Water and
Environment Support
in the ENI Southern Neighbourhood region

Strengthen the water utilities capacities to manage / reduce NRW and detect leakage: Activity No.: N-W-EG-1

Task 5. NRW Training

13-15 February 2023,
Asyut, Egypt

LDK Consultants Global EEIG

This Project is funded by the European Union

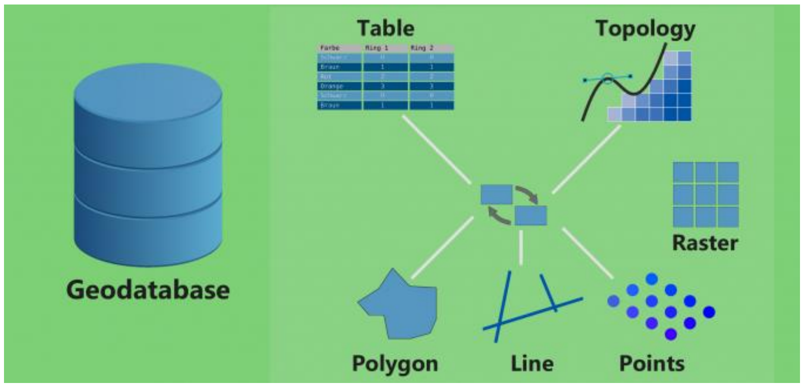
Outlines of the Training Session

1. Customer and GIS DBs combined analysis
2. General Concepts on Network Analysis
3. Use of Epanet 2.00.12
4. Model Construction
5. Field Work and Model Calibration
6. Documentation

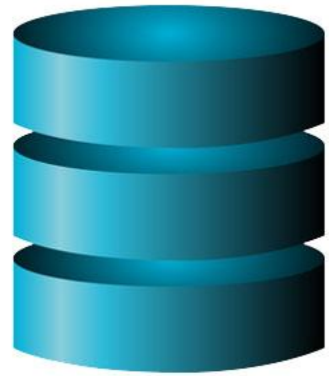
1. Customer and GIS DBs combined analysis

