Chapter 6
Case Evaluations

This chapter presents facility evaluation data of combined sewer in-line and CSO storage tank flushing systems. The objectives of these evaluations included the following:

- Collect dimensional and operational data of combined sewer in-line and CSO storage tank facilities that utilize flushing gates or tipping flushers for cleaning;
- Evaluate the effectiveness of the system design in terms of sediment removal;
- Compare capital and operation and maintenance costs of flushing gate and tipping flusher facilities with other cleaning methods.

Table 6-1 presents a guide outlining the major features of the 18 case studies. Contents of the table include location; flushing function, i.e. flushing of storage pipe, conveyance pipe or tank; tank geometry (rectangular or circular); flushing method, i.e. flushing gate, tipping flusher or other; flushing volumes for pipe configurations, either by generated off-line or in-line compartments; flushing volumes for tanks are noted as in line. Information for other miscellaneous tank reviews are provided following the 18 case studies.

Table 6-1. Overview of Case Studies

Case Number	Location	Flushing Function				Flushing Method		
		Pipe Storage	Pipe Convey.	Tank		Flush Gate		Tipping Flusher
				Rect.	Circular	In-line	Off-line	
1	Marht Wiesentheid, Germany	X				X		
2	Gemeinde Schauenburg, GER	X				X		
3	Stadt Kirchhain, GER	X					X	
4	Stadt Heidenheim, GER		X			X		
5	Markt Grossostheim, GER		X				X	
6	Osterbruch-Opperhausen, GER		X				X	
7	Gemeinde Hettstadt, GER	X					X	
8	Filterstadt-Bernhausen, GER			X		X		
9	Stadt-Essen, GER			X		X		
10	Markt-Wiesentheid, GER			X		X		
11	Stuttgart-Wangen, GER			X		X		
12	Heidenheim-Kleiner-Buhl, GER			X		X		
13	Cheboygan, Michigan				X	X		
14	Sarnia, Ontario, Canada			X		X		
15	Port Colborne, Ontario, Canada			X				X
16	Wheeler Avenue, Kentucky			X				X
17	14^{th} Street Pumping Station, MI			X				X
18	Saginaw Township, MI			X				X

A standard evaluation form was prepared and distributed to operators at several facilities in Germany and in North America. In-line versus off-line refers to the relative location of the flushing volume. Due to space limitations, flush volumes are often generated in-line with main convergence function accomplished by an underflow conduit or channel under the flush volume chamber. Vaults with large flushing volumes are commonly provided by off-line configurations. Average slope refers to the slope of the conduit or section being flushed. Slope of flush volume refers to the floor slope of the flush vault. Flush gate activation is accomplished either by passive float operation termed “hydraulic” or by an active electrical signal from an external location termed “electrical”. Water source refers to the source of the water for flushing, i.e. “local waste” or “external supply”. Performance assessment is defined as follows: “Excellent” – all sediments in channel or bay cleaned with flush; “Good” – substantial removal of sediments in channel, i.e. 90% of flush lane or pipe is cleaned; “Fair” – partial removal of sediments, i.e. 50-70% of flush lane or channel cleaned with flush. The following case studies, consisting of tables and narratives summarize the findings for each site.

Case Studies: Combined Sewer Flushing Facilities using Flushing Gates

The following are summaries of the pipe flushing facilities that were evaluated in Germany.

Case No. 1- Marht Wiesentheid

Details of the Marht Wiesentheid flushing facility are noted in Table 6-2. The in-line CSO storage conduit is a 1.8 m (6 ft diameter) circular pipe, 46.8 m (153 ft) in length. The storage pipe is throttled at its outlet using a flow regulator to maintain outflow equal to twice average dry weather flow (plus infiltration). An inline flushing vault holding 14 cubic meters (3700 gal.) is used to cleanse the storage pipe. The flushing gate is activated by hydraulic float control. Operators note excellent performance in cleansing deposits during flushing.

Table 6-2. Marht Wiesentheid, Germany

Question	Response
In-Line or Off-Line	In-Line
Year Constructed	1992
Flow type	Combined
Pipe size and shape	1800 mm circular
Length	46.8 m
Average Slope	1%
Pipe Material	Concrete
Flush Gate Dimensions (l w)/Material	2.8 m x 1.31 m / Stainless steel
Flush Vault Volume	14 cubic meters
Flush Vault Dimensions (l w h)	2.5 m x 4.84 m x 1.15 m
Slope of flush vault	20%
Water Source	Local waste
Method of Gate Activation	Hydraulic
Frequency of Inspection/Crew Size	After each activation/1 person
Performance Assessment	Excellent

Case No. 2 – Gemeinde Schauenburg

The Gemeinde Schauenburg storage facility (Germany) is very similar to the facility at Marht Wiesentheid (Case 1). Details are noted in Table 6-3. This facility is a CSO storage pipe 2 m (78 inch) circular in diameter 64 m (210 ft) in length. Flushing volume of 5.5 m^3 (1450 gal.) is used and the flushing gate operates by hydraulic float activation. The gate activates when the downstream flow controller permits the storage to drain. The operators note "fair" performance for this facility.

Table 6-3. Gemeinde Schauenburg, Germany

Question	Response
In-Line or Off-Line	In-Line
Year Constructed	1988
Flow type	Combined
Pipe size and shape	2000 mm circular
Length	64 m
Average Slope	1 %
Pipe material	Asbestos Cement
Flush Gate Dimensions (l w) / Material	1.2 m x 0.4 m Stainless steel
Flusher Volume	5.5 cubic meters
Flusher Dimensions (l w h)	2 m x 3 m x 0.91 m
Slope of flush vault	20%
Water Source	Local waste
Method of gate Activation	Hydraulic
Frequency of Inspection/Crew Size	After each activation/2 person
Performance Assessment	Fair

Case No. 3 – Stadt Kirchhain

The Stadt Kirchhain facility, listed in Table 6-4, has an off-line flushing gate that is used to flush the deposited sediments in the 1600 mm pipe to a downstream regulator which empties into a downstream 300 mm sewer. Figure 6-1 depicts the plan view of one of the two off-line flushing vaults used in the Stadt Kirchhain facility (Germany). Figure 6-2 depicts the plan view of the downstream flow control chamber throttling the twin storage pipes.

Table 6-4. Stadt Kirchhain, Germany

Question	Response
In-Line or Off-Line	Off-Line
Year Constructed	1991
Flow type	Combined
Pipe size and shape	1600 mm circular
Length	115 m
Average Slope	0.4%
Pipe material	Concrete
Flush Gate Dimensions (l w)/Material	1.2 m x 0.4 m Stainless steel
Flush Vault Volume	4 cubic meters
Flush Vault Dimensions (l w h)	2 m x 2.5 m x 1 m
Slope of flush vault	20%
Water Source	Local Waste
Method of gate Activation	Electrical
Frequency of Inspection/Crew Size	Not Available
Performance Assessment	Fair

