Somerville, Massachusetts

Evaluation of Flood Reduction Alternatives in Union Square

July 2013

MWH

Final Report

Executive Summary

This report evaluates potential alternatives to reduce flooding and improve level of service (LOS) in Union Square in Somerville, MA during the 10-year, 24-hour NRCS storm event, which was used as the decision basis. LOS is defined as the difference between ground elevation and the peak hydraulic grade line (HGL) during a specific storm event. Even though the 10-year, 24-hour NRCS storm event was used as the target design storm, the impact of larger or more intense events (i.e. the 25-year, 24-hour NRCS event and the July 10th, 2010 event) is also reported herein.

The hydraulic model used in this analysis only includes major flow conveyors within the City of Somerville (18 inches or larger). Local drainage networks are represented by large catchment areas loaded into these main conveyors. Consequently, this hydraulic model is only appropriate for the identification of improvement options but a more detailed network is necessary in order to determine the final, detailed configuration of proposed hydraulic structures should the City pursue the execution of any of the selected alternatives.

With this highly simplified network, using 1-hour time increments hyetographs was deemed too optimistic as local flooding normally occurring in local drainage networks with small pipe sizes is absorbed by the large diameter flow conveyors. On the other hand, 15-minute time increments hyetographs were deemed too pessimistic as peak intensities for the same design storm event become much larger with shorter time increments and could lead to oversized infrastructure. Traditionally, 15-minute time increments are used when the cost of potential damage to affected properties is very high. For this reason, the 30-minute time increment hyetograph for the 10-year, 24-hour NRCS event was selected and used for the basis of decision. However, flooding results using the 15-minute hyetographs for the 10- and 25-year storms are also reported herein.

A total of eight stormwater management and/or detention storage opportunities were identified throughout the Union Square watershed. All proposed storage opportunities involved the capture of clean stormwater with no sanitary contamination. Necessary infrastructure and work to achieve this was identified and included in the project costs. Projects involving sewer separation were not considered in this study because it was deemed cost prohibitive and too disruptive to residents per the CDM's *Sewer Assessment Report* of February 2009 as the Union Square system has no natural outlet. The Union Square watershed currently discharges its dry and wet weather flows to the MWRA system. Dry weather flows and some wet weather flows enter the MWRA's Cambridge Branch Sewer (also known as Cardinal Medeiros Interceptor or CMI) near the McGrath Highway connection via a 28-inch pipe. The CMI's capacity is very limited due to dry and wet weather contributions from East Cambridge as well as limited pumping capacity at the DeLauri pump station in Everett, MA. Excess flows from Somerville exceeding the CMI's capacity overtop the SOM009 CSO structure and are conveyed to the MWRA's Prison Point CSO facility to discharge into the Boston Harbor. This limitation causes severe flooding in Union Square, which is near the connection to the CMI.

In order to alleviate these flooding issues, eight alternatives were evaluated and ranked based on three criteria listed below:

1. Overall flood reduction in the Union Square area with respect to existing conditions.

2. Cost-effectiveness of flood reduction. This was determined using an index calculated as the ratio between percent flood reduction versus millions of dollars spent in construction and design.

3. Impact on the receiving MWRA's CMI located near the Somerville Ave and McGrath Highway intersection as any significant flow increase going into it may impact other CMI communities such as Cambridge.

Model results indicated that only projects geographically close to Union Square would yield significant flood reduction. It also became apparent that underground storage is necessary to achieve substantial flood reduction and improvement in LOS. Two alternatives, one consisting of extending the Somerville Ave drain and installing a tank near the CMI and one consisting of constructing a tank in the Vinal Ave/Summer Street ball field, were the most beneficial from a flood reduction and LOS prospective. However, building a tank near the CMI connection was not as cost-effective and it increased flows into the CMI during the peak of the storm due to increased conveyance capacity from the extension of the Somerville Ave drain with the subsequent impact to other tributary communities.

Similar results were obtained when tank alternatives were combined with no-tank alternatives. Extending the Somerville Ave drain and building a tank near the CMI connection in combination with surface storage in the Vinal Ave/Summer Street field provided the largest flood reduction and LOS improvement. However, the cost and impact to the CMI made it a less desirable option. On the other hand, combining an underground storage tank with surface storage in the Vinal Ave/Summer Street ball field provided substantial flood reduction and LOS improvement and did not affect the CMI negatively. Additionally, this was the most cost-effective combination of alternatives and it was, therefore, selected as the optimum solution.

Contents

1 Background

Union Square in Somerville and its neighboring tributary areas such as Washington Street or Somerville Avenue are vulnerable to flooding during large storm events. Union Square is the point where three large drainage systems converge and its drainage capacity is greatly limited by the receiving MWRA network, which is heavily surcharged. The first major converging system includes catchments tributary to the Washington and Beacon Street combined sewer, which expands to areas in the Davis and Teele Square neighborhoods not directly tributary to the Tannery Brook drain. This tributary area ranges between 600 and 700 acres in size, approximately. The second major converging system is the Somerville Avenue storm drain and combined sewer, which collect sanitary and storm flows from most of the Spring Hill area as well as a small area to the south of Somerville Avenue. This area has been estimated at 170 acres, approximately. The third major converging system is the Summer Street storm drain and combined sewer, which collect sanitary and storm flows from the northern side of Spring Hill and the western side of Prospect Hill and accounts for approximately 100 acres.

Besides being a point of hydraulic convergence, drainage in the Union Square system is greatly conditioned by the limited available capacity of the receiving MWRA's CMI located near the Somerville Ave and McGrath Highway intersection. The CMI takes all sewage (dry and wet weather flows) from the entirety of East Cambridge. The catchment area of this portion of Cambridge extends east of Central Square and north of Main Street up into Somerville. It is noted in Cambridge at Warren Street (boundary between Cambridge and Somerville and site of a MWRA metering station) that this pipe severely surcharges even for small storms with return periods as small as 6 months to 1 year. The central, limiting problem is the limited maximum pumping capacity at MWRA's DeLauri pumping station in Everett. Reverse flow from Somerville and other upstream communities into Cambridge is noted at the Warren Street flow monitoring station during large storms. As a result, upstream sanitary flooding in East Cambridge is severe.

In order to mitigate flooding in Union Square, different alternatives involving surface runoff management and underground stormwater detention storage were identified throughout the entire watershed. Flood volume reductions and level of service improvements in the Union Square area were quantified for each scenario. Probable construction costs were calculated for each alternative and used to rank the cost-effectiveness of design and construction for the 10-year, 24-hour NRCS event. Subsequently, combinations of top alternatives were modeled and ranked based on total flood reductions and cost-effectiveness of the work being proposed.

2 Description of Proposed Alternatives

A total of eight stormwater management alternatives, some of which include sub-alternatives, were identified throughout the City of Somerville to mitigate flooding in the Union Square area. These alternatives do not include any sewer separation work as this was deemed unfeasible and cost prohibitive in the *Sewer Assessment Report* of February of 2009 by CDM. These alternatives were evaluated for cost-effectiveness and hydraulic benefit to the Union Square area. Figure 1 shows the project areas for each of these alternatives.

A brief description of these alternatives is provided below.

<u>Alternative 1:</u> Spring Hill Surface Runoff Management

This project would consist of the following:

1. Removing all existing cross-connections between the old combined sewer and the new storm drain along Somerville Avenue.
2. Installing a flap valve at the downstream end of the Somerville Ave drain before the junction with the Washington Street combined sewer.
3. Throttling catch basins along Spring Hill side streets to allow 30% of the generated surface runoff to reach the Somerville Ave corridor via surface flow.
4. Increasing catch basin capacity along the Somerville Ave corridor to allow capture of new runoff from the Spring Hill area. New catch basins would be of the infiltrating type and located on side streets at intersections with Somerville Ave.

<u>Alternative 2:</u> Spring Hill Surface Runoff Management and Conway Park Stormwater Tank

This project would include the following:

1. Removing all existing cross-connections between the old combined sewer and the new storm drain along Somerville Avenue.
2. Installing a flap valve at the downstream end of the Somerville Ave drain before the junction with the Washington Street combined sewer.
3. Install a 20MGD throttle (e.g. a Hydroslide or orifice) in the Somerville Ave drain near the Somerville Ave/Bow Street intersection and upstream of the flap valve in point 2.
4. Throttling catch basins in Spring Hill side streets to allow 60% of the generated surface runoff to reach the Somerville Ave corridor via surface flow.
5. Increasing catch basin capacity along the Somerville Ave corridor to allow capture of new runoff from the Spring Hill area. New catch basins would be of the infiltrating type and located on side streets at intersections with Somerville Ave.
6. Installing a 2.0 ac-ft (0.65MG) stormwater tank in the Conway Park baseball field connected to the Somerville Ave drain via a static, inlet weir with a crest elevation of approximately 117MDC and a flap valve.

Alternative 3: Summer Street Catchment Surface Runoff Management and Storage

For Alternative 3, two storage options (above and below ground) in the Vinal Ave/Summer Street field were considered and described below:

Sub-Alternative 3.1: Surface storage in the Vinal Ave/Summer Street field

This project would include the following:

1. Throttling catch basins in the Summer Street catchment (92 acres) to allow 30% of surface runoff to move on the surface towards the Summer Street and Vinal Avenue intersection.
2. Regrade local roads and construct up to eight raised cross-walks to direct surface flows to the storage area.
3. Construction of a 1.6 ac-ft (0.5MG) surface storage area in the existing field by building a 2-foot high berm around the perimeter and lowering its ground elevation as necessary.
4. Install a gravel base to allow for storage and high infiltration in the field area.
5. Increasing curb reveal at critical locations to avoid overtopping due to increase in surface runoff in vulnerable spots within the catchment area.

Sub-Alternative 3.2: Underground storage in the Vinal Ave/Summer Street field.

This project would include the following items:

1. Extending the existing Summer Street drain up to the Summer Street/Benton Rd intersection.
2. Providing enough catch basin inlet capacity to increase surface runoff capture within the Summer Street catchment into new/existing drain.
3. Construction of a 2.0 ac-ft, underground, stormwater tank in the Vinal Ave field with a static, inlet weir with a crest elevation of approximately 117 feet MDC and a flap valve.
4. Reconnect building sanitary connections to the existing storm drain (if any) to the adjacent combined sewer in Summer Street.

Alternative 4: Tufts University Area Flow Management

The flow management area around Tufts University was divided in three sub-areas based on current drainage conditions (Figure 2). Alternative 4’s main goal is to achieve that at least 40% of the stormwater runoff enters the drains going towards Medford or the Tannery Brook drains using favorable topography of the area. The flow management sub-areas are described as follows:

1. Separated area: This is a 33.5 acre area between Broadway, Powder House Blvd (from Broadway to Leonard Street intersection), the intersection between Sawyer Ave and College Ave and the Medford line. This area is considered fully separated and therefore, no improvements were deemed necessary.

2. Partially separated area with a dedicated storm drain: This 38-acre area is bound by the Powder House Blvd. (between Leonard St. and Packard Ave), Packard Ave and the Medford line. This area also includes Leonard St.
3. Non-separated area: this area is 41.5 acres in size and is bounded by Packard Ave, Curtis St., and Electric Ave as well as the area between Burnham Street, Packard Ave, Powder House Blvd, and Electric Ave. Other smaller sub-areas are also part of this non-separated area as shown in Figure 2.

Proposed improvements in the partially separated and non-separated area above (79 acres in total) are described as follows:

1. Removal and replacement of existing catch basins tied to existing drains as they may need to increase capacity due to larger runoff volumes. It was assumed that 50% of these new catch basins should be double, infiltration catch basins. These catch basins would be located at the bottom of the hill in Powder House Blvd capturing surface runoff deflected away from the combined system.
2. Extension of the existing storm drain along Powder House Blvd. from Packard Ave to Curtis St.
3. Install new catch basins for this portion of extended storm drain.
4. Throttle catch basins in the non-separated or partially separated areas (79 acres) to allow 40% of surface runoff to move on the surface towards Powder House Blvd.
5. Regrade local roads and construct up to five raised cross-walks where necessary to direct surface flows.
6. Increase curb reveal at critical locations to avoid overtopping due to increase in surface runoff in vulnerable spots within the catchment area.

Alternative 5: Minuteman Area Flow Management

For Alternative 5, two different options were considered in the vicinity of the Minuteman Trail area and described below.

Sub-Alternative 5.1 Upper Minuteman Flow Management

This sub-alternative consists of redirecting 50% of the stormwater runoff generated in the Upper Minuteman Trail area (114 acres) to the Tannery Brook drain instead of the combined sewer system going to the Union Square area (Figure 1). Based on the hydraulic model from CDM, it was assumed that out of these 114 acres, 40 acres of the upper catchment currently drain to the Tannery Brook drain. This project would include the following:

1. Installation of up to thirty, new single catch basins and ten double catch basins will be needed.
2. Throttling of up to twenty-five existing catch basins.
3. Installation, extension, and/or replacement of storm drains to collect new flows.
4. Increasing curb reveal at critical locations to avoid overtopping due to increase in surface runoff in vulnerable locations within the catchment area.
5. Regrade local roads and construct up to four raised cross-walks where necessary to direct surface flows to the Tannery Brook drain.

Sub-Alternative 5.2. Upper and Lower Minuteman Flow Management and Storage Tank

This second sub-alternative consists of deflecting 50% of the surface runoff in the Upper (114 acres) and Lower (41 acres) Minuteman areas to the Tannery Brook drain and installing a 1.0 ac-ft retention tank in an existing public parking lot. Like in Sub-Alternative 5.1, it was assumed that out of the 114 acres of the Upper Minuteman Area, 40 drain to the Tannery Brook drain. This project would include the following:

1. Installation of a 1.0 ac-ft underground storage tank in a public parking lot in Highland Avenue near Davis Square connected to the Tannery Brook, 24-inch, brick drain via a static, inlet weir with a crest elevation of 125 ft-MDC, approximately.
2. Flow management in this area will involve installation of new storm drain pipe and catch basins. It was assumed that 2,400LF of new pipe and thirty, new single catch basins will be necessary.
3. Throttling of twenty existing catch basins currently connected to the Union Square combined sewer.
4. Regrade local roads and construction of up to two raised cross-walks to redirect surface flows.
5. Increase curb reveal at critical locations to avoid overtopping due to increase in surface runoff in vulnerable spots within the catchment area.
6. CCTV of the Tannery Brook, 24-inch, brick drain.

Alternative 6: Broadway/Holland Street/Lower Minuteman/Davis Square Flow Management

For Alternative 6, two different options were considered in the vicinity of the Davis Square area and described below.

Sub-Alternative 6.1: Teele Square/Broadway/Holland Street Flow Management

This sub-alternative consists of redirecting 50% of the stormwater runoff generated in this 62-acre catchment area (see Figure 1) to the Tannery Brook drain instead of the combined sewer system going to the Union Square area. This would be accomplished by increasing the inflow in the existing Broadway and Paulina Street drains connected to the Tannery Brook drain. This project would consist of the following:

1. Throttle up to thirty catch basins currently connected to the Union Square combined sewer.
2. Installation of up to twenty new, single catch basins
3. Regrade local roads and construction of up to two raised cross-walks to redirect surface flows.
4. Increase curb reveal at critical locations to avoid overtopping due to increase in surface runoff in vulnerable spots within the catchment area.

Sub-Alternative 6.2: Holland Street Stormwater Storage Tank

This sub-alternative consists of redirecting 75% of the stormwater runoff generated in this 58-acre catchment area to the Tannery Brook drain instead of the combined sewer system going to the Union Square area. Additionally, a 3.0 ac-ft, stormwater, detention tank is proposed in the Holland Street field between Paulina Street and Simpson Ave (Figure 1). This project would consist of the following:

1. Construction of a 3.0 ac-ft (1MG) underground storage tank in the Holland Street field. The tank would have two inlet pipes tied to the inlet structure: The existing 30-inch RCP drain on Paulina Street and the 12inch pipe on Simpson Ave. The inlet, static weir was modeled at a crest elevation of 121 ft-MDC.
2. Installation of a flap valve in the existing 30-inch drain in Paulina Street in order to prevent backflows from the downstream, overflow structure at Gorham at Holland junction.
3. Throttling up to thirty catch basins currently connected to the Union Square combined sewer.
4. Installation of up to twenty, new single catch basins.
5. Regrade local roads and construction of up to two raised cross-walks to redirect surface flows.
6. Increase curb reveal at critical locations to avoid overtopping due to increase in surface runoff in vulnerable spots within the catchment area.

Alternative 7: Lincoln Park Neighborhood Flow Management

This project would consist of the following:

1. Regrade local roads and construct up to four raised cross-walks to redirect surface flows towards Lincoln Park.
2. Throttle up to fifteen catch basins connected to the combined sewer to redirect 75% of the surface runoff towards Lincoln Park.
3. Increase curb reveal at critical locations to avoid overtopping due to increase in surface runoff in vulnerable spots within the catchment area.
4. Reengineer a section of the park’s grassy area (up to 1 acre) to enhance infiltration of the re-routed runoff and create storage.

Alternative 8: Somerville Ave Drain Line Extension and End-Of-Line Stormwater Storage Tank

This project would consist of the following:

1. Construction of a 2.0 ac-ft tank at a private parking lot along Somerville Ave between Prospect St. and Medford St. The inlet weir was modeled as a 6-foot wide, static, inlet weir with a crest elevation of 111 ft-MDC and a flap valve.
2. Extension of the 66-inch, RCP drain along Somerville Ave to the existing combined sewer connection to the CMI and install a flap valve in the downstream end.
3. Perform catch basin inlet control (40% control) in the Spring Hill area (137 acres) to allow runoff to flow on surface by gravity to the Somerville Ave corridor.

4. Increase catch basin inlet capacity in Somerville Ave corridor to accommodate new surface runoff flows from the Spring Hill area.
5. Perform catch basin inlet control in Summer Street catchment (92 acres) to allow 40% of the surface runoff to flow on surface by gravity down Summer Street.
6. Extend existing Summer Street drain up to Summer/Benton Rd intersection.
7. Provide enough inlet capacity (catch basins) to capture all flows from Summer Street catchment into new/existing drain on this street.
8. CCTV and clean existing drains in Summer Street area.
9. Relocation of building laterals to existing combined sewer, if necessary.
10. Perform catch basin inlet control in the Prospect Hill area (100 acres) to allow 40% of surface runoff to flow on surface by gravity to Somerville Ave.
11. Construction of new drain lines in some side streets in Prospect Hill may become necessary to capture and convey surface runoff to the Somerville Ave drain.
12. Local regrading and repaving as necessary.
13. Increase curb reveal at critical locations to avoid overtopping due to increase in surface runoff in vulnerable spots within the catchment area.
14. Installation of up to seventy (70) new catch basins.
15. Raise cross-walks at up to fifteen different locations to allow strategic conveyance of surface runoff.

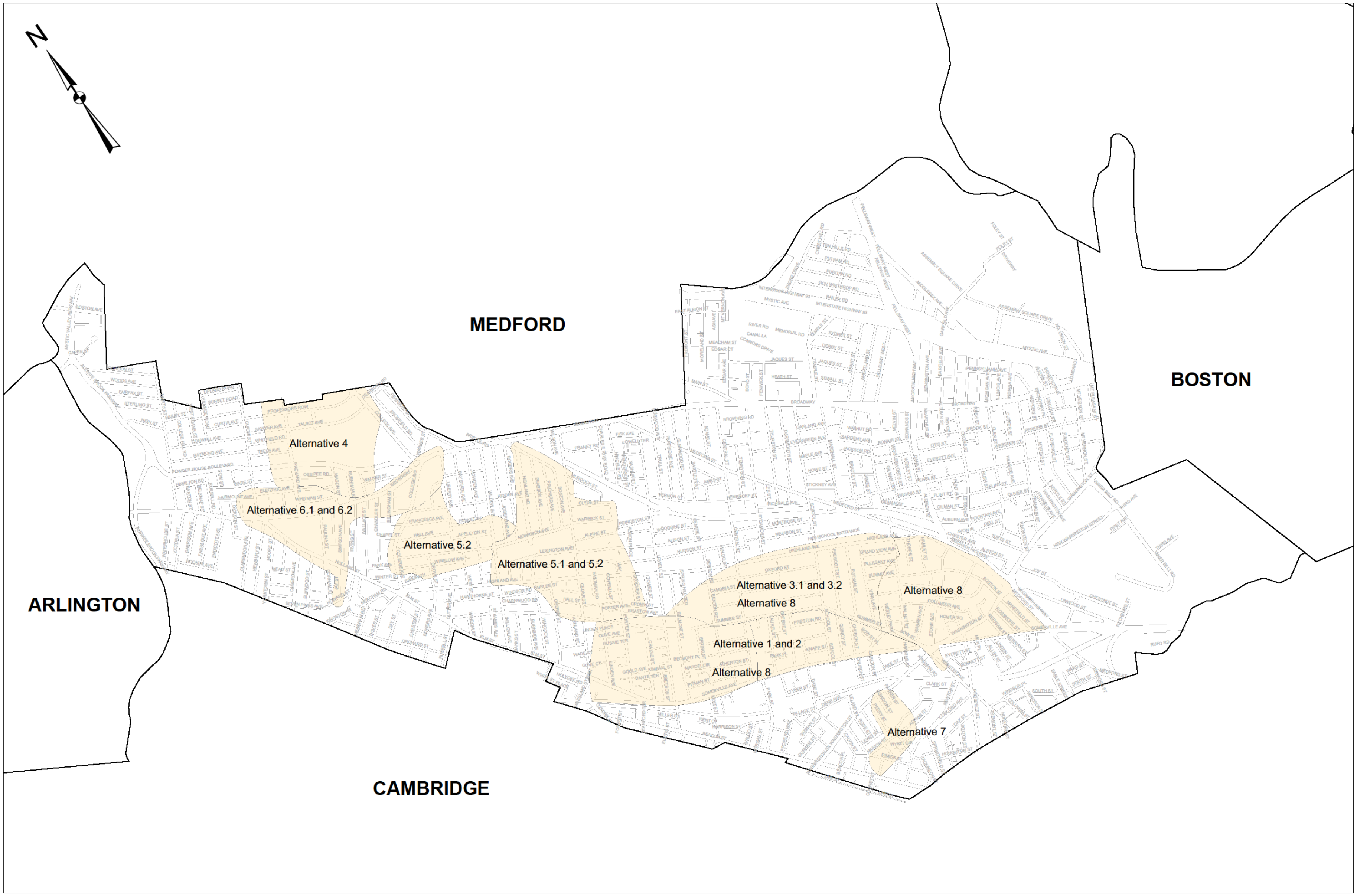


Figure 1. Project area/s for each of the selected improvement alternatives

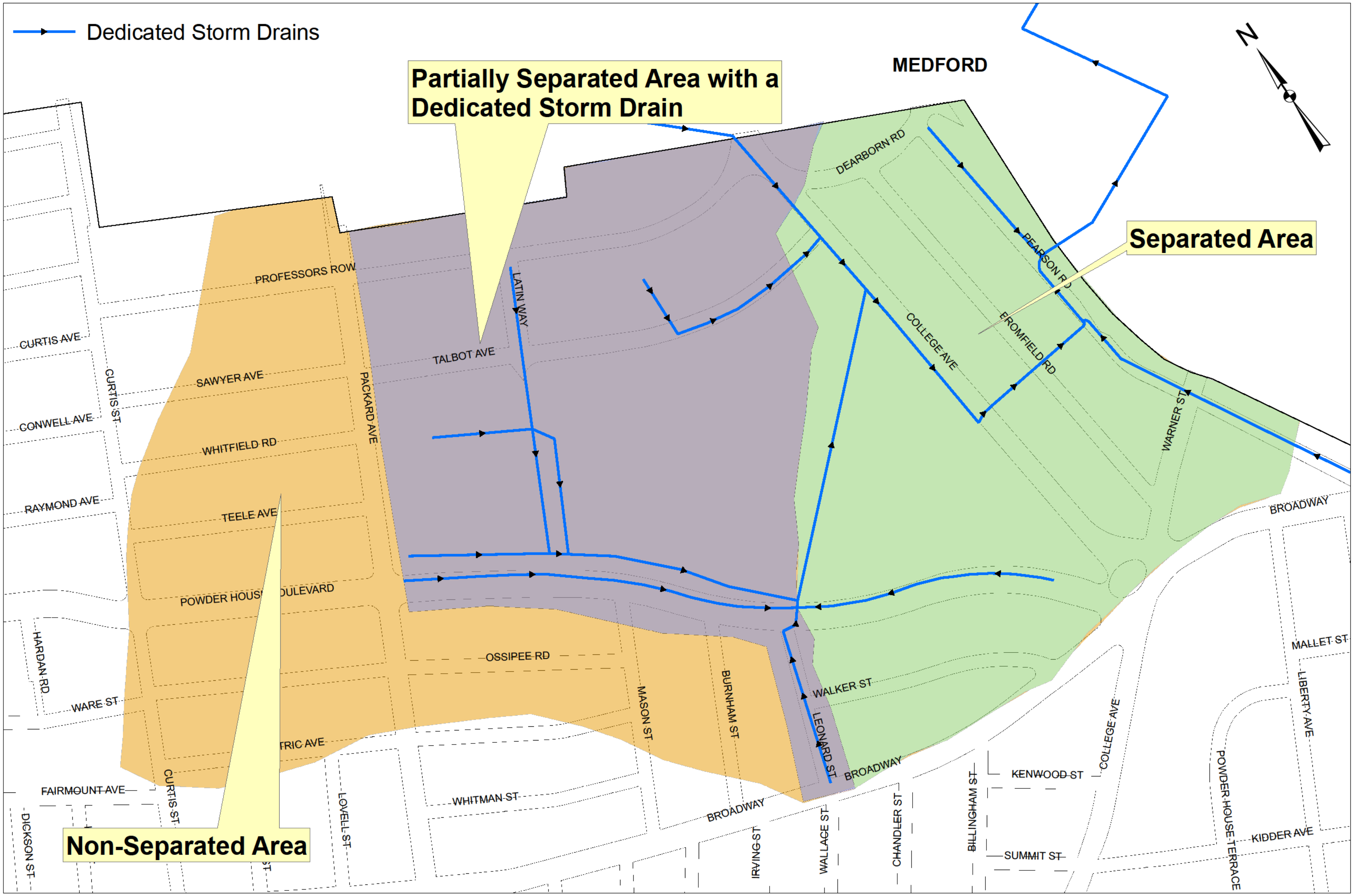


Figure 2. Flow management sub-areas in the Tufts University area

3 Estimates of Probable Cost of Alternatives

Opinion of probable construction, engineering, and management costs are provided in Table 1. The 30-minute time increment hyetograph for the 10-year, 24-hour NRCS storm was used to size the proposed infrastructure and project costs were then estimated accordingly. More detailed cost breakdowns for each project are provided in Attachment 1.

