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MWH

MEMORANDUM

DATE: September 18, 2009

TO: Owen O'Riordan, Cambridge DPW

FROM: William Pisano, Sandy-Kae Gray, MWH

CC: Vin Spada, John Struzziery, SEA;

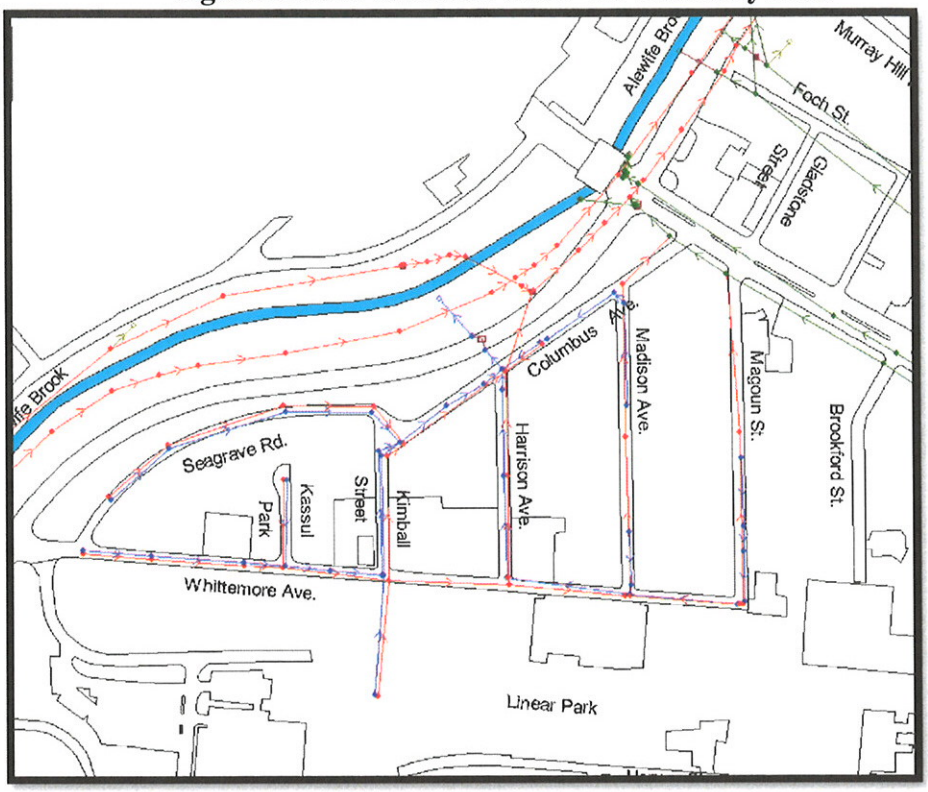
SUBJECT: CAM 400 Contract 13 Area Separation – Hydraulic Analysis

The CAM 400 collection area is approximately 28 acres of mixed residential and commercial use buildings. The area is located in the northern portion of the City of Cambridge (City) and is bounded on the south by Whittemore Avenue and the WR Grace Facility, Magoun Street on the east, and the Alewife Brook Parkway on the northwest. A site plan of the area is provided in Figure 1.

The purpose of this assessment was to complete a detailed investigation and analysis of the CAM 400 drainage area, and to provide design recommendations that address existing combined sewer overflows resulting from common manholes, illicit sanitary connections, inadequate catch basins, and leaking storm drains. Given the significant capital investment and disruption to the community caused by area wide separation projects, additional or upsizing of existing sewers and drains were avoided where possible. All existing sewer and drain inverts were therefore maintained under separated conditions to the maximum extent practicable.

The following hydraulic analysis was performed using the most recent survey, manhole and catch basin inspections, as well as the building connectivity information available. Preliminary assumptions for sanitary sewer and storm drain separation were also incorporated into the model such that the systems were simulated independently.

Figure 1: Site Plan of the CAM 400 Tributary Area



Field Survey and Building Inspections

A detailed survey of the sewers and drains in the CAM 400 area was conducted under the scope of this analysis. The associated manholes and catch basins in the area were also inspected under this effort. During these inspections the condition, size, and invert elevations of the sewer and drain systems were determined. A comprehensive field investigation of approximately 110 buildings (including the WR Grace Facility) was also conducted to verify connectivity to the local sewer and drain systems. Illicit connections and/or sources of inflow were also located within the study area.

Results from the survey, manhole and catch basin inspections, as well as the building inspections were used to update the characteristics of the modeled sanitary and storm drain systems to best reflect known field conditions. Details of these inspections are provided under separate cover. Profiles of the existing sanitary sewers and storm drains are provided in Appendix A and Appendix B, respectively.

There are several common manholes within the area, and the combined sewer system discharges to a regulator structure on the banks of the Alewife Brook. This structure diverts low flows to the 66" diameter MWRA Alewife Brook Conduit Sewer (ABC) through a 10" diameter sewer and permits larger wet weather flows to overflow to the Alewife Brook through a 30" diameter storm drain.

Sanitary Sewer Analysis

The sanitary sewer analysis was conducted using the 1 year-6 month MWRA design storm, for which greater than 3 feet level of service (LOS) is desired for the project area. Baseline conditions for the analysis assumed future separation conditions within the City along the Alewife Brook (including, but not limited to, Contract 7, 8, and 9 areas in West Cambridge with a high degree of private property inflow removal) as well as the future implementation of the MWRA Long-Term Control Plan characteristics. Future proposed separation and floatables control at CAM 401B and CAM 002 was also included in the baseline condition for the CAM 400 analysis.

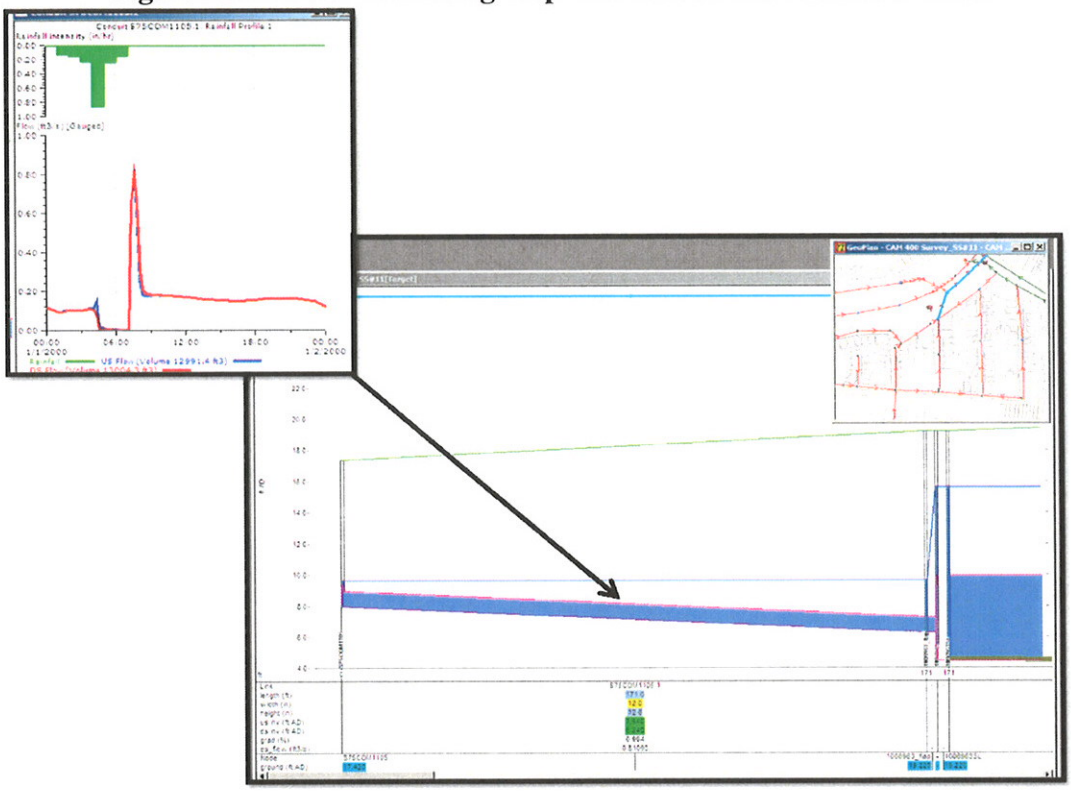
This analysis was primarily conducted to assess the impacts of existing inflow connections to the sanitary sewer as well as to optimize flow to the ABC. Sewer size, inverts, and connectivity within the CAM 400 catchment were updated based on the findings of the recent survey and manhole inspection (see drain profiles provided in Appendix A). Under existing conditions, sanitary flow from Magoun Street and Madison Street are tributary to the CAM 401B combined sewer. The remainder of the area is tributary to the CAM 400 low flow connection to the ABC.

