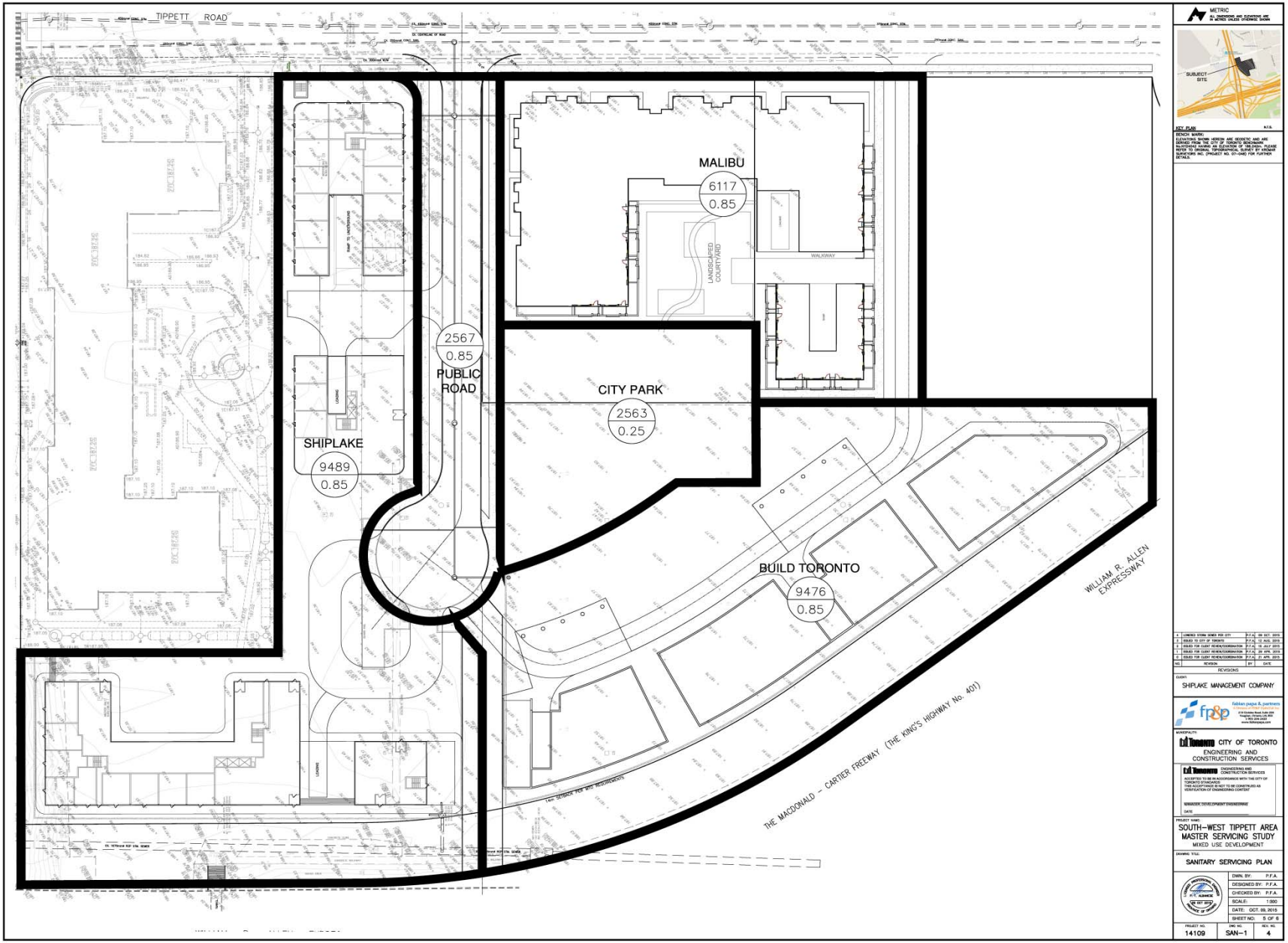
Sanitary Sewer Design

Lecture 1

Definitions

- **Average Daily Flow** (ADF) (Design) - Summation of Land Use Demographics coefficient times the area (acres) corrected for the equivalent rates per City charts.
- **Average Daily Flow** (ADF) (Measured) The total measured quantity of flow tributary to a point divided by the number of days of flow measurement.
- **Sanitary Service (Building Sewer)** - that portion of the sewer lying within private property, between the building and public street sewer easement, or private disposal system. Also, called a House Sewer.
- **Infiltration** - the total extraneous flow entering a sewer system, excluding sanitary sewage, because of poor construction, corrosion of the pipe, ground movement or structural failure through joints, porous walls or breaks.
- **Inflow** - the extraneous flow which enters a sanitary sewer from sources other than infiltration, such as roof drains, basement drains, land drains or manhole covers.
- **Interceptor Sewer** - a collecting sewer that intercepts and collects the sewage from local public sewers and conducts such sewage to a point of treatment or disposal.
- **Main or Trunk Sewer** - a larger sewer that has tributary branches and serves a large area.
- **Outfall Sewer** - a major sewer that receives wastewater from a collecting sewer system or a treatment plant and flows to a point of disposal.
- **Peak Dry Weather Flow** (PDWF) - The maximum flow rate of sewage in a conduit during dry weather.
- **Peak Wet Weather Flow** (PWWF) - The maximum flow rate of sewage in a conduit during a storm event
- **Public Sewer** - any sewer, other than a house connection sewer, which has been constructed in a public street, alley, walk, or other public right-of-way, or in a sewer easement, and is or is proposed to be a part of the sewer system of the City.
- **Relief Sewer** - a sewer that provides additional capacity for other sewers which would flow in excess of their design capacities if not relieved.
- **Sewer Shed** - the drainage area in which sources of sewerage flow to reach a common collection point.

Sanitary Sewer Tributary Area



Sanitary Sewer Design Flows

DESIGN FLOW

- The sanitary sewer flow shall be calculated in accordance with land use and population densities.
- This information may be obtained from the Town.
- Maintenance holes will be the tributary points in design and areas tributary to each MH shall be clearly outlined on the sanitary sewer drainage area plan. In lieu of precise information on development on the whole or any part of a watershed area, reference will be made to the latest zoning plan issued by the Planning Department.

Sanitary Sewer Design Flows

Residential Design Flow

- Average Flow – 240-450 litres/person/day
- Infiltration - 22,500 litres/gross/hectare/day (when foundation drains are connected to the storm sewer)

Commercial

- Average Flow: 180,000 litres/floor hectares/day including infiltration and peaking effect.

Industrial

- Average Flow: 180,000 litres/floor hectares/day including infiltration and peaking effect.

