CHAPTER FIVE

DEVELOPMENT AND EVALUATION OF CSO CONTROL ALTERNATIVES

This chapter presents the methodology used in developing and evaluating CSO control alternatives for Alewife Brook; presents the baseline conditions from which the CSO control alternatives were developed; provides descriptions of the alternatives that were developed; and summarizes the performance of the range of alternatives.

METHODOLOGY

The range of CSO control alternatives presented herein were developed and evaluated at a master planning level of detail, consistent with the approach presented in the December 1994 CSO Conceptual Plan. The following section presents the specific methodology followed in developing and evaluating these alternatives.

Development of Alternatives

The process of developing CSO control alternatives for Alewife Brook generally involved identification of appropriate technologies, sizing the technologies for a range of CSO control levels based on predicted activation frequencies and volumes from the detailed SWMM model, and developing master planning-level layouts for the technologies.

Technologies to be Evaluated. Following the methodology used in the December 1994 CSO Conceptual Plan, the technologies to be evaluated were selected from the following overall list of CSO control technologies:

- Sewer Separation
- CSO Relocation
- Interceptor Relief/Pumping Station Modification
- CSO Consolidation

- In-System Storage
- Near Surface Storage/Treatment
- Deep Tunnel Storage
- Equivalent Primary Treatment
- Screening and Disinfection
- Floatables Control

For planning purposes, "equivalent primary treatment" was assumed to be a detention/treatment tank sized for a peak overflow rate of 4,500 gpd/sf, with fine screening, disinfection and dechlorination. It is recognized that emerging technologies such as chemically-enhanced primary treatment or ballasted flocculation may reduce the footprint and potentially the construction cost of providing equivalent primary treatment, although O&M costs may be higher. The detention/treatment tank, however, was assumed to serve as a reasonable place-holder for the range of treatment technologies for the purpose of cost/benefit analyses.

In the 1994 CSO Conceptual Plan, certain technologies and outfall consolidation options were eliminated from further consideration without developing more detailed cost and performance data, based on system knowledge, SWMM results and input from project workshops. Consistent with this approach, the following technologies were initially eliminated from further consideration:

- CSO relocation. A less-sensitive receiving-water segment is not located in the vicinity of Alewife Brook.
- Individual storage and/or treatment facilities for each outfall. Given the number of outfalls and limited space available along Alewife Brook, this alternative was not considered to be implementable.
- Deep tunnel storage. In the CSO Conceptual Plan, each of the regional deep tunnel storage alternatives that were developed assumed that local, near-surface controls would be provided for the Alewife Brook outfalls. Consistent with this approach, deep-rock tunnel storage alternatives were not evaluated further in this report.

- In-system storage. Based on preliminary modeling, it was apparent from surcharging of the interceptors and upstream piping systems that limited, if any, in-system storage would be available that was not already being used.

- Floatables control. Based on modeling of existing conditions, providing only floatables control, with no reduction in overflow frequency or volume, would not meet the regulatory intent of minimizing CSOs to the maximum extent feasible required for a BCSO designation for Alewife Brook. Since this alternative would not meet the minimum likely water quality designation for the receiving water, it was not considered further.

Sizing Criteria. In order to establish the appropriate level of CSO control for Alewife Brook, it was appropriate to assess both a range of CSO control technologies, as well as a range of design capacities for those technologies. Consistent with the EPA's National CSO Control Policy, the technologies selected for evaluation were sized for the following range of capacities:

- Total elimination of CSO (if feasible)
- Elimination of untreated CSO discharges in the typical year
- Allowing 1 to 4 untreated discharges in the typical year
- Allowing 4 to 7 untreated discharges in the typical year

For alternatives that involved a consolidation conduit, the specific range of alternatives developed included 0, 2 and 4 untreated overflows per year. For the partial sewer separation alternatives that did not include a consolidation conduit, the range of control was expanded to 7 untreated overflows per year. Sizing criteria for individual technologies were based on the criteria presented in Appendix D of the October 1996 Draft Combined Sewer Overflow Facilities Plan and Environmental Impact Report (DEIR). Key criteria that relate to the sizing and/or cost of technologies are summarized in Table 5-1.

TABLE 5-1. SIZING/DESIGN CRITERIA FOR CSO CONTROL TECHNOLOGIES

Technology	Parameter	Design Criteria
Storage Tanks	Maximum sidewater depth	15 ft.
	Vertical clearance between tank ceiling and maximum water surface	10.5 ft.
Primary Treatment Tanks	Peak overflow rate	4,500 gpd/sf
	Minimum detention time	15 minutes
	Minimum sidewater depth	12 ft.
	Vertical clearance between tank ceiling and maximum water surface	10.5 ft.
Consolidation Conduits	Peak flow conveyance capacity for consolidation to storage tank	Peak flow from design storm used for sizing storage
	Peak flow conveyance capacity for consolidation to treatment (primary or screening and disinfection)	Peak flow from the largest storm in the typical year
	Minimum Slope	0.001 ft./ft.
	Minimum diameter for tunnel boring machine with precast segmented liner	8 ft.
	Diameter range for microtunnel with jacked pipe	<8 ft.
Sewer Separation	Maximum reduction in inflow typically achievable[1]	80 percent

Notes: [1] If, on a site specific basis, a higher level of inflow removal is determined to be required to meet a specific CSO control goal, additional cost would be factored into the unit costs for separation.

Siting/Layout Criteria. Consistent with the approach taken in the CSO Conceptual Plan, a cursory evaluation of siting potential was performed for each alternative. Consolidation conduits were routed to avoid passing under existing buildings, and storage/treatment tanks were located in existing "open" areas, which may include parking lots and/or parklands. The Atlas of the City of Cambridge, taken from the City of Cambridge web site, was used as a background map for the locations of streets, buildings and open spaces. The background mapping information should be considered general, and has not been field-verified for this report. Siting issues and other non-monetary factors were qualitatively identified in a tabular format. Categories of siting and non-monetary issues considered for each alternative included the following:

- Construction-related siting impacts
- Long-term siting impacts
- Operations and Maintenance considerations

These categories were carried forward for use in the alternatives evaluation process.

Work Completed to Date. The scope of the CSO control alternatives described in this chapter includes work related to implementing the recommended CSO control plan as presented in the FEIR that has been completed to date, or is committed to being completed. These work items include the following:

- **Outfall Cleaning.** This work involved cleaning of the existing CAM004 outfall, as a short-term measure to improve the hydraulic capacity of the outfall.
- **Fresh Pond Parkway Sewer Separation/Hydraulic Capacity Improvement.** This work represents the first phase of the planned separation of the CAM004 tributary area in accordance with the FEIR recommended plan. Hydraulic evaluations conducted during preliminary design indicated that the existing combined sewer and storm drain trunks that run along Fresh Pond Parkway between the residential CAM004 tributary area and the CSO regulator associated with CAM004 had insufficient capacity to convey peak flows from extreme storm events (e.g. on the order of the 10 year storm). Since surcharging along Fresh Pond Parkway could potentially threaten the Fresh Pond water supply, it was determined that improvements to the conveyance capacity would be required, regardless of the final

CSO control solution for outfall CAM004. This work, identified as Cambridge Contracts 2A and 2B, is approximately 70 percent complete at this time.

- **Orchard Street Sewer Separation.** The Orchard Street area is located in the upstream reach of the CAM002 tributary area. Consistent with the FEIR recommended plan, work to separate this area was completed as an initial step in the complete separation of the CAM002 area. The separate sanitary and separate stormwater pipes were connected to the existing combined sewer trunk tributary to the CAM002 regulator. The remaining upstream CAM002 separation work could not be completed until the hydraulic capacity of the main trunk was increased. Proposed work related to increasing the capacity of the main trunk has been indefinitely suspended, pending resolution of the updated recommended plan for Alewife Brook.

- **Floatables Control.** Various floatables control measures were identified for the outfalls along Alewife Brook in Cambridge during preliminary design. Based on the presumption that the updated recommended plan for Alewife Brook would not feature complete elimination of all outfalls, the floatables control projects are still considered part of the recommended plan.

- **New CAM004 Outfall.** The existing CAM004 outfall was determined in preliminary design to have insufficient capacity to convey flows from storms greater than approximately the 2-year storm. Because of the potential consequences of upstream surcharging adjacent to the water supply at Fresh Pond, construction of the new outfall was considered necessary, regardless of the final CSO solution for outfall CAM004. It should be noted that the storage and treatment alternatives considered for outfall CAM004 were sized for no greater than the flows from the largest storm in the typical year. Thus, even under a storage alternative, outfall conveyance capacity would be required to relieve surcharging during more extreme storm events. The new CAM004 outfall is currently under design, with construction scheduled to be completed by the end of 2002.