Under existing conditions, the sanitary flows are connected to the ABC via a 10" dia. under drain from the CAM 400 regulator. An existing 10" dia. sewer pipe across the Alewife Brook Parkway is collapsed and must be replaced. For the future separated conditions, it is proposed that a new 12" dia. sewer be constructed from intersection of Harrison and Columbus Avenues directly to the connection point with the ABC. This alignment will minimize the length of new sewer to be constructed adjacent to the ABC for the completion of the separation effort.

The ABC is fully surcharged at the 1 year-6 month MWRA design storm and creates significant backwater conditions for the CAM 400 sanitary sewer. The severity of this surcharge is due in part to the theoretical set points simulated at the Alewife Pump Station (i.e. set points assumed for the purposes of the model simulations). Therefore, to eliminate the backflow contribution of the ABC, a 12" dia. flap valve is also proposed at the connection to the relief interceptor. The impact of the flap valve at the junction with the ABC is shown in Figure 2.

Note that the impact of the baffles used for floatables control at CAM 400 and CAM 002, as well as the additional proposed underflow connection to ABC from CAM 002, were confirmed to not impact LOS along the ABC in the vicinity of the connection point of CAM 400.

Figure 2: Flow Isolation using Flap Valve at Alewife Branch Conduit



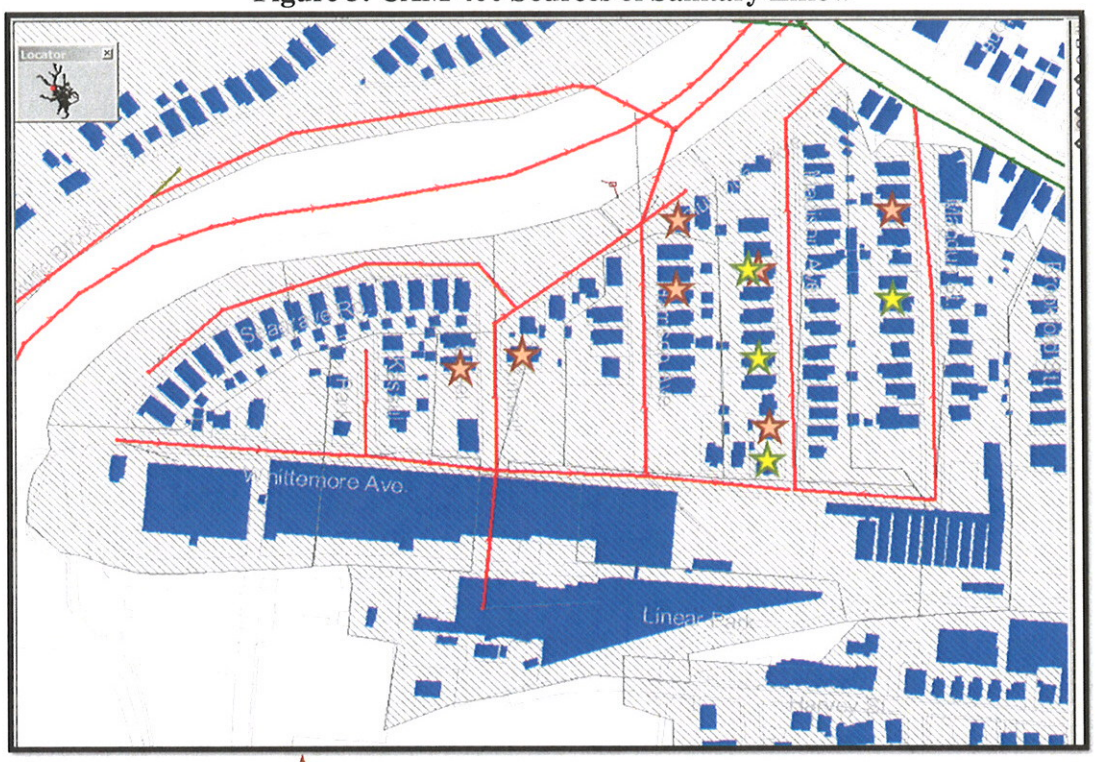
Sump Pump and Flat Roof Drains

Results of the building inspections confirmed the connection of four (4) flat roofs of single-family residential buildings and seven (7) sump pump outlets to the sanitary system. Locations of these inflow contributions are shown in Figure 3. These connections represent wet weather inflow contributions to the sanitary sewer. Roof drain connections are typically intrinsic to the building structure for flat roof connections and are therefore difficult to remove. Removal of sump pump connections are typically feasible, however require significant local legislation to enforce private property removal and the associated construction effort.

These inflow sources were therefore assumed to remain connected to the sanitary sewer under modeled future separated conditions. The area of the building foot print was used to estimate the runoff contribution of the flat roofs, while an average pump discharge of 20 gpm (corresponding to the 1 year 6 hour storm, and based on field investigations performed under the "Alewife Sewer Assessment", July 2006) was used for each sump pump connection. Note that relative to other areas within the City, such as Cambridge Street and Broadway Street, inflow after separation has been observed at be approximately 13% of the impervious contribution area. Prior to the field investigation conducted in the CAM 400 area, the sanitary inflow was therefore also assumed to be 13%. Relative to prior observations, the field verified inflow contribution (equivalent to approximately 2% of the impervious area) observed in the CAM 400 area is low. Note, this impervious area represents the

fraction of the total impervious area (i.e. building and paved areas) associated with buildings with sump pumps and flat roofs)

Figure 3: CAM 400 Sources of Sanitary Inflow



WR Grace Facility

The WR Grace buildings house an operating research and development facility with the capacity to employ up to 200 persons. During the recent field inspection, it was noted that the facility operated with approximately 100 persons currently employed there. The facility also discharged pre-treated process flows to the sanitary sewer. No record information was available regarding the peak discharge of the process flows, however it is estimated that the peak discharge is approximately 100 gpm. The wet well volume of pre-treatment facility is approximately 1,800 gallons.

Due to the nature of the treatment process, these flows are released in batches at pre-determined intervals. The duration of the discharge is expected to be less than an hour, and therefore should not have a detrimental impact on the LOS during a design 1 year - 6 month MWRA design event. It is however feasible that WR Grace can schedule the discharge of the process flows during dry periods and thereby minimize any potential impact system LOS during wet periods. Process flows from the WR Grace Facility were therefore omitted from CAM 400 wet weather simulations. This operational procedure should be coordinated with the facility as needed.

No roof or sump pump connections to the CAM 400 sanitary sewer were identified from the WR Grace building during the recent field inspection.

Madison Avenue and Magoun Street Flows

The model was updated to confirm the size and connectivity of the combined and sewer pipes within the CAM 400 area. Sanitary flows on Madison Avenue and Magoun Street are currently tributary to the CAM 401B combined sewer on Massachusetts Avenue, while the remainder of the area sanitary flows are tributary to the CAM 400 regulator. The model was also updated with the reduced inflow assumption and the flap valve at the connection point to the ABC. With these modifications, it was determined that the LOS would not be adversely impacted if flows from Madison Avenue were also redirected to the connection point with the ABC. The sewer on Columbus Avenue between Harrison Avenue and Madison Avenue was therefore proposed to be replaced and upsized to a 15" dia. sewer. The sewer connection on Columbus Avenue and Madison Avenue is recommended to be plugged to isolate the Madison Avenue flows from Massachusetts Avenue. Another plug on Magoun Street at the manhole weir on Whittemore Avenue is also proposed to isolate sewer flows from Whittemore Avenue toward Massachusetts Avenue. Locations of these upgrades are identified in Figure 4.