Schools and Institutions

- Average Flow: 180,000 litres/gross hectare/day including infiltration and peaking effect.

RECALL: Manning's Equation

$$\mathbf{Q = AR^{2/3} S^{1/2} n^{-1}}$$

Where:

Q = flow (m^3/s)

A = area of pipe (m^2)

R = hydraulic radius (m)

Note R = A/P (Area / Wetted Perimeter)

S = slope (unitless)

n = Manning's or "roughness" coefficient (unitless)

Nominal Dia.	Actual Dia.	Area	Hydraulic Radius	$AR^{2/3}n^{-1}$ n values									
mm	mm	m^2	"R"	0.010	0.011	0.012	0.013	0.015	0.021	0.022	0.024	0.025	0.035
100	101	0.008	0.025	0.069	0.063	0.057	0.053	0.046	0.033	0.031	0.029	0.028	0.020
125	127	0.013	0.032	0.127	0.115	0.106	0.098	0.085	0.060	0.058	0.053	0.051	0.036
150	152	0.018	0.038	0.205	0.186	0.171	0.158	0.137	0.098	0.093	0.085	0.082	0.059
200	203	0.032	0.051	0.444	0.403	r	0.341	0.296	0.211	0.202	0.185	0.177	0.127
250	254	0.051	0.064	0.807	0.733	0.672	0.620	0.538	0.384	0.367	0.336	0.323	0.230
300	305	0.073	0.076	1.314	1.194	1.095	1.011	0.876	0.626	0.597	0.547	0.526	0.375
375	381	0.114	0.095	2.378	2.162	1.982	1.829	1.585	1.132	1.081	0.991	0.951	0.679
450	457	0.164	0.114	3.862	3.511	3.218	2.971	2.575	1.839	1.756	1.609	1.545	1.103
525	533	0.223	0.133	5.821	5.292	4.851	4.478	3.881	2.772	2.646	2.425	2.328	1.663
600	610	0.292	0.153	8.342	7.584	6.952	6.417	5.561	3.972	3.792	3.476	3.337	2.383
675	686	0.370	0.172	11.409	10.372	9.507	8.776	7.606	5.433	5.186	4.754	4.564	3.260
750	762	0.456	0.191	15.098	13.726	12.582	11.614	10.066	7.190	6.863	6.291	6.039	4.314
825	838	0.552	0.210	19.455	17.686	16.213	14.965	12.970	9.264	8.843	8.106	7.782	5.559
900	914	0.656	0.229	24.523	22.294	20.436	18.864	16.349	11.678	11.147	10.218	9.809	7.007
1050	1067	0.894	0.267	37.053	33.684	30.877	28.502	24.702	17.644	16.842	15.439	14.821	10.587
1200	1219	1.167	0.305	52.852	48.047	44.043	40.655	35.235	25.168	24.024	22.022	21.141	15.101
1350	1372	1.478	0.343	72.443	65.857	60.369	55.725	48.295	34.496	32.928	30.184	28.977	20.698
1500	1524	1.824	0.381	95.869	87.153	79.891	73.745	63.912	45.652	43.577	39.945	38.347	27.391
1650	1676	2.206	0.419	123.532	112.302	102.944	95.025	82.355	58.825	56.151	51.472	49.413	35.295
1800	1829	2.627	0.457	155.938	141.762	129.949	119.953	103.959	74.256	70.881	64.974	62.375	44.554
1950	1981	3.082	0.495	192.934	175.394	160.778	148.411	128.623	91.873	87.697	80.389	77.174	55.124
2100	2134	3.577	0.534	235.271	213.883	196.059	180.978	156.847	112.034	106.941	98.030	94.108	67.220
2250	2286	4.104	0.572	282.653	256.957	235.544	217.425	188.435	134.597	128.479	117.772	113.061	80.758
2400	2438	4.668	0.610	335.588	305.080	279.657	258.145	223.725	159.804	152.540	139.828	134.235	95.882
2550	2591	5.273	0.648	394.727	358.842	328.939	303.636	263.151	187.965	179.421	164.469	157.891	112.779
2700	2743	5.909	0.686	459.535	417.759	382.946	353.489	306.357	218.826	208.880	191.473	183.814	131.296
2850	2896	6.587	0.724	531.104	482.822	442.586	408.541	354.069	252.907	241.411	221.293	212.442	151.744
3000	3048	7.297	0.762	608.728	553.389	507.273	468.252	405.819	289.870	276.694	253.637	243.491	173.922

