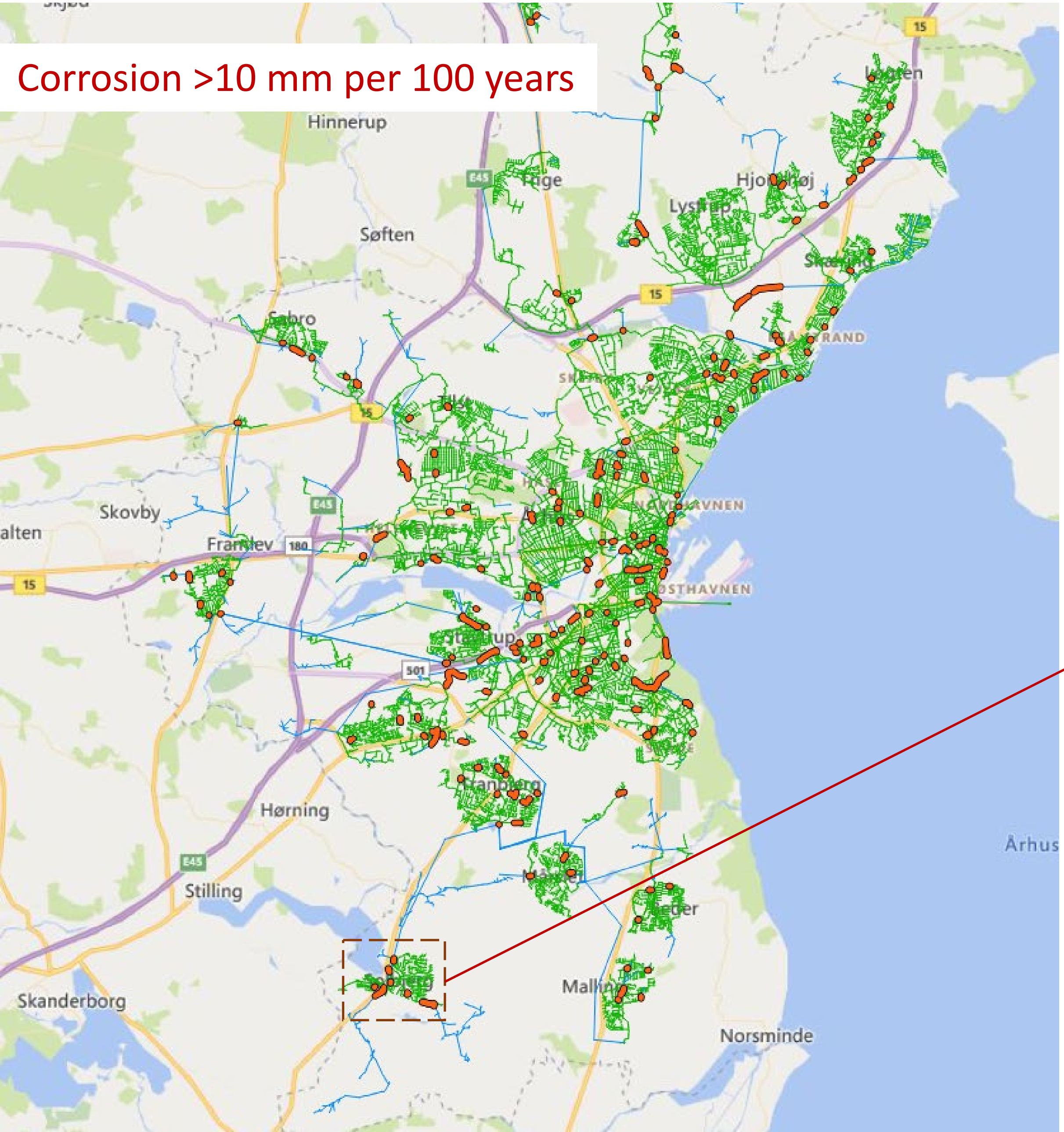


San Francisco, California, USA

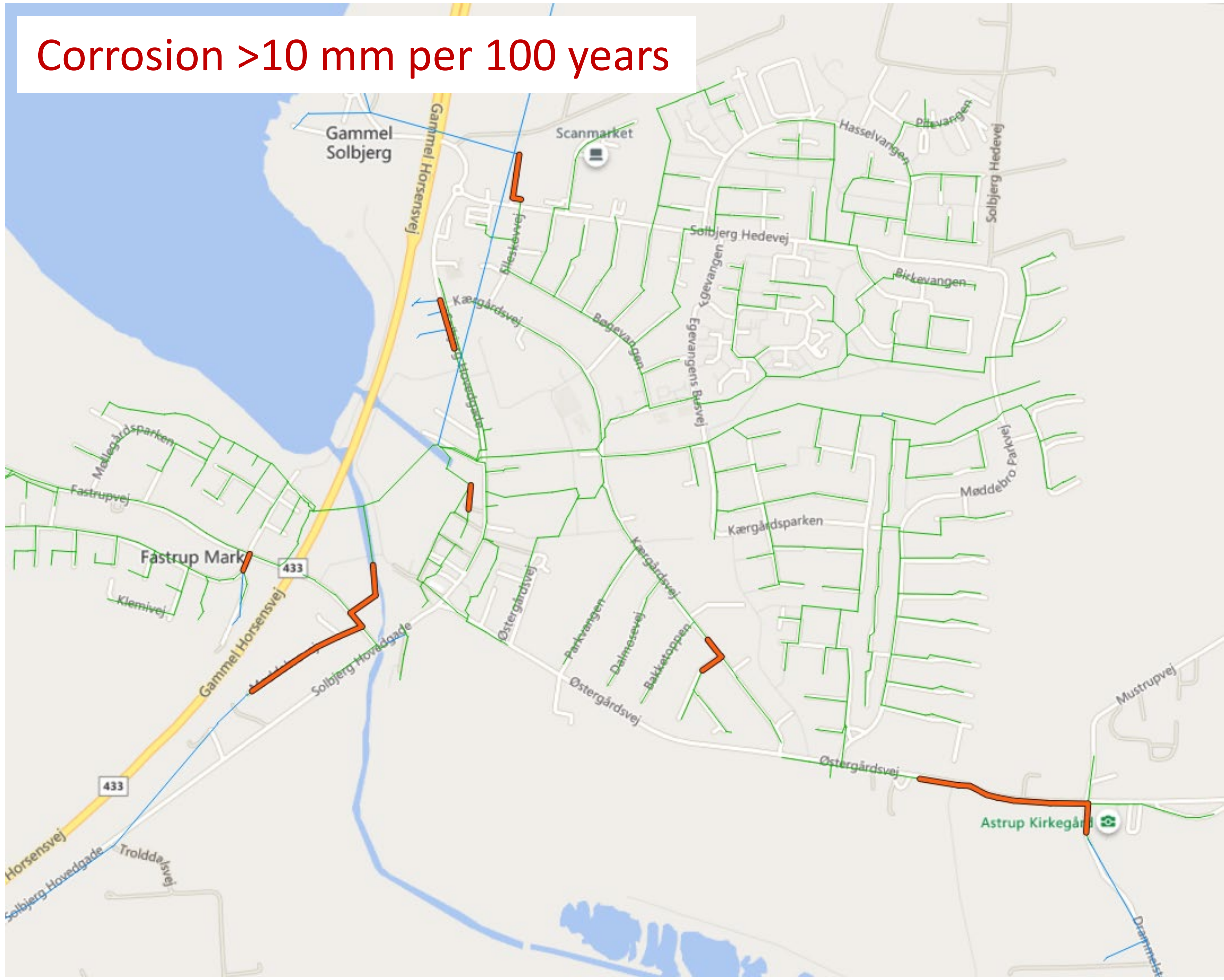
Sewer air H_2S >1 ppm



Getting an overview (Aarhus, Denmark)