- **Berm.** A berm along the west side of Alewife Brook between Route 2 and Massachusetts Avenue is proposed to mitigate existing flooding as well as the impacts of additional stormwater discharge to Alewife Brook.

Costs associated with the above items are presented below.

Evaluation of Alternatives

The CSO control alternatives for Alewife Brook were evaluated based primarily on cost (capital, annual O&M, and net present value) and performance, with additional consideration given to non-monetary factors. The cost/performance analysis emphasized optimizing environmental benefit while ensuring a responsible use of public funds.

Cost. Costs developed for the various alternatives included capital costs, annual O&M costs, and net present value. Construction costs were developed from cost curves that were derived from a range of sources including published cost equations, site-specific cost estimates developed during CSO facilities planning and recent design projects, and contractor's bid tabulations. Estimated annual O&M costs were developed from estimated hours of operation and staff levels, with allowances for chemicals and utilities. More detailed descriptions of the development of construction and O&M costs for each technology, along with relevant cost curves, are presented in the Appendices. All construction costs were adjusted to a March, 2001 Boston-area Engineering News Record Construction Cost Index of 6986.

In accordance with the MWRA's LCCA policy, a 25 percent contingency and 20 percent allowance for engineering and construction management were added to the estimated construction cost to create the estimated capital cost. The one exception to this policy was for the estimated cost for sewer separation in the CAM004 area. A memorandum from SEA dated July 7, 1999, presented a preliminary design level estimate for the construction cost that included a 15 percent contingency (appropriate for preliminary design, according to the MWRA's LCCA policy). Net present value was computed using the MWRA's LCCA spreadsheet, based on a discount rate of 6 percent, an inflation rate of 3.5 percent, an effective discount rate of 3.42 percent, and a 30-year term.

The capital cost of all alternatives was adjusted to include the cost of the work already completed or committed to be completed, as described above. The costs of these items are summarized in Table 5-2. As indicated in Table 5-2, a total of $50,064,000 was added to the capital cost of each of the CSO control alternatives developed below to represent a total program cost for each alternative.

Performance. Performance was assessed in terms of reduction in annual CSO activation frequency and pollutant load. Storage alternatives were assumed to remove 100 percent of the

TABLE 5-2. SUMMARY OF COST OF WORK ITEMS ALREADY COMPLETED OR COMMITTED TO BE COMPLETED

Element	Total Cost
Outfall Cleaning (Contract 1)	$452,500
Fresh Pond Parkway (Contracts 2A and 2B)	$16,171,900
Orchard Street Separation (Contract 3)	$2,509,500
Engineering on Contracts 1 to 3	$6,994,400
Floatables Control (Contracts 4 and 5)	$1,730,400
New CAM004 Outfall (Contract 12)	$10,395,000
Berm	$300,000
MWR003 Floatables Control	$300,000
Contingency (Contracts 4, 5 and 12)	$1,649,500
Engineering (Contracts 4, 5 and 12, and amendments)	$9,560,600
TOTAL	**$50,063,800**

load from the stored volumes, with no removal of load from volumes above the storage capacity. Primary treatment alternatives removed 100 percent of the load from volumes up to the storage capacity of the tank/consolidation conduit. For storms within the design overflow flow rate, effluent fecal coliform bacteria was assumed to be 200 counts/100 ml, with 40 percent TSS removal and 20 percent BOD removal. For storms exceeding the design flow rate, effluent fecal coliform bacteria was assumed to be 5,000 counts/100 ml, with 20 percent TSS removal and 5 percent BOD removal. Screening and disinfection alternatives removed 100 percent of the load from volumes up to the storage capacity of the consolidation conduit. For storms within the design flow rate (the largest peak flow in the typical year), effluent fecal coliform bacteria was assumed to be 200 counts/100 ml, with 5 percent TSS removal and no BOD removal.

Pollutant loadings were established on an annual basis based on predicted annual volumes and average pollutant concentrations. With the exception of fecal coliform bacteria concentration in stormwater, the average pollutant concentrations for untreated CSO and stormwater were the same as were used for the CSO master planning and facilities planning programs. These values were based on sampling programs and research conducted in support of the CSO master planning program. For CSO pollutant concentrations, the master planning data represents the best data available. Recent sampling conducted along Alewife Brook and the Upper Mystic River during 1999 and 2000 to support the Variance indicated that the average stormwater bacteria concentration appeared to be substantially lower than the area-wide average concentration used in master planning and facilities planning. Baseline stormwater bacteria loadings were therefore computed using the average of the more recent data (12,600 #/100ml) in lieu of the average of the earlier data (30,250 #/100ml). The TSS and BOD values for the recent stormwater sampling were relatively close to the values used in master planning, so the master planning values for those parameters were used. The average values for bacteria, TSS and BOD for untreated CSO and stormwater are summarized in Table 5-3. Annual CSO and stormwater volumes were developed from the SWMM typical year simulations.

Cost/Performance Curves. A key aspect of the evaluation process was the development of cost/performance curves, which helped to identify the most cost-effective alternatives based on the "knee of the curve" analysis. The knee of the curve is the point at which further investment in CSO control yields diminishing returns in terms of pollutant load reduction. The curves were developed for CSO-only and total loads of fecal coliform bacteria, TSS, and BOD. In the case of Alewife Brook, "total" annual loads would include pollutant loads from CSO and stormwater discharges.

Non-Monetary Factors. Non-monetary factors were qualitatively assessed in a matrix format, by assigning relative ratings (+, 0, -) to each of the three categories of factors presented in the description of alternatives. The relative ratings were defined as follows:

+	Signified the alternative is better than others for the non-monetary factor rated.
0	Signified the alternative is not as good as some, but better than others for the non-monetary factor rated.
-	Signified the alternative is less suited than others for the factor rated.

The ratings were summed, to provide an overall relative rating of the non-monetary impacts of the alternatives.

TABLE 5-3. AVERAGE POLLUTANT CONCENTRATIONS FOR CSO AND STORMWATER

	Fecal Coliform Bacteria (counts/100ml)	TSS (mg/l)	BOD (mg/l)
Untreated CSO[(1)]	538,000	140	78
Untreated Stormwater[(1)(2)]	12,600	38	20

Notes: (1) Refer to the Draft System Master Plan Baseline Assessment, June 1994, for more detail on the source of the average pollutant concentration values.
(2) Refer to the Draft Results of Stormwater Monitoring for the Upper Mystic River, Spring 2000 for derivation of the average bacteria concentration for untreated stormwater.

BASELINE CONDITIONS

As described in Appendix B, the existing SWMM model for the Alewife Brook tributary area was updated and recalibrated based on the latest available information on system configuration, as well as recent flow monitoring. This model was then used to define the baseline for the current CSO activation frequencies and volumes. Current conditions as well as CSO control alternatives performance were assessed on an annual basis.

A typical year of rainfall to be used to simulate annual performance was originally developed as part of the MWRA's CSO Conceptual Plan program. The typical year was intended to represent one full year of actual rainfall events that would approximate the long-term rainfall record. The year 1992 was selected as the base year from which a "typical" year would be developed because 1992 was relatively close to the 40-year average for total precipitation and distribution of storm size. To provide a better match to the actual 40-year averages, the 1992 rainfall record was adjusted by adding or removing certain storms. For example, compared to the long-term average, the year 1992 had fewer storms over 1 inch and more storms between 0.25 and 1 inch. Thus, two storms between 1 and 2 inches were added and 8 storms between 0.25 and 0.50 inches were removed from the 1992 base year. The typical year consists of 108 storms with a total precipitation of 43.1 inches.

A summary of the predicted annual overflow volumes by storm by outfall for the existing conditions (prior to start of construction on Fresh Pond Parkway) is presented in Table 5-4. Table 5-4 also summarizes the total annual volume and activation frequency by outfall.

As noted in Appendix B, the metering data indicated that a restriction likely existed in the Alewife Brook Branch Sewer (ABBS) upstream of Massachusetts Avenue. Table 5-4 reflects the conditions with this apparent restriction in place. For sizing of CSO control alternatives, it was assumed that this restriction would be located and removed. Removal of the restriction, however, had very little impact on CSO activations or volumes. With the restriction removed, the total annual CSO volume was predicted to be reduced by less than one percent.