Proportional Depth Chart			
D_{flow}/Diam	Q_{act}/Q_{full}	v_{act}/v_{ull}	d/D
0	0	0	0
0.02	0.0007	0.1408	0.02
0.04	0.0030	0.2221	0.04
0.06	0.0071	0.2892	0.06
0.08	0.0130	0.3480	0.08
0.1	0.0209	0.4012	0.1
0.12	0.0306	0.4500	0.12
0.14	0.0421	0.4953	0.14
0.16	0.0555	0.5376	0.16
0.18	0.0707	0.5775	0.18
0.2	0.0876	0.6151	0.2
0.22	0.1061	0.6507	0.22
0.24	0.1263	0.6844	0.24
0.26	0.1480	0.7165	0.26
0.28	0.1712	0.7471	0.28
0.3	0.1958	0.7761	0.3
0.32	0.2218	0.8038	0.32
0.34	0.2489	0.8302	0.34
0.36	0.2772	0.8554	0.36
0.38	0.3066	0.8794	0.38
0.4	0.3370	0.9022	0.4
0.42	0.3682	0.9239	0.42
0.44	0.4003	0.9445	0.44
0.46	0.4330	0.9640	0.46
0.48	0.4662	0.9825	0.48
0.5	0.5000	1.0000	0.5

Proportional Depth Chart			
D_{flow}/Diam	Q_{act}/Q_{full}	v_{act}/v_{ull}	d/D
0.52	0.5341	1.0165	0.52
0.54	0.5685	1.0319	0.54
0.56	0.6030	1.0464	0.56
0.58	0.6375	1.0599	0.58
0.6	0.6718	1.0724	0.6
0.62	0.7060	1.0839	0.62
0.64	0.7397	1.0944	0.64
0.66	0.7729	1.1039	0.66
0.68	0.8055	1.1124	0.68
0.7	0.8372	1.1198	0.7
0.72	0.8680	1.1261	0.72
0.74	0.8976	1.1313	0.74
0.76	0.9258	1.1353	0.76
0.78	0.9525	1.1382	0.78
0.8	0.9775	1.1397	0.8
0.82	1.0004	1.1399	0.82
0.84	1.0211	1.1387	0.84
0.86	1.0391	1.1358	0.86
0.88	1.0542	1.1311	0.88
0.9	1.0658	1.1243	0.9
0.92	1.0733	1.1151	0.92
0.94	1.0757	1.1027	0.94
0.96	1.0714	1.0859	0.96
0.98	1.0567	1.0618	0.98
1	1.0000	1.0000	1