Sanitary Level of Service

With the implementation of the aforementioned model assumptions and upgrades to the sanitary sewer, the LOS for the 1 year - 6 month MWRA design storm event was greater than 5 ft across the CAM 400 area. Results of simulations for the sanitary sewer system are shown in Figure 5. LOS along Magoun Street is greater than 3 ft due to specific shallow pipes as well as the assumed catchment loadings within this sub-catchment.

Figure 4: Isolation of Madison Avenue and Magoun Street Flows

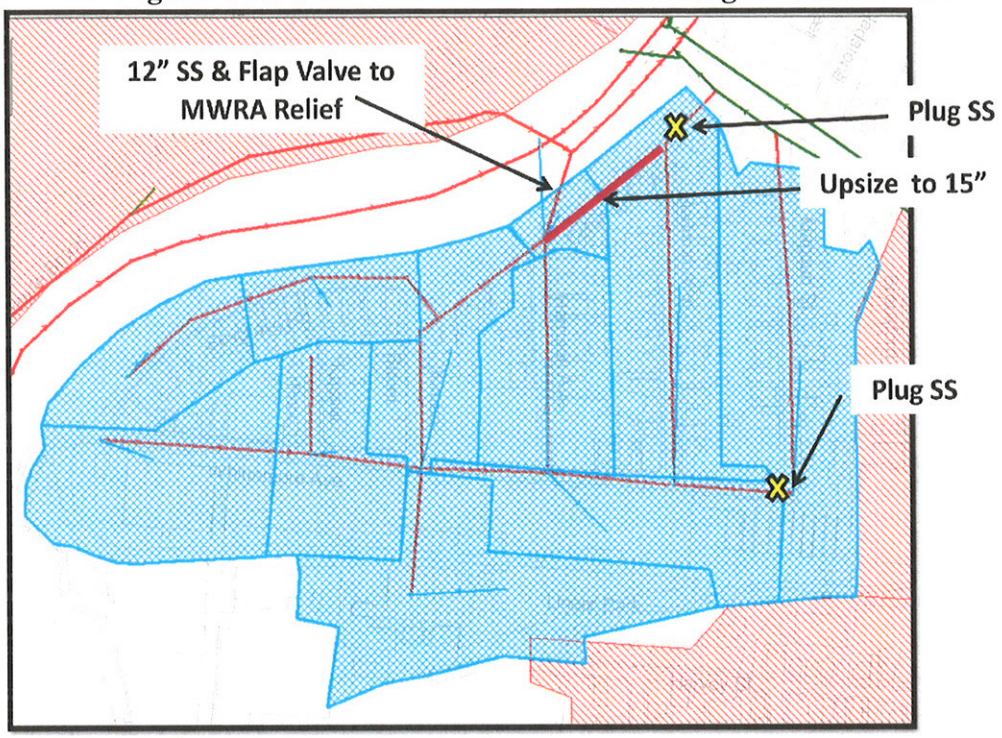
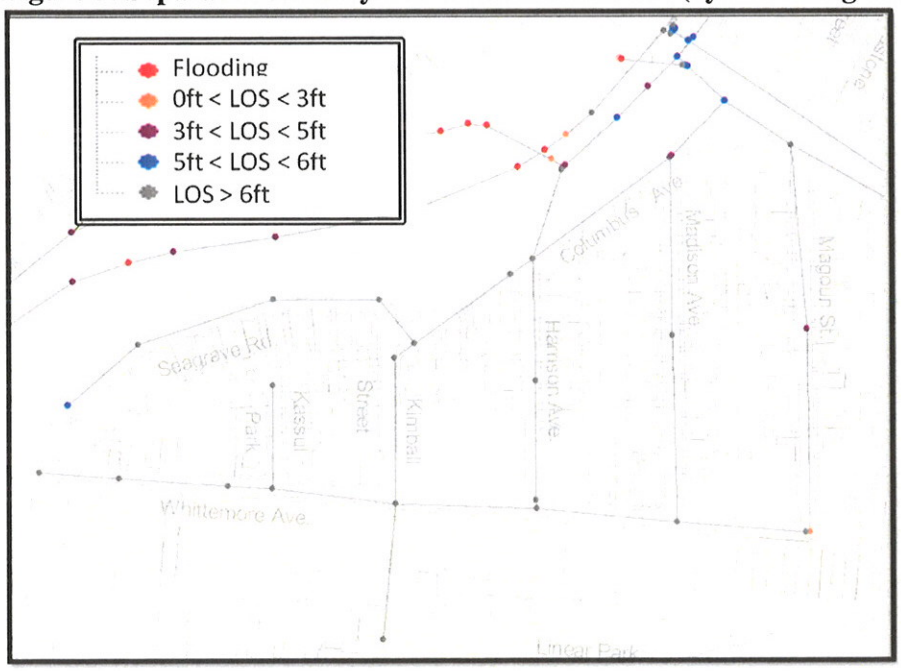


Figure 5: Separated Sanitary Sewer Level of Service (1yr6hr Design Storm)



Storm Drain Analysis

The proposed separated storm drain system was modeled such that the CAM 400 regulator weir was removed and the outlet operated as a dedicated stormwater outfall. A progressive series of design storms (2 year, 5 year, 10 year, and 25 year 24 hour NCRS) were simulated to determine the LOS such that 2 - 2.5 ft of freeboard remained within the system. Note that the minimum acceptable LOS is 1.75 ft (i.e., hydraulic gradient needed to ensure that catch basins function adequately, as accepted in Cambridgeport storm drain efforts). Drain size, inverts, and connectivity within the CAM 400 catchment were updated based on the findings of the recent survey and manhole inspection (see drain profiles provided in Appendix B). As stated previously, beyond the separation of common manholes, construction of proposed additional drains or upsizing of existing drains was minimized.

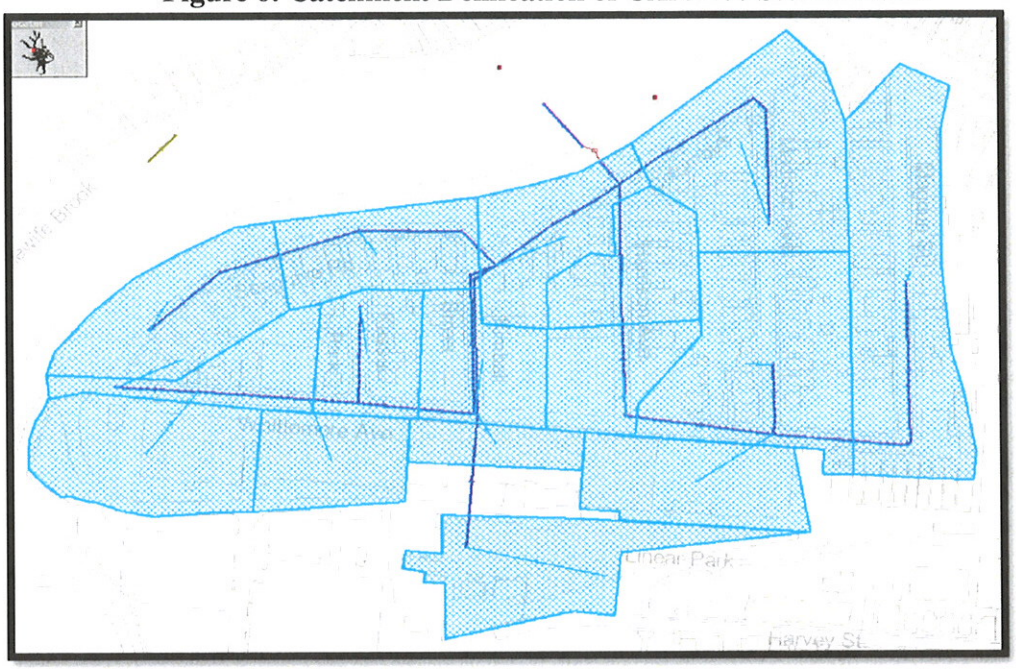
For the development of the separated storm drain model, it was assumed that 100% of the impervious area within the CAM 400 catchment was tributary to the storm drain system. Under existing conditions this is a conservative assumption since it has been noted that presently not all roof drains in the area are directly tributary to the storm drain (i.e. discharge to pervious areas or to the sanitary sewer). However, for future conditions the additional stormwater volumes are expected due to increased storm intensities and volumes resulting from the effects of climate change.