The alternatives were also evaluated assuming that the Phase I Bellis Circle Stormwater Management project is implemented. Additional stormwater detention projects identified under Phase II of the Bellis Circle work would potentially result in further reductions in annual CSO volume.

DEVELOPMENT OF ALTERNATIVES

Following the initial screening of technologies, the following alternatives were carried forward for further development and evaluation:

- CSO elimination by system-wide sewer separation
- Interceptor relief/pumping station modification
- Consolidated near-surface storage conduit
- Consolidated near-surface storage conduit with targeted sewer separation
- Consolidated near-surface storage facility with targeted sewer separation
- Consolidated near-surface primary treatment facility with targeted sewer separation
- Consolidated near-surface screening and disinfection facility with targeted sewer separation
- Targeted sewer separation

TABLE 5-4. SUMMARY OF CSO VOLUMES BY STORM IN TYPICAL YEAR - PRE-CONSTRUCTION CONDITIONS

STORM	STORM	STORM DURATION	TOTAL RAIN DEPTH	AVERAGE INTENSITY	CSO VOLUME (MG) DISCHARGE TO ALEWIFE BROOK									
					ALT0 - BASE CASE									
NO.	EVENT(1)	(hour)	(inch)	(In/hr)	CAM001	CAM002	CAM003	CAM004 CS(2)	CAM004 SD(2)	CAM400	CAM401	CAM401B	SOM001A	TOTAL
1	1/4/1992	21.0	1.15	0.05					0.64			0.27		0.91
2	1/9/1992	4.8	0.16	0.03					0.02					0.02
3	1/14/1992	9.7	0.49	0.05					0.26			0.03		0.29
4	1/23/1992	16.3	1.36	0.08					0.75			0.24		0.99
5	2/14/1992	7.5	0.15	0.02					0.02					0.02
6	2/15/1992	11.2	0.87	0.08					0.45			0.03		0.48
7	2/18/1992	12.3	0.20	0.02					0.04					0.04
8	2/25/1992	17.0	0.83	0.05					0.35					0.35
9	3/6/1992	34.3	1.89	0.06					0.96			0.34		1.30
10	3/11/1992	12.5	0.97	0.08					0.50			0.12		0.62
11	3/19/1992	11.5	0.42	0.04					0.09					0.09
12	3/22/1992	9.8	0.27	0.03					0.04					0.04
13	3/26/1992	10.5	0.67	0.06					0.31					0.31
14	3/28/1992	18.8	0.42	0.02					0.09					0.09
15	4/11/1992	21.5	0.52	0.02					0.14					0.14
16	4/16/1992	30.3	1.02	0.03					0.35					0.35
17	4/22/1992	2.7	0.13	0.05					0.02					0.02
18	4/24/1992	20.5	0.73	0.04					0.27					0.27
19	5/2/1992	5.7	1.14	0.20		0.14			0.94	0.08	0.18	0.57	0.67	2.58
20	5/8/1992	10.0	0.27	0.03					0.07					0.07
21	5/31/1992	29.5	2.24	0.08					1.38	0.02	0.07	1.19	0.01	2.67
22	6/5/1992	17.5	1.34	0.08					0.73	0.02		0.34	0.31	1.40
23	6/20/1992	2.5	0.34	0.14					0.17					0.17
24	6/20/1992	0.5	0.11	0.21					0.02					0.02
25	6/24/1992	5.3	0.33	0.06					0.14					0.14
26	6/24/1992	10.0	0.23	0.02					0.05					0.05
27	7/6/1992	3.0	0.38	0.13					0.18					0.18
28	7/11/1992	0.7	0.22	0.30					0.10					0.10
29	7/14/1992	4.8	0.16	0.03					0.02					0.02
30	7/15/1992	16.3	0.50	0.03					0.20					0.20
31	7/23/1992	13.3	0.41	0.03					0.15					0.15
32	7/29/1992	0.8	0.20	0.27					0.08					0.08
33	7/31/1992	19.0	0.59	0.03					0.26			0.04		0.30
34	8/11/1992	10.8	0.87	0.08		0.16			0.74	0.08	0.19	0.41	1.10	2.68
35	8/14/1992	7.5	0.40	0.05					0.12					0.12
36	8/15/1992	38.7	1.10	0.03					0.33			0.05		0.38
37	8/17/1992	25.7	1.81	0.07		0.22		0.03	1.22	0.09	0.31	0.68	1.37	3.92

TABLE 5-4 (Continued). SUMMARY OF CSO VOLUMES BY STORM IN TYPICAL YEAR - PRECONSTRUCTION CONDITIONS

STORM NO.	STORM EVENT(1)	STORM DURATION (hour)	TOTAL RAIN DEPTH (inch)	AVERAGE INTENSITY (in/hr)	CSO VOLUME (MG) DISCHARGE TO ALEWIFE BROOK									
					ALT0 - BASE CASE									
					CAM001	CAM002	CAM003	CAM004 CS(2)	CAM004 SD(2)	CAM400	CAM401	CAM401B	SOM001A	TOTAL
38	9/3/1992	12.5	1.19	0.10		0.04			0.70	0.03	0.02	0.38	0.65	1.82
39	9/8/1992	3.8	0.19	0.05					0.04					0.04
40	9/9/1992	0.8	0.57	0.76		0.04			0.47	0.05		1.69	0.46	2.71
41	9/11/1992	7.5	0.38	0.05					0.15					0.15
42	9/19/1992	2.5	0.11	0.04					0.01					0.01
43	9/22/1992	22.2	2.79	0.13		0.49		0.05	2.38	0.20	0.86	1.25	2.62	7.85
44	9/26/1992	9.5	0.74	0.08					0.38			0.14		0.52
45	10/9/1992	2.5	0.26	0.10					0.11					0.11
46	10/10/1992	6.7	0.65	0.10					0.41			0.15	0.10	0.66
47	10/10/1992	5.5	0.47	0.09					0.30	0.01		0.09		0.40
48	10/11/1992	13.0	0.65	0.05					0.33			0.04		0.37
49	10/19/1992	2.5	0.11	0.04					0.01					0.01
50	10/21/1992	4.5	0.12	0.03					0.01					0.01
51	10/23/1992	3.3	1.18	0.36	0.01	0.48	0.06	0.24	1.40	0.22	1.11	0.67	2.60	6.79
52	10/24/1992	3.7	0.18	0.05					0.05					0.05
53	10/25/1992	7.5	0.20	0.03					0.01					0.01
54	11/3/1992	28.5	0.94	0.03					0.41			0.08		0.49
55	11/5/1992	12.8	0.31	0.02					0.08					0.08
56	11/21/1992	35.0	1.88	0.05					1.02			0.52		1.54
57	11/24/1992	26.7	0.46	0.02					0.04					0.04
58	11/26/1992	14.7	0.51	0.03					0.16					0.16
59	12/3/1992	8.2	0.82	0.10					0.46			0.10		0.56
60	12/11/1992	39.8	3.88	0.10					2.26			1.07		3.33
61	12/17/1992	14.8	0.58	0.04					0.20					0.20
62	12/29/1992	11.7	0.37	0.03					0.07					0.07
63	12/30/1992	10.3	0.44	0.04					0.12					0.12
TOTAL CSO VOLUME (MG)					**0.01**	**1.57**	**0.06**	**0.32**	**23.78**	**0.80**	**2.74**	**10.49**	**9.89**	**49.66**
CSO ACTIVATION FREQUENCY					**1**	**7**	**1**	**3**	**63**	**10**	**7**	**25**	**10**	

Notes: 1. For reference, the 3-month, 24-hour storm has a total depth of 1.84 inches, and an average intensity of 0.09 in./hr. The 1-year, 24-hour storm has a total depth of 2.79 inches, and an average intensity of 0.13 in./hr.

2. CAM004SD represents CSO discharged at the cross connection between the storm drain and combined sewer systems at Vassal Street. CAM004CS represents the CSO discharged over the weir at the CAM004 CSO regulator.

Each of these alternatives is described in the sections that follow. The general layout of the alternatives is presented in Figure 5-1 (in map pocket). Where an alternative is similar to an alternative that was presented in the CSO Conceptual Plan, a comparison of the CSO Conceptual Plan and current alternative is presented. The descriptions of the alternatives include a tabulation of estimated costs and non- monetary factors. The estimated costs of the CSO Conceptual Plan alternatives are also presented for comparison. The CSO Conceptual Plan costs have been adjusted to the same ENR CCI as the other alternatives, and the net present value recalculated using the same present worth factors as for the other alternatives. The alternatives are further evaluated and compared in a subsequent section of this report.