Data Sources

Geographical Data



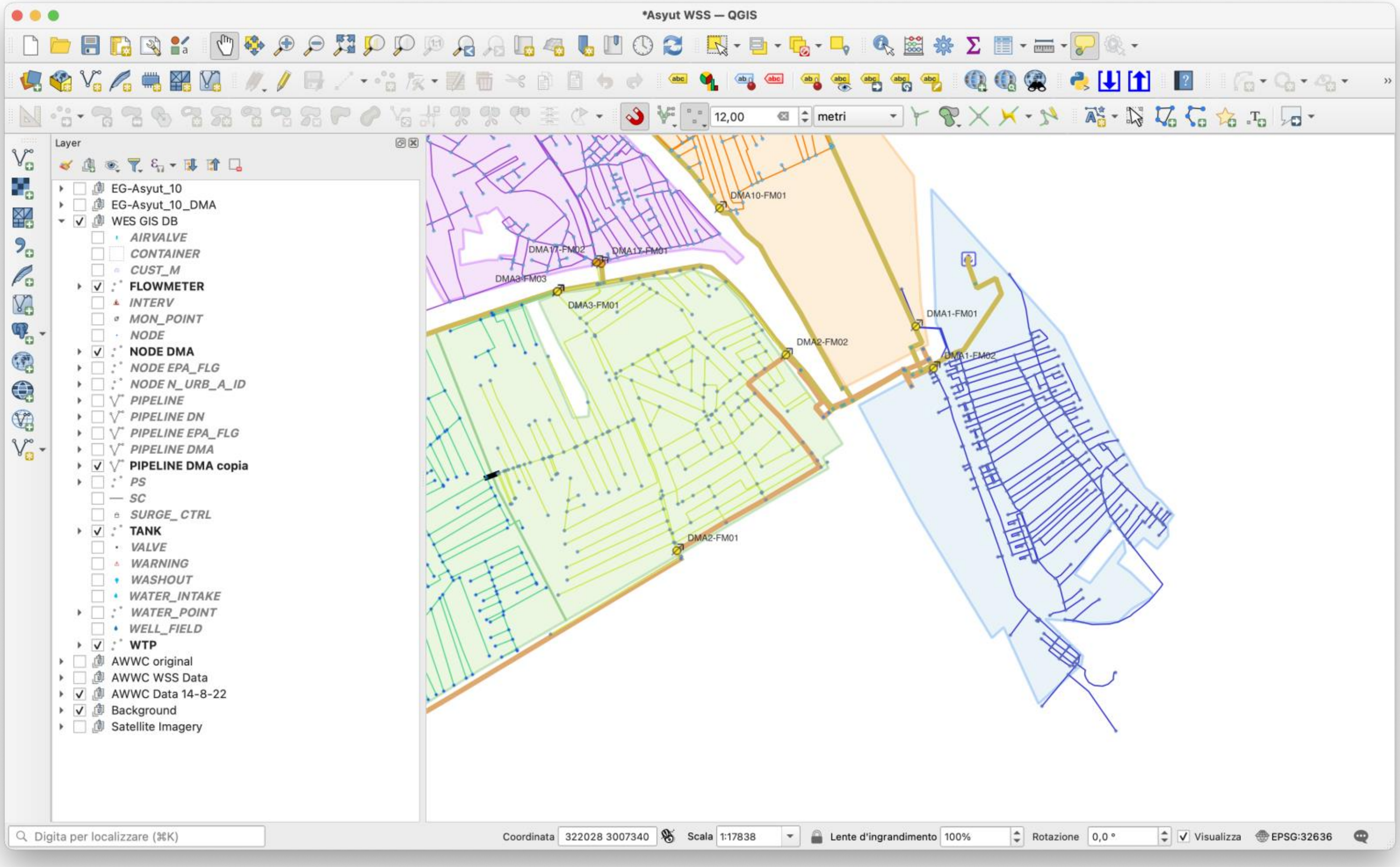
Customer Database



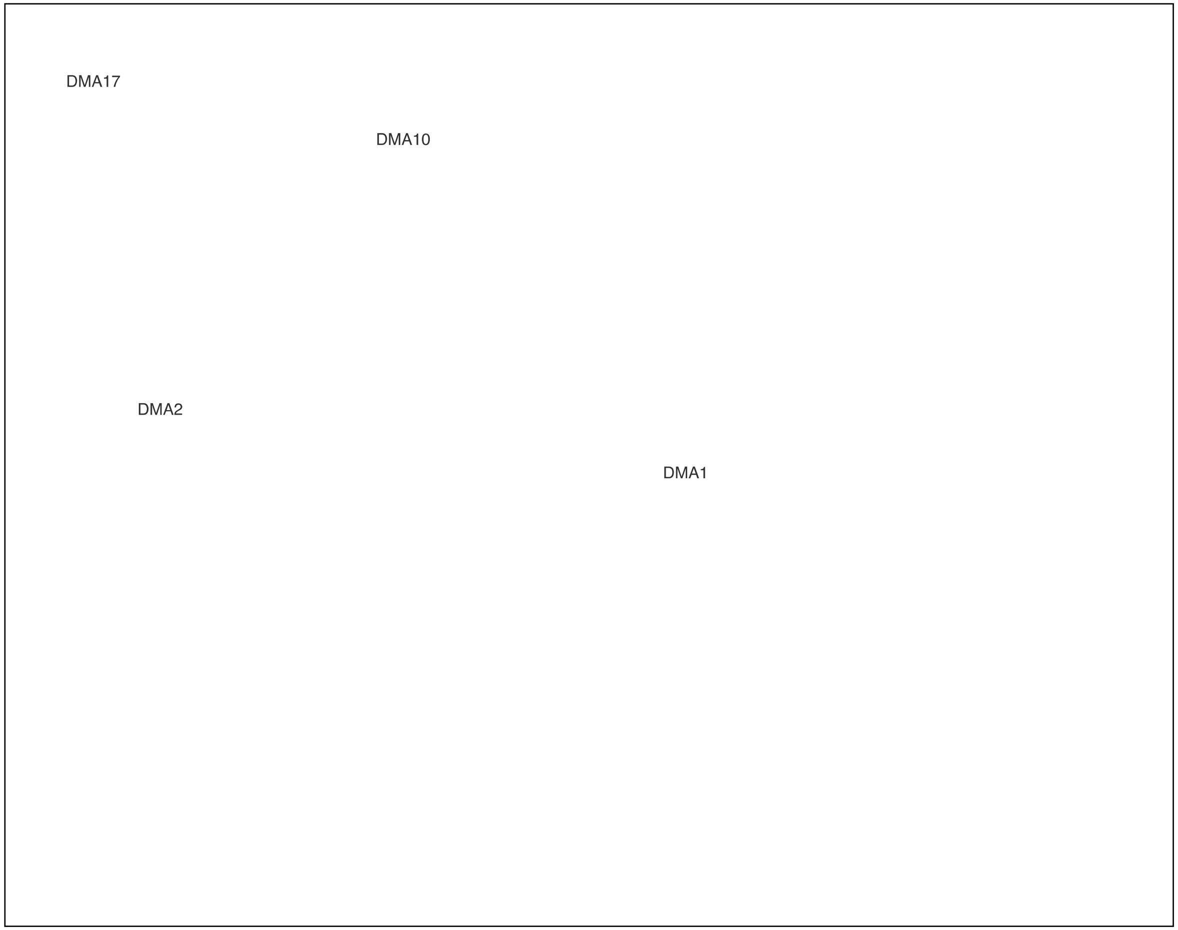
Household Survey Data

Household Database

Geographical DB – WSS data



Geographical DB: Area data



No.	Date	Revision

Approved by:

Beneficiary:
Asyut Water and Wastewater Company

Client:
Project funded by the European Union

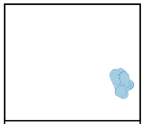
Consultant:
LDK Consultants Global EEIG

Project Title:
Strengthen the water utilities capacities to manage/reduce NRW and detect leakage

Date	Scale	Rev.
02/23/2023	1:10.000	

Water and
Environment Support
in the ENI Southern Neighbourhood region

Geographical DB: Household Survey



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Date	Scale	Rev.
02/23/2023	1:10.000	

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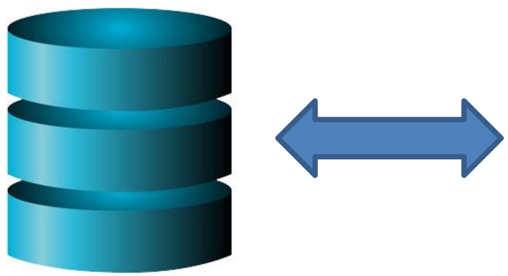
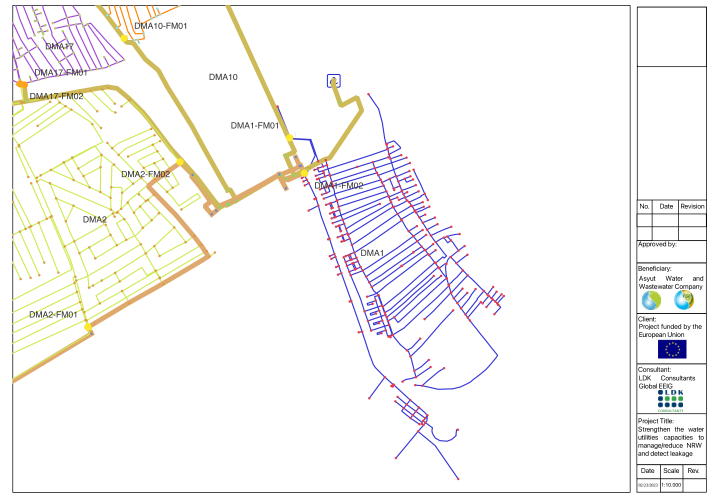
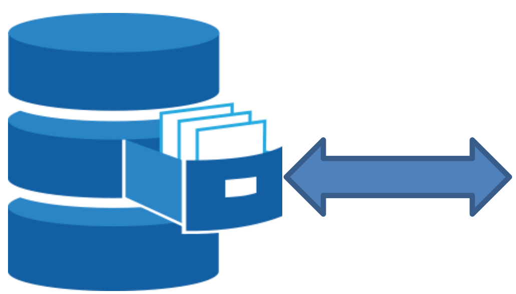
Combined Geo and Alphanumeric Data