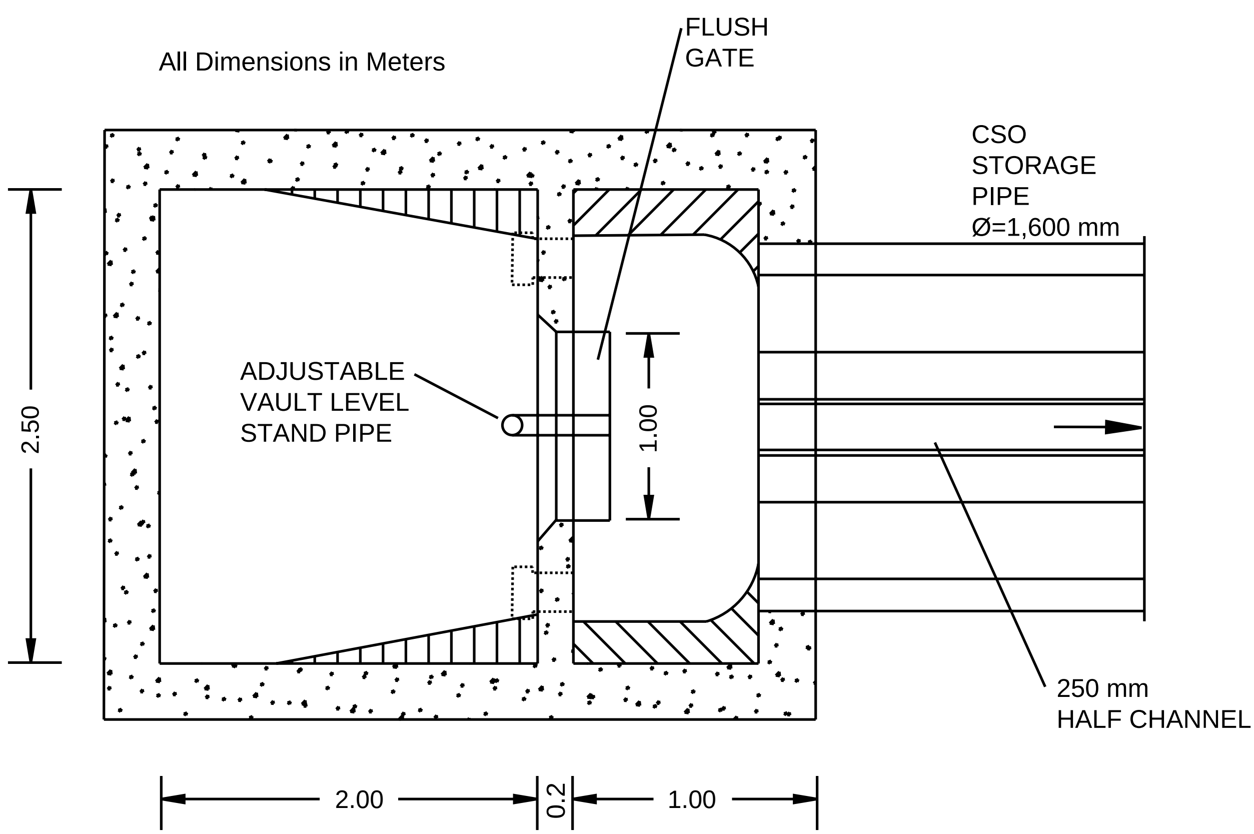


Figure 6-1. Stadt Kirchhain - Off-Line Flushing Vault Plan View

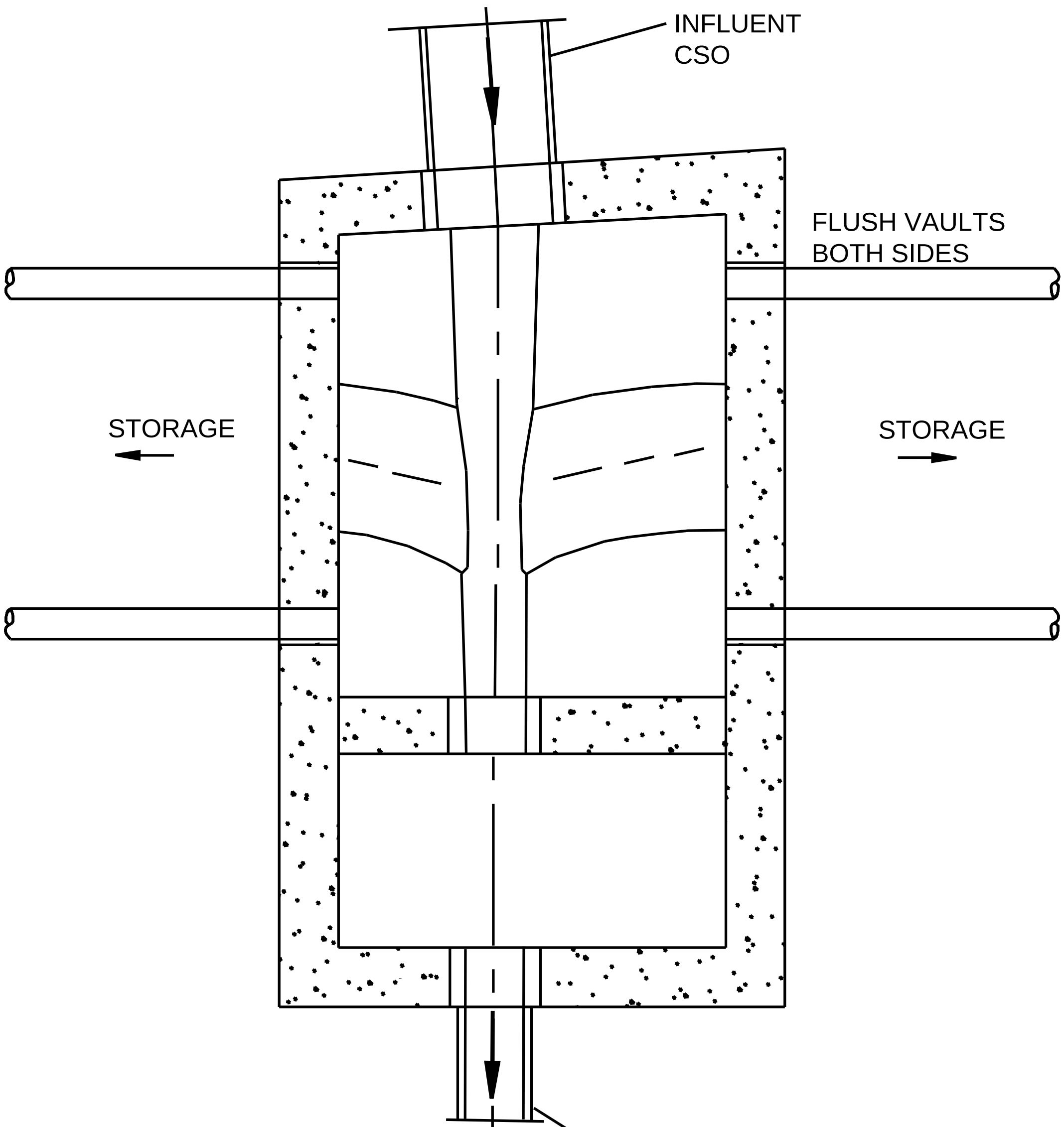


Figure 6-2. Stadt Kirchhain - Plan View Downstream Control Chamber

Case No. 4- Stadt Heidenheim

Details of the Stadt Heidenheim facility are noted in Table 6-5. The Stadt Heidenheim facility has an in-line flushing chamber that is located within the regulator structure on the dry weather conduit. Extreme wet weather flows overtop the weir in the center of the structure into a 1200 mm bypass conduit. Plan and section views of the overall regulator, flushing vault and bypass chamber are depicted in Figures 6-3 and Figure 6-4.

Table 6-5. Stadt Heidenheim, Germany

Question	Response
In-Line or Off-Line	In-Line
Year Constructed	1993
Flow type	Combined
Pipe size and shape	2200 mm circular
Length	240 m
Average Slope	Not Available
Pipe Material	Concrete
Flush Gate Dimensions (l w)/Material	1.2 m x 0.4 m Stainless steel
Flush Vault Volume	10 cubic meters
Flush Vault Dimensions (l w h)	3 m x 5 m x 0.7 m
Slope of flush vault	10%
Water Source	Local Waste
Method of Gate Activation	Hydraulic
Frequency of Inspection/Crew Size	After each activation/2 person
Performance Assessment	Good

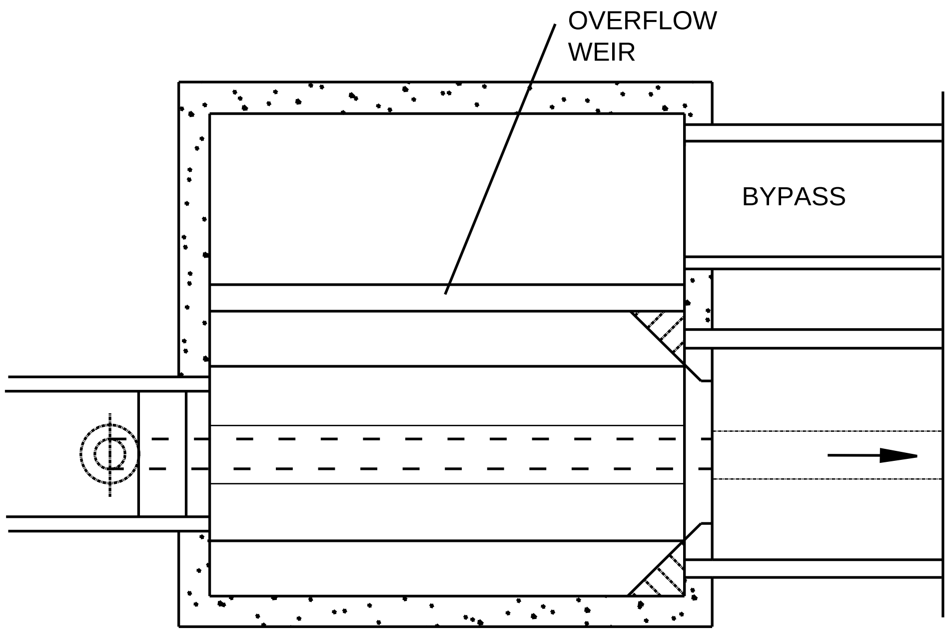


Figure 6-3. Stadt Heidenheim - Plan View

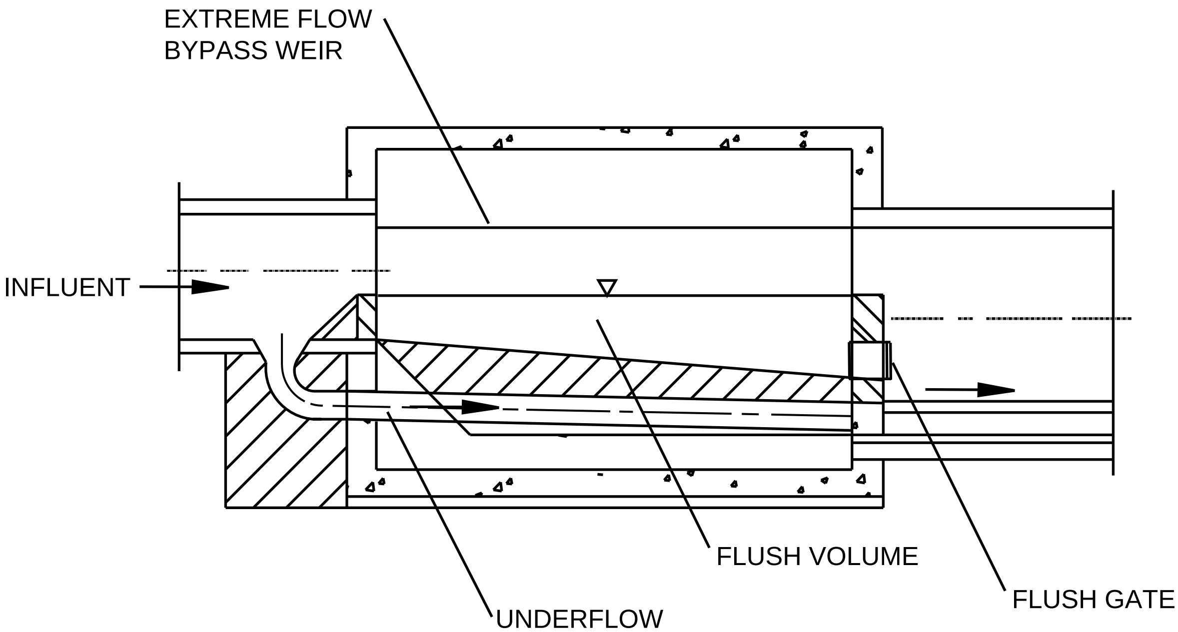


Figure 6-4. Stadt Heidenheim - Section View

Case No. 5 – Markt Grossostheim

Details of the Marktt Grossostheim facility are presented in Table 6-6. The flushing vault and storage facility involves an off-line storage compartment created by a spill weir from the dry weather channel. Extreme overflows can then bypass the side spill storage compartment. These bypasses are controlled by a mechanical operated bending weir. The downstream flow throttle is a mechanical knife valve controlled by direct measurements of a magnetic meter.

Table 6-6. Markt Grossostheim, Germany

Question	Response
In-Line or Off-Line	Off-Line
Year Constructed	1993
Flow type	Combined
Pipe size and shape	2200 mm circular
Length	190 m
Average Slope	9.4%
Pipe material	Not Available
Flush Gate Dimensions(l w) Material	1.5 m x 0.4 m Stainless steel
Flush Vault Volume	15 m^3
Flush Vault Dimensions (l w h)	6.5 m x 2.2 m x 1.03 m
Slope of flush vault	15%
Water Source	Local Waste
Method of Gate Activation	Hydraulic
Frequency of Inspection/Crew Size	After each activation/2person
Performance Assessment	Excellent/Good

Case No. 6 – Osterbruch-Opperhausen

Details of the Osterbruch-Opperhausen facility are noted in Table 6-7. Sectional views of this facility are presented in Figure 6-5. The flushwater chamber is filled by an upstream 100 mm pumped pipe. The flushing gate is utilized to clean the downstream 250 mm combined sewer conduit. The flush vault is placed on the head of the combined sewer and 1000 m (3250 ft) of downstream conduit to a regulator location where flushed solids are discharged into receiving sewer.

Table 6-7. Osterbruch-Opperhausen, Germany

Question	Response
In-Line or Off-Line	Off-Line
Year Constructed	1989
Flow type	Sanitary
Pipe size and shape	250 mm circular
Length	1000 m
Average Slope	0.1%
Pipe material	Vetrified Clay Pipe
Flush Gate Dimensions (l w)/Material	0.5 m x 0.4 m Stainless steel
Flusher Volume	2 m^3
Flusher Dimensions (l w h)	2.4 m x 1.6 m x 0.75 m
Slope of flush vault	20%
Water Source	River Water
Method of Gate Activation	Hydraulic
Frequency of Inspection/Crew Size	After each activation/2person
Performance Assessment	Excellent/Good

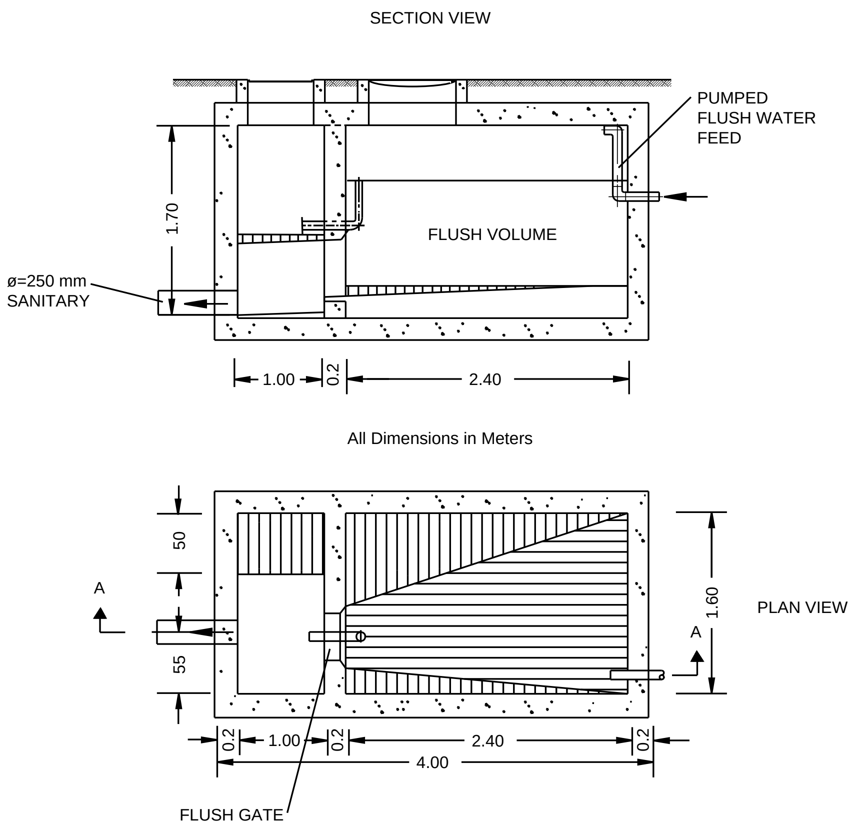


Figure 6-5. Osterbruch-Opperhausen - Sectional Views

Case No. 7 – Geimeide Hettstadt

Details of the Geimeide Hettstadt facility are noted in Table 6-8. The storage element is an off-line CSO pipe conduit 1600 mm (66 inch) in diameter, 224 m (735 ft) in length. The off-line flushing chamber holds 10 m^3 (2700 gal.) and is filled during overflow events. Operators have noted good to fair performance.