CSO Elimination by System-wide Sewer Separation

This alternative would involve the complete sewer separation of the areas tributary to the remaining CSO outfalls to Alewife Brook, and would include separation of CSO regulators currently tributary to the Tannery Brook Drain in Somerville. To model this alternative, it was assumed that separation would achieve 80 percent inflow removal in the areas tributary to all outfalls except CAM401B and SOM01A. For CAM401B, the percentage of runoff entering the nominally separate sanitary system was assumed to be reduced from 17 to 7 percent. For the regulators tributary to SOM01A, it appeared that up to 95 percent inflow removal may be required in some areas to eliminate CSO discharge in the typical year. The need for regulators to remain open for extreme event relief was not evaluated.

Given these considerations, the total area of separation would be approximately 850 acres. A breakdown of tributary area and estimated capital cost by outfall is presented in Table 5-5. For the areas other than CAM002, CAM401B and SOM01A, an average per-acre unit construction cost developed by the City of Cambridge for separation in the upper areas tributary to outfall CAM004 was used to estimate the cost of separation. For CAM002, cost originally developed for the CAM002 area by the City of Cambridge was used. For outfalls CAM401B and SOM01A, an additional contingency was added to the average CAM004 cost per acre, to account

TABLE 5-5. TRIBUTARY AREAS OF CSO OUTFALLS TO ALEWIFE BROOK, AND ESTIMATED COST FOR COMPLETE SEWER SEPARATION

Outfall	Approximate Tributary Area (acres)	Estimated Capital Cost per Acre	Estimated Capital Cost for Complete Sewer Separation
CAM001	4	$76,900	$308,000
CAM002	89	$218,700	$19,460,000
CAM401A/B[1]	250	$115,400	$28,850,000
SOM01A	278	$115,400	$32,100,000
MWR003	N/A[2]	N/A[2]	N/A[2]
CAM401A/B New Outfall[3]			$15,000,000
Subtotal	**621**		**$95,718,000**
CAM004	214	$76,900	$16,457,000
CAM400	14	$76,900	$1,077,000
Common Costs for Work Completed/Committed[4]			$50,060,000
Subtotal	**228**		**$67,600,000**
Grand Totals	**849**		**$163,318,000**
Annual O&M Cost			($19,100)
Net Present Value			$129,000,000

Notes: (1) A clear distinction between the CAM401A and CAM401B tributary areas cannot be made at this time. The total tributary area to the CAM401A and B regulators is estimated at 250 acres.

(2) MWR003 is located directly on the Alewife Brook Conduit.

(3) It is assumed that a new outfall on the same order of magnitude and cost of the new CAM004 outfall would be required to carry additional wet weather flows from the CAM401 area to Alewife Brook.

(4) See Table 5-2 for breakdown of Common Costs.

for the complexity and shallow slopes of the existing collection system. It is also assumed that a major additional storm drain outfall would be required to convey the separated drainage from the CAM401 area to Alewife Brook under a complete separation scenario. These costs do not include measures to mitigate the impact of the additional stormwater flows resulting from sewer separation on Alewife Brook in terms of scour velocities and potential flooding.

As previously noted, all costs were adjusted to an ENR CCI of 6988. The negative O&M cost reflects an estimate of the savings in pumping costs at Alewife Brook Pumping Station and North Main Pumping Station resulting from the reduction in wet weather flow to the interceptor system. Table 5-6 presents the non-monetary factors for complete sewer separation. Additional discussion of the complete sewer separation alternative is presented in Chapter Six.

Interceptor Relief/Pumping Station Modification

The Alewife Brook Pumping Station is located at the intersection of the Mystic Valley and Alewife Brook Parkways in Somerville. The pumping station features three 26 mgd pumps and one 8 mgd pump, along with a gravity bypass. The 26 mgd pumps and the gravity bypass discharge to the North Metropolitan Relief Sewer (NMRS), and the 8 mgd pump discharges to the North Metropolitan Trunk Sewer (NMTS). The NMTS and NMRS are tributary to the Chelsea Creek Headworks.

In the November 1994 Technical Memorandum on Intermediate Projects, alternatives for potentially reducing CSO discharges along Alewife Brook by increasing the pumping capacity at Alewife Brook Pumping Station were developed and evaluated. Specific alternatives considered included:

- Increasing pumping capacity by changing the operation of the existing pumps
- Increasing pumping capacity by installing new pumps
- Increasing the size of the wetwell

At the time of that report, the maximum pumping capacity utilized during wet weather was estimated at 58 mgd. Records of actual flow rate pumped were not available at that time. Modeling at that time indicated that brief flooding was predicted in the pump discharge chamber during the 1-year storm. Removal of stop logs on various downstream siphon chambers was predicted to reduce, but not eliminate, the flooding, and had minimal effect on CSOs to Alewife

TABLE 5-6. NON-MONETARY FACTORS FOR COMPLETE SEWER SEPARATION

Non-Monetary Factor	Comment
Short-Term Siting Impacts	Extensive construction-related impacts along most streets in the tributary areas. Total construction duration likely greater than 10 years. Feasibility of siting facilities to mitigate high flow rates and volumes on Alewife Brook uncertain.
Long-Term Siting Impacts	Potential long-term impact of multiple detention/retention facilities to mitigate impacts of high flows on Alewife Brook
O&M Considerations	Marginally reduced run time for pumps at Alewife Brook Pump Station and North Main Pump Station

Brook. The report concluded that increasing the pumping capacity at Alewife Brook Pumping Station would not be appropriate due to the lack of additional flow capacity in the downstream NMTS and NMRS.

As described in Appendix B, flow records are now available that indicate that the maximum pumping capacity at Alewife Brook Pumping Station is approximately 75 mgd. In addition, the updated model does not predict flooding in the pumping station discharge chamber in the 1-year storm.

The first step in the re-evaluation of Alewife Brook Pumping Station capacity was to simulate the pumping station in SWMM as a free discharge. This simulation would provide an indication of the maximum peak flow that could be delivered to the pumping station by the Alewife Brook Conduit and Alewife Brook Branch Sewer during the typical year, as well as the impact of that conveyance capacity on upstream CSOs. Under the free discharge conditions, the peak flow to the pumping station in the typical year was 103 mgd. In total, nine storms in the typical year generated flows greater than the existing maximum pumping capacity of 75 mgd. The free discharge had relatively little impact on CSO frequency and volume. Activation frequencies decreased by no more than two per year, and the total annual volume discharged was reduced by approximately 12 percent (from 51.4 to 45.4 million gallons).

The pumping station was then simulated with a peak pumping capacity of 110 mgd. However, the free discharge run indicated that increasing the peak flow in the interceptors had little effect on the major existing CSO discharge at CAM004, as well as the discharge at CAM400. In addition, enlarging the dry weather flow connections at CAM002, CAM401B and SOM01A had previously been shown to reduce activations at these locations. It made sense, therefore, to evaluate increasing the pumping capacity with an alternative that included separation of CAM004 and CAM400, as well as enlarging the dry weather flow connections at CAM002, CAM401B and SOM01A. Under this alternative, with the peak pumping capacity of 110 mgd, the peak hydraulic grade line in the NMRS downstream of the pumping station surcharged to within approximately two feet of grade. Compared with a similar run (separation at CAM004 and CAM400; enlarging the dry weather flow connections at CAM002, CAM401B and SOM01A) but with the existing pumping capacity of 75 mgd, the 110 mgd pumping capacity reduced the annual CSO volume by 12 percent (from 8.5 to 7.5 million gallons), while outfall activation frequencies were generally reduced by one or two per year (overall frequency ranged from 0 to 9 per year).

Discussions with MWRA operations staff at the Alewife Brook Pumping Station indicated that the current pump operating levels are set to provide sufficient suction head on the pumps. Increasing the pumping capacity to 110 mgd could potentially require construction of a new wetwell to maintain the appropriate suction head. Relief of a portion of the downstream NMRS would also be required to reduce the peak surcharge elevation.

From these results, the following conclusions were drawn:

- Providing relief of the Alewife Brook Conduit and/or Alewife Brook Branch Sewer would not be appropriate. As indicated by the free discharge simulation, the existing interceptors are capable of delivering 103 mgd to the pumping station. Pumping at a rate of 110 mgd, however, would result in an unacceptably high hydraulic grade line in the NMRS downstream of the pumping station. Thus, there is insufficient downstream capacity to carry flows greater than the peak flow that could currently be delivered to the pumping station by the existing interceptors.