Zooming in on the details



What the WATS concept covers

- Biological processes
  - Aerobic transformations (oxygen is present)
  - Anoxic transformations (nitrate is present, no oxygen)
  - Anaerobic transformations (sulphide, mercaptans, methane)
- Chemical processes
  - Oxidation
  - Precipitation
  - Liquid-gas mass transfer
  - Wastewater buffer system: pH, alkalinity
- Hydraulics
  - Rout water through the network (semi-steady state, non-uniform flow)
  - Rout air through the network (balancing water drag and pipe friction)
  - Gas release to the urban atmosphere (balancing air flows)
- Management solutions
  - Ferric Iron, Ferrous Iron, Hypochlorite, Hydrogen peroxide, Nitrate, Oxygen, Magnesium hydroxide, Sodium hydroxide, Forced ventilation, and more
- Stochastic modelling for extreme event statistics and sensitivity analysis

Sewer processes are simulated by solving a large number of coupled non-linear differential equations describing processes.

This is akin to the approach of Activated Sludge models, Anaerobic Digester models, and similar engineering process models

The concept contains many processes and parameters

Substance	Compound #	Unit	Buffer equation
Carbonate	31	e	
Sulfide ($S_{(-II)}$)	13	e	
Acetic acid (VFA) (S_A)	2a	e	
Propionic acid (VFA) (S_A)	2b	e	
Ammonia	32	e	
Amines	33	e	
Phosphate	34	e	
Bisulfate	35	e	
Carboxyl groups other than acetic and propionic acid	36	e	

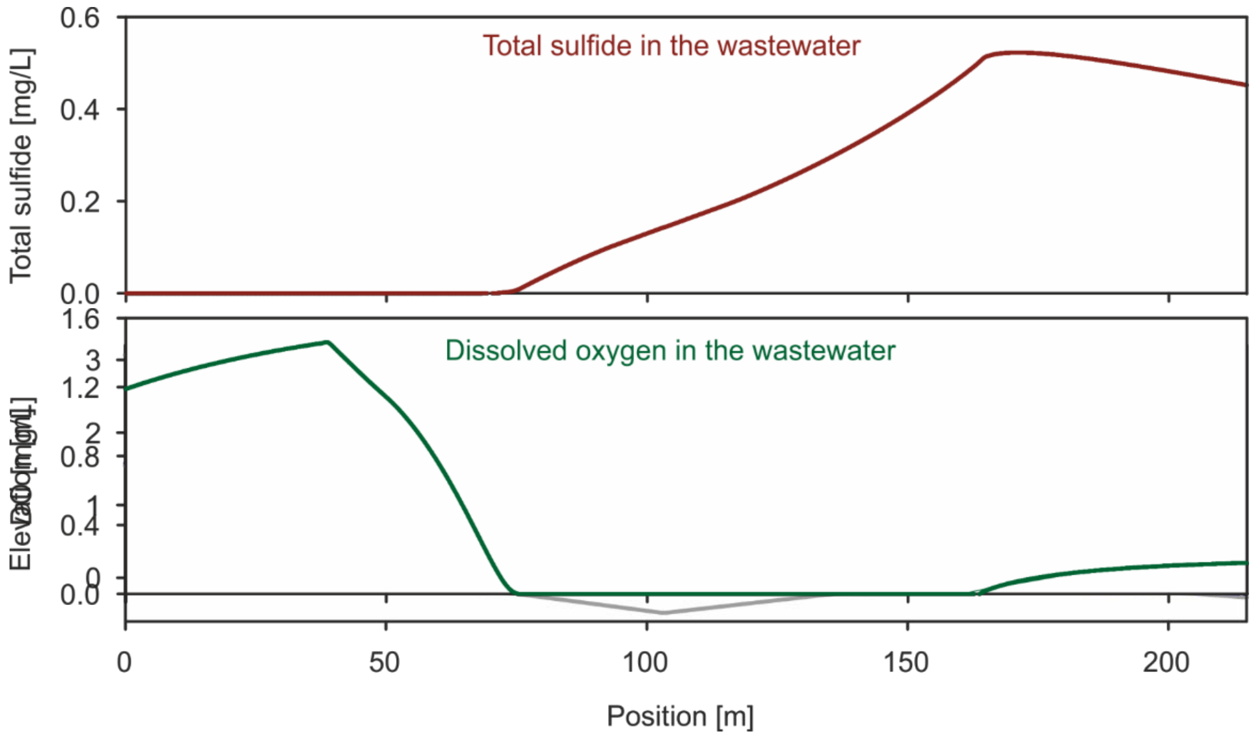
Gas phase processes and liquid-gas mass transfer

	Process #
Oxygen mass transfer, between liquid and gas	62
CO_2 mass transfer between liquid and gas	63
H_2S mass transfer between liquid and gas	64
Methyl mercaptane mass transfer between liquid and gas	65
H_2S absorbed on a pipe wall	66
H_2S oxidation, concrete	67
Sulfuric acid corrosion, concrete	68

Type of process		Process equations
Bulk water growth		
Aerobic growth in bulk water	69	
Anoxic growth on NO_3^- in bulk water	70	
Anoxic growth on NO_3^- in bulk water	71	
Aerobic maintenance in bulk water	72	
Anoxic maintenance in bulk water when NO_3 is present	73	
Anoxic maintenance in bulk water when NO_3 is absent	74	
Minimum total bulk water maintenance rate	75	If r4 + r5 + r6 is less than the minimum maintenance rate given above, then the
Aerobic growth in biofilm	76	
Anoxic growth in biofilm on NO_3	77	
Anoxic growth in biofilm on NO_3	78	
Hydrolysis		
Aerobic hydrolysis, $X_{S,fast}$, in bulk water	79	
Aerobic hydrolysis, $X_{S,med}$, in bulk water	80	
Aerobic hydrolysis, $X_{S,slow}$, in bulk water	81	
Anoxic hydrolysis, $X_{S,fast}$, in bulk water	82	
Anoxic hydrolysis, $X_{S,med}$, in bulk water	83	
Anoxic hydrolysis, $X_{S,slow}$, in bulk water	84	
Anaerobic hydrolysis, $X_{S,fast}$, in bulk water	85	
Anaerobic hydrolysis, $X_{S,med}$, in bulk water	86	
Anaerobic hydrolysis, $X_{S,slow}$, in bulk water	87	
Aerobic hydrolysis, $X_{S,fast}$, in biofilm	88	
Aerobic hydrolysis, $X_{S,med}$, in biofilm	89	
Aerobic hydrolysis, $X_{S,slow}$, in biofilm	90	
Anoxic hydrolysis, $X_{S,fast}$, in biofilm	91	
Anoxic hydrolysis, $X_{S,med}$, in biofilm	92	
Anoxic hydrolysis, $X_{S,slow}$, in biofilm	93	
Anaerobic hydrolysis, $X_{S,fast}$, in biofilm	94	
Anaerobic hydrolysis, $X_{S,med}$, in biofilm	95	
Anaerobic hydrolysis, $X_{S,slow}$, in biofilm	96	
Fermentation		
Anaerobic fermentation, biofilm, on S_F	97	
Anaerobic fermentation, bulk water, on S_F	98	
Anaerobic fermentation, biofilm, on X_F	99	
Anaerobic fermentation, bulk water, on X_F	100	
Decay of fermenters	101	

