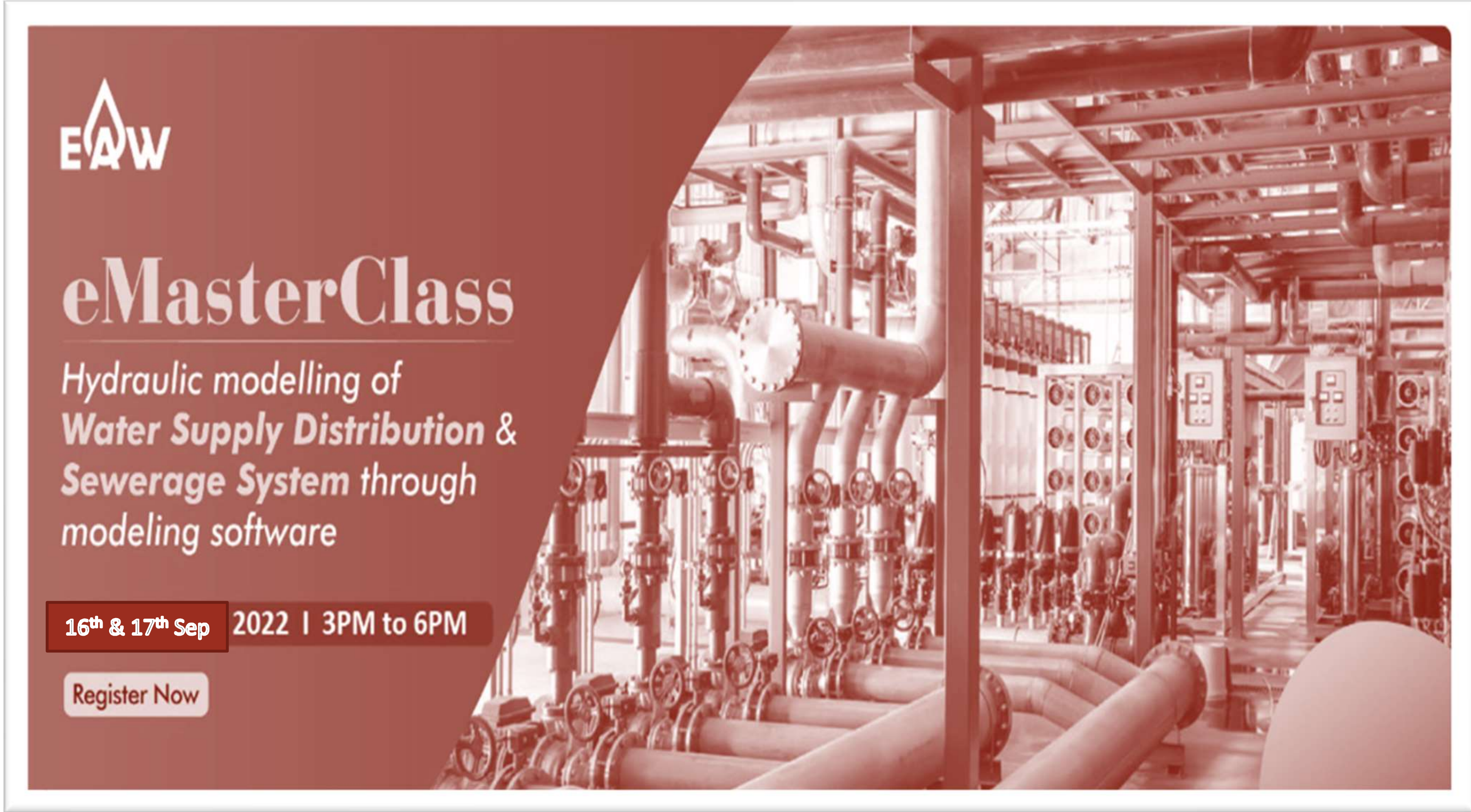
Hydraulic modelling of sewerage Sewerage system through modelling software



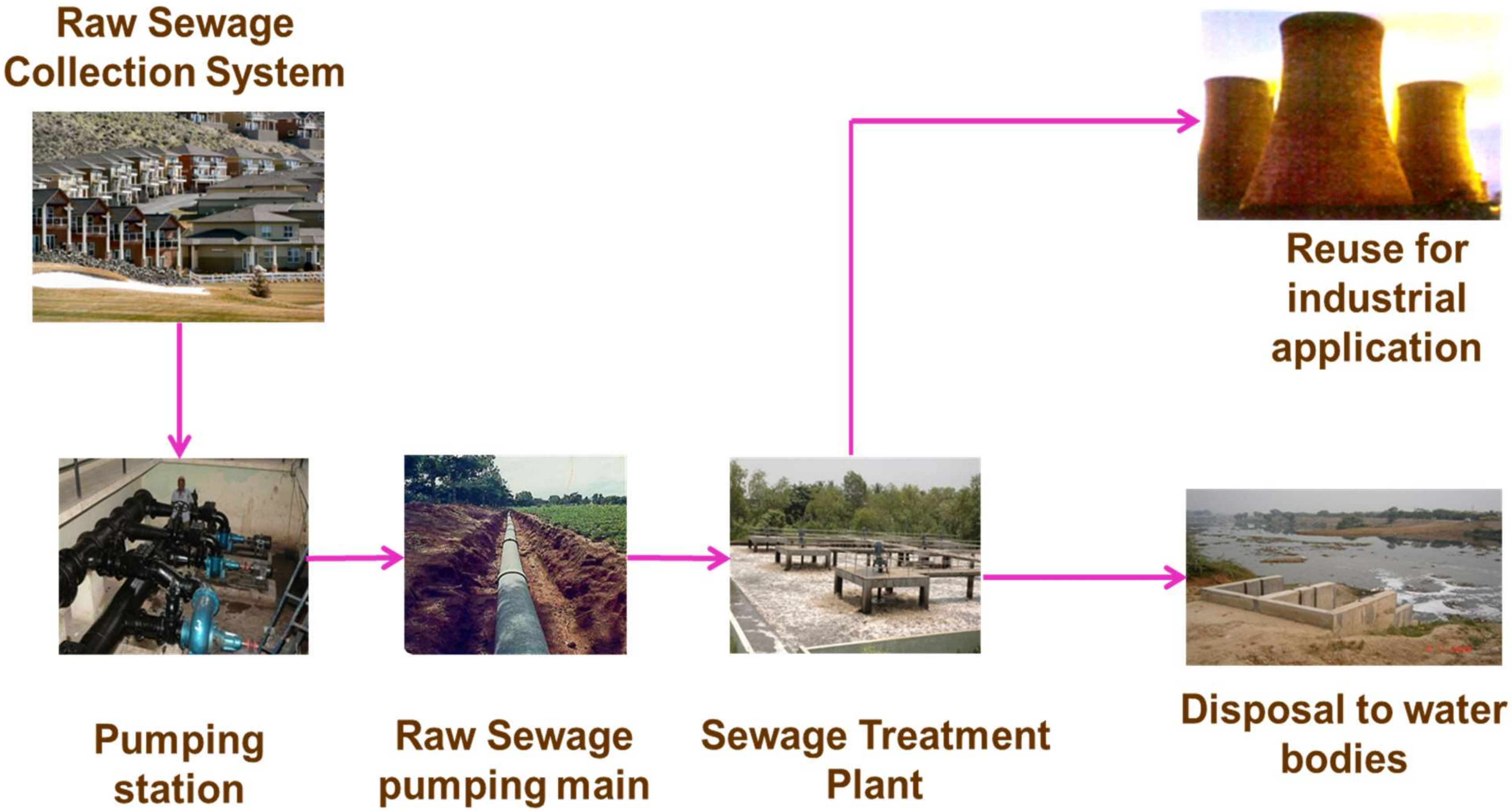
Date of Training : 17.09.2022

Course Contents

- Overview on Sewerage network components
- Design parameters (Population Projection, Design period, Peak factor, Pipe materials, velocity criteria, pipe flow (d/D) constraints)
- Basics on Hydraulics of Sewer network system
- Creation of Hydraulic model of a Sewer network
  - Requirements of Hydraulic model
  - Modelling software elements
  - Building a Hydraulic model & Its Process
  - Happening inside a Hydraulic model
  - Locating of Outfalls & Creation of Sewerage zone in the Hydraulic model.
  - Optimisation of sewer network through hydraulic models.
  - Scenario creation and management.
- Benefits & Use of Simulated model results from a Hydraulic model

Sewerage network components

Sewerage system is to collect and transport sewage from various point sources to the point of treatment or discharge



Design Parameters – (1 /2)

Projection of future population

Expected population for the Intermediate year (15 years) and ultimate year (30 years) is worked out adopting the census population from the say present 2011 year and past decades by following different methods.

- Arithmetical Increase
- Incremental Increase
- Geometric Progression
- Line of Best Fit Method
- Exponential Method
- Population Forecast by Semi - log
- District decadal growth rate

Unit Sewage Flow : 80 % of Water supplied (i.e 135 lpcd / 150 lpcd)

Peak Factor :

Contributory Population	Peak Factor
Upto 20,000	3.00
20,000 – 50,000	2.50
50,000 – 750,000	2.25
Above 750,000	2.00

Design Parameters – (2 /2)

Design Period

- Base year – Year at which project is expected to be completed.
- Intermediate design year – 15th Year from Base year.
- Ultimate design year -30th Year from Base Year.