- Increasing the pumping capacity to 110 mgd, in conjunction with separation of CAM004 and CAM400, and enlarging the dry weather flow connections at CAM002, CAM401B and SOM01A, resulted in only marginally improved CSO reduction compared with a similar alternative with the pumping station at its existing capacity of 75 mgd. The 110 mgd pumping capacity also resulted in an unacceptably-high peak hydraulic grade line downstream of the pumping station.

- Providing relief of the NMRS downstream of the pumping station, in combination with either relief of the Alewife Brook Conduit and/or Alewife Brook Branch Sewer or increased pumping capacity would still provide only marginally improved CSO reduction in comparison with alternatives that do not include increased conveyance capacity.

For these reasons, increasing the conveyance capacity of the Alewife Brook interceptor system and Alewife Brook Pumping Station is not recommended, and these alternatives were not developed further.

Consolidated Near-Surface Storage Conduit

This alternative would involve constructing an approximately 4,500 lf conduit from a location adjacent to the Alewife MBTA Station to the vicinity of outfall SOM01A. Based on the required diameter, it was assumed that the conduit would be constructed using a tunnel boring machine with a precast segmented tunnel liner. A near-surface connecting conduit would run from the CAM004/401 outfall to the downstream shaft near the Alewife MBTA Station. The tunnel would be mined from this shaft. The consolidation conduit would extend approximately 300 feet north of outfall SOM01A, into an area where sufficient space would potentially be available for locating the upstream shaft for removal of the tunnel boring machine and installation of the odor control equipment. The contents of the storage conduit would be emptied by pumping to the Alewife Brook Conduit at the end of a storm via pump-out facilities provided at the downstream shaft, near the MBTA station. Preliminary routing of the consolidation conduit was intended to avoid passing under existing buildings. Alternative conduit sizes were developed to allow 0, 2, or 4 overflows in the typical year. Table 5-7 presents the size and estimated capital costs, annual O&M costs and net present value for the storage conduit alternatives, while Table 5-8 summarizes the non-monetary factors. The capital costs in Table 5-7 include the $50.1 million cost for work already completed or committed, that will be common to all alternatives.

TABLE 5-7. SIZE AND ESTIMATED COST FOR CONSOLIDATED STORAGE CONDUIT ALTERNATIVES

Level of Control Based on Typical Year	Consolidation Conduit Size		Estimated Costs		
	Length (lf)	Diameter (ft)	Capital	Annual O&M	Net Present Value
0 overflows	4,500	17.5	$136,000,000	$212,000	$121,000,000
2 overflows	4,500	12.5	$109,000,000	$212,000	$97,400,000
4 overflows	4,500	10.5	$108,000,000	$212,000	$96,100,000
CSO Conceptual Plan alt. 1-year storm control	10,900	11	$61,500,000	$400,000	$58,600,000
CSO Conceptual Plan alt. 3-month storm control	7,700	5	$29,400,000	$44,000	$26,100,000

TABLE 5-8. NON-MONETARY FACTORS FOR CONSOLIDATED STORAGE CONDUIT ALTERNATIVES

Non-Monetary Factor	Comment
Short-Term Siting Impacts	Construction-related disruptions at main mining shaft near MBTA station for duration of construction, and periodic disruptions at equipment removal shaft, dropshaft and diversion structure locations along Alewife Brook.
Long-Term Siting Impacts	Relatively small pump-out facility at downstream end may fit below grade. Odor control facility at upstream end likely to be above grade. Public opposition to siting is likely, and identification of suitable sites will be difficult.
O&M Considerations	Routine maintenance required on equipment; periodic cleaning of accumulated grit in consolidation conduit likely required

In the CSO Conceptual Plan, the consolidation/storage conduit alternative sized for the 1-year storm ran from the vicinity of regulator RE041 to the Alewife Brook Pump Station. The consolidation conduit sized for the 3-month storm ran from regulator RE041 to outfall SOM001. Since outfalls SOM004, SOM002A/003, and SOM001 have since been closed by the City of Somerville, it would no longer be necessary to extend the consolidation conduit further north of outfall SOM01A (except as necessary to locate an equipment removal shaft).

Consolidated Near-surface Storage Tank

This alternative would involve constructing a storage tank in the vicinity of the Alewife MBTA station with a consolidation conduit running south from outfall SOM01A. A connecting conduit would direct the flow from the CAM004/401 outfall directly to the storage facility. The contents of the storage tank would be returned by pumping to the Alewife Brook Conduit after the end of the storm. For planning purposes, the consolidation conduit was sized to convey the peak flow from the design storm that served as the basis for sizing the storage facilities. For example, to provide zero overflows in the typical year, the consolidation conduit was sized to convey the peak flow from the largest storm in the typical year, and the combined storage capacity of the consolidation conduit and storage tank was set to equal the total overflow volume from the largest storm in the typical year.

Based on the required diameter of the consolidation conduit, it was assumed the conduit would be constructed by microtunneling/jacked pipe. Since the upstream shaft at SOM01A would not need to be as large as for a larger-diameter tunnel boring machine/precast segmented liner system, it was assumed that the consolidation conduit would end just north of outfall SOM01A. The storage tank would be configured to take advantage of available storage capacity in the consolidation conduit.

Alternative facility sizes were developed to allow 0, 2, or 4 overflows in the typical year. Table 5-9 presents the size and estimated capital costs, annual O&M costs and net present value for the storage conduit/tank alternatives, while Table 5-10 summarizes the non-monetary factors. The capital costs in Table 5-9 include the $50.1 million cost for work already completed or committed, that will be common to all alternatives.

In the CSO Conceptual Plan, the consolidation-to-storage tank alternative sized for the 1-year storm included a consolidation conduit that ran from the vicinity of regulator RE041 to outfall SOM001, with a storage tank located in the vicinity of the Alewife MBTA station. Since outfalls SOM004, SOM002A/003, and SOM001 have since been closed by the City of Somerville, it would no longer be necessary to extend the consolidation conduit further north of outfall SOM01A. This alternative sized for a 3-month level of control was eliminated from further consideration following the spring 1994 workshops, and was not presented in the CSO Conceptual Plan.

Consolidated Near-surface Primary Treatment Facility

This alternative would be similar to the consolidation near-surface storage alternative, except that the downstream tank would be sized to provide equivalent primary treatment, and would include fine screening, disinfection and dechlorination equipment. The facility would be similar in concept to the MWRA's Cottage Farm and Prison Point CSO Facilities. The primary treatment tank would be configured to take advantage of storage capacity in the consolidation conduit before discharging. It is anticipated that the discharge from the facility would require pumping to Alewife Brook, and the volume of flow remaining in the tank and consolidation conduit at the end of a storm would be pumped back to the Alewife Brook Conduit. Alternative facility sizes were developed such that 0, 2, or 4 storms in the typical year would result in flows that would exceed the design overflow rate of 4,500 gpd/sf. The consolidation conduit for all alternatives was sized to convey the largest storm in the typical year. Where flows would exceed the design overflow rate, a reduced level of treatment was assumed. The consolidation-to-

TABLE 5-9. SIZE AND ESTIMATED COST FOR CONSOLIDATED STORAGE TANK ALTERNATIVES

Level of Control Based on Typical Year	Storage Tank Size (MG)	Consolidation Conduit Size		Estimated Costs		
		Length (lf)	Diameter (ft)	Capital	Annual O&M	Net Present Value
0 overflows	7.0	4,180	6	$133,000,000	$723,000	$125,000,000
2 overflows	3.0	4,180	6	$107,000,000	$487,000	$99,200,000
4 overflows	2.3	4,180	4.5	$99,700,000	$487 ,000	$92,800,000
CSO Conceptual Plan alt. 1-year storm control	3.9	7,700	5	$48,500,000	$400,000	$47,300,000

TABLE 5-10. NON-MONETARY FACTORS FOR CONSOLIDATED STORAGE TANK ALTERNATIVES

Non-Monetary Factor	Comment
Short-Term Siting Impacts	Construction-related disruptions at tank site near MBTA station, and at jacking and receiving shafts, dropshafts and diversion structure locations along Alewife Brook.
Long-Term Siting Impacts	Tank and pumping equipment would be below grade, but tank odor control facility likely to be above grade. Odor control facility at upstream end of conduit likely to be above grade. Public opposition to siting of tank and upstream odor control facility is likely, and identification of a suitable site will be difficult.
O&M Considerations	Cleanup of tank required after each activation. Routine maintenance required on equipment; periodic cleaning of accumulated grit in consolidation conduit likely required

primary treatment tank alternative was eliminated from further consideration following the spring 1994 workshops, due to a low preliminary ranking compared with other alternatives, and was not presented in the CSO Conceptual Plan.