Customer Database

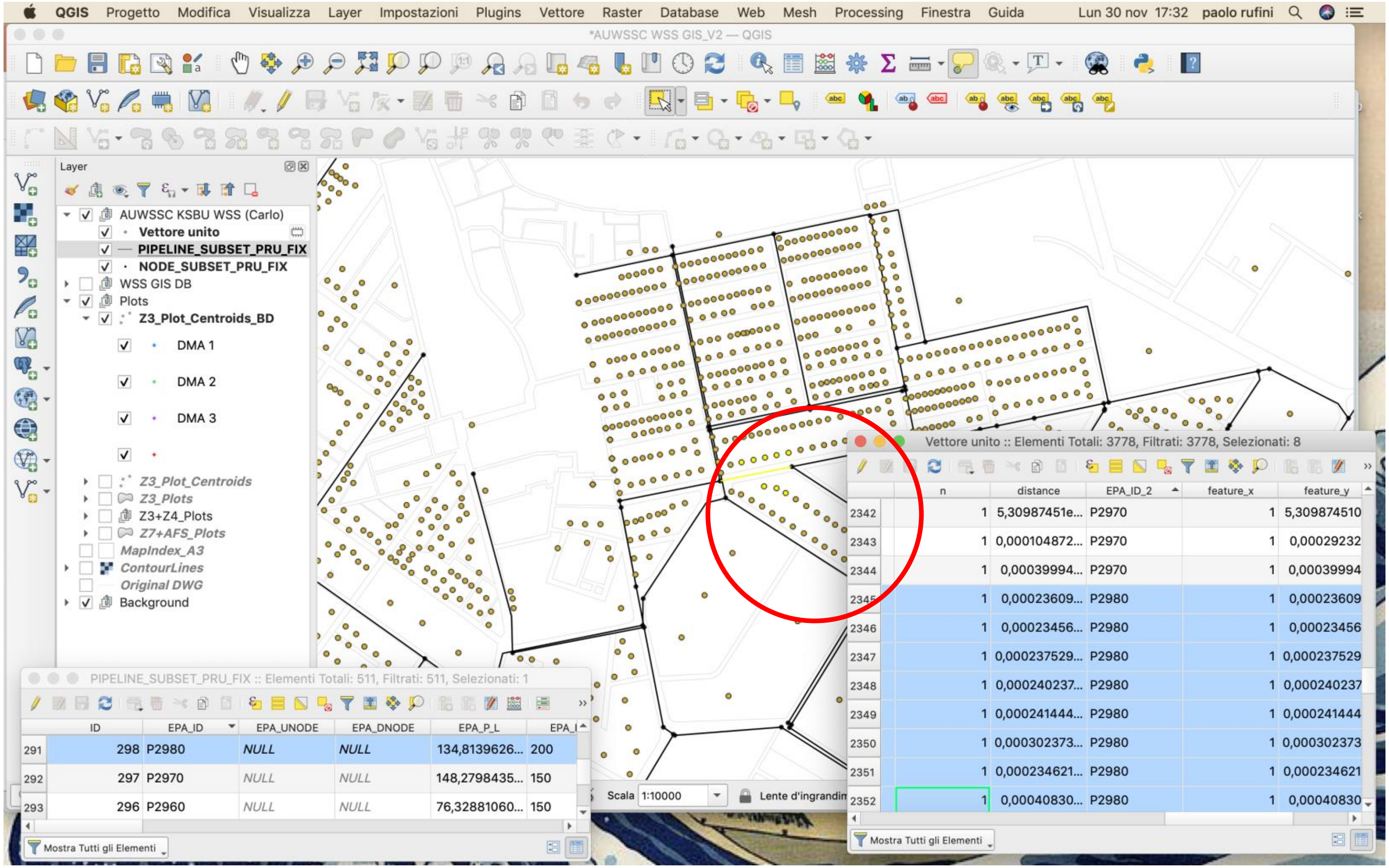




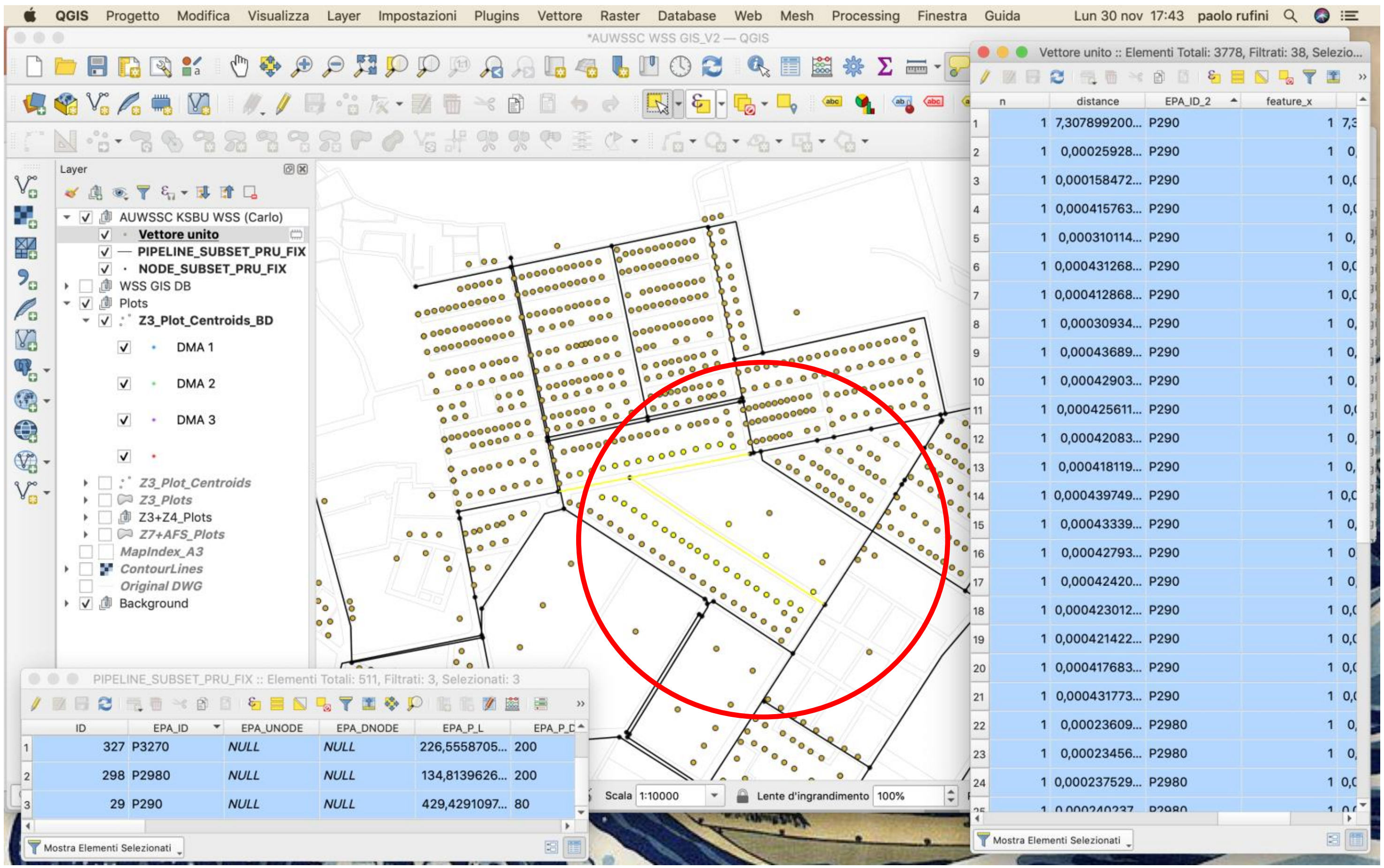
Household Database



Assign customer/household a pipe ID



Assign customer/household a node ID



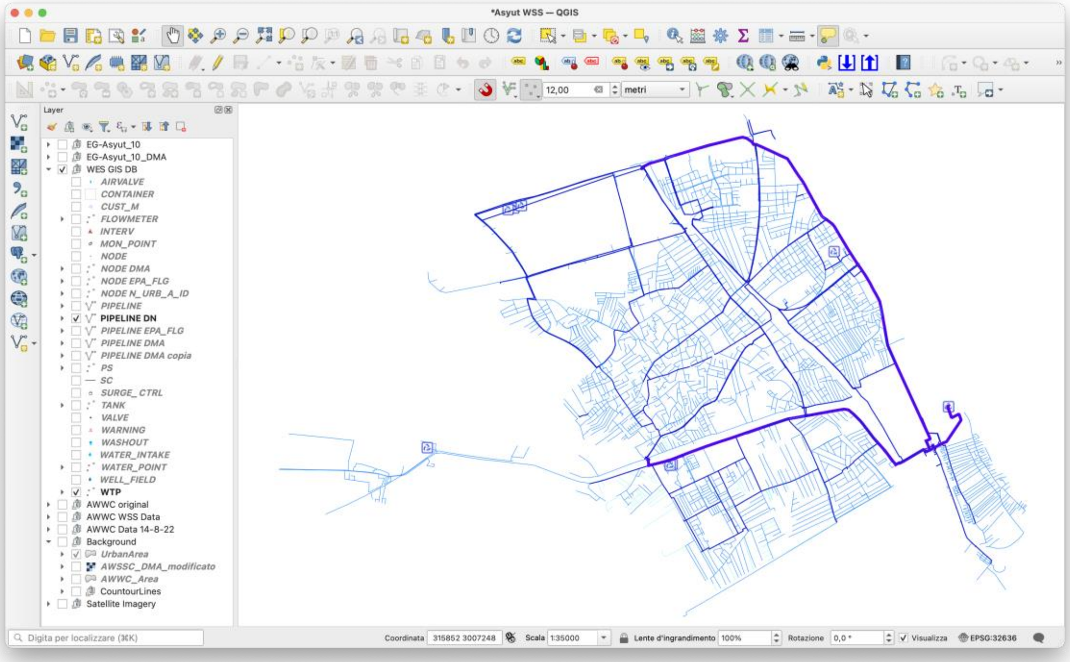
TEA-BREAK

2. Network Analysis

General Concepts on Network Analysis

There are numerous reasons for constructing a network model:

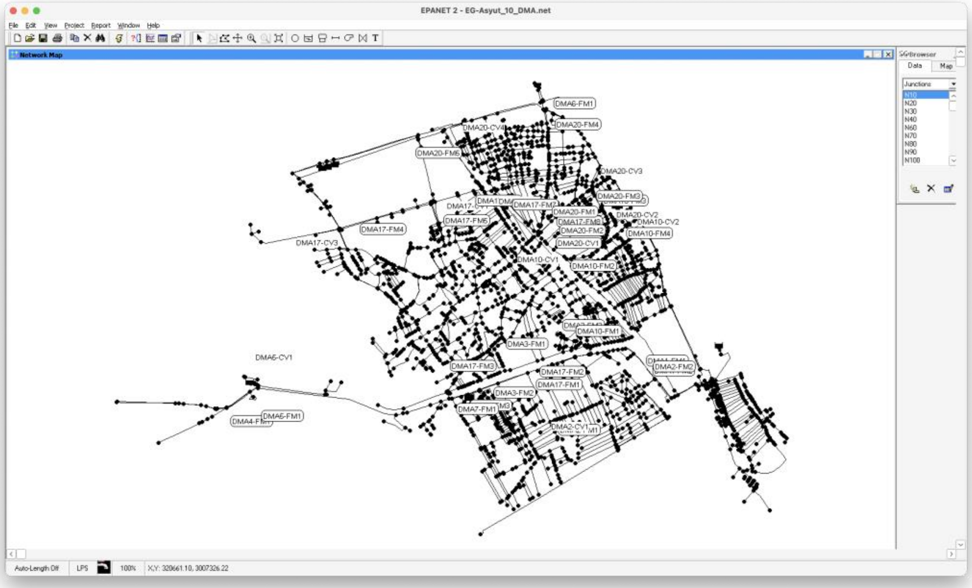
1. understanding the behaviour of supply and distribution systems;
2. identifying and resolving system anomalies (e.g. closed valves);
3. assessing the levels of service;
4. assessment of the carrying capacity of the existing system;
5. design of reinforcements to the system to meet future demand;



General Concepts on Network Analysis

There are numerous reasons for constructing a network model:

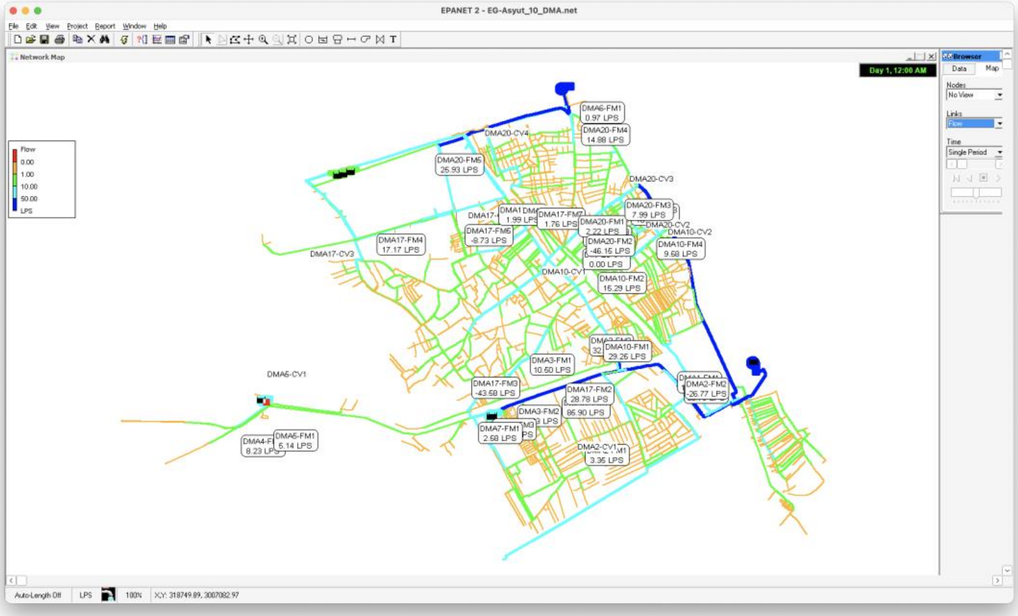
6. assessment of new resource options;
7. design of new distribution systems;
8. assessment of the effect of rehabilitation techniques ;
9. design of leakage control schemes (district mete ring and pressure control);
10. as part of the process in reducing pumping costs;



General Concepts on Network Analysis

There are numerous reasons for constructing a network model:

11. assessing the value and design of distribution monitoring schemes;
12. contingency planning: answering "what if?" questions;
13. Daily operational use: such as rerouting around bursts or maintenance work;
14. identifying causes and solutions to supply problems ;
15. assessing the financial contribution required for supplies to new developments;



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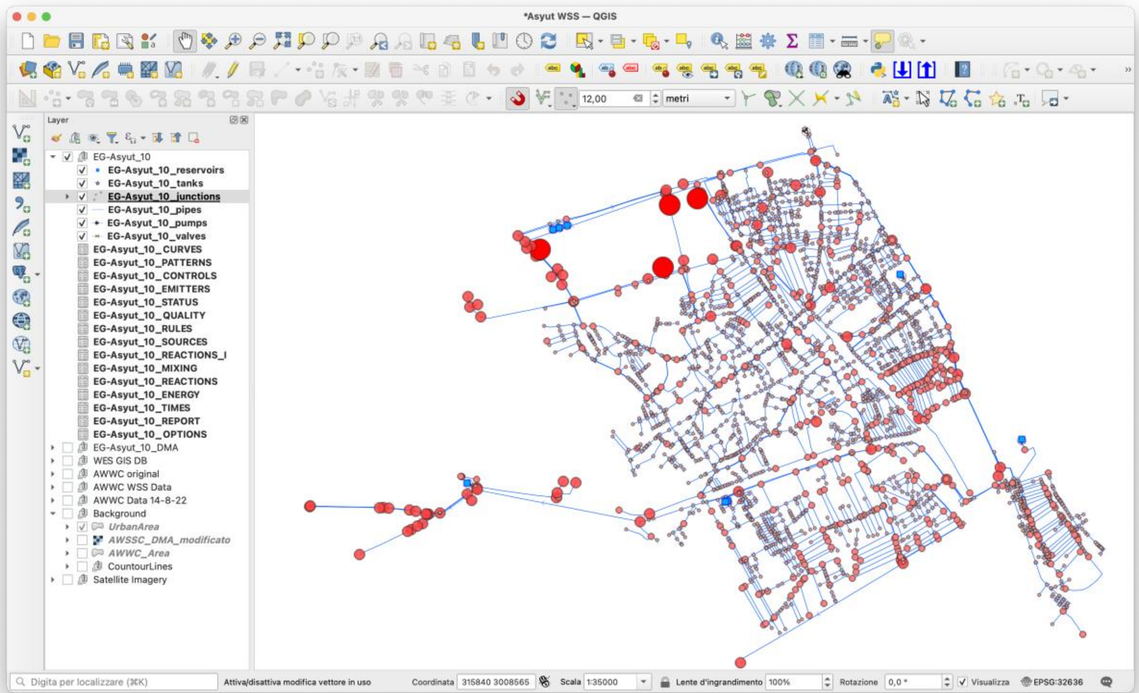
General Concepts on Network Analysis

