FINAL
CSO CONCEPTUAL PLAN
AND SYSTEM MASTER PLAN

PART III
INFILTRATION/INFLOW
STRATEGIES

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PART III
CHAPTER NINE
INTRODUCTION

This part of the report describes the methodology used to develop I/I control alternatives and the results of evaluations performed on each alternative. The range of I/I control alternatives presented in the following sections were developed in conjunction with CSO, interceptor, and secondary treatment strategies to compare overall costs and benefits under the System Master Plan (SMP).

I/I control alternatives were based on the review and analysis of extensive data and on various assumptions regarding the effectiveness of I/I rehabilitation measures. Data used to evaluate the level of I/I within community collection systems throughout the MWRA service area include flow data from the MWRA Wastewater Metering System, service area community I/I and SSES reports, and applicable data on I/I programs from other wastewater collections systems where extensive investigations and/or remediations have been conducted. I/I alternatives presented and discussed in this report apply to community collection systems only, since these are the systems for which extensive data exist.

I/I alternatives presented in this report also focus on community systems because the greatest percentage of extraneous flow originates in the community systems and not the MWRA interceptor network. Although the MWRA owns and operates an extensive interceptor network, these interceptors comprise less than one percent of the miles of pipe tributary to MWRA treatment facilities. The ongoing MWRA T.V. and manhole inspection program and the analysis of meter data under the I/I control program serve to identify sources of I/I into MWRA interceptors. When I/I sources directly into the MWRA system are identified, remediation measures are undertaken.

The general objective of I/I strategies was to evaluate flow reductions upstream of facilities being investigated under the CSO, interceptor, and secondary treatment strategy tasks. This objective was addressed by identifying potentially feasible I/I rehabilitation programs of various magnitudes, using applicable technologies, at various locations where data indicate that I/I control needs potentially exist. The estimated reduction of I/I, with associated reduction costs, were integrated with results developed under the other strategies to evaluate trade-offs between I/I control and the cost-effective downsizing of CSO, interceptor, and secondary treatment facilities.

Table 9-1 presents the average annual flow components for the MWRA system as developed from 1991 and 1992 MWRA meter system data. As shown, the infiltration component represents approximately one-half of the annual flow and is the largest flow component on an annual basis. Monthly average infiltration rates vary, with the highest rates typically occurring during the high groundwater months of March, April, and May. Because the average annual inflow values in Table 9-1 are averaged over 365 days of the year regardless of wet or dry days, inflow only comprises 10 to 12 percent of the annual flow; in later chapters of this part of the report, it is shown that inflow is the most significant component when evaluating peak flow rates and quantities.

DEFINITIONS

Following are definitions of basic I/I related terms used in the following chapters. Definitions for other I/I related terminology used are provided in Appendix K.

Public and Private I/I Sources

For purposes of quantifying I/I sources and related costs of reduction, I/I sources may be identified as private or public sources. Private I/I sources are those sources which originate on private property, the most common sources being defective building services, roof leader connections and sump pump connections. Removal of private sources is often problematic due to public funding, access, and legal issues relating to work on private property. Public I/I sources are those sources which are located in the public right of way, the most common

TABLE 9-1. ANNUAL AVERAGE FLOW COMPONENTS FROM 1991 AND 1992 MWRA WASTEWATER METERING SYSTEM DATA

Year	Average Sanitary Flow (Mgd)	%	Average Infiltration Flow (Mgd)	%	Average Inflow Flow (Mgd)	%	Sum Annual Average Flow (Mgd)
1991	160	41%	189	49%	38	10%	387
1992	149	41%	173	47%	44	12%	367

sources being manhole and pipeline defects, and catch basin connections to the wastewater collection system. Figure 9-1 shows some typical public and private sources of I/I.

Infiltration

Infiltration is dry weather flow resulting from the leakage of groundwater into collection systems through pipeline, manhole, and building service defects. Public infiltration sources include, but are not limited to, sewer defects such as pipe joints, cracks, punctures, and leaking manholes. Private sources would include defective service connections. Because infiltration can occur along the entire length of the sewer system and is influenced by the size of the conduits, a common system performance measure for infiltration is gallons per day per inch diameter-mile of sewer (gpdim). Infiltration should be minimized to the extent that it is cost-effective to do so. In most systems, particularly older ones such as the MWRA system, infiltration cannot be totally eliminated.

Inflow

Inflow is defined as wet weather flow resulting from the entry of stormwater into the sewer system. The two types of inflow are Direct and Indirect. Direct inflow sources are those sources which collect stormwater surface runoff and are directly connected to the sanitary

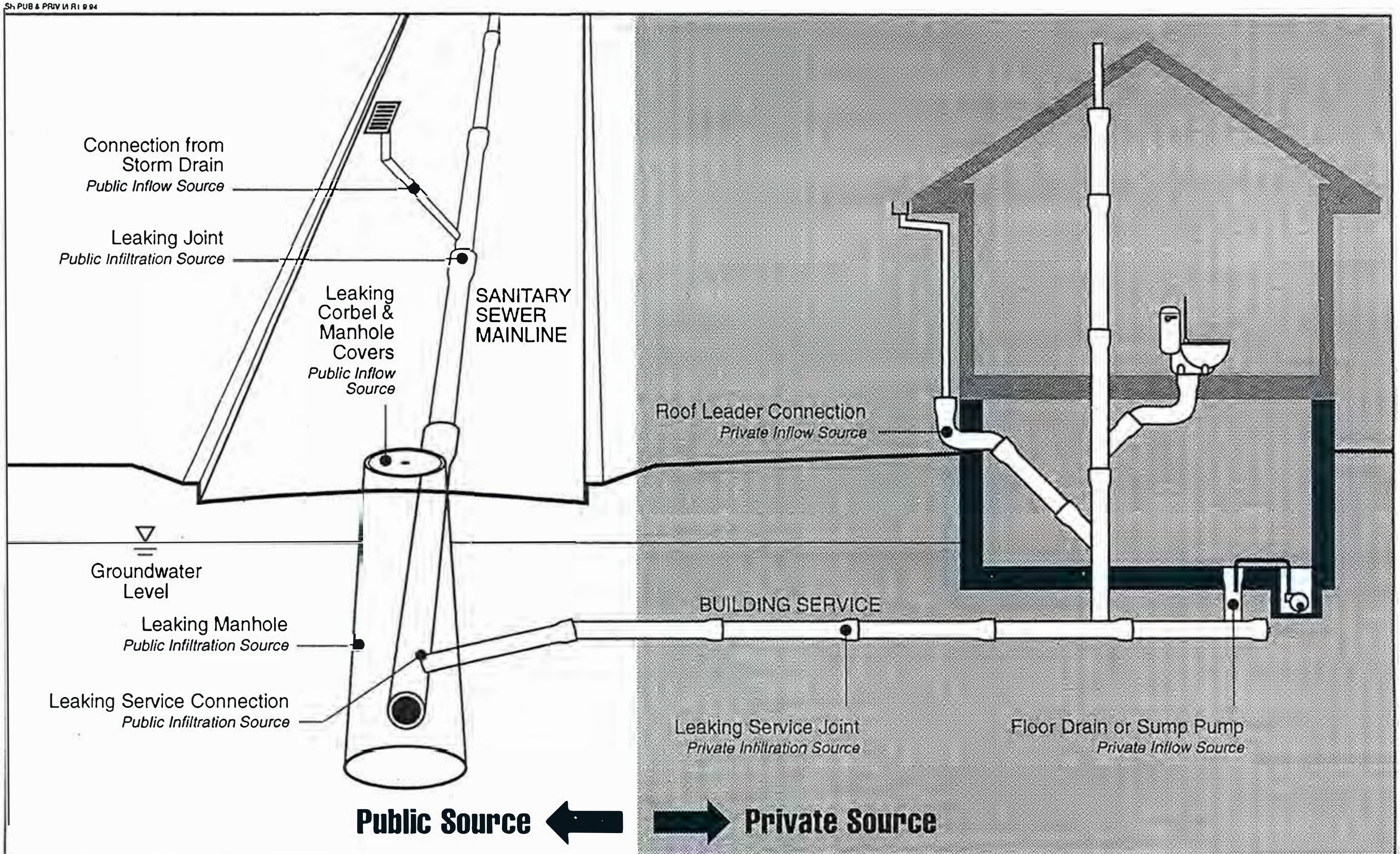

FIGURE 9 - 1
PUBLIC & PRIVATE SOURCES OF I/I

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sewer such as catch basins (i.e. direct public inflow source) and roof leaders (direct private inflow source); direct inflow sources are generally not permitted under sewer use regulations in separately sewered communities. Indirect inflow is sometimes referred to as Rainfall Induced Infiltration. Indirect inflow sources are the same as those by which dry-weather infiltration enters the system (joints, cracks, punctures, and manholes) but is distinguished from infiltration because it occurs as a result of wet weather events. Indirect inflow may continue to enter the collection system for several days following a rain event. Inflow can occur over the entire length of the sewer system, but is less dependent on the size of the sewer lines than infiltration. A common system performance measure for inflow is million gallons per mile (mg/mile) of sewer.

REPORT ORGANIZATION

This part of the report is organized into five chapters and four appendices as follows:

- Chapter Nine provides background information with several definitions of terms which are frequently used.
- Chapter Ten provides baseline flow data developed from recent MWRA Wastewater Metering System data.
- Chapter Eleven presents the assumptions, considerations, and methodology used in developing I/I data, estimating reductions, and related costs.
- Chapter Twelve presents the results of three I/I reduction alternatives developed for consideration under the SMP.
- Chapter Thirteen provides the recommended I/I control plan included in the SMP.
- Appendix K provides a more detailed listing of definitions for terms used throughout the I/I chapters of the report.
- Appendix L provides supplemental information regarding cost development and effectiveness of removal. Also included is a listing of I/I and SSES reports completed for member communities, and a summary by community of I/I reductions included in the SMP.

- Appendix M provides excerpts from the I/I database created as part of this study to assist in evaluating reductions on a public connection basis.

- Appendix N provides a summary of baseline I/I data and general system information by public connection as included in the I/I database described in Chapter 12.

The information presented in this part of the report is summarized in Part One - Recommended Plan.

PART III

CHAPTER TEN

BASELINE INFILTRATION AND INFLOW QUANTITIES

Baseline infiltration and inflow quantities for each community are based primarily on 1991 and 1992 MWRA Wastewater Metering System data. Where projects to reduce I/I are underway, or are planned to be conducted, the anticipated I/I reductions have been included in the baseline assessment. MWRA funded I/I reduction projects which are proposed for construction in the near future (prior to 1997) were included in the future planned condition baseline. For example, infiltration reduction projects in Newton, Winchester, Melrose, Randolph, Weymouth, Braintree and Stoughton are expected to reduce peak flows by a total of 3 mgd; inflow reduction projects in Norwood, Everett, Medford, Belmont and Boston are expected to reduce peak inflow by 11.3 million gallons for the 1-year, 6-hour storm. The I/I system assessment addressed infiltration and inflow that is tributary to MWRA interceptors via more than 800 public connections located in the 43 service area communities. Annual averages and peak values for infiltration and inflow quantities have been developed for each community.

The MWRA Wastewater Metering System is used to gather wastewater flow data from each community. Estimates of infiltration and inflow components were derived through analyses of continuous wastewater flow data for 1991 and 1992. Table 10-1 provides a summary of the baseline I/I quantities for the North, South, and CSO communities. Table 10-2 presents an I/I summary by community and provides system performance values (gpdim and mg/mile) on a community basis. The infiltration quantities in these tables represent peak infiltration as desegregated to system-wide public connections throughout the MWRA system. The disaggregation process is described in Chapter Eleven. Four day inflow quantities in Tables 10-1 and 10-2 represent predictions by the calibrated and verified RUNOFF block of the system-wide SWMM model. Quantities of direct versus indirect inflow were estimated by inspection of 4-day inflow hydrographs produced by the model. The model produced the 4-day inflow quantities based on the 1-year, 6-hour design storm, and provided inflow data at

TABLE 10-1. SUMMARY OF BASELINE I/I QUANTITIES

System	Total Peak Infilt.[1] (mgd)	% of Total Infilt.	Total 4-Day Inflow[2] (mg)	Total Direct Inflow[3] (mg)	% of Total Inflow	Total Indirect Inflow[3] (mg)	% of Total Inflow
NORTH	80.72	34%	99.5	38.32	23%	61.25	36%
SOUTH	94.07	39%	68.86	24.01	14%	44.85	27%
CSO	63.92	27%	N/A	N/A	N/A	N/A	N/A
TOTAL	238.71	100%	168.43	62.32	37%	106.10	63%

(1) Peak Infiltration quantities as desegregated to public connections based on 1991 and 1992 MWRA Meter System data, and I/I and SSES reports.
(2) 4-Day Inflow quantities as determined by flow model.
(3) Direct Inflow assumed to be 60% of the first-day inflow as determined by inspection of 4-day inflow hydrographs produced by flow model; Indirect Inflow is the remaining amount of inflow.

15 minute intervals for a 4-day period. Graphs of this data were plotted for each public connection. Direct inflow quantities were based on the assumption that 60 percent of the inflow occurring on the first day of the storm was from direct inflow sources; remaining quantities were assumed to be indirect inflow.

System performance values for infiltration by public connection range from nearly zero to over 35,000 gpdim; system performance values for inflow range from nearly zero to more than 1.4 mg/mile. These data are included in Appendix N. It may be assumed that greater successes in I/I reduction could be achieved at public connections with higher system performance values, when evaluated on a cost-per-gallon-removed basis.

Infiltration and inflow rates may vary significantly from month to month and from year to year. In general, infiltration rates are a function of groundwater levels, and inflow rates are a function of precipitation or rainfall; higher than average groundwater levels and higher than average rainfall will result in increased levels of infiltration and inflow, respectively.