Methyl mercaptan formation		
Anaerobic formation	102	
Aerobic oxidation	103	
H_2S formation		
H_2S formation, biofilm, on S_F (+S_A)	104	If (S_O>10*$K_{O,HS}$) or ((S_{NO3}+S_{NO2})>10*$K_{NO,HS}$) then rate = 0
H_2S formation, bulk water, on S_F (+S_A)	105	
H_2S formation, biofilm, on X_F	106	If (S_O>10*$K_{O,HS}$) or ((S_{NO3}+S_{NO2})>10*$K_{NO,HS}$) then rate = 0
H_2S formation, bulk water, on X_F	107	
Decay of sulfate reducers	108	
H_2S oxidation, water		
Sulfide oxidation, aerobic, chemical, bulk water	109	
Sulfide oxidation, aerobic, biological, bulk water	110	
Sulfide oxidation, aerobic, biofilm	111	
Sulfide oxidation, anoxic, chemical, bulk water	112	
Sulfide oxidation, anoxic, biological, bulk water	113	
Sulfide oxidation, anoxic, biofilm	114	
H_2S precipitation		
Ferrous and ferric precipitation of sulfide	115	If S(-II) < $C_{pe(S-II)}$ then instantaneous, else zero; (obs this is a stoichiometric parameter which did not physically fit into the table)
Chemical oxidation		
Oxidation of sulfide by H_2O_2	116	
Oxidation of organic matter by H_2O_2	117	
Oxidation of sulfide by NaOCl	118	
Oxidation of organic matter by NaOCl	119	
Transport between phases		
Oxygen mass transfer, between liquid and gas	120	For a drop KLaO2 is calculated from an empirical equation for the oxygen deficit ratio. The oxygen deficit ratio is converted into a KLa value as ... For a hydraulic minor loss, the energy loss in m water column is used as H_{drop}
CO_2 mass transfer between liquid and gas	121	
H_2S mass transfer between liquid and gas	122	
Methyl mercaptane mass transfer between liquid and gas	123	
Tracer gas (any type of solubility in water)	124	
H_2S oxidation, gas		
H_2S absorbed on a pipe wall	125	
H_2S oxidation, concrete	126	Instantaneous
Sulfuric acid corrosion, concrete	127	Instantaneous

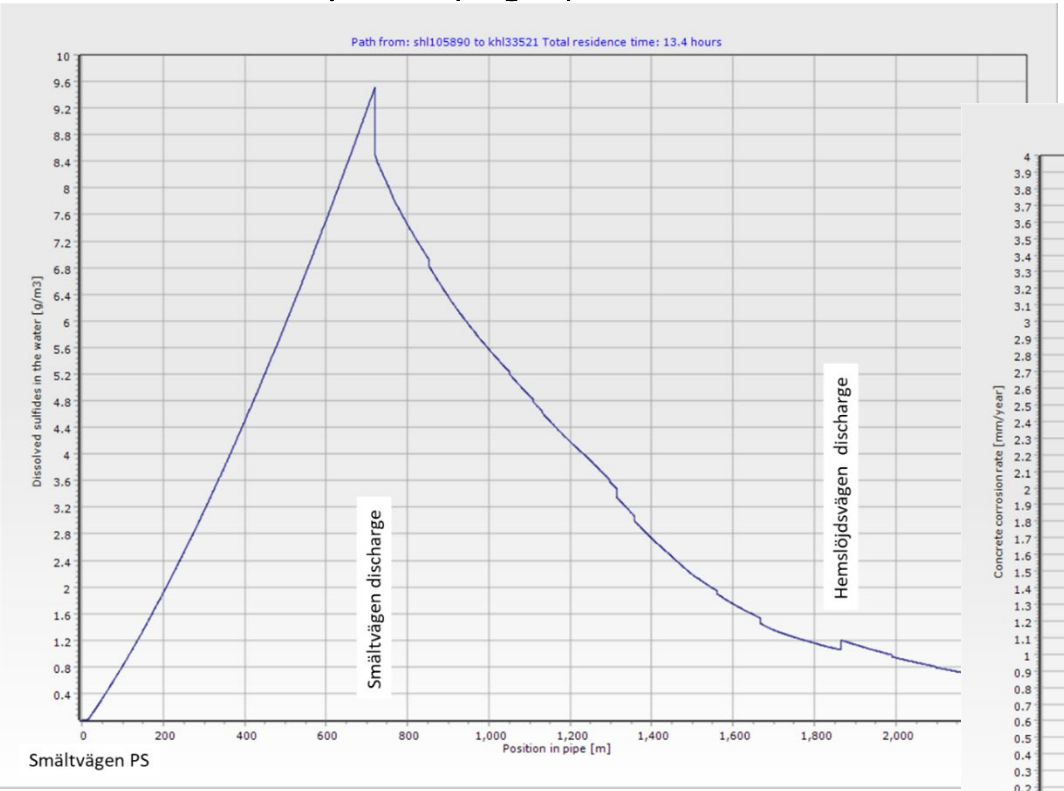
Each pipe is simulated, meter for meter



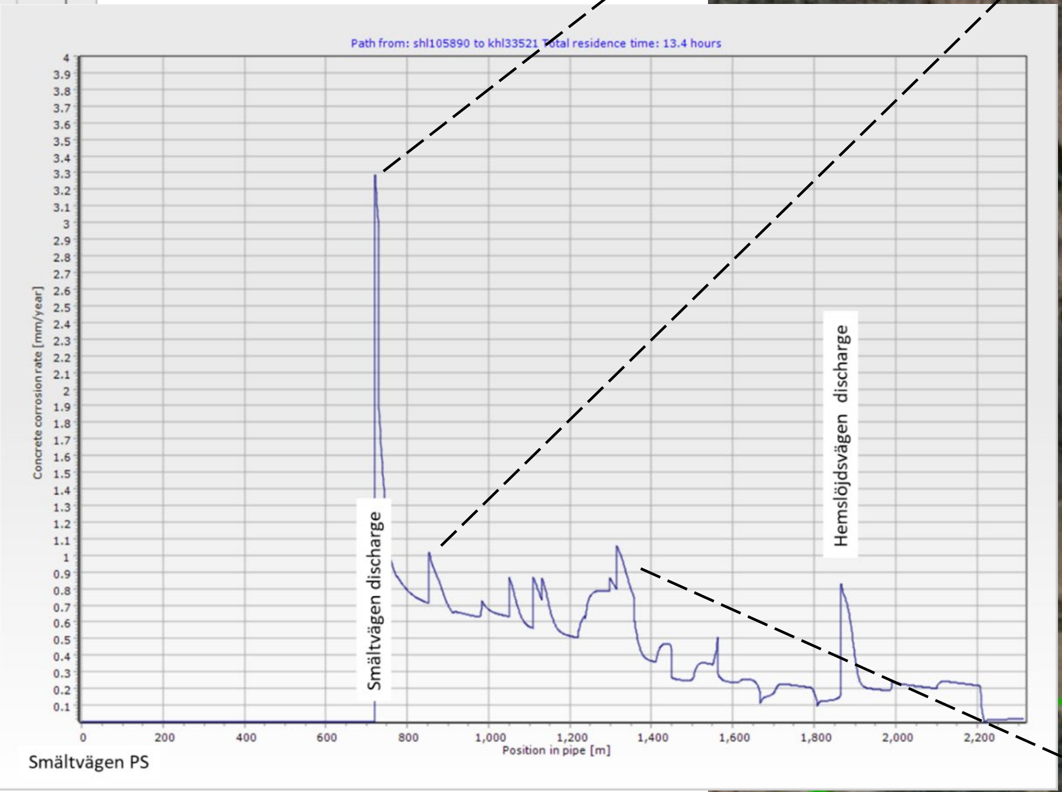
A simulation example
– 215 m of gravity pipe with backwater