Table 1. Probable Construction, Engineering, and Management Costs for the Proposed Alternatives

Alternative	Probable Construction Cost	Probable Engineering & Management Cost	Total Cost*
Alt. 1	$526,300	$181,000	$710,000
Alt. 2	$4,204,500	$1,424,000	$5,600,000
Alt. 3.1	$856,300	$288,000	$1,100,000
Alt. 3.2	$3,976,200	$1,355,000	$5,300,000
Alt. 4	$742,000	$253,000	$1,000,000
Alt. 5.1	$1,344,800	$456,000	$1,800,000
Alt. 5.2	$4,036,000	$1,435,000	$5,400,000
Alt. 6.1	$510,000	$180,000	$700,000
Alt. 6.2	$4,246,000	$1,435,000	$5,700,000
Alt. 7	$446,700	$149,000	$600,000
Alt. 8**	$10,516,700	$3,580,000	$14,100,000

*Rounded to the nearest $10,000 (projects with a total cost between $100k and 1M) or to the nearest $100,000 (projects with a total cost greater than $1M).

**Costs include the extension of the Somerville Ave drain. If this work were to be executed under the Union Square Revitalization Project, the total cost of Alternative 8 would range between $6M and $7M, approximately.

4 Hydraulic Analysis and Alternative Ranking

4.1 Model Development and Calibration

The Somerville model used by MWH in the development of the *CAM017 Facilities Report* of 2006 was kept as the baseline for this analysis as its calibration seemed to provide more accurate results than the network provided by CDM. Further changes in the initial model consisted of incorporating the most up to date, existing conditions model for East Cambridge, updating the configuration of the SOM009 overflow structure, modifying the operation of the Prison Point CSO facility during extreme storm events, and including the latest model update in the Somerville's Marginal network per the 2009 calibration described in the *Sewer Assessment Report* of February 2009 by CDM. The most significant system differences between the new MWH hydraulic model used in this analysis and the model provided by CDM are listed in Table 2. For calibration, four different storms from 2003 were used, one of which was almost equivalent to a 2-year, 24-hour NRCS storm. Calibration plots and rainfall characteristics for each storm are provided in Attachment 2.

Table 2. Main differences between the CDM and the MWH hydraulic models

	CDM Model	MWH Model
SOM009 Overflow Weir Elevation (ft-MDC)	104.7	103.2*
Somerville Ave drain	Not included	Included
East Cambridge	Simplified, outdated network	Detailed, 2013 updated network
Prison Point operation	Inlet sluices open with 12 feet of head in the intake chamber	Inlet sluices open with 10 feet of head in the intake chamber
Total area tributary to the CMI (acres)**	1,527	1,262

*The weir at SOM009 was lowered to 103.2 ft-MDC after the July 10th, 2010 storm per correspondence with MWRA's David Kubiak.

**Estimated tributary catchment size using GIS is 1,360 acres. MWH model does not include a 66-acre catchment directly tributary to the Tannery Brook in the most recent CDM calibration (it was deemed irrelevant to the Union Square area).

4.2 Hydraulic Benefit of Alternatives Evaluated Individually

The overall benefit of alternatives was evaluated and ranked by looking at the provided flood relief, their total cost and cost-effectiveness, as well as their improvement in LOS. Impact to the receiving MWRA's CMI was subsequently evaluated for the top alternatives.

Flood volumes for the proposed alternatives during the 10- and 25-year, 24-hour NRCS design storms as well as the July 10th, 2010 storm (short, very intense storm that caused major flooding throughout the City) are reported in Table 3 (15-minute hyetographs) and Table 4 (30-minute hyetographs).

Flood volumes for each alternative were quantified in five major system areas: (1) the Union Square Area, (2) Beacon Street, (3) Somerville Ave corridor between Elm Street and the first intersection with Bow Street moving easterly, (4) Upper Union Square system, and (5) the

Tannery Brook system. At the same time, the Union Square area was sub-divided in three smaller areas: Union Square proper, Washington Street, and the Somerville Ave corridor between Union Square and the MWRA's CMI. The different reporting areas are depicted in Figure 3.

Ten and twenty-five year LOS plots (using 30-minute increment hyetographs) for the three alternatives with the least amount of flooding in the Union Square area (Alternative 8, Alternative 3.2, and Alternative 2) are presented in Figures 4 through 11.

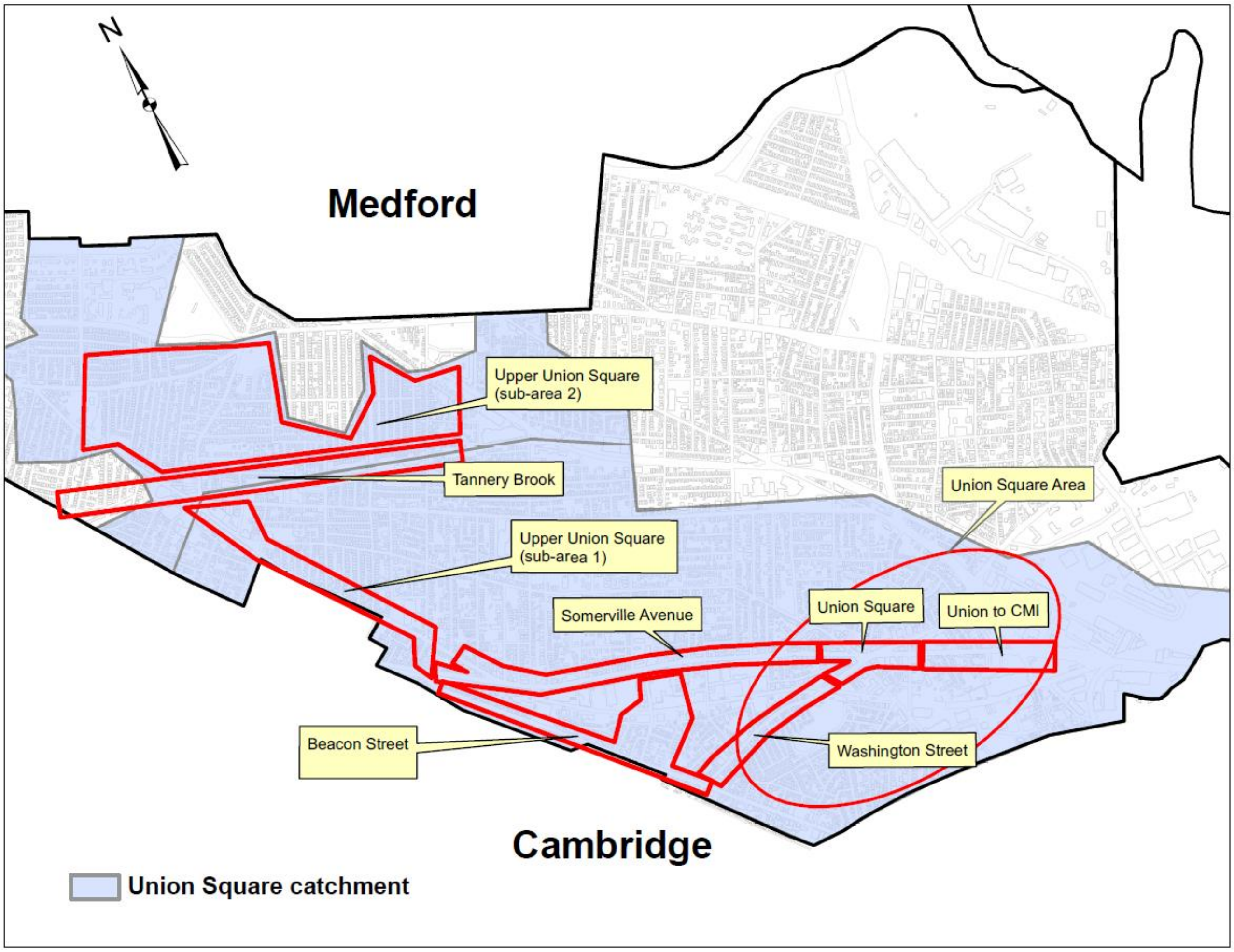


Figure 3. Flood reporting areas in the Union Square's tributary catchment area

Table 3. Flood volumes (in MG) using 15-minute time increment hyetographs for the 10- and 25-year 24-hour NRCS and the July 10th, 2010 storm events

	Union square Area			**TOTAL UNION SQUARE**	**Beacon Street**	**Somerville Avenue**	**Upper Union Square**	**Tannery Brook**	**TOTAL OVERALL**
	Union Square	**Union Sq. to CMI**	**Washington Street**						
10Y-24H Storm (15-min increments)									
Existing Conditions	0.132	0.007	0.137	**0.276**	0.083	0.021	0.466	0.183	**1.029**
Alt. 1	0.157	0.007	0.160	**0.324**	0.075	0.008	0.466	0.183	**1.056**
Alt. 2	0.067	0.006	0.079	**0.152**	0.060	0.005	0.465	0.182	**0.864**
Alt. 3.1	0.092	0.006	0.108	**0.206**	0.076	0.019	0.466	0.183	**0.950**
Alt. 3.2	0.043	0.004	0.059	**0.106**	0.064	0.017	0.465	0.183	**0.835**
Alt. 4	0.131	0.007	0.136	**0.274**	0.082	0.021	0.309	0.182	**0.868**
Alt. 5.1	0.132	0.007	0.137	**0.276**	0.082	0.021	0.447	0.209	**1.035**
Alt. 5.2	0.131	0.007	0.136	**0.274**	0.080	0.021	0.378	0.175	**0.928**
Alt. 6.1	0.132	0.007	0.137	**0.276**	0.082	0.021	0.280	0.275	**0.934**
Alt. 6.2	0.131	0.007	0.137	**0.275**	0.082	0.021	0.174	0.165	**0.717**
Alt. 7	0.110	0.006	0.126	**0.242**	0.080	0.020	0.465	0.183	**0.990**
Alt. 8	0.018	0.009	0.028	**0.055**	0.049	0.003	0.465	0.183	**0.755**
25Y-24H Storm (15-min increments)									
Existing Conditions	0.384	0.061	0.316	**0.761**	0.235	0.059	1.200	0.485	**2.740**
Alt. 1	0.535	0.064	0.355	**0.954**	0.237	0.028	1.210	0.485	**2.914**
Alt. 2	0.287	0.062	0.268	**0.617**	0.194	0.251	1.205	0.485	**2.752**
Alt. 3.1	0.276	0.060	0.255	**0.591**	0.213	0.055	1.200	0.485	**2.544**
Alt. 3.2	0.187	0.057	0.189	**0.433**	0.190	0.051	1.200	0.485	**2.359**
Alt. 4	0.384	0.063	0.316	**0.763**	0.235	0.059	0.900	0.485	**2.442**
Alt. 5.1	0.384	0.063	0.315	**0.762**	0.234	0.059	1.110	0.540	**2.705**
Alt. 5.2	0.382	0.063	0.315	**0.760**	0.234	0.059	1.003	0.520	**2.576**
Alt. 6.1	0.383	0.063	0.316	**0.762**	0.232	0.059	0.876	0.706	**2.635**
Alt. 6.2	0.383	0.063	0.316	**0.762**	0.232	0.059	0.656	0.499	**2.208**
Alt. 7	0.353	0.061	0.300	**0.714**	0.228	0.058	1.200	0.485	**2.685**
Alt. 8	0.092	0.220	0.007	**0.422**	0.156	0.085	1.200	0.486	**2.246**
July 10th, 2010 Storm									
Existing Conditions	1.656	0.249	0.719	**2.624**	0.986	0.287	3.840	1.499	**9.236**
Alt. 1	2.120	0.258	0.788	**3.166**	1.004	0.280	3.846	1.500	**9.796**
Alt. 2	1.317	0.254	0.716	**2.287**	0.929	0.886	3.842	1.500	**9.444**
Alt. 3.1	1.302	0.246	0.622	**2.170**	0.920	0.272	3.840	1.500	**8.702**
Alt. 3.2	1.128	0.243	0.582	**1.953**	0.890	0.264	3.840	1.500	**8.447**
Alt. 4	1.656	0.254	0.719	**2.629**	0.986	0.287	3.230	1.499	**8.631**
Alt. 5.1	1.630	0.253	0.728	**2.611**	0.991	0.286	3.399	1.610	**8.897**
Alt. 5.2	1.624	0.252	0.727	**2.603**	0.987	0.285	3.113	1.666	**8.654**
Alt. 6.1	1.629	0.254	0.719	**2.602**	0.986	0.286	3.234	1.992	**9.100**
Alt. 6.2	1.630	0.254	0.719	**2.603**	0.986	0.286	2.830	1.860	**8.565**
Alt. 7	1.530	0.249	0.707	**2.486**	0.976	0.284	3.601	1.500	**8.847**
Alt. 8	0.808	0.787	0.500	**2.095**	0.807	0.084	3.860	1.500	**8.346**

*Reported flood volumes are obtained from the available hydraulic model which only includes the main conveyance pipes in the Somerville system. Potential, localized flooding in side streets with smaller size pipes is not reflected in this model.

Table 4. Flood volumes (in MG) using 30-minute time increment hyetographs for the 10- and 25-year 24-hour NRCS storm events

	Union Square Area			**TOTAL UNION SQUARE**	**Beacon Street**	**Somerville Avenue**	**Upper Union Square**	**Tannery Brook**	**TOTAL OVERALL**
	Union Square	**Union Sq. to CMI**	**Washington Street**						
10Y-24H Storm (30-min increments)									
Existing Conditions	0.054	0.001	0.064	**0.119**	0.042	0.007	0.138	0.082	**0.388**
Alt. 1	0.094	0.001	0.099	**0.194**	0.048	0.003	0.138	0.082	**0.466**
Alt. 2	0.035	0.001	0.044	**0.080**	0.024	0.000	0.137	0.082	**0.323**
Alt. 3.1	0.043	0.001	0.057	**0.101**	0.040	0.007	0.138	0.082	**0.367**
Alt. 3.2	0.013	0.000	0.020	**0.033**	0.028	0.033	0.138	0.082	**0.315**
Alt. 4	0.054	0.001	0.063	**0.118**	0.042	0.007	0.077	0.082	**0.326**
Alt. 5.1	0.054	0.001	0.064	**0.118**	0.042	0.007	0.126	0.088	**0.381**
Alt. 5.2	0.054	0.001	0.063	**0.118**	0.042	0.007	0.112	0.076	**0.355**
Alt. 6.1	0.054	0.001	0.064	**0.118**	0.042	0.007	0.052	0.118	**0.337**
Alt. 6.2	0.054	0.001	0.063	**0.118**	0.041	0.007	0.026	0.077	**0.269**
Alt. 7	0.048	0.001	0.057	**0.105**	0.041	0.007	0.138	0.082	**0.373**
Alt. 8	0.006	0.006	0.010	**0.022**	0.020	0.000	0.138	0.082	**0.261**
25Y-24H Storm (30-min increments)									
Existing Conditions	0.256	0.038	0.234	**0.528**	0.165	0.032	0.642	0.271	**1.638**
Alt. 1	0.398	0.041	0.297	**0.736**	0.178	0.017	0.641	0.271	**1.843**
Alt. 2	0.217	0.037	0.216	**0.470**	0.130	0.052	0.639	0.271	**1.562**
Alt. 3.1	0.195	0.037	0.126	**0.428**	0.154	0.029	0.641	0.271	**1.453**
Alt. 3.2	0.112	0.033	0.129	**0.366**	0.129	0.026	0.640	0.271	**1.432**
Alt. 4	0.256	0.038	0.234	**0.528**	0.165	0.032	0.442	0.270	**1.437**
Alt. 5.1	0.255	0.038	0.233	**0.526**	0.164	0.031	0.603	0.293	**1.618**
Alt. 5.2	0.255	0.038	0.233	**0.526**	0.164	0.031	0.559	0.294	**1.575**
Alt. 6.1	0.255	0.038	0.233	**0.526**	0.162	0.031	0.392	0.393	**1.505**
Alt. 6.2	0.254	0.038	0.233	**0.525**	0.158	0.031	0.270	0.334	**1.318**
Alt. 7	0.234	0.037	0.219	**0.490**	0.160	0.031	0.608	0.199	**1.488**
Alt. 8	0.070	0.211	0.080	**0.361**	0.103	0.007	0.641	0.271	**1.382**

*Reported flood volumes are obtained from the available hydraulic model which only includes the main conveyance pipes in the Somerville system. Potential, localized flooding in side streets with smaller size pipes is not reflected in this model.

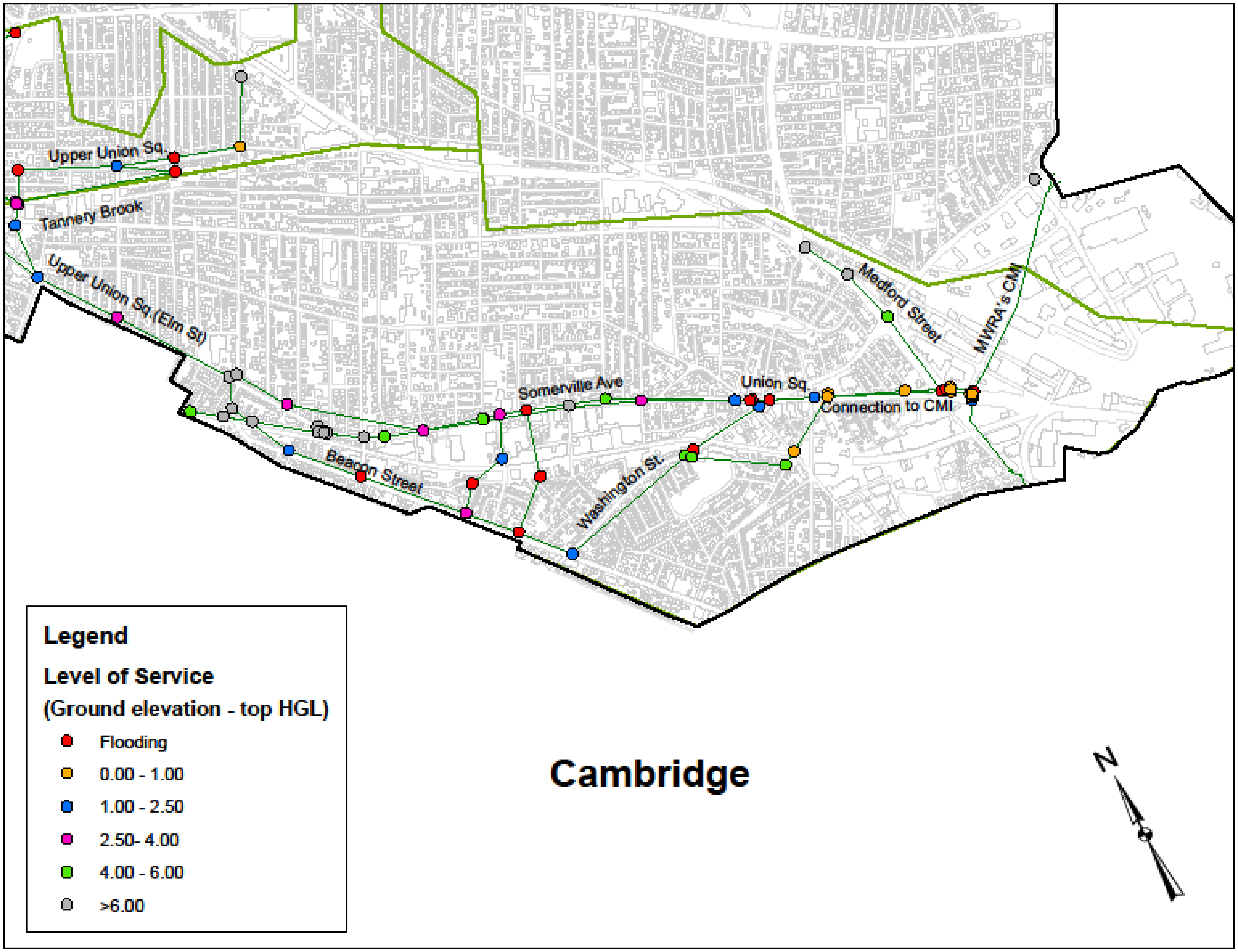


Figure 4. LOS in the Union Square and Somerville Ave areas in existing conditions during the 10-year, 24-hour NRCS storm

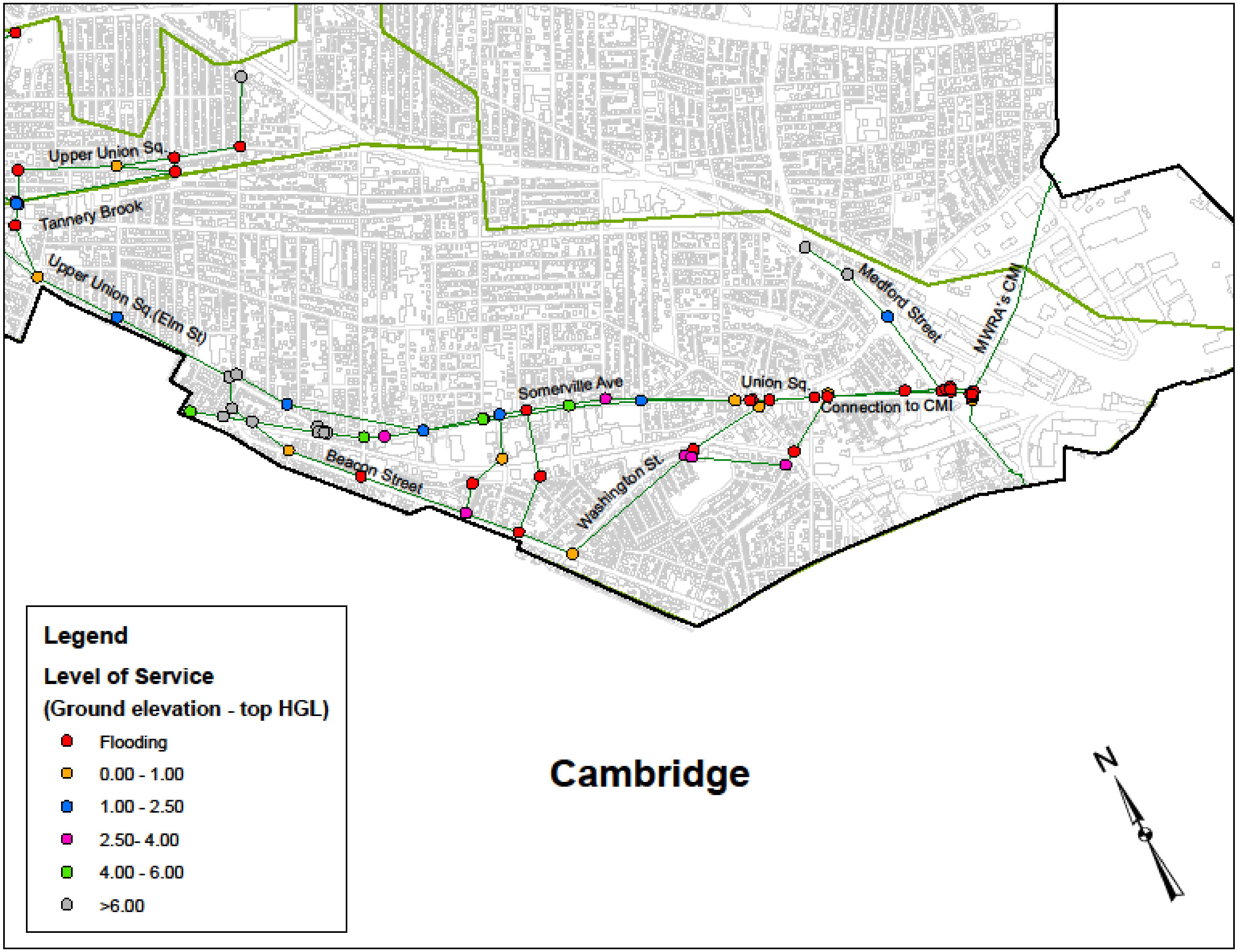


Figure 5. LOS in the Union Square and Somerville Ave areas in existing conditions during the 25-year, 24-hour NRCS storm

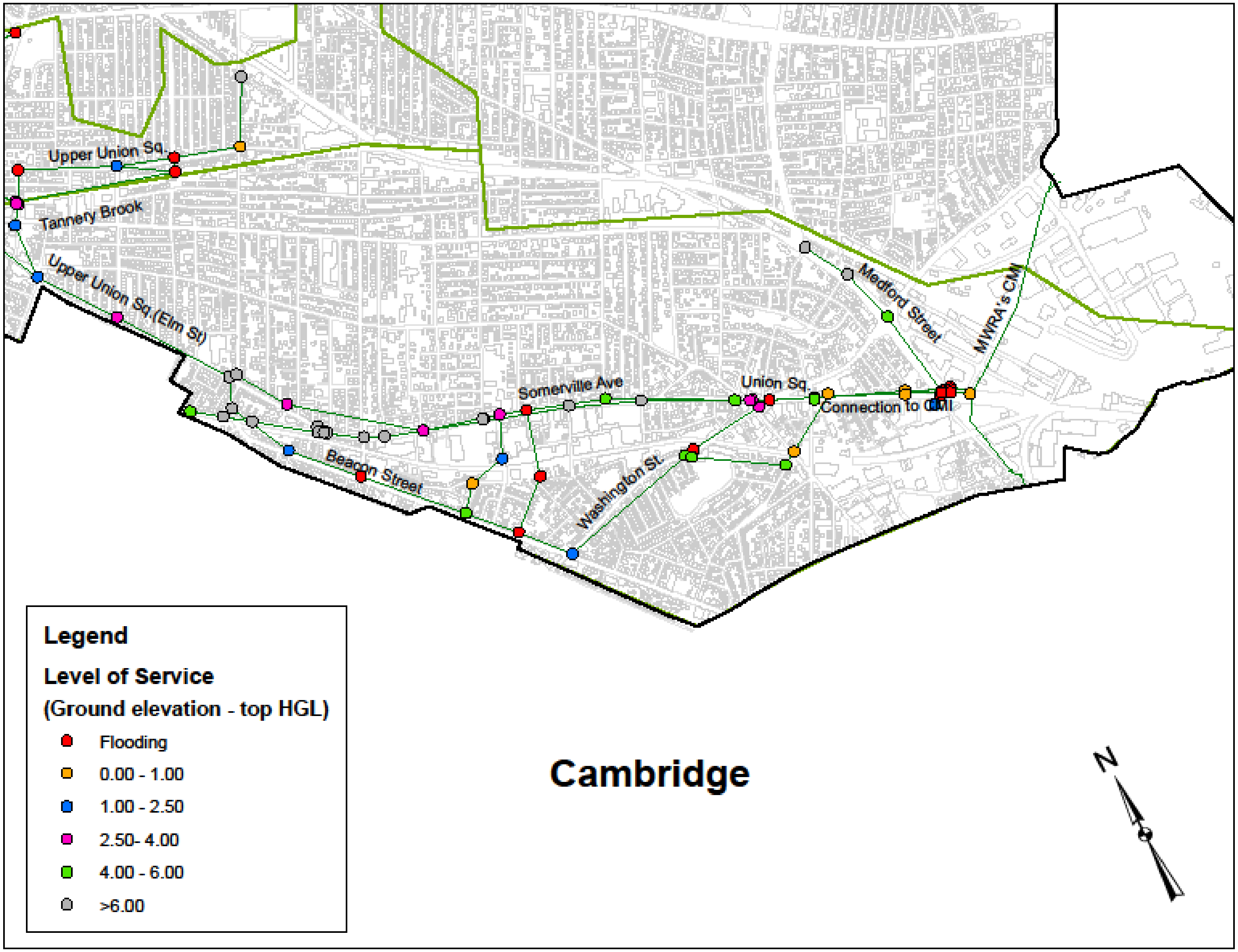


Figure 6. LOS in the Union Square and Somerville Ave areas with Alternative 8 during the 10-year, 24-hour NRCS storm