TABLE 10-2. BASELINE I/I QUANTITIES AND SYSTEM PERFORMANCE VALUES BY COMMUNITY

			INFILTRATION		INFLOW	
Community	Miles of Sewer	Sewer Inch-Miles	Total Peak Infiltration (mgd)	Total Peak Infiltration (gpdim)	1Y 6H 4-Day Inflow (mg)	1Y 6H 4-Day Inflow (mg/mile)
	A	B	C	D = C/B	E	F = E/A
NORTH SYSTEM						
Arlington	103	840	2.7018	3,216	2.2444	0.0218
Bedford	67	552	1.7500	3,170	0.7342	0.0110
Belmont	76	686	2.3600	3,440	3.3653	0.0443
Brookline (North Only)	29	752	2.6600	3,537	1.9914	0.0687
Burlington	107	1,042	2.5100	2,409	2.4685	0.0231
Everett	57	497	3.6000	7,243	8.3553	0.1466
Lexington	156	1,157	6.4825	5,603	2.6246	0.0168
Malden	100	717	3.8041	5,306	3.8486	0.0385
Medford	115	724	8.3710	11,562	16.3826	0.1425
Melrose	74	584	3.9320	6,733	1.0335	0.0140
Milton (North Only)	6	66	0.3200	4,848	5.8236	0.9706
Newton (North Only)	127	1,190	6.4800	5,445	1.6032	0.0126
Reading	90	800	1.6320	2,040	1.1645	0.0129
Revere	78	832	3.2600	3,918	9.0545	0.1161
Stoneham	63	450	3.2819	7,293	1.5098	0.0240
Wakefield	78	1,861	2.6600	1,429	3.3407	0.0428
Waltham	137	1,151	6.6000	5,734	2.5718	0.0188
Watertown	75	603	2.6300	4,362	2.6100	0.0348
Wilmington	19	259	0.8800	3,398	0.3100	0.0163
Winchester	83	633	3.6240	5,725	2.3696	0.0285
Winthrop	31	293	3.3500	11,433	23.1408	0.7465
Woburn	135	1,405	7.8300	5,573	3.0183	0.0224
NORTH SYSTEM TOTALS:	1,806	17,094	80.7192	4,722	99.5651	0.0551
CSO SYSTEM						
Boston (North Only)	596	7,924	50.0000	6,310	N/A	N/A
Cambridge	163	2,000	7.0300	3,515	N/A	N/A
Chelsea	41	584	1.6900	2,894	N/A	N/A
Somerville	128	1,500	5.2000	3,467	N/A	N/A
CSO COMMUNITY TOTALS:	928	12,008	63.9200	5,323	N/A	N/A
SOUTH SYSTEM						
Ashland	18	207	0.4800	2,319	0.3365	0.0187
Boston (South Only)	244	3,149	14.9367	9,892	19.8918	0.1143
Braintree	134	1,031	5.0800	1,613	5.9850	0.0245
Brookline (South Only)	79	454	5.2969	5,138	6.2939	0.0470
Canton	60	582	1.7395	3,832	0.9263	0.0117
Dedham	81	712	6.4999	11,168	3.2766	0.0546
Framingham	275	1,756	4.0100	5,632	3.2393	0.0400
Hingham	31	270	1.0400	592	0.2321	0.0008
Holbrook	31	312	0.5300	1,963	0.3757	0.0121
Milton (South Only)	76	438	4.8304	15,482	3.6154	0.1166
Natick	103	825	2.0502	4,681	1.0539	0.0139
Needham	119	834	3.2200	3,903	2.6663	0.0259
Newton (South Only)	137	1,389	11.3995	13,668	6.9261	0.0582
Norwood	94	927	4.1700	3,002	1.0647	0.0078
Quincy	240	1,715	11.2625	12,149	5.3888	0.0573
Randolph	101	1,138	1.8000	1,050	1.4631	0.0061
Stoughton	58	621	2.2100	1,942	1.0845	0.0107
Walpole	54	401	1.6300	2,625	0.8760	0.0151
Wellesley	130	947	4.3200	10,773	1.9139	0.0354
Westwood	74	627	1.1800	1,246	0.7351	0.0057
Weymouth	174	1,510	6.3800	10,175	1.5119	0.0204
SOUTH SYSTEM TOTALS:	2,313	19,845	94.0657	4,740	68.8569	0.0298
GRAND TOTALS:	**5,047**	**48,947**	**238.7049**	**4,877**	**168.4220**	**0.0334**

NORTH SYSTEM

In the North System, the 4-day inflow volumes by public connection for the 1-year, 6-hour storm ranged from in excess of 1.3 mg/mile to nearly zero, with most values under 0.05 mg/mile. North system total 4-day inflow for the 1-year, 6-hour storm is predicted to be 99.5 mg, excluding inflow from portions of the north system that have CSOs. Infiltration rates ranged from approximately 39,000 gpdim to nearly zero on a public connection basis. Peak infiltration is predicted to be 80.7 mgd. For comparison, results from the 1992 MWRA Wastewater Metering System Analysis showed that on average, infiltration contributed 54 mgd in the North System (excluding combined sewer communities); peak infiltration rates were approximately 69 mgd. These differences are indicative of variations in infiltration rates from month to month and year to year.

SOUTH SYSTEM

South system 4-day inflow volumes by public connection for the 1-year, 6-hour storm ranged from nearly zero to more than 2.0 mg/mile. As in the North system, most values were less than 0.05 mg/mile. The high 4-day inflow volumes expressed on a mg/mile basis served to focus inflow control efforts on areas where inflow reductions should be possible. South system total 4-day inflow for the 1-year, 6-hour storm is predicted to be 68.9 mg. Infiltration rates ranged from approximately 48,000 gpdim to nearly zero on a public connection basis. Peak infiltration is predicted to be 94.1 mgd. For comparison, results from the 1992 MWRA Wastewater Metering System Analysis show that, on average, infiltration contributes 54 mgd in the South System; peak infiltration rates were approximately 76 mgd in 1992.

COMBINED SEWER SYSTEM

Combined sewer areas are defined as tributary areas that contain combined sewers which flow to regulators that can discharge overflows to receiving waters (or to conduits leading to receiving waters). Inflow quantities in the combined sewer communities were not addressed under I/I strategies, because wet weather flow enters the system in these areas by design. Inflow quantities in combined sewer communities are discussed in detail in Part Two, CSO Strategies. On a public connection basis, infiltration rates ranged from 23,000 gpdim to approximately 2,000 gpdim. Peak infiltration in the combined sewer system is predicted to be 63.9 mgd. For comparison, results from 1992 MWRA Metering data indicate an average infiltration rate of 65 mgd from the combined sewer communities and a peak infiltration rate of 72 mgd.

PART III

CHAPTER ELEVEN

DEVELOPMENT OF I/I DATA AND COSTS FOR REHABILITATION

Results of flow analyses derived from the MWRA Wastewater Metering System were adjusted as described in Chapter 10 to provide baseline infiltration and inflow rates for each community. This information was used to apportion or disaggregate I/I quantities to each public connection. Quantities were disaggregated to public connections based on (in order of preference): 1) MWRA meter data when a meter was located at or near the public connection, 2) available information from community I/I and SSES reports where specific locations and quantities of I/I had been identified, and 3) length of tributary footage and inch-diameter miles to the public connection when no specific information was available to estimate I/I at the public connection. Footage and inch-diameter mile information was obtained from several sources including community SSES studies, the SAMS GIS layer analysis, and MWRA Community I/I Questionnaires. These data have been used to develop I/I control alternatives and to estimate I/I reductions and related costs at the public connection level.

INFORMATION FROM COMMUNITY SEWER SYSTEM STUDIES

During the 1970s, the USEPA and the State of Massachusetts sponsored Infiltration/Inflow Grant Programs which resulted in numerous reports and studies (i.e. I/I Studies and Sewer System Evaluation Surveys) being performed by MWRA member communities. A listing of I/I and SSES reports completed for member communities that were used in this study is presented in Appendix L. Typically, the studies employed short-term flow metering programs in conjunction with assorted investigative tasks such as flow isolation, television inspection, and smoke testing for purposes of identification of infiltration and inflow sources. In general, the goal of these programs was to reduce I/I by completing three phases: Study, Design, and Construction. When Federal and State sponsored grant programs were postponed, most communities had not completed the 3-phase process. In many cases, the detailed investigations that are required to identify I/I sources for purposes of designing and constructing rehabilitations were not yet complete. For these reasons, only limited data were available regarding specific sources of I/I in each community. In those cases where communities have performed construction for I/I reduction, the reduction was accounted for in the baseline flows.

AVAILABLE TECHNOLOGIES FOR I/I REHABILITATION

I/I reduction alternatives must include considerations for issues such as program phasing, affordability, implementability, and anticipated performance. One important factor in addressing each of these issues is the proposed technology to be used to achieve the objectives of the I/I alternative.

In general, the technologies available for I/I reduction strategies include the following:

- Replacement of existing sewers and manholes with materials which are more water tight. Spot repairs or replacement of extended reaches of sewer could be included.
- Grouting of leaks with chemical or cementitious grouts to stop the flow of I/I.
- Relining of existing pipes and manholes with flexible liners such as plastic pipe or resin impregnated cloth.
- Removal/rerouting of direct inflow sources, such as storm drains which are connected to sanitary sewers.
- Separation of direct inflow sources such as sump pumps, roof leaders, and groundwater drains.

These methods of rehabilitation were applied in a general way to estimate potential I/I reduction levels and to provide the basis for estimating costs for various I/I alternatives. A review of available information was conducted to evaluate the effectiveness, cost, and other factors for I/I rehabilitation projects which have been completed in the MWRA service area, United States and abroad. This information was used to develop realistic cost estimates and/or projections of I/I removal.

EFFECTIVENESS OF SEWER REHABILITATION FOR I/I CONTROL

The effectiveness of sewer rehabilitation for I/I control must be considered separately for infiltration and inflow.

Direct Inflow Reduction

Significant inflow reductions have been achieved in the MWRA service area where direct sources of inflow, such as cross-connections from storm drain catch basins to sanitary sewers, have been disconnected from the sanitary sewer and rerouted to storm drainage areas, thus reducing quantities of direct inflow to sewerage facilities; inflow reduction techniques such as this do not directly involve the "rehabilitation" of sanitary sewers but may be considered to be more of a surface drainage improvement since new storm drain pipe is installed in the process. Direct inflow sources have been the primary target of MWRA community I/I control efforts because these sources are easy to identify and are generally simple and inexpensive to correct with obvious benefits in reducing peak wet weather flows through wastewater pump stations and other facilities. As noted in Table 11-1, inflow quantities comprise only a small percentage of the annual flow volumes from any given community when all flow components are considered (i.e. sanitary flow, infiltration, and inflow). This is because inflow is storm related and occurs a small percentage of the time on an annual basis. For this reason, the operation and maintenance cost of wastewater treatment of inflow is much less than that of infiltration when evaluated on the basis of annual cost-per-gallon treated. Inflow has more of an impact on capital costs associated with the sizing of wastewater treatment and pumping facilities required to accommodate peak wet weather flows.

TABLE 11-1. DISTRIBUTION OF I/I BASED ON SYSTEM PERFORMANCE CRITERIA AND I/I SOURCE (1)

INFILTRATION			
GPDIM Range	No. of Public Connections in GPDIM Range	Sum Peak Infiltration (mgd)	% of Total Infiltration
> 20,000	26	13.26	6%
10,000 - 20,000	83	34.59	14%
5,000 - 10,000	164	63.99	27%
3,000 - 5,000	155	100.61	42%
< 3,000	269	26.26	11%
TOTAL	697	238.71	100%
INFLOW			
MG/MILE Range	No. of Public Connections in MG/MILE Range	Sum Total Inflow (mg)	% of Direct Inflow
> 0.700	33	28.14	17%
0.180 - 0.700	35	26.24	16%
0.095 - 0.180	41	32.13	19%
0.040 - 0.095	176	38.06	23%
< 0.040	412	43.87	26%
TOTAL	697	168.44	100%

(1) Distribution for total North, South, and CSO Systems.

INFILTRATION		Estimated Contribution Infiltration From Source %
Source Description		
Mainline Defects (Public)	Offset Joints, Cracked Pipes, House Service Connections to Main, Leaking MH Walls, Connections	30%
Manholes (Public)	Leaking Manhole Walls, Connections	10%
House Services (Private)	Service Lateral Sewer Leakage	60%
	TOTAL>	100%

INFLOW		Estimated Contribution Inflow From Source %
Source Description		
Direct Sources	(Public) Direct Connections Storm Sewers, MH Pickholes & Covers Below Grade	20%
	(Private) Sump Pumps/Basement Floor Drains, Roof Leaders, Yard/Area Drains	20%
Indirect Sources	(Public) Offset Joints, Cracked Pipes, House Service Connections to Main, Leaking MH Walls, Connections	30%
	(Private) Service Lateral Sewer Leakage	30%
	TOTAL>	100%

Sewer Rehabilitation for Infiltration Reduction

Sewer rehabilitation for infiltration reduction has been implemented to a lesser extent in MWRA communities when compared to inflow reduction. Rehabilitation of sanitary sewers is performed to reduce infiltration and/or for purposes of maintaining the structural integrity of pipelines and manholes. Sewer rehabilitation measures also reduce indirect inflow quantities, as infiltration and indirect inflow sources are essentially the same. In MWRA communities, sewer rehabilitation has been performed primarily for structural purposes, as reduction of infiltration has taken on a lower priority when compared to the potential costs of emergency repairs incurred when pipelines collapse. In addition, the identification and removal of infiltration sources is difficult and more costly on average than removal of inflow sources, and resulting benefits and effectiveness in reducing infiltration are less obvious. As shown in Table 9-1, infiltration is approximately one-half of the annual flow volume. This infiltration volume is comprised of the multitude of drips originating at leaking pipe joints, manholes, building services, connections of building services to the main sewer, and various other sources.

A summary of I/I quantities based on system performance criteria, and estimated percentages of I/I by source is presented in Table 11-1. As shown, those public connections with high system performance values (gpdim and mg/mile) make up only a small percentage of I/I in the wastewater collection system. These data imply that while I/I reduction efforts should be prioritized at public connections with higher system performance values (in order to result in more cost-effective levels of I/I reduction), the distribution of I/I in most of the collection system is fairly uniform, and costs would increase proportionally as higher levels of reduction are pursued. Percentages of I/I by source are based on a review of information from available reports in the MWRA service area and the New England region where more detailed investigations (e.g. detailed source data from television inspection, smoke testing, building inspections, dye water flood/trace programs) have been performed providing specific information regarding I/I.

The effectiveness of sewer rehabilitation programs is difficult to assess because accurate flow measurements should be taken before and after rehabilitation in the rehabilitated segments of sewer, accounting for any changes in groundwater levels or rainfall quantities; these flow measurements are rarely taken because of the associated costs involved. Flow data required to verify infiltration reductions should be obtained with area-specific flow measurements, utilizing continuous flow meters such as those used in the MWRA Wastewater Metering System in conjunction with flow isolation techniques, which are measured in the rehabilitated segment of sewer before and after rehabilitation. MWRA meters are often located downstream of several public connections, and typically quantify flows from relatively large tributary areas. Depending on the location and scope of the I/I reduction project, these meters may be insufficient to directly quantify I/I reductions in upstream areas. Continuous flow meters such as those used in the MWRA metering system could supply supporting information regarding reduction of annual I/I volumes, but numerous meters would typically be required in the upstream member community systems to adequately evaluate I/I source reductions. Flows in community systems are constantly changing, and because of the inherent difficulties in estimating the infiltration/inflow component of the flows, I/I measurement may be considered inexact under the best conditions. While the methods of performing rehabilitations are well documented, the effectiveness in actually reducing I/I is not. Studies have been performed outside of the MWRA service area to measure the effectiveness of various rehabilitation programs. Conclusions indicate that designers were often overly optimistic in their I/I reduction predictions, and costs for reduction were often underestimated. Reasons for this include:

- The effects of groundwater migration (i.e. the tendency for groundwater to move from a rehabilitated defect to a previously non-leaking defect) may not have been understood;
- Many of the rehabilitation programs did not include rehabilitation of building services, which have since been identified as major contributors of I/I;
- Antecedent conditions, such as groundwater levels or rain events, may not have been properly accounted for when calculating I/I rates.

In recent years there have been advancements in the field of sewer rehabilitation. At the present time, new techniques are proceeding on a trial basis, and experience with the application of developing technologies for rehabilitation is limited. Sewer rehabilitation projects utilizing new technologies such as in-situ lining methods have been performed primarily for structural purposes. For these reasons, a conservative approach consistent with the limited level of documented performance data available, was used to estimate I/I reductions and related costs for I/I strategies.

System Characterization and Assumptions of Effectiveness

MWRA Wastewater Metering data and subsequent analyses provide the means necessary to characterize the system response to rainfall (inflow) and seasonal changes in groundwater levels (infiltration). MWRA metering data were used in conjunction with flow model results to estimate infiltration, direct inflow, and indirect inflow components of I/I. For the purpose of estimating I/I reductions and associated costs for alternatives developed in Chapter 12, assumptions were made regarding the effectiveness of sewer rehabilitations based on currently available technologies. In general, assumptions pertaining to the effectiveness of I/I rehabilitation methods were based on the limited performance data available and engineering judgement.

Following is a discussion of each I/I component and the assumptions applied regarding the effectiveness of available technologies in reducing I/I.