Stockholm – Smältvägen force main

Dissolved sulphide (mg/L)



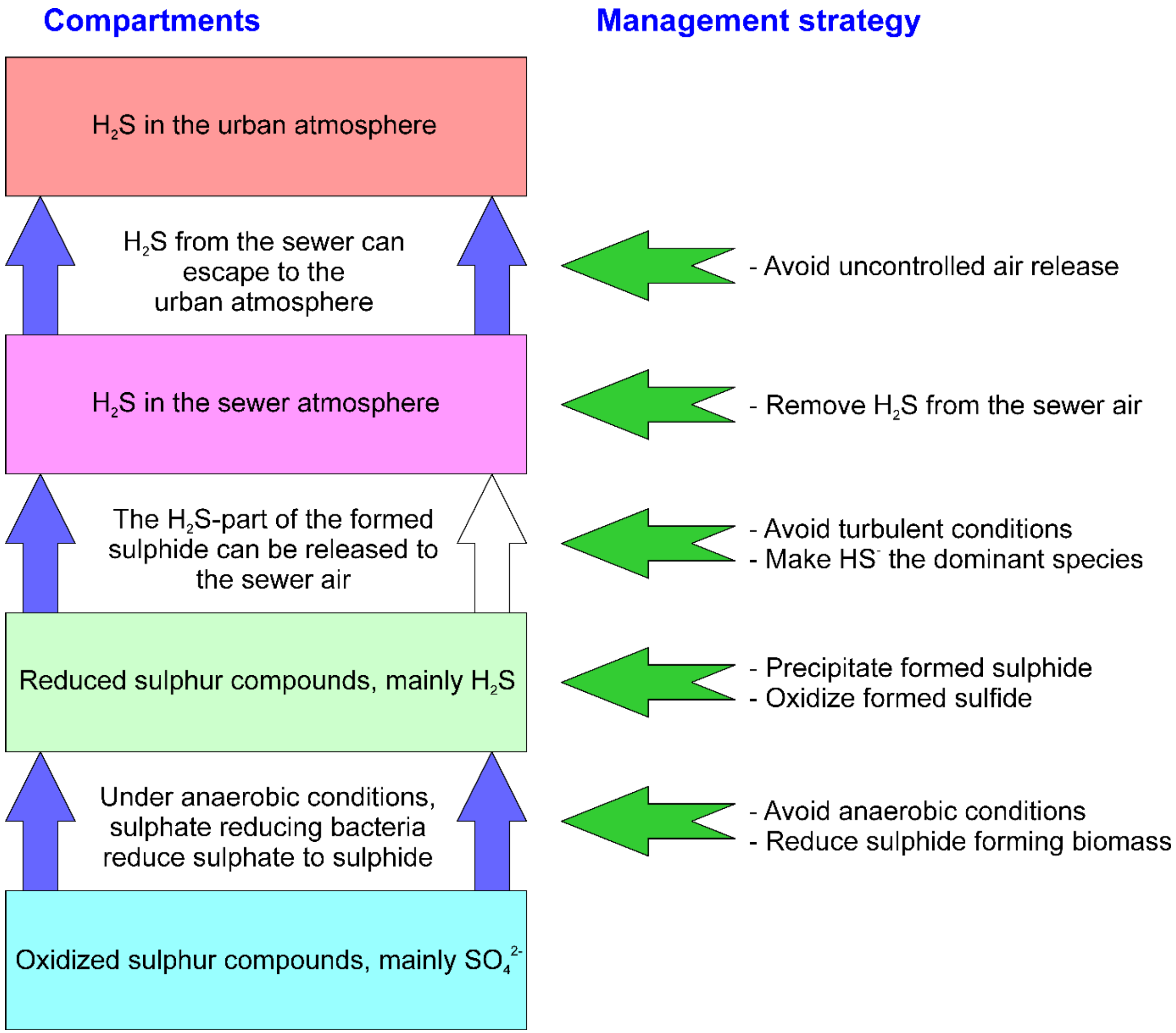
Concrete corrosion (mm/y)



Identifying solutions

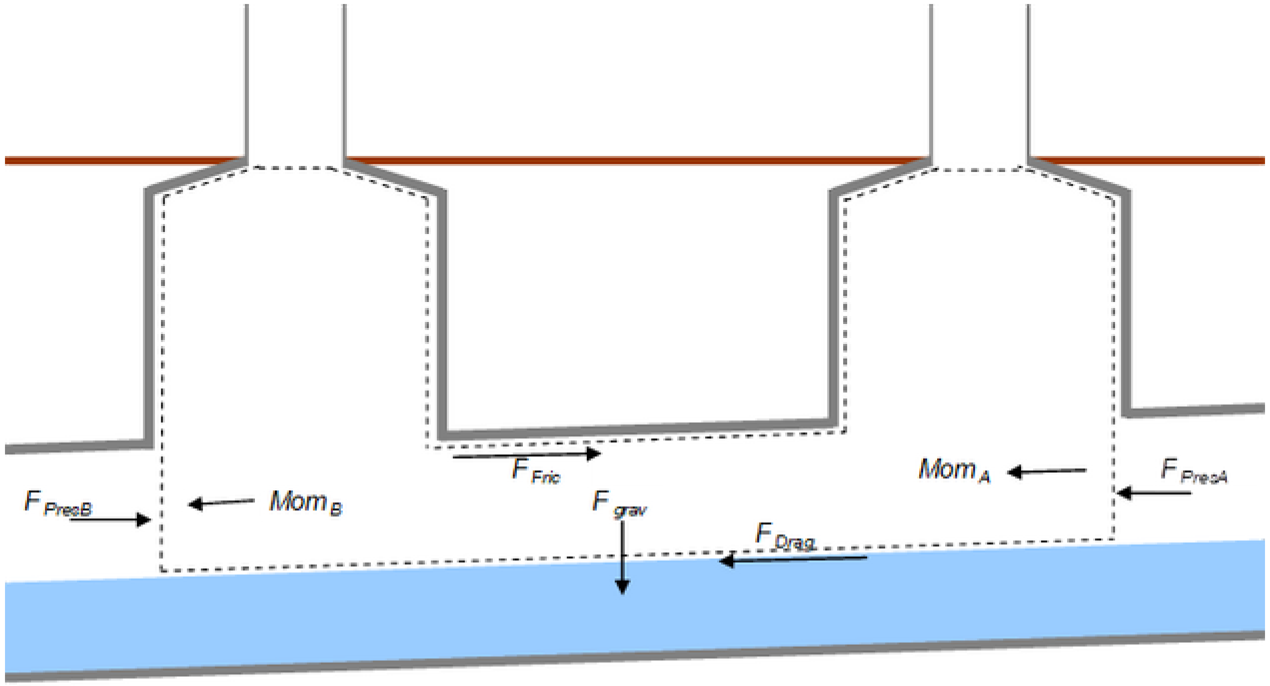
There are many tools in the toolbox

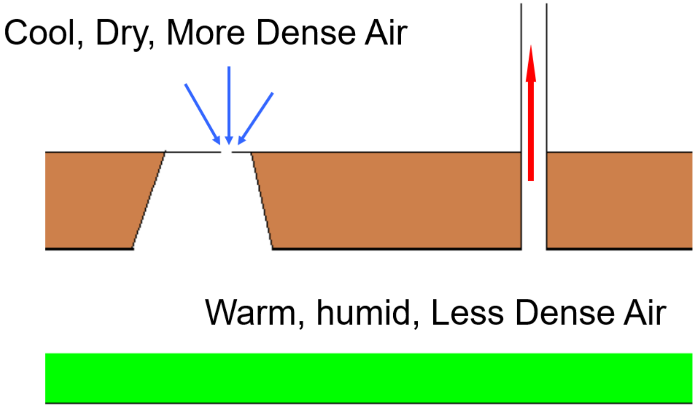
They can be tested by the model before running expensive field trials