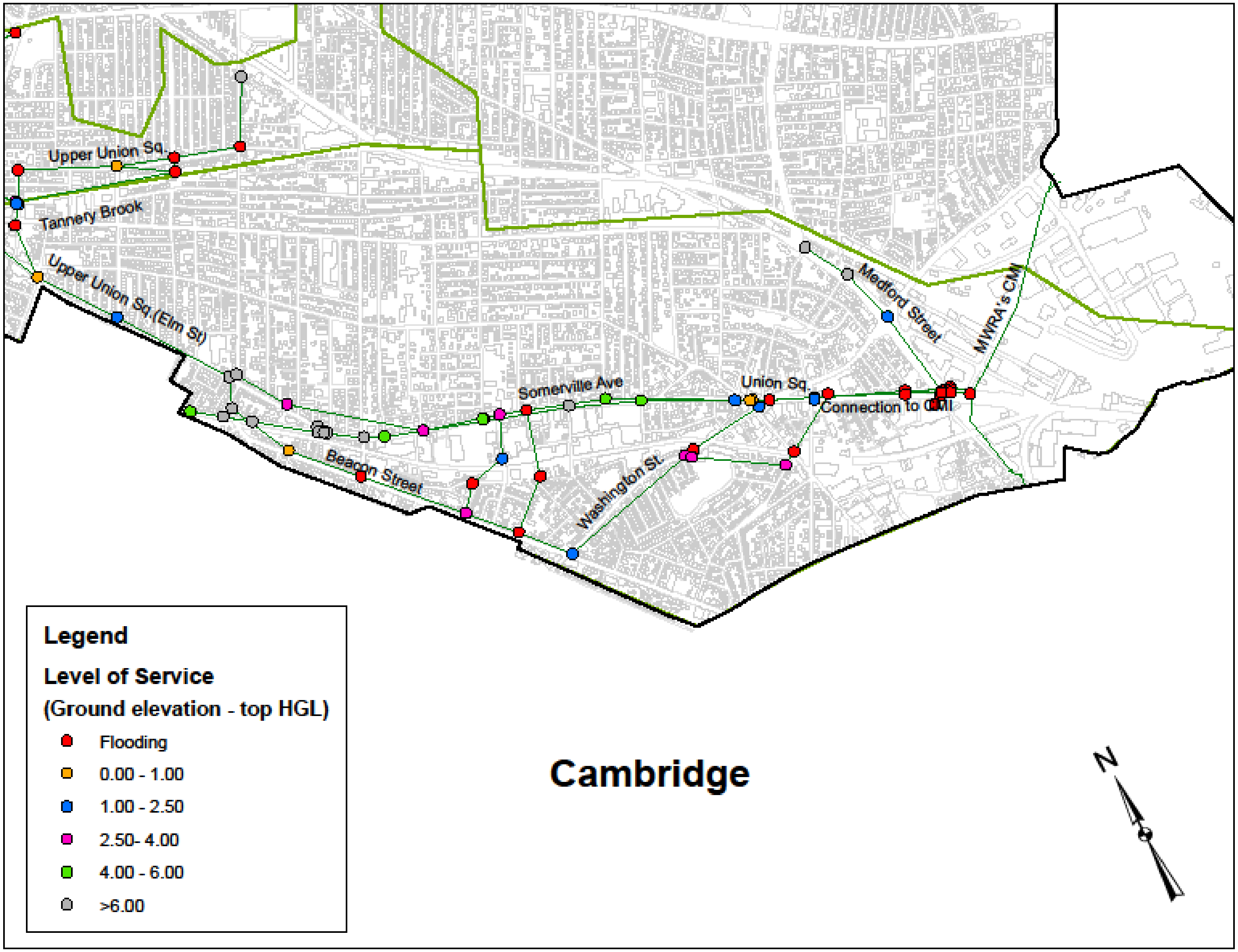


Figure 7. LOS in the Union Square and Somerville Ave areas with Alternative 8 during the 25-year, 24-hour NRCS storm

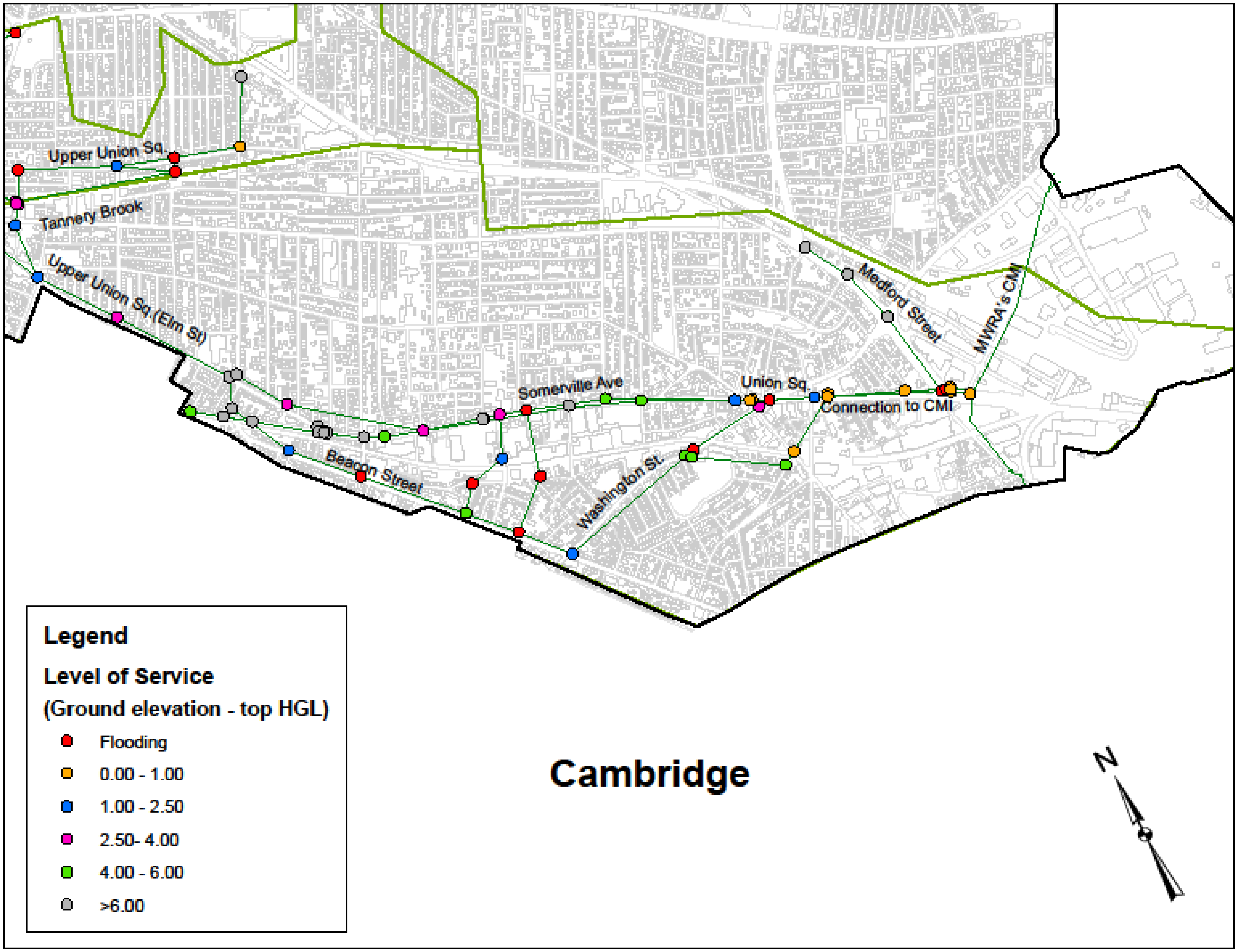


Figure 8. LOS in the Union Square and Somerville Ave areas with Alternative 3.2 during the 10-year, 24-hour NRCS storm

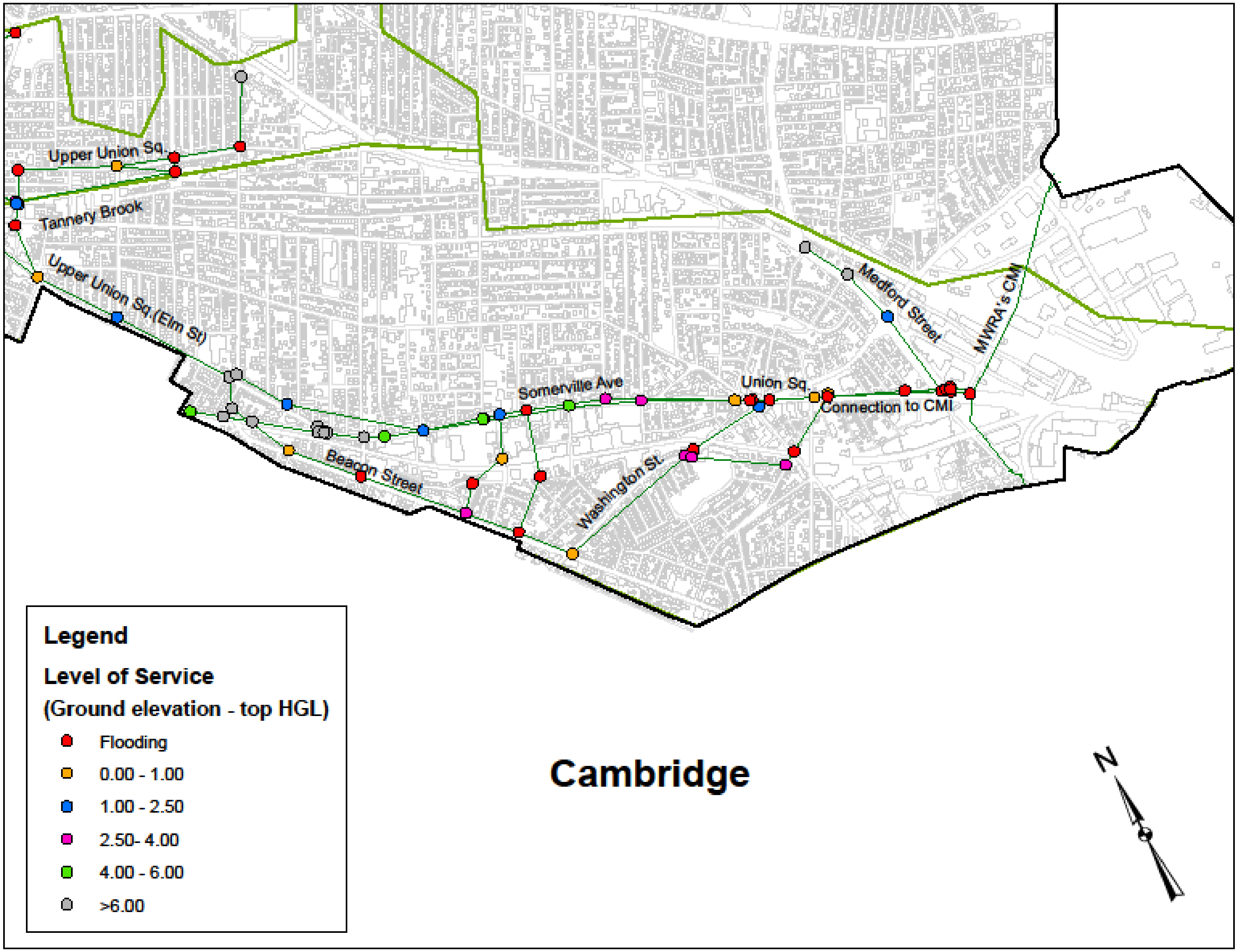


Figure 9. LOS in the Union Square and Somerville Ave areas with Alternative 3.2 during the 25-year, 24-hour NRCS storm

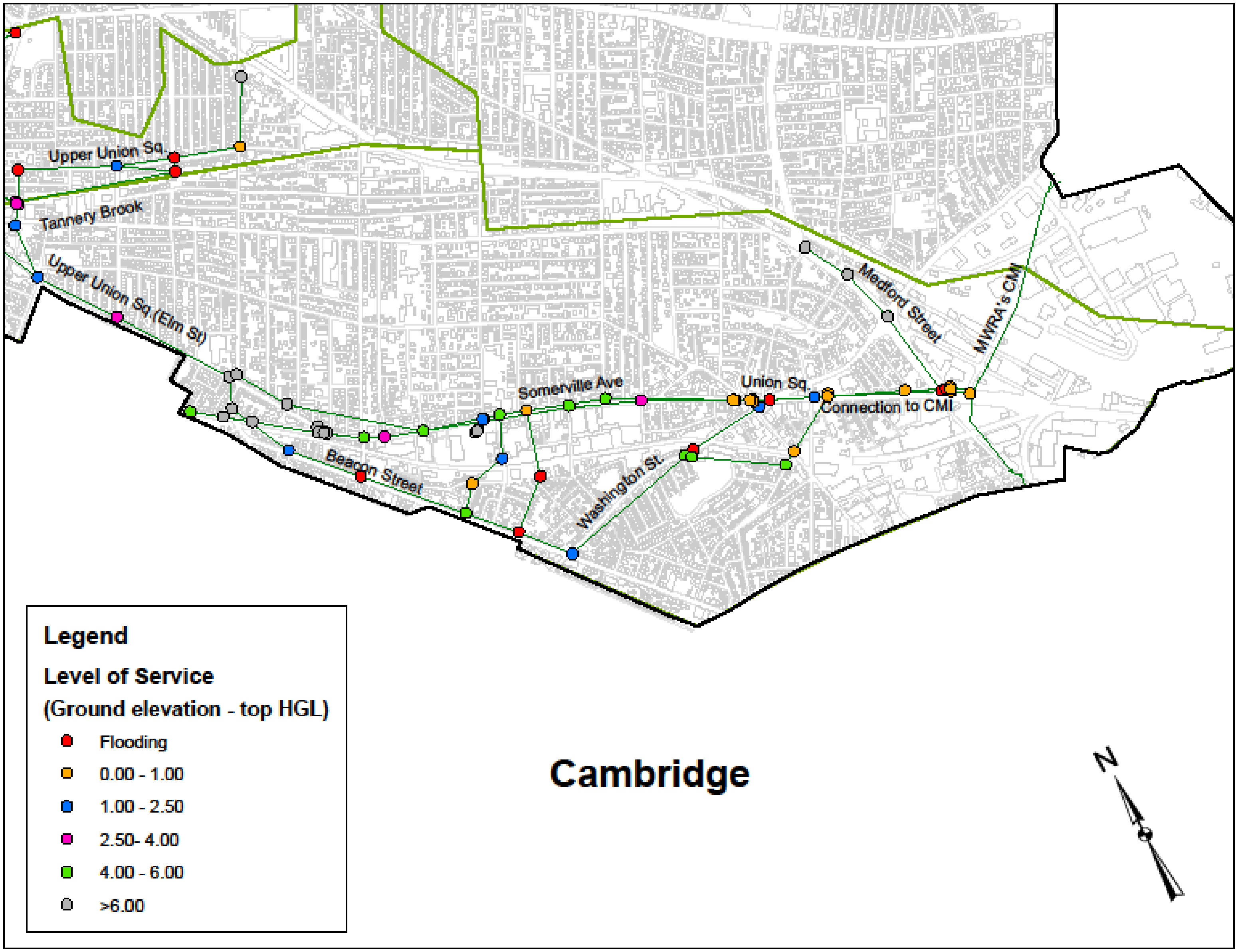


Figure 10. LOS in the Union Square and Somerville Ave areas with Alternative 2 during the 10-year, 24-hour NRCS storm

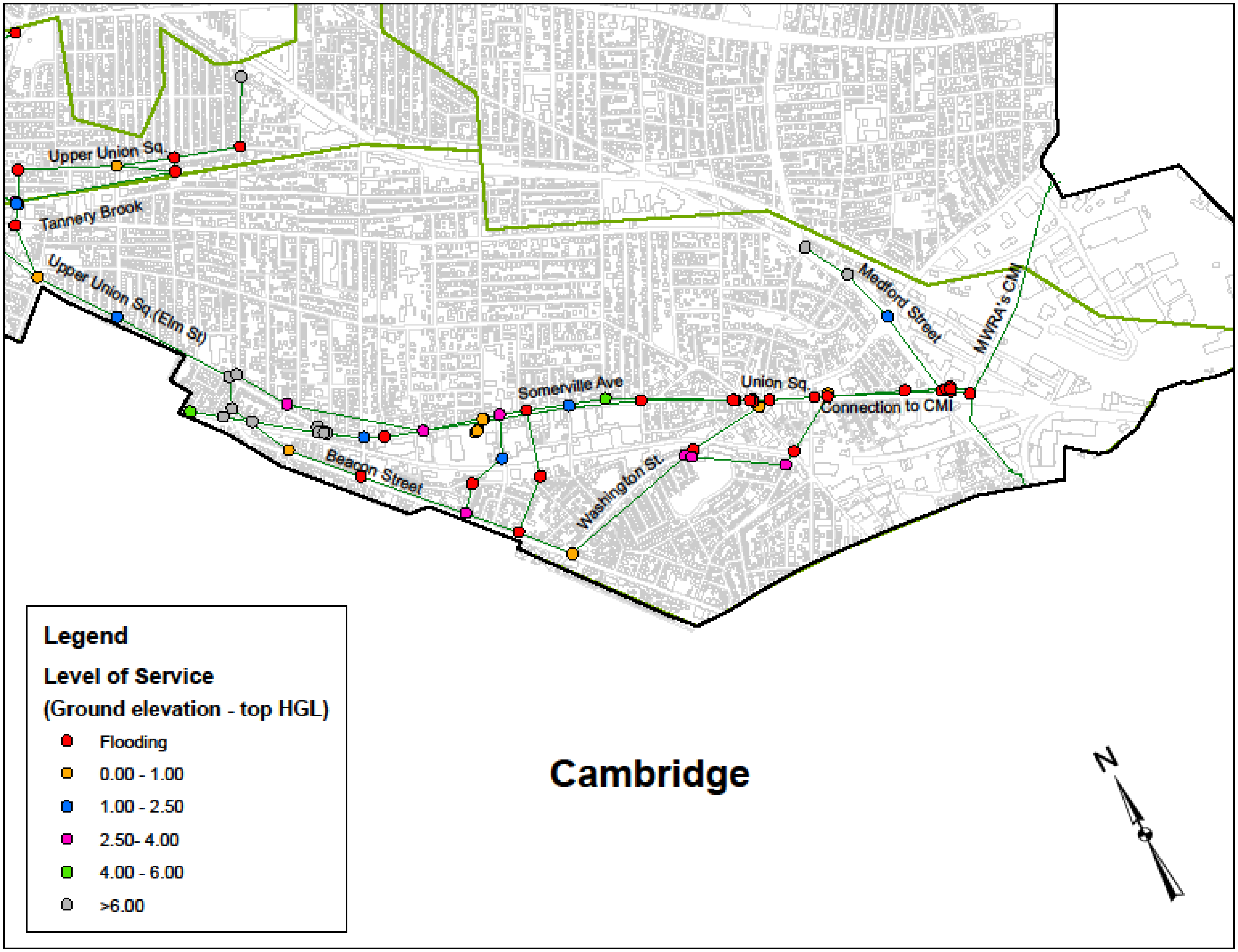


Figure 11. LOS in the Union Square and Somerville Ave areas with Alternative 2 during the 25-year, 24-hour NRCS storm

4.3 Ranking of Alternatives Evaluated Individually

Projects or alternatives were ranked based on flood reduction and cost-effectiveness criteria described below. Results are provided in Table 5.

(1) Flood reduction in the Union Square area during the 10-year, 24-hour NRCS event using 30-minute time increments (see Figure 3 for Union Square area boundaries).

(2) Cost-effectiveness of flood reduction alternatives in the Union Square area (calculated as % flooding removed per $M spent) during the 10-year, 24-hour event (with 30-minute time increments).

Table 5. Alternative ranking based on the flood reduction and cost-effectiveness criteria for the 10-year, 24-hour storm event

Flood Reduction		**Cost-Effectiveness**	
Alternative	**Flood Reduction (MG) [%]**	**Alternative**	**Cost-Effectiveness Index***
Alt. 8	0.0973 [81.8%]	Alt. 7	19.0
Alt. 3.2	0.0857 [71.2%]	Alt. 3.1	13.9
Alt. 2	0.0394 [33.1%]	Alt. 3.2	13.4
Alt. 3.1	0.0182 [15.3%]	Alt. 2	5.9
Alt. 7	0.0135 [11.4%]	Alt. 8	5.8
Alt. 6.2	Negligible reduction	Alt. 6.1	Negligible benefit
Alt. 5.2	Negligible reduction	Alt. 4	Negligible benefit
Alt. 4	Negligible reduction	Alt. 5.1	Negligible benefit
Alt. 6.1	Negligible reduction	Alt. 6.2	Negligible benefit
Alt. 5.1	Negligible reduction	Alt. 5.2	Negligible benefit
Alt. 1	Negligible reduction	Alt. 1	No benefit

* Calculated as percent of flooding removed per million dollars spent using the 30-minute, 10- year, 24-hour NRCS hyetograph.

4.4 Hydraulic Benefit of Combinations of Best Alternatives

Based on the flood reduction and cost-effectiveness results shown in Table 5, each of the tank alternatives that provided substantial flood reduction (i.e. Alternative 8, 3.2, and 2) were combined with relevant no-tank alternatives (i.e. Alternatives 7 and 3.1). Resulting flood volumes are provided below in Table 6. Level of service plots for the top two combinations with regard to flood reduction in the Union Square area (i.e. Alternative 3.2 or Alternative 8 combined with Alternative 3.1, see Table 6) are provided in Figures 12 to 15.

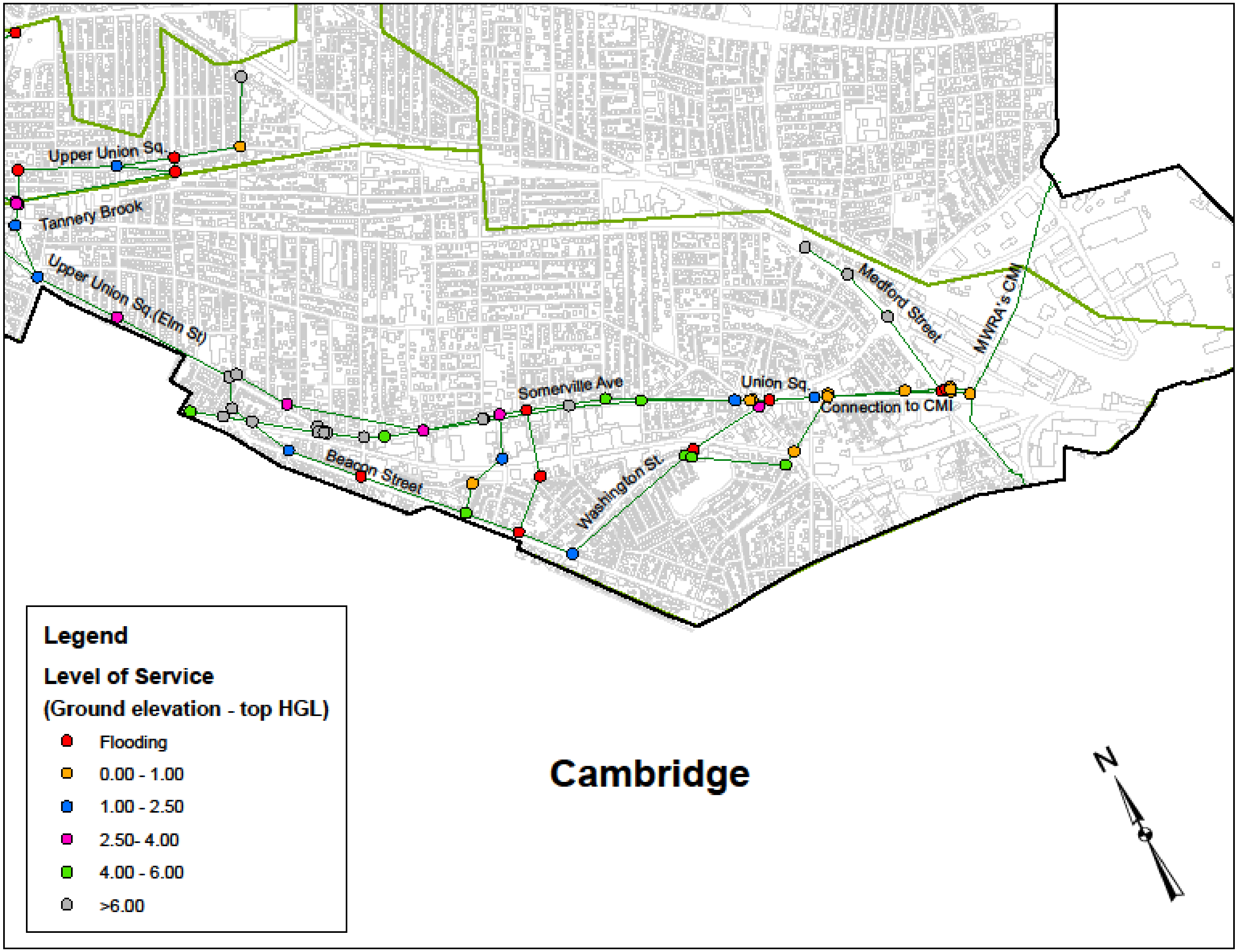


Figure 12. LOS in the Union Square and Somerville Ave areas with Alternatives 3.2 and Alternative 3.1during the 10-year, 24-hour NRCS storm