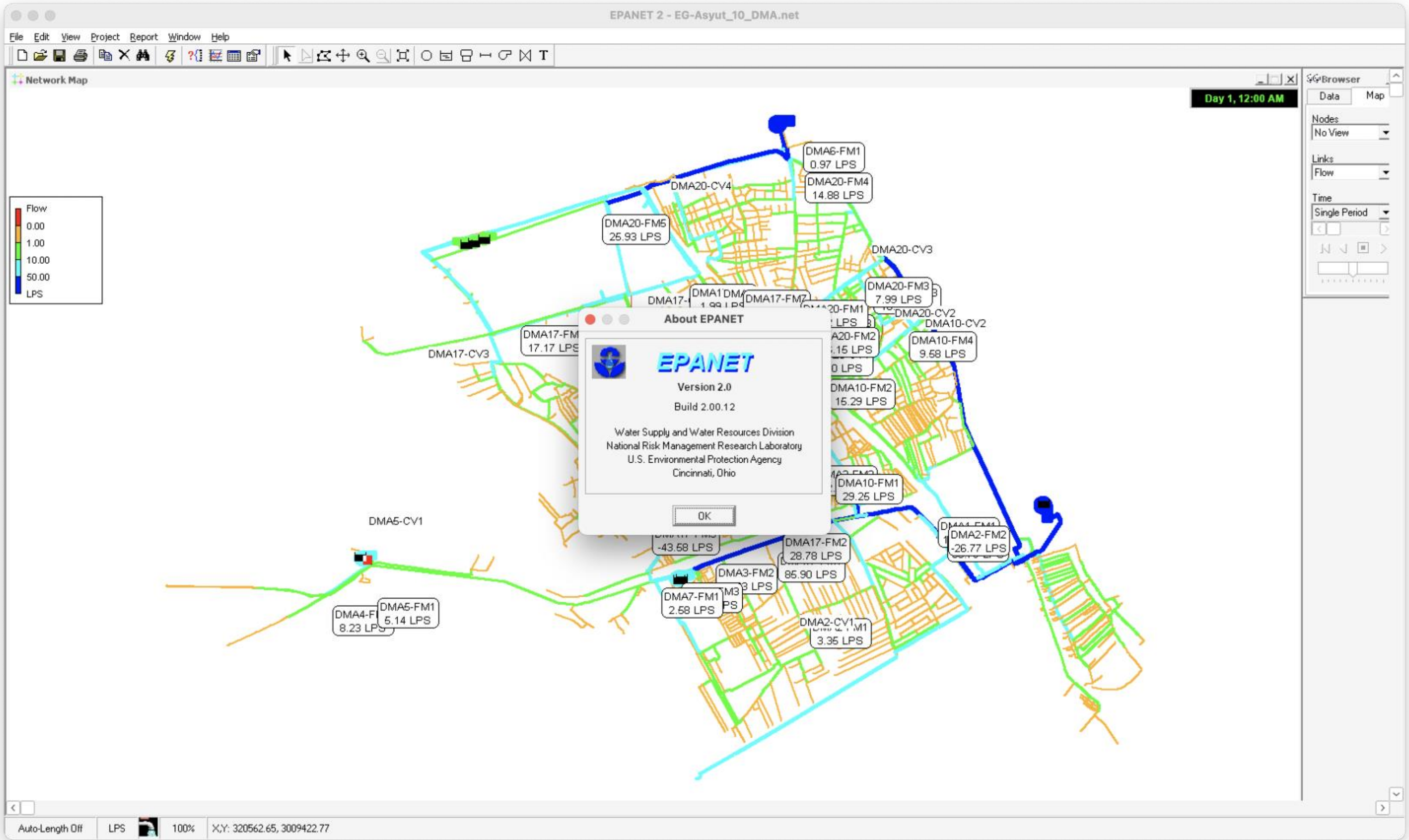
There are numerous reasons for constructing a network model:

16. water quality investigation requiring the study of flow paths;
17. source utilisation studies.

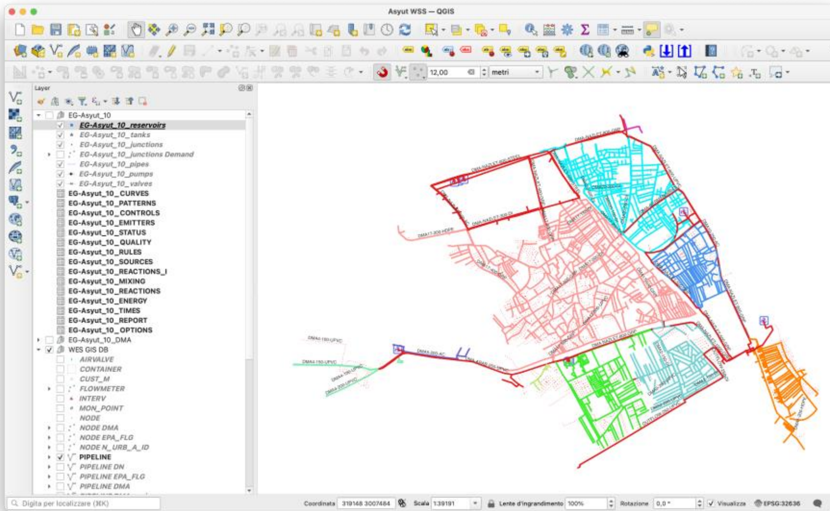


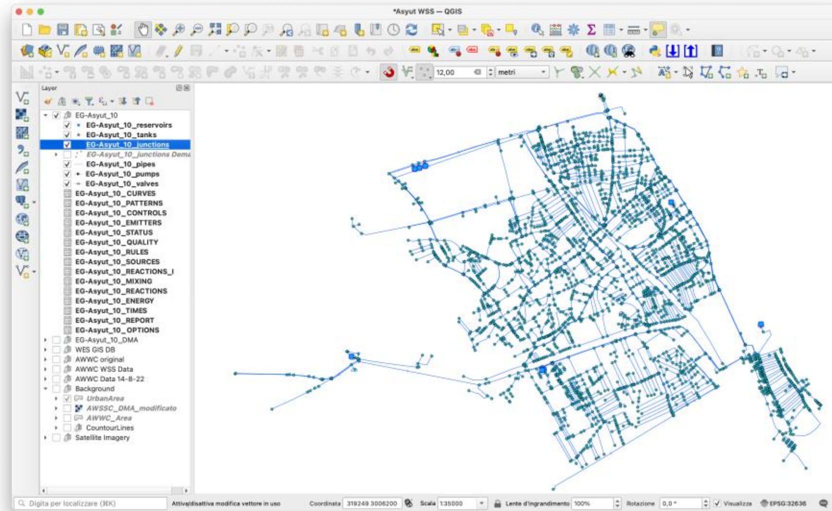
3. Use of Epanet 2.00.12

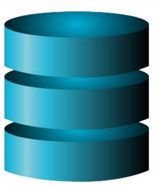
General Concepts on the use of EPANET 2.00.12



General Concepts on the use of EPANET 2.00.12







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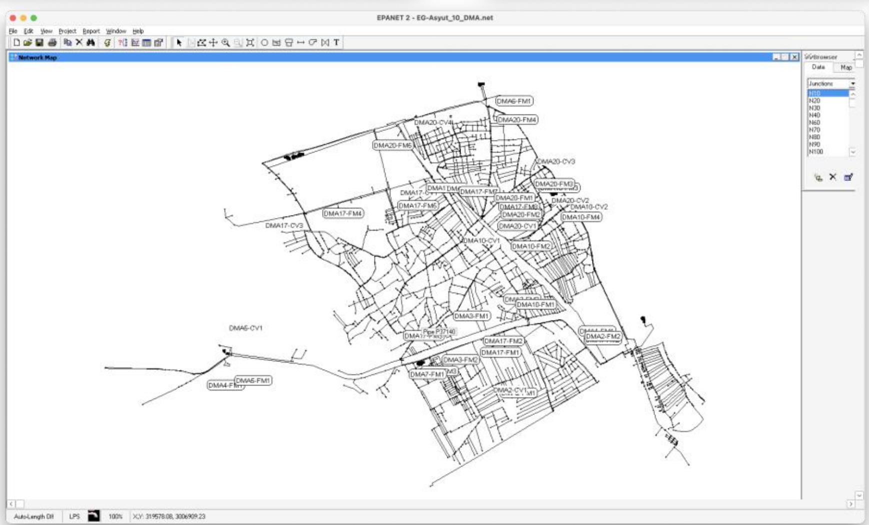

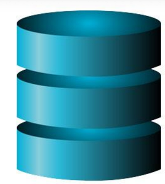

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File.RPT

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General Concepts on the use of EPANET 2.00.12