Peaking Factors

Harmon equation: (most commonly used)

$$PF = 1.0 + \frac{14.0}{4.0 + \left(\frac{P}{1000}\right)^{0.50}}$$

where P = population

Babbit Peaking Factor: (NOT commonly used)

$$P.F. = \frac{5}{\sqrt[5]{P}}$$

where P = population in thousands

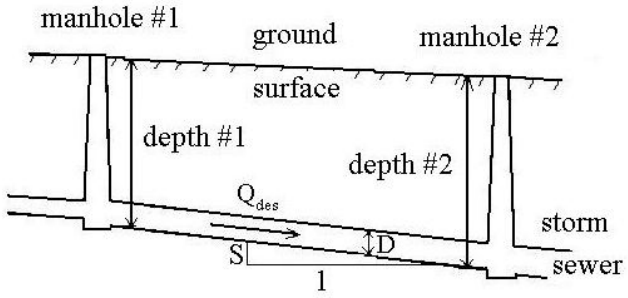
Sanitary Sewer Design

Pipe Capacities

- Sewer capacities will be computed by using Manning's Formula on a basis of sewer pipe flowing full.

Roughness Coefficients

- For all sizes and pipe material, n = 0.013



Longitudinal Section of Storm Sewer

Velocity and Grade

- Minimum velocity 0.75m/second
- Maximum velocity 3.65m/second
- Minimum grade 0.5% for all local sewers
- Minimum grade of the first upstream leg 1.0%
- Velocity change from one pipe to another in a manhole will not exceed 0.60m/second.

Sanitary Sewer Calculations (Putting it all together)

City of Toronto - Engineering Department
SANITARY SEWER DESIGN SHEET

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100 Ranleigh Avenue

Project No.: 09075
Designed By: Jason Jenkins, P.Eng., P.E.
Checked By: Paolo Albanese, P.Eng.
Date: April 28, 2015

Mannings 'n' = 0.013
Infiltration Flow (Dry Weather Flow)= 0.26 L/s/ha
Infiltration Flow (Extreme Wet Weather Flow)= 3.00 L/s/ha
Harmond Peaking Factor M = $PF = 1.0 + \frac{14.0}{4.0 \times \left(\frac{P}{1000}\right)^{0.50}}$

Location	from M.H.	to M.H.	DESIGN FLOW CALCULATIONS: Area (ha)	Density (ppha)	Population	Cumulative Area (ha)	Cumulative Population	Peaking Factor M	Sewage Flow (1) (L/s)	Infiltration Flow (2) (L/s)	Foundation Drain (3) (L/s)	Retail (4) (L/s)	Total Flow, Qd (1) thru (4) (L/s)	SEWER DESIGN & ANALYSIS: Nominal Diameter (mm)	Pipe Slope (%)	Pipe Length (m)	Nominal Full Flow Capacity, Qf (L/s)	Nominal Full Flow Velocity (m/s)	Percent of Full Flow Qd/Qf	Actual Flow Velocity V (m/s)	Remarks
SUBJECT SITE UNDER DRY-WEATHER FLOW CONDITIONS																					
									(240 L/s)	0.26 L/s/ha											
PRE-DEVELOPMENT			0.2596	--	23.00	0.260	23.00	4.37	0.279	0.067			0.35								
POST-DEV.			0.2596	--	78.00	0.260	78.00	4.27	1.735	0.067			1.80								
									(450 L/s)	0.26 L/s/ha	Net Increase (L/s) =		1.46								
SUBJECT SITE UNDER EXTREME WET-WEATHER FLOW CONDITIONS														Sanitary Service Design							
									(240 L/s)	3.00 L/s/ha											
PRE-DEVELOPMENT			0.2596	--	23.00	0.260	23.00	4.37	0.279	0.779			1.06								
POST-DEV.			0.2596	--	78.00	0.260	78.00	4.27	1.735	0.779			2.51	150	2.00%	9.00	21.538	1.22	12%	0.81	New Service OK
									(450 L/s)	3.00 L/s/ha	Net Increase (L/s) =		1.46								

Population Densities

Apartments =	*2.7 persons / unit (if > 148 units/ha)*
Apartments =	*400 persons / ha (if < 148 units/ha)*
Office =	*3.3 persons / 100 m2*
Commercial / Retail =	*1.1 persons / 100 m2*
Single Family Dwelling=	*3.5 persons / unit*
Industrial =	*136 persons / ha*
Church =	*86 persons / ha*

Flows

240.0 L/cap/day	*(1) EXISTING Domestic sewage flow*
450.0 L/cap/day	*(1) PROPOSED Domestic sewage flow*
0.26 L/s/ha	*(2) Infiltration flow ** **(Use 3.0 L/s/ha for Extreme Wet Weather Flow***
5 L/s/ha	*(3) Foundation flow (If no storm flows)*
180,000 L/ha/day	*(4) Commercial, Industrial, or Institutional sewer flow*
3.0 m/s	*Maximum flow velocity for pipe flowing full*
0.6 m/s	*Minimum flow velocity for pipe flowing partially full (actual flow)*