Diameter of the sewers and the slope should be decided to meet the following conditions

- Minimum size of the sewer should be not less than 150mm.
- If any future development is anticipated beyond the head reach, the starting sewer can be of 200mm diameter.

Velocity

The velocity of flow and slopes (grade) of sewers are very important criteria in the sewer design.

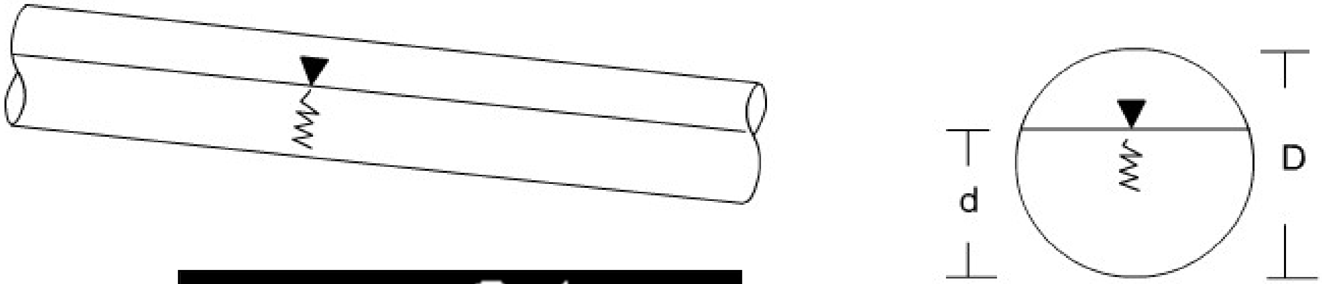
A self-cleansing velocity of 0.6 m/s and 0.8 m/s should be maintained at the present peak flow, and at the ultimate peak flow respectively.

D/d ratio :

Sewer section should be designed to run at partial full condition always not exceeding 0.80 full depth at the ultimate peak flow.

Basics on Hydraulics of Sewer Network System (1/2)

Equation for flow

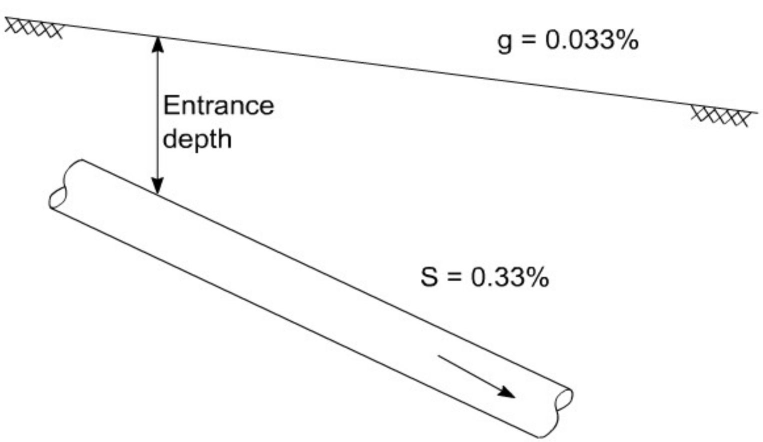


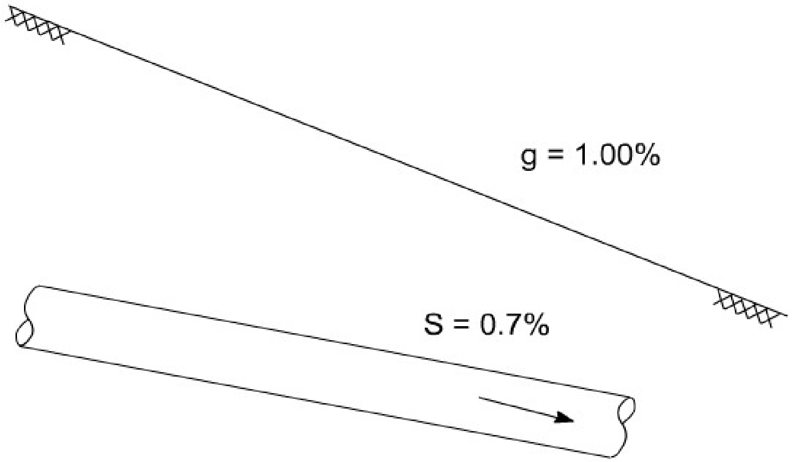
$$v = \frac{1}{n} r_h^{2/3} \sqrt{S_o}$$

v = velocity; a = flow area; r_h = hydraulic radius; S_o = sewer slope; n = roughness coefficient; d = flow depth ; D = sewer diameter

Sewer is designed for steady, uniform free surface flow conditions d/D < 0.8

Basics on Hydraulics of Sewer Network System (2/2)





- Sewer grade > ground slope
- Sewer becomes deeper and deeper
- Pumping may be necessary

- Ground slope > minimum slope required
- Sewer slope > minimum slope required
- Sewer slops < ground slope
- A fall becomes necessary

What does Hydraulic modelling software does?

Given:
System map
Physical properties
Loading data

Software packages :
SewerGEMS
SWMM (USEPA)
Infoworks ICM SE
Canal ++ (tandler.com) &
Many more etc.

Determines:
Flow, velocity, depth
in each conduit
Level in
each manhole, wet well /Outfall depth

Creation of Hydraulic model of a Sewer network

Major Activities in Creation of Hydraulic Model

- ✓ Population data collection and Wastewater flow estimation.
- ✓ Field Topographical Survey
- ✓ Base Map preparation and creation of network
- ✓ Existing sewerage system study.
- ✓ Adequacy of existing sewerage system through detailed analysis.
- ✓ Design of new sewer Collection network

Creation of Hydraulic model of a Sewer network

Future Demand Projections :

The demand growth is considered based on the following criteria:

a) Growth of domestic population based on population density
b) Growth of non-domestic and industrial/institutional population in proportion to the customer survey
c) Bulk flow based on existing customers and expected future growth
d) Provision for Infiltration to be considered based on soil conditions of the project area.

Sewage Pumping station and Lifting station &Wetwell etc :

a) To be preferably Located at lowest point

b) The location of the service reservoir should be such as to maintain the depth of the sewer system consistent with its cost effectiveness.

c) Lifting & Pumping stations:
For localities with higher depths, boosters may be provided instead of increasing the size of mains or depth of manhole unduly for maintaining the required depth.

Base map Creation & Network marking:

a) Conduct field surveys
b) Fix the alignment of trunk main
c) Prepare topographical map of the project area/town
d) Prepare cross-sections of streets etc
e) Mark tentative lay out of network
f) Show positions of reservoirs,
g) Mark the existing pipes, valves and other appurtenances

Sewer Network design

a) Estimate inflow based on population density
b) Assume appropriate diameters
c) Analyze the system for depth of manholes
d) Check for satisfaction of constraints
e) Assume another set of diameters
f) Repeat the process
g) Select the system: satisfies all the constraints and is most economical

Elements in a Network Modelling

- Point
  - Manhole
  - Pressure junction
  - Junction chamber
  - Catch basin
  - Pump
  - Wet well
  - Pond outlet
  - Outfall
- Line
  - Conduit
  - Channel
  - Pressure pipe
  - Gutter
- Polygon
  - Catchment
  - Pond

Elements in a Network Modelling

Manholes:

Manholes reference number

Ground elevation

Invert elevation

Manhole inflow

Pipes/conduits:

Pipe reference number

Length of the pipe line between manholes

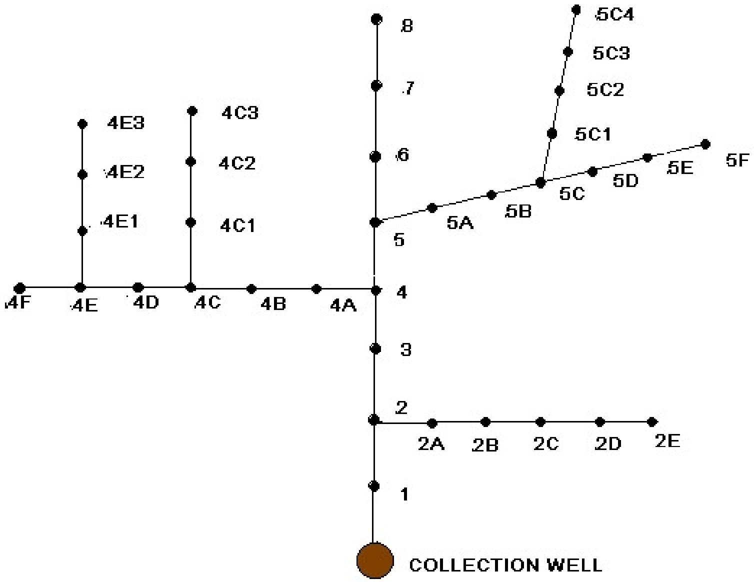
Diameter of the pipe line

Material of the pipe line

Mannings Coefficient ('n' Value)

Outfalls:

- Outfall location
- Ground Elevation.
- Invert Elevation.