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EG-Asyut_10

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 N20             58          0                            ;
 N30             54.2        0                            ;
 N40             61.8        0                            ;
 N60             58.1        0.1366                       ;
 N70             56          0                            ;
 N80             56.34       0                            ;
 N90             56.2        0                            ;
 N100            60.4        0.1175                       ;
 N110            56.9        0                            ;
 N120            58.4        0.1458                       ;
 N130            61.3        0.1175                       ;
 N140            56          0.1458                       ;
 N150            59.9        0.1458                       ;
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 N180            59.2        0                            ;
 N190            55.7        0.1458                       ;
 N200            55.9        0.1458                       ;
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 N220            59.61       0.1458                       ;
 N230            59.6        0.1458                       ;
 N240            57.1        0.1458                       ;
 N250            57.12       0.1458                       ;
 N260            55.8        0.1175                       ;
 N270            56.89       0                            ;
 N280            56.9        0                            ;
 N290            59.6        0                            ;
 N300            59.6        0                            ;
 N310            58.8        0.1079                       ;
 N320            58.8        0.1079                       ;
 N330            62.36       0.1175                       ;
 N340            58.37       0.1458                       ;
 N350            58.4        0.1458                       ;
 N360            55.57       0.1175                       ;
```

EG-Asyut_10.rpt

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Page 1                                          24/09/2022 18:38:44
**********************************************************************
*                             E P A N E T                            *
*                     Hydraulic and Water Quality                    *
*                     Analysis for Pipe Networks                     *
*                             Version 2.0                            *
**********************************************************************

Input File: EG-Asyut_10.net

EG-Asyut_10

Link - Node Table:
----------------------------------------------------------------------
Link            Start           End                 Length  Diameter
ID              Node            Node                     m        mm
----------------------------------------------------------------------
P10             N160            N170               0.25554       100
P20             N200            N210               0.27785       200
P30             N220            N230               0.27514       200
P40             N240            N250               0.35735       150
P50             N270            N280                0.3956       400
P60             N290            N300                0.4134       400
P70             N310            N320               0.43829       300
P80             N340            N350               0.51924       100
P90             N360            N370               0.51547       150
P130            N440            N450               0.61033       200
P140            N460            N470               0.61401       300
P150            N480            N490               0.63349       200
P160            N500            N510               0.65147       100
P170            N520            N530               3.52261       150
P180            N190            N540               0.76323       300
P190            N550            N560               0.82856       100
P200            N570            N580               0.85908       200
P210            N590            N600               0.88324       100
P220            N610            N620               0.91526       150
P230            N630            N640               0.91303       300
P250            N670            N680               0.97186       150
P260            N690            N700               0.98486       100
P270            N710            N720               1.00239       300
```

4. Model Construction

General Concepts on how to approach a WSS network Model - Model construction

Before starting to build a network model there must be clear statement of the aims and objectives of the task.

The model of the network may be required for new design, leakage control, pump scheduling, source optimisation, rehabilitation planning, general operational use or all of these.

These objectives will determine:

1. **the type of model, e.g. single point in time or simulation model,**
2. **the level of detail necessary,**
3. **the amount of resources and timescale of the project.**

General Concepts on how to approach a WSS network Model - Model construction

Sufficient data will need to be collected from various sources to build the model. **This information will probably be in a number of formats and it is essential that an assessment or a clear indication is made of the extent and quality of the existing system's records.**

Any additional local knowledge that is available from inspectors, distribution engineers, etc. needs to be considered and recorded if necessary.

The system records may include:

1. distribution network records drawings;
2. source and reservoir details - layouts and pipework, pump curves, valving, etc.;
3. existing flow meters, telemetry, system monitoring;
4. leakage zone meters;

General Concepts on how to approach a WSS network Model - Model construction

5. metered consumption and billing records;
6. age and condition of mains, where known, mains laying records, burst main report forms;
7. pump details;
8. demand forecasts;
9. general system operation (including local knowledge).

It is important that an accurate and thorough check is made of the system records to ascertain and have corrected obvious anomalies, errors, omissions, prior to commencing model building. It is also important that site visits are made to check on the accuracy and completeness of as-built drawings.

General Concepts on how to approach a WSS network Model - Model construction

Pipes to be included in the model are derived from an inspection of available mains records. Guidelines for pipes to include for various types of models are given in the table. This is a task where experience is essential and this table should not be considered as a standard ruling.

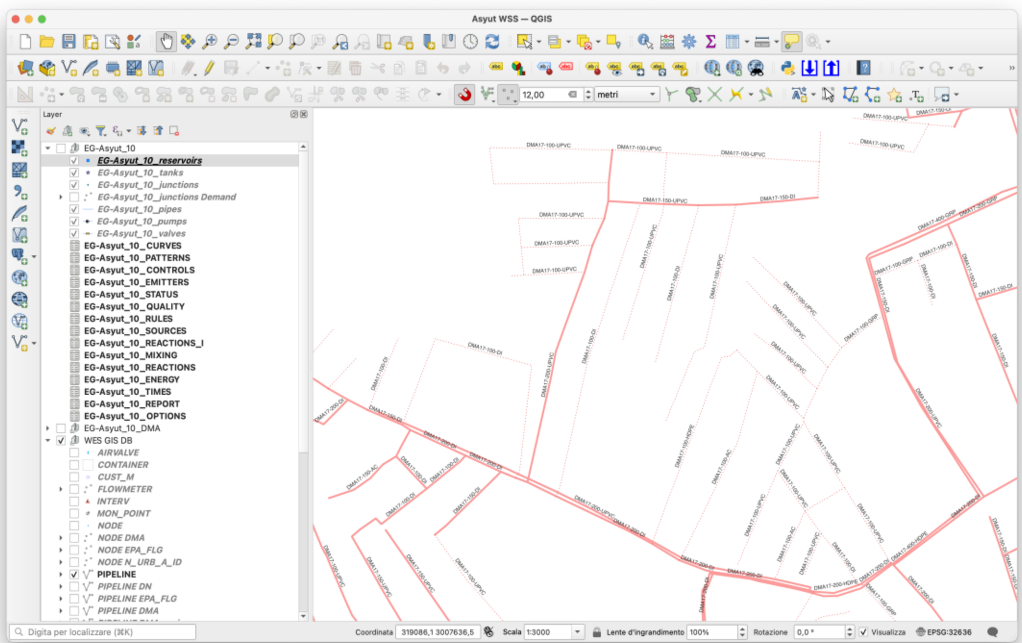
MODEL USE	PIPES TO BE MODELLED
Strategic model to be used for source management and pump scheduling	Primary/strategic trunk supply system connecting sources to be scheduled with centres of demand – generally ≥200mm diameter
Detailed operational use, designing a leakage or pressure control scheme, rehabilitation planning, system reinforcement planning.	All pipes ≥150mm diameter and some important 100mm and 80mm pipes may have to be included where they are significant carriers.

Pipe selection

General Concepts on how to approach a WSS network Model - Model construction

The diameter of the mains to be included in the model are normally taken from the network drawings. However, care must be taken when relating these values to internal dimensions.

The wall thickness of some materials varies as does the way materials are recorded e.g. the outside dimension of MDPE and steel are normally recorded and not the internal dimension. In such cases actual internal dimension should be used.

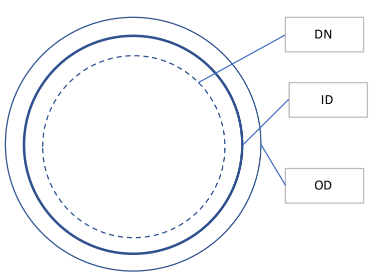


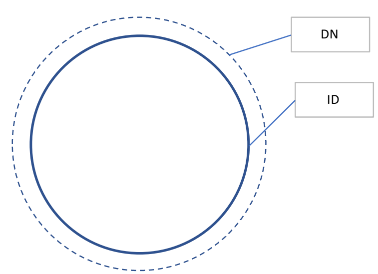
General Concepts on how to approach a WSS network Model - Model construction