Population Equivalents

Single Family Dwelling =	*3.5*
Semi-Detached =	*2.7*
Townhouse =	*2.7*
Duplex =	*2.3*
Triplex =	*3.7*
Apartment / Condo =	*1.4*
Bachelor / 1 Bedroom =	*1.4*
2 Bedroom =	*2.1*

PRE Development Population Count

Property Type	ha	Density	Population
Church	0.2596	86	22.3
TOTAL:	0.2596		23

POST Development Population Count

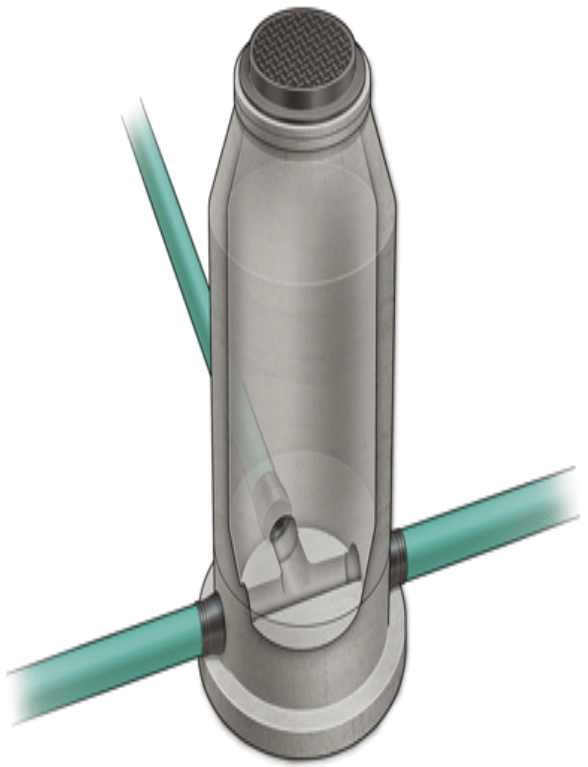
Residential Type	# of Units	Density	Population
1 Bedroom	18	1.4	25.2
2 Bedrooms	25	2.1	52.5
3 Bedrooms	0	3.1	0.0
TOTAL:	43		78

Sanitary Sewer Design Cont'd

- The first leg of a sanitary sewer will be sized at 200 mm. All other lengths will be a minimum of 250 mm diameter.
- Measured from the final centerline, finished road elevation to the sewer obvert will be:
  - Residential areas - minimum 2.5m
  - Industrial areas - minimum 2.5m
  - Commercial areas - minimum 3.65m

Sanitary Sewer Manholes

- MH's are required at each change in alignment, grade, material and at all junctions, except where radius pipe is used in sizes 1050mm diameter and over.
- MH spacing (typ.):
  - 110m for 250 mm diameter to 750 mm diameter
  - 120m for 825 mm diameter to 1200 mm diameter
  - 150m for pipe sizes over 1200 mm diameter.
- Type and size of maintenance holes should be specified on the profiles and a detail of the benching will be shown on the plan portion of the drawing for cases when the benching differs from the Agency Standard.
- The maximum change in the direction of flow in any sanitary sewer maintenance hole shall be 90°.



Sanitary Sewer Manholes Cont'd

- A sufficient drop will be provided across the maintenance hole to compensate for energy losses due to changes in flow direction and velocity.
- Where the difference in elevation between the maintenance hole inlet and outlet pipes exceed 600 mm, a drop structure shall be provided as per Standard Drawings. Where the drop is between 200 mm and 600 mm, the pipe grades shall be adjusted, such that the maximum drop is 200 mm. No internal drop structures will be permitted for main line sewer.
- The obverts on the upstream side of a maintenance hole will in no case be lower than those on the downstream side