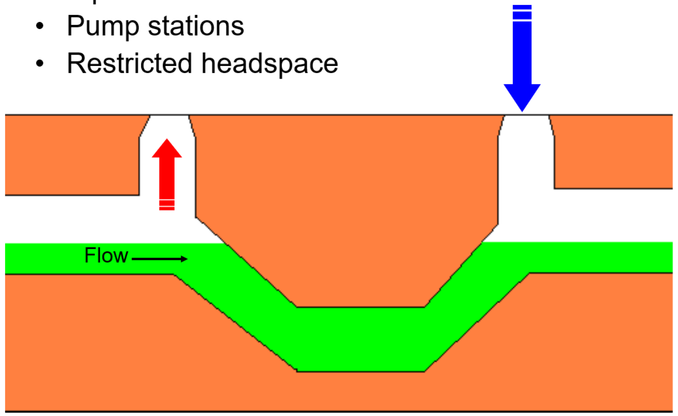
Mega-Vent

Solves the momentum balance of the air flow
Gives pressure and air velocities in all pipes

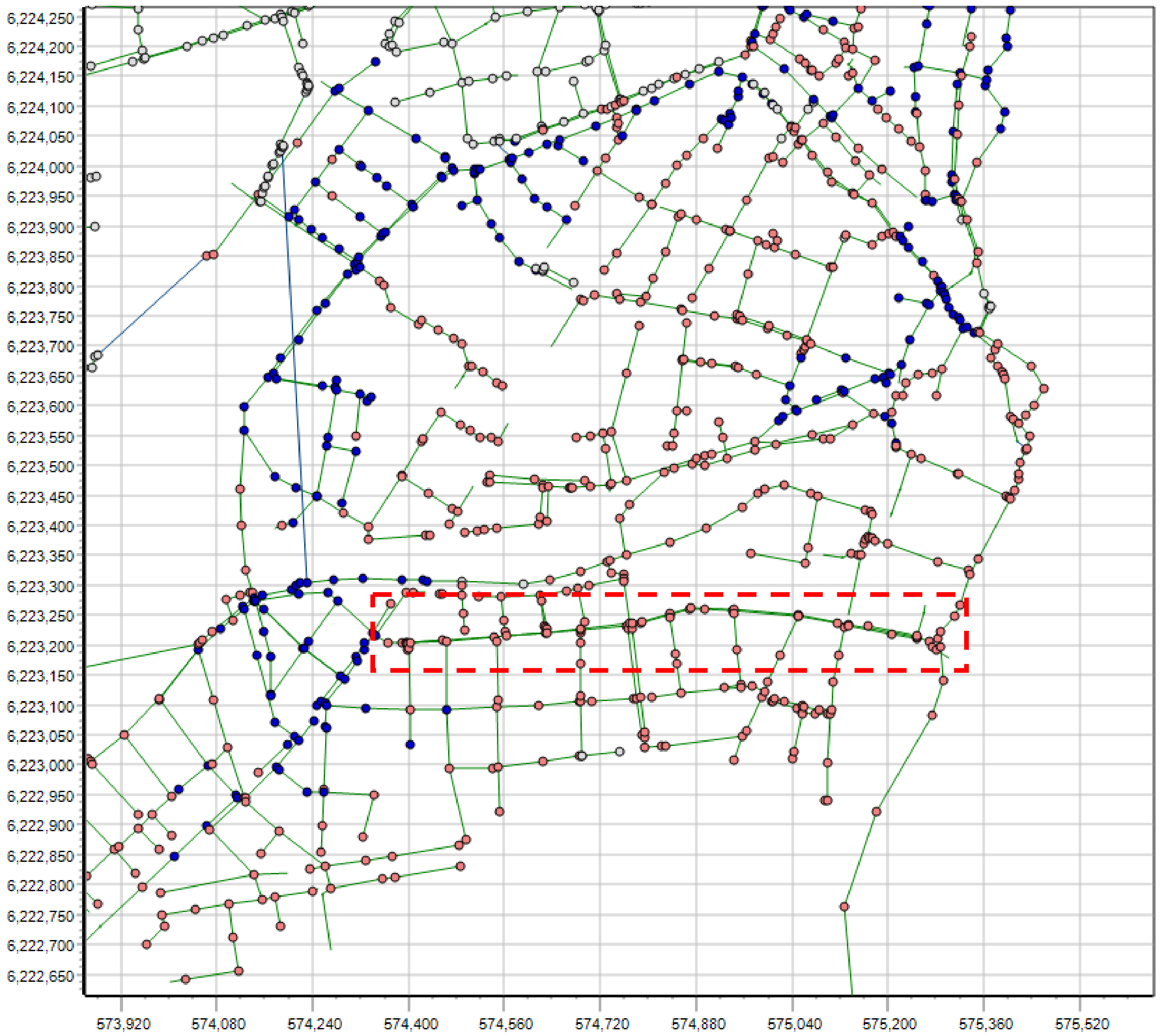