Infiltration. Infiltration reductions and related costs are based on an assumption of the percentage of infiltration identified within a given portion of the system. Review of SSES studies has shown that infiltration may be concentrated in portions of the system. Sewers located in areas with high groundwater levels, such as in proximity to a river or lake, tend to have higher infiltration rates; these areas could be targeted for infiltration reduction based on the reasonable assumption that greater quantities of infiltration could be removed for each rehabilitation dollar spent. It is generally assumed that areas with higher gpdims will achieve a greater percent reduction. Initial scenarios for peak infiltration reduction assumed that 40 percent of the infiltration would exist within 25 percent of the system; costs for identification (i.e. flow metering, TV inspection, etc.) of the infiltration assumed that the entire system would be studied, with the conclusion that 40 percent of infiltration would be identified in 25 percent of the system; this portion of the system (i.e. 25 percent) would be rehabilitated, and rehabilitation costs were based on that quantity of pipe. Rehabilitation was estimated to remove 50 percent of the infiltration for any reach due to the effects of groundwater migration; therefore, 20 percent of the system-wide infiltration could be eliminated if it was assumed that 40 percent of infiltration was identified in 25 percent of the system, and the pipe in that portion of the system was fully rehabilitated.

Available technologies applied for infiltration reduction generally include testing, sealing and grouting, and replacement in extreme cases where pipe is badly deteriorated. Grouting cannot be applied to cracked or broken pipe and has not been proven to be extremely effective in reducing infiltration. Sliplining methods have been used as well, but with limited success.

Direct Inflow. Direct inflow quantities were based on the 4-day inflow hydrographs developed at each public connection for the 1-year, 6-hour storm. It was assumed that 60 percent of the inflow occurring on the first day of the storm was representative of the direct inflow quantity in the public connection tributary area. The remaining quantity was assumed to be the indirect inflow quantity. It was also assumed that 50 percent of total direct inflow was derived from public sources, and 50 percent from private sources.

Direct public inflow sources such as catch basin connections are relatively inexpensive to identify, and rehabilitations are typically inexpensive to design provided that a storm drain exists in proximity to the catch basin to be disconnected from the sanitary sewer. Construction costs can vary considerably depending on the length of new storm drain required. The industry rule of thumb is that inflow from direct public sources (e.g. catch basins) are generally less expensive to remove on a gallons-per-day basis from the system than inflow from direct private sources (e.g., roof leaders, area drains, sump pumps). Hydrographs developed from the flow model were used in conjunction with information from available sewer system evaluation studies to identify areas with high levels of direct inflow.

Direct private inflow sources are considered more expensive to remove on a cost-per-gallon-removed basis than direct public inflow due to factors concerning work on and/or access to private property. The technologies involved are often conceptually simple, for example, disconnect the roof leader or sump pump from the building service and reroute the discharge to a storm drain or surface area. Assuring that the source stays disconnected is often difficult as property owners may reconnect rather than spend the money to reroute the discharge to a storm drain or other appropriate drainage area. Direct private inflow sources are generally identified by conducting a house to house inspection and smoke testing program which is often costly and time consuming. Although most connections of this type are illegal under most municipal sewer regulations, property owners are not required to allow entry and would tend to refuse entry if they knew the purpose of the investigation. Typically, municipalities would provide guidance to the property owner in rerouting the flow from sump pumps or roof leaders, but costs would be borne by the property owners. In some cases, sump pumps may be prohibited from being connected to storm drains, particularly if potentially contaminated floor drainage could be tributary to the sump.

Indirect Inflow Reduction. Because infiltration sources and indirect inflow sources are essentially the same, these sources are most easily identified during high groundwater periods when infiltration can be directly observed via television inspection. Reduction of indirect inflow sources (e.g. leaking pipe joints, building services) are not considered directly for rehabilitation, as infiltration reduction programs identify and rehabilitate most of these defects. For these reasons, it was assumed that indirect inflow reduction would be proportional to the percentage of infiltration reduced, without additional costs above that required for infiltration reduction.

ESTIMATED COSTS FOR SEWER SYSTEM REHABILITATION

Costs developed for I/I control alternatives described in Chapter 12 are generally proportional to the quantity of I/I to be removed from the system. Costs related to study, design, and construction were included. Infiltration reduction costs were directly related to the length and diameter of sewer to be rehabilitated, and inflow reduction costs were estimated based on the quantities of public and private inflow to be removed, and are directly proportional to these quantities. Indirect inflow reduction costs were not developed as it was assumed that the defects by which indirect inflow enters the system are the same as those rehabilitated under the infiltration reduction program; indirect inflow quantities reduced would therefore be proportional to the percentage of infiltration reduced under the given I/I control strategy.

Unit cost information and assumptions applied in developing costs for I/I reduction are presented in Table 11-2. Examples of the methodology used to develop I/I reductions and associated costs for I/I control alternatives presented in Chapter 12 are included in Appendix L.

DEVELOPMENT OF PUBLIC CONNECTION DATABASE

To facilitate analyses of the I/I control alternatives, a database was developed which includes current flow data and system information. Data at each public connection was included and summarized to show the relative contribution of infiltration and inflow at each public connection and from each community. The data can be organized to show the I/I characteristics of flow tributary to the Deer Island treatment plant, major interceptors, and to the locations of major CSOs. These presentations and data quantifications facilitated a clearer understanding of where the areas of significant I/I flows in the member communities are located, and which parts of the MWRA collection system are most significantly impacted by I/I flows.

TABLE 11-2. UNIT COSTS OF I/I REHABILITATION

Item	Unit	Unit Cost (1) $	Comments / Assumptions / Cost Factors
STUDY/ INVESTIGATION			
SMOKE TESTING (1 BLOWER)	LF	$0.18	UNIT COST INCREASES WITH DIAMETER
DW FLOOD W/CLEAN & TV INSPEC.	LF	$2.10	UNIT COST INCREASES WITH DIAMETER
DYE WATER TRACE	SITE	$65.00	
GW GAUGE, INSTALL& MAINTAIN	SITE	$350.00	
PRE-TV FLOW ISOLATION	LF	$0.15	UNIT COST INCREASES WITH DIAMETER
LIGHT CLEAN PRIOR TO TV	LF	$0.70	UNIT COST INCREASES WITH DIAMETER
TV INSPECTION	LF	$0.70	----------------
SUM TV INSPECTION/L.F.	LF	**$1.55**	
HOUSE SERVICE TV INSPECTION	EACH	$350.00	ASSUMES ACCESSIBLE FROM BUILDING
MANHOLE INSPECTION	EACH	$32.00	
FLOW ISOLATION, MH TO MH REACHES	LF	$0.15	
UNIT COST TO IDENTIFY INFILTRATION	LF	$0.56	COST OF FIELD INVESTIGATION (SEE APPENDIX B)
ENGINEERING COSTS RELATED TO ABOVE WORK MAY BE ESTIMATED			
AT APPROXIMATELY 12% OF THE SUBCONTRACTOR COST FOR PERFORMING THE WORK.			
CONSTRUCTION			
REPAIR FOR INFILTRATION REMOVAL			
REPLACE HOUSE SERVICE	EACH	$2,000.00	REPLACE ENTIRE LENGTH FROM MAIN TO BUILDING
INSITU REHAB HSE SERVICE	EACH	$3,000.00	INSITU FORM
SPOT REPAIR	EACH	$1,000.00	
SEWER EXCAVATE AND REPLACE	LF	$120.00	UNIT COST INCREASES WITH DIAMETER
INSITU REHAB (INSITU FORM)	LF	$120.00	# OF CONN'S, BYPASS REQ'MTS ARE MAJOR FACTORS
ROOT CONTROL	LF	$2.00	UNIT COST INCREASES WITH DIAMETER
MANHOLE SEALING	EA	$1,000.00	ASSUME 10' DEPTH, BRICK MANHOLE
JOINT TEST & SEAL	JOINT	$27.00	
GUNNITE (BRICK WORK), 36" SEWER	LF	$65.00	
REHAB. SERVICE CONNECTION AT MAIN	EACH	$600.00	REHAB. SERVICE IN PUBLIC R.O.W. (SEE APPENDIX B)
REHAB. OF MAINLINE SEWER	LF	$25.00	ASSUMES GROUTING, REPAIRS, ETC. (SEE APPENDIX B)
INFLOW DEFECTS			
PONDING MANHOLE-RAISE TO GRADE	EACH	$400.00	
MANHOLE FRAME & COVER REPLACEMENT	EACH	$1,000.00	INCLUDES PAVEMENT RESTORATION
CROSS CONNECTION PLUGGING	EACH	$5,000.00	
REDIRECT ROOF LEADER	EACH	$200.00	DIRECT BLDG OWNER TO DISCONNECT, AND INSPECT
INFLOW REDUCTION (DIRECT PRIVATE)	GAL	$5.00	INCLUDES STUDY, DESIGN,& CONSTR COSTS (SEE APP B)
INFLOW REDUCTION (DIRECT PUBLIC)	GAL	$1.00	INCLUDES STUDY, DESIGN,& CONSTR COSTS (SEE APP B)
OTHERS			
ENGINEERING DESIGN COST IS ESTIMATED AT			
15% OF CONSTRUCTION COST			
REMOVAL OF HAZ. MATERIALS	TON	$330.00	DEBRIS FROM HEAVY CLEANING OF SEWERS
DISPOSAL OF HAZ. MATERIALS	TON	$300.00	DEBRIS FROM HEAVY CLEANING OF SEWERS

(1) Unless otherwise specified, cost provided is for an 8" to 12" diameter pipe.

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The database also facilitated the flow data analyses and development of cost data required in the evaluation of the various I/I control alternatives. The basic structure of the database included the public connection number as the "key" field. In general, the database was structured according to the following groups of information:

- General System Data: this grouping of data includes information such as the tributary footage or miles, inch-diameter miles, estimated number of building services, and downstream MWRA interceptor relative to the public connection number.

- Infiltration Worksheet: estimates of infiltration reductions and related costs were developed in this grouping.

- Inflow Worksheet: estimated inflow reductions and related costs were developed in this group.

- Infiltration Summary: baseline infiltration quantities in mgd and gpdim at each public connection were included. Infiltration reduction data and associated costs developed in the worksheets were presented in the summary.

- Inflow Summary: baseline inflow quantities in gallons and mg/mile at each public connection were included. Inflow reduction data and associated costs developed in the worksheets were presented in the summary.

Adjustments made to the database allowed the analyses to focus on selected criteria such as system performance values (i.e. gpdim, mg/mile), inflow and infiltration rates, costs, community, geographical area, etc. Appendix M provides excerpts from sections of the database.

PART III

CHAPTER TWELVE

ALTERNATIVES FOR SYSTEM-WIDE I/I REDUCTION

In developing alternatives for I/I reduction, the initial task was to identify potential alternatives comprised of appropriate I/I reduction technologies. Screening criteria were developed to identify and eliminate alternatives that were clearly infeasible on the basis of excessive cost, implementation constraints, or other important factors. As one strategy area evolved, the impact on other strategy areas was checked as appropriate. Reduced levels of I/I were estimated for geographic areas where the greatest I/I problems potentially exist, and I/I reductions associated with the alternatives were assessed to determine hydraulic impacts on CSO, interceptor, and secondary treatment strategies.

CONSIDERATIONS IN DEVELOPING ALTERNATIVES

In the development of alternatives for I/I control, information from I/I and SSES reports completed for MWRA communities was reviewed to estimate quantities and determine locations of I/I that had been identified. The conclusion from this review was that the majority of MWRA communities have had at least some Phase I SSES (i.e. flow metering, flow isolation) work completed, and only limited amounts of Phase II work (e.g. investigations such as television inspection work required to identify specific locations of I/I) have been completed. Due to the resulting lack of detailed information concerning the location and identification of specific I/I sources in the MWRA region, assumptions were made regarding quantities and the distribution of I/I in each member community's system where deemed necessary. For the purpose of estimating I/I reductions and related costs, information obtained from the SSES reports and MWRA wastewater metering program was used in conjunction with various assumptions and engineering judgement to assign I/I rates and volumes to public connections in each community as described in Chapter Eleven of this report. Considerations and assumptions applied in the development of I/I control alternatives are outlined below:

- Review of I/I and SSES reports suggests that, in general, infiltration and inflow sources can be attributed to sources as was shown in Table 11-1.

- Costs developed for I/I control alternatives include study, design, and construction costs.

- For the purpose of estimating rehabilitation costs, infiltration sources were separated into public and private source categories; inflow sources were further categorized into public direct, private direct, private indirect and public indirect sources. Investigative and construction costs for removal of public source I/I are generally less expensive on a per gpd basis than private sources. Administrative costs associated with private source removal are often significant due to factors relating to work on private property. In the past, significant amounts of I/I have been shown to originate from private sources, such as house service lateral connections (private source infiltration and indirect inflow) and sump pumps, roof leader and floor drain connections (private source inflow).

- Indirect inflow volumes (e.g. 4-day inflow in gallons) enter sewers through many of the same defects as infiltration. As described in Section 3, reduction of indirect inflow sources were not considered directly for rehabilitation, as infiltration reduction programs identify and rehabilitate the same defects. For these reasons, it was assumed that indirect inflow reduction would be proportional to the percentage of infiltration reduced, without additional costs above that required for infiltration reduction. Reduction of indirect inflow would only occur in areas targeted for infiltration reduction.

- The evaluation approach for assessing infiltration was based on MWRA analyses of flow measurements which have been conducted by the MWRA since 1991 at over 175 locations. Infiltration was assumed to equal the lowest measured night flows during dry weather periods multiplied by a factor to account for night-time sanitary flows. Infiltration estimates by community were disaggregated to nearly 700 public connections, so that the gpdim rate at each public connection could be computed.

- The evaluation approach for assessing inflow involved the use of the CSO and interceptor model to compute the 4-day inflow volume at the public connections. The model's RUNOFF block was calibrated against extensive inflow data developed by the MWRA from its Wastewater Metering Program. Baseline inflow volumes were derived by using the calibrated RUNOFF block of SWMM and the 1-year, 6-hour design storm required by state I/I guidelines. Inflow was then computed using model output data for the 1-year, 6-hour storm on a gallon per mile basis for each public connection.

Alternatives developed for I/I control considered the factors outlined above and were based on the desired level of I/I to be removed from the system. Several basic assumptions regarding sources of I/I, effectiveness and costs of rehabilitation, and distribution of I/I were discussed in previous sections. Assumptions which were common to the development of the alternatives are summarized below.

- Costs developed for the alternatives include study, design, and construction costs.

Infiltration:

- Up to 50 percent reduction of infiltration can be achieved in a given area if it is attempted to rehabilitate 100 percent of public and private infiltration sources in that given area.

- Costs of infiltration reduction are based primarily on footage of sewer to be rehabilitated.

- Private sources of infiltration are assumed to contribute 60 percent of total infiltration.

- Rehabilitation for infiltration reduction is assumed to remove a proportional quantity of indirect inflow, at no cost above that required for the infiltration reduction. In CSO communities, inflow quantities were not addressed in this part of the report. For this reason, indirect inflow reductions associated with infiltration reductions in CSO communities were not developed.

Inflow:

- Up to 90 percent of direct public inflow quantities and 50 percent of direct private inflow quantities can be removed assuming these sources are identified and rehabilitated.

- Public and private sources of direct inflow contribute in equal amounts to the total direct inflow; public and private sources of indirect inflow contribute in equal amounts to the total indirect inflow.