DI PIPE					
DN	OUTSIDE DN (mm)	WALL THICKNESS (mm) K9	WALL THICKNESS (mm) K10	Din (mm) K9	Din (mm) K10
40	56	6	6	50,00	50,00
50	66	6	6	60,00	60,00
60	77	6	6	71,00	71,00
65	82	6	6	76,00	76,00
80	98	6	6	92,00	92,00
100	118	6	6	112,00	112,00
125	144	6	6	138,00	138,00
150	170	6	6,5	164,00	163,50
200	222	6,3	7	215,70	215,00
250	274	6,8	7,5	267,20	266,50
300	326	7,2	8	318,80	318,00
350	378	7,7	8,5	370,30	369,50
400	429	8,1	9	420,90	420,00
450	480	8,6	9,5	471,40	470,50
500	532	9	10	523,00	522,00
600	635	9,9	11,1	625,10	623,90
700	738	10,9	12	727,10	726,00
800	842	11,7	13	830,30	829,00
900	945	12,9	14,1	932,10	930,90
1000	1048	13,5	15	1034,50	1033,00
1100	1152	14,4	16	1137,60	1136,00
1200	1255	15,3	17	1239,70	1238,00
1400	1462	17,1	19	1444,90	1443,00
1500	1565	18	20	1547,00	1545,00
1600	1668	18,9	21	1649,10	1647,00
1800	1875	20,7	23	1854,30	1852,00
2000	2082	22,5	25	2059,50	2057,00

HDPE PIPE					
OUTSIDE DN (mm)	INSIDE DN (mm)				
	PN 2,5	PN 4	PN 6	PN 10	PN 16
110	104,6	101,60	97,4	90	79,8
125	118,8	115,40	110,8	102,2	90,8
140	133	129,20	124	114,6	101,6
160	152	147,60	141,8	130,8	116,2
180	171,2	166,20	159,6	147,2	130,8
200	190,2	184,60	177,2	163,6	145,4
225	214	207,80	199,2	184	163,4
250	237,6	230,70	221,6	204,6	181,6
280	266,2	258,60	248,2	229,2	201,4
315	299,6	290,80	279,2	257,8	229,0
355	337,6	327,80	314,8	290,6	258,0
400	380,4	369,40	354,6	327,4	290,6
450	428	415,60	399	368,2	327,0
500	475,4	461,80	443,4	409,2	
560	532,6	517,20	496,6	458,4	
630	599,2	581,80	558,6	515,6	
710	675,2	655,60	629,6		
800	760,8	738,80	709,4		
900	856	831,20	798		
1000	951	923,60	887		
1200	1141,2	1108,20			
1400	1331,4	1293,00			
1600	1521,6	1477,60			

ID =DN + (OD - DN) +2*WALL THICKNESS/2





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General Concepts on how to approach a WSS network Model - Model construction

DESIGN COEFFICIENT TABLES

Manning's Equation Roughness Coefficient (n)

Pipe Material	ID	Range		Typical design Value
POLYETHYLENE	HDPE	0,008	0,011	0,009
CAST IRON	CI	0,012	0,015	0,013
DUCTILE IRON	DI	0,012	0,015	0,013
CORRUGATED STEEL	CS	0,021	0,030	0,024
CONCRETE	C	0,012	0,016	0,015
VITRIFIED CLAY	VC	0,011	0,017	0,013
SPIRAL RIB METAL	SRM	0,012	0,013	0,013
CORRUGATED METAL (ANNULAR)	CMA	0,022	0,027	0,024
CORRUGATED METAL (HELIC AL)	CMH	0,011	0,023	0,020

Hazen-Williams Friction Factor (c)

Pipe Material	ID	Range		Average Value	Typical design Value
POLYETHYLENE	HDPE	160	150	155	150
PVC	PVC	160	150	155	150
CEMENT	CM	160	130	148	140
STEEL	ST	160	130	148	140
WELDED STEEL	WS	150	80	130	100
SEAMLESS STEEL	SS	150	80	130	100
CAST IRON	CI	150	80	130	100
DUCTILE IRON	DI	150	80	130	100
CONCRETE	C	152	85	120	100
CORRUGATED STEEL	CS			60	60

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General Concepts on how to approach a WSS network Model - Model construction

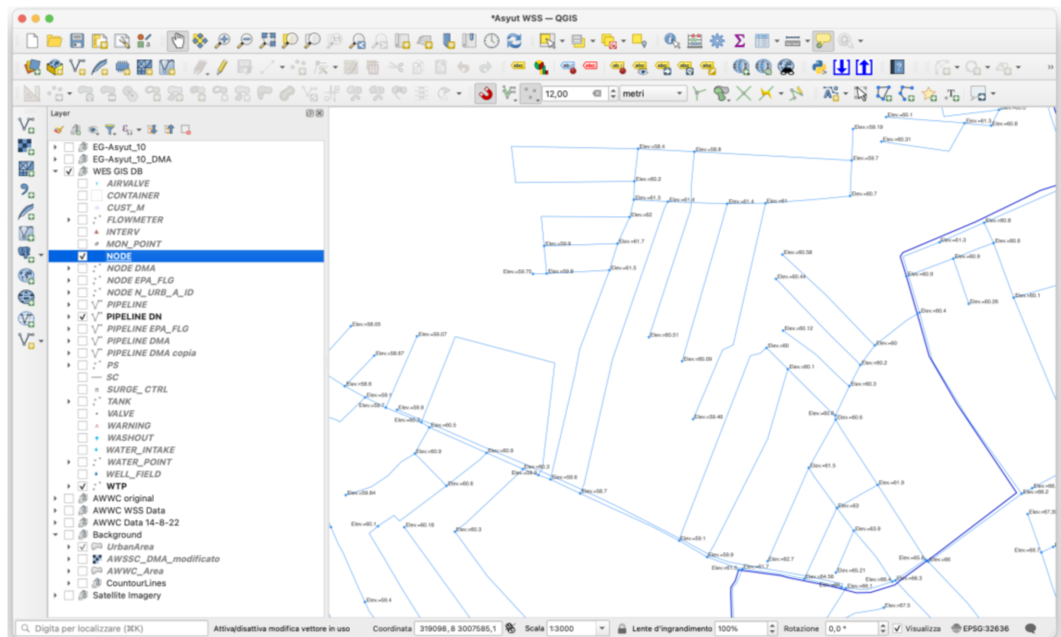
Node points are required to identify pipe junctions, locations of change of pipe characteristics, connections to system features (such as reservoirs, pumps and valves), centres of demand and field measurement points.

The number of nodes at which field measurements of pressure are made to calibrate the model should be at least 15% of the number of nodes in the network model. For models in excess of 500 nodes, while 15% is the desirable minimum coverage this may be progressively reduced down to a minimum of 10% for models of 1000 nodes or more. These measurements should be taken at points spread throughout the system but concentrated at key pipe junctions but should be discussed with local staff to ensure current/potential problem areas are also monitored. This pressure monitoring is in addition to field measurements of flow and pressure at all source and abstraction points to the system.

General Concepts on how to approach a WSS network Model - Model construction

The elevation (AOD) of nodes to be used for field pressure measurement should be determined by a field levelling exercise (to within an accuracy of ±25mm).

However the elevation (AOD) recorded for all nodes within the model should normally be taken as the level of the road adjacent to the property with the highest elevation (AOD) within the nodal area. This value should be interpolated from existing map(s) to an accuracy of ±0.5m.



General Concepts on how to approach a WSS network Model - Model construction

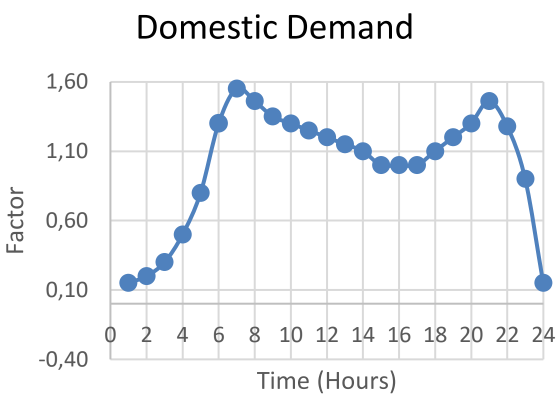
The consumption of water in a network is often referred to as demand. **The allocation of demand is the largest unknown parameter in network analysis and so must be considered with great thought**. The method is often site specific.