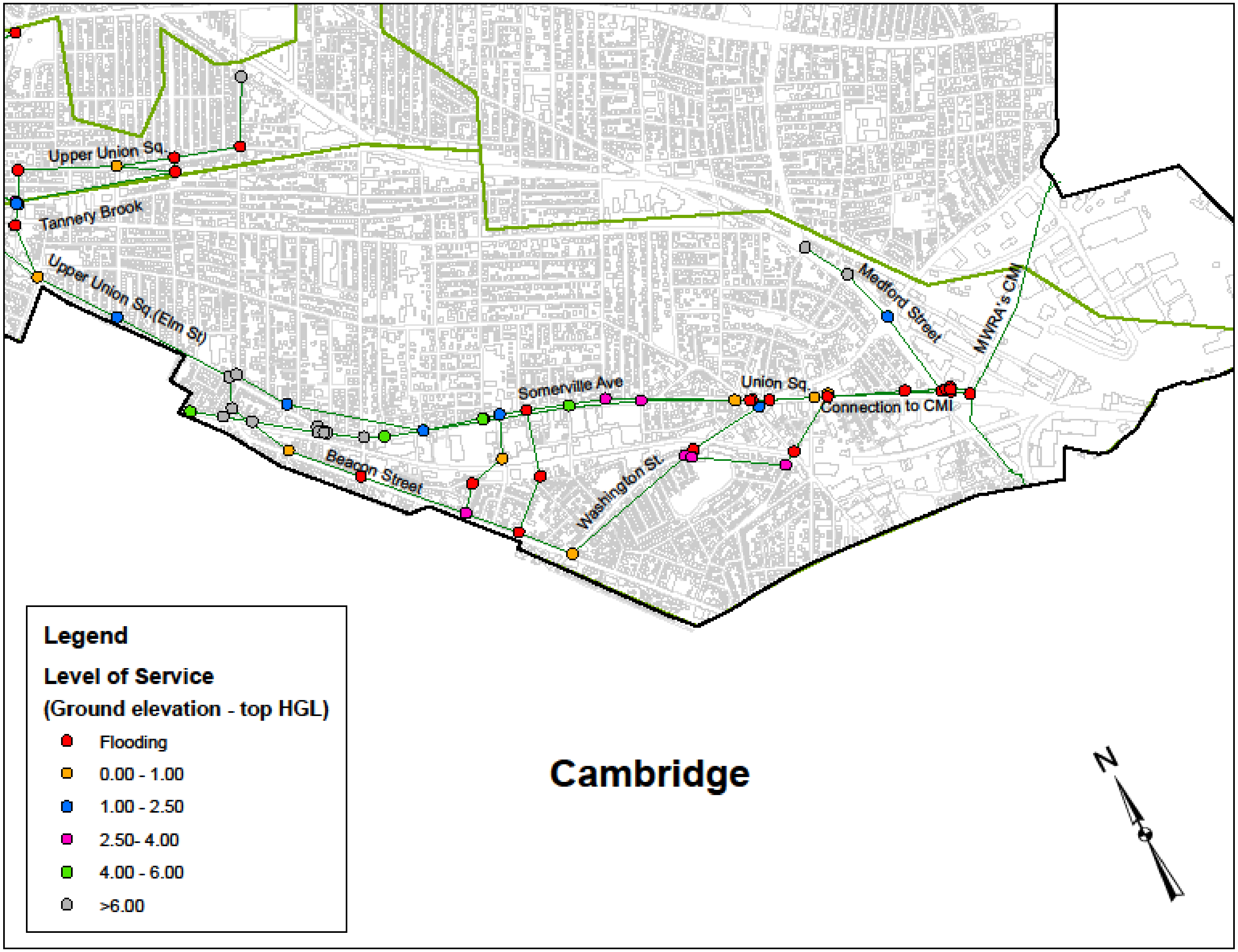


Figure 13. LOS in the Union Square and Somerville Ave areas with Alternatives 3.2 and Alternative 3.1during the 25-year, 24-hour NRCS storm

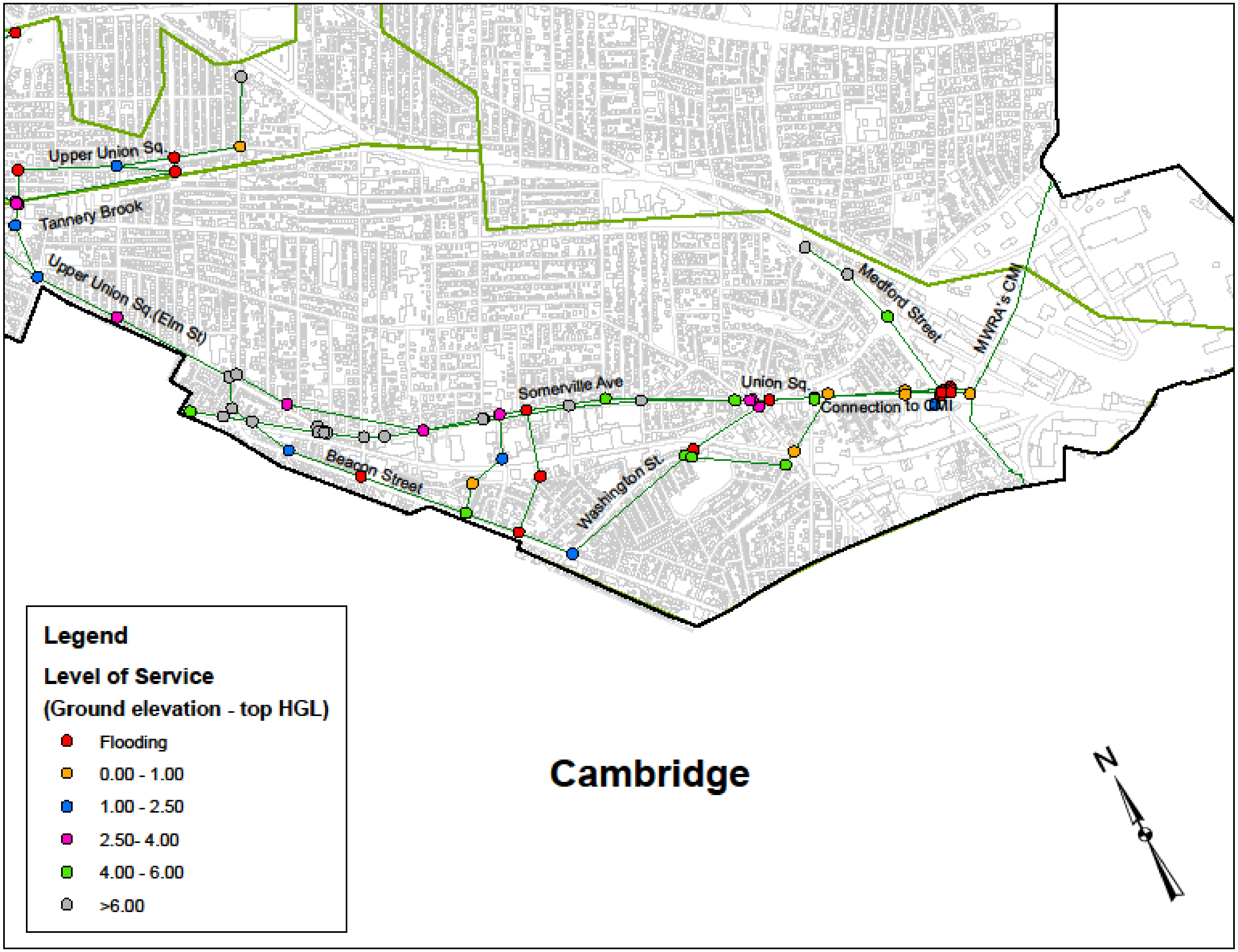


Figure 14. LOS in the Union Square and Somerville Ave areas with Alternatives 8 and Alternative 3.1during the 10-year, 24-hour NRCS storm

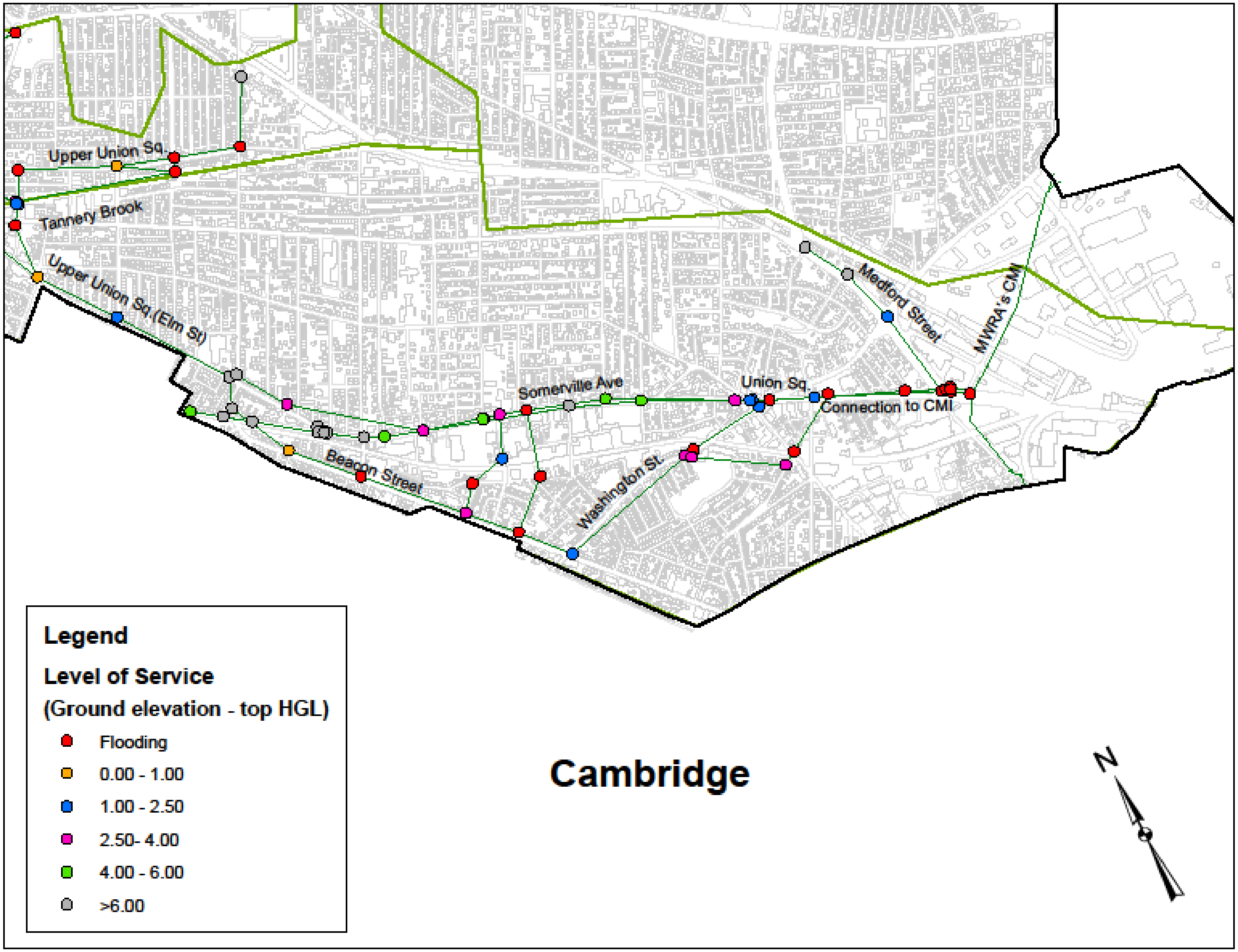


Figure 15. LOS in the Union Square and Somerville Ave areas with Alternatives 8 and Alternative 3.1during the 25-year, 24-hour NRCS storm

Table 6. Flood volumes (in MG) using 30-minute time increment hyetographs for the 10- and 25-year 24-hour NRCS storm events for different combinations of alternatives

	Union Square Area			**TOTAL UNION SQUARE**	**Beacon Street**	**Somerville Avenue**	**Upper Union Square**	**Tannery Brook**	**TOTAL OVERALL**
	Union Square	**Union Sq. to CMI**	**Washington Street**						
10Y-24H Storm (30-min increments)									
Existing Conditions	0.054	0.001	0.064	**0.119**	0.042	0.007	0.138	0.082	**0.388**
Alt3.2+Alt 7	0.014	0.000	0.022	**0.036**	0.029	0.005	0.137	0.082	**0.289**
Alt 3.2+Alt 3.1	0.010	0.000	0.017	**0.027**	0.027	0.005	0.137	0.082	**0.277**
Alt 8 + Alt 7	0.004	0.005	0.006	**0.015**	0.017	0.000	0.127	0.082	**0.241**
Alt 8+ Alt 3.1	0.002	0.002	0.005	**0.009**	0.017	0.000	0.127	0.082	**0.235**
Alt 2 + Alt 7	0.029	0.000	0.037	**0.067**	0.025	0.000	0.137	0.082	**0.311**
Alt 2 + Alt 3.1	0.032	0.000	0.045	**0.077**	0.026	0.000	0.137	0.082	**0.322**
25Y-24H Storm (30-min increments)									
Existing Conditions	0.256	0.038	0.234	**0.528**	0.165	0.032	0.642	0.271	**1.638**
Alt3.2+Alt 7	0.144	0.034	0.158	**0.336**	0.133	0.026	0.640	0.271	**1.406**
Alt 3.2+Alt 3.1	0.133	0.034	0.146	**0.312**	0.128	0.025	0.640	0.271	**1.248**
Alt 8 + Alt 7	0.060	0.208	0.065	**0.333**	0.096	0.006	0.641	0.271	**1.347**
Alt 8+ Alt 3.1	0.052	0.187	0.064	**0.303**	0.096	0.006	0.641	0.271	**1.317**
Alt 2 + Alt 7	0.200	0.036	0.203	**0.439**	0.135	0.260	0.640	0.271	**1.744**
Alt 2 + Alt 3.1	0.171	0.036	0.180	**0.387**	0.130	0.289	0.639	0.271	**1.716**

4.5 Ranking of Combinations of Alternatives

Similar to the individual alternatives, combinations of alternatives were ranked using the flood reduction and the cost-effectiveness criteria. For the cost-effectiveness of combinations of alternatives, the size of the tanks and other proposed drainage infrastructure was left the same as in the individual alternatives. However, tank size reductions are likely when alternatives are combined to prevent or reduce flooding during the 10-year design event (e.g. 11% of Alternative 3.2's tank capacity remains unused during the 10-year design event when in combination with Alternative 3.1). Table 7 presents the ranking of combinations of alternatives.

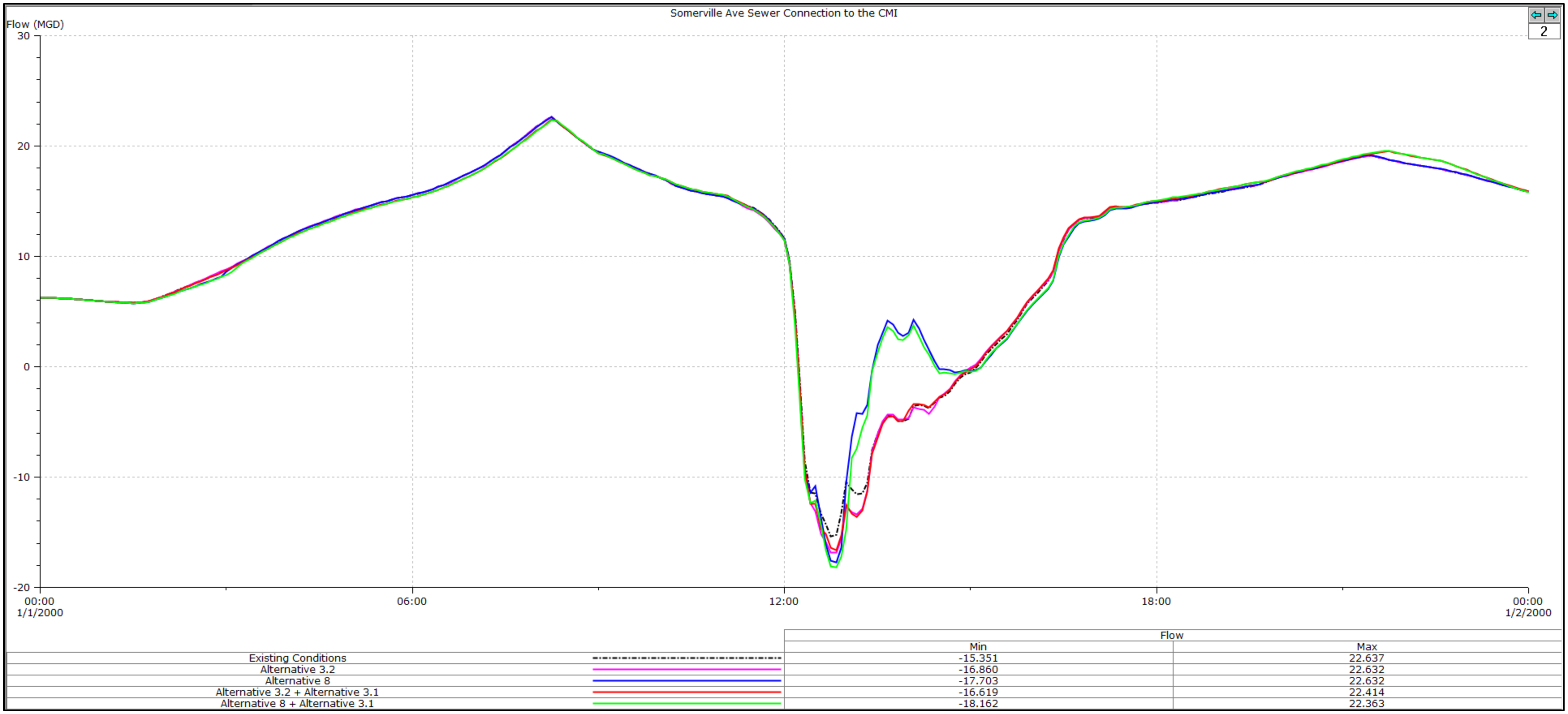
Table 7. Combination of alternatives ranking based on the flood reduction and the cost-effectiveness criteria with the 10-year, 24-hour storm event

Flood Reduction		**Cost-Effectiveness**	
Combination	**Flood Reduction (MG) [%]**	**Alternative**	**Cost-Effectiveness Index***
Alt. 8+ Alt. 3.1	0.110 [92.7%]	Alt. 3.2 + Alt. 3.1	12.1
Alt. 8 + Alt. 7	0.104 [87.5%]	Alt. 3.2 + Alt. 7	11.8
Alt. 3.2 + Alt. 3.1	0.092 [77.3%]	Alt. 2 + Alt. 7	7.0
Alt. 3.2 + Alt. 7	0.083 [69.6%]	Alt. 8 + Alt. 3.1	6.1
Alt. 2 + Alt. 7	0.052 [43.7%]	Alt. 8 + Alt. 7	5.9
Alt. 2 + Alt. 3.1	0.042 [35.0%]	Alt. 2 + Alt. 3.1	5.2

* Calculated as percent of flooding removed per million dollars spent using the 30-minute, 10- year, 24-hour NRCS hyetograph.

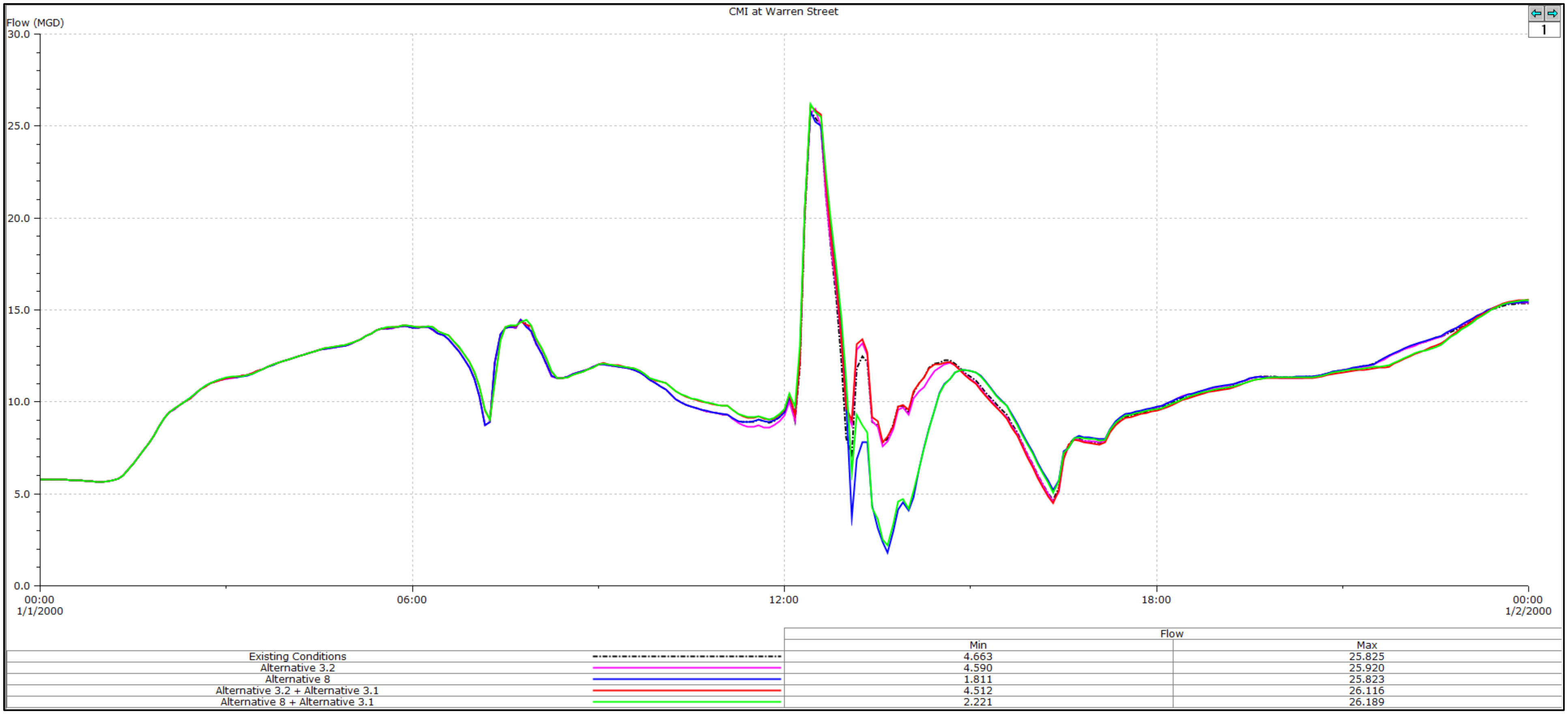
4.6 Effect of Best Alternatives to the MWRA's CMI

The impact that would result from implementing the best alternatives or combinations of alternatives to the CMI was evaluated at three different locations : (1) at the 28-inch pipe connecting the 84-inch combined sewer in Somerville Avenue to the CMI, (2) at the pipe immediately downstream of the SOM009 overflow, and (3) at the last CMI reach within Cambridge (Warren Street). Hydrographs for the 10-year, 24-hour storm for the selected scenarios are provided in Figures 16 through 18.



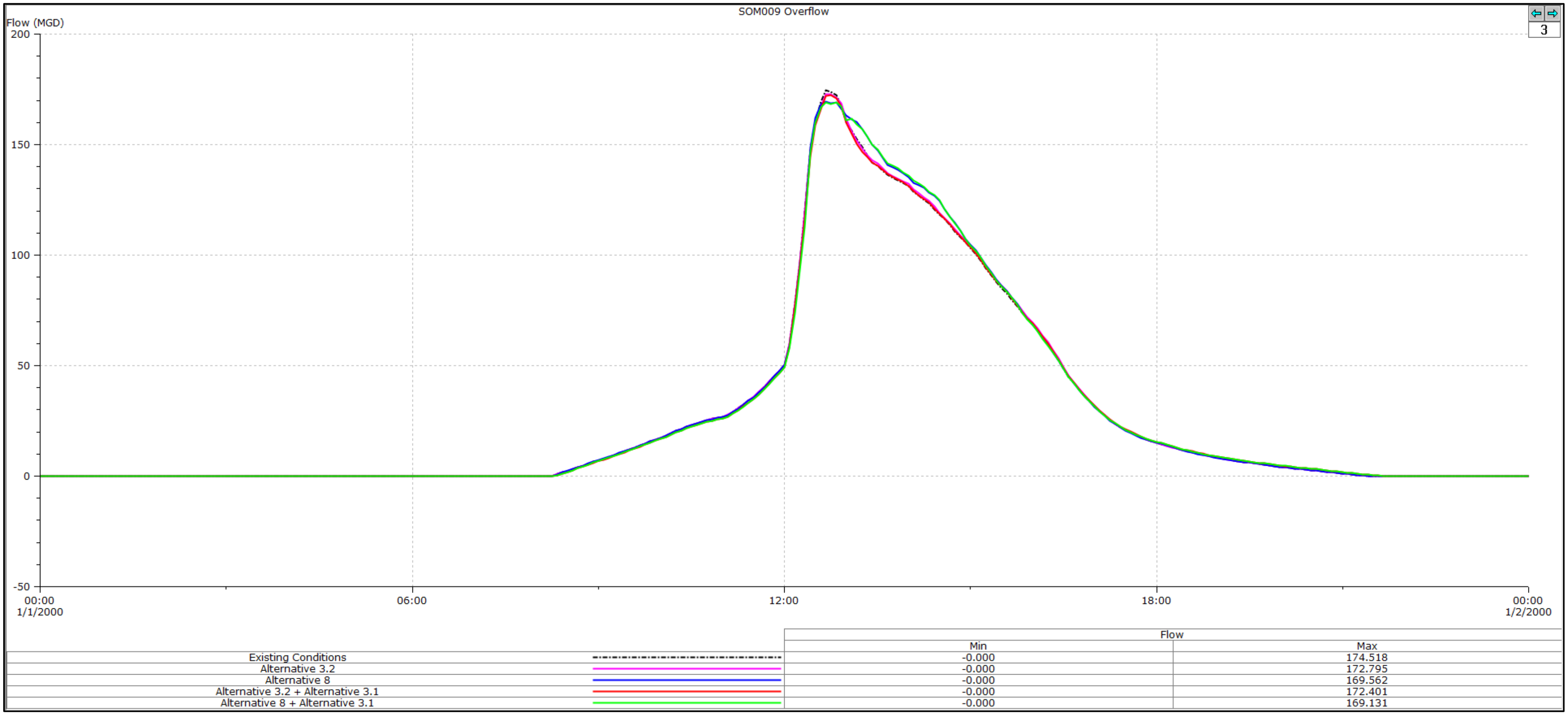
		Flow	
		Min	Max
Existing Conditions	-·-·-·-	-15.351	22.637
Alternative 3.2	—	-16.860	22.632
Alternative 8	—	-17.703	22.632
Alternative 3.2 + Alternative 3.1	—	-16.619	22.414
Alternative 8 + Alternative 3.1	—	-18.162	22.363

Figure 16. Flow contributions from the Union Square watershed to the CMI during the 10-year, 24-hour storm under different alternative scenarios.