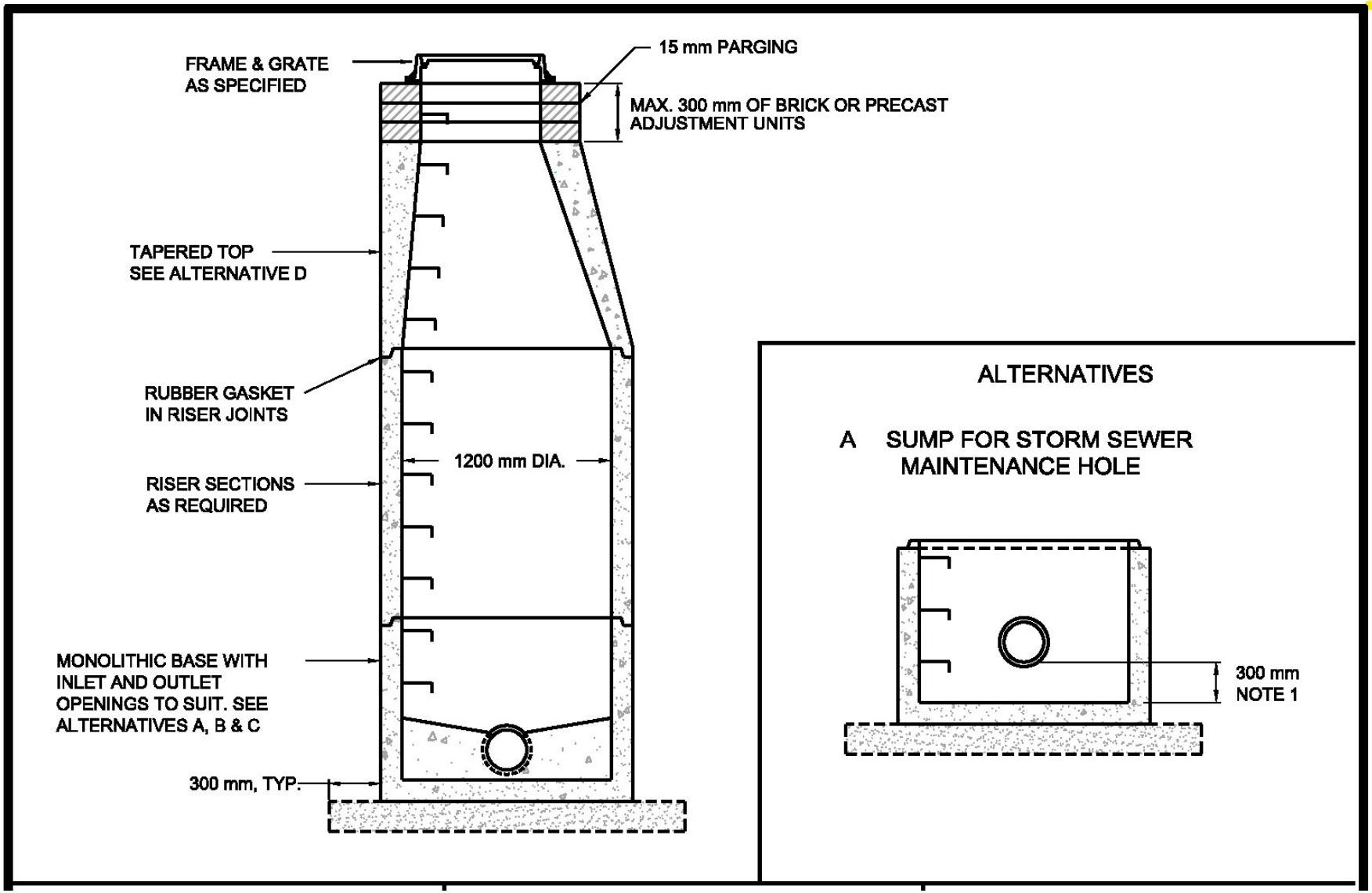
Sanitary Sewer Manholes Cont'd

- No maintenance hole shall be located closer than 1.50m from any curb face or other service.
- Although the Standard Drawings provide details for maintenance holes up to certain maximum depths, the Consulting Engineer will analyze, individually, each application of the standards related to soil conditions, loading and other pertinent factors to determine structure suitability. In all cases where the standards are not applicable, maintenance holes must be individually designed and detailed.
- When any dimension of a maintenance hole exceeds those on Standard Drawings, the maintenance hole must be designed and individually detailed.
- A minimum clearance of 300 mm shall be provided between the outside of all pipe barrels at all points of pipe crossings. Where the minimum clearance cannot be obtained, the crossing is to be encased in 15 MPa concrete.
- A minimum clearance of 2.5m horizontally shall be provided between the outside pipe barrels of sanitary sewer pipes and watermain pipes, as per the M.O.E. Requirements.
- Maintenance holes shall be required at the street line for all sanitary service connections to commercial, industrial, institutional and multiple residential blocks.