Table 6-8. Gemeinde Hettstadt, Germany

Question	Response
In-Line or Off-Line	Off-Line
Year Constructed	1992
Flow type	Combined
Pipe size and shape	1600 mm circular
Length	224 m
Average Slope	0.5%
Pipe material	Concrete
Flush Gate Dimensions (l w)/Material	1.5 m x 0.4 m Stainless steel
Flusher Volume	10 cubic meters
Flusher Dimensions (l w h)	5 m x 2.7 m x 0.75 m
Slope of flush vault	15%
Water Source	Local Waste
Method of Gate Activation	Hydraulic
Frequency of Inspection/Crew Size	After each activation/2person
Performance Assessment	Good/Fair

Hydraulic Analysis Flushing Gate Performance for Sewers

The Stormwater Management Model (SWMM) with Extended Transport Block (EXTRAN) was used to investigate the efficiency of the German sewer pipes that use flushing technology. Simulation output takes the form of water surface elevations and discharge at selected system locations. EXTRAN was developed by the U.S. EPA and is described in total in the User's Manual, EPA/600/3-88/001b.

The basic conveyance element input data required in EXTRAN are specifications for shape, size, length, roughness, connecting junctions and ground (rim) and invert elevations. These data for pipe and tank flushing were obtained from the evaluations of the German facilities. Pipe and tank lengths were discretized into two or three equal sections. These discretizied sections varied from 15 to 30 meters (50 to 100 feet). Pipe sections were assumed to be circular (equivalent diameters calculated) and tank sections (flushing bays) were assumed to be rectangular. An additional 30 meter (100 feet) section was added to the downstream tank conduit to simulate a grit pit. The following parameters were kept constant in both pipe and tank simulations:

- Computation time increment = 1 second
- Manning roughness coefficient = 0.015
- Gate opening time in 10 seconds
- Flow hydrographs at the flushing gate are assumed to increase linearly from zero to a constant flow rate in 5 seconds and also to decrease linearly from the constant rate to zero in 5 seconds.
- Upstream of the conduit/tank was assumed to be the input and downstream was assumed to be a free overflow.

Table 6-9 summarize the hydraulic data (length, slope, size and flush volume) and results (velocity, depth, and flush volume/length of flush) from the respective flushing gates determined from the evaluations of the German facilities. The listed results are at the downstream end of the pipe or channel flushed. At the far right hand side of Table 6-9 is listed the operator observation. Qualitative operator observations have excellent agreement with the quantitative modeled velocity. For example the terminal velocity of Stadt Kirchhain is 0.60 m/s, which is the lowest velocity, and the operator observe only "Fair" flushing results.

Table 6-9. Summary of Pipe Flushing Results

Location	Length (m)	Slope	Size (m)	Velocity (m/s)	Depth (m)	Flush Vol. (m^3)	Operator Observation
Marht Wiesentheid	47	1.0%	1.8	3.1	0.40	14	Excellent
Stadt Heidenheim	241	1.0%	2.2	1.0	0.09	10	Good
Stadt Kirchhain	115	0.4%	1.6	0.60	0.07	4	Fair
Markt Grossostheim	191	0.94%	2.2	1.2	0.11	15	Excellent / Good

Case Studies: CSO Storage Tank Flushing Facilities using Flush Gates

The following are summaries of the CSO tank flushing facilities that were evaluated in Germany and North America.

Case No. 8 – Filterstadt-Bernhausen

Details of the Filterstadt-Bernhausen CSO tank facility using flush gates to cleanse the tank after activations are noted in Table 6-10. The tank volume is 1000 m^3 and consists of two unequal sized bays (5.65 m and 4.65 m). Flushing is accomplished by two vaults with two flusher systems per bay. No flushing training walls are provided. The end channel transports the flushed deposits to a central throttled outlet. The flush gates are activated by hydraulic float control when the tank drains after an event through a 300 mm (12 inch) throttle.

Table 6-10. Filterstadt-Bernhausen, Germany

Question	Response
Year Constructed	1990
Type of Flow	Combined
Covered or Open Tank	Covered
Number Of Bays	2
Number of Flushers/Bay	2
Training Walls per Flusher	No
Flush Channel Dimensions (l w h)	36 m x 5 m x 3.5 m
End Trough Dimensions l w d	8 m x 12 m x 1.2 m
Flush Channel Slope	2.5%
Flush Gate Dimensions(l w) Material	1.5/1.75 m x 0.4 m Stainless steel
Flush Vault Volume	2@ 10 m^3 / 2@ 8.5 m^3
Flush Vault Dimensions (l w h)	2.5 m x 5.65 m x 1.0 2.5 m x 4.65 m x 1.0 m
Slope of flush vault	20%
Water Source	Combined
Method of Gate Activation	Hydraulic
Method of Removing Flushed Sediments	Underflow Throttle (400 mm) to WWTP
Frequency of Inspection/Crew Size	After each activation/Not Available
HVAC System/Type	Yes/Grating
Odor Control System/Type	No
Electrical System Explosion Proof	No
Performance Assessment	Good

Case No. 9 – Stadt-Essen

Details of the Stadt-Essen storage facility are noted in Table 6-11, has each flush vault equipped with two gates, and training walls are not installed within individual bays. The Stadt Essen layout is depicted in Figures 6-6 and 6-7. It features a unique inlet scheme where the underflow is concentrated in a vortex chamber that discharges back to the dry weather sewer. Once the underflow capacity is exceeded, the influent channel to the flushing gates fills which in turn fills the flush vaults and tank. The flushed sediments are collected in the mud sump for discharge back to the dry weather sewer.

Table 6-11. Stadt-Essen, Germany

Question	Response
Year Constructed	1993
Type of Flow	Combined
Covered or Open Tank	Covered
Number Of Bays	3
Number of Flushers/Bay	2
Training Walls per Flusher	Yes
Flush Channel Dimensions (l w h)	55 m x 3 m x 3.4 m
End Trough Dimensions l w d	5 m x 20 m x 0.5 m
Flush Channel Slope	0.5%
Flush Gate Dimensions (l w)/Material	1.5/1.75 m x 0.4 m Stainless steel
Flusher Volume	12 m^3
Flusher Dimensions (l w h)	4 m x 1.4 m x 2.85 m (2) 3.20 m (4)
Slope of flush vault	20%
Water Source	Combined
Method of Gate Activation	Electric
Method of Removing Flushed Sediments	Underflow Sluice Gate (200 mm) to WWTP
Frequency of Inspection/Crew Size	Not Available
HVAC System/Type	Yes/ Ventilation Pipes - 300 mm Intake and 450 mm Exhaust
Odor Control System/Type	No
Electrical System Expolosion Proof	No
Performance Assessment	Good