Catchment Delineation

The field survey and building inspections confirmed that both storm and combined flows within the CAM 400 area (from Seagrave Road to Madison Street) are tributary to the regulator structure at Harrison and Columbus Avenues (see Figure 6). Overflows are regulated by a weir (7.25' wide and 4' high). After full separation of the catchment area, these existing storm drains and combined sewers will function as storm drains and the weir will be replaced with a sluice gate in the renovated stormwater outfall structure.

At present, there is an 18" dia. storm drain and a 24" dia. combined sewer on Kimball Street. For separated conditions, sanitary contributions are recommended to be removed such that the combined sewer will function as a storm drain. This new drain is then recommended to be connected to the storm drain on Columbus Avenue with a 50 ft length of 24" dia. drain pipe.

Figure 6: Catchment Delineation of CAM 400 Storm Drains



River Elevation

The survey and field investigation confirmed that several segments of the storm drain and combined sewer system are below the river elevation. The CAM 400 outlet elevation is approximately 10.34' CCB, while the river elevation at low tide is 11.34' CCB. Therefore, even prior to a rain event, much of the system capacity is utilized with at least 1 ft of standing water. Along Columbus Avenue there is also a section of adversely sloped drain for which the depth of the submergence is greater on sections of Kimball Street, Harrison Avenue, and Seagrave Road (see Figures 7a, 7b, and 7c).

Simulations were performed assuming that the "high" elevation of the river occurred after the peak of the storm, thereby creating a favorable backwater condition for the system typically observed in the summer and fall seasons (see Figure 8a). "High" elevation refers to the peak river level during the wet runoff period. The coincidence of the peak of the storm with "high" elevation (see Figure 8b) is an unfavorable condition which would create the most severe back water conditions, such as in the spring season. Selected simulations were performed using unfavorable conditions for the 2 year and 5 year 24 hour storm design events. Water level variations referenced in this analysis were derived from the observed river elevations at the CAM 400 outfall presented in the "CAM 004 Area Hydrologic and Hydraulic Report, April 2003". During wet weather events, the elevation of the river rises 13.8', 14.3', and 16.3' CCB for the 2 year, 5 year, and 10 year 24 hour storm design storms respectively.

Note that during the evaluation of the performance of the CAM 400 outlet, it was determined that a second outfall would not provide additional relief for the storm

drain system due to the back water conditions of the river.

Significant sediment control is also required for the storm drains within the CAM 400 area due to impact of the river backwater that will slow the velocity draining through the system and promote the deposition of solids in critical areas upstream of the outfall structure.

Figure 7a: Impact of River Elevation (Kimball and Columbus)

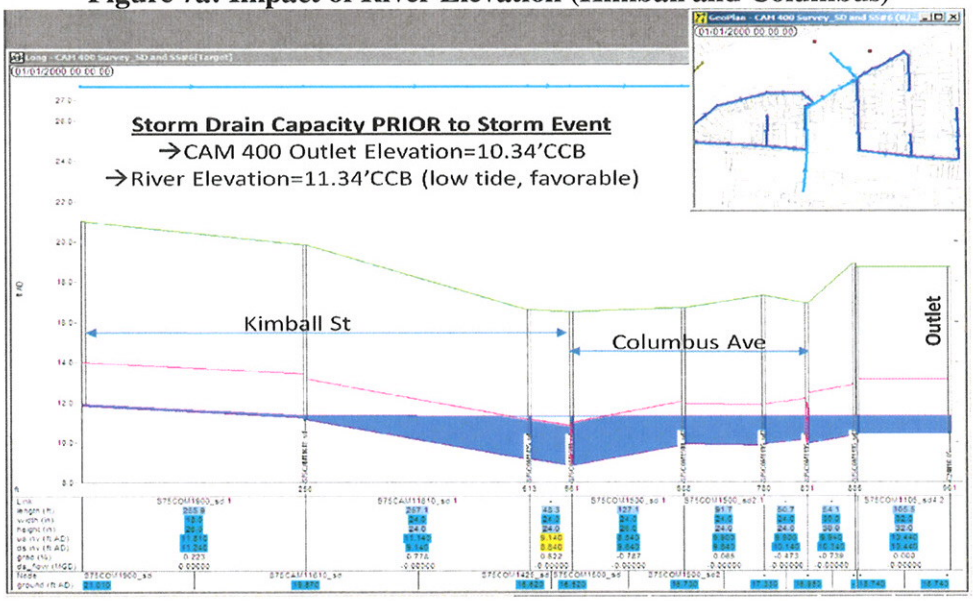


Figure 7b: Impact of River Elevation (Harrison)

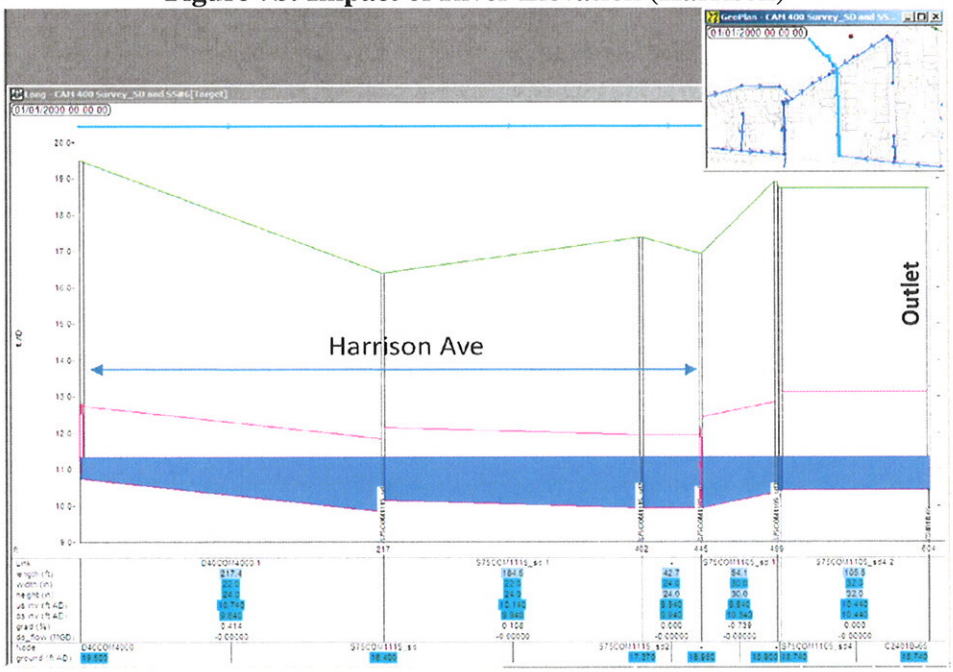


Figure 7c: Impact of River Elevation (Seagrave and Columbus)