Old Brick Sewer

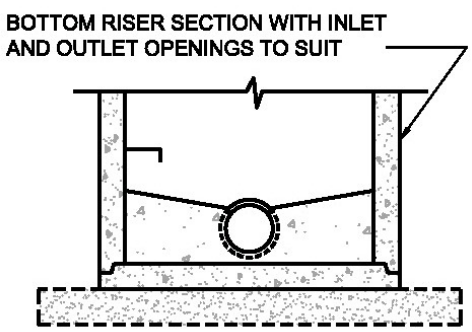
Today's Sewer Manhole

City of Toronto T-701.010

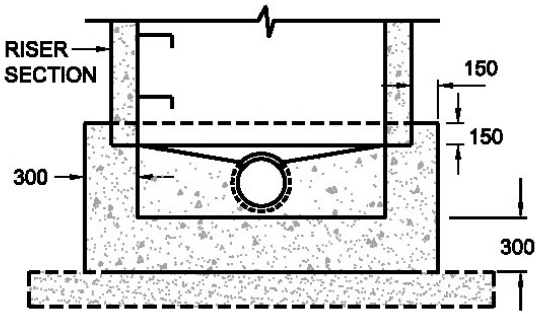


City of Toronto T-701.010

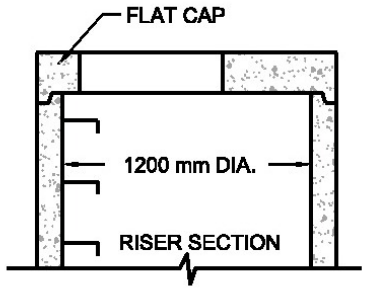
B PRECAST SLAB BASE



C CAST IN PLACE BASE



D PRECAST FLAT CAP



NOTES:

1. THE SUMP IS MEASURED FROM THE LOWEST INVERT.
2. 150 mm OF COMPACTED GRANULAR A OR UNSHRINKABLE FILL TO BE PLACED ALL AROUND THE MAINTENANCE HOLE.
3. PRECAST CONCRETE COMPONENTS ACCORDING TO OPSD 701.030, OPSD 701.031 AND OPSD 701.032.
4. STRUCTURES EXCEEDING 5.0m IN DEPTH TO INCLUDE SAFETY PLATFORM ACCORDING TO OPSD 404.020
5. PIPE SUPPORT ACCORDING TO T-708.020.
6. FOR BENCHING DETAILS, MAXIMUM PIPE HOLE DIAMETERS AND FLOW CONFIGURATIONS, SEE T-701.021.
7. ALL DIMENSIONS ARE NOMINAL.
8. PARGING SHALL BE 1:3 MORTAR MIX.
9. WATERPROOFING OVER PARGING TO BE TWO HEAVY COATS OF BITUMEN.
10. WHERE PIPES JOIN AT MAINTENANCE HOLE, JOINTS ARE TO BE WATERTIGHT WITH THE APPROVED SEAL.
11. FIRST STEP TO BE 75 mm TO 300 mm BELOW FRAME. LAST STEP TO BE 300 mm ABOVE BENCHING OR 600mm ABOVE INVERT IF NO BENCHING.

All dimensions are in millimetres unless otherwise shown.

TORONTO

ENGINEERING AND CONSTRUCTION SERVICES STANDARD DRAWING

REV 3 | APR 2014

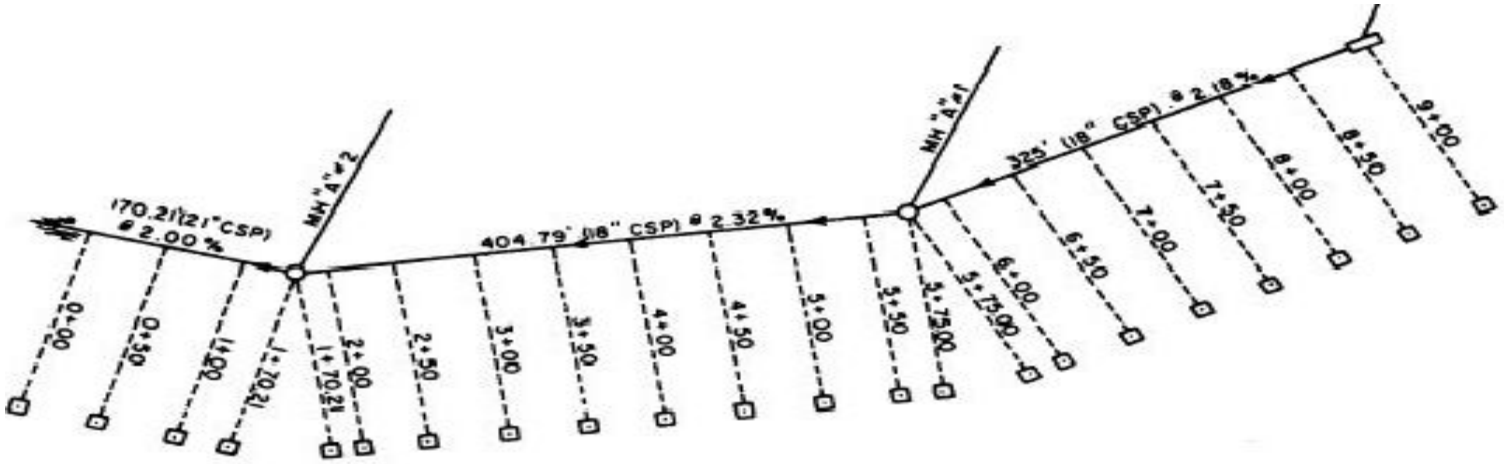
PRECAST MAINTENANCE HOLE
1200 mm DIAMETER