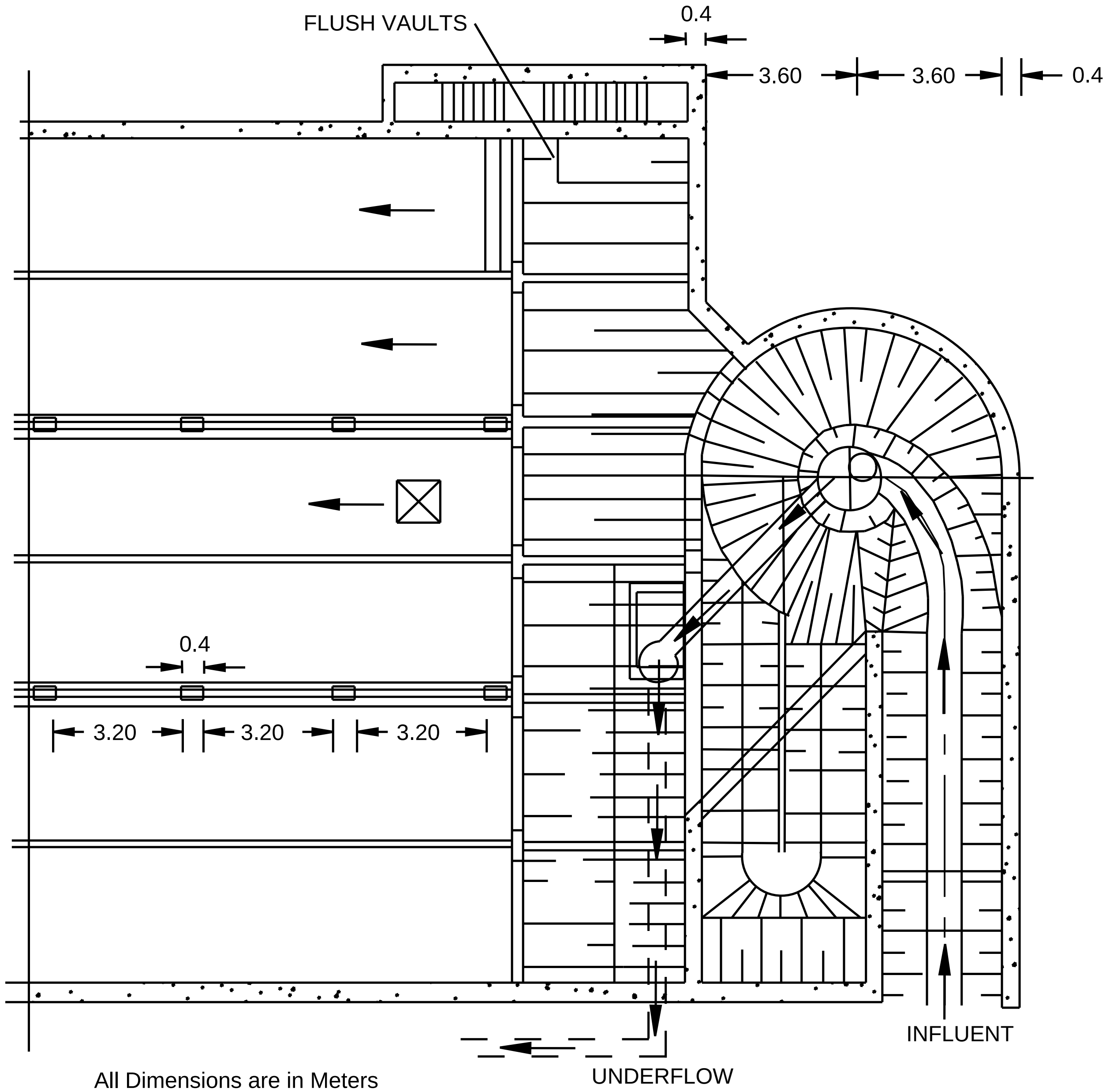


Figure 6-6. Stadt-Essen - Plan View, Tank Influent

All Dimensions are in Meters

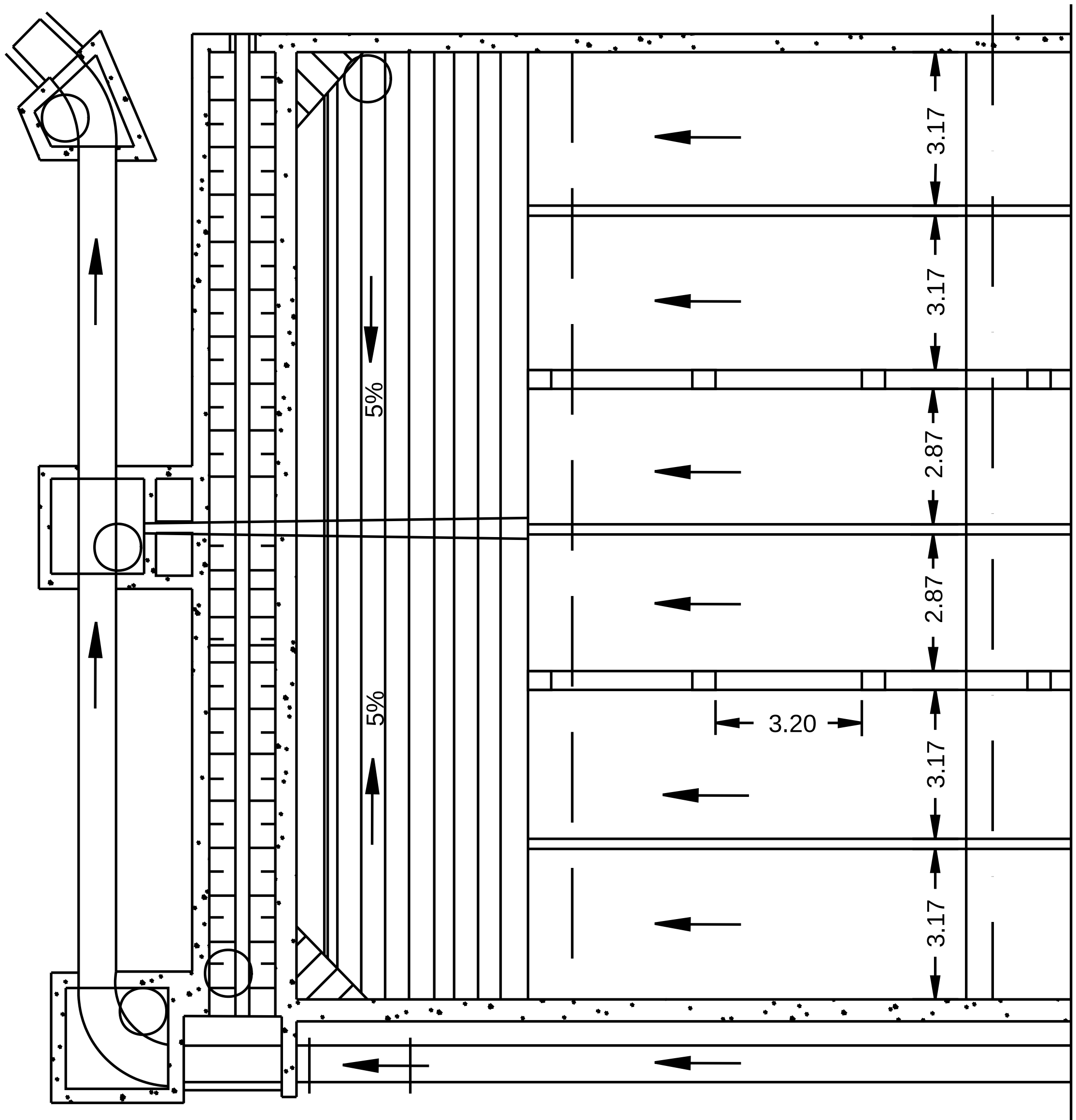


Figure 6-7. Stadt-Essen - Plan View, Tank Effluent

Case No. 10 – Markt-Wiesentheid

A section view of this facility is depicted in Figure 6-8. This facility has a unique flush vault filling arrangement. Flow enters the facility at the effluent end of the tank via a dry weather conduit integral to the tank that is regulated downstream. As flow in the dry weather conduit increases during wet weather, flow surcharges a 300 millimeter conduit that is connected at the springline of the dry weather conduit on an adverse slope which fills the flush vaults.

Table 6-12. Markt-Wiesentheid, Germany

Question	Response
Year Constructed	1992
Type of Flow	Combined
Covered or Open Tank	Open
Number Of Bays	5
Number of Flushers/Bay	1
Training Walls/Flusher	Yes
Flush Channel Dimensions (l w h)	41 m x 4.84 m x 3 m
End Trough Dimensions l w d	2 m x 25 m x 0.5 m
Flush Channel Slope	1.5%
Flush Gate Dimensions (l w)/Material	2.8 m x 0.4 m Stainless steel
Flusher Volume	12.7 m^3
Flusher Dimensions (l w h)	2.5 m x 4.8 m x 1.3 m
Slope of flush vault	20%
Water Source	Combined
Method of Gate Activation	Electric
Method of Removing Flushed Sediments	Underflow Flap Gate
Frequency of Inspection/Crew Size	Not Available
HVAC System/Type	No
Odor Control System/Type	No
Electrical System Expolosion Proof	No
Performance Assessment	Excellent/Good

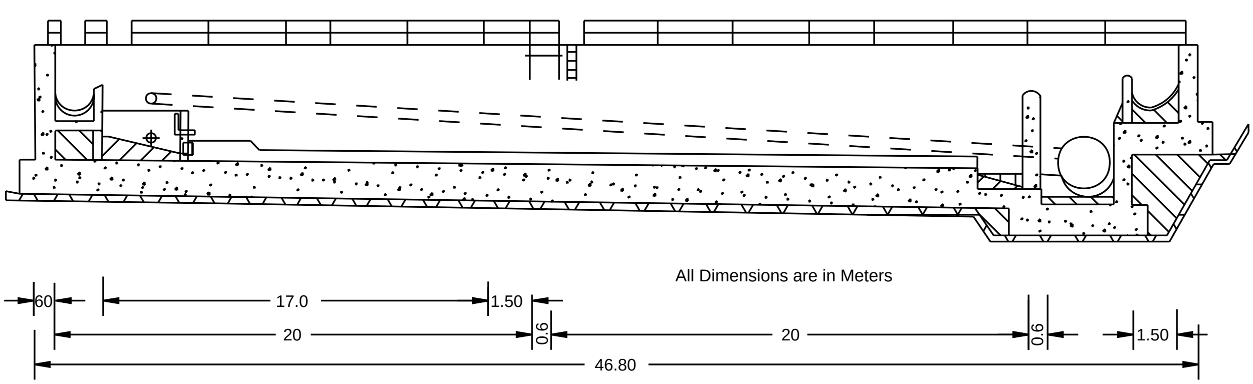


Figure 6-8. Markt-Wiesentheid - CSO Storage Tank, Section View

Case No. 11- Stuttgart-Wangen

Details of the Stuttgart-Wangen CSO storage facility are provided in Table 6-13. The tank consists of a single rectangular bay 67m (220 ft) in length with rectangular cross section 3.6 m x 1.8 m (12 ft x 6 ft). The flush gate is activated by external electric signal after the tank section has been noted by level sensor to drain.

Table 6-13. Stuttgart-Wangen, Germany

Question	Response
Year Constructed	1993
Type of Flow	Combined
Covered or Open Tank	Covered
Number Of Bays	1
Flush Channel Dimensions (l w h)	67 m x 3.6 m x 1.8 m
End Trough Dimensions l w d	6.5 m x 3.6 m x 0.9 m
Flush Channel Slope	0.5%
Flush Gate Dimensions (l w)/Material	2.8 m x 0.4 m Stainless steel
Flusher Volume	18 m^3
Flusher Dimensions (l w h)	5 m x 3.6 m x 1.15 m
Slope of flush vault	14.5%
Water Source	Combined
Method of Gate Activation	Electric
Method of Removing Flushed Sediments	Pumps
Frequency of Inspection/Crew Size	Not Available
HVAC System/Type	Yes/Ventilated Manhole Lids
Odor Control System/Type	No
Electrical System Expolosion Proof	No
Performance Assessment	Excellent/Good

Case No. 12 – Heidenheim-Kleiner-Buhl

Details of the Heidenheim-Kleiner-Buhl CSO storage facility are provided in Table 6-14. The flush gates are activated in sequence by external electric signal after the tank contents have been noted to drain. Level in the receiving sewer is also noted prior to activating the flush gates

Table 6-14. Heidenheim-Kleiner-Buhl, Germany

Question	Response
Year Constructed	1992
Type of Flow	Combined
Covered or Open Tank	Covered
Number Of Bays	6
Number Flushers/Bay	1
Training Walls/Flusher	Yes
Flush Channel Dimensions (l w h)	30 m x 4.85 m x 3.6 m
End Trough Dimensions l w d	5 m x 17.5 m x 1.5 m
Flush Channel Slope	1.0%
Flush Gate Dimensions (l w)/Material	1.85 m x 0.4 m Stainless steel
Flusher Volume	28.5 m^3
Flusher Dimensions (l w h)	5 m x 2.5 m x 1.45 m
Slope of flush vault	15%
Water Source	Combined
Method of Gate Activation	Electric
Method of Removing Flushed Sediments	Underflow Sluice Gate to WWTP
Frequency of Inspection/Crew Size	Not Available
HVAC System/Type	Yes/Ventilation Shafts
Odor Control System/Type	No
Electrical System Explosion Proof	Yes
Performance Assessment	Excellent/Good

Case No. 13 - Cheboyan

Details of the circular CSO storage facility utilizing the flush gate technology in Cheboyan, Michigan are noted in Table 6-15. This facility features a circular tank construction with a diameter of 30.5 m (100 ft) Seven flushing bays direct flush waves across the length of the tank to a sump channel on one side of the tank. This flushing configuration is the first ever for circular tanks. In Germany, there are 3 circular tanks using flush gate technology but the flushing arrangement features flushing vaults located at the center of the tank with flushing lanes extending in a radial direction to the end trough at the tank perimeter. Figure 6-9 depicts plan and section views of the CSO circular storage tank in Cheboyan, Michigan. Photos of this facility are presented in Figure 6-10.