Table 5-11 presents the size and estimated capital costs, annual O&M costs and net present value for the consolidation-to-primary treatment alternatives, while Table 5-12 summarizes the non-monetary factors. The capital costs in Table 5-11 include the $50.1 million cost for work already completed or committed, that will be common to all alternatives.

Consolidated Near-surface Screening and Disinfection Facility

This alternative would be similar to the consolidated near-surface primary treatment alternative, except that the downstream tank would be replaced with a screening and disinfection/ dechlorination facility. The facility would be similar to the MWRA's Somerville Marginal, Fox Point and Commercial Point CSO facilities. The screening and disinfection/dechlorination facility would be configured to take advantage of storage capacity in the consolidation conduit before discharging. It is anticipated that the discharge from the facility would require pumping to Alewife Brook, and the volume of flow remaining in the consolidation conduit at the end of a storm would be pumped back to the Alewife Brook Conduit. This alternative was only sized for the largest storm in the typical year, and was not evaluated in the CSO Conceptual Plan.
Table 5-13 presents the size and estimated capital cost, annual O&M cost and net present value for the consolidation-to-screening/disinfection alternative, while Table 5-14 summarizes the non-monetary factors. The capital costs in Table 5-13 include the $50.1 million cost for work already completed or committed, that will be common to all alternatives.

TABLE 5-11. SIZE AND ESTIMATED COST FOR CONSOLIDATED PRIMARY TREATMENT FACILITY ALTERNATIVES

Level of Control Based on Typical Year	Primary Treatment Tank Size (MG)	Consolidation Conduit Size		Estimated Costs		
		Length (lf)	Diameter (ft)	Capital	Annual O&M	Net Present Value
0 overflows(1)	2.1	4,180	6	$147,000,000	$464,000	$134,000,000
2 overflows(1)	2.0	4,180	6	$121,000,000	$464,000	$111,000,000

Notes: (1) Overflow in this context means occasions when the peak flow rate through the facility exceeds the design overflow rate of 4,500 gpd/sf. These flows would receive a level of treatment considered to be "less than primary treatment".

TABLE 5-12. NON-MONETARY FACTORS FOR CONSOLIDATED PRIMARY TREATMENT FACILITY ALTERNATIVES

Non-Monetary Factor	Comment
Short-Term Siting Impacts	Construction-related disruptions at tank site near MBTA station, and at jacking and receiving shafts, dropshafts and diversion structure locations along Alewife Brook.
Long-Term Siting Impacts	Primary treatment tank and pumping equipment would be below grade, but facility odor control equipment and chemical storage and feed equipment likely to be housed in an above-grade structure. Odor control facility at upstream end of consolidation conduit likely to be above grade. Periodic chemical deliveries required. Public opposition to siting is likely, and identification of a suitable site will be difficult
O&M Considerations	Cleanup of tank required after each activation. Routine maintenance required on equipment; periodic cleaning of accumulated grit in consolidation conduit likely required.

TABLE 5-13. SIZE AND ESTIMATED COST FOR CONSOLIDATED SCREENING AND DISINFECTION FACILITY ALTERNATIVE

Level of Control Based on Typical Year	Peak Design Flow (mgd)	Consolidation Conduit Size		Estimated Costs		
		Length (lf)	Diameter (ft)	Capital	Annual O&M	Net Present Value
0 untreated overflows	117	4,180	7	$103,000,000	$325,000	$93,600,000

TABLE 5-14. NON-MONETARY FACTORS FOR CONSOLIDATED SCREENING AND DISINFECTION FACILITY ALTERNATIVE

Non-Monetary Factor	Comment
Short-Term Siting Impacts	Construction-related disruptions at screening/disinfection facility site near MBTA station, and at jacking and receiving shafts, dropshafts and diversion structure locations along Alewife Brook
Long-Term Siting Impacts	Screening and pumping equipment would be below grade, but odor control equipment and chemical storage and feed equipment likely to be housed in an above-grade structure. Odor control facility at upstream end likely to be above grade. Periodic chemical deliveries required. Public opposition to siting is likely, and identification of a suitable site will be difficult; may require detention/retention facilities to mitigate peak flows.
O&M Considerations	Cleanup of screening facility required after each activation. Routine maintenance required on equipment; periodic cleaning of accumulated grit in consolidation conduit likely required.

Consolidated Near-surface Storage Conduit with Targeted Sewer Separation

In the CSO Conceptual Plan, it was recognized that separation of the area tributary to outfall CAM004 would significantly reduce the volume of flow tributary to the interceptor system. This reduction in flow would reduce the peak hydraulic grade line in the interceptors, which would, in turn, result in reduced CSO discharges at other outfalls along the Alewife Brook. Separation of outfall CAM004 would therefore significantly reduce the size of a consolidation conduit required to capture the CSOs along Alewife Brook. In the current analysis, certain other relatively low-cost projects have been identified that, in conjunction with separation of CAM004, would further reduce the volume of CSO to be captured in a consolidation conduit. These projects include:

- Separation of common manholes upstream of outfall CAM400, and implementation of the recommended system optimization plan (SOP). The original SOP called for routing a separate storm drain around the regulator, and raising the overflow weir. Based on information from the city of Cambridge, it appears that what was indicated to be a separate drain on the Cambridge 100-scale sewer maps was, in fact, cross-connected with the sanitary system via common manholes. The recommended SOP could not, therefore, be implemented until the upstream common manholes were separated.

- Enlarging the local connections between the interceptor system and the regulators associated with outfalls CAM002, CAM401B and SOM01A. SWMM analyses indicated that a number of overflows are caused at these locations due to the restricted capacity of the local connections. In each case, increasing the size of the connections would involve less than 50 feet of new pipe. The work would, however, be complicated by the location of these regulators, at or near the intersection of Massachusetts Avenue and Route 16.

- Providing a hydraulic relief gate at outfall MWR003. This gate would minimize discharges from outfall MWR003 in smaller storms, and would open to allow additional relief during larger storms to protect upstream hydraulic grade lines.

With the targeted separation and minor pipe work noted above, this alternative would be similar to the consolidation/storage conduit alternative, except that the diameter of the consolidation/storage conduit required to meet the range of CSO controls would be reduced. This alternative was sized for 0, 2 and 4 overflows in the typical year. For the 0 overflows per year alternative, it is assumed that the conduit would be installed by tunnel boring machine with precast segmented tunnel liner. For the 2 and 4 overflows per year alternatives, it was assumed that the conduit would be installed by microtunneling/jacked pipe. In the CSO Conceptual Plan, this alternative was developed for control of the 1-year storm, only.

Table 5-15 presents the size and estimated capital costs, annual O&M costs and net present value for the storage conduit with partial sewer separation alternatives, while Table 5-16 summarizes the non-monetary factors. The capital costs in Table 5-15 include the $50.1 million cost for work already completed or committed, that will be common to all alternatives.

TABLE 5-15. SIZE AND ESTIMATED COST FOR CONSOLIDATED STORAGE CONDUIT WITH TARGETED SEWER SEPARATION ALTERNATIVES

Level of Control Based on Typical Year	Consolidation Conduit Size		Estimated Costs		
	Length (lf)	Diameter (ft)	Capital	Annual O&M	Net Present Value
0 overflows	4,500	11.5	$137,000,000	$209,000	$121,000,000
2 overflows	4,180	6.5	$106,000,000	$209,000	$94,700,000
4 overflows	4,180	3.5	$88,400,000	$209,000	$79,400,000
CSO Conceptual Plan alt. 1-year storm control	3,800	6	$42,800,000	$33,000	$37,500,000

TABLE 5-16. NON-MONETARY FACTORS FOR CONSOLIDATED STORAGE CONDUIT WITH TARGETED SEWER SEARATION ALTERNATIVES

Non-Monetary Factor	Comment
Short-Term Siting Impacts	For 0 overflow/yr alternative, construction-related disruptions at main mining shaft site near MBTA station for the duration of the construction, and periodic disruption at the equipment removal shaft. For the 2 and 4 overflow/yr alternatives, construction-related disruptions at the jacking and receiving shafts. For all alternatives, periodic disruptions at dropshafts and diversion structure locations along Alewife Brook, in most streets in the CAM004 and CAM400 tributary areas, and in the vicinity of the intersection of Massachusetts Avenue and Fresh Pond Parkway.
Long-Term Siting Impacts	Pumping equipment would be below grade, but odor control facility at upstream end likely to be above grade. Public opposition to siting of shafts and odor control facility is likely, and identification of suitable sites will be difficult. Detention basin or constructed wetland area required to attenuate peak stormwater flows.
O&M Considerations	Routine maintenance required on equipment; periodic cleaning of accumulated grit in consolidation conduit likely required.