Building a Network Modelling & its Process

Network Data- System Layout

Data
- coordinates of each pipe segment and manhole
- locations of wet wells, pumps, appurtenances
- pipe connectivity, lengths
- pipe diameters, materials
- pipe invert levels and manhole elevations

Data Sources
- maps – paper/CAD
- construction/as-built drawings
- corporate GIS system
- asset-management systems
- work orders
- field survey data

Hydraulic Properties

Data
- pipe roughness
- pump curves

Data Sources
- manufacturers’ specifications
- contractor submittals
- literature values
- field tests

Sanitary flows

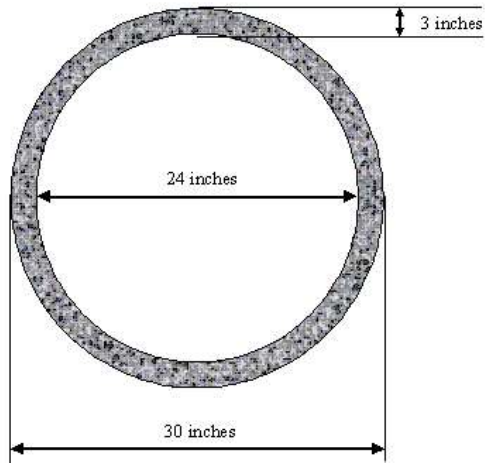
Data
- location of each source
- min, max, mean daily flows
- diurnal patterns
- projections

Data Sources
metering
maps, aerial photos
census data

Building a Network Modelling & its Process

Defining Gravity Pipes

- Internal diameter
- Length (schematic or scaled)
- Material
- Roughness as Manning's n
- Shape
- Invert elevations (set to upstream/downstream pipe)
- Number of sections

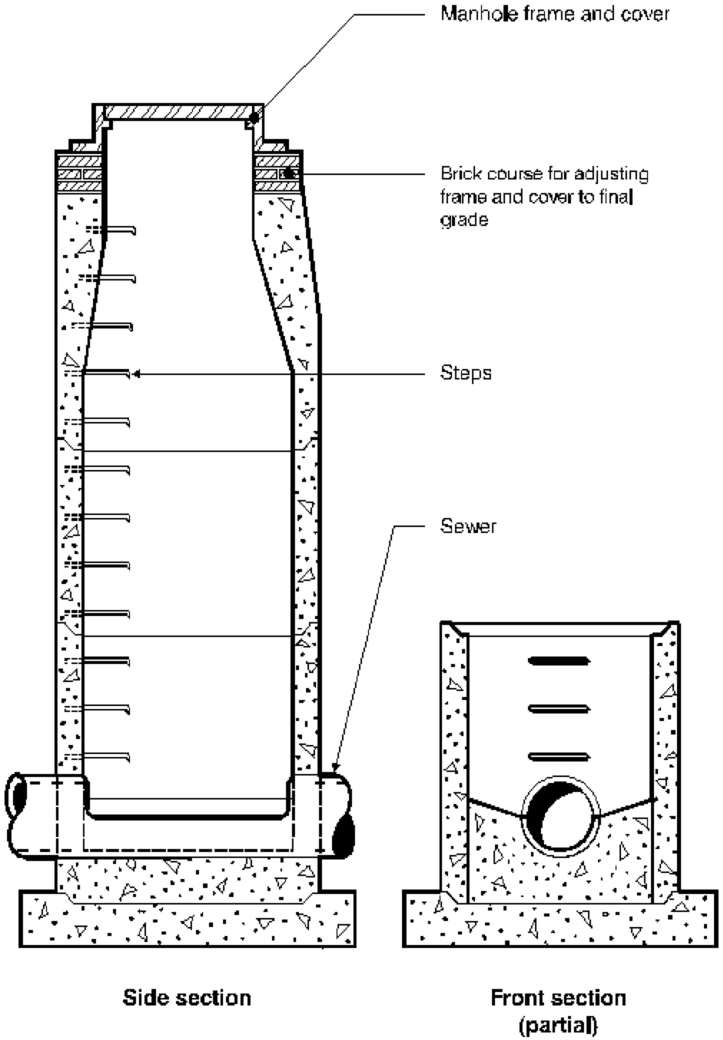


Building a Network Modelling & its Process

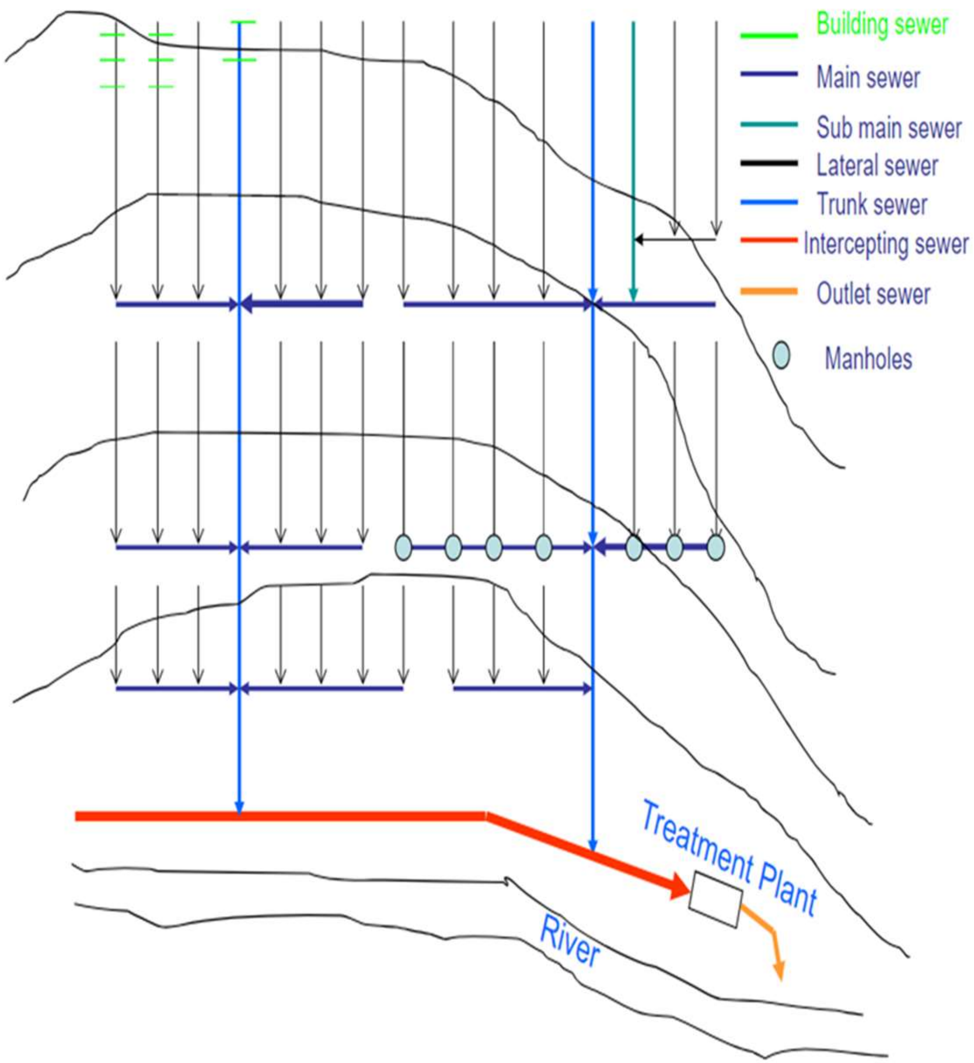
Defining Manholes

- Invert elevation- bottom of pipe entering manhole
- Rim elevation
- Structure size- common diameter of manholes
- Drop manhole- incoming sewage transported down vertical shaft