- Siphons
- Pump stations
- Restricted headspace

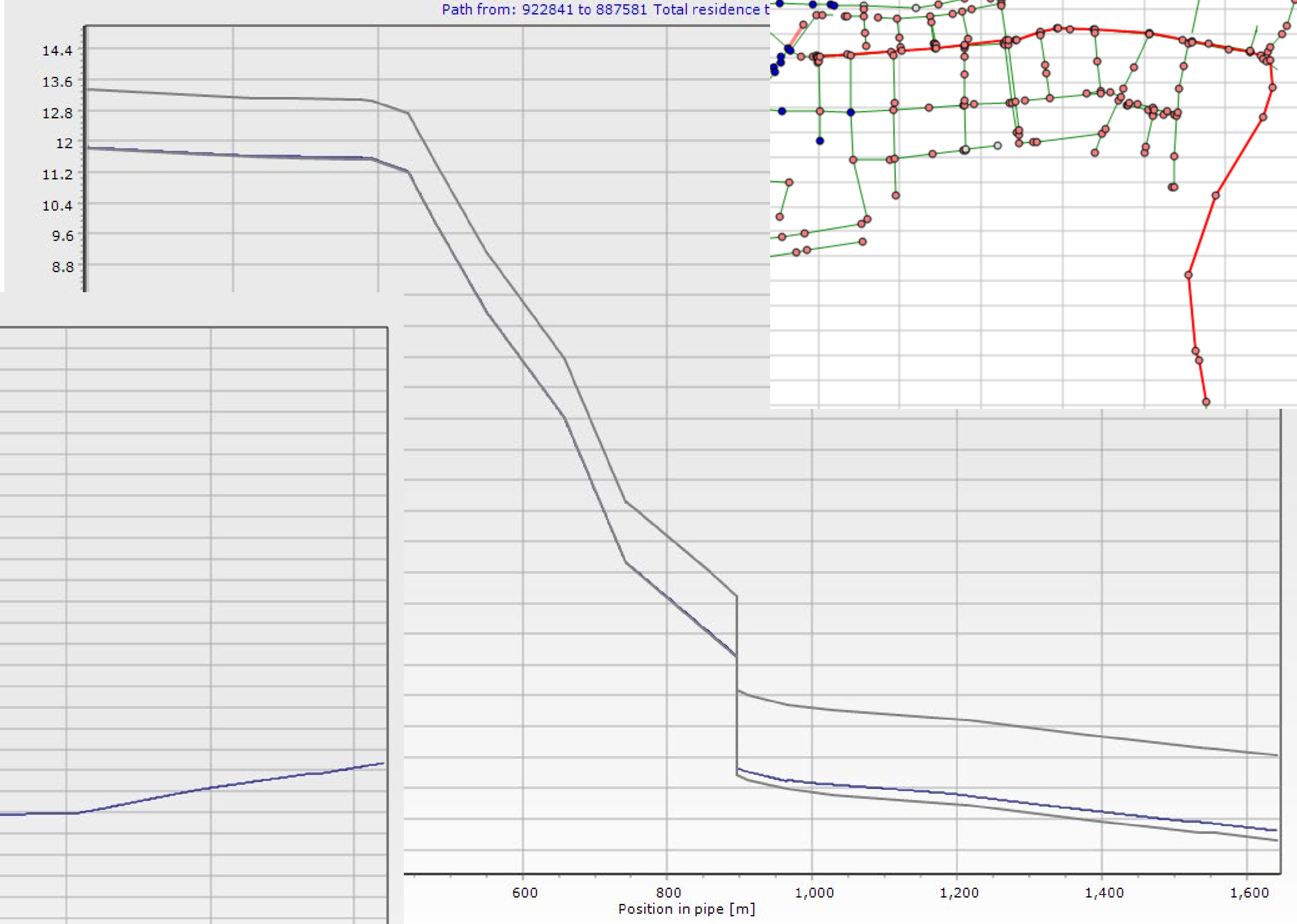


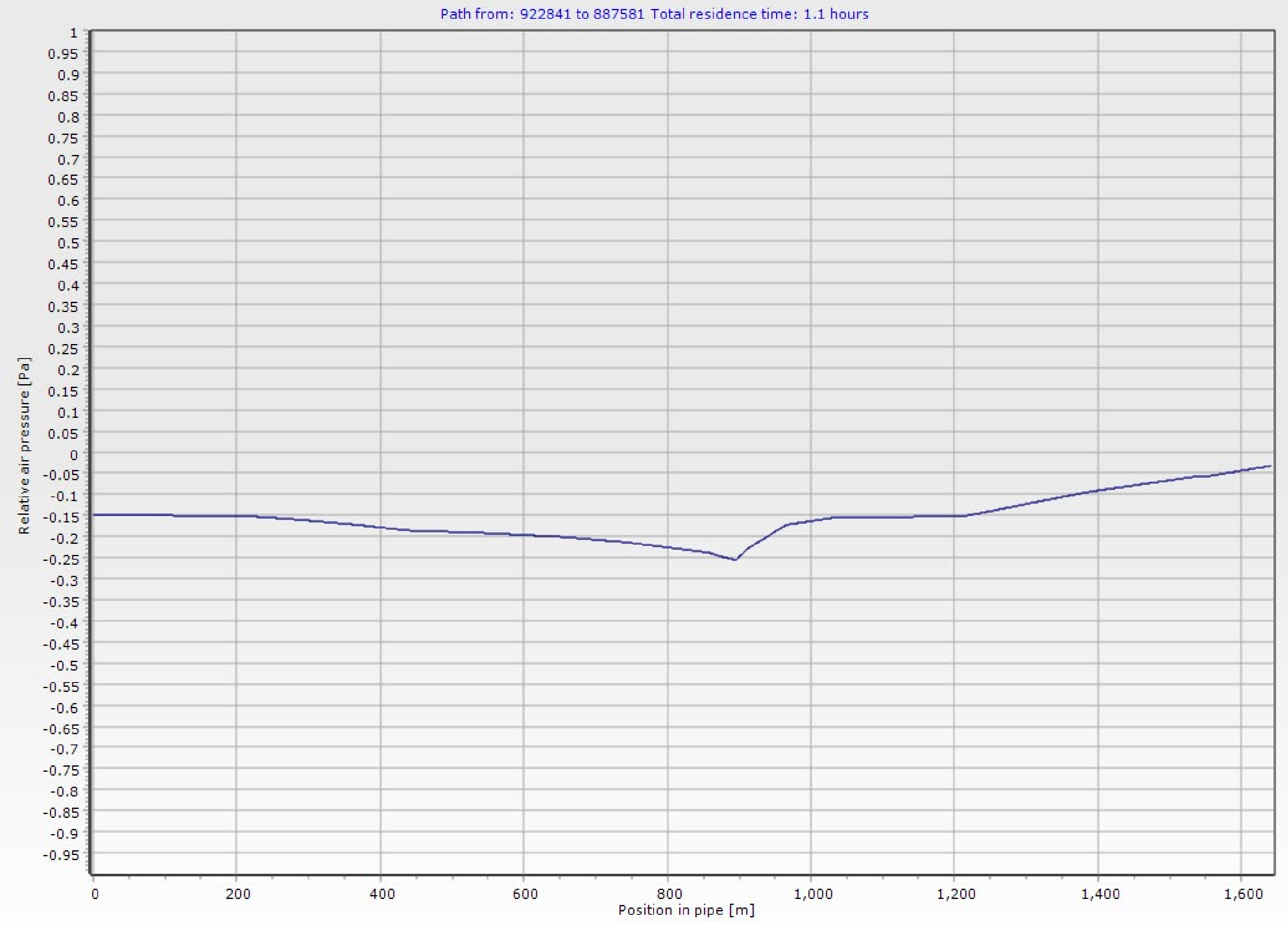
Blue nodes: Positive pressure
Red nodes: Negative pressure