		Flow	
		Min	Max
Existing Conditions	-·-·-·-	4.663	25.825
Alternative 3.2	───	4.590	25.920
Alternative 8	───	1.811	25.823
Alternative 3.2 + Alternative 3.1	───	4.512	26.116
Alternative 8 + Alternative 3.1	───	2.221	26.189

Figure 17. Flows in the CMI at Warren Street (Cambridge, MA) under different alternative scenarios during the 10-year, 24-hour storm



		Flow	
		Min	Max
Existing Conditions	-·-·-·-·-·-	-0.000	174.518
Alternative 3.2	———	-0.000	172.795
Alternative 8	———	-0.000	169.562
Alternative 3.2 + Alternative 3.1	———	-0.000	172.401
Alternative 8 + Alternative 3.1	———	-0.000	169.131

Figure 18. 10-year, 24-hour hydrograph at the SOM009 CSO overflow

5 Discussion

The hydraulic model results indicated that only projects in areas geographically close to Union Square have a significant impact with regards to flood reduction in the Union Square area depicted in Figure 3. Projects in the upper Union Square watershed such as those in alternatives 4, 5.1, 5.2, 6.1, and 6.2 do not bring any flood reduction benefit to this area, most likely because of their great distance to the area of interest. Flooding in Union Square is caused for the most part by large, rapid peak flows generated by three major systems that converge into a 66-inch, RCP pipe in Union Square. The three converging systems are the Summer Street catchment drain and combined sewer (92 acres), the Somerville Avenue drain and combined sewer (137 acres) and the Washington Street combined sewer pipe that conveys flows from the rest of the Union Square watershed. The Summer Street and Somerville Ave watersheds are relatively close to Union Square and have rapid peak flows due to proximity and steep topography (Spring Hill and part of Prospect Hill). The Washington Street pipe is a major flow conveyor and merges with these two systems near Union Square competing for the available capacity in the existing 66-inch pipe. The conveyance capacity of this pipe is limited and currently insufficient to absorb the peak flows generated during large storms and is aggravated by the limited capacity of the receiving MWRA's CMI. This problem becomes more acute with high intensity storms as indicated by the differences in flood volumes between the 15- and 30-minute hyetographs (Table 3 and 4, respectively) as well as the flood volumes generated by the storm July 10th, 2010 storm (Table 3).

Consequently, alternatives with project areas far from Union Square may have a significant flood reduction benefit in upper regions but do not seem to bring any local benefit in the area of interest. Alternatives involving construction of underground storage tanks in the vicinity of Union Square (i.e. Alternatives 8, Alternative 3.2, and Alternative 2) provide the most significant flood reductions during the 10-year storm (0.10, 0.09, and 0.07MG, respectively, Table 5).

With respect to level of service, none of the alternatives alone is able to totally eliminate flooding in the Union Square area (different degrees of flooding always occur in one of the Union Square junction manholes, in Washington Street and near the CMI connection in all scenarios) (Figures 4 through 11). However, Alternative 8, which includes extension of the Somerville Ave drain and construction of a 2.0 ac-ft tank near the CMI connection seems to provide the most significant improvement in level of service in the vicinity of Union Square with respect to the rest of best alternatives (Figure 6 and 7). It is important to keep in mind that this is a rather basic hydraulic model with only the main trunk lines represented in the network. Consequently, main points of convergence such as the Union Square junction manhole may overestimate flooding at that location as local pipe networks are not represented in the model and loaded directly onto manholes as large catchment areas. In reality, catchment loadings are distributed more evenly, which spreads flooding throughout the network, which would include small diameter pipes.

If alternatives are ranked based on cost-effectiveness of flood reduction, it becomes apparent that no-tank alternatives provide the most benefit per dollar spent but are not able to provide substantial flood reduction by themselves (15.3% and 11.4% for Alternatives 3.1 and Alternative 7, respectively; see Table 5). Surface runoff management in the Lincoln Park neighborhood

(Alternative 7) is the most cost-effective but only ranks fifth in total flood reduction (Table 5). Alternative 3.1 (surface storage in the Vinal Ave/Summer St. ball field) is the second most cost-effective alternative but only ranks fourth in flood reduction (Table 5).

As for tank options, Alternative 3.2 at Vinal Ave and Summer St. is the most balanced alternative. It is able to provide a 71% flood reduction during the 10-year storm event and is more cost-effective than Alternative 8 and Alternative 2, which would locate the tanks near the connection to the CMI and at Conway Park in Somerville Ave, respectively (Table 5).

Because of the differences between alternative ranking using the flood reduction and the cost-effectiveness criteria, combinations of tank and no-tank alternatives were evaluated. Flood reduction results of combinations of alternatives (Table 6) are consistent with the individual results with Alternative 8 combinations leading the ranking (up to 93% flood reduction) followed by alternative 3.2 and 2 combinations (up to 77% and 44% flood reduction, respectively; Table 7). However, the cost-effectiveness ranking of combinations of alternatives is clearly led by configurations including Alternative 3.2 (Table 7). Cost-effectiveness of combinations including alternatives 2 and 8 is approximately half of that of Alternative 3.2's (Table 7).

When evaluating the different alternatives individually and in combination, it was assumed that Alternative 8 would need to be executed in full. However, it is MWH's understanding that there is a possibility that the extension of the Somerville Ave drain from Union Square to a location near the connection to the CMI will most likely be executed as part of the Union Square Revitalization Project. The cost of such work, which was included in the total cost for Alternative 8, was estimated approximately at $7M to $8M, which leaves approximately another $6M to $7M for full execution of Alternative 8. If the extension of the Somerville Avenue drain proceeds under that project, the cost effectiveness of Alternative 8 would increase significantly reaching an index between 13.6 and 11.7, very similar to that of Alternative 3.2 (Table 5). If the remaining work of Alternative 8 is then combined with Alternative 3.1 to achieve the largest possible flood reduction (93%, Table 7), the cost –effectiveness index would range between 13 and 11.4, which is very close to the cost-effectiveness index values of Alternative 3.2 combinations (Table 7).

Implementation of tank alternatives 8 or 3.2 would result in an increase of negative flows from the CMI into the Somerville system as the proposed storage tanks would free up space that would fill back up by backflows from the CMI, which is heavily surcharged (Figure 16). This increase in backflows would be mostly relieved by the SOM009 overflow structure during the 10-year event. The resulting increase in backflows would translate into a slight increase of peak HGLs near the CMI connection with Alternative 8 (~ 0.1 feet) or a net decrease with Alternative 3.2 (~ 0.25 feet).

Implementation of Alternative 8 alone or in combination with Alternative 3.1 results in a net increase of volume entering the CMI (Figure 16), which translates in reduced ability for upstream systems (i.e. East Cambridge) to push flow as less capacity is available in the CMI (Figure 17). Conversely, Alternative 3.2 alone or in combination doesn't substantially change the hydraulics in the MWRA system or exacerbate draining issues in upstream communities (Figure

17). With respect to overflows over SOM009, none of the proposed alternatives significantly alters the flow volume reaching Prison Point during the 10-year storm (Figure 18).

6 Conclusions

- The hydraulic model indicated that significant flood reduction in the vicinity of Union Square can be achieved by executing mitigation projects that are physically close to the problem area. Projects in the Upper Union Square catchment bring negligible or no benefit to Union Square in terms of flood reduction.

- Significant flood reduction in Union Square by a single alternative alone can only be achieved using detention storage tanks. Alternative 8 and 3.2 are the top two alternatives with 82% (0.1MG) and 77% (0.09MG) of flood reduction during the 10-year, 24-hour event, respectively.

- The proposed no-tank alternatives alone provided modest flood reductions (up to 15%) but were the most cost-effective.

- Alternative 8 provides the most significant improvement in level of service for the Union Square area and its surroundings followed by Alternative 3.2. The junction manhole in the middle of Union Square floods in all storm events and alternative scenarios. However, this manhole is especially sensitive to flooding in the hydraulic model due to three main factors: (1) convergence of two major lines (i.e. Somerville Ave and Washington Street combined sewers), (2) direct loading of a large catchment area into that manhole (200 acres, which include Summer Street area, part of Prospect Hill and the surroundings of Union Square towards Webster Avenue), and (3) rapid peak flows from the Washington Street and Somerville Ave combined sewers as well as from the Summer Street catchment.

- Combinations of tank and no-tank alternatives resulted in the same flood reduction rankings as when the alternatives were evaluated individually. Alternative 8 combinations rank the highest with flood reductions up to 93%, followed by Alternatives 3.2 and Alternative 2 combinations with flood reductions up to 77% and 44%, respectively.

- Alternative 3.2 combined with no-tank alternatives is the most cost-effective with index values close to 12. Cost-effectiveness of Alternative 8 and 2 combinations are approximately half this value (index value up to 7 in best case). If the Somerville Avenue drain line extension is to be executed under the Union Square Revitalization Project, the cost-effectiveness of completing Alternative 8 or its combinations would be the highest or second highest of all the tank scenarios and very close to that of Alternative 3.2.

- Combination of Alternative 8 and 3.1 would result in a very significant improvement of level of service in the Union Square area with respect to existing conditions. Combinations of Alternatives 3.2 and 3.1 result in a more moderate improvement but level of service would still remain marginal in most locations within the Union Square area during the 10-year, 24-hour storm. Again, the junction manhole where the

Somerville Ave and the Washington Street drain converge floods in all modeled combination scenarios for the same reasons stated above.

- Alternative 8 alone or in combination would increase the flow volume entering the CMI during the peak of the storm or shortly after. The increase in conveyance capacity generated by the extension of the Someville Avenue drain would push flows towards the CMI more rapidly with the subsequent increase in volumes entering the CMI pipe. This would decrease its already limited capacity even further and negatively affect the East Cambridge system. Alternative 3.2 alone or in combination does not significantly alter the hydraulics in the MWRA's CMI with respect to existing conditions during the 10-year, 24-hour event.

7 Recommendations

Based on the results provided in this document, it is MWH recommendation to execute Alternative 3.2 (storage tank in the Vinal Ave/Summer St. ball field) in combination with Alternative 3.1(surface storage and infiltration enhancements in the Vinal Ave/Summer St. ball field) as they provide significant flood reduction (77%), are highly cost-effective with respect to the rest of evaluated alternatives and do not significantly alter the hydraulics of the receiving MWRA system. The performance of this combination of alternatives could be further improved by providing larger surface storage (i.e. constructing a higher berm) and/or sub-surface storage (i.e. installing a thicker gravel layer) in Alternative 3.1. In order to determine the final, optimum configuration for this alternative, additional detailed modeling is required in the Summer Street watershed and the Union Square area, which was not available at the time this study was performed.

It is MWH's opinion that, while Alternative 8 alone or in combination provides the largest flood reduction, its overall cost and significant alteration of the existing flow patterns in the CMI, makes it a less desirable option than Alternative 3.2. However, if the Somerville Ave drain is extended under the Union Square Revitalization Project, Alternative 8 becomes significantly more cost-effective. Additional, detailed modeling is necessary in order to determine the final configuration and find a feasible solution to avoid negative impacts to Somerville near the CMI connection and to the rest of communities serviced by the CMI system.

Attachment 1:
Opinion of Probable Project Costs

MWH
Boston

JLL
5/16/2013

City of Somerville
Stormwater Management Projects
Project #1
Surface Runoff Management in Spring Hill

Opinion of Probable Construction Costs

Currency: USD-United States-MAY 2013 Dollar

Grand Total Price: **$ 710,000**

Item #	Description	Quantity	UOM	Unit Price	Total Price	Comments
A.	**Capital Expenditures**				**$526,250**	
1	Install CB Inlet Controls in Spring Hill Area	69	ea	$2,500	$171,250	at 1 CB/2 ac, restrictors
2	Increase CB Inlet Capacity in Summerville Area	20	ea	$12,000	$240,000	double catch basins
3	Install 66" Throttle/Flap Valve	1	ea	$50,000	$50,000	
4	Traffic Mitigation	1	ls	$15,000	$15,000	
5	Contractor Mobilization/General Conditions	1	ls	10%	$50,000	
				Running Subtotal:	**$526,300**	
B.	**Project Management**				**$181,000**	
1	Construction Oversight & Mgt	1	ls	5%	**$30,000**	Allowanec
2	Engineering	1	ls	6%	**$30,000**	<ditto>
3	Geotechnical	1	ls	2%	**$11,000**	"
4	Engineering During Construction	1	ls	1%	**$5,000**	"
5	Misc Owner's Soft Costs (All)	1	ls	0%	**$0**	Excluded
6	Land Acquisition	1	ls	0%	**$0**	ditto
7	Scope Contingency/Market Conditions	1	ls	20%	**$105,000**	Scope definition/market allowance/estimating
8	Interest During Construction	1	ls	0%	**$0**	Excluded, allowance for financing costs
9	Owner's Construction Contingency/Mgt Reserve	1	ls	0%	**$0**	Excluded, allowance for changed field conditions
				Grand Total:	**$710,000**	Total Estimated Constr Costs w/ Contingency
			Cost Range:	**$500,000**	**$800,000**	Per AACE cost estimate guidelines

Assumptions:

1) Non-standard environmental mitigations excluded.

Notes

1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 30%
2) Pricing basis = 2nd Qtr 2013, escalation to midpoint of construction is excluded.
3) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
4) Owner soft costs and project management expenses excluded.
5) Special Inspections not included.

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MWH
Boston

JLL
5/16/2013

City of Somerville
Storm water Management Projects
Project #2
Conway Park Underground Tank

Opinion of Probable Construction Costs

Currency: USD-United States-MAY 2013 Dollar

Grand Total Price: $ 5,600,000

Item #	Description	Quantity	UOM	Unit Price	Total Price	Comments
A.	**Capital Expenditures**				**$4,204,500**	
1	Install U/G 3 ac-ft Storm water Tank	600,000	gal	$3.00	$1,800,000	
2	Tank Dewatering Pumps	2	ea	$50,000	$100,000	say 100 hp/pump
3	6" DI Force Mains to (e) 60" Storm Drain Pipeline	300	lf	$120	$36,000	1- 300' run
4	Inlet Structure	1	ea	$300,000	$300,000	incls 4' static weir & deep utility obstruction
5	36" RCP Inlet Pipe	200	lf	$390	$78,000	at 15' deep
6	36" Inlet Flap Valve	1	ea	$23,000	$23,000	
7	Install CB Controls	69	ea	$2,500	$172,500	
8	Increase CB Inlet Capacity	20	ea	$12,000	$240,000	double catch basins
9	Install 66" Throttle/Flap Valve	1	ea	$50,000	$50,000	
10	Hazardous Waste Mitigation Allowance	1	ea	$700,000	$700,000	pb, TPH soil contamination
11	Permitting Mitigation Allowance	1	ea	$100,000	$100,000	scope TBD
12	Restore Playground Area	1	ea	$150,000	$150,000	
13	Traffic Mitigation	1	ls	$75,000	$75,000	
14	Contractor Mobilization/General Conditions	1	ls	10%	$380,000	
				Running Subtotal:	**$4,204,500**	
B.	**Project Management**				**$1,424,000**	
1	Construction Oversight & Mgt	1	ls	5%	**$210,000**	Allowance
2	Engineering	1	ls	6%	**$250,000**	<ditto>
3	Geotechnical	1	ls	2%	**$84,000**	"
4	Engineering During Construction	1	ls	1%	**$40,000**	"
5	Misc Owner's Soft Costs (All)	1	ls	0%	**$0**	Excluded
6	Land Acquisition	1	ls	0%	**$0**	ditto
7	Scope Contingency/Market Conditions	1	ls	20%	**$840,000**	Scope definition/market allowance/estimating
8	Interest During Construction	1	ls	0%	**$0**	Excluded, allowance for financing costs
9	Owner's Construction Contingency/Mgt Reserve	1	ls	0%	**$0**	Excluded, allowance for changed field conditions
				Grand Total:	**$5,600,000**	Total Estimated Constr Costs w/ Contingency
	Cost Range:			**$3,800,000**	**$6,200,000**	Per AACE cost estimate guidelines

Assumptions:

1) Non-standard environmental mitigations excluded.

Notes

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3) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
4) Owner soft costs and project management expenses excluded.
5) Special Inspections not included.

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MWH **JLL**
Boston 5/16/2013

City of Somerville
Storm water Management Projects
Project #3a
Summer Street/Vinal Ave Surface Runoff Mgt & Surface Storage

Opinion of Probable Construction Costs

Currency: USD-United States-MAY 2013 Dollar

Grand Total Price: $ 1,100,000

Item #	Description	Quantity	UOM	Unit Price	Total Price	Comments
A.	**Capital Expenditures**				**$856,346**	
1	Install CB Inlet Controls in Summer Street Area	46	ea	$2,500	$115,000	at 1 CB/2 ac, restrictors
2	Lower Grade of (e) Baseball Field by 4'	5,500	cys	$15.00	$82,500	excavate to waste w/I 5 miles of site
3	Provide Gravel Base Material for Adsorption	2,750	cys	$55	$151,250	at say 2'
4	Construct 2' High Berm Around Field	165	cys	$40	$6,596	
5	15" PVC Throttle Outlet Valve	1	ea	$15,000	$15,000	
6	Install Raised Cross-walks	8	ea	$30,000	$240,000	
7	Remove/Replace (e) Concrete Curbs	1,000	lf	$40	$40,000	
8	Replace Concrete Sidewalk	6,000	sf	$6	$36,000	
9	Restore Baseball Field	1	ls	$50,000	$50,000	
10	Traffic Mitigation	1	ls	$50,000	$50,000	
11	Contractor Mobilization/General Conditions	1	ls	10%	$70,000	
				Running Subtotal:	**$856,300**	
B.	**Project Management**				**$288,000**	
1	Construction Oversight & Mgt	1	ls	5%	**$40,000**	Allowance
2	Engineering	1	ls	6%	**$50,000**	<ditto>
3	Geotechnical	1	ls	2%	**$17,000**	"
4	Engineering During Construction	1	ls	1%	**$10,000**	"
5	Misc Owner's Soft Costs (All)	1	ls	0%	**$0**	Excluded
6	Land Acquisition	1	ls	0%	**$0**	ditto
7	Scope Contingency/Market Conditions	1	ls	20%	**$171,000**	Scope definition/market allowance/estimating
8	Interest During Construction	1	ls	0%	**$0**	Excluded, allowance for financing costs
9	Owner's Construction Contingency/Mgt Reserve	1	ls	0%	**$0**	Excluded, allowance for changed field conditions
				Grand Total:	**$1,100,000**	Total Estimated Constr Costs w/ Contingency
			Cost Range:	**$700,000**	**$1,200,000**	Per AACE cost estimate guidelines

Assumptions:

1) Non-standard environmental mitigations excluded.

Notes

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2) Pricing basis = 2nd Qtr 2013, escalation to midpoint of construction is excluded.
3) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
4) Owner soft costs and project management expenses excluded.
5) Special Inspections not included.

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MWH **JLL**
Boston 5/16/2013

City of Somerville
Stormwater Management Projects
Project #3b
Summer Street/Vinal Ave Surface Runoff Mgt & Underground Storage

Opinion of Probable Construction Costs

Currency: USD-United States-MAY 2013 Dollar

Item #	Description	Quantity	UOM	Unit Price	Total Price	Comments
				Grand Total Price:	$ 5,300,000	
A.	**Capital Expenditures**				**$3,976,150**	
1	Extend (e) Summer Street Drain - 18"	1,400	lf	$315	$441,000	pvc. 15' deep
2	Extend (e) Summer Street Drain - 15"	800	lf	$263	$210,000	<ditto>
3	Provide Additional Inlet Capacity for Summer St Drain	11	ea	$7,250	$79,750	at 200' , sgl CB
4	Install U/G 3 ac-ft Stormwater Tank	600,000	gal	$3.00	$1,800,000	
5	Tank Dewatering Pumps	2	ea	$50,000	$100,000	say 100 hp/pump
6	6" DI Force Mains to (e) 51" Brick Drain	300	lf	$120	$36,000	1- 300' run
7	Inlet Structure	1	ea	$300,000	$300,000	incls 4' static weir & deep utility obstruction
8	24" RCP Inlet Pipe	200	lf	$360	$72,000	at 15' deep
9	24" Inlet Flap Valve	1	ea	$16,000	$16,000	
10	Restore Baseball Field	1	ls	$50,000	$50,000	
11	CCTV Inspection/Clean Brick Drain	1,220	lf	$20	$24,400	51" to 20"
12	Relocate Illicit Bldg Laterals to Combined Sewer	15	ea	$18,000	$270,000	100' of <12"
13	Install New 4' Drain Manholes for Drain Line Extend	9	ea	$8,000	$72,000	
14	Install CB Inlet Controls	46	ea	$2,500	$115,000	at 1 CB/2 ac, restrictors
15	Traffic Mitigation	1	ls	$50,000	$50,000	
16	Contractor Mobilization/General Conditions	1	ls	10%	$340,000	
				Running Subtotal:	**$3,976,200**	
B.	**Project Management**				**$1,355,000**	
1	Construction Oversight & Mgt	1	ls	5%	**$200,000**	Allowance
2	Engineering	1	ls	6%	**$240,000**	<ditto>
3	Geotechnical	1	ls	2%	**$80,000**	"
4	Engineering During Construction	1	ls	1%	**$40,000**	"
5	Misc Owner's Soft Costs (All)	1	ls	0%	**$0**	Excluded
6	Land Acquisition	1	ls	0%	**$0**	ditto
7	Scope Contingency/Market Conditions	1	ls	20%	**$795,000**	Scope definition/market allowance/estimating
8	Interest During Construction	1	ls	0%	**$0**	Excluded, allowance for financing costs
9	Owner's Construction Contingency/Mgt Reserve	1	ls	0%	**$0**	Excluded, allowance for changed field conditions
				Grand Total:	**$5,300,000**	Total Estimated Constr Costs w/ Contingency
			Cost Range:	**$3,600,000**	**$5,900,000**	Per AACE cost estimate guidelines

Assumptions:

1) Non-standard environmental mitigations excluded.

Notes

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2) Pricing basis = 2nd Qtr 2013, escalation to midpoint of construction is excluded.
3) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
4) Owner soft costs and project management expenses excluded.
5) Special Inspections not included.

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MWH **JLL**
Boston 5/16/2013

City of Somerville
Storm water Management Projects
Project #4
Tufts University Area Storm water Management

Opinion of Probable Construction Costs

Currency: USD-United States-MAY 2013 Dollar

Grand Total Price: **$ 1,000,000**

Item #	Description	Quantity	UOM	Unit Price	Total Price	Comments
A.	**Capital Expenditures**				**$742,000**	
1	Remove & Replace (e) Catch Basins	10	ea	$7,250	$72,500	single
2	Remove & Replace (e) Catch Basins	10	ea	$12,750	$127,500	double
4	Extend Drain Lines - 18"	500	lf	$360	$180,000	
5	Install New 4' Drain Manholes for Drain Line Extend	3	ea	$8,000	$24,000	
6	Install CB Inlet Controls	40	ea	$2,500	$100,000	at 1 CB/2 ac, restrictors
7	Increase Curb Reveal for Increased Surface Flows	1,500	lf	$40	$60,000	
8	Replace Concrete Sidewalk	6,000	sf	$6	$36,000	
9	Remove/Regrade/Replace AC Road Section	4	ea	$10,500	$42,000	2,100 sf/location
10	Traffic Mitigation	1	ls	$40,000	$40,000	
11	Contractor Mobilization/General Conditions	1	ls	10%	$60,000	
				Running Subtotal:	**$742,000**	
B.	**Project Management**				**$253,000**	
1	Construction Oversight & Mgt	1	ls	5%	**$40,000**	Allowance
2	Engineering	1	ls	6%	**$40,000**	<ditto>
3	Geotechnical	1	ls	2%	**$15,000**	"
4	Engineering During Construction	1	ls	1%	**$10,000**	"
5	Misc Owner's Soft Costs (All)	1	ls	0%	**$0**	Excluded
6	Land Acquisition	1	ls	0%	**$0**	ditto
7	Scope Contingency/Market Conditions	1	ls	20%	**$148,000**	Scope definition/market allowance/estimating
8	Interest During Construction	1	ls	0%	**$0**	Excluded, allowance for financing costs
9	Owner's Construction Contingency/Mgt Reserve	1	ls	0%	**$0**	Excluded, allowance for changed field conditions
				Grand Total:	**$1,000,000**	Total Estimated Constr Costs w/ Contingency
			Cost Range:	**$700,000**	**$1,100,000**	Per AACE cost estimate guidelines

Assumptions:

1) Non-standard environmental mitigations excluded.

Notes

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2) Pricing basis = 2nd Qtr 2013, escalation to midpoint of construction is excluded.
3) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
4) Owner soft costs and project management expenses excluded.
5) Special Inspections not included.

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MWH **JLL**
Boston 5/16/2013

City of Somerville
Storm water Management Projects
Project #5a
Upper Minuteman Trail Area Flow Management

Opinion of Probable Construction Costs

Currency: USD-United States-MAY 2013 Dollar

Grand Total Price: $ 1,800,000

Item #	Description	Quantity	UOM	Unit Price	Total Price	Comments
A.	**Capital Expenditures**				**$1,344,750**	
1	Remove & Replace (e) Catch Basins	18	ea	$7,250	$130,500	single
2	Remove & Replace (e) Catch Basins	5	ea	$12,750	$63,750	double
4	Extend Drain Lines - 18"	1,500	lf	$360	$540,000	12' deep
5	Install New 4' Drain Manholes for Drain Line Extend	6	ea	$8,000	$48,000	
6	Install CB Inlet Controls	25	ea	$2,500	$62,500	restrictors
7	Increase Curb Reveal for Increased Surface Flows	1,000	lf	$40	$40,000	
8	Replace Concrete Sidewalk	5,000	sf	$6	$30,000	
9	Remove/Regrade/Replace AC Road Section	4	ea	$5,000	$20,000	1000 sf/location
10	Install Raised Cross-walks	8	ea	$30,000	$240,000	
11	Traffic Mitigation	1	ls	$50,000	$50,000	
12	Contractor Mobilization/General Conditions	1	ls	10%	$120,000	
				Running Subtotal:	**$1,344,800**	
B.	**Project Management**				**$456,000**	
1	Construction Oversight & Mgt	1	ls	5%	**$70,000**	Allowance
2	Engineering	1	ls	6%	**$80,000**	<ditto>
3	Geotechnical	1	ls	2%	**$27,000**	"
4	Engineering During Construction	1	ls	1%	**$10,000**	"
5	Misc Owner's Soft Costs (All)	1	ls	0%	**$0**	Excluded
6	Land Acquisition	1	ls	0%	**$0**	ditto
7	Scope Contingency/Market Conditions	1	ls	20%	**$269,000**	Scope definition/market allowance/estimating
8	Interest During Construction	1	ls	0%	**$0**	Excluded, allowance for financing costs
9	Owner's Construction Contingency/Mgt Reserve	1	ls	0%	**$0**	Excluded, allowance for changed field conditions
				Grand Total:	**$1,800,000**	Total Estimated Constr Costs w/ Contingency
			Cost Range:	**$1,200,000**	**$2,000,000**	Per AACE cost estimate guidelines

Assumptions:

1) Non-standard environmental mitigations excluded.