- Quantities of direct and indirect inflow were based on the 4-day inflow hydrographs generated by the flow model. Direct inflow quantities were based on a percentage of the first-day inflow quantity from the hydrographs. Under the first alternative developed (High Level of I/I Control), it was assumed that the direct inflow quantity was equal to 100 percent of the first-day inflow quantity; under subsequent alternatives, it was assumed that direct inflow was equal to 60 percent of the first-day inflow.

- Assume a unit cost of $1 per gallon removed for direct public inflow (includes study, design and construction).

- Assume a unit cost of $5 per gallon removed for direct private inflow (includes study, design and construction).

Key assumptions and criteria specific to the development of each I/I control alternative are presented in Table 12-1.

HIGH-LEVEL I/I CONTROL IN ALL COMMUNITIES

The results of an aggressive I/I reduction strategy, which consists of the "comprehensive" rehabilitation of I/I sources in the public and private sectors is presented in Table 12-2. Comprehensive rehabilitation would be required to minimize the effects of groundwater migration in order to achieve maximum I/I reductions in an area. This alternative represents the most aggressive strategy and provides the upper limit of I/I reduction developed under the three strategies presented in this report. Based on the assumptions outlined in Table 12-1, it was estimated that 20 percent of infiltration and 43 percent of the total inflow quantity would be removed due to the 90 percent reduction in direct inflow. As shown in Table 12-2, it was estimated that an additional 12.34 mg of indirect inflow would be reduced as a result of infiltration rehabilitations. As discussed in Chapter Eleven, indirect inflow reductions are assumed to be proportional to the infiltration reductions, and carry no costs above costs estimated for infiltration rehabilitation. Costs for this alternative include work on public and private property. Research of I/I reduction programs conducted across the country indicates that very few comprehensive rehabilitation plans have been implemented; no extensive comprehensive rehabilitation programs have been performed in the MWRA service area. I/I reduction programs performed in the MWRA service area generally have focused on the reduction of public sector inflow sources.

TABLE 12-1. COMPARISON OF I/I REDUCTION PLANS

High Level I/I Control in all Communities	I/I Control Based on Prioritization of System Performance Criteria	I/I Control Based on Selected System Performance Criteria
Assume comprehensive rehabilitation plan will remove I/I from public and private sources; I/I Reductions would be proportional in all communities. Assumptions for Infiltration Removal • Assume 40% of infiltration can be identified in 25% of the system; this assumption was applied at each public connection. • Based on the assumption that rehabilitation in any given area will be 50% effective in achieving reductions; half of the infiltration, or 20% (i.e. 40% x 0.5) was assumed to be removed at each public connection. • Costs were developed assuming public and private sources would be rehabilitated in 25% of the system. Assumptions for Inflow Removal • Assume public and private sources of direct inflow would be targeted for reduction. • Assume that 90% of direct public inflow quantity would be removed. • Assume 50% reduction of direct private inflow quantities.	Assume reductions would be prioritized and implemented based on system performance values, beginning with rehabilitations at public connections with the highest values; Cost-benefit relationships were developed and plotted (cumulative I/I reduced vs. cumulative rehab costs) to determine a beneficial levels of I/I control. This alternative was evaluated for Comprehensive rehabilitations, and Public-source-only rehabilitations (Mainline). Assumptions for Infiltration Removal Comprehensive Rehabilitation Plan • 100% of area, including public and private sources, would be rehabilitated to achieve the maximum infiltration reduction of 50%. • Reductions of public and private source quantities are proportional to infiltration levels provided in Table 3-1 (i.e. 60% from private sources, 40% from public sources) • Assume 50% reduction of public sources and 50% reduction of private sources Public Source Rehabilitation Plan (Mainline) • Assume 100% of public infiltration sources are rehabilitated. • Because 40% of total infiltration flow is assumed from public sources, and 50% reduction in public source infiltration can be achieved, result is overall infiltration reduction of 20%. Assumptions for Inflow Removal Comprehensive Rehabilitation Plan • Assume Direct Public Inflow quantities can be reduced by 75%. • Assume Direct Private Inflow quantities can be reduced by 35% Public Source Rehabilitation Plan (Mainline) • Assume Direct Public Inflow quantities can be reduced by 75%; No reductions of Direct Private Inflow quantities would be made.	Assume communities would achieve I/I reductions at various levels based on system performance values (gpdim and mg/mile). Levels of reduction are based on the assumption that member communities will remove I/I to reduce local costs related to transporting and treating I/I. Assumptions for Infiltration Removal • Assume rehabilitation of public infiltration sources only. • Levels of infiltration reduction at each public connection are based on the system performance value (gpdim) as follow: >20,000 gpdim 10% reduction 10,000-20,000 7.5% reduction 5,000-10,000 5% reduction 3,000-5000 2.5% reduction <3,000 gpdim no reduction Assumptions for Inflow Removal • Assume rehabilitation of direct inflow sources only. • Assume that no reduction will be implemented at those public connections with less than 0.04 mg/mile • Levels of direct public inflow reduction and direct private inflow reduction at each public connection are based on system performance values (mg/mile) as follow: Direct Public Inflow: >0.7 mg/mile 50% reduction 0.18-0.7 37.5% reduction 0.095-0.18 25% reduction 0.04-0.095 12.5% reduction <0.04 mg/mile no reduction Direct Private Inflow: >0.7 mg/mile 10% reduction 0.18-0.7 7.5% reduction 0.095-0.18 5% reduction 0.04-0.095 2.5% reduction <0.04 no reduction

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TABLE 12-2. SUMMARY OF I/I REDUCTIONS AND ESTIMATED COSTS HIGH LEVEL I/I CONTROL IN ALL COMMUNITIES

INFILTRATION				
System	Total Peak Infiltration (mgd)	Estimated Infiltration Removed (mgd)	Percent of Infiltration Removed	Estimated Cost of Infiltration Removal
	A	B	C=B/A	F
North	80.72	16.14	20%	$99,180,000
INDIRECT INFLOW REMOVED VIA INFILTRATION REHAB=6.87MG				$0
South	94.07	18.81	20%	$118,590,000
INDIRECT INFLOW REMOVED VIA INFILTRATION REHAB=5.47 MG				$0
CSO	63.92	12.78	20%	$67,910,000
INDIRECT INFLOW REMOVED VIA INFILTRATION REHAB=N/A				$0
Total	238.71	47.73	20%	$285,680,000

INFLOW				
System	Total Inflow (mg)	Estimated Direct Inflow Removed (1) (mg)	Percent of Total Inflow Removed	Estimated Cost for Direct Removal
	A	B	C=B/A	D
North	99.57	44.70	45%	$108,560,000
South	68.86	28.10	41%	$68,020,000
CSO	N/A	N/A	N/A	N/A
Total	168.42	72.80	43%	$176,570,000

(1) Quantities of direct inflow removed under this alternative were based on the initial assumption that Direct inflow =100% of the first day inflow ; this assumption was later revised to Direct inflow=60% of 1st day inflow for development of subsequent alternatives.

N/A -- Not Applicable; inflow reductions not assessed in combined sewer areas under I/I Strategy tasks.

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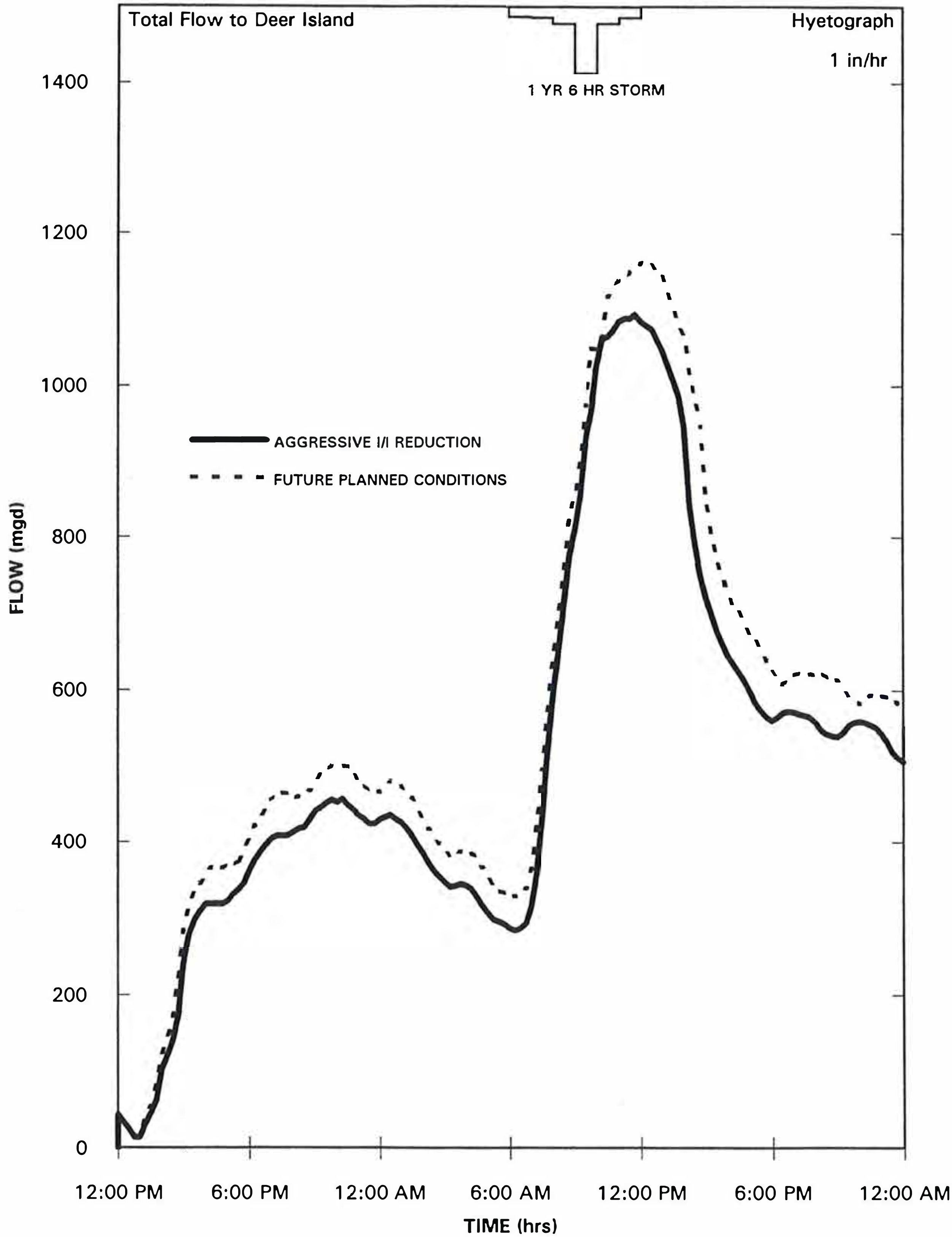

FIGURE 12-1. COMPARISON OF FUTURE PLANNED CONDITIONS AND AGGRESSIVE I/I REDUCTION

The impact of this plan on CSO volumes, interceptor surcharging, and WWTP flows was assessed using the system-wide hydraulic model. The results of this assessment, which are shown in Table 12-3 and Figure 12-1, indicate that aggressive I/I controls (with an estimated cost of $463 million) would not significantly impact the cost or sizing of CSO, interceptor, or WWTP options.

I/I CONTROL BASED ON PRIORITIZATION OF SYSTEM PERFORMANCE CRITERIA

The results of an I/I control alternative based on system performance criteria are presented in Tables 12-4 and 12-5. Table 12-4 provides the results for comprehensive (public plus private source) rehabilitation, and Table 12-5 presents the results of this alternative assuming the rehabilitation of public I/I sources only. Results were developed by prioritizing or sorting of the public connections based on the system performance criteria for infiltration (gpdim) and inflow (mg/mile).

The system performance criterion for infiltration reduction was the gpdim value, which was derived on a public connection basis by taking the ratio of the peak infiltration quantity and the inch-diameter miles to the public connection. In general, infiltration rates in a given service area are largely a function of the length and diameter of the tributary sewerage. Areas with higher gpdim values may be viewed as having higher concentrations of infiltration, and it may be further assumed that greater success would be achieved, both economically and in infiltration quantities removed, if infiltration reductions were focused in these areas.

The system performance criterion for inflow reduction was the mg/mile value, which was derived on a public connection basis by taking the ratio of the 4-day inflow quantity and the miles of tributary sewer to the public connection. Data analyses performed have shown a relationship between inflow and miles of tributary sewer. The inflow per mile relationship was determined to be a more appropriate performance measure rather than inflow per inch-

TABLE 12-3. RESULTS OF AGGRESSIVE I/I REDUCTIONS

Parameter	Future Planned Conditions	Aggressive I/I Reductions	Percent Reduction
CSO Volume, mg	151	149	1
Surcharged Interceptor Junctions[1]	1,246	1,208	3
Interceptor Flooding, mg[2]	14	13	7

1. This parameter reflects the number of nodes (junctions) within the hydraulic model at which interceptor surcharging occurred. It provides a relative measure of the extent of surcharging throughout the system under future planned versus aggressive I/I reduction conditions.

2. Interceptor flooding represents the volume of wastewater predicted to overflow from the MWRA interceptor system at non-CSO locations.

diameter mile because the number of direct inflow sources in a service area is more a function of the length or miles of tributary sewers. Although indirect inflow quantities could be related to the gpdim relationship, inflow reductions were focused on the reduction of direct inflow.

Cost-benefit relationships were developed and plotted to attempt to determine a cost-beneficial level of I/I control (e.g., knee-of-the-curve). Plots were derived by assuming the I/I control would first address the portion of a community's system that has the highest infiltration or inflow system performance values, and then address each successive area in order of descending infiltration/inflow system performance value. An example plot is shown in Figure 12-2. These relationships generally did not exhibit a clear cost-beneficial point (knee-of-the-curve) and suggested that even if I/I rehabilitation was prioritized and implemented in this manner, costs would increase relatively uniformly as higher levels of control were pursued. The curves are also indicative of the fact that relatively few areas within community systems have infiltration/inflow rates that are significantly higher than others, as was shown in Table 11-1. Based on the evaluation of the cost-benefit curves, a clear level of I/I control could not be determined.

TABLE 12-4. SUMMARY OF I/I REDUCTIONS AND ESTIMATED COSTS I/I CONTROL BASED ON PRIORITIZATION OF SYSTEM PERFORMANCE CRITERIA

COMPREHENSIVE REDUCTION (PUBLIC AND PRIVATE I/I SOURCES)				
INFILTRATION				
System	Total Peak Infiltration (mgd)	Estimated Infiltration Removed (mgd)	Percent of Infiltration Removed	Estimated Cost of Infiltration Removal
	A	B	C=B/A	F
North	80.72	40.36	50%	$522,930,000
INDIRECT INFLOW REMOVED VIA INFILTRATION REHAB=30.63 MG				$0
South	94.07	47.03	50%	$586,830,000
INDIRECT INFLOW REMOVED VIA INFILTRATION REHAB=22.43 MG				$0
CSO	63.92	31.96	50%	$304,650,000
INDIRECT INFLOW REMOVED VIA INFILTRATION REHAB=N/A				$0
Total	238.71	119.35	50%	$1,414,420,000
INFLOW				
System	Total Inflow (mg)	Estimated Direct Inflow Removed (mg)	Percent of Total Inflow Removed	Estimated Cost for Direct Removal
	A	B	C=B/A	D
North	99.57	21.07	21%	$47,890,000
South	68.86	13.20	19%	$30,010,000
CSO	N/A	N/A	N/A	N/A
Total	168.42	34.27	20%	$77,900,000

N/A -- Not Applicable; inflow reductions not assessed in combined sewer areas under I/I Strategy tasks.