Table 6-15. Cheboygan, Michigan

Question	Response
Year Constructed	1997
Type of Flow	Combined
Covered or Open Tank	Open
Number Of Bays	7
Number Flushers/Bay	1
Training Walls/Flusher	Yes
Flush Channel Dimensions (l w h)	See Figure 6-9
End Trough Dimensions l w d	See Figure 6-9
Flush Gate Dimensions (l w)/Material	2.8 m x 0.4 m Stainless steel
Flush Channel Slope	2.0%
Flusher Volume	13 - 16 m^3
Flusher Dimensions (l w h)	See Figure 6-9
Slope of flush vault	20%
Water Source	WWTP Effluent
Method of Gate Activation	Hydraulic
Method of Removing Flushed Sediments	Underflow Pipe to WWTP
Frequency of Inspection/Crew Size	Not Available
HVAC System/Type	No
Odor Control System/Type	No
Electrical System Explosion Proof	No
Performance Assessment	Excellent/Good

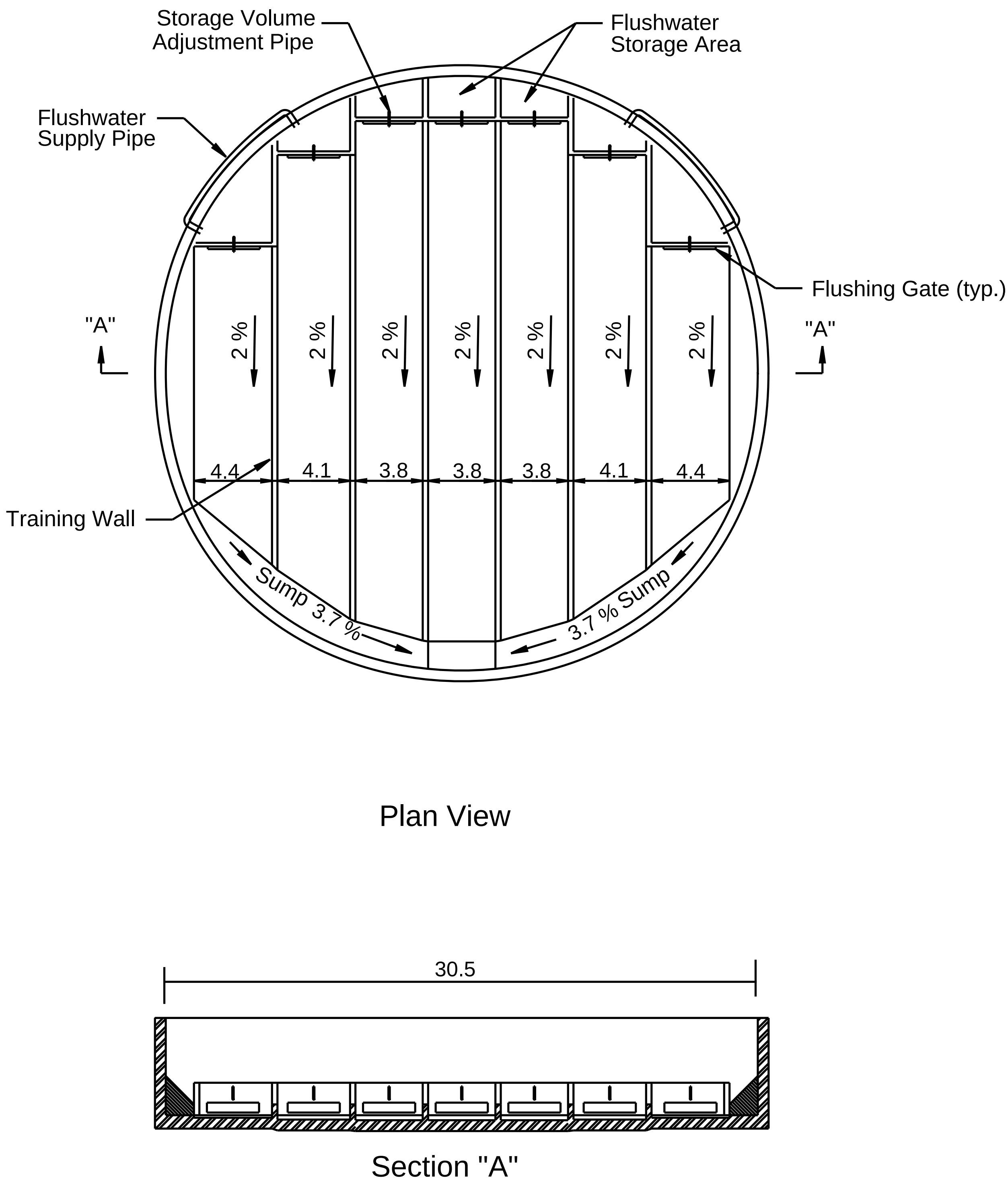


Figure 6-9. Cheboygan - Circular CSO Storage Tank, Plan and Section Views

Figure 6-10. Cheboygan - Photograhs of Circular CSO Storage Tank

Case No. 14 - Sarnia

Details of the first North American CSO storage facility located in Sarnia, Ontario, Canada utilizing the flush gate technology are given in Table 6-16. This facility is an underground covered tank with a storage volume of 8400 m^3 (2.2 million gallons). Twenty flushers cleanse the tank after each event. Plan and sectional views of this facility are provided in Figure 6-11 and Figure 6-12. Photos of the hydraulic gate opening mechanism are shown in Figure 6-13. The operation of this facility has been noted as excellent.

Table 6-16. Sarnia, Ontario Canada

Question	Response
Year Constructed	1996
Type of Flow	Combined
Covered or Open Tank	Closed
Number Of Bays	10
Number of Flushers/Bay	2
Training Walls/Flusher	Yes
Flush Channel Dimensions (l w h)	38.5 m x 3.9 m x 0.5 m
End Trough Dimensions l w d	2 m x 79.7 m x 0.7 m
Flush Gate Dimensions (l w)/Material	2.8 m x 0.4 m Stainless steel
Flush Channel Slope	2.0%
Flusher Volume	10 m^3
Flusher Dimensions (l w h)	2.5 m x 3.5 m x 1.6 m
Slope of flush vault	20%
Water Source	Combined
Method of Gate Activation	Hydraulic
Method of Removing Flushed Sediments	Sluice Gate to WWTP
Frequency of Inspection/Crew Size	Not Available
HVAC System/Type	Not Available
Odor Control System/Type	Not Available
Electrical System Explosion Proof	Not Available
Performance Assessment	Excellent

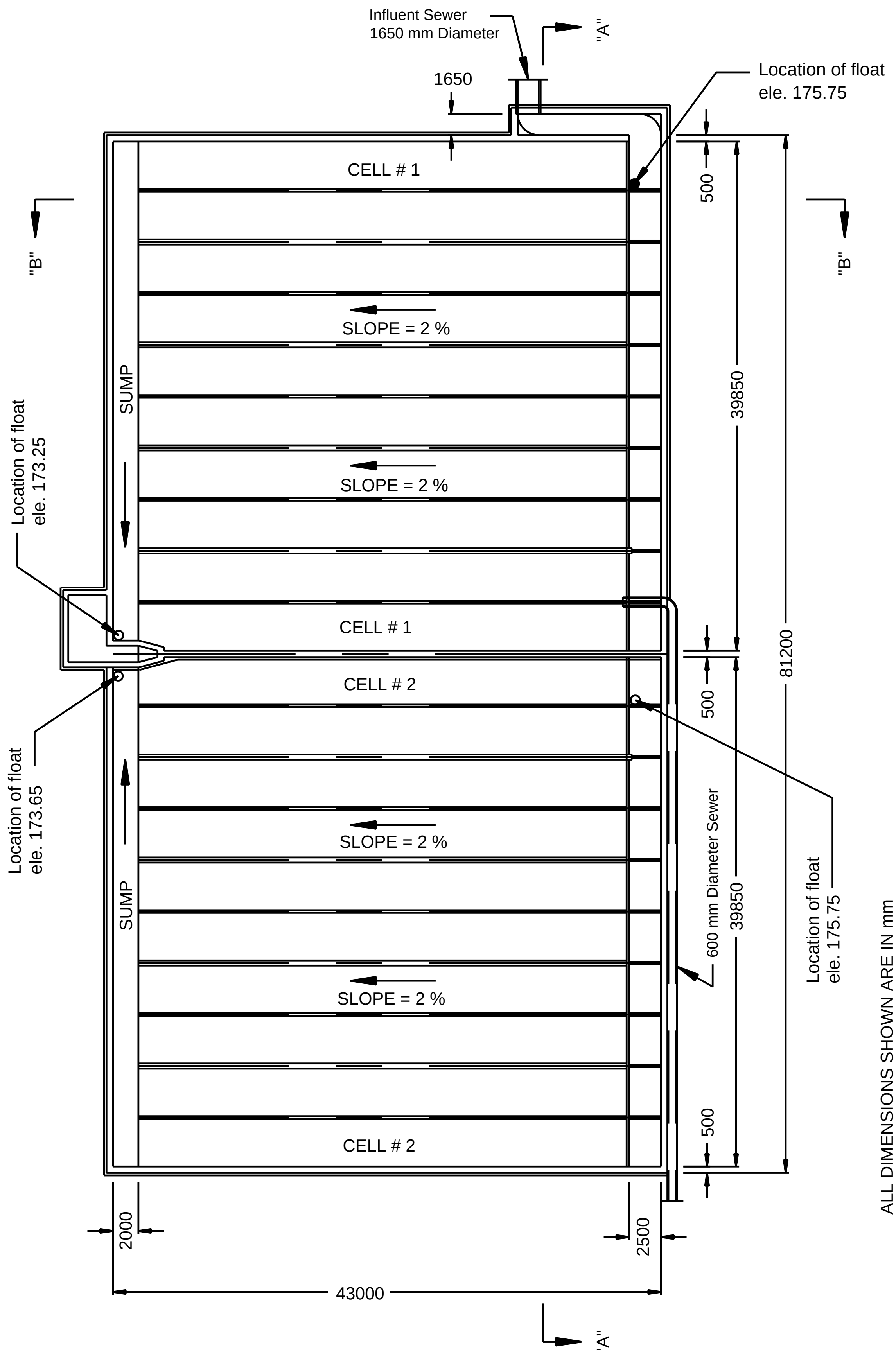


Figure 6-11. Sarnia - CSO Storage Tank, Plan View

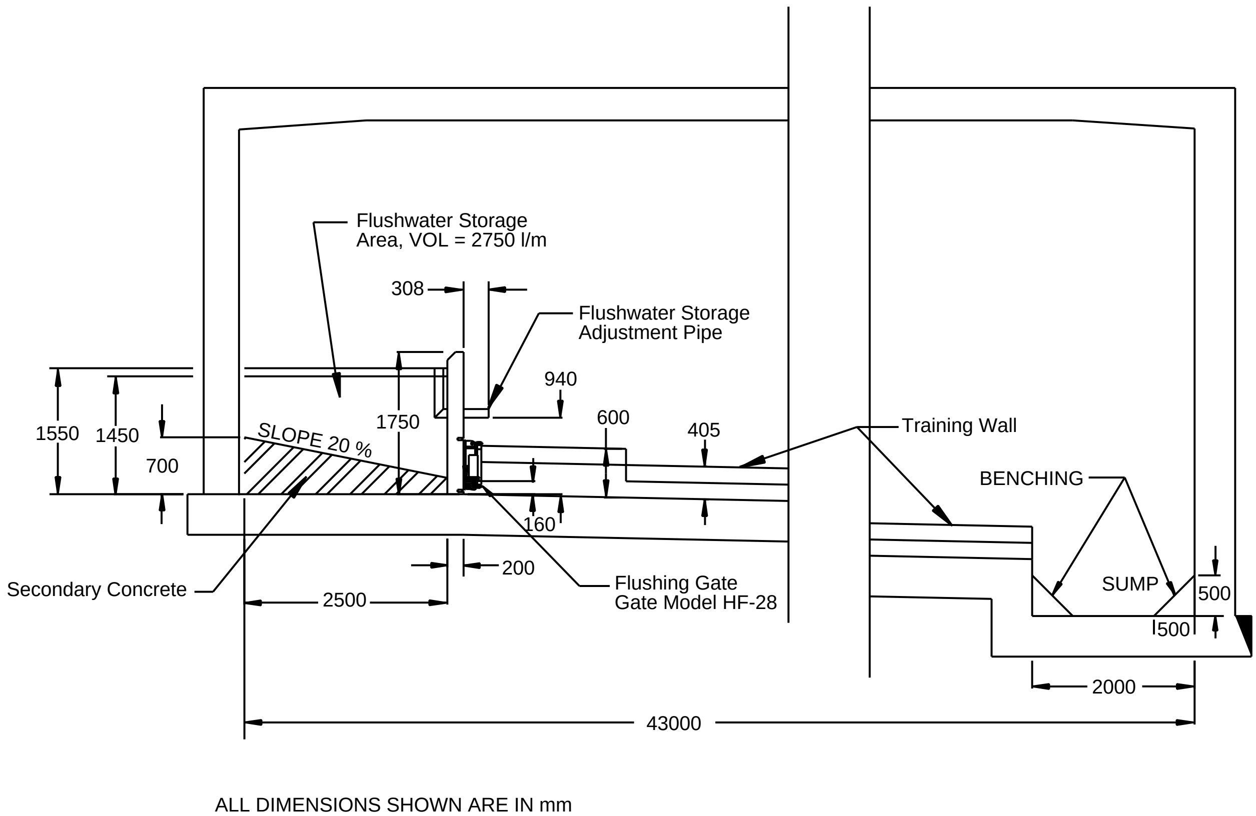


Figure 6-12. Sarnia - CSO Storage Tank, Section View

Figure 6-13. Sarnia - Photographs of Hydraulic Opening Mechanism

Hydraulic Analysis of Flushing Gates for Rectangular Tanks

Summary results of SWMM EXTRAN simulations of flush gate performance for five rectangular tank for five rectangular tanks are presented in Table 6-17. Flushing volumes computed from the construction drawings are used as inputs into rectangualer open channels (flushing lane). Velocities shown are computed at the end section of the flush lane, just prior to discharge into the end channel. There is good agreement between velocity and operator observations.