T-701.010

NTS | SHEET 1

Horizontal Alignment

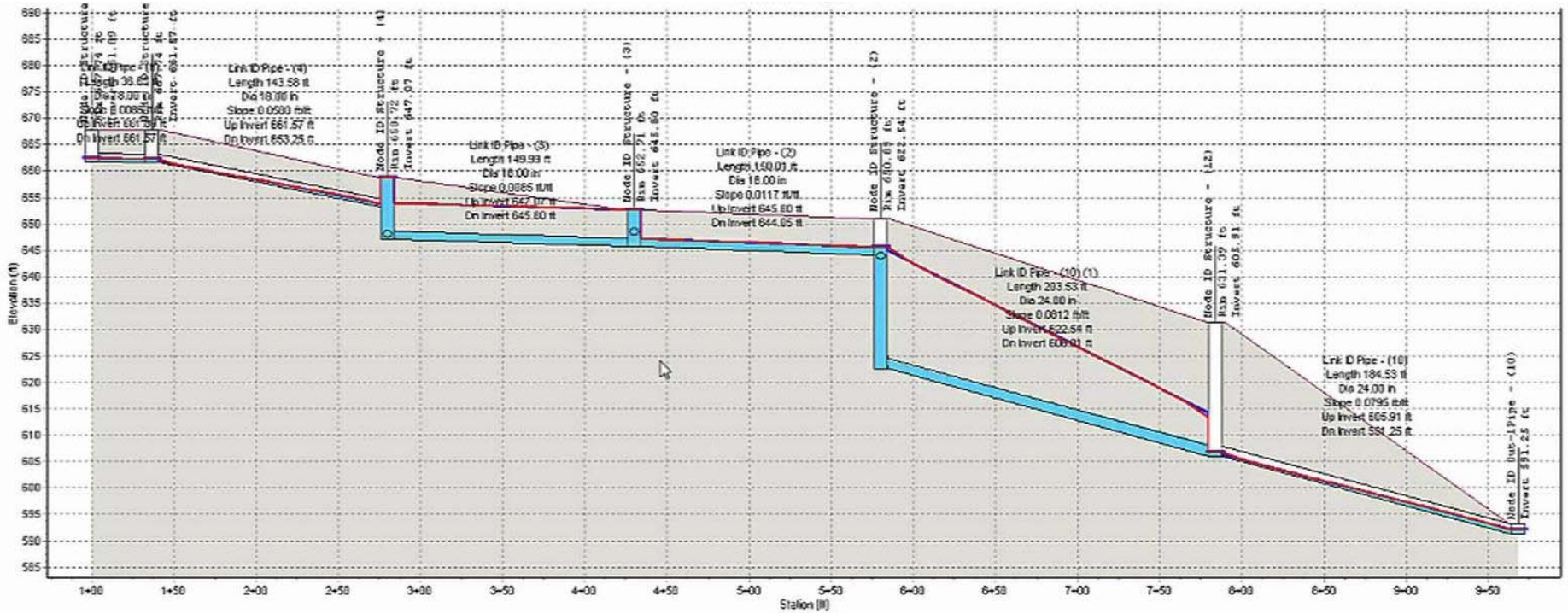
- The alignment of a sanitary sewer should be as simply and straight as possible.
- A curved alignment is allowed but an access structure for maintenance purposes shall be constructed at both ends of the curve. A curved alignment can be achieved by playing with the give within the bell and spigot.
- An angle point should be avoided but if necessary, an access structure for maintenance purposes shall be constructed at the angle point.



Bell and Spigot RCP Sewer

Vertical Alignment

- The most economical design will be the shallowest.
- An access structure for maintenance should be constructed when there are:
  - Changes in elevation.
  - Changes in slope.
- If significant changes in elevation, use a DROP STRUCTURE.



Internal Drop Structures

External Drop Structure

Common Sewer Materials

- VCP – Vitrified Clay Pipe
- RCP – Reinforced Concrete Pipe
- CP – Concrete Pipe
- ACP – Asbestos Cement Pipe
- PVC – Polyvinyl Chloride Pipe
- HDPE – High Density Polyethylene Pipe