Consolidated Near-surface Storage Tank with Targeted Sewer Separation

This alternative was similar to the consolidated storage tank alternative, except that the volume of CSO to be captured would be reduced by the targeted sewer separation upstream of outfalls CAM004 and CAM400, and minor piping changes at the CAM002, CAM401B and SOM01A regulators described above. In the CSO Conceptual Plan, this alternative was developed for control of the 1-year storm, only. In the current analysis, it was found that the size of the tanks required to provide the 2 and 4 overflows per year levels of control would be less than 0.4 million gallons. It did not seem reasonable to construct such small tanks at the end of the consolidation/storage conduit, so these alternatives were not evaluated further. Table 5-17 presents the size and estimated capital costs, annual O&M costs and net present value for the storage conduit/tank with partial sewer separation alternative, while Table 5-18 summarizes the non-monetary factors. The capital costs in Table 5-17 include the $50.1 million cost for work already completed or committed, that will be common to all alternatives.

Consolidated Near-surface Primary Treatment Facility with Targeted Sewer Separation

This alternative would have been similar to the consolidated primary treatment facility alternative, except that the quantity of CSO to be treated and the design flow rate would be reduced by the targeted sewer separation upstream of outfalls CAM004 and CAM400, and minor piping changes at the CAM002 and CAM401B regulators described above. However, in sizing this alternative, it was found that the total volume of storage available in the primary treatment tanks plus the consolidation conduit would have been greater than the total CSO volume to be treated (note that the primary treatment tanks are sized based on a peak overflow rate and a minimum side water depth). Therefore, this alternative was not developed further. This alternative was similarly not developed for the CSO Conceptual Plan.

TABLE 5-17. SIZE AND ESTIMATED COST FOR CONSOLIDATED STORAGE FACILITY WITH TARGETED SEWER SEPARATION ALTERNATIVE

Level of Control Based on Typical Year	Storage Tank Size (MG)	Consolidation Conduit Size		Estimated Costs		
		Length (lf)	Diameter (ft)	Capital	Annual O&M	Net Present Value
0 overflows	2.1	4,180	7	$132,000,000	$446,000	$120,000,000
CSO Conceptual Plan alt. 1-year storm control	1.86	3,800	6	$34,800,000	$321,000	$34,400,000

TABLE 5-18. NON-MONETARY FACTORS FOR CONSOLIDATED STORAGE FACILITY WITH TARGETED SEWER SEPARATION ALTERNATIVE

Non-Monetary Factor	Comment
Short-Term Siting Impacts	Construction-related disruptions at tank site near MBTA station, at jacking and receiving shafts, dropshafts and diversion structure locations along Alewife Brook, in most streets in the CAM004 and CAM400 tributary areas, and in the vicinity of the intersection of Massachusetts Avenue and Fresh Pond Parkway.
Long-Term Siting Impacts	Tank and pumping equipment would be below grade, but tank odor control facility likely to be above grade. Odor control facility at upstream end likely to be above grade. Identification of a site for the storage tank will be difficult, and public opposition to siting is likely. Detention basin/constructed wetland required to attenuate peak stormwater flows.
O&M Considerations	Cleanup of tank required after each activation. Routine maintenance required on equipment; periodic cleaning of accumulated grit in consolidation conduit likely required.

Consolidated Near-surface Screening and Disinfection Facility with Targeted Sewer Separation

This alternative would be similar to the consolidated screening and disinfection facility alternative, except that the quantity of CSO to be treated and the design flow rate would be reduced by the targeted sewer separation upstream of outfalls CAM004 and CAM400, and minor piping changes at the CAM002, CAM401B and SOM01A regulators described above. This alternative was only sized for the largest storm in the typical year, and was not evaluated in the CSO Conceptual Plan. Table 5-19 presents the size and estimated capital cost, annual O&M cost and net present value for the consolidation-to-screening/disinfection alternative, while Table 5-20 summarizes the non-monetary factors. The capital costs in Table 5-19 include the $50.1 million cost for work already completed or committed, that will be common to all alternatives.

Targeted Sewer Separation

The intent of the targeted sewer separation alternatives was to focus the separation work in areas where sewer separation would have the most benefit, then to assess whether removal of inflow from those areas would also benefit less-active outfalls by reducing the hydraulic grade line in the interceptor system. Targeted separation alternatives were therefore initially targeted at the most active outfalls. CSO activation frequencies and volumes for Alewife Brook CSOs prior to the start of construction of Contracts 2A and 2B along Fresh Pond Parkway are summarized in Table 5-21 (along with other alternatives that are discussed below).

As part of the reassessment of CSO control alternatives for Alewife Brook, targeted sewer separation alternatives were evaluated for outfalls CAM002, CAM004, CAM400, CAM401B and SOM01A. Separation of outfall CAM001 was not evaluated, since the outfall is not predicted to activate in the typical year. Outfall MWR003 is a side-outlet relief directly off of the Alewife Brook Conduit, and does not have a regulator-specific upstream tributary area. Outfall CAM401A is affected by backwater from the Rindge Avenue combined sewer, which

TABLE 5-19. SIZE AND ESTIMATED COST FOR CONSOLIDATED SCREENING AND DISINFECTION FACILITY WITH TARGETED SEWER SEPARATION ALTERNATIVES

Level of Control Based on Typical Year	Peak Design Flow (mgd)	Consolidation Conduit Size		Estimated Costs		
		Length (lf)	Diameter (ft)	Capital	Annual O&M	Net Present Value
0 untreated overflows	164	4,180	8	$123,000,000	$319,000	$111,000,000

TABLE 5-20. NON-MONETARY FACTORS FOR CONSOLIDATED SCREENING AND DISINFECTION FACILITY WITH TARGETED SEWER SEPARATION ALTERNATIVES

Non-Monetary Factor	Comment
Short-Term Siting Impacts	Construction-related disruptions at screening/disinfection facility site near MBTA station, at jacking and receiving shafts, dropshafts and diversion structure locations along Alewife Brook, in most streets in the CAM004 and CAM400 tributary areas, and in the vicinity of the intersection of Massachusetts Avenue and Fresh Pond Parkway.
Long-Term Siting Impacts	Screening and pumping equipment would be below grade, but odor control equipment and chemical storage and feed equipment likely to be housed in an above-grade structure. Odor control facility at upstream end likely to be above grade. Identification of a site for the screening and disinfection facility will be difficult, and public opposition to siting is likely. May require detention/retention facility to attenuate peak CSO flows. Detention basin/constructed wetland required to attenuate peak stormwater flows.
O&M Considerations	Cleanup of screening facility required after each activation. Routine maintenance required on equipment; periodic cleaning of accumulated grit in consolidation conduit likely required

has a tributary area of over 250 acres. Separation of this area was not evaluated, for the following reasons:

- CSO discharges to Alewife Brook could be cost-effectively minimized without separation of outfall CAM401A.
- Due to the size and complexity of the CAM401A tributary area, the cost of separation would be very high.

- The existing CAM401A outfall may not have sufficient capacity to discharge increased stormwater flows associated with sewer separation. Increasing the hydraulic capacity of the outfall would add further cost to this alternative.

- Given the level of control predicted to be achieved under the revised recommended plan, providing a higher level of control at outfall CAM401A through additional targeted sewer separation was judged not to be cost-effective.

As described above, the combination of targeted sewer separation upstream of outfalls CAM004 and CAM400, and minor piping changes at the CAM002, CAM401B and SOM01A regulators was assessed in conjunction with outfall consolidation alternatives as a means for reducing the size and cost of the consolidation alternatives. In developing targeted sewer separation alternatives that would be considered in lieu of an outfall consolidation to storage or treatment alternative, an additional array of targeted separation and/or local piping changes were considered.

The range of targeted separation alternatives evaluated are described below. The performance of the alternatives is presented in Table 5-21.

Targeted Separation Alternative A. This alternative included the following elements:

- Complete sewer separation upstream of CAM004, including the hydraulic relief gate at outfall MWR003.

- Separation of common manholes upstream of outfall CAM400, and implementation of the recommended system optimization plan (SOP).