Table 6-17. Summary of Tank Flushing Results

	Length (m)	Slope	Width (m)	Height (m)	Velocity (m/s)	Depth (m)	Flush Vol. (m^3)	Observation
Filderstadt-Berhausen	36	2.5%	5	3.5	1.33	0.05	8.5	Good
Stadt Essen	55	0.5%	3	3.4	0.92	0.07	12	Good
Markt Wiesentheid	41	1.5%	4.84	3.0	1.30	0.06	12.7	Excellent / Good
Stuttgart Wangen	67	0.5%	3.6	1.8	0.83	0.06	18	Excellent / Good
Heidenheim Kleiner Buhl	30	1.0%	4.85	3.6	1.61	0.06	28.5	Excellent / Good

Evaluation of Flushing Gates for Tanks

Flushing gates use a flushing water storage compartment separated from the actual CSO tank to produce a flushing transient wave for cleaning the tank floor and to wash the settled matter into a mud sump of adequate volume and suitable benching at the opposite tank side.

The following design considerations are important for maximizing the effectiveness of flushing rectangular tanks using flush gate technology:

- The tank inlet should be designed such that flushing water reservoirs are filled before the storm tank compartments. This ensures that the necessary supply of flushing water to clean tanks from short storms of small volume. Filling the tank at the effluent side of the tank requires additional conduits to fill the flushing water reservoirs located at the influent tank side. Careful hydraulic considerations are necessary to assure adequate filling of all desired storage units.

- Depending on the tank filling concept, the inlet overflows should route the inflow sequentially into the different tank compartments. Overflow weirs of different heights can control inflow to individual compartments.

- The tank floor should be horizontal across the direction of flushing, and sloped from 0.5 to 2%.

- The flusher opening must be a minimum of 150 mm above the tank floor.

- Larger tanks should be compartmentalized into bays with a width of 3 to 5 m. Training walls should be sized to prevent the flush wave from spilling into adjacent bays.

- The tank side walls should be perpendicular to tank floor with no fillets to ensure cleaning of side walls.

- The tank side walls should be hand troweled to a smooth finish. No sidewall spray systems are necessary provided a smooth finish is achieved.

- The "mud sump" volume depends on the flushing volume, and hence of the width of the individual flushing bay as well as the possibility to flush the entire tank with multiple cells in sequential mode. The mud sump generally has a central emptying pit with a sluice gate or pump outlet. The bottom of the sump slopes gently towards this outlet sump, with a step between the tank bottom and the beginning of the slope. This step is important in order to contain the reflected wave in the mud sump.

- An adjustable standpipe in the flushing water reservoir allows for "fine-tuning" of the flushing volume in case the reflected wave throws water and debris back onto the tank floor.

- A 5% lateral slope of the mud sump is frequently used. In case of large tanks and one outlet this will result in fairly deep outlets.

- The flush volume depends on the length, width and slope of the flushing bay, and is roughly $1m^3$/m width and per 10 m length at a slope of 0.5%. A slope of 1 % reduces this requirement by 15%, and a 2% slope reduces the requirement by 25%. A maximum flushing length of 105m for normal tanks is suggested.

- The flushing gate mechanism is released hydraulically, either by means of an autonomous float mechanism, or by means of a more sophisticated control system that utilizes other criteria such as interceptor and WWTP capacity, for flushing and emptying (Parente et al., 1995).

Case Studies: CSO Storage Tanks Utilizing Tipping Flusher Technology

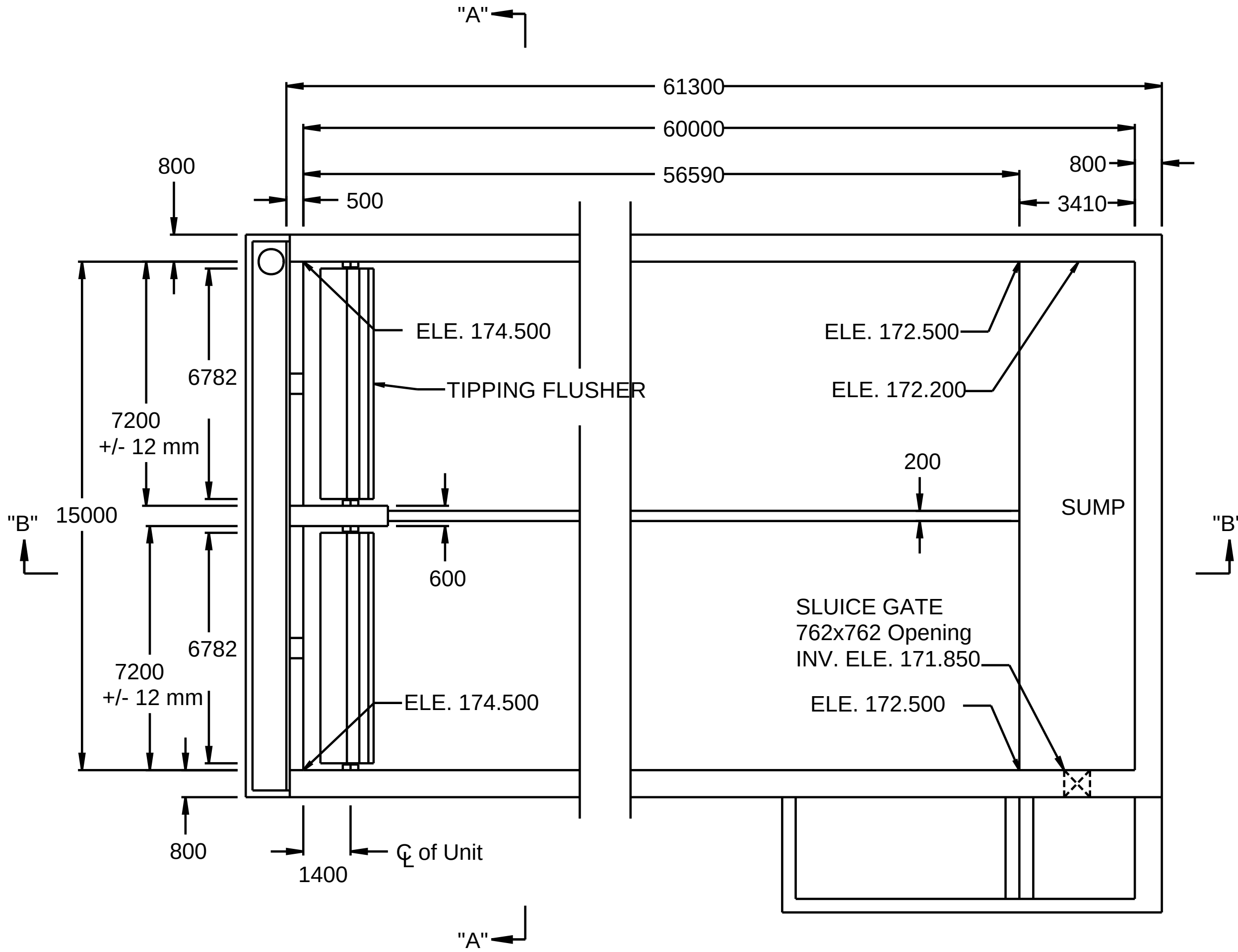
The following tables summarize the evaluations of the tipping flusher rectangular tank facilities.

Case No. 15 – Port Colborne

Details of the Port Colborne, Ontario CSO storage facility utilizing tipping flushers are given in Table 6-18. Plan and profile views of this facility are presented in Figure 6-11. Photos of this facility are shown in Figure 6-12.

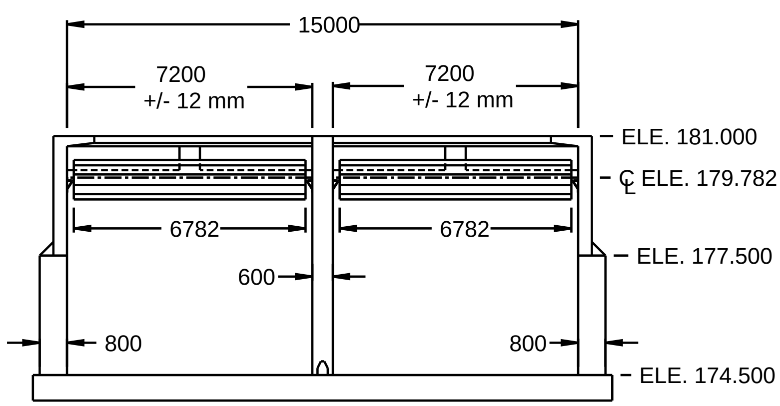
Table 6-18. Port Colborne, Ontario, Canada

Question	Response
Year Constructed	1996
Type of Flow	Combined
Covered or Open Tank	Open
Number Of Bays	2
Flushers/Bay	2
Training Wall/Flusher	Yes
Flush Channel Dimensions (l w h)	57 m x 7.2 m x 0.6 m
Height Off Floor	5.3 m
Front or Rear Tip	Rear
Fillet Radius	1.4 m
End Trough Dimensions l w d	3.4 m x 13.8 m x 0.65 m
Flush Channel Slope	1.5%
Flush Volume	8.2 m^3
Water Source	Fresh
Method of Removing Flushed Sediments	Underflow Sluice Gate
Frequency of Inspection/Crew Size	Not Available
HVAC System/Type	No
Odor Control System/Type	No
Electrical System Explosion Proof	No
Performance Assessment	Excellent



PLAN VIEW

ALL DIMENSIONS SHOWN ARE IN mm



SECTION "A"-"A"

Figure 6-14 (a/b). Port Colborne - CSO Storage Tank, Plan and Section Views

Figure 6-15. Port Colborne - CSO Storage Tank, Plan View

Case No. 16 – Wheeler Avenue

Details of the Wheeler Avenue, Louisville, Kentucky CSO storage facility are provided in Table 6-19. Plan view of the Wheeler Avenue facility is presented in Figure 6-16. Photos of the facility are provided in Figure 6-17.