Natural ventilation

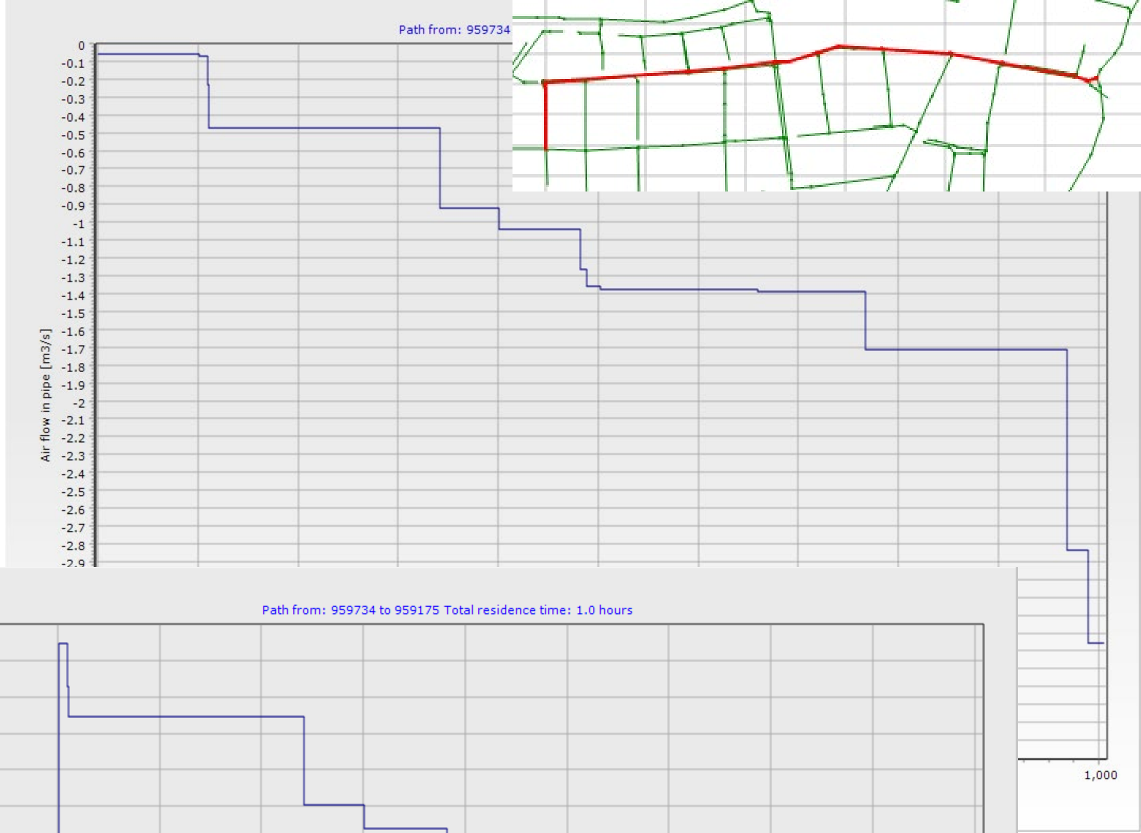
Pressure

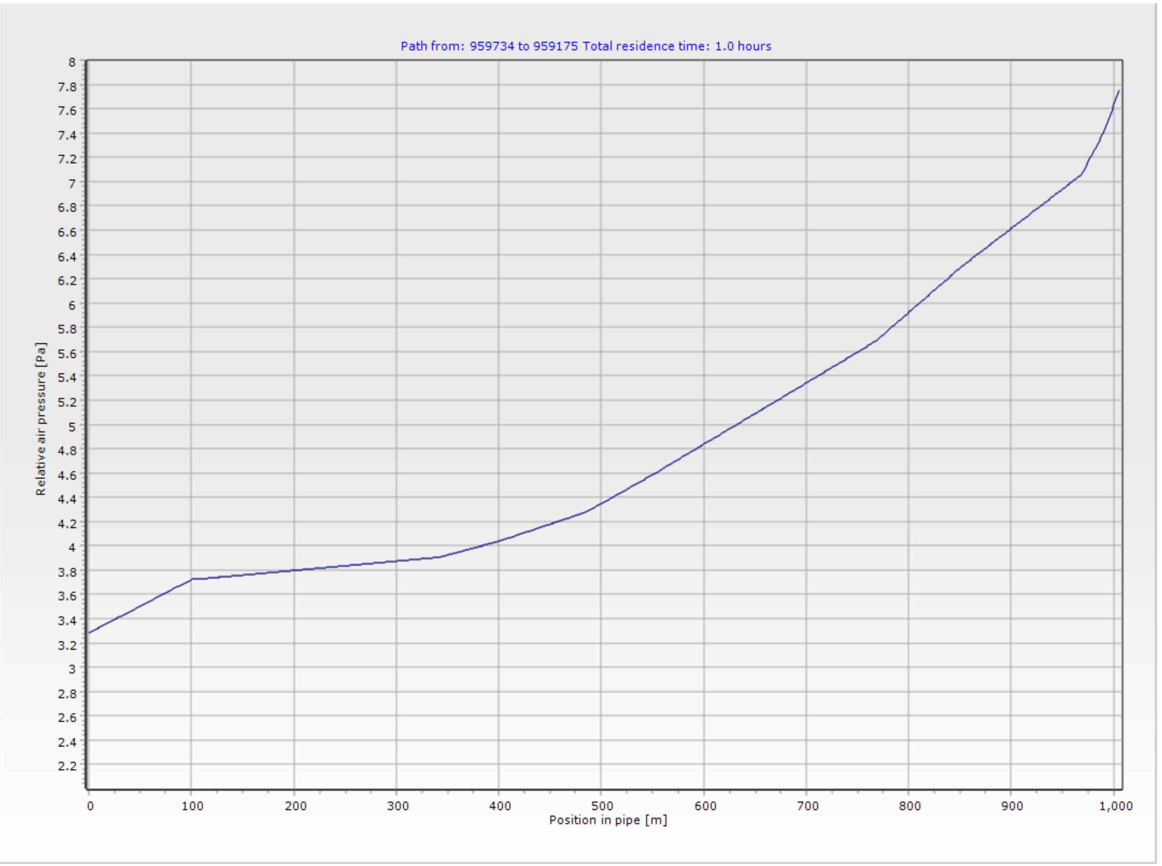


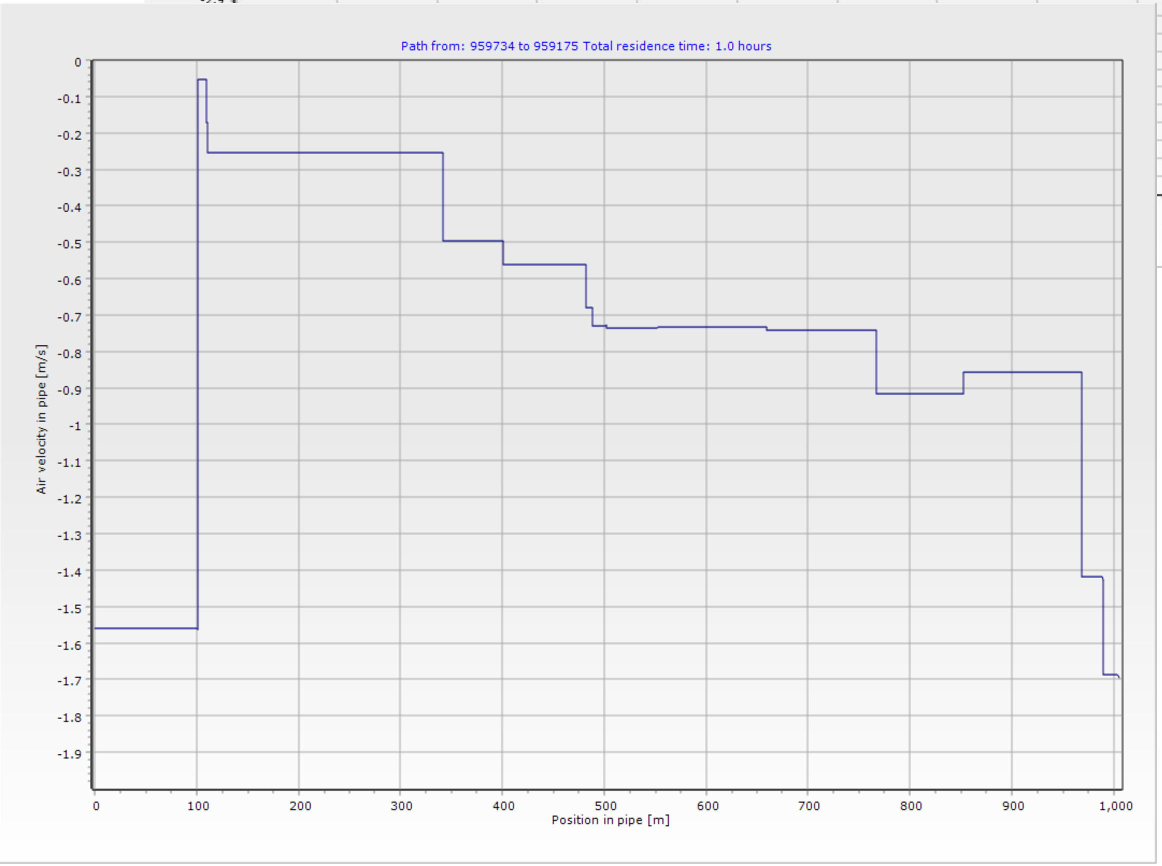


Forced ventilation

Pressure, velocities, flows

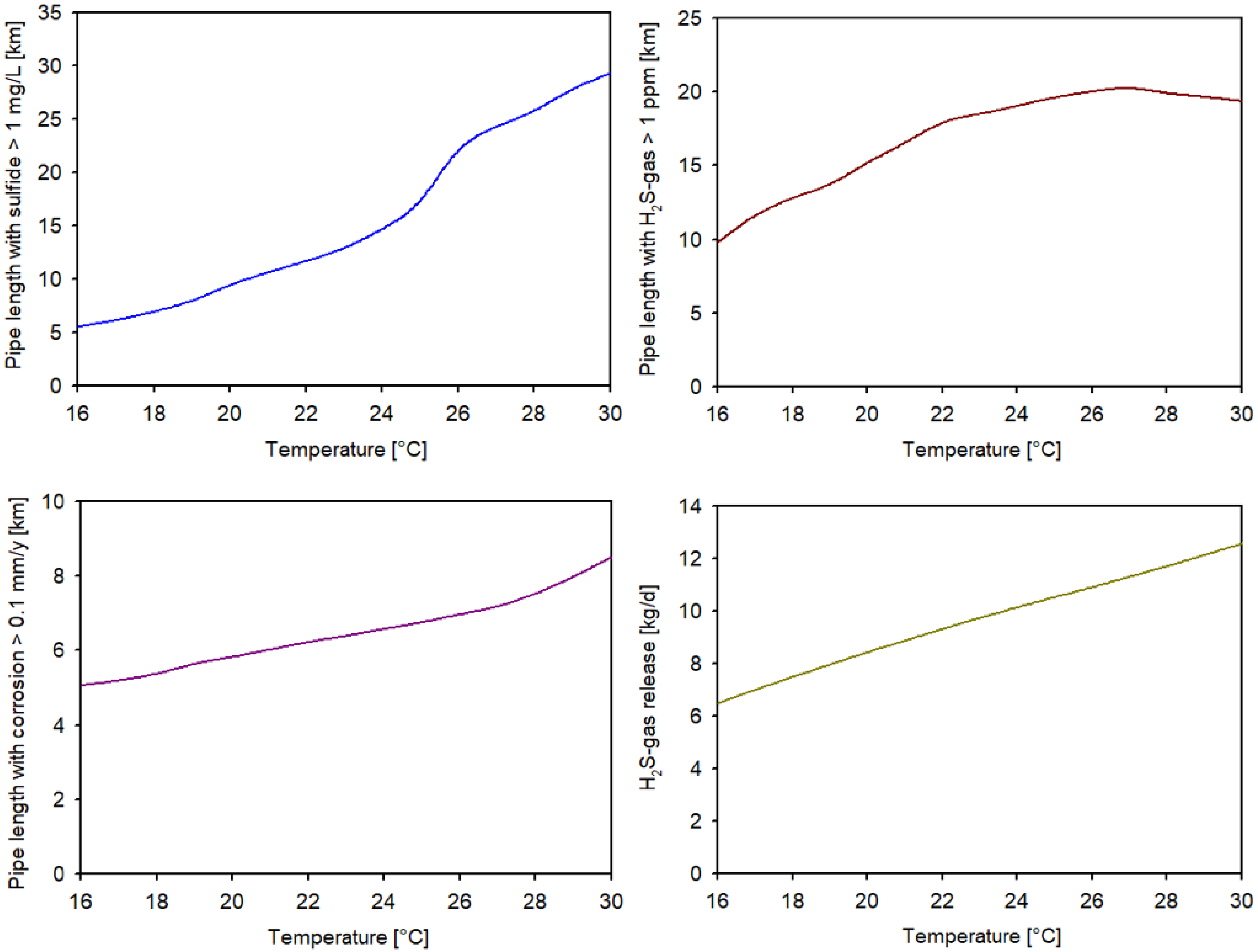