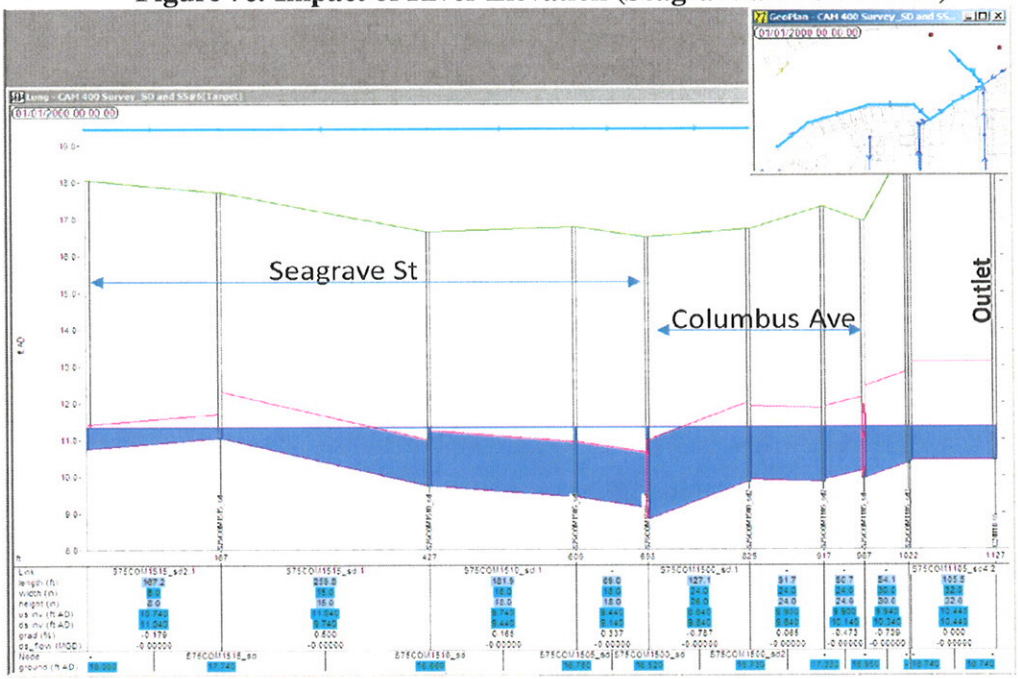


Figure 8a: Variation of River Elevations, Favorable

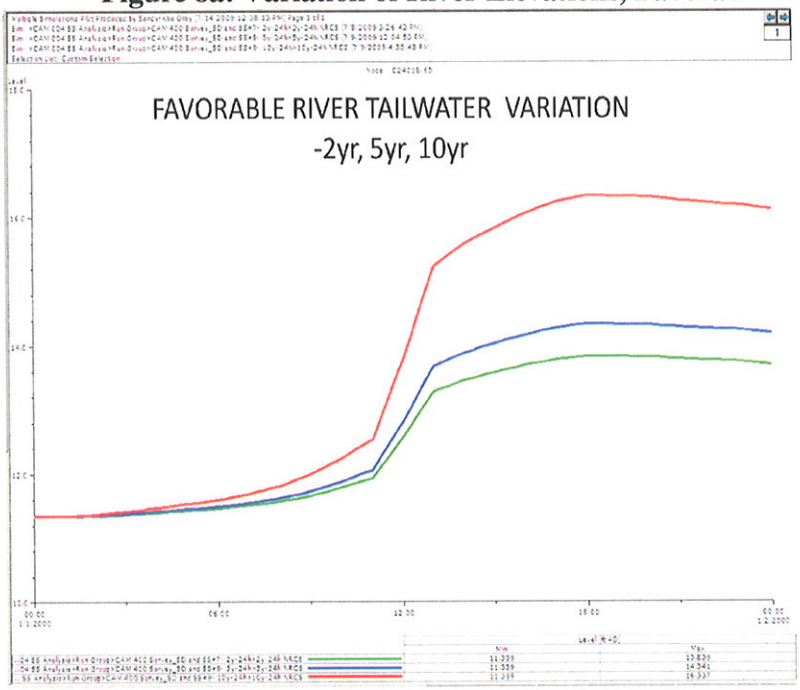
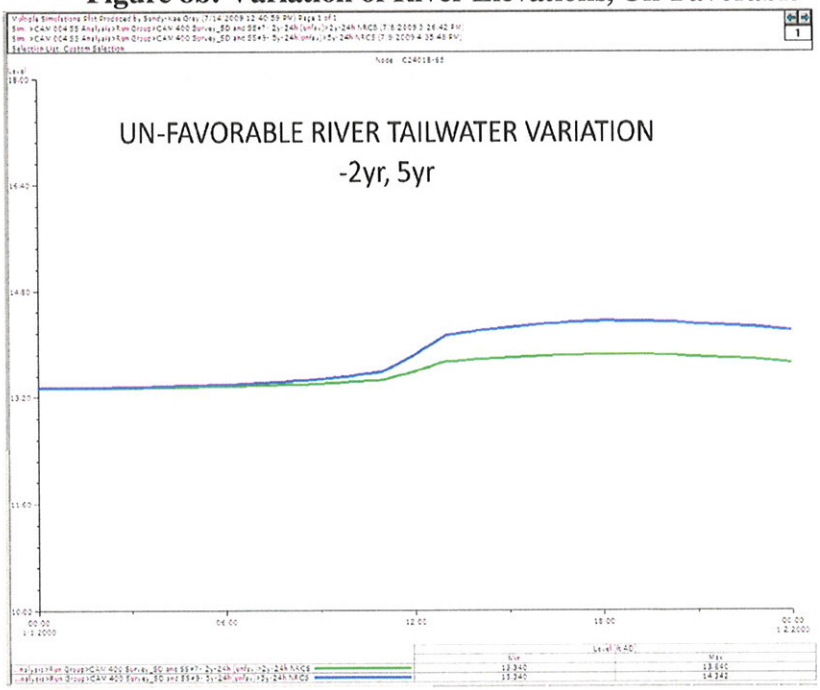


Figure 8b: Variation of River Elevations, Un-Favorable



Level of Service

LOS for the proposed separated storm drain system was assessed. A critical low elevation area was identified along Harrison Avenue which receives local area flows as well as flows from Magoun Street, Madison Avenue, and the eastern end of Whittemore Avenue. LOS at this location was 2.6 ft for the 2 year 24 hour storm design storm with favorable river elevation influence of the river (see Figure 9a). For the 5 year 24 hour storm design storm with unfavorable river elevation influence, the LOS at this location was 2.1 ft (see Figure 9b). Overall LOS for the separated storm drain system will therefore be on the order of the 5 year 24 hour storm, even with unfavorable river elevation conditions.

WR Grace Facility

Findings from the recent survey as well as the building inspections were used to delineate the contributions of impervious areas for the WR Grace facility. Based on field observations, it was assumed that the majority of the roof and pavement areas from the facility are tributary to the storm drain on Whittemore Avenue. There is a section of the roof and pavement area from the WR Grace facility that is tributary to a wetland detention area on the south side of the buildings (see Figure 10). The storage volume available in the wetland area is approximately 0.14 MG, and presently approximately 6.4 Ac of impervious and pervious area is tributary to the system.

Under the proposed separation conditions, there are two additional buildings on the south west side of Whittemore Avenue that could potentially be separated from the storm drain system and instead re-directed to the wetland area (see Figure 11). The impact to LOS and CSO peak flow/volume with the removal of neither, one, or both buildings was also evaluated. Results of this evaluation are provided in Table 1. These results indicate that there is a marginal benefit to removing these buildings from the CAM 400 storm drain system, as the LOS at critical low elevation areas (such as Harrison Avenue) are more influenced by the variation of the river elevation (particularly at the 5 year 24 hour event). Other areas impacted LOS are shown in Figures 12a and 12b, and are listed in Table 2.