S. No.	Depth (m)	Diameter (mm)
1	0.90 – 1.65	900
2	1.65-2.30	1200
3	2.30-9.0	1500



Building a Network Modelling & its Process



Design, Analysis and Network modelling

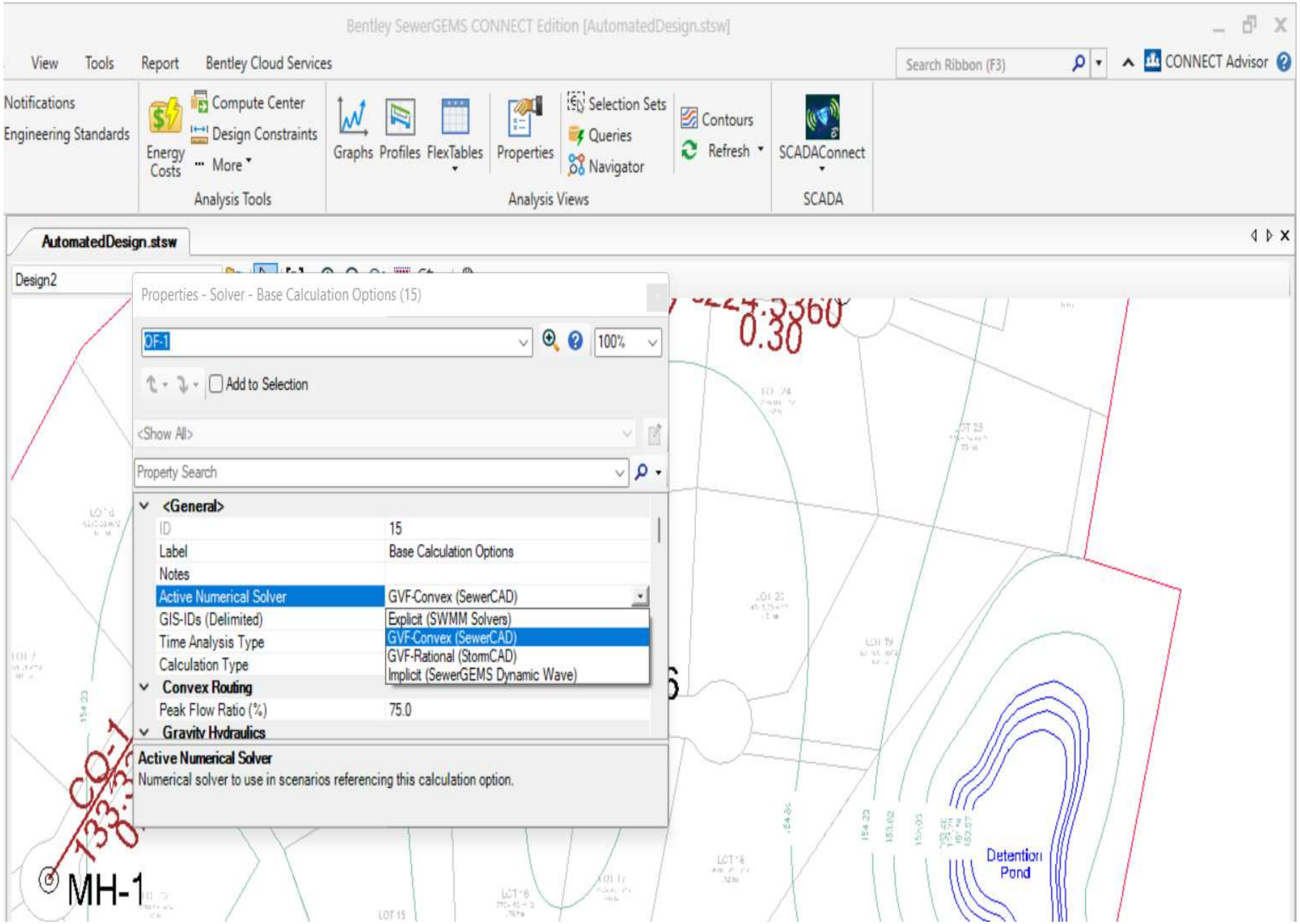
Strategic hydraulic model can be developed using any available Hydraulic modelling latest software (SewerGEms, Excel Spread sheets etc.)

like elevation, Wastewater inflow, peak factor for manholes and diameter, length, manning's (friction) coefficient for the pipes.

Major Elements in a Hydraulic Model :

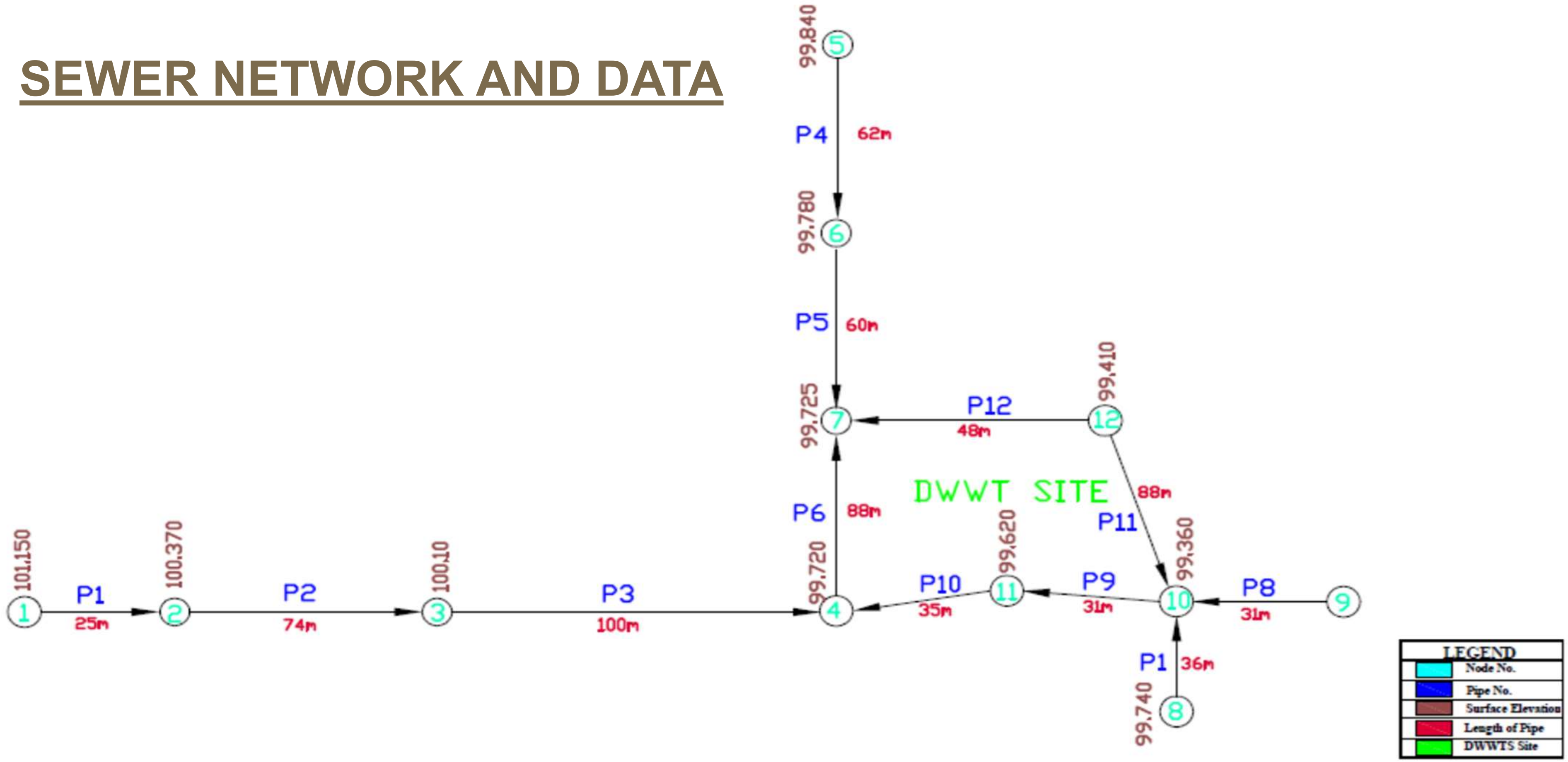
- **Manholes**
- **Pipes**
- **Outfalls (Wells & Pumping stations)**