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TABLE 12-5. SUMMARY OF I/I REDUCTIONS AND ESTIMATED COSTS I/I CONTROL BASED ON PRIORITIZATION OF SYSTEM PERFORMANCE CRITERIA

MAINLINE REDUCTION (REDUCTION OF PUBLIC I/I SOURCES ONLY)

INFILTRATION

System	Total Peak Infiltration (mgd)	Estimated Infiltration Removed (mgd)	Percent of Infiltration Removed	Estimated Cost of Infiltration Removal
	A	B	C=B/A	F
North	80.72	16.14	20%	$340,630,000
INDIRECT INFLOW REMOVED VIA INFILTRATION REHAB=12.25 MG				$0
South	94.07	18.81	20%	$396,800,000
INDIRECT INFLOW REMOVED VIA INFILTRATION REHAB=8.97 MG				$0
CSO	63.92	12.78	20%	$183,130,000
INDIRECT INFLOW REMOVED VIA INFILTRATION REHAB=N/A				$0
Total	238.71	47.74	20%	$920,560,000

INFLOW

System	Total Inflow (mg)	Estimated Direct Inflow Removed (mg)	Percent of Total Inflow Removed	Estimated Cost for Direct Removal
	A	B	C=B/A	D
North	99.57	14.37	14%	$14,370,000
South	68.86	9.00	13%	$9,000,000
CSO	N/A	N/A	N/A	N/A
Total	168.42	23.37	14%	$23,370,000

N/A -- Not Applicable; inflow reductions not assessed in combined sewer areas under I/I Strategy tasks.

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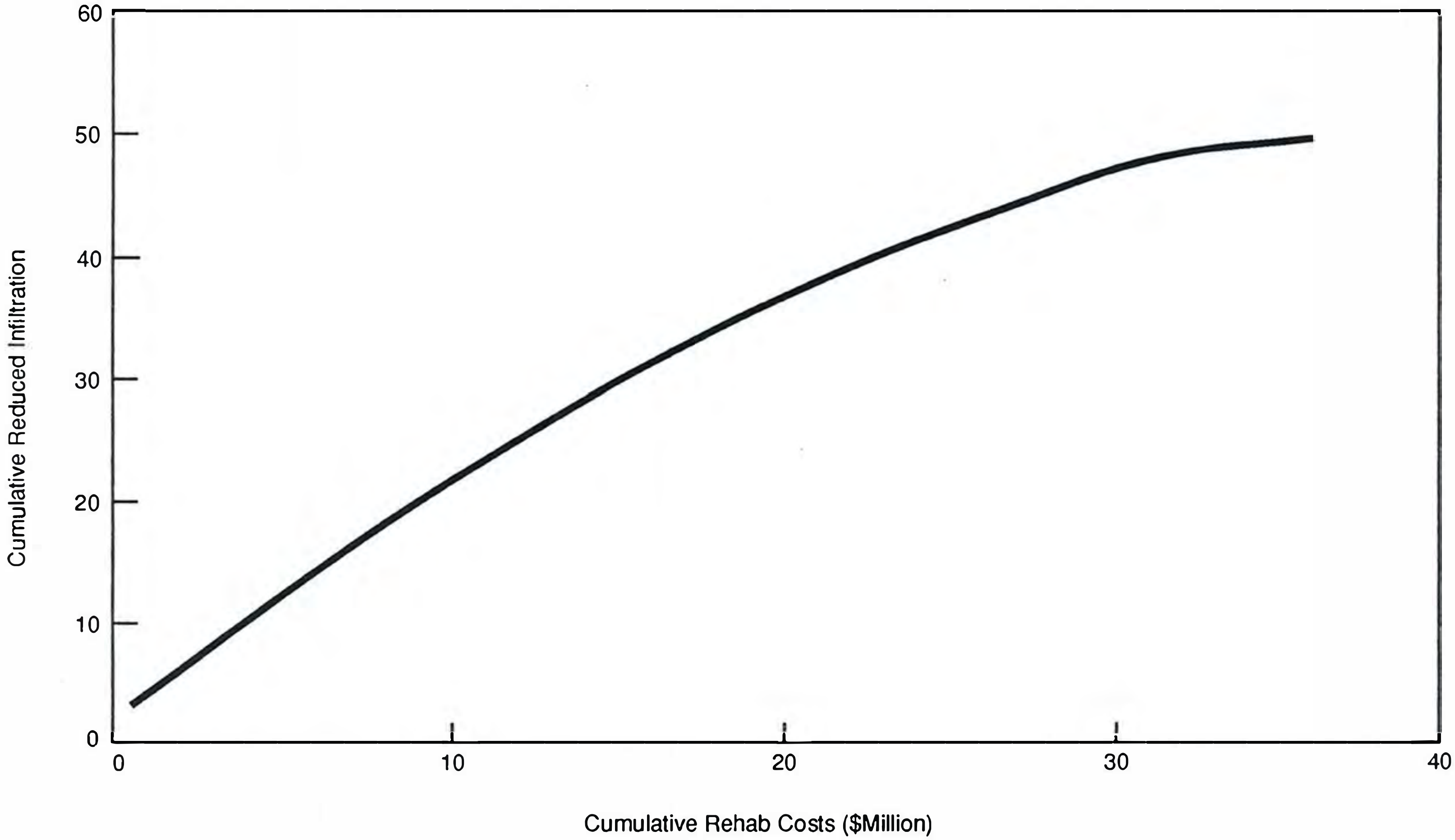

Note: Comprehensive reduction refers to rehabilitation of infiltration source on both public and private property.
A maximum estimated infiltration reduction of 50% could be achieved

FIGURE 12-2. CUMULATIVE INFILTRATION REHABILITATION COST VERSUS INFILTRATION REDUCTION FOR MEDFORD

I/I CONTROL BASED ON SELECTED SYSTEM PERFORMANCE CRITERIA

An I/I control alternative based on selected system performance criteria was developed by assuming that varying I/I reduction levels would be achieved based on the gpdim and mg/mile system performance values. The basis of this alternative was the assumption that communities would be motivated to reduce I/I based on a number of factors, including: increasing transportation and treatment (T&T) costs associated with I/I; increasing local T&T costs due to factors such as aging community sewer lines and laterals; inflow reduction requirements mandated by Massachusetts DEP for MWRA interceptor projects; increases in pump station operation and maintenance costs; and increased community costs in terms of MWRA flow-based charges. This suggests that I/I reduction programs will be implemented in MWRA communities for the purpose of minimizing I/I at levels deemed cost-effective by the communities. A portion of the I/I reductions expected to be achieved under this alternative are expected to offset increases in I/I that would otherwise occur due to the aging sewerage infrastructure. The levels of I/I reductions proposed at public connections under this alternative, which are based on the system performance value are presented in Table 12-6.

As indicated in Table 12-6, more aggressive I/I reductions are anticipated to occur in those portions of each community's collection system that have higher infiltration and inflow system performance values. Infiltration and inflow rates for the ranges used to vary the reduction percentages in Table 12-6 are shown geographically in Figures 12-3 and 12-4. These figures indicate that there are relatively few areas with the highest levels of infiltration and inflow, and that much of the system can be characterized has having only moderately high infiltration and inflow rates.

The results of this I/I reduction plan are outlined in Table 12-7. Reductions consist of a 9.6 mgd reduction in peak infiltration, which represents 4 percent of the 239 mgd peak infiltration total. In addition, a reduction in indirect inflow of 3.88 mg based on the 1-year, 6-hour storm is estimated as a result of sewer system rehabilitation necessary for achieving

TABLE 12-6. SELECTED I/I CONTROL LEVELS BASED ON SYSTEM PERFORMANCE VALUES

INFILTRATION (1)		INFLOW (2)		
GPDIM Range	Proposed Percent of Overall Infiltration Reduction	MG / Mile Range	Proposed Percent of Direct Public Inflow Reduction	Proposed Percent of Direct Private Inflow Reduction
>20,000	10%	>0.7	50%	10%
10,000 - 20,000	7.5%	0.18 - 0.7	37.5%	7.5%
5,000 - 10,000	5%	0.095 - 0.18	25%	5%
3,000 - 5,000	2.5%	0.04 - .0095	12.5%	2.5%
< 3,000	0%	< 0.04	0%	0%

(1) Assume no infiltration reduction from private infiltration sources; reduction to be achieved by rehabilitation of public sources only.

(2) Reduction of indirect inflow shall be proportional to the percent reduction of infiltration.

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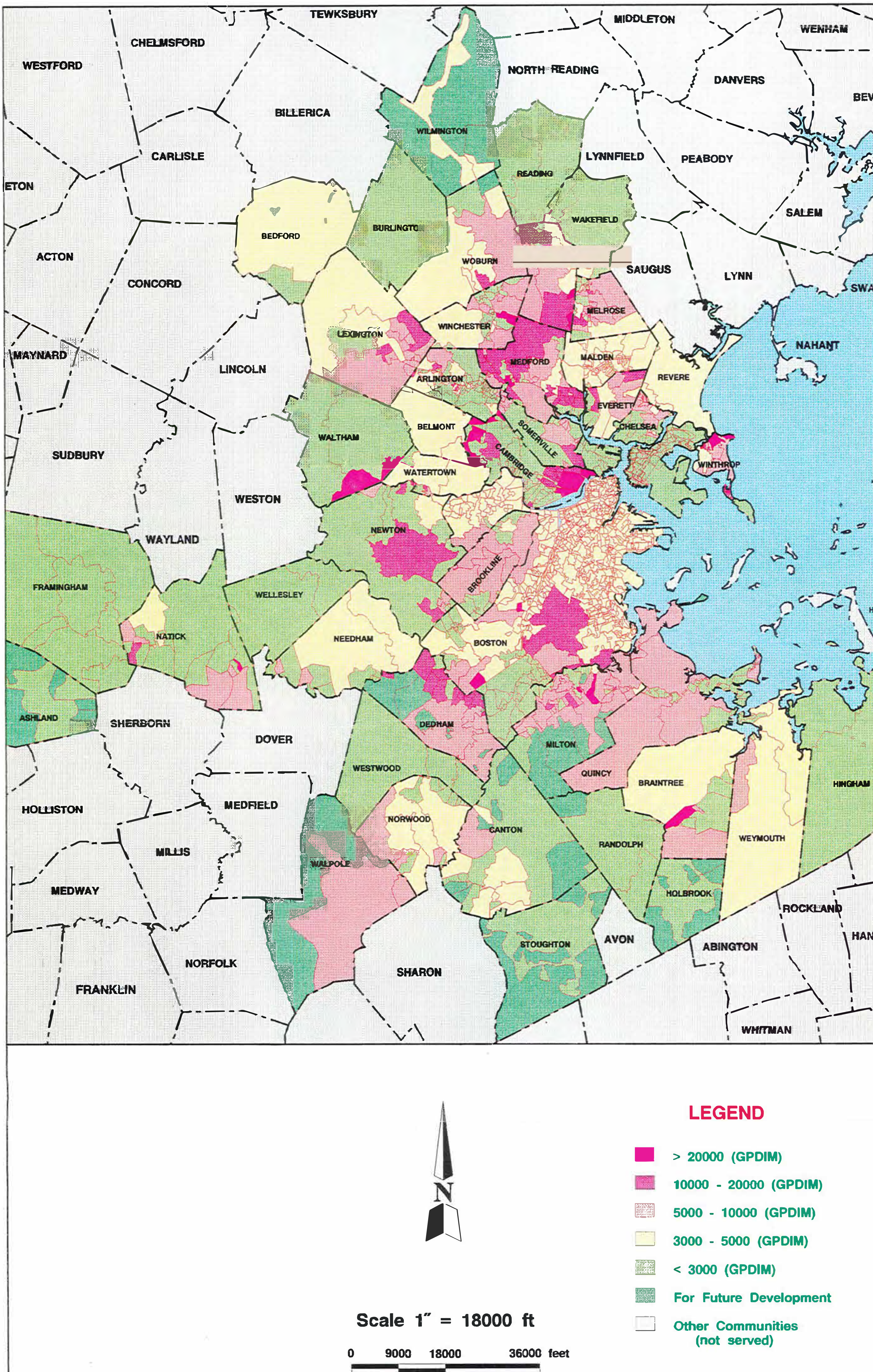

FIGURE 12-3.
RANGES OF INFILTRATION RATES FOR
MWRA SERVICES AREA COMMUNITIES

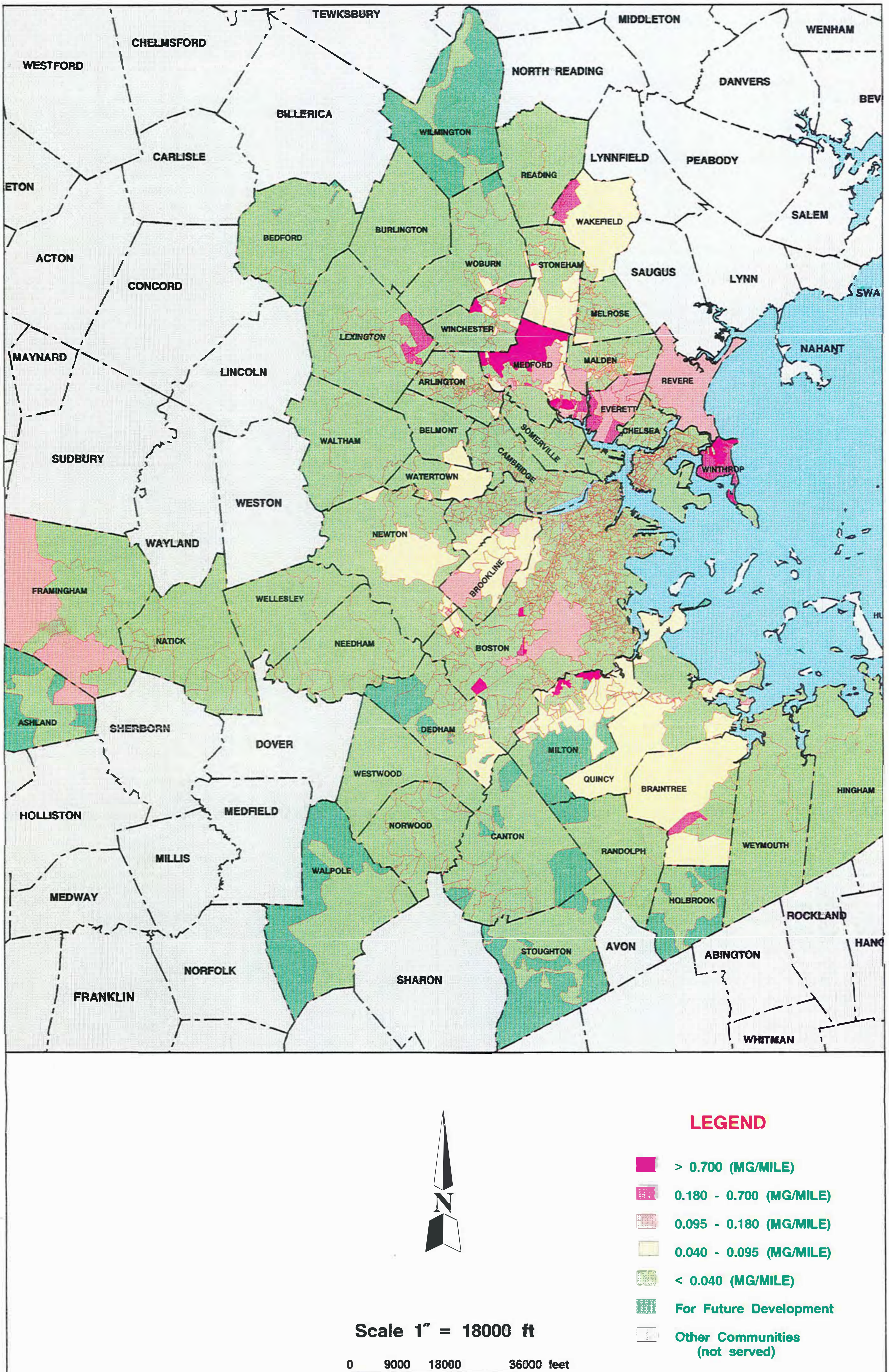

FIGURE 12-4. RANGES OF INFLOW RATES FOR MWRA SERVICES AREA COMMUNITIES

TABLE 12-7. SUMMARY OF I/I REDUCTIONS AND ESTIMATED COSTS I/I BASED ON SELECTED SYSTEM PERFORMANCE CRITERIA

INFILTRATION				
System	Total Peak Infiltration (mgd)	Estimated Infiltration Removed (mgd)	Percent of Infiltration Removed	Estimated Cost for Infiltration Removal
	A	B	C=B/A	F
NORTH	80.72	3.64	5%	$43,850,000
INDIRECT INFLOW REMOVED VIA INFILTRATION REHAB=2.31MG				$0
SOUTH	94.07	3.87	4%	$48,700,000
INDIRECT INFLOW REMOVED VIA INFILTRATION REHAB=1.57 MG				$0
CSO	63.92	2.10	3%	$29,030,000
INDIRECT INFLOW REMOVED VIA INFILTRATION REHAB=N/A				$0
TOTAL	238.71	9.61	4%	$121,580,000

INFLOW				
System	Total Inflow (mg)	Estimated Direct Inflow Removed (mg)	Percent of Total Inflow Removed	Estimated Cost for Direct Inflow Removal
	A	B	C=B/A	D
NORTH	99.57	6.45	6%	$10,750,000
SOUTH	68.86	2.61	4%	$4,350,000
CSO	N/A	N/A	N/A	N/A
TOTAL	168.42	9.06	5%	$15,100,000

N/A = Not Applicable; inflow reductions not assessed in combined sewer areas under I/I Strategy tasks.