Notes

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2) Pricing basis = 2nd Qtr 2013, escalation to midpoint of construction is excluded.
3) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
4) Owner soft costs and project management expenses excluded.
5) Special Inspections not included.

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MWH **JLL**
Boston 5/16/2013

City of Somerville
Storm water Management Projects
Project #5b
Lower Minuteman Trail Area Flow Management

Opinion of Probable Construction Costs

Currency: USD-United States-MAY 2013 Dollar

Grand Total Price: **$ 5,400,000**

Item #	Description	Quantity	UOM	Unit Price	Total Price	Comments
A.	**Capital Expenditures**				**$4,036,000**	
1	Install U/G 1 ac-ft Storm water Tank	325,000	gal	$4.00	$1,300,000	
2	Tank Dewatering Pumps	2	ea	$50,000	$100,000	say 100 hp/pump
3	6" DI Force Mains to (e) 60" Storm Drain Pipeline	100	lf	$120	$12,000	8' deep
4	Inlet Structure	1	ea	$150,000	$150,000	incls 4' static weir & deep utility obstruction
5	24" Brick Drain	200	lf	$390	$78,000	at 15' deep
6	15" Inlet Flap Valve	1	ea	$10,000	$10,000	
7	Hazardous Waste Mitigation Allowance	1	ea	$500,000	$500,000	pb, TPH soil contamination
8	Permitting Mitigation Allowance	1	ea	$100,000	$100,000	scope TBD
9	Restore Parking Area	1	ea	$150,000	$150,000	
10	New PVC Drain Piping - 18"	2,400	lf	$270	$648,000	12' deep
11	New Single Catch Basins	30	ea	$6,500	$195,000	
12	Install CB Inlet Controls	30	ea	$2,500	$75,000	restrictors
13	Install New 4' Drain Manholes for Drain Line Extend	12	ea	$8,000	$96,000	
14	Install Raised Cross-walks	2	ea	$35,000	$70,000	50' & 30'
15	Remove/Regrade/Replace AC Road Section	3	ea	$5,000	$15,000	1000 sf/location
16	Increase Curb Reveal for Increased Surface Flows	1,500	lf	$40	$60,000	
17	Replace Concrete Sidewalk	7,500	sf	$6	$45,000	
18	CCTV Inspection/Clean Brick Drain	600	lf	$20	$12,000	51' to 20"
19	Traffic Mitigation	1	ls	$50,000	$50,000	
20	Contractor Mobilization/General Conditions	1	ls	10%	$370,000	
				Running Subtotal:	**$4,036,000**	
B.	**Project Management**				**$1,371,000**	
1	Construction Oversight & Mgt	1	ls	5%	**$200,000**	Allowance
2	Engineering	1	ls	6%	**$240,000**	<ditto>
3	Geotechnical	1	ls	2%	**$81,000**	"
4	Engineering During Construction	1	ls	1%	**$40,000**	"
5	Misc Owner's Soft Costs (All)	1	ls	0%	**$0**	Excluded
6	Land Acquisition	1	ls	0%	**$0**	ditto
7	Scope Contingency/Market Conditions	1	ls	20%	**$810,000**	Scope definition/market allowance/estimating
8	Interest During Construction	1	ls	0%	**$0**	Excluded, allowance for financing costs
9	Owner's Construction Contingency/Mgt Reserve	1	ls	0%	**$0**	Excluded, allowance for changed field conditions
				Grand Total:	**$5,400,000**	Total Estimated Constr Costs w/ Contingency
			Cost Range:	**$3,700,000**	**$6,000,000**	Per AACE cost estimate guidelines

Assumptions:

1) Non-standard environmental mitigations excluded.

Notes

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MWH **JLL**
Boston 5/16/2013

City of Somerville
Stormwater Management Projects
Project #6a
Broadway/Teele Square Area

Opinion of Probable Construction Costs

Currency: USD-United States-MAY 2013 Dollar

Grand Total Price: **$ 700,000**

Item #	Description	Quantity	UOM	Unit Price	Total Price	Comments
A.	**Capital Expenditures**				**$510,000**	
1	New Single Catch Basins	20	ea	$6,500	$130,000	
2	Install CB Inlet Controls	30	ea	$2,500	$75,000	restrictors
3	Install Raised Cross-walks	2	ea	$30,000	$60,000	530'
4	Remove/Regrade/Replace AC Road Section	3	ea	$5,000	$15,000	1000 sf/location
5	Increase Curb Reveal for Increased Surface Flows	2,000	lf	$40	$80,000	
6	Replace Concrete Sidewalk	10,000	sf	$6	$60,000	
7	Traffic Mitigation	1	ls	$50,000	$50,000	
8	Contractor Mobilization/General Conditions	1	ls	10%	$40,000	
				Running Subtotal:	**$510,000**	
B.	**Project Management**				**$180,000**	
1	Construction Oversight & Mgt	1	ls	5%	**$30,000**	Allowance
2	Engineering	1	ls	6%	**$30,000**	<ditto>
3	Geotechnical	1	ls	2%	**$10,000**	"
4	Engineering During Construction	1	ls	1%	**$10,000**	"
5	Misc Owner's Soft Costs (All)	1	ls	0%	**$0**	Excluded
6	Land Acquisition	1	ls	0%	**$0**	ditto
7	Scope Contingency/Market Conditions	1	ls	20%	**$100,000**	Scope definition/market allowance/estimating
8	Interest During Construction	1	ls	0%	**$0**	Excluded, allowance for financing costs
9	Owner's Construction Contingency/Mgt Reserve	1	ls	0%	**$0**	Excluded, allowance for changed field conditions
				Grand Total:	**$700,000**	Total Estimated Constr Costs w/ Contingency
			Cost Range:	**$500,000**	**$800,000**	Per AACE cost estimate guidelines

Assumptions:

1) Non-standard environmental mitigations excluded.

Notes

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MWH **JLL**
Boston 5/16/2013

City of Somerville
Storm water Management Projects
Project #6b
Holland Street Tank

Opinion of Probable Construction Costs

Currency: USD-United States-MAY 2013 Dollar

Grand Total Price: **$ 5,700,000**

Item #	Description	Quantity	UOM	Unit Price	Total Price	Comments
A.	**Capital Expenditures**				**$4,246,000**	
1	Install U/G 3 ac-ft Storm water Tank	1,000,000	gal	$2.50	$2,500,000	
2	Tank Dewatering Pumps	2	ea	$50,000	$100,000	say 100 hp/pump
3	6" DI Force Mains to (e) 60" Storm Drain Pipeline	150	lf	$120	$18,000	8' deep
4	Inlet Structure	1	ea	$250,000	$250,000	incls 4' static weir & deep utility obstruction
5	30" RCP Drain	100	lf	$450	$45,000	at 15' deep
6	12" RCP Drain	200	lf	$180	$36,000	
7	30" Inlet Flap Valve	1	ea	$20,000	$20,000	
8	Hazardous Waste Mitigation Allowance	1	ea	$100,000	$100,000	pb, TPH soil contamination
9	Permitting Mitigation Allowance	1	ea	$100,000	$100,000	scope TBD
10	Restore Playground Area	1	ea	$150,000	$150,000	
11	New Single Catch Basins	20	ea	$6,500	$130,000	
12	Install CB Inlet Controls	30	ea	$2,500	$75,000	restrictors
13	Install New 5' Drain Manholes for Drain Line Extend	2	ea	$8,000	$16,000	
14	Install New 8' Drain Manholes for Drain Line Extend	1	ea	$11,000	$11,000	
15	Install Raised Cross-walks	2	ea	$35,000	$70,000	50' & 30'
16	Remove/Regrade/Replace AC Road Section	4	ea	$5,000	$20,000	1000 sf/location
17	Increase Curb Reveal for Increased Surface Flows	2,000	lf	$40	$80,000	
18	Replace Concrete Sidewalk	10,000	sf	$6	$60,000	
19	Traffic Mitigation	1	ls	$75,000	$75,000	
20	Contractor Mobilization/General Conditions	1	ls	10%	$390,000	
				Running Subtotal:	**$4,246,000**	
B.	**Project Management**				**$1,435,000**	
1	Construction Oversight & Mgt	1	ls	5%	**$210,000**	Allowance
2	Engineering	1	ls	6%	**$250,000**	<ditto>
3	Geotechnical	1	ls	2%	**$85,000**	"
4	Engineering During Construction	1	ls	1%	**$40,000**	"
5	Misc Owner's Soft Costs (All)	1	ls	0%	**$0**	Excluded
6	Land Acquisition	1	ls	0%	**$0**	ditto
7	Scope Contingency/Market Conditions	1	ls	20%	**$850,000**	Scope definition/market allowance/estimating
8	Interest During Construction	1	ls	0%	**$0**	Excluded, allowance for financing costs
9	Owner's Construction Contingency/Mgt Reserve	1	ls	0%	**$0**	Excluded, allowance for changed field conditions
				Grand Total:	**$5,700,000**	Total Estimated Constr Costs w/ Contingency
			Cost Range:	**$3,900,000**	**$6,300,000**	Per AACE cost estimate guidelines

Assumptions:

1) Non-standard environmental mitigations excluded.

Notes

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MWH **JLL**
Boston 5/16/2013

City of Somerville
Storm water Management Projects
Project #7
Lincoln Park Neighborhood Flow Management

Opinion of Probable Construction Costs

Currency: USD-United States-MAY 2013 Dollar

Grand Total Price: **$ 600,000**

Item #	Description	Quantity	UOM	Unit Price	Total Price	Comments
A.	**Capital Expenditures**				**$446,700**	
2	Install CB Inlet Controls	15	ea	$2,500	$37,500	restrictors
4	Install Raised Cross-walks	4	ea	$30,000	$120,000	530'
5	Remove/Regrade/Replace AC Road Section	12,000	sf	$5.00	$60,000	
6	Increase Curb Reveal for Increased Surface Flows	700	lf	$40	$28,000	
7	Replace Concrete Sidewalk	4,200	sf	$6	$25,200	
9	Install Gravel Base at Field Area - 2'	1,600	cys	$60	$96,000	1/2 acre infiltration area
10	Traffic Mitigation	1	ls	$40,000	$40,000	
11	Contractor Mobilization/General Conditions	1	ls	10%	$40,000	
				Running Subtotal:	**$446,700**	
B.	**Project Management**				**$149,000**	
1	Construction Oversight & Mgt	1	ls	5%	**$20,000**	Allowance
2	Engineering	1	ls	6%	**$30,000**	<ditto>
3	Geotechnical	1	ls	2%	**$9,000**	"
4	Engineering During Construction	1	ls	1%	**$0**	"
5	Misc Owner's Soft Costs (All)	1	ls	0%	**$0**	Excluded
6	Land Acquisition	1	ls	0%	**$0**	ditto
7	Scope Contingency/Market Conditions	1	ls	20%	**$90,000**	Scope definition/market allowance/estimating
8	Interest During Construction	1	ls	0%	**$0**	Excluded, allowance for financing costs
9	Owner's Construction Contingency/Mgt Reserve	1	ls	0%	**$0**	Excluded, allowance for changed field conditions
				Grand Total:	**$600,000**	Total Estimated Constr Costs w/ Contingency
	Cost Range:			**$400,000**	**$700,000**	Per AACE cost estimate guidelines

Assumptions:

1) Non-standard environmental mitigations excluded.

Notes

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MWH
Boston

JLL
5/16/2013

City of Somerville
Storm water Management Projects
Project #8
Somerville Ave Drain Line Extension, Flow Mgt & Target Parking Lot Tank

Opinion of Probable Construction Costs

Currency: USD-United States-MAY 2013 Dollar

Grand Total Price: **$ 14,100,000**

Item #	Description	Quantity	UOM	Unit Price	Total Price	Comments
A.	**Capital Expenditures**				**$10,516,650**	
1	Install U/G 2 ac-ft Storm water Tank	650,000	gal	$3.00	$1,950,000	
2	Tank Dewatering Pumps	2	ea	$50,000	$100,000	say 100 hp/pump
3	6" DI Force Mains to (e) 66" Storm Drain Pipeline	200	lf	$120	$24,000	8' deep
4	Inlet Structure	1	ea	$200,000	$200,000	incls 4' static weir & deep utility obstruction
5	36" RCP Inlet Conveyance	200	lf	$540	$108,000	at 15' deep
6	36" Inlet Flap Valve	1	ea	$23,000	$23,000	
7	Extend 66" RCP at Somerville Ave	1,000	lf	$990	$990,000	
8	Extend 72" RCP at Somerville Ave	1,000	lf	$1,080	$1,080,000	
9	Install New 11' Drain Manholes for Drain Line Extend	12	ea	$15,000	$180,000	
10	Connect to New Pipe to 66"	1	ea	$10,000	$10,000	
11	66" Inlet Flap Valve	1	ea	$36,000	$36,000	
12	Install CB Inlet Controls at Summer Street	69	ea	$2,500	$171,250	restrictors
13	Increase CB Inlet Capacity in Summerville Area	20	ea	$12,000	$240,000	double catch basins
14	Extend (e) Summer Street Drain - 18"	1,400	lf	$315	$441,000	pic. 15' deep
15	Extend (e) Summer Street Drain - 15"	800	lf	$263	$210,000	<ditto>
16	New Single Catch Basins	20	ea	$6,500	$130,000	
17	CCTV Inspection/Clean Brick Drain	1,720	lf	$20	$34,400	51" to 20"
18	Relocate Illicit Bldg Laterals to Combined Sewer	50	ea	$18,000	$900,000	100' of <12"
19	Install CB Inlet Controls at Prospect Area	50	ea	$2,500	$125,000	restrictors
20	New Drain Line - 18" at Prospect Hill Area	1,400	lf	$315	$441,000	pic. 15' deep
21	New Drain Line - 15" at Prospect Hill Area	800	lf	$263	$210,000	<ditto>
22	Install New 4' Drain Manholes for Drain Line Extend	15	ea	$8,000	$120,000	
23	New Single Catch Basins for Drain Line Extension	50	ea	$6,500	$325,000	
24	New Double Catch Basin for Drain Line Extension	15	ea	$12,000	$180,000	
25	Install Raised Cross-walks	15	ea	$35,000	$525,000	50' & 30'
26	Increase Curb Reveal for Increased Surface Flows	3,000	lf	$40	$120,000	
27	Replace Concrete Sidewalk	18,000	sf	$6	$108,000	
28	Remove/Regrade/Replace AC Road Section	15	ea	$20,000	$300,000	15 locations at 20'x200'
29	Utility Relocation	1	ls	$100,000	$100,000	
30	Traffic Mitigation	1	ls	$175,000	$175,000	
31	Contractor Mobilization/General Conditions	1	ls	10%	$960,000	
				Running Subtotal:	**$10,516,700**	
B.	**Project Management**				**$3,580,000**	
1	Construction Oversight & Mgt	1	ls	5%	**$530,000**	Allowance
2	Engineering	1	ls	6%	**$630,000**	<ditto>
3	Geotechnical	1	ls	2%	**$210,000**	"
4	Engineering During Construction	1	ls	1%	**$110,000**	"
5	Misc Owner's Soft Costs (All)	1	ls	0%	**$0**	Excluded
6	Land Acquisition	1	ls	0%	**$0**	ditto
7	Scope Contingency/Market Conditions	1	ls	20%	**$2,100,000**	Scope definition/market allowance/estimating
8	Interest During Construction	1	ls	0%	**$0**	Excluded, allowance for financing costs
9	Owner's Construction Contingency/Mgt Reserve	1	ls	0%	**$0**	Excluded, allowance for changed field conditions
				Grand Total:	**$14,100,000**	Total Estimated Constr Costs w/ Contingency
			Cost Range:	**$9,600,000**	**$15,600,000**	Per AACE cost estimate guidelines

Assumptions:

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MWH **JLL**
Boston 5/16/2013

City of Somerville
Storm water Management Projects
Project #8
Somerville Ave Drain Line Extension, Flow Mgt & Target Parking Lot Tank

Opinion of Probable Construction Costs

Currency: USD-United States-MAY 2013 Dollar

Grand Total Price: **$ 14,100,000**

Item #	Description	Quantity	UOM	Unit Price	Total Price	Comments

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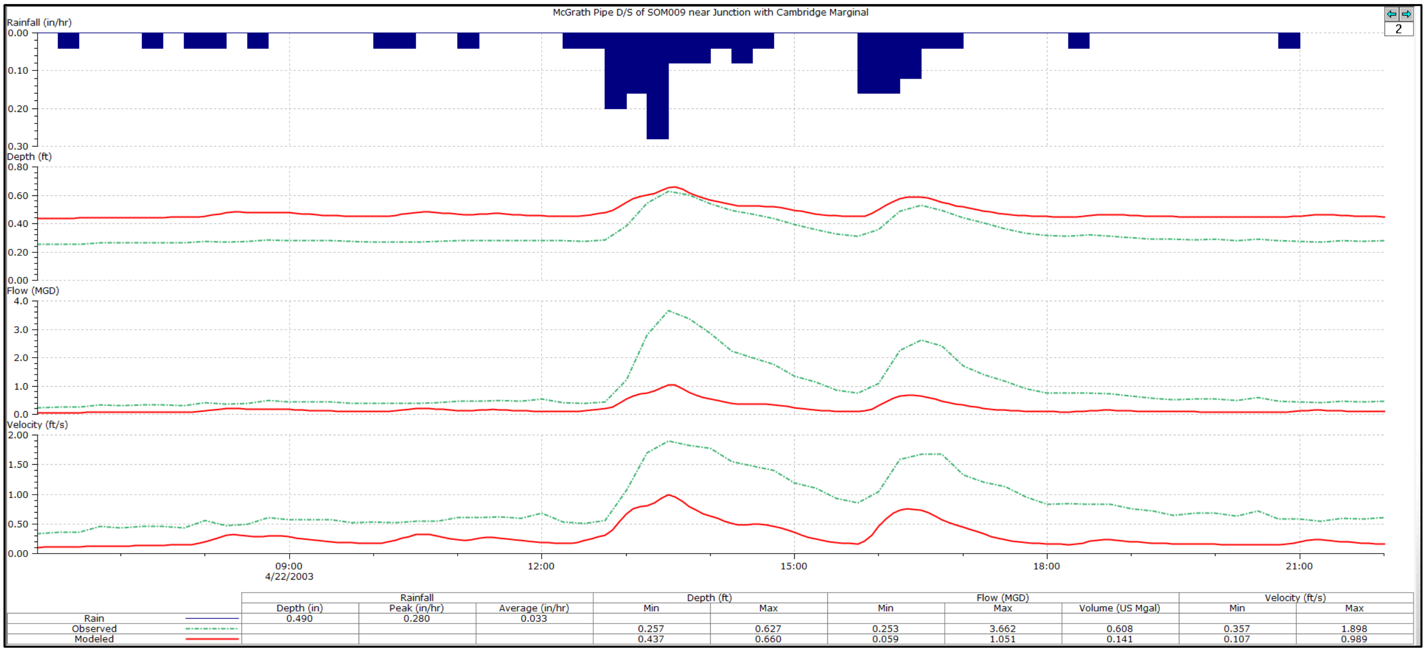
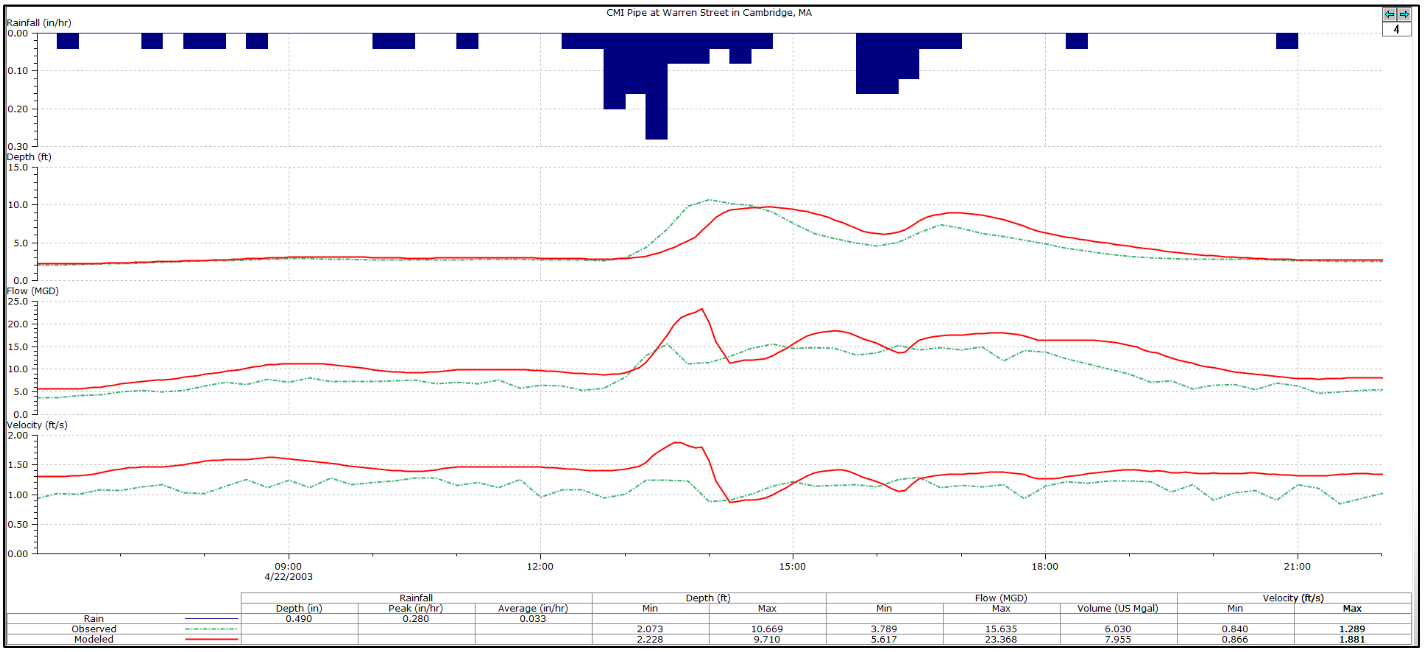
Attachment 2:
Model Calibration Plots



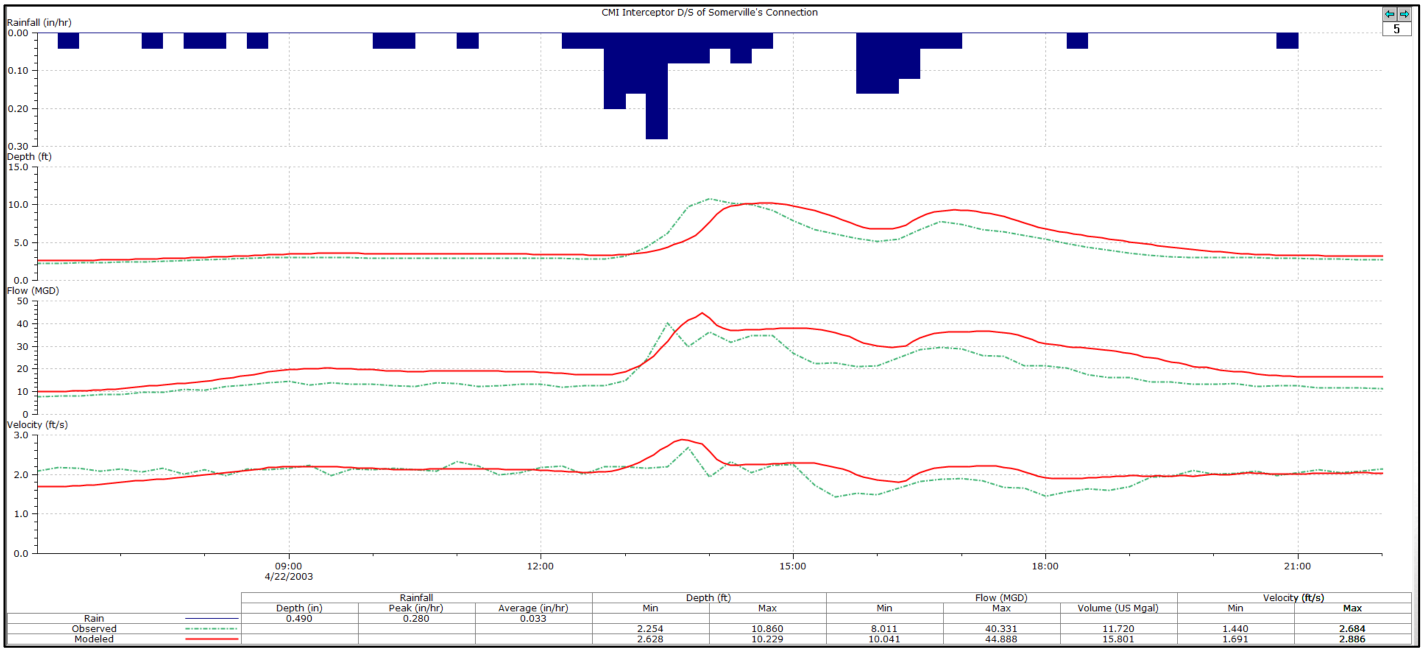
	Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
	Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	0.490	0.280	0.033							
Observed				0.257	0.627	0.253	3.662	0.608	0.357	1.898
Modeled				0.437	0.660	0.059	1.051	0.141	0.107	0.989

Figure A.1.1. Calibration plot in the McGrath Highway pipe downstream of SOM009 during the 04/22/2003 storm