Happening inside a Hydraulic model



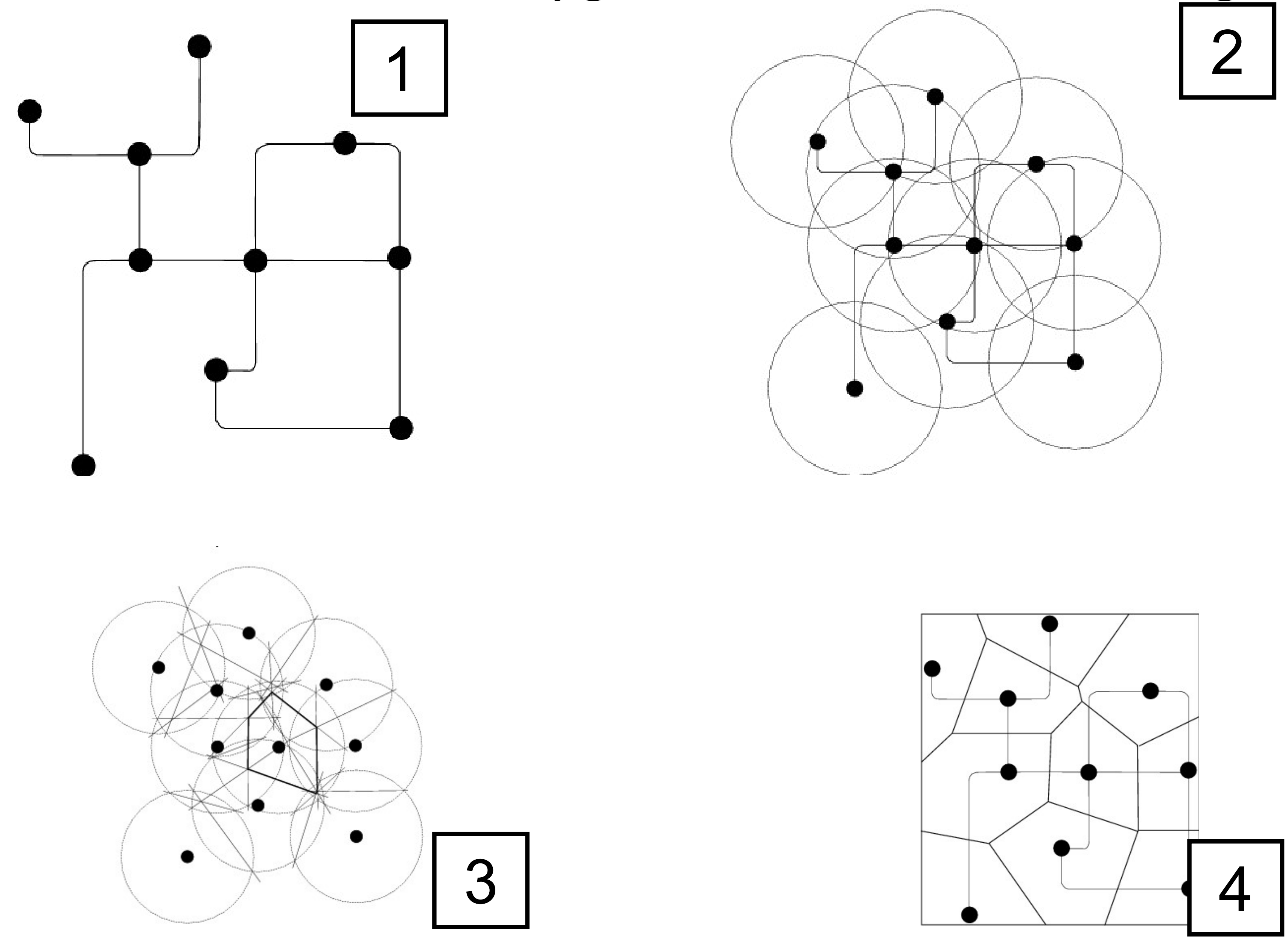
Happening inside a Hydraulic model

SEWER NETWORK AND DATA



Happening inside a Hydraulic model

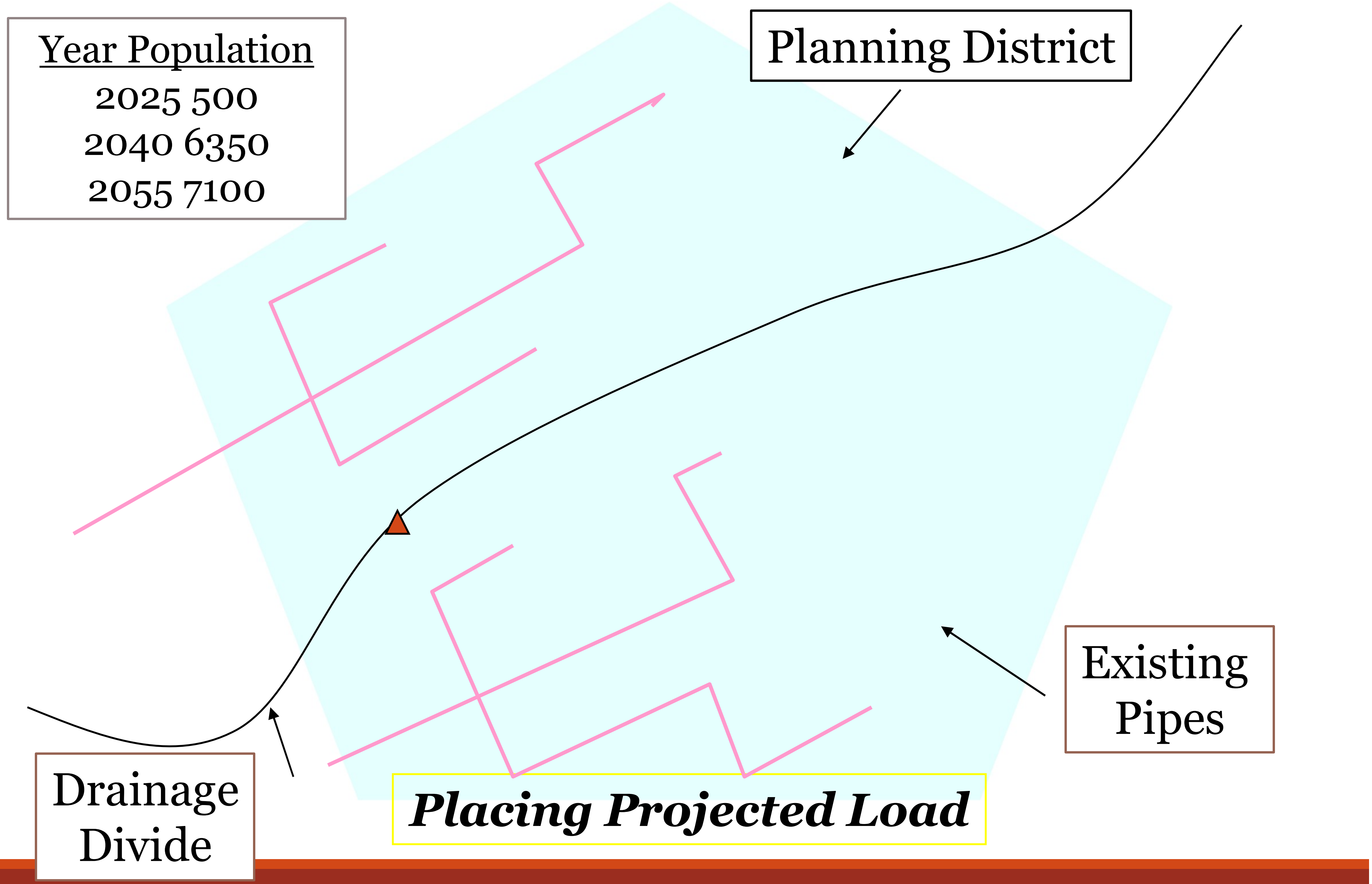
Thiessen Polygon Generation for loading



Happening inside a Hydraulic model

				GL at Respective nodes					
Pipe No. (n)	Upstream_node No.	Downstream_node No.	Order of pipe	Upstream (m)	Downstream (m)	Pipeslope (choosen)	Population	Length (m)	D_chosen (m) (Choosen)
1.00	1.00	2	1	101.15	100.37000	0.03120	450	25	0.1
2.00	2.00	3	2	100.37	100.01000	0.00700	554.4	74	0.1
3.00	3.00	4	3	100.01	99.72000	0.00600	283.2	100	0.15
4.00	5.00	6	1	99.84	99.78000	0.02000	222	62	0.1
5.00	6.00	7	2	99.78	99.72500	0.02000	18	60	0.1
6.00	4.00	7	4	99.72	99.72500	0.00350	54	88	0.2
7.00	8.00	10	1	99.3	99.36000	0.01700	276	36	0.1
8.00	9.00	10	1	99.3	99.36000	0.01300	372	36	0.1
9.00	10.00	11	2	99.36	99.62000	0.00600	36	30	0.15
10.00	11.00	4	3	99.62	99.72000	0.00600	12	35	0.15
11.00	12.00	10	1	99.41	99.36000	0.00900	656.4	88	0.1
12.00	12.00	7	1	99.41	99.72500	0.03000	26.4	48	0.1

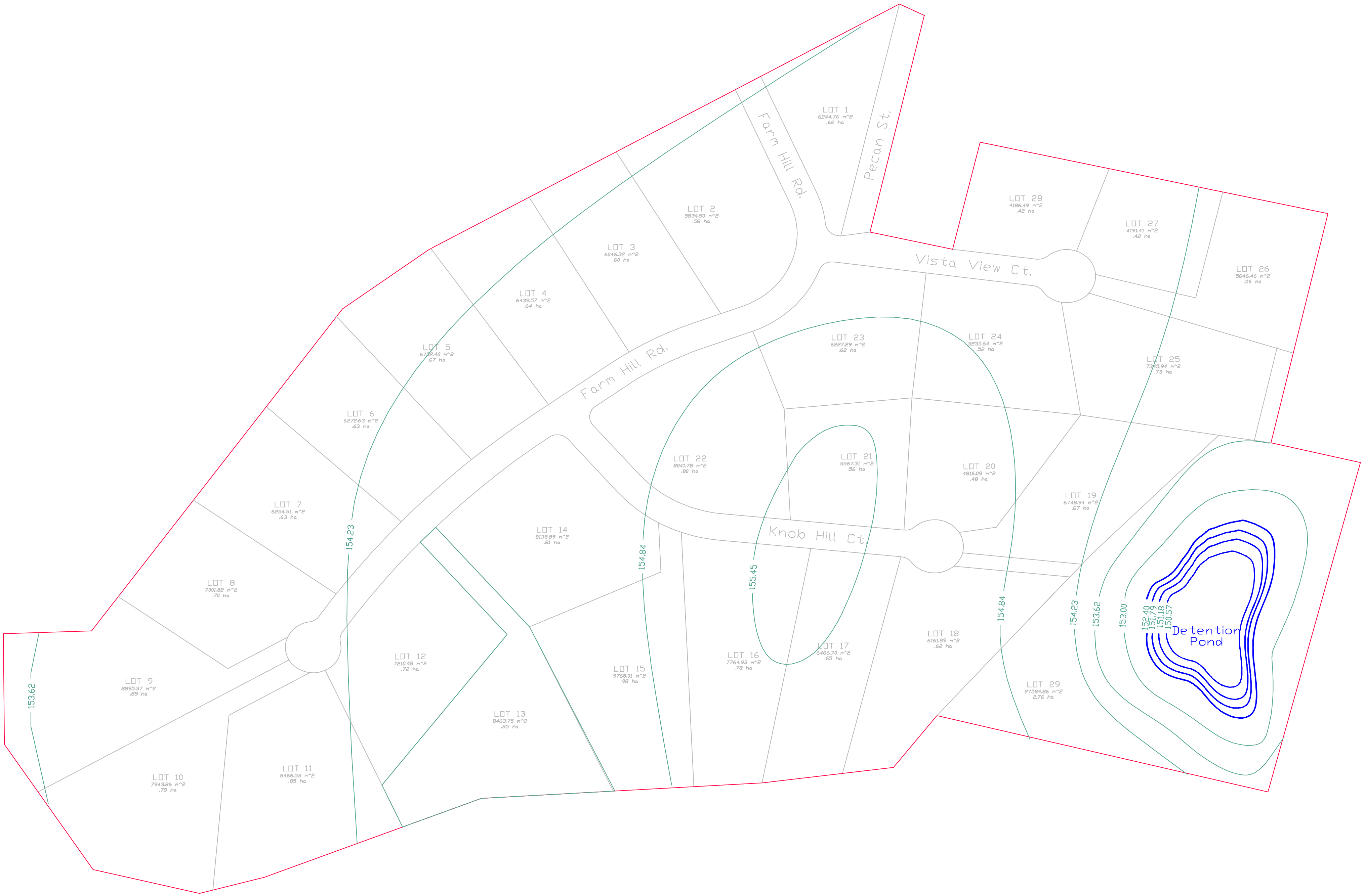
Locating of Outfalls & Creation of Sewerage zone in the Hydraulic model.