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the predicted peak infiltration reduction. The estimated cost of this infiltration (plus indirect inflow) reduction is $121 million. Table 12-8 presents the key assumptions and I/I control levels for this alternative.

Inflow reductions are assessed based on the 1-year, 6-hour storm prescribed for use in I/I evaluations by DEP. Reductions in direct inflow volume on the order of 9.1 mg, or five percent of the 168 mg four-day inflow volume associated with the 1-year, 6-hour storm are predicted. The estimated cost of this inflow reduction is $15 million.

TABLE 12-8. BASIS OF I/I REDUCTION PLAN INCLUDED IN THE SMP

INFILTRATION	INFLOW		
* Reductions anticipated through rehabilitation of public sector (service area community) sources. These typically include cracks in pipes and manholes and leaky pipe joints.	* Inflow volume is 40% from direct sources (catch basins, roof leaders) and 60% from indirect sources (leaks into pipes and manholes)		
	* Direct inflow volume is 50% from public sources and 50% from private sources		
	Public Direct Inflow (20%)	Private Direct Inflow (20%)	Indirect Inflow (60%)
	* Reductions anticipated through removal of catch basins and other public direct sources.	* Reductions anticipated through removal of roof leaders, area and perimeter drains and other private direct sources.	* Reductions anticipated through rehabilitation of infiltration sources (indirect inflow enters via the same sources as infiltration.)
1. >20,000 GPDIM; 10% reduction 2. 10,000-20,000; 7.5% reduction 3. 5,000-10,000; 5% reduction 4. 3,000-5,000; 2.5% reduction 5. <3,000 GPDIM; no reduction	1. >0.7 mg/mile; 50% reduction 2. 0.18-0.7; 37.5% reduction 3. 0.095-0.18; 25% reduction 4. 0.04-0.095; 12.5% reduction 5. <0.04 mg/mile; no reduction	1. >0.7 mg/mile; 10% reduction 2. 0.18-0.7; 7.5% reduction 3. 0.095-0.18; 5% reduction 4. 0.04-0.095; 2.5% reduction 5. <0.04 mg/mile; no reduction	1. Remove in same areas targeted for infiltration reductions 2. Remove at same percentages as infiltration (range from 0 to 10%)

Notes:
1. GPDIM is an abbreviation for gallons per day per inch diameter-mile of sewer, and is a measure of infiltration rate. Higher rates are generally conducive to greater reduction percentages.
2. Mg/mile is an abbreviation for million gallons per mile, and is measure of the degree of inflow. Higher degrees of inflow are generally conducive to greater inflow reductions.

PART III

CHAPTER THIRTEEN

I/I CONTROL PLAN INCLUDED IN THE SMP I/I STRATEGIES

The initial I/I control plan developed represented an aggressive level of I/I reduction. The result of this assessment indicated that aggressive I/I controls (with an estimated cost of $462 million) would not significantly impact the cost or sizing of CSO, interceptor, or WWTP options.

Based on these results, cost-benefit relationships were developed to attempt to discern a cost-beneficial level of I/I control by assuming I/I control would first address the portion of a community's system that has the highest I/I system performance values (i.e. gpdim and mg/mile), and then address each successive area in order of descending infiltration/inflow performance value. The cost-benefit relationships generally did not exhibit a clear cost-beneficial point; costs would increase relatively uniformly as higher levels of control were pursued.

Based on the results of simulating a high level of I/I control, it did not appear that there would be a cost trade-off between I/I control and other strategy areas, and based on the evaluation of cost-benefit curves, a clear level of I/I control could not be determined. It was, however, judged reasonable to assume that I/I reductions would be achieved by communities in the MWRA service area during the planning period of the SMP. Factors such as aging community sewer trunk lines and laterals, DEP mandated inflow reductions, and community costs (both in terms of MWRA flow-based charges and local costs for transporting wastewater) suggest that I/I reductions will continue to occur and should be factored into the SMP. Further, if I/I control is neglected and extraneous flows allowed to increase, high cost capital improvement projects may be required in the future to handle increased system flows.

SUMMARY OF I/I REDUCTION LEVELS INCLUDED IN THE SMP

Because there are no clear trade-offs or net cost savings to the MWRA in terms of CSO, interceptor, or secondary treatment strategies versus expenditures to reduce I/I, the recommended plan for I/I control included in the SMP does not involve actions by the MWRA. However, for the reasons outlined above, a level of I/I reduction has been assumed and included in the hydraulic analyses of CSO, interceptor, and secondary treatment strategies. The key assumptions of this I/I reduction plan were based on selected I/I control levels criteria which were outlined in Table 12-8.

It is anticipated that the infiltration and inflow reductions outlined in Table 12-7 will be implemented by the service area communities throughout the SMP planning period at a total cost of $136 million. As the individual communities move forward from the conceptual planning level on which this report is based to more detailed planning (e.g., Phase II SSES investigations), recommended I/I control levels will be re-evaluated. More site-specific I/I data, consideration of local transportation and treatment (T&T) costs, identification of cost-effective I/I removal in accordance with MA DEP I/I Guidelines, and MWRA flow-based rates may significantly influence levels of I/I control pursued.

The impact of the level of I/I control included in the SMP on CSO volumes, interceptor surcharging, and treatment plant flows is presented in Table 13-1 and Figure 13-1. These indicate that the level of I/I control expected to be implemented will not impact the cost or sizing of CSO, interceptor, or treatment plant options.

IMPLEMENTATION CONSIDERATIONS

In general, infiltration and inflow reduction involves performing the investigations necessary to identify I/I, followed by design and construction to remove it. Programs of this nature have had limited success, and typically have been a low priority in most MWRA communities. When funding from EPA for SSES and I/I reduction programs (90 percent and

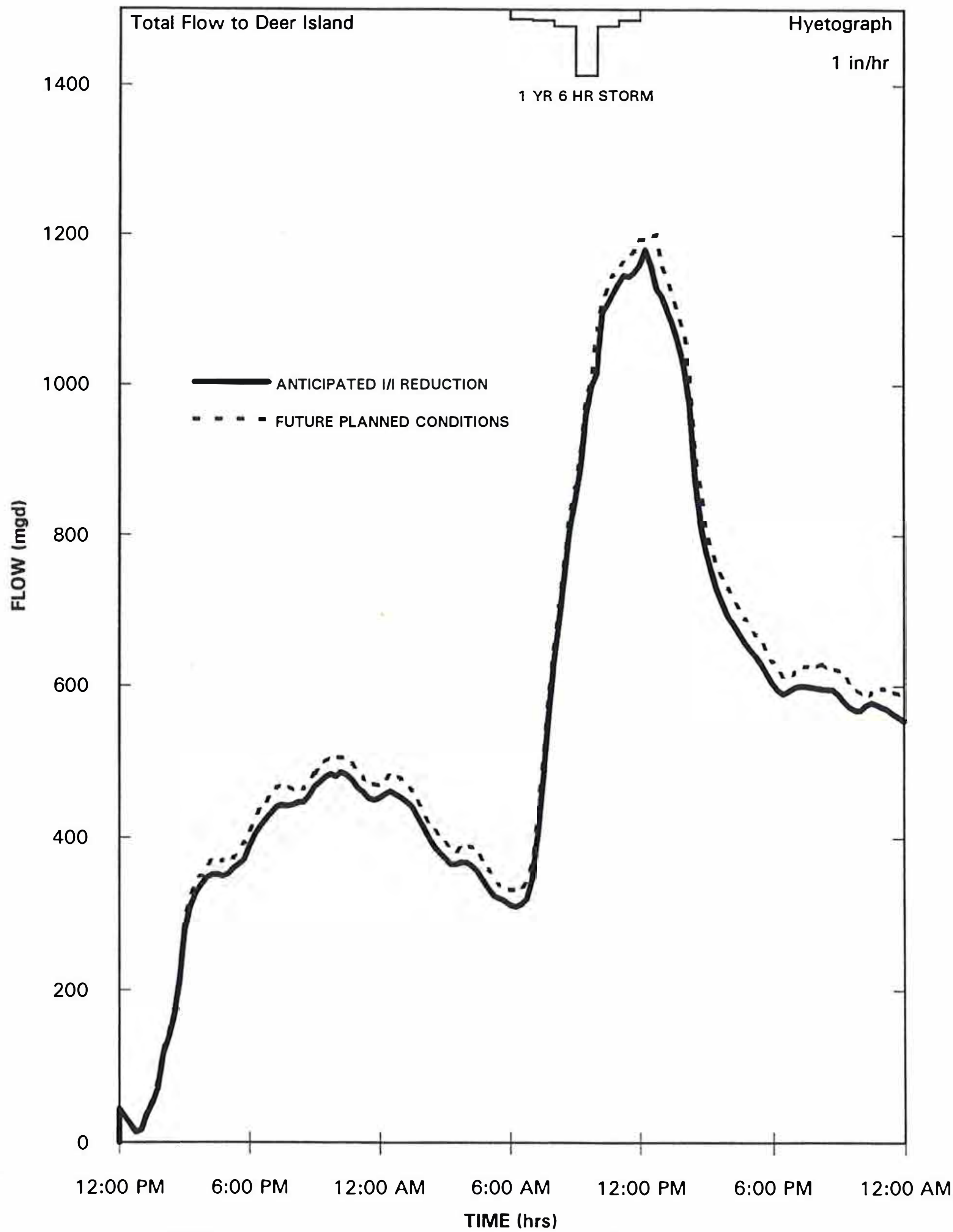

FIGURE 13-1. COMPARISON OF FUTURE PLANNED CONDITIONS AND I/I REDUCTIONS INCLUDED IN THE SMP

TABLE 13-1. RESULTS OF I/I REDUCTIONS INCLUDED IN THE SMP

Parameter	Future Planned Conditions	I/I Reductions in SMP[3]	Percent Reduction
CSO Volume, mg	151	150	1
Surcharged Interceptor Junctions[1]	1,246	1,244	0
Interceptor Flooding, mg[2]	14	13	7

1. This parameter reflects the number of nodes (junctions) within the hydraulic model at which interceptor surcharging occurred. It provides a relative measure of the extent of surcharging throughout the system under future planned versus I/I reductions included in the SMP.

2. Interceptor flooding represents the volume of wastewater predicted to overflow from the MWRA interceptor system at non-CSO locations.

3. Results are based on peak infiltration reductions and inflow reductions from the 1-year, 6-hour storm.

75 percent grant program) was discontinued in the late 1980s, many MWRA communities postponed or scaled back their I/I reduction programs. Financial constraints and considerations may also influence the long term I/I reduction strategy. Examples of financial constraints and considerations include the availability of local funds for I/I projects and the planned implementation of flow-based billing. Non-monetary factors and costs related to rehabilitation work on private property (i.e. roof leader and sump pump connections) will vary for each community.

Implementation constraints identified in developing I/I strategies include the unknowns regarding I/I, such as the locations of infiltration and inflow and the means and costs required for removal. MWRA Wastewater Metering System data were used to estimate I/I components in each community, and assumptions were made regarding the level of construction that would be necessary to remove the I/I in various areas of the system. Existing SSES and I/I report data provide clues as to areas where I/I may be concentrated, but detailed investigations (i.e. Phase II SSES) needed to locate I/I have not yet been conducted in most communities. Sources of I/I originating on private property, such as house service connections and sump pumps are estimated to comprise more than 50 percent of I/I. Issues relating to work on private property make the removal of these private sources problematic and expensive. Levels of commitment to I/I reduction programs vary with each community depending on local costs associated with transporting I/I. Communities with higher annual costs related to wastewater pumping would be more inclined to reduce I/I than those communities which are served primarily by gravity sewers. Aging and deteriorated sewerage infrastructure will need to be replaced in extreme cases, resulting in reduction of I/I. In general, local wastewater transportation costs and I/I levels, combined with the potential impact of MWRA flow-based billing will provide the impetus for future I/I reductions. At this time, the MWRA I/I Local Financial Assistance program provides the major incentive for continuing I/I reduction programs in many communities, and its continuation for the purpose of future control of I/I should be carefully evaluated.

PART IV
CHAPTER FOURTEEN
INTRODUCTION

This part of the report describes the development of interceptor strategies and the selection of recommended interceptor projects as part of MWRA's SMP. The interceptor strategies presented in the following sections were developed in conjunction with I/I, CSO, and secondary treatment strategies described in other parts of this report to compare overall costs and benefits and account for hydraulic interactions among the strategies. Interceptor strategy alternatives were based on the review and application of extensive data, including results from the MWRA Wastewater Metering Program, record drawings of the interceptor system, and hydraulic analyses using the system-wide EXTRAN Model.

This part of the report contains five chapters. In this chapter, the interceptor improvement plan objectives, planning considerations and criteria are presented. This is followed by a description of the interceptor system assessment under baseline hydraulic conditions in Chapter Fifteen. Chapter Sixteen describes how project costs were developed, and Chapter Seventeen presents the development of interceptor alternative projects. The recommended interceptor plan is presented in Chapter Eighteen.

OBJECTIVES AND RELATIONSHIP TO SMP

The objectives of interceptor strategies in the overall context of the System Master Plan were to ensure that the transport system could hydraulically serve community needs under design conditions and, where feasible, to cost-effectively reduce CSO control facility needs or reduce peak flows to the treatment plant to a degree that could result in a reduction in secondary treatment facilities. Each of these general objectives is discussed in the paragraphs that follow.