- Enlarging the local connections between the interceptor system and the regulators associated with outfalls CAM002, CAM401B and SOM01A.

- Relief of the connection between the ABBS and the ABC where the Rindge Avenue combined sewer connects to the ABBS. This alternative reduced the peak hydraulic grade line in the Rindge Avenue combined sewer, which in turn reduced overflows at the CAM401 regulator on Sherman Street near Pemberton.

Targeted Separation Alternative B. This alternative included all of the elements of Targeted Separation Alternative A, with the addition of the following:

- Separation of the area tributary to the Massachusetts Avenue combined sewer upstream of Cedar Street, and installation of a new drain between Cedar Street and Alewife Brook.

Targeted Separation Alternative A with Separation of CAM401B. Outfall CAM401B relieves what is nominally indicated on the City of Cambridge 100-scale sewer maps as a separate sanitary sewer that runs up Massachusetts Avenue, turns onto Cottage Street, then continues into the CAM401A/Rindge Avenue tributary area. Meter data indicate that approximately 17 percent of the rainfall that lands on this tributary area gets into the pipe tributary to outfall CAM401B as inflow, suggesting a significant degree of cross-connection with the combined system in that area. The effect of reducing the level of inflow from 17 to 10 percent in conjunction with Targeted Sewer Separation Alternative A was assessed. As indicated in Table 5-21, the estimated cost of this alternative was not developed due to uncertainty over the scope of separation work required to achieve the reduction in inflow. In addition, if the MWRA were required to achieve a higher level of control than predicted with Alternative A, then Targeted Separation Alternative B appeared to be a better-defined and likely more cost-effective means to achieve a higher level of control than CAM401B inflow reduction.

Targeted Separation Alternative B with Completed Separation of Outfall CAM002. Targeted sewer separation alternative B, as described above, included separation of the area tributary to the Massachusetts Avenue combined sewer upstream of Cedar Street, and installation of a new drain between Cedar Street and Alewife Brook. Under alternative B, the Cedar Street tributary area and the Massachusetts Avenue combined sewer between Cedar Street and regulator RE021 would remain combined. Another alternative was considered that was similar to alternative B, except that it included complete separation of the CAM002 tributary area. The cost and performance of this alternative are presented in Table 5-21.

Targeted Separation of Outfall CAM004 Only. Development of the targeted sewer separation alternatives was an iterative process, and one of the first iterations to be evaluated was separation of the CAM004 tributary area only. The predicted results of separation of just outfall CAM004 are presented in Table 5-21. As indicated in Table 5-21, separation of outfall CAM004 is predicted to reduce the total annual volume of CSO to Alewife Brook by about half, compared with conditions prior to Contract 2A/2B construction. While virtually all of the volume reduction occurs at CAM004, separation of this area removes a significant quantity of wet weather flow from the interceptors along Alewife Brook. The benefit of this reduction in flow would not be realized, however, without increasing the size of the dry weather flow connections at the regulators associated with outfalls CAM002, CAM401B and SOM01A, as recommended under Targeted Sewer Separation Alternative A.

Targeted Separation of Outfall SOM01A. Outfall SOM01A provides relief of the Tannery Brook Drain, which runs from Alewife Brook through Davis Square in Somerville. The City of Somerville is currently studying the Tannery Brook Drain, in part to assess the feasibility of separating the drain. A total of five upstream regulators discharge CSO to the Tannery Brook Drain. At the downstream end, the drain is connected through an orifice opening to the Alewife Brook Conduit, with a transverse weir controlling overflow to Alewife Brook. The upstream regulators are therefore internal regulators, tributary to the downstream regulator at the Alewife Brook Conduit. One scenario for separation of the Tannery Brook Drain would be to separate the areas tributary to the upstream regulators, eliminate any direct sanitary connections to the Tannery Brook Drain, close the orifice connection to the interceptor, and convert the system to a separate storm drain.

Preliminary model runs were conducted to assess the degree of inflow removal that would be required to allow closure of the upstream regulators. Under existing conditions, the most active upstream regulator on the Tannery Brook Drain is predicted to activate 37 times in the typical year, and the total annual CSO volume tributary to the Tannery Brook Drain from the upstream regulators is 16.4 million gallons. If sewer separation could remove 80 percent of the inflow tributary to the upstream regulators, the maximum upstream regulator activation frequency would be reduced to 10 and the annual volume to 1.8 million gallons. At 95 percent inflow removal, the activation frequency would be 6, with a volume of 0.7 million gallons. Based on detailed sewer separation studies in Boston, it appears that 80 percent inflow removal through sewer separation is generally achievable, but 95 percent inflow removal would likely require difficult and expensive separation of internal building plumbing.

The studies being conducted in Somerville, and subsequent studies that are being considered, may identify other alternatives for addressing the flows from the Tannery Brook Drain. Alternatives that may be proposed by the City of Somerville that would convert the Tannery Brook Drain to a separate storm drain, or otherwise reduce either the volume discharged at outfall SOM01A or the peak flow tributary to the Alewife Brook Conduit, would be consistent with the MWRA's currently-recommended plan for Alewife Brook. For this reason, and given the uncertainty over the cost and scope of separation required to convert the Tannery Brook Drain to a separate storm drain, this alternative was not carried forward for this report.

The cost and the performance in terms of activation frequency and volume of the targeted separation alternatives are presented in Table 5-21. The capital costs in Table 5-21 include the $50.1 million cost for work already completed or committed that will be common to all alternatives. Table 5-22 presents data for total annual activations by outfall, and annual activations greater than 0.05 MG by outfall, for Targeted Separation Alternatives A and B. The point to be made with this table is that predicted annual activation frequency is not necessarily the best indicator of performance for these targeted separation alternatives, since the predicted volume associated with a number of these remaining activations is relatively small. Table 5-23 presents non-monetary factors for the targeted sewer separation alternatives.

PERFORMANCE OF ALTERNATIVES

The performance of the range of CSO control alternatives was assessed in terms of annual pollutant load removed. Reductions in loadings of fecal coliform bacteria, TSS, and BOD were computed based on discharge volumes and average pollutant concentrations. Table 5-24 presents the annual CSO pollutant load reductions for the range of alternatives, along with the CSO load reduced as a percentage of the baseline CSO load, and the total pollutant load reduced as a percent of the baseline total load. For Alewife Brook, the total load computations include separate stormwater discharges, and factor in the increase in stormwater discharge associated

TABLE 5-22. SUMMARY OF PERFORMANCE OF TARGETED SEWER SEPARATION ALTERNATIVES

Outfall	Existing Conditions		Alternative A		Alternative B	
	Total Annual Activa-tions	**Annual Activa-tions >0.05 MG**	**Total Annual Activa-tions**	**Annual Activa-tions >0.05 MG**	**Total Annual Activa-tions**	**Annual Activa-tions >0.05 MG**
CAM001	1	0	5	1	4	1
CAM002	7	5	4	3	1	1
MWR003	1	1	5	4	4	3
CAM004cs	3	2	0	0	0	0
CAM004sd	63	48	0	0	0	0
CAM400	10	5	5	2	5	1
CAM401	8	6	5	3	3	3
CAM401B	25	20	7	5	8	5
SOM01A	10	9	3	3	3	2
SOM01A upstream regs	N/A	N/A	N/A	N/A	N/A	N/A
Total Annual Vol, MG	49.7		7.4		5.2	

TABLE 5-23. NON-MONETARY FACTORS FOR TARGETED SEWER SEPARATION ALTERNATIVES

Non-Monetary Factor	Comment
Short-Term Siting Impacts	Construction-related impacts along most streets in the tributary areas to be separated (CAM004, CAM400, CAM002 and/or SOM01A, depending on the alternative)
Long-Term Siting Impacts	Detention basin/constructed wetland required to attenuate peak stormwater flows.
O&M Considerations	Marginally reduced run time for pumps at Alewife Brook Pump Station and North Main Pump Station

with the sewer separation alternatives. As indicated in Table 5-24, for CSO loads, annual fecal coliform bacteria reductions range from 79 to 100 percent, while TSS and BOD load reductions range from approximately 47 to 100 percent. On a total load basis, including stormwater loads, annual fecal coliform bacteria reductions range from 28 to 47 percent, while TSS and BOD load reductions range from negative values (net increase in load) to 17 percent.

Cost/performance relationships are discussed in Chapter Six, and the effect of the reduction in pollutant loads on attainment of water quality standards in Alewife Brook is discussed in Chapter Seven.