Locating of Outfalls & Creation of Sewerage zone in the Hydraulic model.

- The sewage generated from an area is collected through a sewer network consists of sewers and conveyed to the sewage pumping station for onward conveyance to the sewage treatment plant for further treatment and disposal.
- The sewer network is formulated with the help of contours. Generally, the sewage pumping station (SPS) is located at low-lying area of the catchments.
- In addition to the contour levels, the distance of the farthest point of the network from the SPS is also taken into consideration while deciding the number of sub-catchment areas or zones of the sewage collection system.
- After formulation of the zones with networks, manholes are marked at every 30 metres apart from junctions and change in directions.
- The network consists of trunk sewer, main sewer, submain, branch, sub-branch and laterals etc. and the line numbers were given accordingly.
- Manhole numbers are assigned based on the line number.
- The nomenclatures of manhole numbers are generally as per the guidelines specified by Central Public Health & Environmental Engineering Organisation (CPHEEO) Manual.

Locating of Outfalls & Creation of Sewerage zone in the Hydraulic model.



Locating of Outfalls & Creation of Sewerage zone in the Hydraulic model.

- Select sewage treatment and disposal location depending up on the availability of land or water courses,
- Divide the town into number of zones,
- Factors to be considered in zoning:
  - *Railway line, NH, river etc., can be treated as zone boundaries since gravity sewer crossing of these features is expensive.*
  - *An area of the town having a descending slope can form a zone*
  - *To restrict the depth of cutting to the pre-determined level (5 to 6m) since excavation under ground water table condition and / or in hard rock is difficult and expensive.*
  - *The site is available for the pumping station.*
  - *Exceeding the maximum depth of cutting for short lengths to avoid introduction of lift station is permitted.*

Locating of Outfalls & Creation of Sewerage zone in the Hydraulic model.

- Main pumping station (MPS) is located nearer to the STP site. MPS will collect sewage from all zones and pump to STP
- SPS of one of the zones nearer to STP may be converted as MPS
- Prepare a map of sewer network by aligning the sewer lines in roads along the natural slope of the terrain to drain into the collection well,
- Don't align sewers against the slope and across the ridges
- In exceptional case, aligning across a small ridge is permitted
- Consider subsoil condition and level of ground water table and fix the maximum depth of cutting, which may be 5 to 6m,
- For the assumed zoning, mark the trunk sewer alignment
- By rough calculation assuming an average grade of 1 in 200 calculate the depth of excavation and check with the maximum depth of cutting
- If the calculated depth is within the permissible depth of excavation proceed further for the detailed designing of the collection system adopting the zoning.
- If the calculated depth of cutting exceeds the permissible cutting, revise the zoning of the town, by shifting the location of pumping station or introducing additional pumping station/lift stations.

Scenario Creation and Management

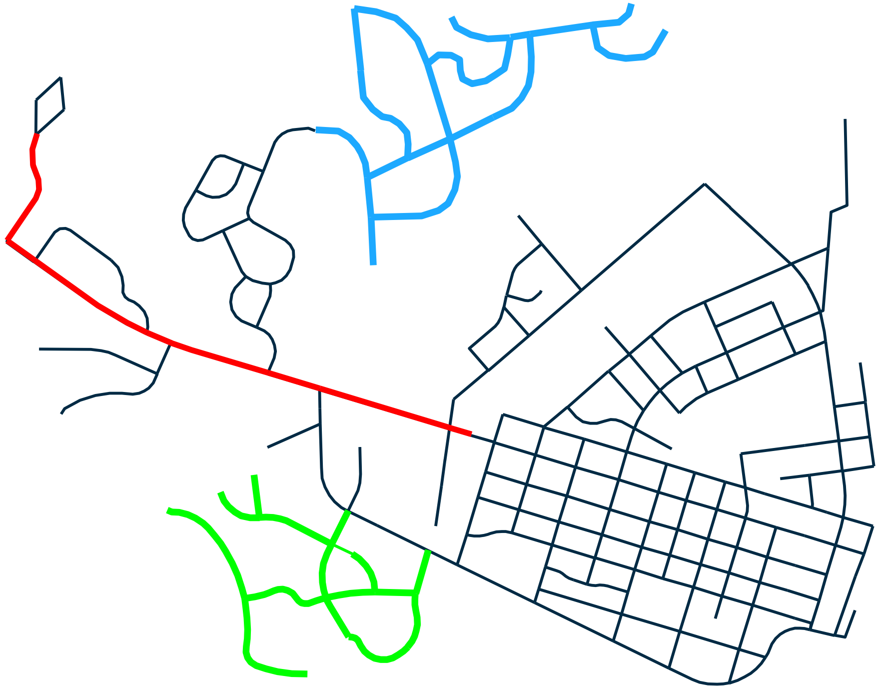
- Scenario = single run of model
  - contains type of run
  - points to alternative sets
- Alternatives = data set
  - building block of scenarios
- Inheritance = building alternative and scenarios from previous
  - Add = no data
  - Duplicate = copy but no link
  - Child = link data sets