Provide Service to Communities

MWRA interceptors properly serve the tributary communities when they convey the community flow without detrimental back-up under design flow conditions. In addition to avoiding back-ups in community systems that might cause overflows from sanitary sewers or loss of service, the MWRA interceptors should not surcharge or overflow under design conditions. In non-CSO areas where no direct overflows to drainage systems or water courses exist, interceptor overflows can result in the direct discharge of sewage from manholes. This in turn can result in local flooding and/or discharges through local drainage systems into waterways.

Reduce CSO

Interceptors should be configured to minimize overflows from combined sewer areas. Reductions in CSO could conceivably be achieved through interceptor strategies by conveying all dry and as much wet weather flow as possible to downstream treatment facilities, storing wet weather flow within the interceptor, and/or transferring flow from an overloaded interceptor to an underloaded interceptor.

Reduce Peak Flow to Deer Island

Flow into the headworks facilities immediately results in flow into the treatment plant, as the connecting tunnel systems are always full. Therefore, a reduction in peak flows into the plant can only be achieved by a reduction in flow to a headworks. Reduction in the peak flows to the headworks facilities could be a benefit if a system-wide reduction in peak flows could be achieved which is large enough to enable a cost-effective reduction in secondary treatment capacity. Any such plant capacity reduction would have to be evaluated under more extreme hydrologic conditions than the design criteria for interceptor strategies (1-year, 6-hour storm event) to ensure that reliable plant operation could be achieved.

PLANNING CONSIDERATIONS AND CRITERIA

Key planning considerations and criteria have been addressed at a master planning level for both cost development as well as evaluation of impacts. The methods of cost development are described in Chapter Sixteen and other planning considerations are discussed in the paragraphs that follow.

Hydraulic Planning Criteria

Evaluation of interceptor performance was based on flows and hydraulic gradients resulting from simultaneous occurrence of peak sanitary flow (derived as 1.25 times average sanitary flow), peak infiltration, and inflow corresponding to a 1-year, 6-hour storm event. The storm was timed so its peak rainfall intensity would coincide with the peak diurnal flow. Sanitary flow, infiltration and inflow quantities were based on future planned conditions, and included the impacts of ongoing I/I reduction projects, interceptor projects, and system optimization plans (SOPs) to reduce CSOs. Sanitary and infiltration flows were developed by the Authority and included in the system-wide hydraulic model. Inflow was simulated in the model as described in the June, 1994 System Master Plan Baseline Assessment report. Future planned conditions are further defined in Chapter Fifteen.

Interceptor Evaluation Criteria

Interceptor evaluations were based on hydraulic performance as determined by the EXTRAN model. Physical condition or structural integrity of interceptors was not evaluated in detail. Where hydraulic relief was required, the age and size of the conduit lacking adequate capacity was considered in terms of replacement of the conduit versus installation of a new parallel pipe. In future facilities planning efforts, it is expected that more detailed evaluations including criteria such as physical conduit conditions and alternative routes for relief conduits would be used to determine optimum relief strategies.

Other Sewerage Division Planning Efforts

Presently, MWRA is at different stages of planning for several interceptors, including the Braintree Weymouth project, the Cummingsville Branch Sewer and Relief Sewer project, and the Upper Neponset Valley project. Of these, the Braintree Weymouth facilities plan has been completed and has been incorporated into the model as a future planned condition. The Cummingsville Branch Sewer and the Upper Neponset Valley Sewer facilities planning are on-going planning efforts and have not been included in the model. A preliminary recommendation has been made for the Cummingsville project and an ENF has been submitted to MEPA. An EIR is not expected to be required. The Upper Neponset Valley project will require preparation of an updated facilities plan as well as an EIR. For these systems, the existing conduits were modeled and evaluated based on hydraulics, independent of on-going MWRA facilities planning.

PART IV

CHAPTER FIFTEEN

BASELINE INTERCEPTOR HYDRAULIC CONDITIONS

An assessment of the interceptor system under baseline conditions was performed in order to identify interceptor segments that were in need of relief, and/or represented in-system storage or flow transfer opportunities. Baseline conditions for this assessment are those which will exist in 1997, referred to as future planned conditions. The following paragraphs describe the MWRA interceptor system, define the future planned conditions, identify the assessment approach and measures of system performance, and present the baseline performance of the MWRA interceptor system.

DESCRIPTION OF SYSTEM

The interceptor system is generally divided into two parts, the North System and the South System, which convey flows to the Deer Island North Main Pumping Station and to the Nut Island Headworks and South System Pumping Station, respectively. The North System can also be divided into the North Metropolitan portion, which is tributary to the Chelsea Creek Headworks and the Boston Main Drainage portion, which is tributary to the Ward Street and Columbus Park Headworks. In addition, a separate portion of the North System conveys flow tributary to the East Boston (Caruso) Pumping Station through the North Metropolitan Trunk Sewer to the Winthrop Terminal Facility at Deer Island.

The North and the South System interceptors are shown on Figures 15-1 and 15-2. These figures also indicate those interceptors which surcharge and which overflow under baseline hydraulic conditions, as discussed later in this section.

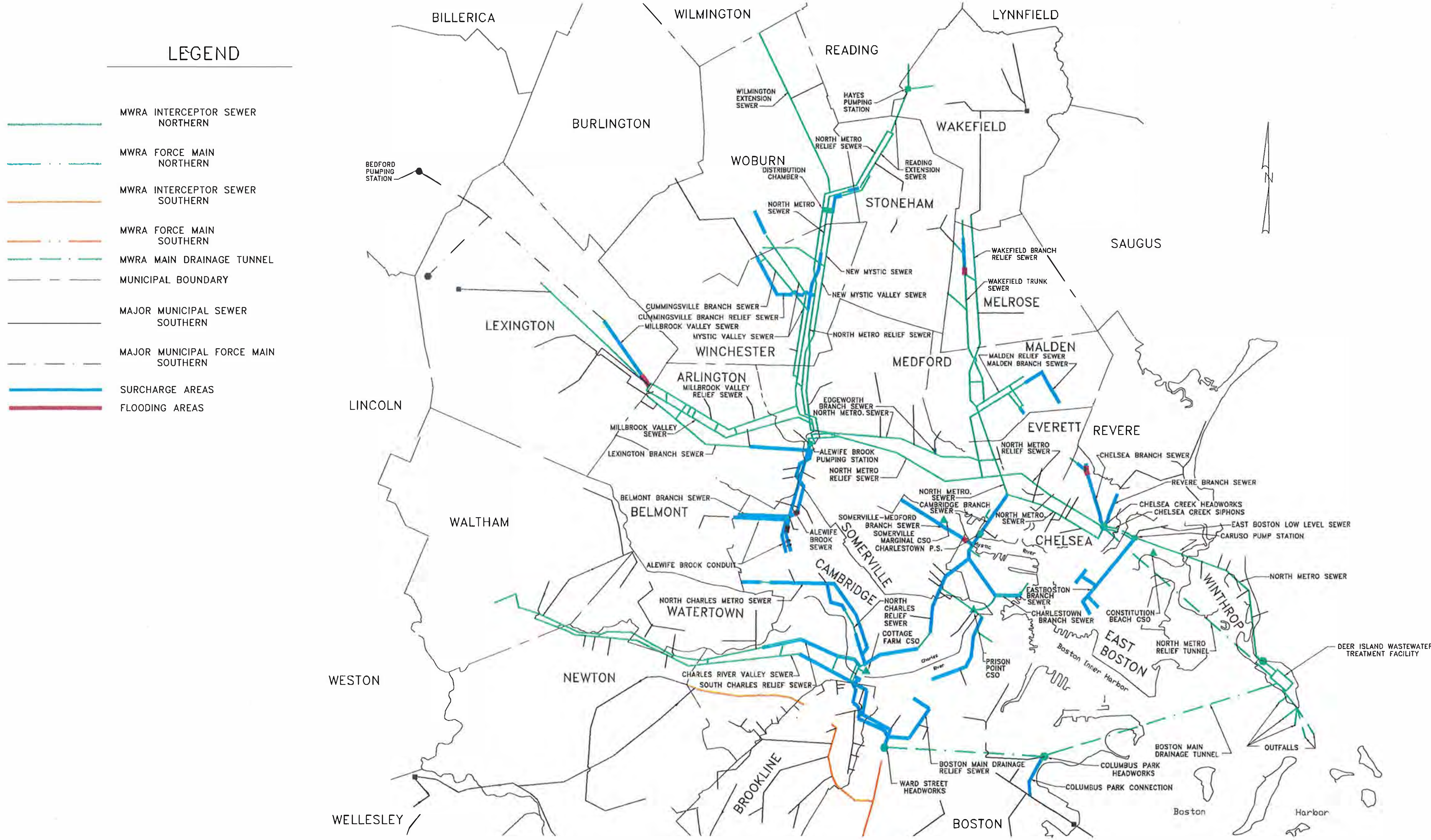

FIGURE 15-1.
NORTH SYSTEM BASELINE CONDITIONS

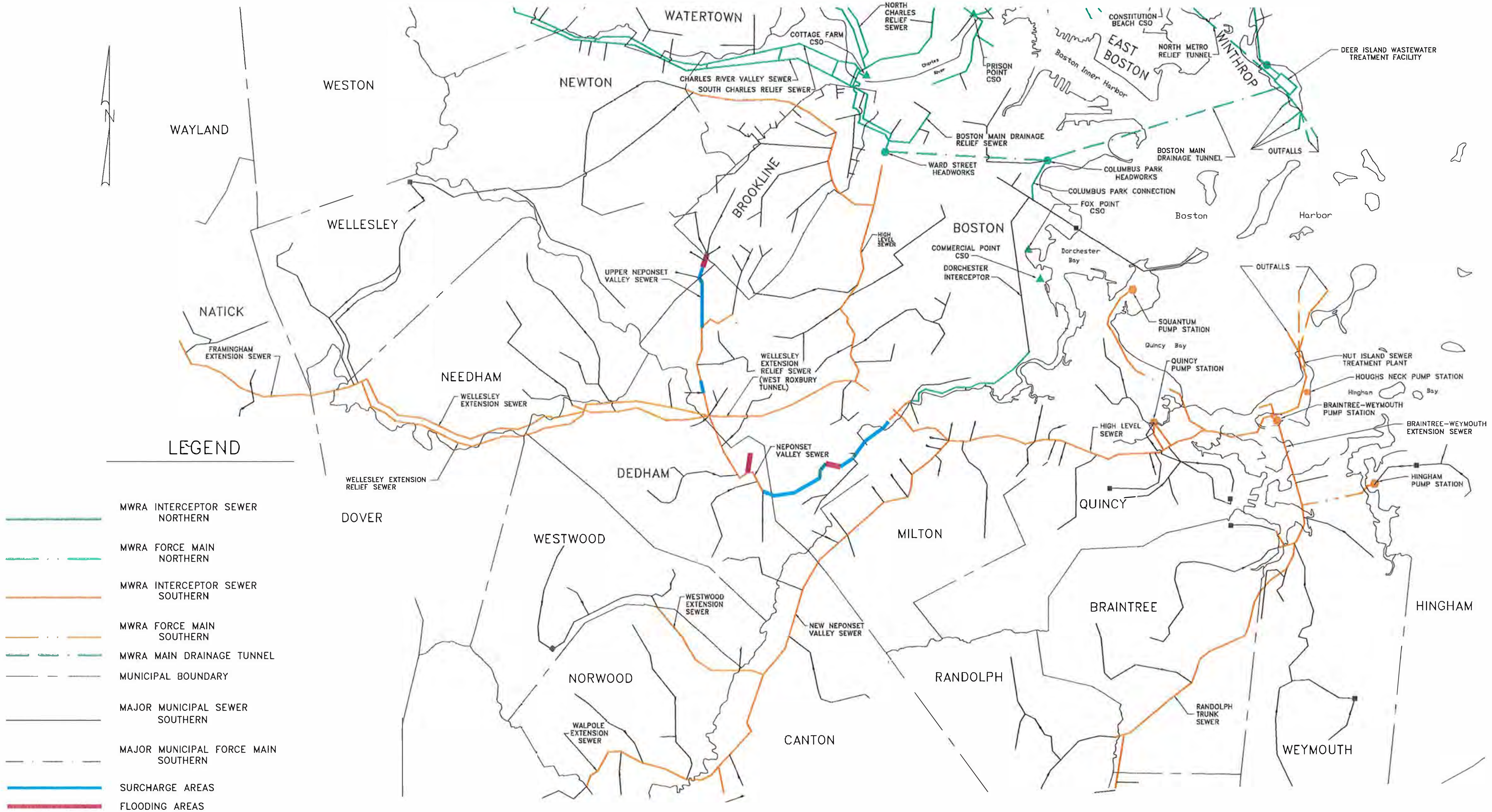

FIGURE 15-2.
SOUTH SYSTEM BASELINE CONDITIONS

FUTURE PLANNED CONDITIONS

The system conditions characterized as baseline or future planned conditions include a number of system improvements and modifications which are under construction or will be completed under previous capital improvement commitments. Compared to existing conditions, future planned conditions include the following elements:

- Four batteries of primary treatment at Deer Island
- Total pumping capacity of 1,270 mgd at Deer Island
- Full implementation of the following collection system projects as defined in already approved facilities plans:

  Braintree-Weymouth Extension Sewer
  Framingham Extension Relief Sewer
  New Neponset Valley Relief Sewer
  Quincy Pump Stations and Force Mains
  Wellesley Extension Sewer and Wellesley Extension Relief Sewer

- Full implementation of recommended SOPs and Intermediate Projects
- Full implementation of currently defined I/I reduction programs, including:

  Established South System removal goals
  Other projects defined under the I/I financial assistance program

For portions of the system that are included in future planned conditions but are in various stages of design or construction, hydraulic gradients predicted by the model could not be compared to meter data because the future planned facilities were not operational during the metering period. However, the modeled gradients were used and are most probably conservative because most portions of the future planned interceptors would have lower friction factors than the Manning's "n" of 0.015 used in the model. For example, the Framingham Relief Sewers will be PVC lined and will have a lower "n" value.

ASSESSMENT APPROACH AND PERFORMANCE MEASURES

Hydraulic conditions in the MWRA transport system were evaluated based on the MWRA's permanent metering throughout the Authority system, input from MWRA Sewerage Division staff on known problems within interceptors such as overflows or backup, and evaluation using the system-wide EXTRAN hydraulic model.

MWRA permanent flow meters installed within the interceptor network and on community connections were reviewed and used to calibrate the EXTRAN model. In addition, temporary meters, generally installed in CSO areas and meters installed for the South System Interim Wastewater Metering Project were used in the calibration. Meter data consisted of both water level and flow versus time in the interceptor system. In addition to its use in model development and calibration, meter data were reviewed to verify hydraulic conditions at key locations throughout the interceptor network and to identify problem areas and potential interceptor strategies.

The entire MWRA interceptor system was modeled in considerable detail. Modeled pipe segments were defined at changes in size, slope, or configuration of the physical interceptor network. Interceptor data included inverts, crowns, rim elevations, and the size and shape of conduits. These data were obtained from plans and records of the interceptor system and/or from the Authority's System Analysis Management System (SAMS) program database. The model was calibrated based on hydraulic grade line, flow, and rainfall throughout the modeling period.

The function of the MWRA interceptor network is to convey community wastewater flows to the headworks, and on to the treatment plants. Interceptor system performance measures reflecting this intended function include the ability of the interceptors to convey flow under design conditions without surcharging, flooding or overflowing.