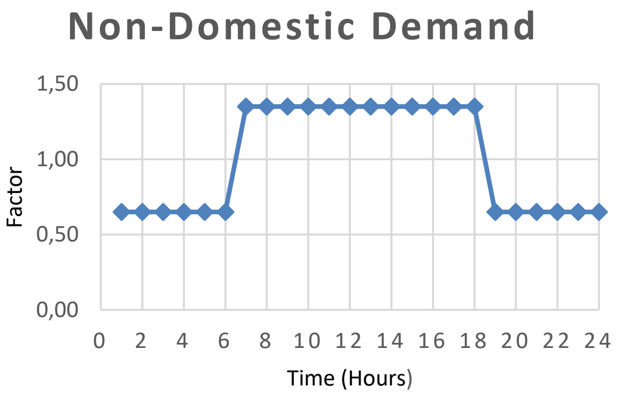
For each node point with a demand i.e. demand node, the total demand can normally be split into three basic types:

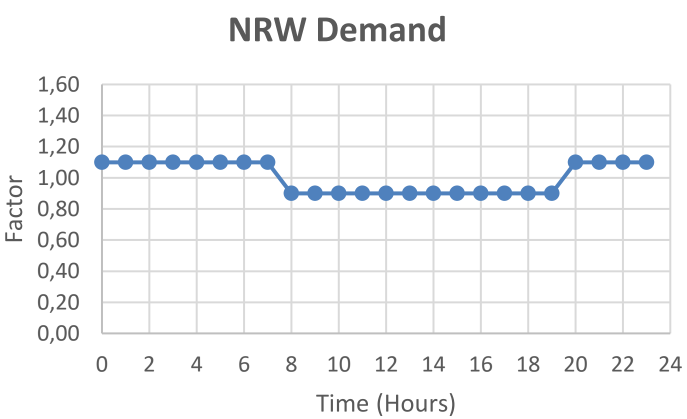
- **metered demand**, in turn divided into:
  - Domestic
  - Non-domestic (commercial, school, hospital, etc).
  - industrial;
- **Leakage**
- **Special customers** (large consumers).

Obviously the use to which the model is put will determine the actual type of demand allocation.

General Concepts on how to approach a WSS network Model - Model construction







5. Field Work and Calibration

General Concepts on how to approach a WSS network Model – Field Work

The network model must be compared with the real system it represents to demonstrate that it behaves similarly. Consequently a variety of field measurements and calibrations of the elements and of the entire system need to be made. The most important (field) measurements are a record of simultaneous flow and pressure measurements within the network at selected nodes.

This activity is commonly known as the "field test".

The field test may also need to be supplemented with simultaneous measurements of very large consumer meters, detailed monitoring of control valve performance and actual pump characteristics.

It is important that before commencing the field test exercise, checks are carried out to ensure as far as possible that the system is operating as believed or as represented by the model.

General Concepts on how to approach a WSS network Model – Field Work

The various field test measurements which are essential for network analysis are listed below:

a) Carry out simultaneous measurements of all inflows and outflows, and flows on selected mains within the network.
b) Carry out simultaneous pressure measurements at selected nodes.
c) Monitor reservoir levels.
d) Log major metered users consumption.
e) Pump tests head/flow behaviour curves.

General Concepts on how to approach a WSS network Model – Field Work

it is essential that appropriate equipment is used capable of providing the necessary information to the required accuracy. **Such equipment should be properly maintained and calibrated at regular intervals in accordance with manufacturers' recommendations or on a regular basis (e.g. at least annually).**

The table gives an indication of the type and amount of equipment that would be needed to carry out a synchronised field test of the whole area. Actual numbers of equipment will depend upon the size of the model and the complexity of the system.

MODEL TYPE	MAJOR EQUIPMENT ITEMS		
	PRESSURE RECORDERS	FLOW RECORDERS	LEVEL TRANSDUCERS
Simple e.g. town of less than 30,000 population	20–40	2–6	2–4
Town of about 300,000 population, several pressure zones detail sufficient to design a leakage control scheme	40–80	5–15	4–8
Division or Company strategic model of about 1 million population	60–120	15–30	10–20

Field test equipment requirements

General Concepts on how to approach a WSS network Model – Field Work

The field test should normally be carried out for a minimum of a 48 hour continuous period. This time period should give a sufficient number of different flow patterns to calibrate the model. However in some cases it may be advantageous to monitor the system for a longer period of time.

During the field test simultaneous measurements e.g. pressure and flow measurements, at all agreed equipment installation points, should be taken. **All field measurements should be related to a common time-base.**

Flow and pressure readings and service reservoir levels should be taken and stored a minimum of every 5 minutes during the field test period. All data loggers shall be synchronised to within ±15 seconds of each other and to within ±15 seconds of Greenwich mean time.

General Concepts on how to approach a WSS network Model – Calibration

A network model can only be useful as a tool if the Water Utility knows that its behaviour is representative of the real system. This is particularly true when attempting to convince operational staff of the necessity to take action based on a model prediction.

Consequently, the flows and pressures that the model predicts must be compared with the measured inflows and outflows and measured pressures from the field test. If good agreement between the predicted results and field data cannot be obtained, then the model is not a true representation of the part of the real system where serious discrepancies remain.

Models can be calibrated at one or more snapshot conditions. For improved results, calibration can be for a 24 hour simulation period.

General Concepts on how to approach a WSS network Model – Calibration

The following guidelines represent the acceptable performance criteria against which modelled flows and pressures should agree with recorded field data.

Flows

1) Modelled trunk main flows (where the flow is more than 10% of the total demand) **±5% of measured flows**
2) Modelled trunk main flows (where flow is less than 10% of total demand) **±10% of measured flows**

Pressures

1. **85%** of field test measurements **±0.5**m or ±5% of maximum head-loss across system whichever is greater.
2. **95%** of field test measurements **±0.75m** or ±7.5% of maximum head-loss across system whichever is greater.
3. **100%** of field test measurements **±2m** or ±15% of maximum head-loss across system whichever is greater.

6. Documentation

General Concepts on how to approach a WSS network Model – Documentation

It should be stressed that models are built not just to solve an immediate problem. They will probably be used at some time in the future, possibly years later, by someone not conversant with the model building.

Consequently it is essential that detailed, legible and comprehensive records are kept. These records will be continually referred to during the model calibration period and time used in organising them will be well spent.

When the network model has been completed sufficient documentation should be produced such that the network model can be properly used, maintained and updated.

General Concepts on how to approach a WSS network Model – Documentation

A typical network analysis report will consist of the following:

MAIN REPORT

1. summary;
2. objective of study;
3. description of study area;
4. description of method - normally only additions or amendments to accepted techniques;
5. description of each model produced - typically including observations, evaluation of field data, anomalies resolved and unresolved, peculiarities of the system, any non-standard modelling undertaken (e.g. pumping station modelled as a reservoir);
6. results of predictive work;
7. conclusions and recommendations;
8. references to sources of information.

General Concepts on how to approach a WSS network Model – Documentation

APPENDICES (BOUND WITH MAIN REPORT)

- list of input data;
- measured pump characteristic curve calibration;
- pressure point levels;
- calibration computer run, flow and pressure comparisons.

APPENDICES (BOUND SEPARATELY)

- surveying/levelling book (unless carried out by a separate contractor);
- flow and pressure from field measurements.

General Concepts on how to approach a WSS network Model – Documentation

DRAWINGS

- base map geographic showing study area (often 1:10000 or 1:50000);
- base maps or scaled overlays showing included pipework with diameters and node numbers, and nodal areas. Larger scale maps where necessary to show nodal areas;
- schematic diagram, approximately to scale, showing additional nodal and pipe data;
- A4 size location plans (scale 1:1250 or 1:2500 plan) of all tapping points and hydrants.

Questions & Answers

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