Scenario Creation and Management

Scenario Management

Current Scenario

- Year 2025 Scenario
  - Year 2040 Scenario
- New Diameter Scenario



Alternatives

Physical: Calibrated

Demand: Current

Active Topology: Current

Physical: 2025

Inflow: 2025

Active Topology: New 2025

Physical: Extended 2040

Inflow: 2040

Active Topology: New 2040

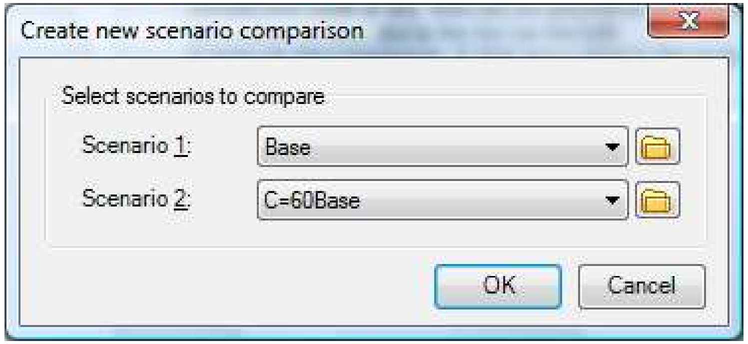
Physical: New Design

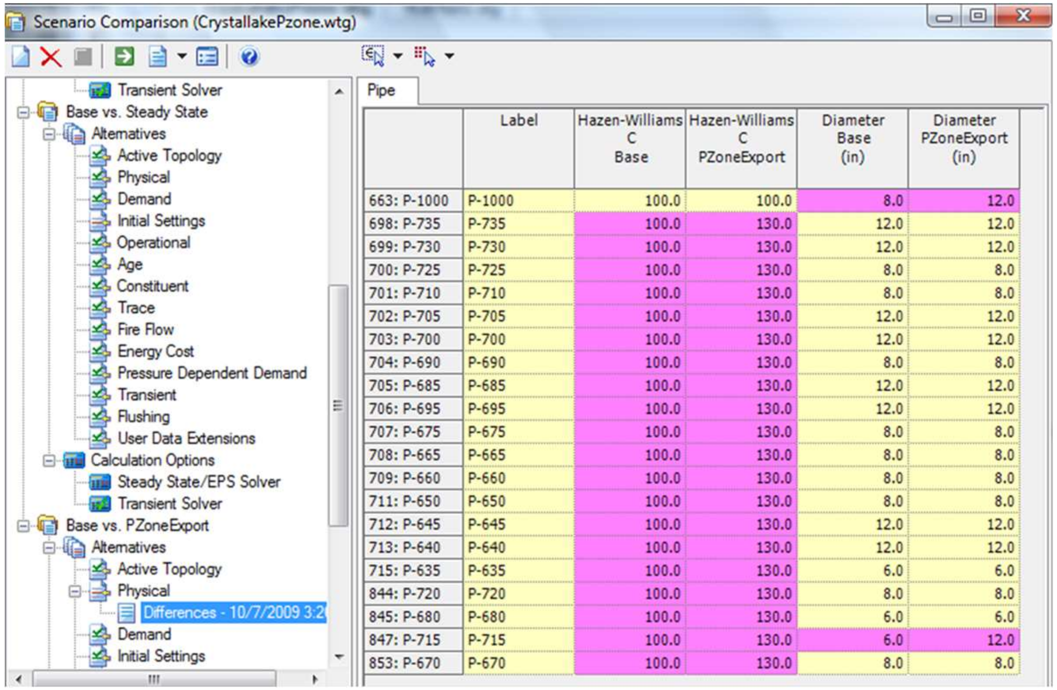
Inflow: Max 2055

Active Topology: New 2055

Scenario Management

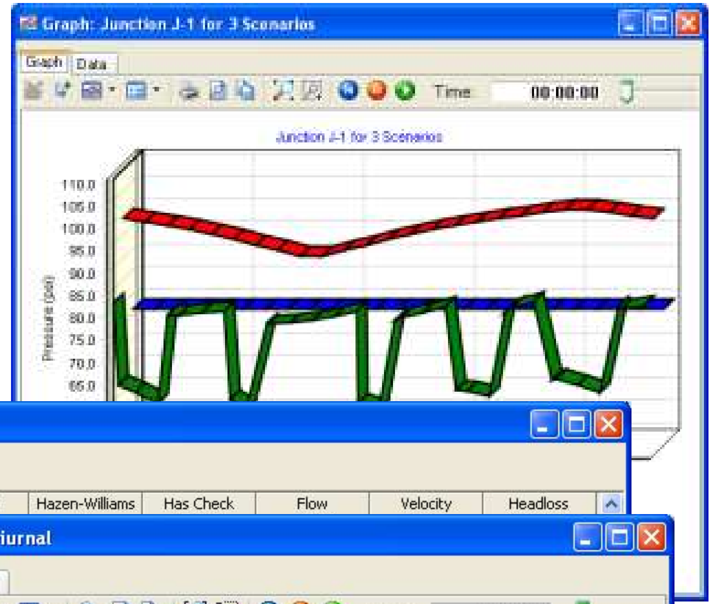
- Tools > Scenario Comparison
- Pick two scenarios to compare
- View alternative differences
- For any alternative, select GO for element details
- Can create selection set of elements
- Can highlight elements in drawing
- Log the time when comparison done