Table 6-19. Wheeler Avenue, Louisville, Kentucky

Question	Response
Year Constructed	1997
Type of Flow	Combined
Covered or Open Tank	Open
Number Of Bays	1
Number Flusher/Bay	4
Training Wall/Flusher	Yes
Flush Channel Dimensions (l w h)	38 m x 4 m x 0.41 m
Height Off Floor	2.9 m
Front or Rear Tip	Rear
Fillet Radius	1.2 m
End Trough Dimensions l w d	2.4 m x 19 m x 0.6 m
Flush Channel Slope	1.6%
Flush Volume	6 m^3
Water Source	Fresh
Method of Removing Flushed Sediments	Underflow Sluice Gate
Frequency of Inspection/Crew Size	Not Available
HVAC System/Type	No
Odor Control System/Type	No
Electrical System Explosion Proof	No
Performance Assessment	Excellent

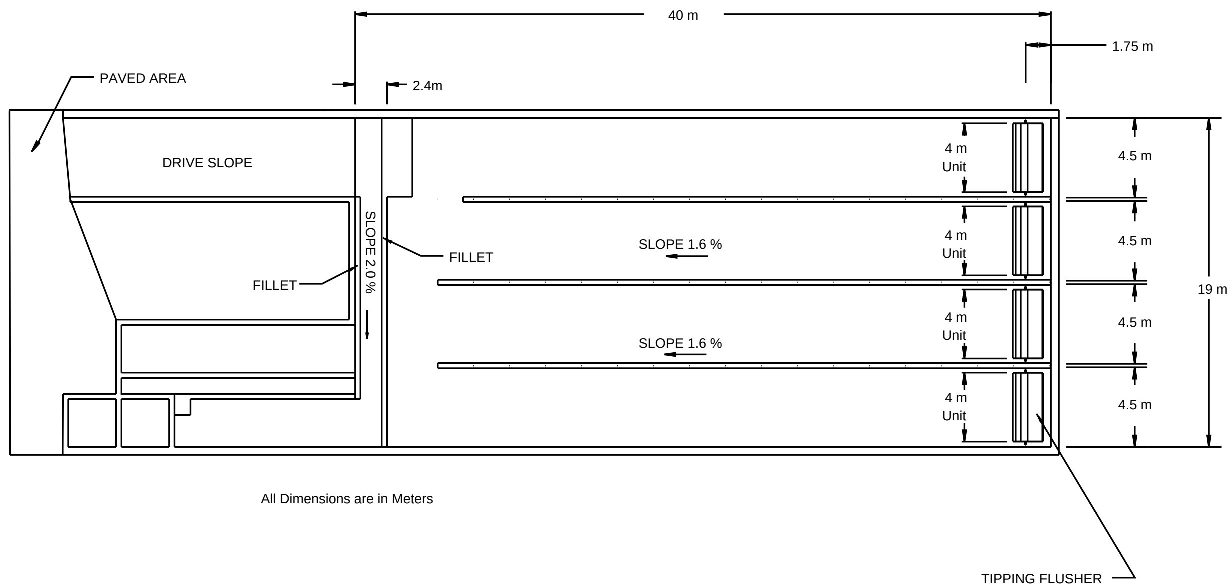


Figure 6-16. Wheeler Avenue - CSO Storage Tank, Plan View

Figure 6-17a. Wheeler Avenue - Photographs of Overall CSO Storage Tank

Figure 6-17b. Wheeler Avenue - Photographs of Filling Tipping Flushers and Overall CSO Storage Tank

Case No. 17 – 14th Street Pumping Station

The 14th Street Pumping Station in Saginaw Michigan functions as a regulation facility to pass dry weather flow to the East Side Tunnel leading to the WWTP, and as a pump station with 3 pumps, each with 2800 lps (100 cfs) capacity, to dewater drainage from four low-level trunk sewers discharging from the 14th Street district 80 hectares (200 acres). Land is mostly heavy industrial car manufacturing together with scattered residences. Pumped overflows occur about 12 times per year. The fifth main sewer to the station drains the 16th Street district with an 340 hectares (850 acre) catchment. The 16th Street district is long and narrow in shape, flat, and discharges into a 14-foot arch pipe with little slope. Solids deposition is considerable. Excess wet weather flows discharge over backwater gates into box culverts (collecting the pumped discharge from the station), and then proceeds through a 762 m (2500 ft) open ditch to the Saginaw River. Overflows occur 30-40 times per year. A wet weather connection from the 16th Street sewer into the station's wet well is used only in emergency. The total hydraulic flow capacity tributary to the 14th Street Pumping Station from both districts is about 13,000 lps (460 cfs).

The layout of the 14th Street Pumping Station treatment complex during wet weather operation is shown in Figures 6-18. It includes the following features:

- 22,000 m^3 (6.0 million gallons) of various storage elements consisting of in-line, first flush off-line, detention sedimentation treatment storage, underflow storage from vortex separators, and ditch storage overflow with pump back.

- Outflows from all storage facilities are equipped with vortex throttles to permit continuous gravity drainage to WWTP.

- All concrete tanks use tipping bucket flushers for ease in cleanup.

- Vortex solids separators precede conventional sedimentation tanks to ease solids cleanup.

Initially, first flush related flow from both the 16th Street and 14th Street districts are captured by in-system storage (2850 m^3, 0.75 million gallons) and then by tanks B1 and B2 (8550 m^3, 1.5 million gallons), Both tanks have vortex throttles to permit continuous drainage to the WWTP. This is the first in the United States of this type of CSO storage.

When Tanks B1 and B2 are filled, pumped discharge occurs with initial processing by three 11 m (36 ft) diameter reinforced concrete vortex solids separators each with a maximum capacity of 2830 l/s (100 cfs). Pumped underflow from the separators passes to Tank B3 (throttled outflow to WWTP). Treated overflow from the vortex separators discharges in a channel over the top of existing box culverts and into a new 7600 m^3 (2 million gallons) detention and storage facility (Tank B4) with chlorination. Outflow from the separators can also bypass Tank B4 and discharge directly into box culverts draining to the Saginaw River.

Tank B4 will provide 45 minutes of detention with "one pump on" (common event) and will provide further treatment of "clear water" overflow from the vortex solids separator. The overflow from Tank B4 discharges into the box culverts draining to the ditch. New backwater gate structures were installed near the River and the ditch rehabbed (stone lined and reverse graded) to create 9500 cubic meters (2.5 million gallons) of inexpensive storage. Retained ditch storage is drained after an event to a new drop shaft discharging to the East Side Tunnel.

Long term simulations indicate that the "continuous drain" operation for Tanks B1 and B2 permit capture with bleedback to WWTP without disinfection of half the annual runoff volume. Although the 1 year 1-hour storm is the most severe design condition, the more likely events of concern are spring multiple day intermittent rainfall events. The vortex tank throttles permits optimized overall utilization of Tank B1 and B2 and the complex of vortex separators with Tank B4 treatment.

The sum of all tank discharges (vortex throttles) plus the two dry weather underflow vortex throttles had to equal existing wet weather discharge from this catchment. This new requirement was imposed by regulating agencies since the City was planning to accept dry weather flows from nearby communities deactivating small WWTPs.

Additional estimated cost savings associated with the sedimentation tank tipping bucket flushers in contrast to conventional high pressure spray systems are significant (approximately 33 percent) while the requirement for flushing water was decreased by 25 percent (Pisano, 1985).

A total of 23 tipping flushers are used to clean tanks B1 (4 tipping flushers), B2 (2 tipping flushers), B3 (6 tipping flushers), and B4 (10 tipping flushers). The performance of this cleansing system has been noted by the maintenance staff to be very satisfactory. Only one flush per lane is required. Figure 6-20 depicts a photo of tanks B1 through B3. Figure 6-22 depicts a photo of tank B4 after overflow activation. Since the facility is very close to the WWTP, draindown of all tanks is typically accomplished in 6-12 hours. Photos depicting a cleaning sequence for Tank B4 are depicted in Figures 6-23 (a to d).

Figure 6-18. 14th Street Pumping Station - Tanks B1, B2 and B3

Figure 6-19. 14th Street Pumping Station - Tank B4

Figure 6-20a. 14th Street Pumping Station - Flushing and Sequence for Tank B4

Figure 6-20b. 14th Street Pumping Station - Flushing and Sequence for Tank B4

Figure 6-20c. 14th Street Pumping Station - Flushing and Sequence for Tank B4

Case No. 18- Saginaw Township Center Road Storage Tank

The first operational tipping flusher sedimentation tank installation within the United States, the Center Road Storage Tank, is located in Saginaw Township, Michigan. The tank was constructed in 1989 and handles overflows from a catchment of 514 hectares (1270 acres) with a design peak flow of 5943 lps (210 cfs).

The tank has no odor control provisions, and contains multiple bays with a total volume of 19000 m^3 (5 million gallons). In the first third of the tank which is utilized as first-flush storage, three tipping flushers are used to clean heavy sediments and sand. Water cannons and fire hoses are used to clean the remainder of the tank.

The tipping flushers cleanse a length of approximately 55 m (180 ft). Generally the performance of the tipping flushers has been satisfactory. However, two flushes are necessary after major storms as sediments contain some inorganic material. Flush waves have been observed to break up into rivulets near the end of the flushing lane.

Evaluation of Tipping Flushers

The following design considerations are important for maximizing the effectiveness of flushing rectangular tanks using tipper flusher technology:

- The size of a tipping flusher (TF) required to clean a given tank depends on the flushing distance, the height the unit is suspended above the tank invert, and the slope of tank floor in the flushing direction. The TF's vary in size from 0.02 - 2 m^3/ m (12 to 160 gal/foot) of flusher length, with a maximum length/span of approximately 11 m (35 feet).
- The maximum effective flushing length is between 160- 175 ft because the wave cannot be sustained and tends to break up into rivulets beyond this distance. Experience with flushing in the 55 to 60

meters (180 to 200 ft) range is mixed, and it has been observed that often 2 flushes are necessary to achieve adequate cleaning.

- Tank floors should slope from the flusher location to the collection trough at 1 - 3 % (2 % is desirable because quality control is difficult for flatter slopes).
- Tipping flushers require flushing lanes that are about equal to the width of the flusher to control the flow direction of the flush wave. This is accomplished by training walls that are about 0.4 to 0.6 m (15 to 18 inches) high, and run the full length of the tank terminating at the collection trough.
- All walls parallel to the path of flushing flow should be perpendicular to the tank bottom, with no fillets, to ensure the lower wall edges are cleaned.
- There is an upper effective height limit for placement of the tipping flusher where additional height does not enhance the flusher's performance further, (approximately 5.5 m, or 18 ft).
- The wall beneath the flushers must be continuous (i.e., contain no openings, penetrations or obstructions), to assure wave continuity.
- Side walls should be hand troweled to ensure smooth surface. No sidewall spray systems are necessary.
- Tanks with shallow sidewater depth of sidewater depth of long length are a concern using tipping flusher technology as the gate will tip near floor level.

Other Flushing Case Studies

Other researchers (Parente et. al., 1995) have collected survey data for several European CSO rectangular tank facilities using flush gates. The following are brief summaries of the findings.

City of Essen, Germany

The City of Essen has two CSO tanks utilizing flushing gates. One facility, in operation since 1991, has a volume of 1500 m^3 (395,000 gallons). The tank is divided into 3 bays with each bay approximately 5 m (16 ft) wide and 34 m (112 ft) long. The cleaning effectiveness was reported as very good without a need for any manual cleaning.

The second facility, in operation since 1993, has a volume of 2700 m^3 (710,000 gallons). The tank is divided into 6 bays with each bay approximately 2.5 m (8 ft) wide and 46 meters (151 ft) long. The cleaning effectiveness was reported as very good with a need to clean walls once a year due to the heavily polluted corrosive wastewater handled by the tank.

City of Konstanz, Germany

The City of Konstanz has a CSO tank utilizing flushing gates. The facility, in operation since 1992, hs a volume of 2000 m^3. The tank is divided into 3 bays with each bay approximately 7 m (23 ft) wide and 18 m (59 ft) long. The cleaning effectiveness was reported as generally good. Konstanz is located on a lakeshore with minimal slopes and heavy accumulation of sediment inside the sewer system during dry weather. During rain events, excess water is pumped to storm overflow tanks, with heavy first-flush concentration. The filling of the tank is from flushing water reservoir side, with heavy matter spilling into the flushing vaults. These materials clutters the flusher gate and mechanism, which occasionally fails to close properly because of debris and clogging. His preference was to use pre-clarified water for the flushing reservoirs to reduce potential for clogging the gate. The tank is drained by gravity through a regulator back to the pump station. The tank control system is programmable, allowing for adjustments in accordance with operation experience.