Figure 9a: Critical Level of Service at Harrison Avenue, 2 year 24 hour Event

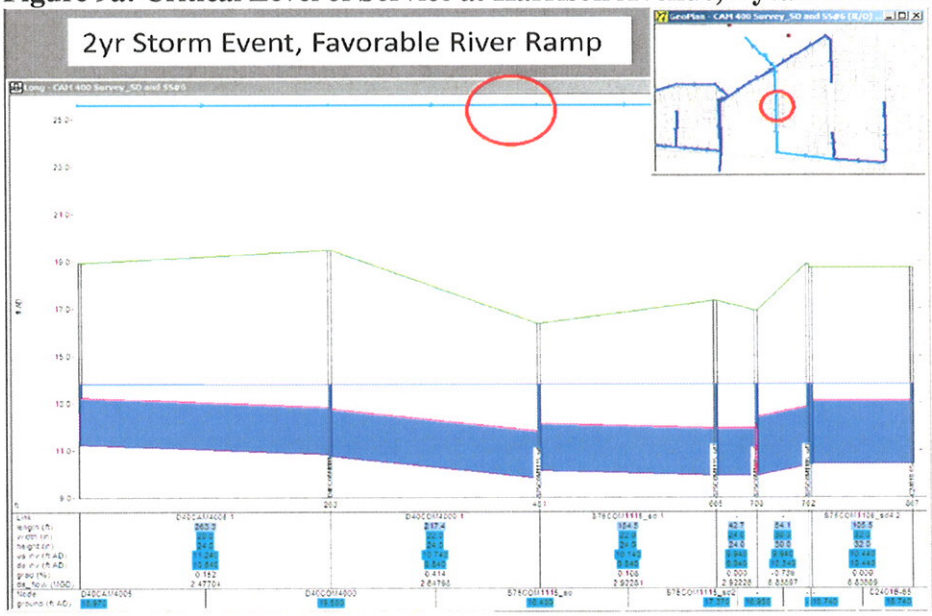


Figure 9b: Critical Level of Service at Harrison Avenue, 5 year 24 hour Event

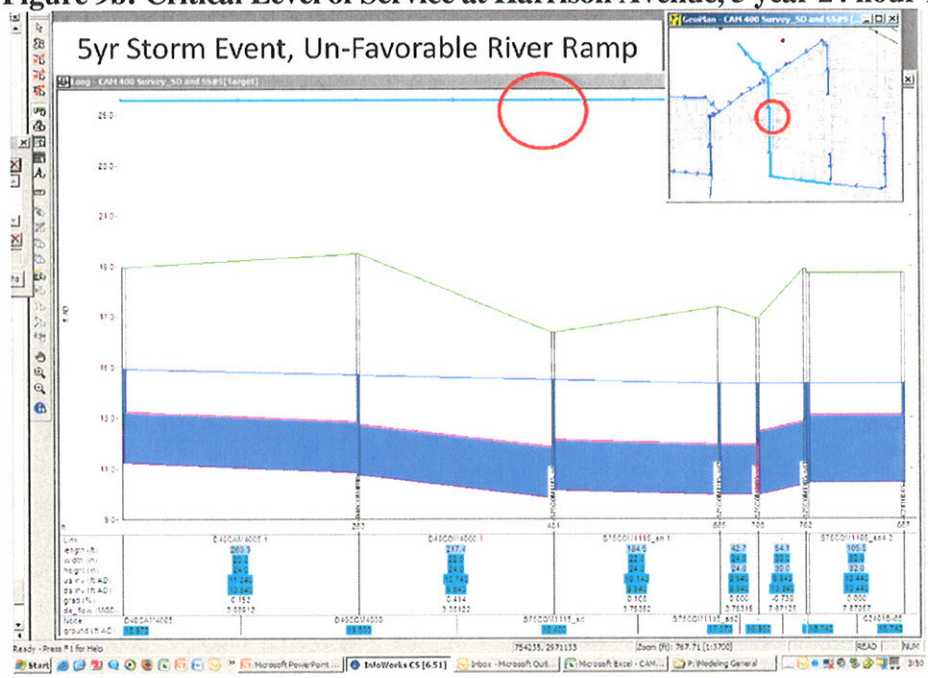


Figure 10: Catchment Area to WR Grace Wetland

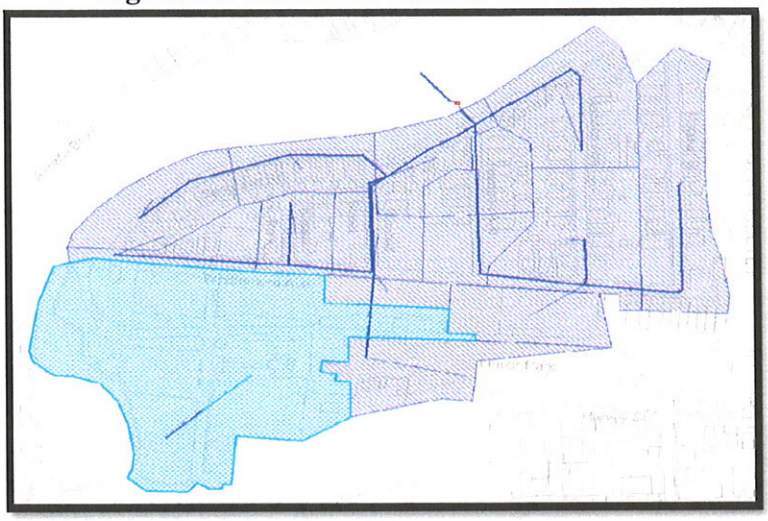


Figure 11: Removal of Runoff from WR Grace Buildings

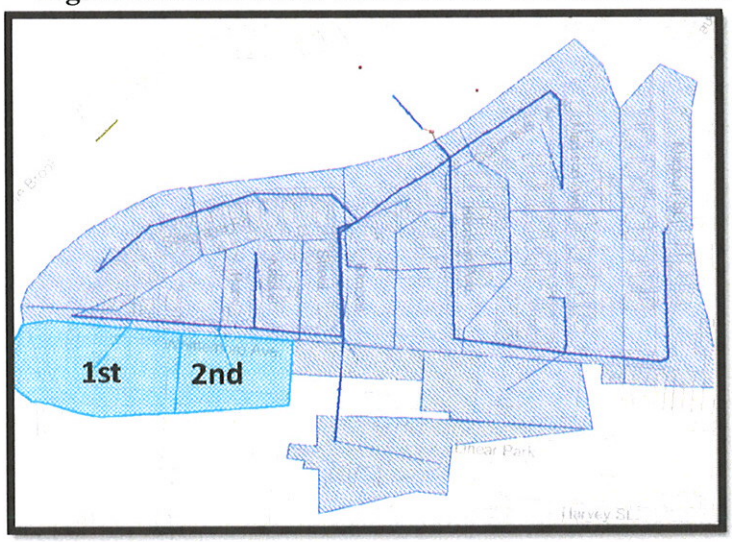


Table 1: Impact of Removal of Runoff from WR Grace Buildings

Design Storm	Run #	Alewife River Condition	Contri. of Grace Bldg Removed [1]	LOS @ Harrison Avenue (low spot), ft	Peak Flow to CAM 400 Outfall, MGD	Peak Vol. to CAM 400 Outfall, MG
2yr-24hr	763	Fav	0	2.56	6.76	0.93
2yr-24hr	764	Fav	1	2.56	6.40	0.88
2yr-24hr	765	Un-Fav	1	2.39	6.52	0.91
5yr-24hr[2]	781	Fav	0	2.06	8.86	1.17
5yr-24hr[2]	766	Fav	1	2.06	8.41	1.11
5yr-24hr[2]	768	Fav	2	2.06	7.52	1.01
5yr-24hr[2]	782	Un-Fav	0	1.81	8.97	1.21
5yr-24hr[2]	771	Un-Fav	2	1.87	7.64	1.05
10yr-24hr[3]	770	Fav	2	0.06	9.30	1.22

1. Contri. of Removed Grace Bldgs

Grace Bldg	Storm Event	Total Area (Ac)	Assumed Imperv. Area (Ac)	Peak Runoff, mgd	Peak Runoff, mg
1st	2yh24hr	1.09	70%	0.36	0.05
2nd	2yh24hr	1.87	100%	0.65	0.08