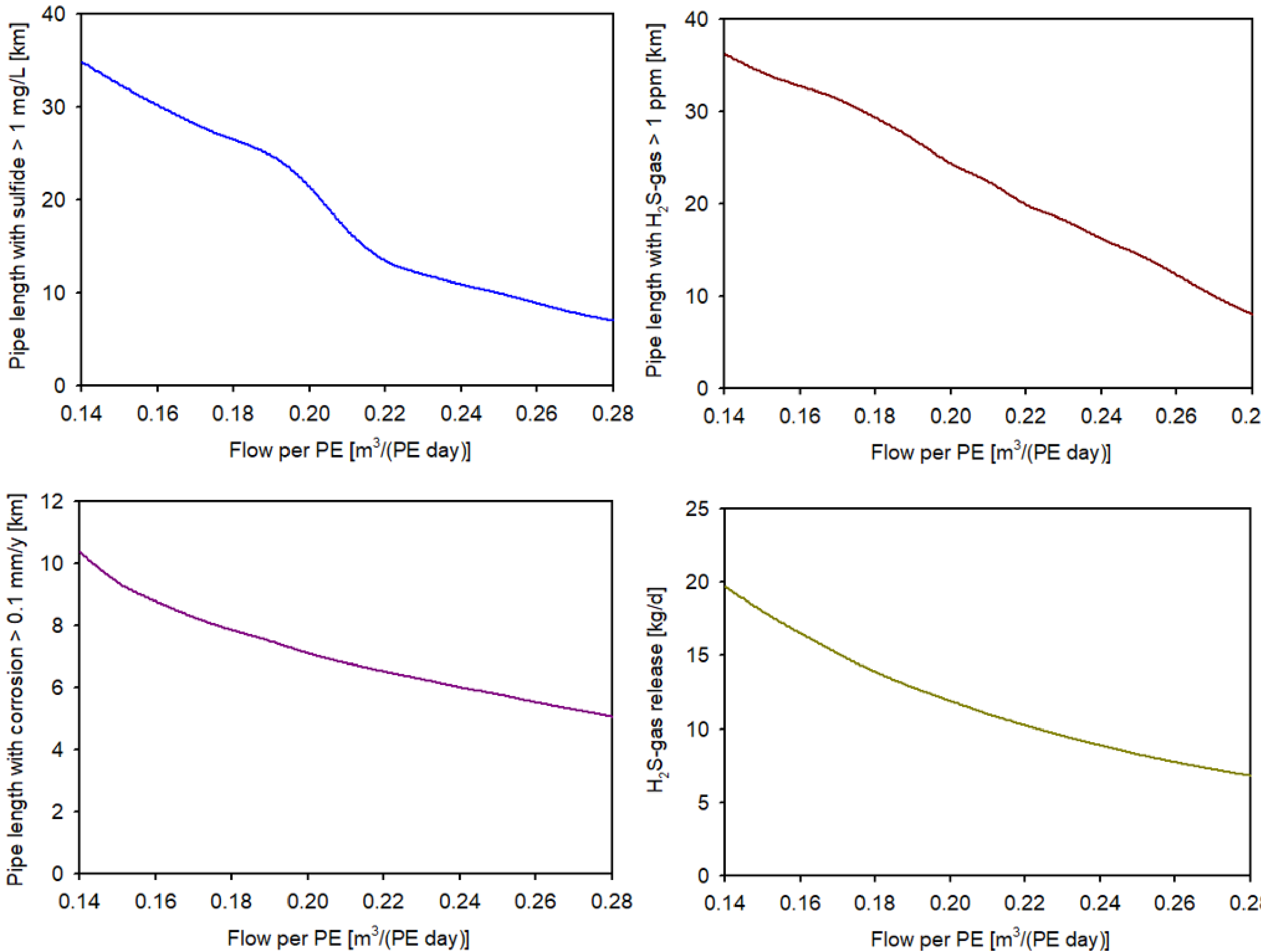
Forecasting urban densification, climate change, etcetera

The impact of temperature



Forecasting urban densification, climate change, etcetera

The impact of per capita water usages




And so much more
CA141988