City of Augsburg, Germany

The City of Augsburg has a covered CSO tank utilizing flushing gates. The facility, in operation since 1994, has a volume of 4900 m^3 (1.3 million gallons). The tank is divided into 9 bays with each bay approximately 5 m (16 ft) wide and 50 m (164 ft) long. The cleaning effectiveness was reported as very good without a need for any manual cleaning. The flushing reservoirs are filled first and no problems with solids accumulating/clogging the gate have been reported. Some sediments deposit on wall crowns and weir sills and require occasional hosing down were reported. The tank floor was clean, with no deposition in the corners. In order to prevent clogging of the sludge pumps when emptying the mud sump, the owner installed mixing equipment to keep heavy sludge concentrations and debris in suspension during operation. The City has found stainless steel conduits to be more dependable then copper for the hydraulic flushing gate actuators.

City of Elizabeth, New Jersey - Mechanical Flap Gate Flusher

Flushing of large diameter combined sewers was investigated during the City of Elizabeth Combined Sewer Pollution Abatement Program completed in 1986. The program concluded that daily flushing of sewers particulary prone to solids deposition in seven subsections of the City by constructing 12 flushing modules would reduce the first flush overflow pollution by approximately 28%.

A total of 12 flushing modules were installed in sewers ranging in size from 0.45 to 1.4 m (18 to 54 inches) with slopes as low as 0.02% and were designed to produce sewer flushing in pipe runs up to 305 m (1000ft) long. Figure 6-22 presents plan and section views for a typical Elizabeth flushing system.

The flushing modules are underground structures with above ground control cabinets. Each module has a dry and a wet chamber. The wet chamber is constructed around the existing sewer and houses a hydraulically operated flap gate mounted on a shaft across the sewer supported on two bearings. The flap gate is sized to match the dimension of the sewer in which it is installed. The flap gate is normally open but closes at a controlled time (usually at night, during periods of low flow). The gate is designed to automatically open when the stored sewage volume rises to a preset level needed to create a flushing wave adequate to resuspend and transport the deposited sewage solids to the interceptor at a flow rate which will not cause overflow at the downstream regulators. The wet chamber also contains level switches and ultrasonic level sensors to provide signals for opening and closing of the gate. The dry chamber is adjacent to the wet chamber and houses the mechanical and electrical equipment such as the flap gate actuator, the hydraulic power unit as well as auxiliary equipment. A number of facilities are still in operation. No performance evaluations of these facilities have been conducted. This facility is unique in the United States and another such facility has yet to be installed.

Case Studies: Cost Effectiveness Studies of CSO Tank Cleaning Methods

The following two case studies present cost effectiveness evaluations that were prepared for CSO storage tanks in North America. The Eastern Beaches study compares cost effectiveness of tipping flushers with other methods. The Sarnia study compares cost effectiveness of flushing gates and tipping flushers with other methods.

Case Study: Eastern Beaches, Toronto, Ontario, Canada

Environment Canada in conjunction with the International Joint Commission has designated the City of Toronto Waterfront as one of the 42 Remedial Action Plan (RAP) areas within the Great Lakes drainage basin. The City of Toronto has been carrying out an extensive program of pollution abatement over the past 30 years to meet the RAP objectives. The City has prepared a pollution abatement program for CSO and stormwater runoff and has developed a Sewer System Master Plan for the combined and storm sewers. As a component of the Master Plan, the Eastern Beaches, located within the City of Toronto, were determined to have first priority in pollution abatement to ensure that the beaches remain open for body contact water recreational purposes. Environmental Assessment studies analyzed various pollution abatement strategies and determined that detention tanks would be the most feasible alternative for controlling pollution originating from CSO and stormwater runoff entering the nearshore waters along the Eastern Beaches (Parente et. al., 1994).

The first of two tanks, located at Kennilworth Avenue, was put into service in July 1990 to intercept 1 CSO and 5 storm sewer outfalls. High volume spray nozzle cleaning system was used to cleanse sediments from the tank after activations. This tank has been in operation for the past 4 years and has been monitored with respect to pollution abatement efficiency, beach closure impacts and operation/maintenance impacts. Monitored data from this tank indicated that the seasonal pollutant removal from the beach area has averaged approximately 2,800 kilograms (6160 pounds) of sediments and 130 kilograms (286 pounds) of BOD. The resultant beach closures has been reduced from 35% prior to tank installation down to 4% of the swimming season.

Based on the encouraging monitoring results from the first installation, the City has proceeded with the installation of a second tank at MacLean Avenue to remove all other CSO within the immediate area. This second tank, approximately 3.5 times larger than the first tank, has a storage volume of 8,000 m^3 (2.1 million gallons) and is located approximately 1 kilometer (0.62 miles) east of the first tank.

Design criteria for the MacLean Avenue detention tank included the following:

- Provide 8,000 m^3 (2.1 million gallons) of storage (4,000 m^3 for CSO and 4000 m^3 for stormwater runoff) to eliminate untreated CSO and stormwater discharge to beach area;

- Operation and maintenance concerns to address the most efficient cleaning system, water conservation considerations, minimal entry requirements, and control of possible odors.

- Due to the site constraints, the detention tank dimensions were finalized having a length of 100 m (330 ft), a width of 15 m (49 ft) and average depth of 6 m (20 ft).

Operation and Maintenance

During the design phase of the MacLean Avenue tank, discussions were held with the operating staff regarding their experience in operating the first tank for the past 4 years and also their experience in operating a combined sewage balancing tank further up the system which was constructed in 1914. In addition to this transfer of operating experience, contact was made with several other municipalities designing or operating combined sewage tanks to obtain their experience. The main comments/requirements from the various sources identified the following operating features related to tank flushing and odor control:

- Efficient method of cleaning is essential to minimize manned entry requirements and to ensure deposition of sediments does not occur;

- An odor control system is essential to prevent public complaints during tank operation.

During the process of detaining the flows, settlement of suspended solids will occur. To minimize and facilitate removal of the settled solids, the detention tank will be cleaned after every usage. Three methods for removal of the sediments were investigated: tipping flushers, flushing spray, and manual cleaning. Flushing spray and manual cleaning systems are described below.

Flushing Spray

A spray flushing system utilizes spray nozzles oriented in such a manner that the spray from the nozzles covers the entire floor area and the floor has sufficient grade to ensure effective sediment transport. These nozzles generally require water at a relatively high pressure and large volumes to provide the scouring of the sediments. The tank floor requires a longitudinal slope of 2% and lateral slope of 10%. The floor is graded to divert the wash water to a sump where it is pumped to the sanitary sewer.

The spray nozzles are selected to provide sufficient wash water volume and pressure that the settled sludge is re-suspended. From experience at the Kennilworth detention tank, selected nozzles with a capacity of 3.85 lps (50.8 gpm) at a pressure of 415 kPa (60 psi) are required, Because of the high flow and pressure demands, cleaning of the first tank is carried out in sections.

Manual Cleaning

This method requires manned entry to the tank during the cleaning process and the use of hoses to flush the tank floor. Manual cleaning ensures a high level of effectiveness because the operators can be flexible with the usage of time and water based on the level of sediments to be removed. This method is the most labor intensive and most hazardous due to the requirement of working in a confined space. The equipment cost of this alternative is minimal, but the operational cost is higher due to the longer time the maintenance crews have to remain on site. This does not include cost of mobile equipment such as hoses, safety equipment, etc. The volume of flushing water required will vary due to personnel work practices, but is anticipated to be equal to or greater than that required by the flushing spray method. This method is being applied for cleaning the High Park tank constructed in 1914.

The cost comparison of the three cleaning systems is shown in Table 6-20.

Table 6-20. Capital and Operation and Maintenance Cost Comparison

Type of Cleaning System	Storage Volume (m^3)	Floor Area (m^2)	Unit Construction Cost ($/$m^2$)	Unit O & M Cost ($/$m^2$)
Tipping Flusher (MacLean Avenue)	8000	1360	141	0.075
Flushing Spray (Kennilworth Avenue)	2250	660	290	0.30
Manual Cleaning (High Park)	2400	790	2	1.77

*Excludes water and electrical costs.

In evaluating these tank flushing alternatives and evaluating experiences with all three practices, it was determined that the tipping flusher alternative was the most effective and economical. The flushing system for each compartment consists of a TF at each end of the tank compartment with the tank floor sloped at a grade of 2% to a central channel designed to intercept the flush wave and its re-suspended sediments. To incorporate water conservation practices in this design and since the flush water supply is not required to be at a high operating pressure, a small pump has been installed to pump lake water through the outfall force main and into the TF. A valve system has been installed such that the force main may be operated both as a discharge main and also as an intake main.

Odor Control

The odor control for the venting system of the second tank is similar to the first tank. The venting system is designed to convey the displaced air during the tank filling process by means of an underground pipe system to the surface control structure where the air is passed through an air filter system consisting of activated carbon. The treated air is then expelled to the atmosphere approximately 6 m (20 ft) above ground surface. A similar system has been in operation at the first tank with the filter media requiring replacement after 3 years of operation.

The housing for the filter system is located approximately 130 m (426 ft) west of the tank. The structure also houses the main control center for all the mechanical equipment and monitoring system.

Case Study: Sarnia Ontario

The pollutant loadings from combined sewer overflows (CSO's) and storm water outfall discharges to the Sarnia waterfront and the St. Clair River have resulted in beach postings, reduced waterfront recreational activities and degradation of aquatic habitat. The City of Sarnia carried out a Pollution Control Planning (PCP) Study to develop a master plan in reducing the pollution loadings to the Sarnia waterfront. One of the recommendations of the PCP study is to construct four CSO tanks that would intercept and retain CSO during storm events. The first of the recommended CSO tanks is located at the Devine Street outfall, which has a contributory area equivalent to 40 percent of the combined sewer area within the City of Sarnia. The required size of the tank was determined to be 10,700 m^3 (2.8 million gallons) such that the tank would reduce CSO discharge events to the St. Clair River to between 3 to 5 events per year (Parente et.al., 1995).

The purpose of this detention tank (see Case No. 14, Table 6-16 for evaluation data of this facility) is to detain the overflow volume until the conveyance capacity and/or treatment capacity is available. During the operation of the facility, settlement of suspended solids will occur along the bottom of the tank. It is therefore necessary to remove the settled solids after each event to eliminate caking, the accumulation of these solids, and to avoid the formation of gases and odors as a result of decaying organics.

The design of the tank was to incorporate the most efficient and reliable cleaning method such that operation and maintenance would not impose high demands during tank operations. The detention tank is situated within an existing residential park with an available effective hydraulic depth (outlet elevation to overflow elevation) of 4.3 m (14 ft). Based on the existing site restrictions and storage volume requirements, this tank requires a cleaning system to effectively clean a floor with a surface area of 3,440 m^2 (37,000 ft^2).

Cleaning Alternatives
The following four cleaning methods were identified for the Devine Street CSO tank:

- Manual Cleaning
- Flushing Spray
- Tipping Flusher, and
- Flushing Gate.

The estimated capital, operation and maintenance costs for the four flushing alternatives for the tank are provided in Table 6-21.

Table 6-21. Alternatives Capital and Operation and Maintenance Cost Assessment

Alternative	Capital Cost	Capital Cost/m^2	O & M Cost/Event	O & M Cost/m^2
Manual	$10,000	$2.91	$6600	$1.92
Flushing Spray	$680,000	$197.67	$1548	$0.45
Tipping Flusher	$525,000	$152.62	$378	$0.11
Flushing Gate	350,000	$101.74	$250	$0.07

Operation and maintenance costs include labor, cost of potable water for cleaning at $0.40/$m^3$, and cost of sewage treatment for external flushwater at $0.45/$m^3$.

Due to water conservation and the lower capital cost, the flushing gate system using detained sewage was selected to be the most cost effective alternative. This system requires less mechanical equipment such as valves and supply lines that are necessary for an external water source. The operation and maintenance costs tend to be marginally lower since no additional costs are incurred for the supply of potable water for flushing purposes and the associated treatment costs for the flush water.