2. Addl MHs along Seagrave and Columbus have LOS 2.2-2.4ft (as shown)

Design Storm	Run #	Alewife River Condition	Contri. of Grace Bldg Removed [1]	LOS @ Harrison Avenue (low spot), ft
5yr-24hr[2]	766	Fav	1	2.06

3. Majority of MHs have LOS 0.2-2.4ft (as shown)

Design Storm	Run #	Alewife River Condition	Contri. of Grace Bldg Removed [1]	LOS @ Harrison Avenue (low spot), ft
10yr-24hr[3]	770	Fav	2	0.06

Figure 12a: Removal of Runoff from ONE WR Grace Building, 5 year 24 hour

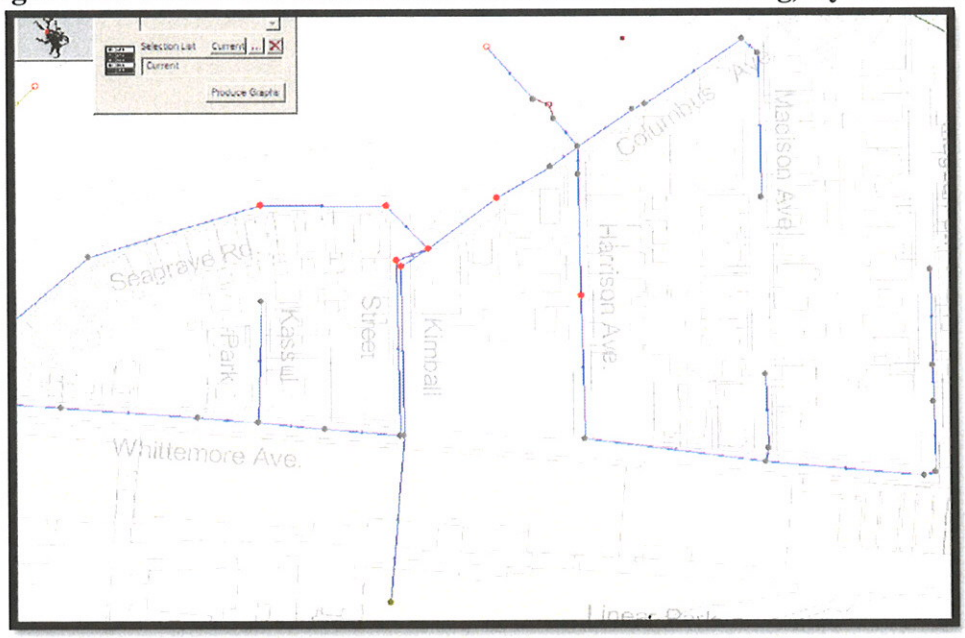


Figure 12b: Removal of Runoff from TWO WR Grace Buildings, 10 year 24 hour

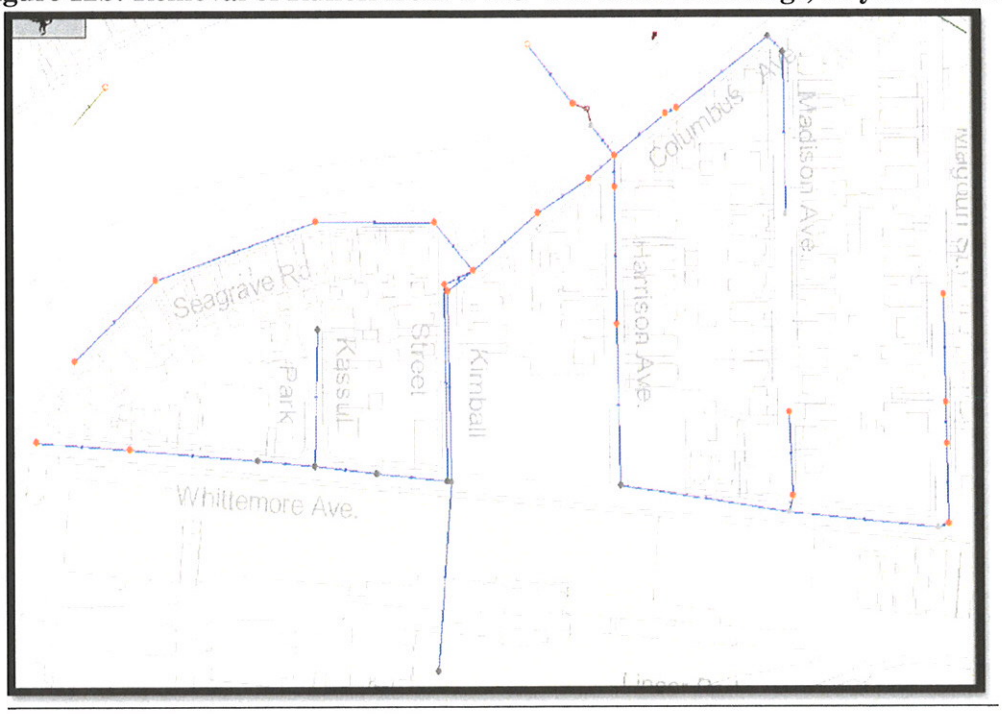


Table 2: Impact of Removal of Runoff from WR Grace Buildings, Level of Service

Storm Drain

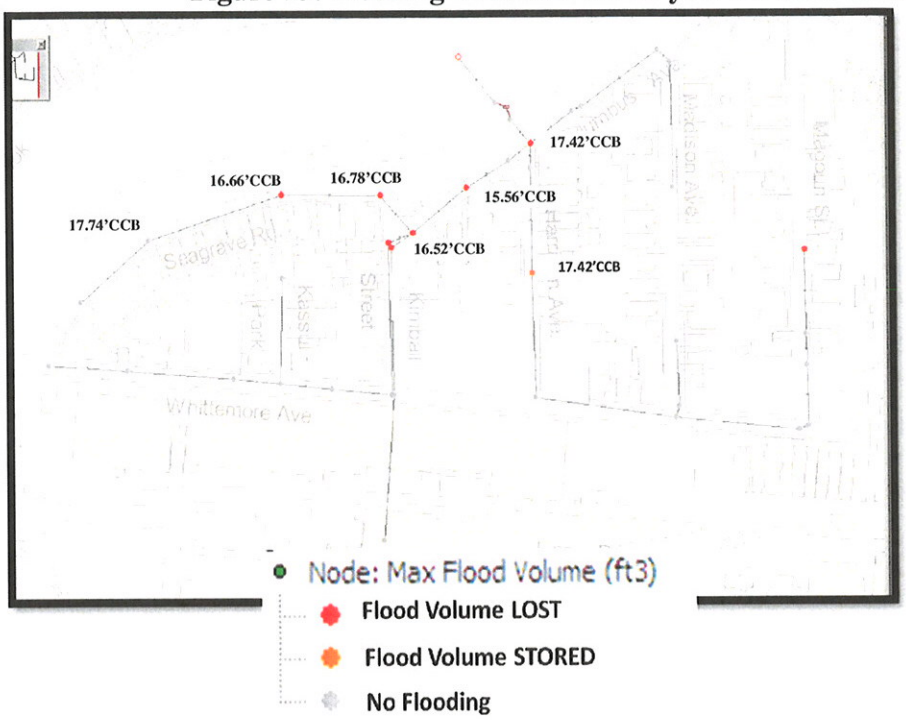
Level of Service, ft																			
MH Location		Run 765	MH Location		Run 766	MH Location	Run 768	MH Location		Run 771	MH Location		Run 770
S75COM1115_sd		2.39	S75COM1505_sd		2.44	S75COM1505_sd	2.44	S75COM1505_sd		2.44	D40COM4200		2.41
			D40CMH1425		2.39	D40CMH1425	2.39	D40CMH1425		2.39	D40CAM4105		2.06
			S75COM1115_sd		2.06	S75COM1115_sd	2.06	D40CMH1425		2.30	D40CMH1425		0.39
			S75COM1425_sd		2.28	S75COM1425_sd	2.28	S75COM1115_sd		1.87	D40COM4020		2.30
			S75COM1500_sd		2.41	S75COM1500_sd	2.18	S75COM1425_sd		2.19	D40COM4100		2.27
			S75COM1500_sd		2.18	S75COM1500_sd2	2.39	S75COM1500_sd		2.09	D40COM4100		2.18
			S75COM1500_sd2		2.39	S75COM1510_sd	2.32	S75COM1500_sd2		2.39	D40COM4200		1.92
			S75COM1510_sd		2.32			S75COM1500_sd2		2.35	D40COM4205		1.71
								S75COM1505_sd		2.34	D40COM4210		1.41
								S75COM1510_sd		2.20	D400MH0005		1.83
											D400MH0010		1.83
											S75COM1105_sd		0.61
											S75COM1105_sd2		0.99
											S75COM1105_sd4		2.40
											S75COM1115_sd		0.06
											S75COM1115_sd2		1.03
											S75COM1425_sd		0.28
											S75COM1500_sd		0.18
											S75COM1500_sd2		0.39
											S75COM1505_sd		0.44
											S75COM1510_sd		0.32
											S75COM1515_sd		1.40
											S75COM1515_sd2		1.72
											S75COM1715_sd3		2.27
Maximum		2.39			2.44		2.44			2.44			2.41
Minimum		2.39			2.06		2.06			1.87			0.06
Average		2.39			2.31		2.29			2.26			1.35