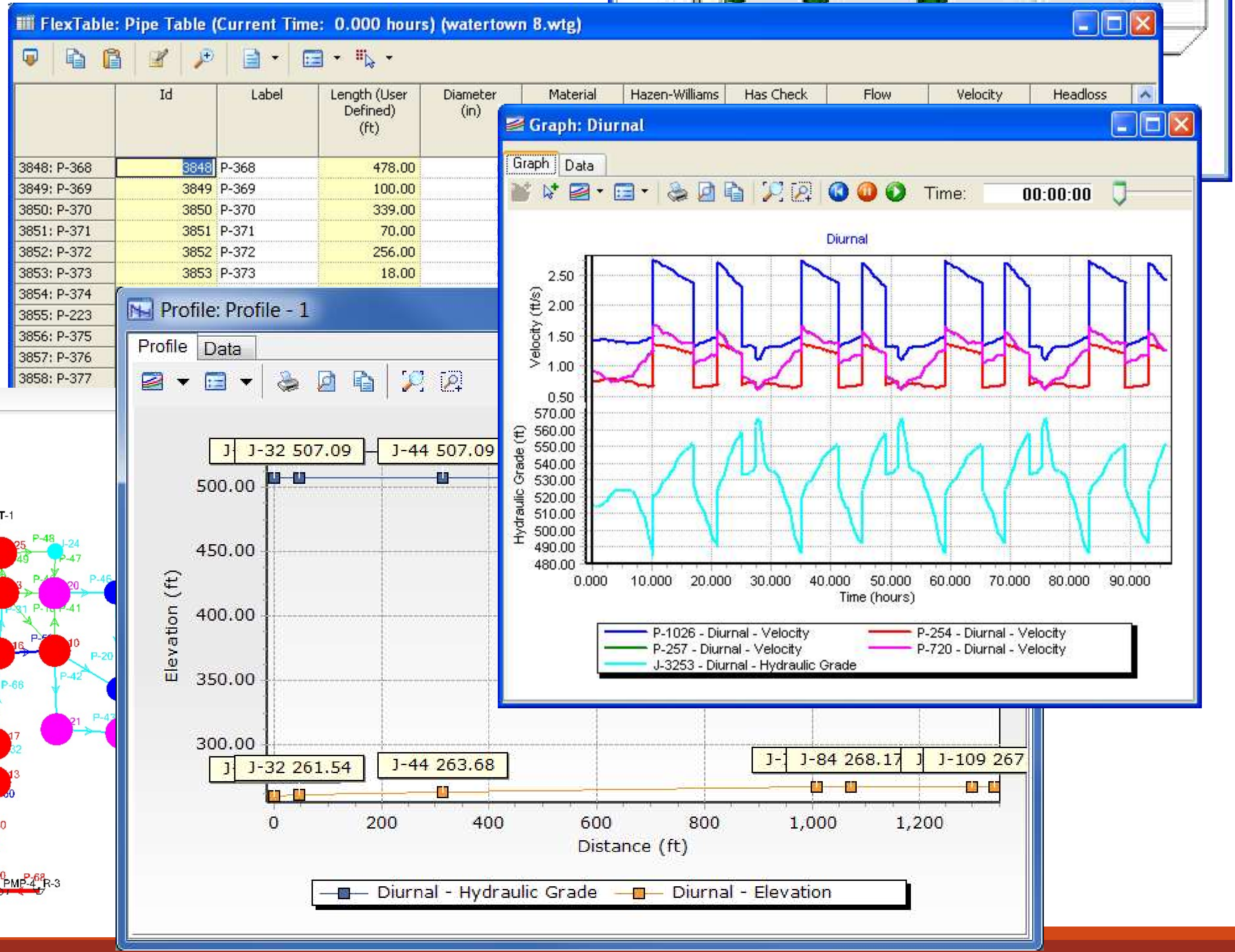


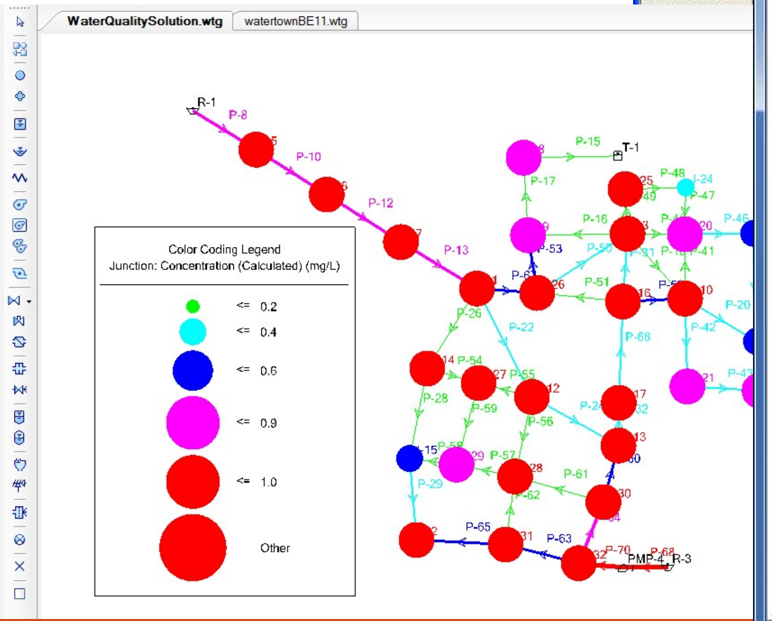


Review Results

- Color Coding/Annotation
- FlexTables
- Graphs
- Profiles







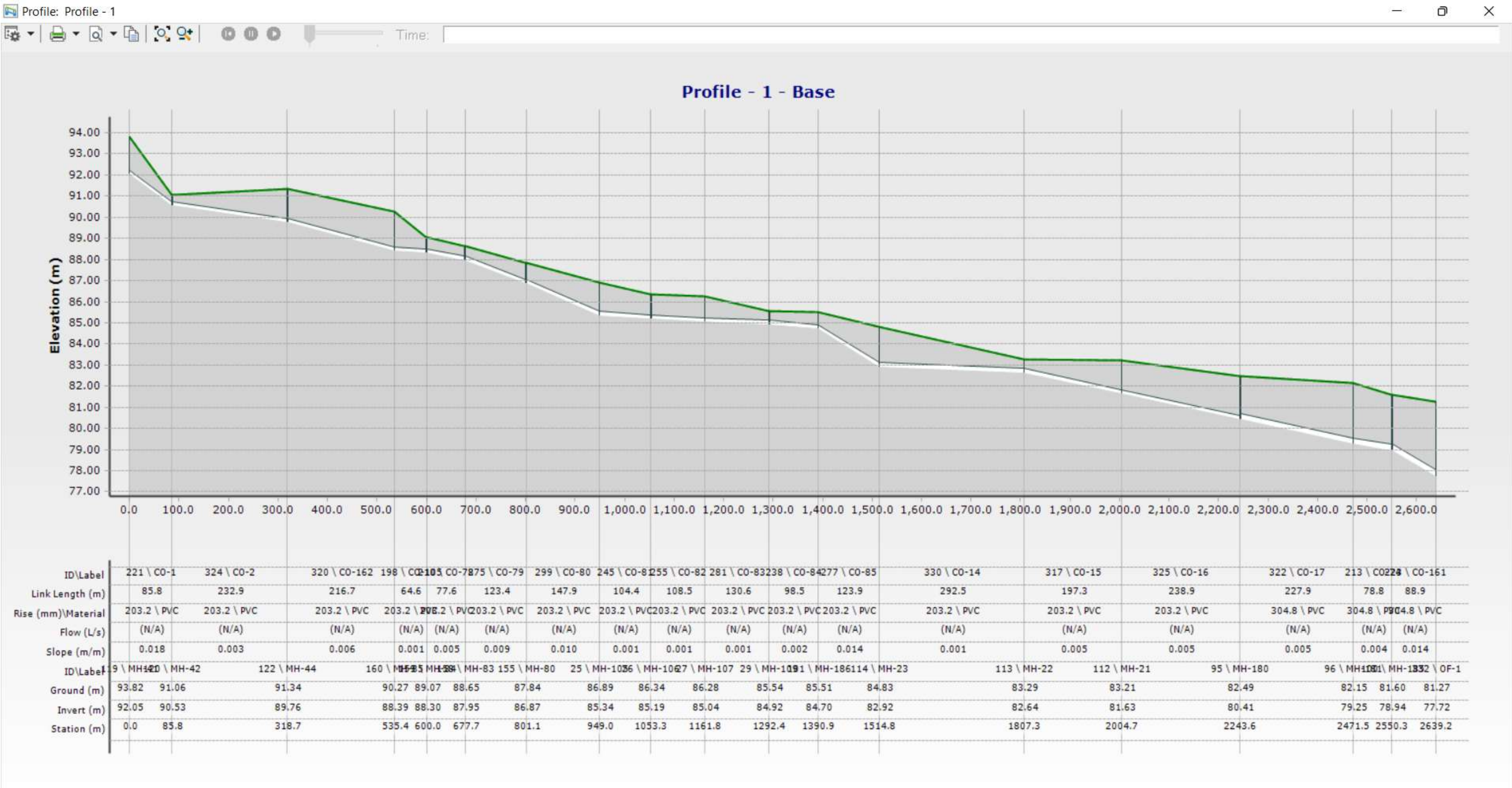
HYDRAULIC STATEMENT OF SEWER NETWORK

FlexTable: Conduit Table (Current Time: 0.000 hours) (GeospatialProgress.stsw)

	ID	Label	Start Node	Set Invert to Start?	Invert (Start) (m)	Stop Node	Set Invert to Stop?	Invert (Stop) (m)	Length (Scaled) (m)	Slope (Calculated) (m/m)	Section Type	Diameter (mm)	Manning's n	Capacity (Full Flow) (L/s)	Notes
221: CO-1	221	CO-1	MH-41	☑	92.05	MH-42	☑	90.53	85.8	0.018	Circle	203.2	0.013	45.54	
324: CO-2	324	CO-2	MH-42	☑	90.53	MH-44	☑	89.76	232.9	0.003	Circle	203.2	0.013	19.67	
310: CO-4	310	CO-4	MH-45	☑	94.38	MH-37	☑	91.21	172.0	0.018	Circle	203.2	0.013	46.45	
308: CO-5	308	CO-5	MH-37	☑	91.21	MH-46	☑	89.92	163.6	0.008	Circle	203.2	0.013	30.38	
191: CO-6	191	CO-6	MH-46	☑	89.92	MH-87	☑	89.00	59.5	0.015	Circle	203.2	0.013	42.55	
186: CO-7	186	CO-7	MH-87	☑	89.00	MH-65	☑	87.48	55.6	0.027	Circle	203.2	0.013	56.59	
201: CO-8	201	CO-8	MH-65	☑	87.48	MH-81	☑	86.78	65.9	0.011	Circle	203.2	0.013	35.27	
188: CO-9	188	CO-9	MH-81	☑	86.78	MH-67	☑	86.48	57.5	0.005	Circle	203.2	0.013	24.71	
327: CO-10	327	CO-10	MH-67	☑	86.48	MH-71	☑	85.23	244.2	0.005	Circle	203.2	0.013	24.48	
216: CO-11	216	CO-11	MH-71	☑	85.23	MH-72	☑	84.82	81.8	0.005	Circle	203.2	0.013	24.22	
175: CO-12	175	CO-12	MH-72	☑	84.82	MH-73	☑	83.06	34.4	0.051	Circle	203.2	0.013	77.36	
237: CO-13	237	CO-13	MH-73	☑	83.06	MH-23	☑	82.92	98.1	0.001	Circle	203.2	0.013	12.92	
330: CO-14	330	CO-14	MH-23	☑	82.92	MH-22	☑	82.64	292.5	0.001	Circle	203.2	0.013	10.59	
317: CO-15	317	CO-15	MH-22	☑	82.64	MH-21	☑	81.63	197.3	0.005	Circle	203.2	0.013	24.48	
325: CO-16	325	CO-16	MH-21	☑	81.63	MH-180	☑	80.41	238.9	0.005	Circle	203.2	0.013	24.45	
322: CO-17	322	CO-17	MH-180	☑	80.41	MH-181	☑	79.25	227.9	0.005	Circle	304.8	0.013	71.98	
298: CO-18	298	CO-18	MH-35	☑	87.78	MH-33	☑	87.31	147.3	0.003	Circle	203.2	0.013	19.33	
302: CO-20	302	CO-20	MH-36	☑	92.35	MH-37	☑	91.21	151.2	0.008	Circle	203.2	0.013	29.71	
184: CO-21	184	CO-21	MH-55	☑	86.56	MH-54	☑	85.34	53.7	0.023	Circle	203.2	0.013	51.55	
208: CO-22	208	CO-22	MH-54	☑	85.34	MH-53	☑	85.04	75.1	0.004	Circle	203.2	0.013	21.62	
193: CO-23	193	CO-23	MH-53	☑	85.04	MH-52	☑	84.89	60.3	0.002	Circle	203.2	0.013	17.06	
233: CO-24	233	CO-24	MH-52	☑	84.89	MH-51	☑	84.73	94.1	0.002	Circle	203.2	0.013	14.11	
244: CO-25	244	CO-25	MH-51	☑	84.73	MH-63	☑	84.43	104.2	0.003	Circle	203.2	0.013	18.36	
230: CO-26	230	CO-26	MH-63	☑	84.43	MH-62	☑	84.12	93.3	0.003	Circle	203.2	0.013	19.72	
326: CO-27	326	CO-27	MH-62	☑	84.12	MH-69	☑	83.80	242.8	0.001	Circle	203.2	0.013	12.42	
232: CO-30	232	CO-30	MH-56	☑	85.34	MH-57	☑	84.80	94.1	0.006	Circle	203.2	0.013	25.93	
229: CO-31	229	CO-31	MH-57	☑	84.80	MH-58	☑	84.56	92.9	0.003	Circle	203.2	0.013	17.40	
217: CO-32	217	CO-32	MH-58	☑	84.56	MH-183	☑	84.34	84.8	0.003	Circle	203.2	0.013	17.43	
220: CO-33	220	CO-33	MH-183	☑	84.34	MH-62	☑	84.12	85.2	0.003	Circle	203.2	0.013	17.39	
276: CO-35	276	CO-35	MH-74	☑	83.21	MH-75	☑	83.09	123.5	0.001	Circle	203.2	0.013	10.67	
214: CO-36	214	CO-36	MH-75	☑	83.09	MH-73	☑	83.06	80.1	0.000	Circle	203.2	0.013	6.62	
295: CO-37	295	CO-37	MH-68	☑	85.65	MH-70	☑	84.82	143.8	0.006	Circle	203.2	0.013	25.99	
248: CO-38	248	CO-38	MH-70	☑	84.82	MH-69	☑	83.80	105.5	0.010	Circle	203.2	0.013	33.65	
218: CO-39	218	CO-39	MH-184	☑	86.26	MH-62	☑	84.12	84.8	0.025	Circle	203.2	0.013	54.34	
177: CO-40	177	CO-40	MH-49	☑	90.22	MH-50	☑	87.66	38.5	0.066	Circle	203.2	0.013	88.18	
228: CO-41	228	CO-41	MH-50	☑	87.66	MH-51	☑	84.73	92.6	0.032	Circle	203.2	0.013	60.85	
180: CO-42	180	CO-42	MH-47	☑	91.44	MH-48	☑	90.14	49.0	0.027	Circle	203.2	0.013	55.72	
234: CO-43	234	CO-43	MH-48	☑	90.14	MH-50	☑	87.66	94.3	0.026	Circle	203.2	0.013	55.48	

155 of 155 elements displayed

TYPICAL VIEW OF HYDRAULIC PROFILE OF SEWER NETWORK



Benefits & Use of Simulated model results from a Hydraulic model

- Creation of Digital twins of Sewerage Infrastructures.
- Help in implementing an efficient Sewage collection and conveyance system.
- Rezoning of the Sewerage system with help of Hydraulic modeling.
- To take decision on rehabilitation and replacement of sewer pipes in existing network.
- To identify defects in sewer network.

Q & A ?

Useful References for self learning and training of Hydraulic modelling and design of water supply and sewer network

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9. http://cpheeo.gov.in/cms/manual-on-sewerage-and-sewage-treatment.php
10. http://cpheeo.gov.in/cms/manual-on-water-supply-and-treatment.php
11. https://mohua.gov.in/pdf/624eb498862a7Guidelines-for-Planning-Design-and-Implementation-of-24x7-Water-Supply-Systems.pdf

Thank You !

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