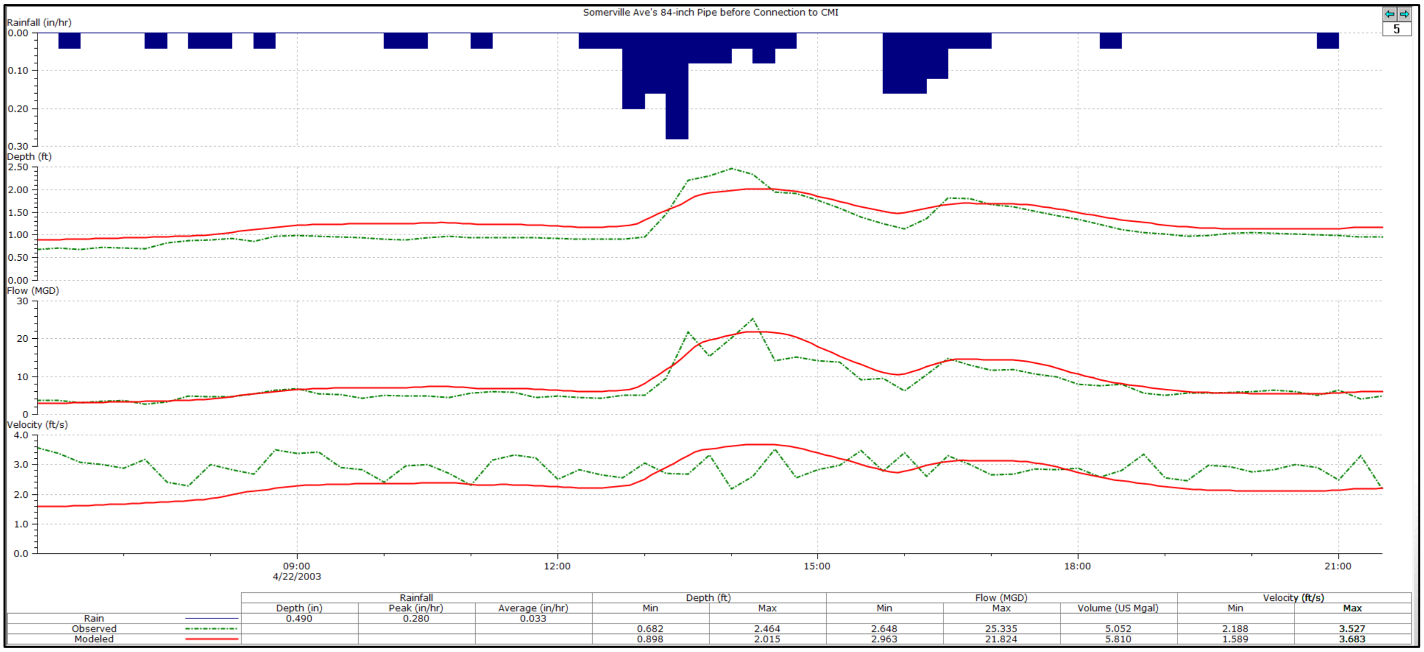
	Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
	Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	**Max**
Rain	0.490	0.280	0.033							
Observed				2.073	10.669	3.789	15.635	6.030	0.840	**1.289**
Modeled				2.228	9.710	5.617	23.368	7.955	0.866	**1.881**

Figure A.1.2. Calibration plot in the MWRA’s CMI in Warren Street in Cambridge, MA during the 04/22/2003 storm



		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	**Max**
Rain	——	0.490	0.280	0.033							
Observed	-·-·-·				2.254	10.860	8.011	40.331	11.720	1.440	**2.684**
Modeled	——				2.628	10.229	10.041	44.888	15.801	1.691	**2.886**

Figure A.1.3. Calibration plot in the MWRA's CMI downstream of the Somerville Ave connections during the 04/22/2003 storm

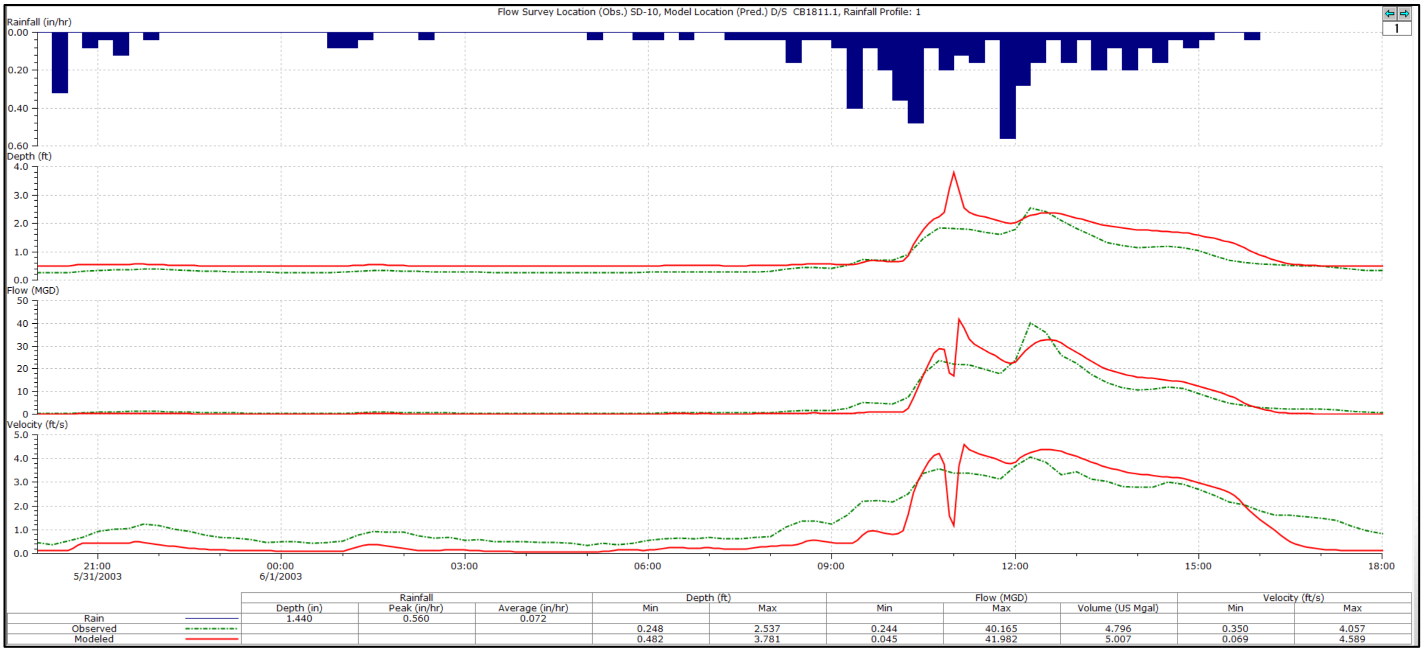


		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	**Max**
Rain	——	0.490	0.280	0.033							
Observed	-·-·-·				0.682	2.464	2.648	25.335	5.052	2.188	**3.527**
Modeled	——				0.898	2.015	2.963	21.824	5.810	1.589	**3.683**

Figure A.1.4. Calibration plot in the 84-inch, Somerville Ave's sewer before Connection to the CMI during the 04/22/2003 storm

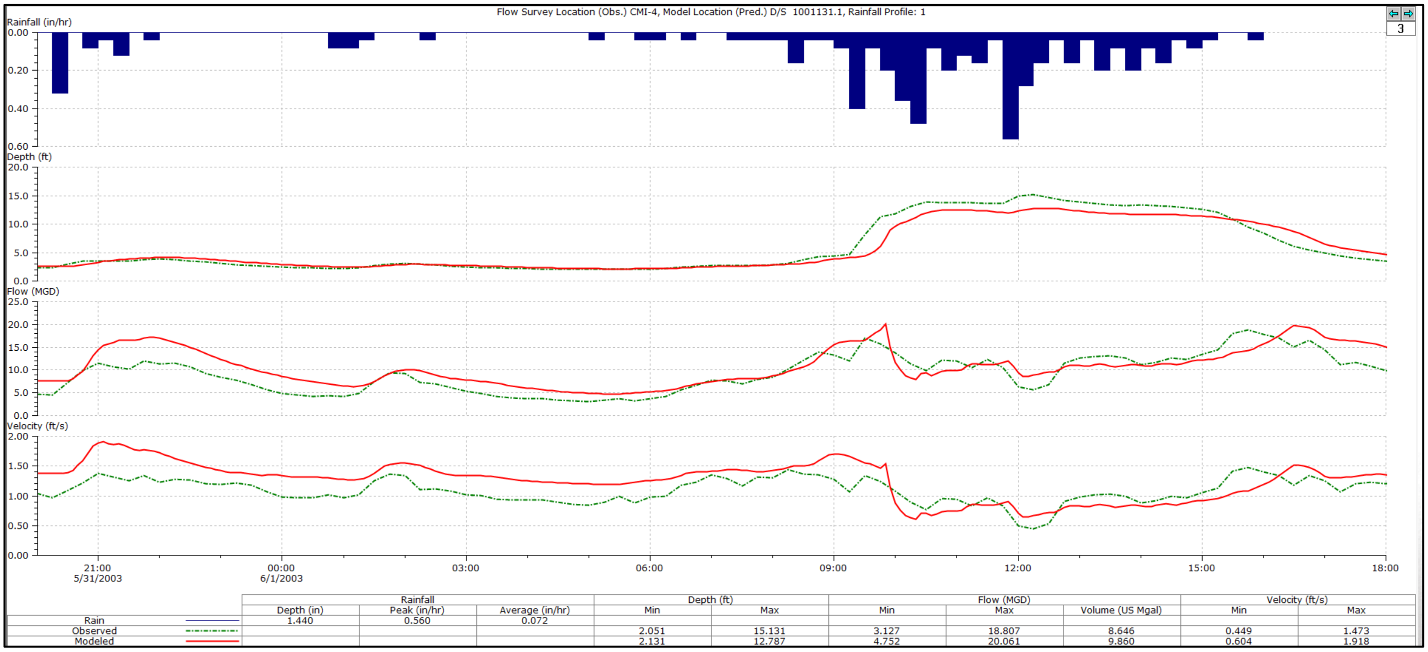
		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	**Max**
Rain	—	0.490	0.280	0.033							
Observed	-·-·-				0.427	2.067	0.251	4.040	0.670	0.791	**4.009**
Modeled	—				0.491	6.106	0.702	1.947	0.837	0.181	**3.550**

Figure A.1.5. Calibration plot in the 26x41”Somerville Ave’s sewer before Connection to the CMI during the 04/22/2003 storm



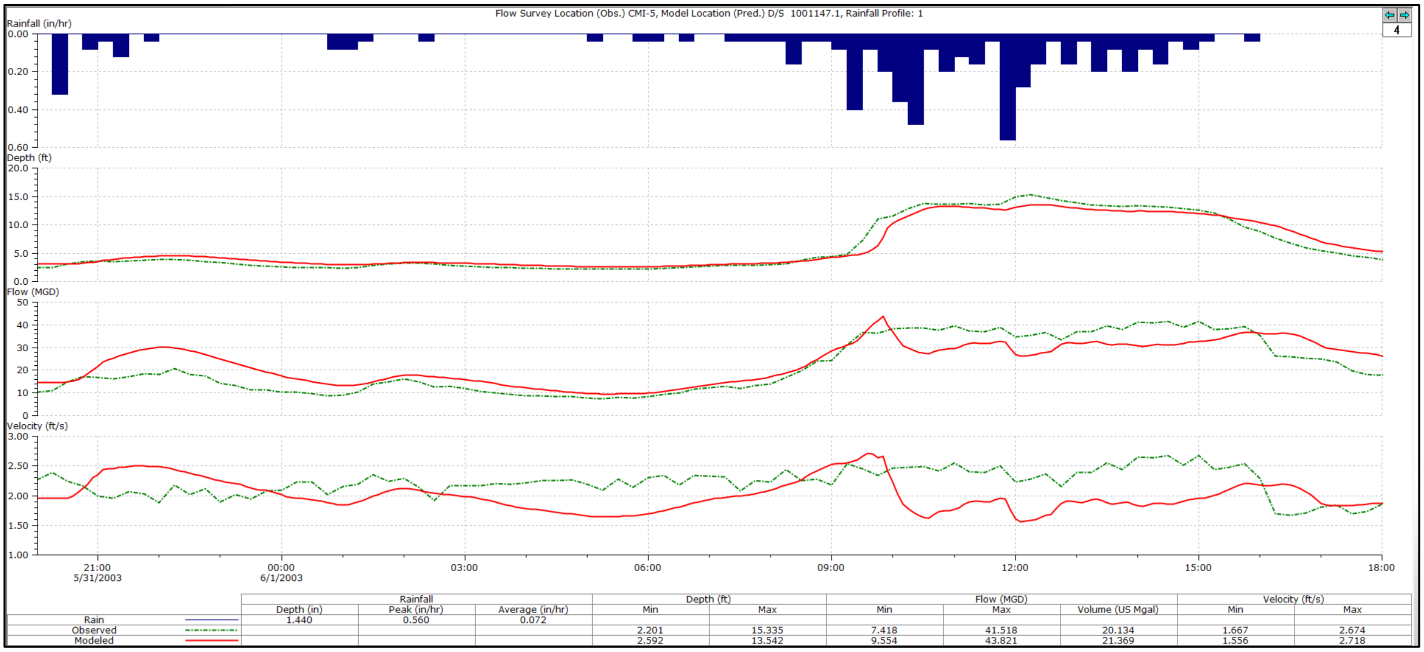
		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	———	1.440	0.560	0.072							
Observed	-·-·-·-				0.248	2.537	0.244	40.165	4.796	0.350	4.057
Modeled	———				0.482	3.781	0.045	41.982	5.007	0.069	4.589

Figure A.1.6. Calibration plot in the McGrath Highway pipe downstream of SOM009 during the 06/01/2003 storm



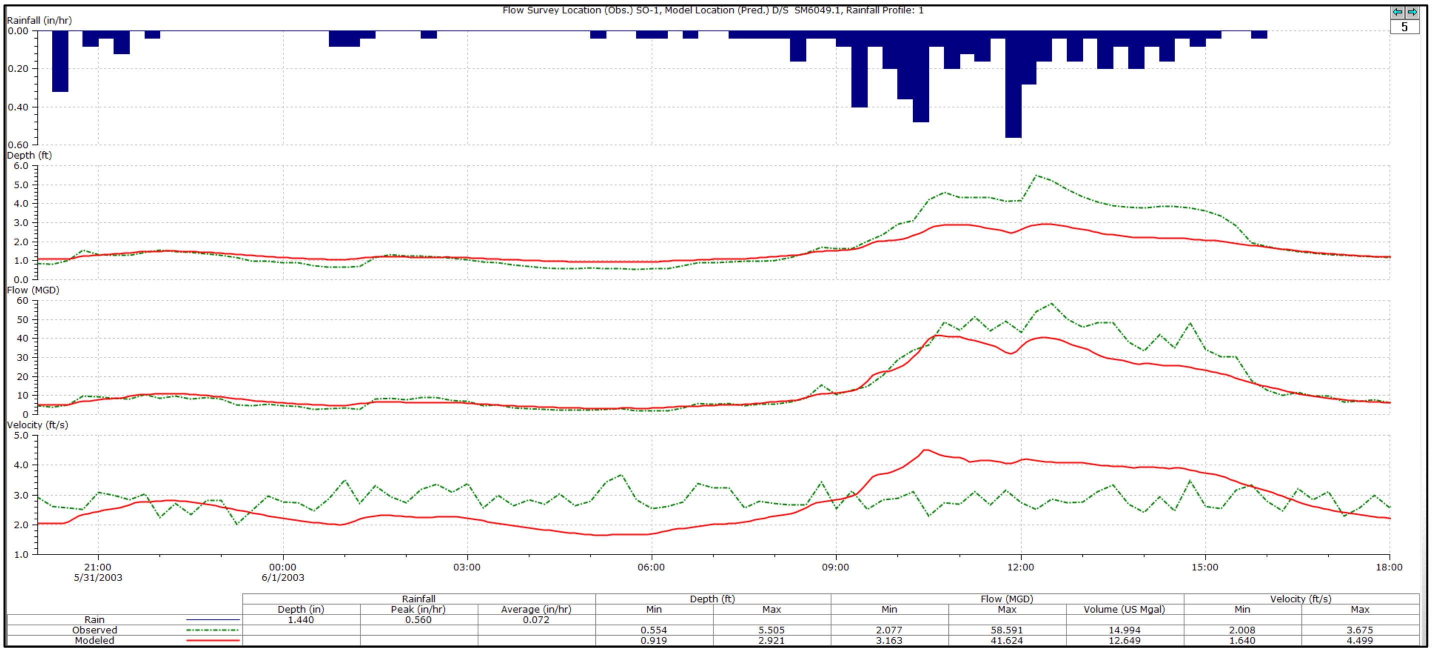
		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	———	1.440	0.560	0.072							
Observed	-·-·-·-				2.051	15.131	3.127	18.807	8.646	0.449	1.473
Modeled	———				2.131	12.787	4.752	20.061	9.860	0.604	1.918

Figure A.1.7. Calibration plot in the MWRA’s CMI in Warren Street in Cambridge, MA during the 06/01/2003 storm



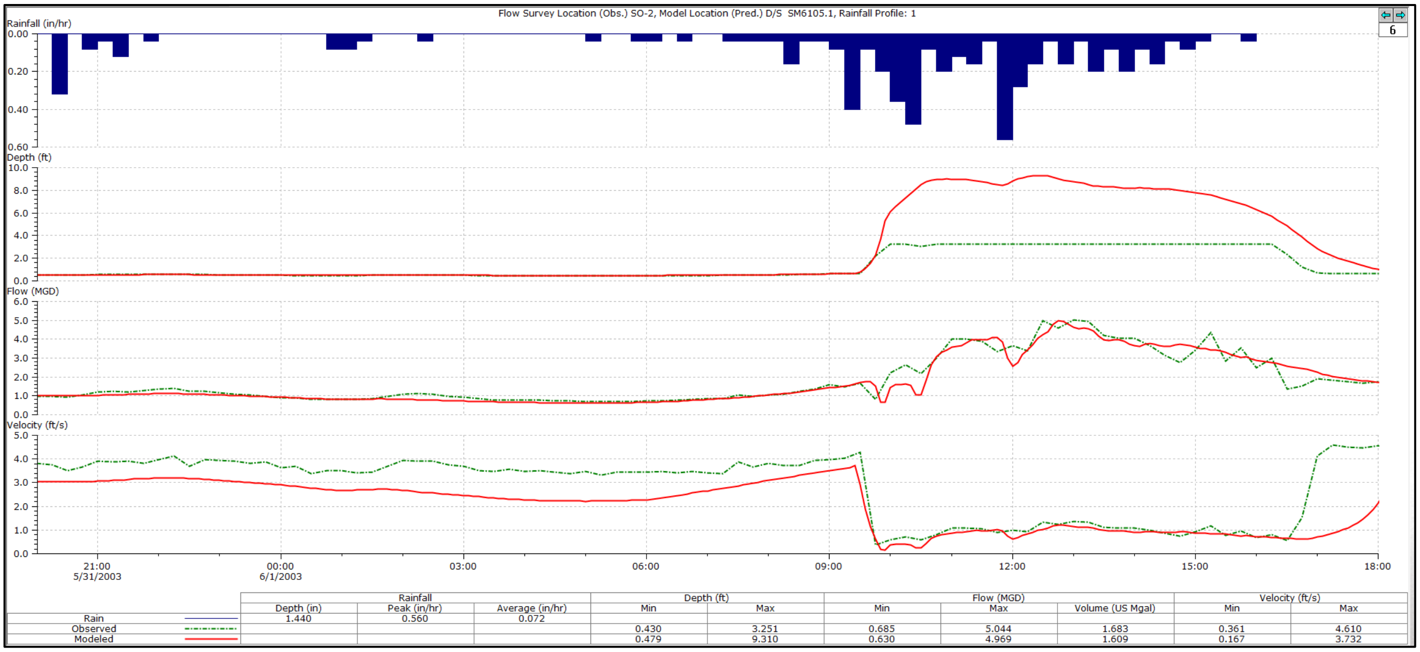
		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	—	1.440	0.560	0.072							
Observed	-·-·-				2.201	15.335	7.418	41.518	20.134	1.667	2.674
Modeled	—				2.592	13.542	9.554	43.821	21.369	1.556	2.718

Figure A.1.8. Calibration plot in the MWRA’s CMI downstream of the Somerville Ave connections during the 06/01/2003 storm



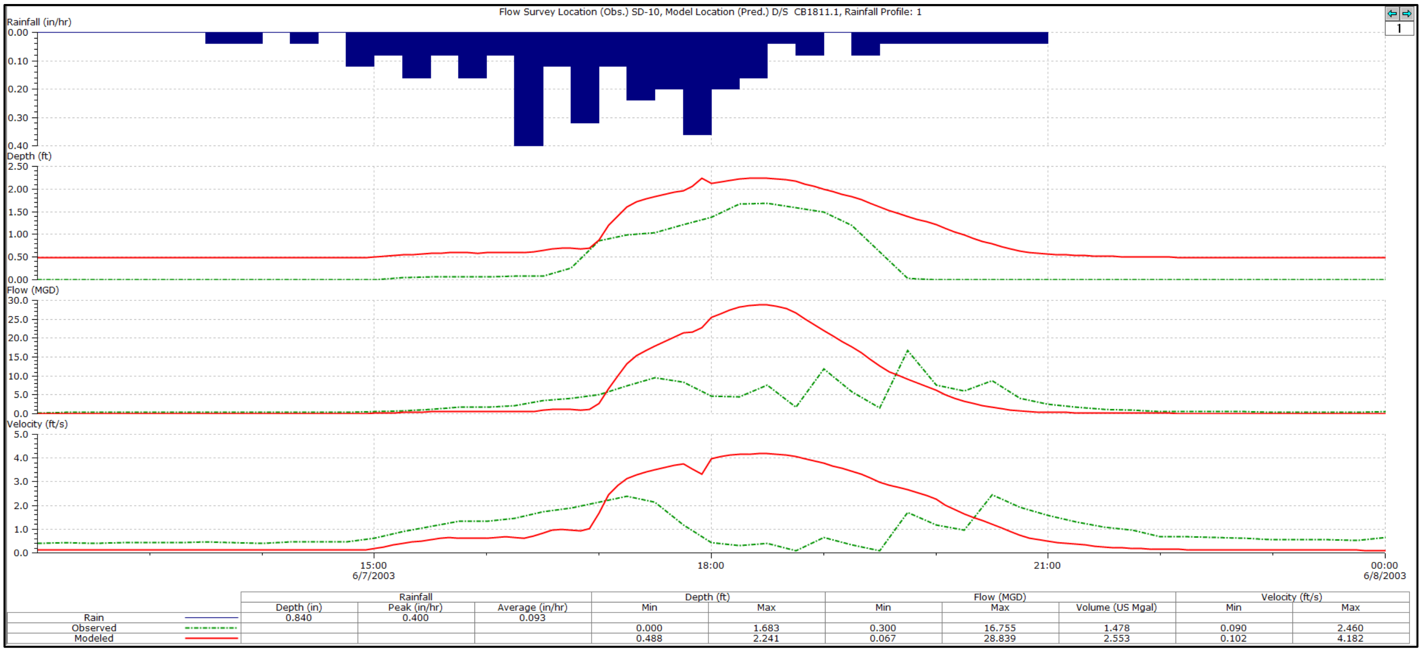
		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	—	1.440	0.560	0.072							
Observed	-·-·-				0.554	5.505	2.077	58.591	14.994	2.008	3.675
Modeled	—				0.919	2.921	3.163	41.624	12.649	1.640	4.499

Figure A.1.9. Calibration plot in the 84-inch, Somerville Ave’s sewer before Connection to the CMI during the 06/01/2003 storm



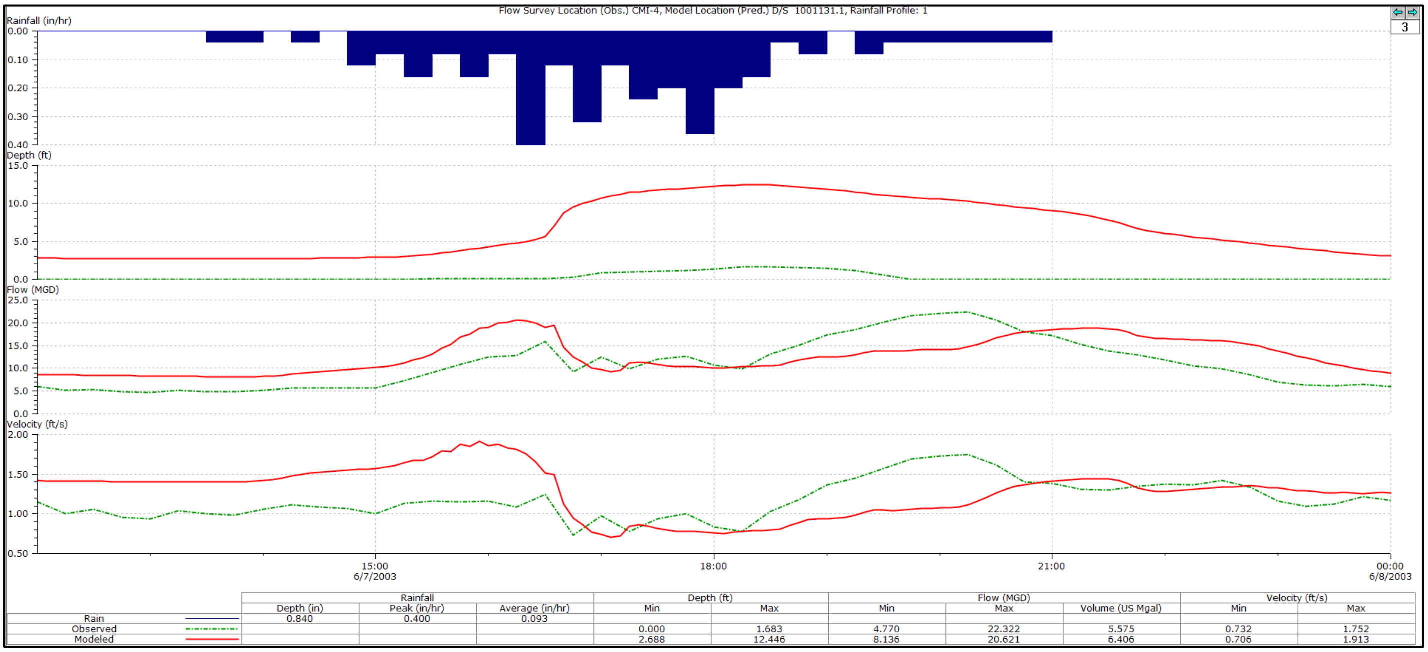
		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	—	1.440	0.560	0.072							
Observed	-·-·-				0.430	3.251	0.685	5.044	1.683	0.361	4.610
Modeled	—				0.479	9.310	0.630	4.969	1.609	0.167	3.732

Figure A.1.10. Calibration plot in the 26x41"Somerville Ave's sewer before Connection to the CMI during the 06/01/2003 storm