Large Storm Events

The impact of flooding during the 25 year 24 hour design storm was evaluated for the proposed separated storm drain system. Locations of flooding during this extreme event are indicated in Figure 13, and profiles of the peak water level during this event are shown for Seagrave Road and Columbus Avenue in Figure 14a, and Harrison Avenue in Figure 14b.

Note that the peak river elevation for the 10 year and 25 year 24 hour design storm is 16.33' CCB and 17.24' CCB. Due to the topography of the area, flooding on Harrison Avenue is likely to re-enter the storm drain system post the occurrence of an extreme storm event due to higher elevation areas along Columbus Avenue. The flat, low lying areas along Seagrave Road and Columbus Avenue, however, are expected to remain flooded post the occurrence of an extreme storm event. FEMA maps of the CAM 400 area also indicate that much of Seagrave Road and Columbus Avenue are within the 100 year flood plain (see Appendix C). Surveyed surface elevations along Seagrave Road and Columbus Avenue are included in Figure 13. This information confirms that LOS beyond the 10 year and 25 year 24 hour design storm will be impacted by the elevation and high water level variation of the adjacent Alewife Brook.

Figure 13: Flooding Locations for 25 year 24 hour Event



MH Location	Flood Volume, MG
S75COM1500_sd	0.89
S75COM1425_sd	0.34
S75COM1500_sd2	0.23
S75COM1510_sd	0.15
S75COM1105_sd	0.14
D40CMH1425	0.07
S75COM1505_sd	0.02
D40COM4210	0.00
Total	**1.85**

***Surveyed manhole rim elevations noted at flooding locations.**

Figure 14a: Peak Water Level 25 year 24 hour Event, Harrison Avenue

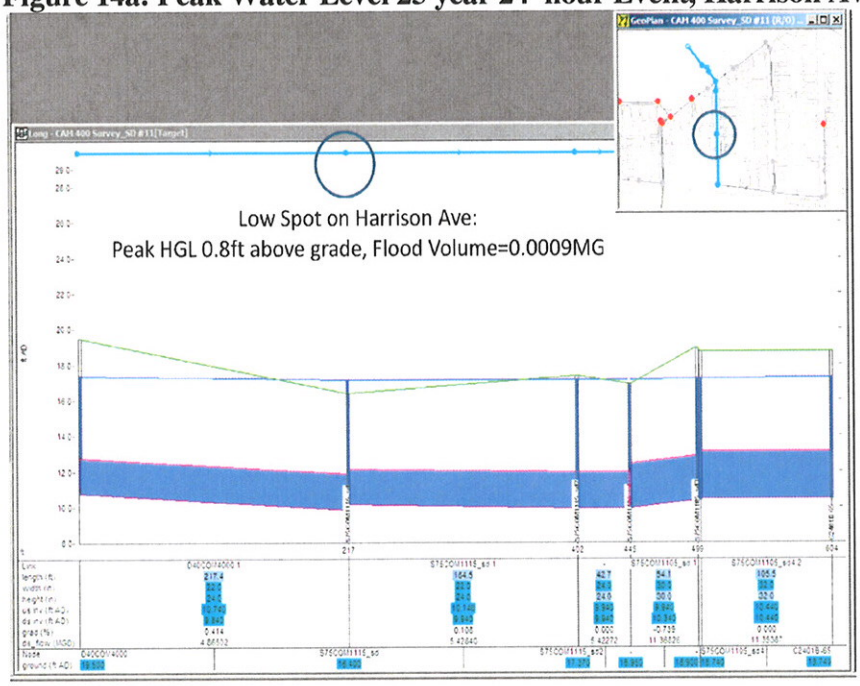
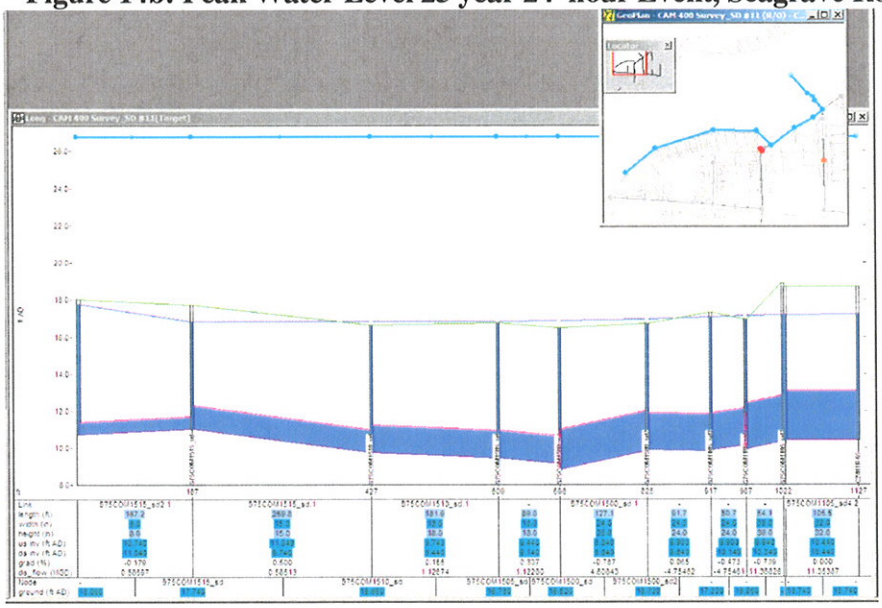


Figure 14b: Peak Water Level 25 year 24 hour Event, Seagrave Road



Conclusion

Separation of sewer and storm drain systems within the CAM 400 area can feasibly be constructed without the addition of a new storm drain outlet or other major system reconstruction.

A flap valve is needed at the connection of the sewer system to the ABC, and flows from Madison Avenue should be redirected to the CAM 400 connection. Field observed inflow sources within the catchment area (2%) are significantly less than preliminary assumptions (13%), such that adequate LOS is achieved for the 1 year 6 hour event without the elimination of these connections.

The weir structure at the CAM 400 outlet should be removed from the separated storm drain system and sediment control will be needed throughout the drain system due to the back water impact of the Alewife Brook elevations. The combined sewer on Kimball Street will be separated and connected to the storm drain system. Note that the minimum acceptable LOS on a storm drain system is 1.75 ft, and therefore adequate LOS was achieved for the 5 year 24 hour event prior to the removal of runoff contributions from the WR Grace Buildings. Removal of the runoff contributions from Grace Buildings should proceed in stages to provide a higher order of LOS as needed throughout the separation program.