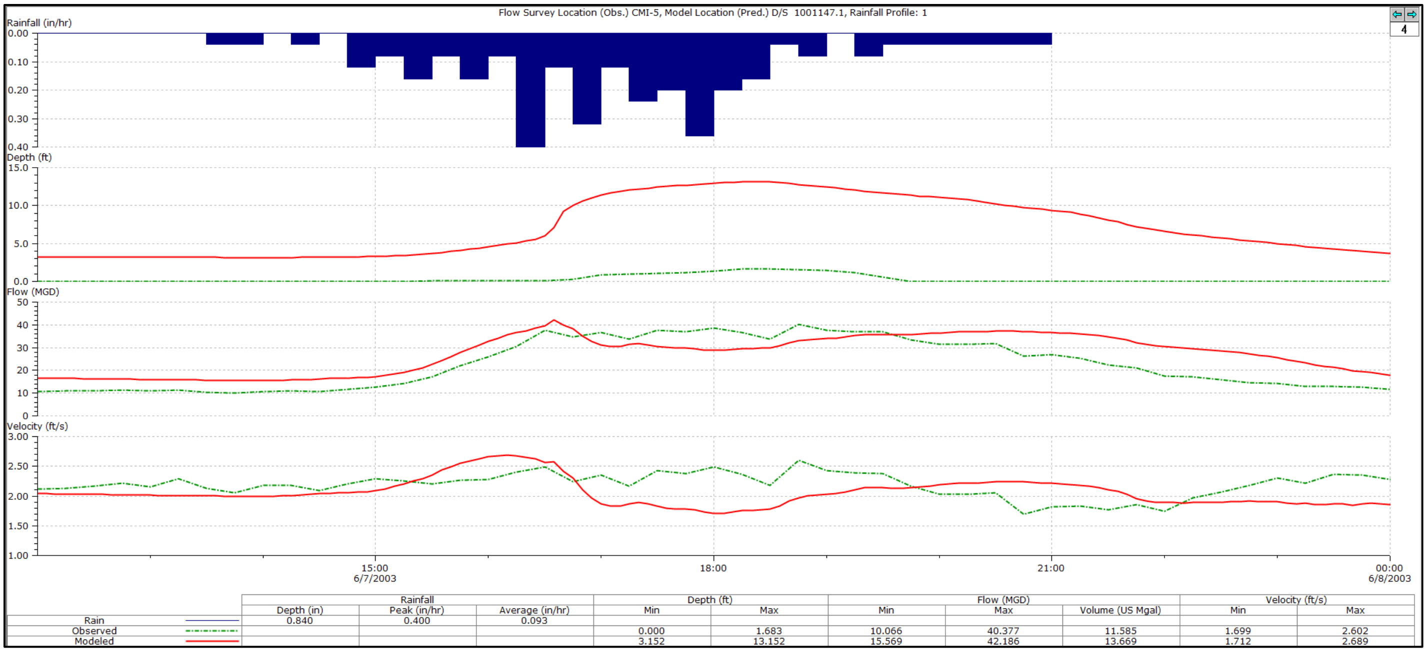
		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	──	0.840	0.400	0.093							
Observed	-·-·-				0.000	1.683	0.300	16.755	1.478	0.090	2.460
Modeled	──				0.488	2.241	0.067	28.839	2.553	0.102	4.182

Figure A.1.11. Calibration plot in the McGrath Highway pipe downstream of SOM009 during the 06/07/2003 storm



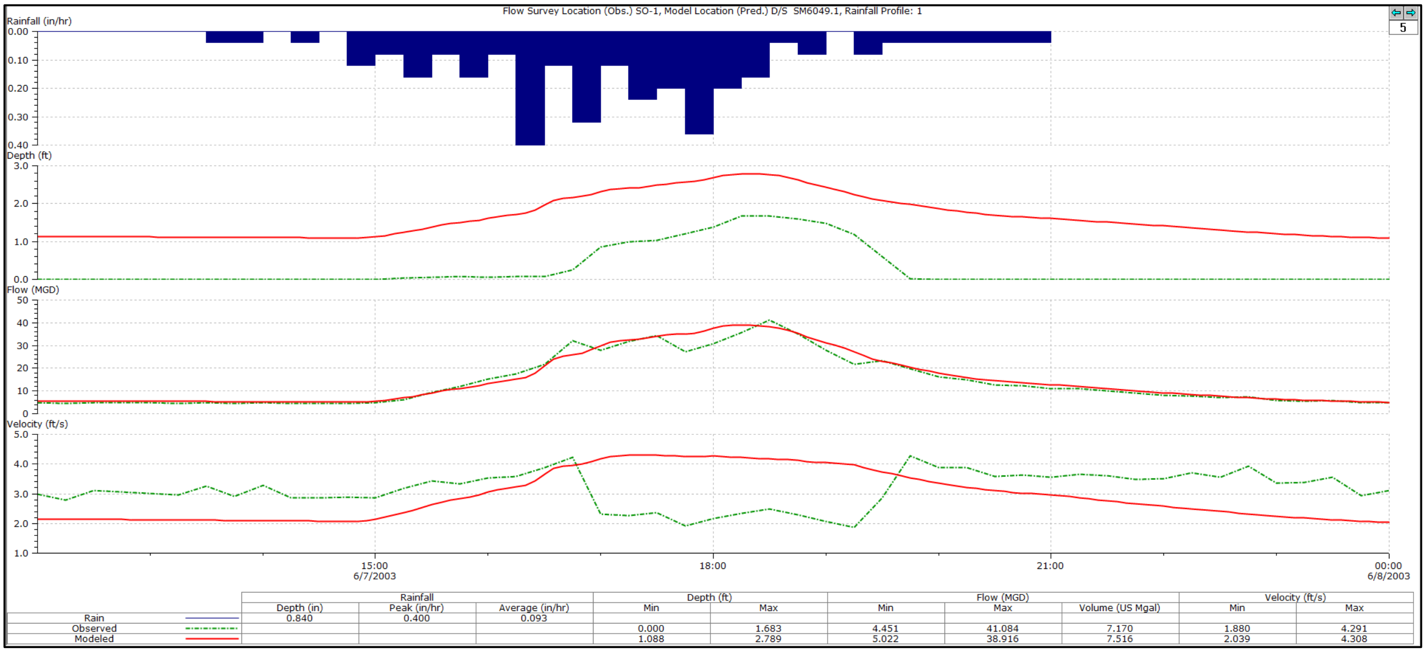
		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	──	0.840	0.400	0.093							
Observed	-·-·-				0.000	1.683	4.770	22.322	5.575	0.732	1.752
Modeled	──				2.688	12.446	8.136	20.621	6.406	0.706	1.913

Figure A.1.12. Calibration plot in the MWRA’s CMI in Warren Street in Cambridge, MA during the 06/07/2003 storm



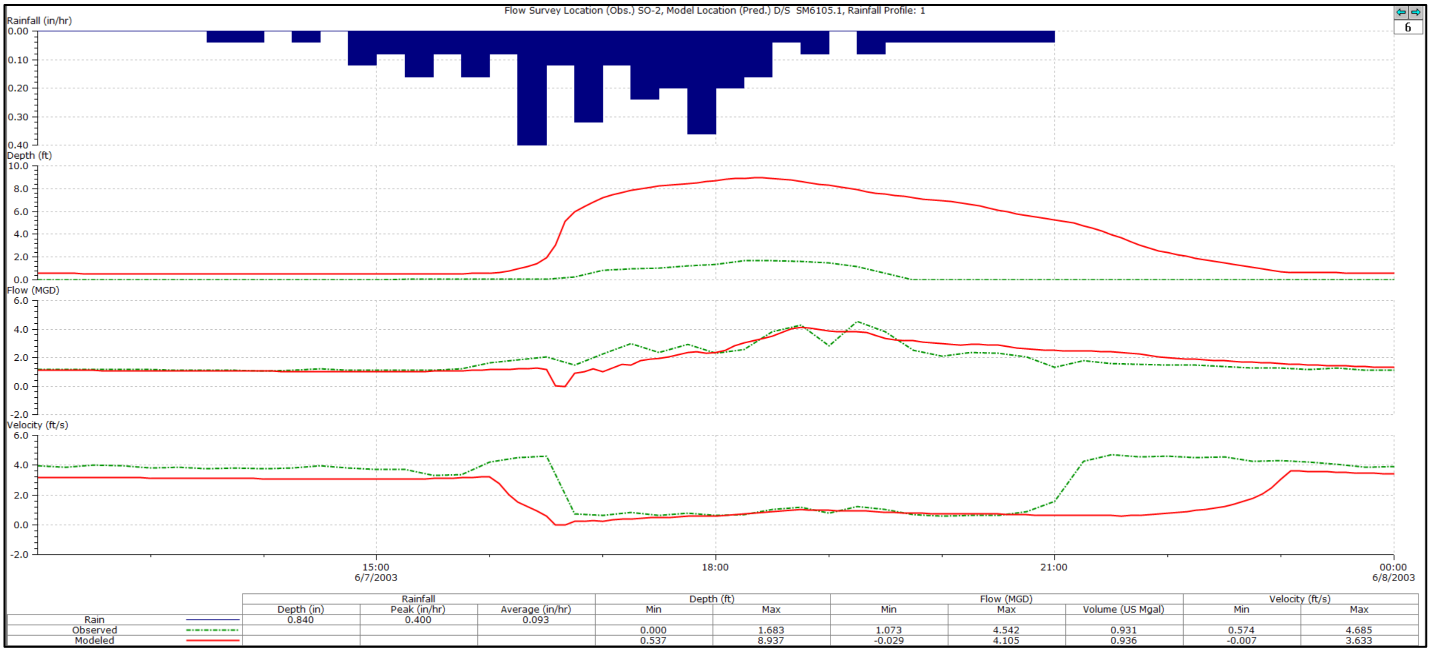
		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	—	0.840	0.400	0.093							
Observed	-·-·-				0.000	1.683	10.066	40.377	11.585	1.699	2.602
Modeled	—				3.152	13.152	15.569	42.186	13.669	1.712	2.689

Figure A.1.13. Calibration plot in the MWRA’s CMI downstream of the Somerville Ave connections during the 06/07/2003 storm



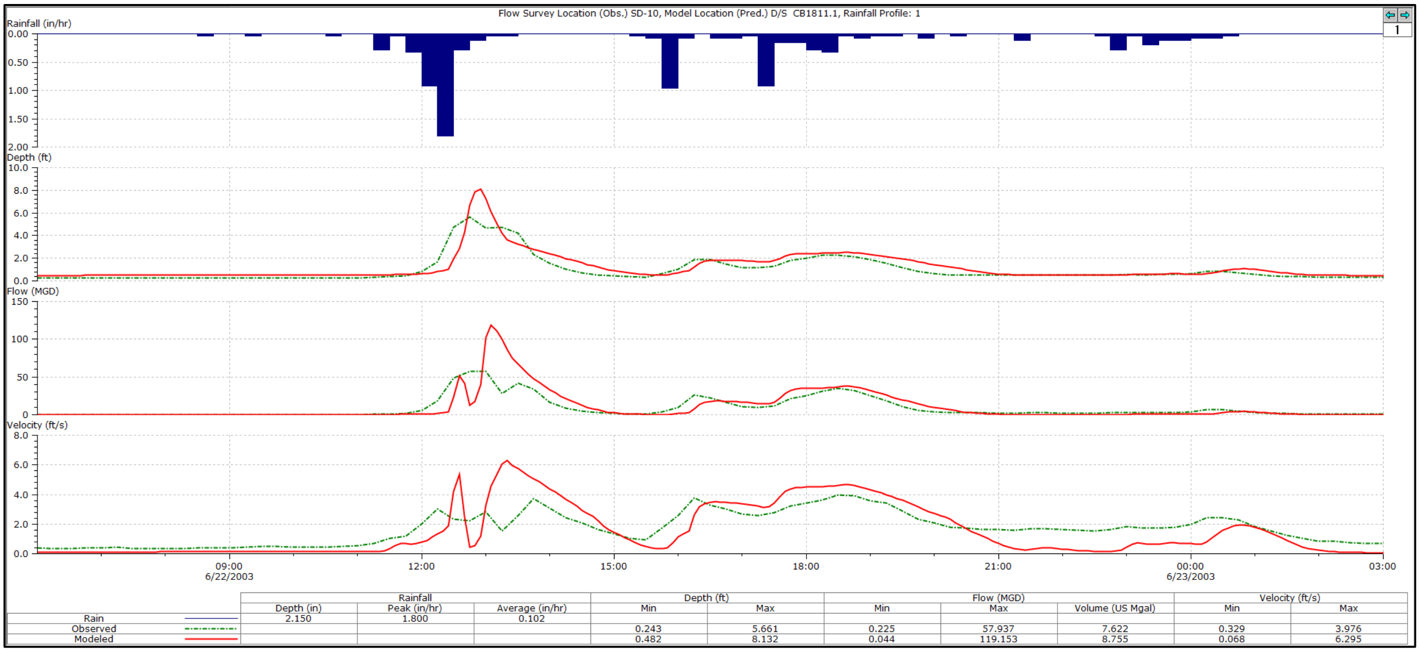
		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	—	0.840	0.400	0.093							
Observed	-·-·-				0.000	1.683	4.451	41.084	7.170	1.880	4.291
Modeled	—				1.088	2.789	5.022	38.916	7.516	2.039	4.308

Figure A.1.14. Calibration plot in the 84-inch, Somerville Ave’s sewer before Connection to the CMI during the 06/07/2003 storm



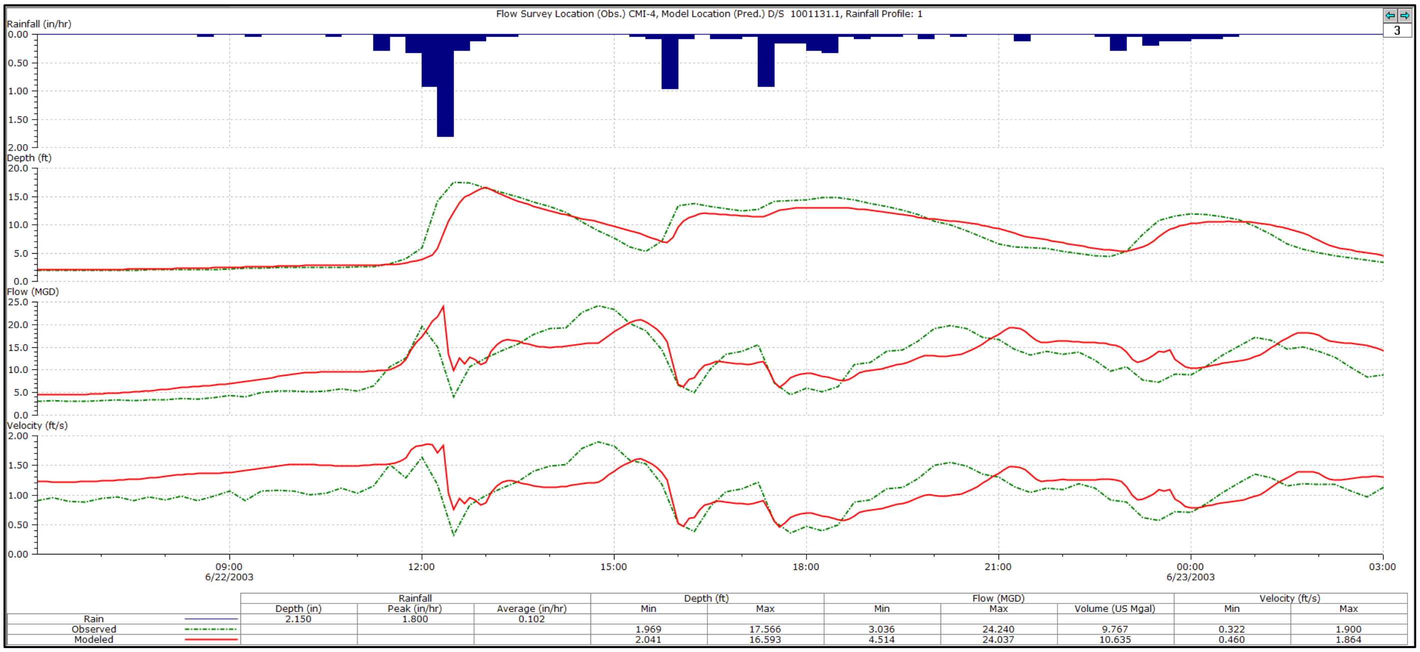
		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	——	0.840	0.400	0.093							
Observed	-·-·-				0.000	1.683	1.073	4.542	0.931	0.574	4.685
Modeled	——				0.537	8.937	-0.029	4.105	0.936	-0.007	3.633

Figure A.1.15. Calibration plot in the 26x41"Somerville Ave's sewer before Connection to the CMI during the 06/07/2003 storm



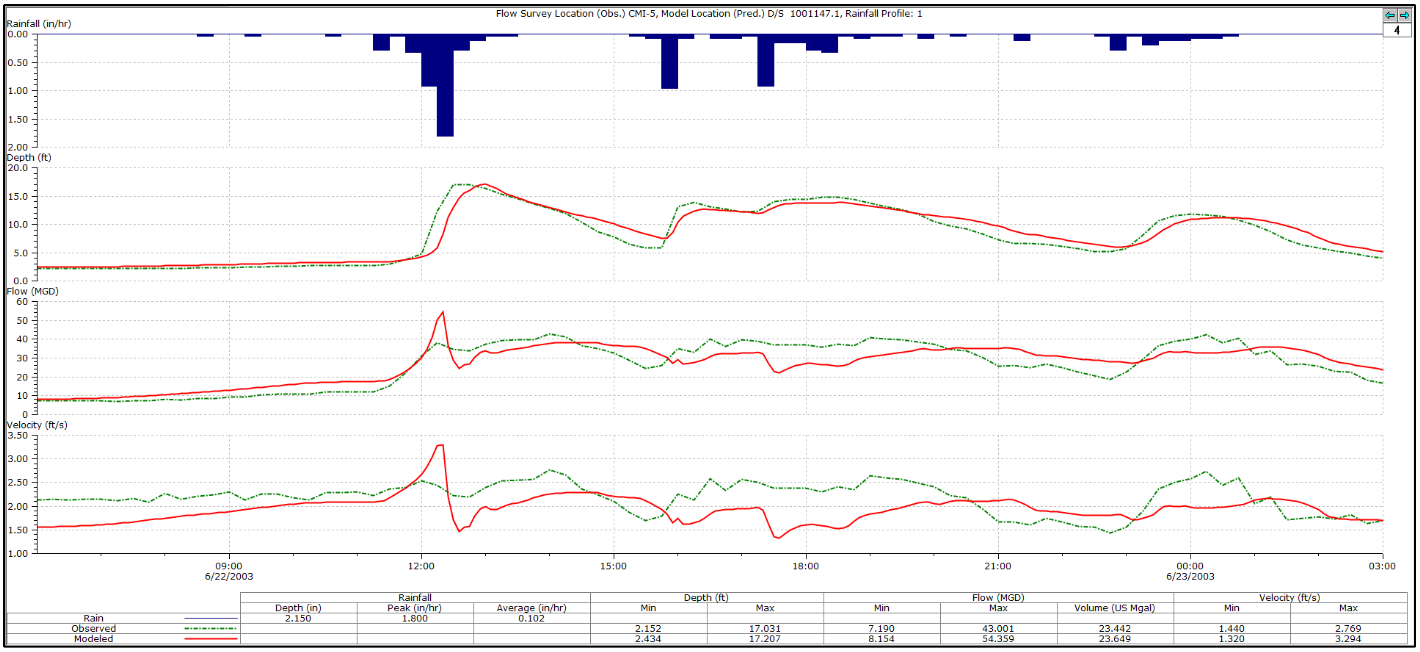
	Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
	Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	2.150	1.800	0.102							
Observed				0.243	5.661	0.225	57.937	7.622	0.329	3.976
Modeled				0.482	8.132	0.044	119.153	8.755	0.068	6.295

Figure A.1.16. Calibration plot in the McGrath Highway pipe downstream of SOM009 during the 06/22/2003 storm



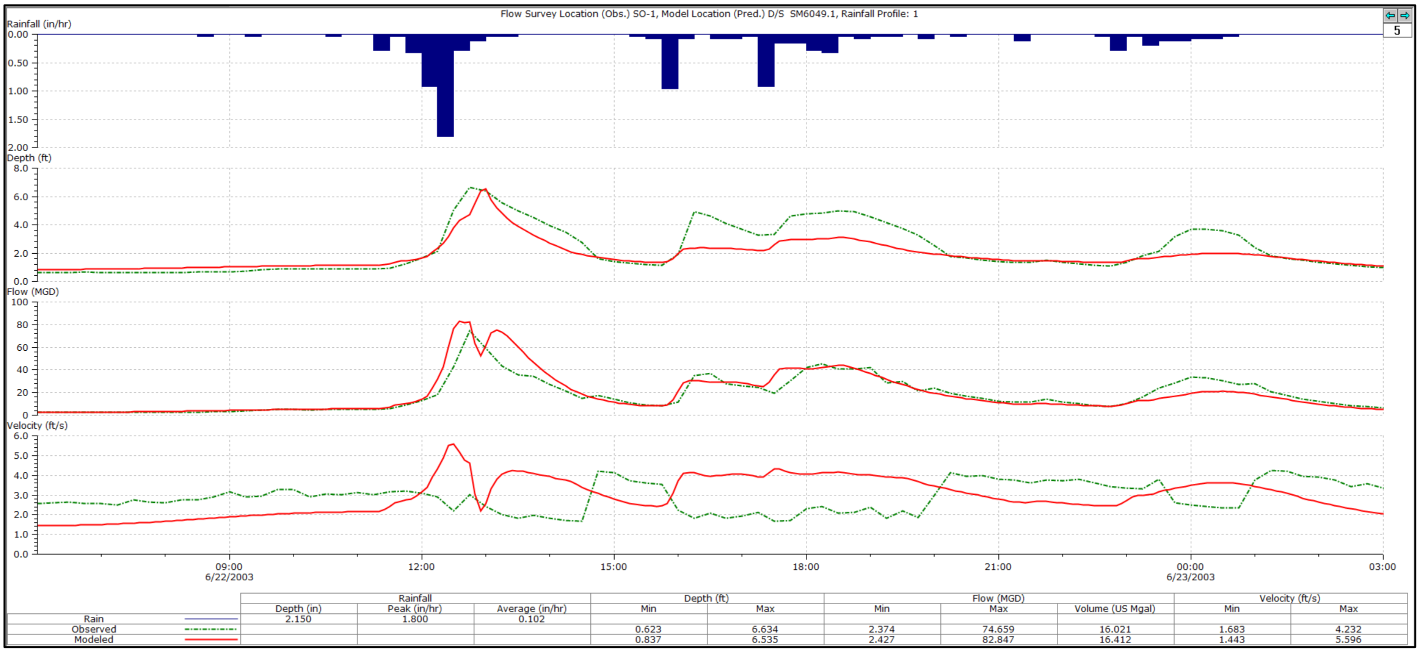
	Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
	Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	2.150	1.800	0.102							
Observed				1.969	17.566	3.036	24.240	9.767	0.322	1.900
Modeled				2.041	16.593	4.514	24.037	10.635	0.460	1.864

Figure A.1.17. Calibration plot in the MWRA’s CMI in Warren Street in Cambridge, MA during the 06/22/2003 storm



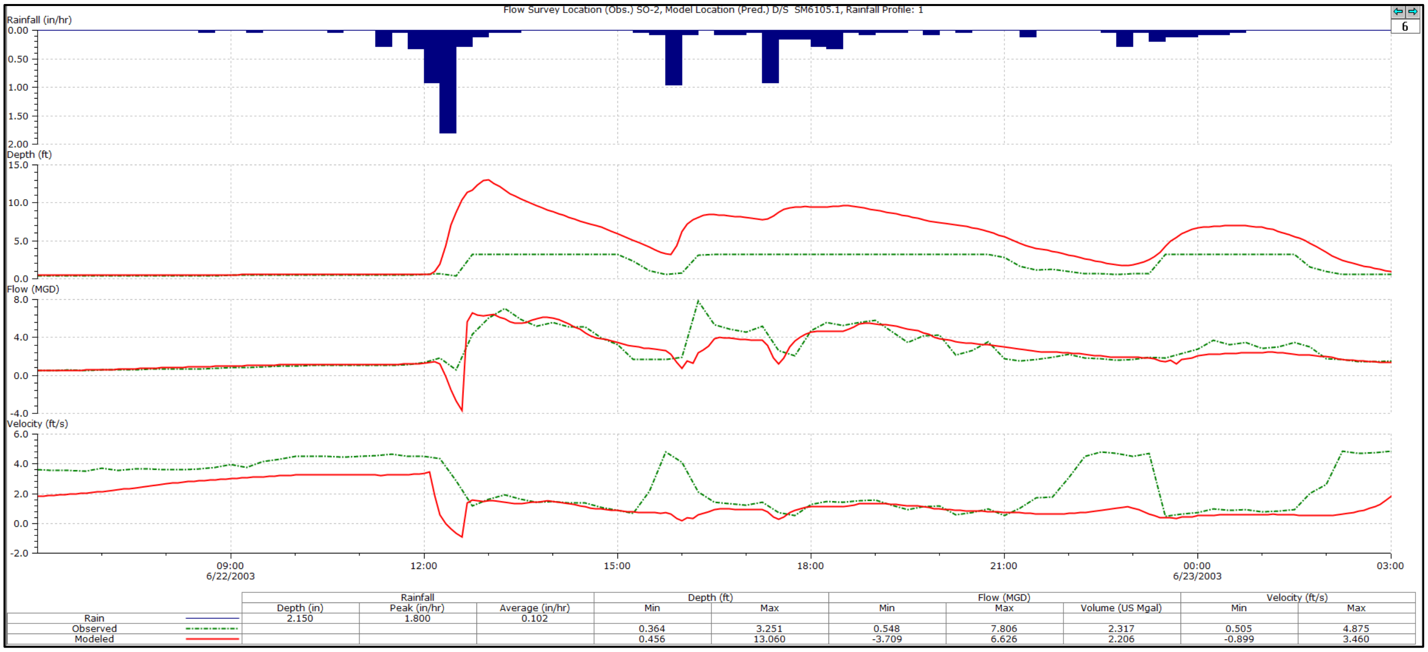
		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain		2.150	1.800	0.102							
Observed					2.152	17.031	7.190	43.001	23.442	1.440	2.769
Modeled					2.434	17.207	8.154	54.359	23.649	1.320	3.294

Figure A.1.18. Calibration plot in the MWRA’s CMI downstream of the Somerville Ave connections during the 06/22/2003 storm



		Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
		Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain		2.150	1.800	0.102							
Observed					0.623	6.634	2.374	74.659	16.021	1.683	4.232
Modeled					0.837	6.535	2.427	82.847	16.412	1.443	5.596

Figure A.1.19. Calibration plot in the 84-inch, Somerville Ave’s sewer before Connection to the CMI during the 06/22/2003 storm



	Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
	Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	2.150	1.800	0.102							
Observed				0.364	3.251	0.548	7.806	2.317	0.505	4.875
Modeled				0.456	13.060	-3.709	6.626	2.206	-0.899	3.460

Figure A.1.20. Calibration plot in the 26x41”Somerville Ave’s sewer before Connection to the CMI during the 06/22/2003 storm