Surcharging

Surcharging refers to interceptors flowing full. While short duration surcharging in itself is not necessarily a problem, it is an indication of risk of overflows from manholes or adverse back-up into the community sewer system. A measure of how close a sewer is to surcharging is the ratio of flow depth (d) to the conduit height (D) commonly referred to as d/D. Another significant factor used in evaluating the risk of flooding in surcharged conduits is the depth from ground surface to the hydraulic grade line (HGL). Depth from the ground surface to the hydraulic grade line is less of a concern in CSO portions of the system, where an overflow can relieve the system under extreme conditions to prevent back-ups and potential property damage. Upstream of CSO portions of the system, a depth of 6 ft. from ground surface to hydraulic grade line was used as a measure of the significance of surcharging. A 6 ft. depth is representative of a typical basement floor depth below the ground surface. Provided that hydraulic gradients in the MWRA system remain below that depth, there is reduced risk of surcharging causing adverse impacts on community sewer service.

Flooding and Overflows

Flooding and sanitary sewer overflows (SSOs) occur when the hydraulic grade line exceeds the ground surface. Flooding and SSOs can be measured by their frequency of occurrence, duration and discharge volumes.

Similar to CSO discharges, flooding and SSOs from sanitary sewers present a problem in terms of adverse environmental impacts. Unlike CSOs, which are piped to receiving waters to reduce the potential for human contact, SSOs typically run overland and can effect streets and resident's homes. This increases the potential health hazard associated with SSOs.

When significant flooding is relieved by improvements to a surcharged interceptor, increased flow in downstream conduits can be expected, and the impact of such increased flow must be evaluated. This was accomplished through the use of the system-wide hydraulic model.

Model Output Data

For the evaluation of surcharge and flooding, the Junction Summary output from the model defines the depth and duration of surcharge as well as the duration of flooding at each node. This output also indicates the depth of the HGL below the ground surface. An example of the Junction Summary model output data is shown in Table 15-1. At junction numbers such as 7081 in the table, no surcharging or flooding occurs. At 7105, however, surcharging occurs up to 0.5 feet for 2,160 minutes, and no flooding occurs. At junctions such as 7129, 7141 and 7151 both surcharging and flooding occur.

An example of the Conduit Summary model output data is shown in Table 15-2. The Conduit Summary output from the model defines the peak flow (for each conduit) as well as capacity of each conduit in accordance with Manning's equation. In addition, the output lists the ratio of the peak flow to the capacity of the conduit flowing full (ratio of max. to design flow in Table 15-2). For a surcharged conduit, this ratio provides an effective parameter for evaluating the cause of surcharge. If the ratio is greater than 1.0, such as for conduit number 34062, this indicates that the conduit has insufficient capacity to convey the peak flow under the baseline condition without surcharging. If the ratio is less than 1.0 and surcharge is present, the surcharge is caused by a downstream back-up or restriction. In some cases it is possible to have insufficient conduit capacity (ratio greater than 1.0) as well as a downstream restriction.

TABLE 15–2. EXAMPLE OF EXTRAN MODEL CONDUIT SUMMARY OUTPUT DATA

CONDUIT NUMBER	DESIGN FLOW (CFS)	DESIGN VELOCITY (FPS)	CONDUIT VERTICAL DEPTH (IN)	MAXIMUM COMPUTED FLOW (CFS)	TIME OF OCCURENCE HR.	TIME OF OCCURENCE MIN.	MAXIMUM COMPUTED VELOCITY (FPS)	TIME OF OCCURENCE HR.	TIME OF OCCURENCE MIN.	RATIO OF MAX. TO DESIGN FLOW	MAXIMUM INV. AT UPSTREAM (FT)	DEPTH ABOVE CONDUIT ENDS DOWNSTREAM (FT)	LENGTH OF NORMAL FLOW (MIN)	CONDUIT SLOPE (FT/FT)
34002	46.00	3.66	48.00	7.30	34	3	1.76	1	34	0.16	1.08	2.01	2103.3	0.00137
34004	43.20	3.43	48.00	7.30	33	0	2.58	33	56	0.17	1.13	1.08	0.0	0.00120
34006	43.20	3.43	48.00	7.30	33	53	2.54	1	14	0.17	1.11	1.13	2082.2	0.00120
34008	43.20	3.44	48.00	7.30	33	49	2.56	33	32	0.17	1.11	1.11	1529.7	0.00121
34010	43.20	3.43	48.00	7.30	33	44	2.56	33	39	0.17	1.11	1.11	966.5	0.00120
34014	38.10	3.96	42.00	7.30	33	35	2.91	33	29	0.19	1.04	1.11	2115.7	0.00191
34016	34.20	3.56	42.00	7.30	33	33	2.87	33	26	0.21	1.13	1.04	5.2	0.00154
34018	37.50	3.90	42.00	7.30	33	27	2.85	33	24	0.19	1.05	1.13	2126.7	0.00185
34020	29.00	4.10	36.00	7.30	33	22	3.37	33	17	0.25	1.03	1.05	2134.3	0.00251
34022	17.50	3.56	30.00	7.31	33	19	3.45	33	19	0.42	1.20	1.03	0.0	0.00242
34024	17.50	3.57	30.00	6.28	33	14	2.95	33	14	0.36	1.04	1.20	2159.5	0.00243
34026	18.70	3.80	30.00	6.28	33	10	3.35	33	4	0.34	1.00	1.04	2130.5	0.00276
34030	19.10	3.90	30.00	3.37	33	14	2.31	11	19	0.18	0.71	1.00	2154.0	0.00289
34032	20.90	4.26	30.00	3.37	33	8	3.03	32	14	0.16	0.72	0.71	2135.7	0.00346
34034	15.50	3.15	30.00	3.37	33	4	−9.51	0	0	0.22	0.88	0.72	5.3	0.00190
34158	87.10	3.36	69.00	52.50	34	30	3.91	0	33	0.60	4.16	4.52	2.7	0.00071
34066	86.60	3.33	69.00	52.50	34	28	2.79	34	23	0.61	3.69	4.16	10.3	0.00070
34068	23.90	3.37	36.00	26.30	34	25	3.72	34	25	1.10	3.78	3.69	1.8	0.00140
34062	23.90	3.37	36.00	26.30	34	25	3.72	34	25	1.10	3.78	3.69	1.8	0.00140
34070	86.00	3.31	69.00	52.50	34	22	3.81	0	22	0.61	3.58	3.78	21.5	0.00069
34072	86.00	3.31	69.00	52.60	34	16	3.81	0	19	0.61	3.40	3.58	42.0	0.00069
34074	85.60	3.30	69.00	52.60	34	14	3.35	32	42	0.61	3.33	3.40	35.3	0.00068
34076	86.40	3.33	69.00	52.60	34	12	3.41	33	7	0.61	3.29	3.33	30.8	0.00070
34080	80.50	3.10	69.00	52.60	34	11	3.40	33	23	0.65	3.34	3.29	0.0	0.00060
34162	87.80	3.38	69.00	34.60	34	19	2.32	11	56	0.39	3.12	3.34	0.0	0.00072
34086	87.50	3.37	69.00	34.60	34	10	2.65	10	43	0.40	2.68	3.12	201.2	0.00071
34088	87.20	3.36	69.00	34.60	34	7	2.98	33	35	0.40	2.59	2.68	17.5	0.00071
34090	64.40	2.48	69.00	31.50	34	2	2.78	8	32	0.49	2.67	2.59	0.0	0.00039
34094	37.50	2.44	53.04	28.90	34	1	3.24	34	1	0.77	3.47	1.54	0.0	0.00192
34096	36.10	2.35	53.04	28.90	33	57	−2.53	0	0	0.80	3.23	3.47	3.8	0.00178
34098	36.10	2.36	53.04	28.40	33	55	2.48	33	34	0.79	2.95	3.23	2112.3	0.00179
34100	41.40	2.70	53.04	28.20	33	51	2.74	33	30	0.68	2.68	2.95	2129.3	0.00180
34102	41.40	2.70	53.04	28.30	33	48	2.91	33	27	0.68	2.68	2.68	1164.0	0.00180
34104	38.70	3.08	48.00	34.10	33	46	4.30	0	7	0.88	2.71	2.68	2.7	0.00033
34112	68.30	4.45	53.04	22.70	33	3	4.30	0	1	0.33	2.90	2.43	36.8	0.00177
34116	33.30	4.71	36.00	9.96	33	2	4.16	33	2	0.30	1.23	1.76	0.2	0.00332
34118	33.30	4.72	36.00	10.30	32	39	4.00	32	38	0.31	1.15	1.23	2111.7	0.00333
34120	33.60	4.76	36.00	10.50	32	37	4.25	32	37	0.31	1.26	1.02	0.0	0.00338
34124	53.00	7.49	36.00	9.18	32	35	5.62	32	35	0.17	0.85	0.84	22.2	0.00839
34128	33.60	4.76	36.00	8.80	32	33	4.05	32	33	0.26	1.14	0.93	0.0	0.00338

TABLE 15–1. EXAMPLE OF EXTRAN MODEL JUNCTION SUMMARY OUTPUT DATA

JUNCTION NUMBER	GROUND ELEVATION (FT)	UPPERMOST PIPE ELEVATION (FT)	CROWN ELEVATION (FT)	MEAN JUNCTION AVERAGE % CHANGE	MAXIMUM JUNCTION ELEV. (FT)	TIME OF OCCURENCE HR.	MIN.	FEET OF SURCHARGE AT MAX ELEVATION	FEET MAX DEPTH IS BELOW GROUND ELEVATION	LENGTH OF SURCHARGE (MIN)	LENGTH OF FLOODING (MIN)	MAXIMUM JUNCTION AREA (SQ.FT)
7081	118.00	114.45	111.40	0.0091	113.03	22	6	0.00	4.97	0.0	0.0	1535
7083	118.00	113.98	111.20	0.0084	112.47	22	3	0.00	5.53	0.0	0.0	2068
7085	120.00	113.81	111.17	0.0077	112.23	22	0	0.00	7.77	0.0	0.0	1226
7087	118.00	113.60	110.70	0.0055	111.48	22	1	0.00	6.52	0.0	0.0	1209
7089	116.00	112.07	109.47	0.0088	110.70	22	1	0.00	5.30	0.0	0.0	1161
7091	125.00	111.87	109.38	0.0082	110.46	22	0	0.00	14.54	0.0	0.0	1460
7103	114.50	114.50	105.53	0.0164	111.51	21	59	0.00	2.99	0.0	0.0	15810
7105	112.00	108.25	108.75	0.0048	108.75	0	0	0.50	3.25	2160.0	0.0	188.9
7107	116.00	113.21	110.24	0.0693	116.00	18	0	2.79	0.00	64.3	0.2	31670
7109	119.00	104.68	103.44	0.1264	113.05	22	0	8.37	5.95	259.0	0.0	58940
7181	119.00	113.60	111.37	0.0037	111.84	22	0	0.00	7.16	0.0	0.0	24520
7115	110.00	109.25	108.75	0.0027	108.75	0	0	0.00	1.25	0.0	0.0	1545
7117	113.10	105.61	108.75	0.0062	108.88	21	27	3.27	4.22	2160.0	0.0	8648
7119	113.20	111.99	109.33	0.0010	109.43	22	10	0.00	3.77	0.0	0.0	13510
7121	113.30	105.61	103.68	0.0737	109.59	21	19	3.98	3.71	196.7	0.0	12420
7123	110.00	107.12	108.75	0.0023	108.75	0	0	1.63	1.25	2160.0	0.0	6415
7125	115.00	114.00	111.02	0.0097	111.73	22	10	0.00	3.27	0.0	0.0	6763
7127	110.00	108.56	108.75	0.0020	108.75	0	0	0.19	1.25	2160.0	0.0	798.8
7129	115.00	114.28	109.48	0.0178	115.00	21	15	0.72	0.00	83.0	69.8	20320
7131	120.00	117.78	108.84	0.0031	109.77	22	2	0.00	10.23	0.0	0.0	1551
7133	115.00	113.81	108.78	0.0107	109.75	21	58	0.00	5.25	0.0	0.0	4350
7135	115.00	112.81	108.78	0.0087	109.73	22	0	0.00	5.27	0.0	0.0	4874
7137	112.00	111.81	108.78	0.0079	109.73	22	0	0.00	2.27	0.0	0.0	4164
7139	112.00	111.51	108.75	0.0010	108.75	0	0	0.00	3.25	0.0	0.0	1544
7141	115.00	112.57	109.18	0.0355	115.00	21	15	2.43	0.00	125.0	43.7	51600
7143	115.00	111.63	108.54	0.0543	115.00	21	43	3.37	0.00	152.5	0.2	61950
7147	115.00	110.02	107.25	0.0677	114.38	22	10	4.36	0.62	235.7	0.0	41100
7149	115.00	109.67	106.71	0.0718	114.07	22	10	4.40	0.93	248.0	0.0	21130
7151	115.00	110.98	108.23	0.0512	115.00	21	6	4.02	0.00	176.8	55.7	52480
7153	115.00	109.58	107.26	0.0288	111.78	21	42	2.20	3.22	240.2	0.0	100400
7155	115.00	112.75	108.84	0.0155	111.19	21	0	0.00	3.81	0.0	0.0	6711

Notes: At junction 7081 neither surcharging nor flooding occur.
At junction 7105 surcharging occurs without flooding.
At junction 7129 both surcharging and flooding occur.

BASELINE SYSTEM PERFORMANCE

Interceptor performance under baseline hydraulic conditions is addressed in the paragraphs that follow. The development of interceptor relief needs as well as potential interceptor flow transfer or in-system storage strategies is described in Chapter Seventeen.

Interceptor capacities and hydraulic conditions at peak flow during the 1-year, 6-hour storm are listed in Tables 15-3 and 15-4 for the North and South Systems, respectively. The data are presented for interceptor reaches of about one to five miles in length. These reaches include several sections and, therefore are not uniform in size and slope, but variations are limited. Both weighted and functional capacities are listed for each interceptor reach. The weighted capacity is the arithmetic average of the interceptor section capacities, determined from Manning's equation, weighted by the length of the section. The functional capacity is an estimate of the actual capacity of the interceptor reach, determined from the capacities of the individual sections and based on judgment.

For the 1-year, 6-hour storm, Tables 15-3 and 15-4 also list the relative flow depth, d/D, at peak flow, the excess capacity (functional capacity minus peak flow), the maximum surcharge duration and height and the duration of overflow (length of time when the hydraulic grade line exceeds the elevation of the manhole rim).

In the North System, Table 15-3 shows that approximately half of the 50 interceptor reaches are predicted to experience surcharging during the 1-year, 6-hour storm, but only five reaches have flooding or SSOs. In some of the reaches where overflows do not occur, the surcharge heights are high (over 6 ft.) This indicates that there are numerous potential problem areas in the North System which need to be evaluated.

In the South System, only four of the 36 interceptor reaches are predicted to experience surcharging and two have flooding/SSOs. This is in part due to a number of system improvement and relief projects which have been or are being implemented by the Authority.

TABLE 15–3. INTERCEPTOR HYDRAULICS – NORTH SYSTEM

9/28/94

INTERCEPTOR	LENGTH (FT)	SIZE RANGE D x W (IN) D	W	CAPACITY WEIGHTED/ FUNCTIONAL (MGD)	1 Yr. – 6 Hr. PEAK FLOW (MGD)	MAX. d/D	EXCESS CAPACITY (MGD)	MAX. SURCHARGE DURATION (MIN)	MAX. SURCHARGE HEIGHT (FT)	MAXIMUM OVERFLOW DURATION (MIN)
NORTH METRO SEWER										
Section 2 – 6	18024	102 108	110.5 111	125.0 118.0	125	0.9	0	0	0.0	0
Section 7 – 16	19551	98 108	106.5 110.5	123.4 120.0	94.8	0.5	25.2	0	0.0	0
Section 16 – 22	28219	40 70	42 76.5	28.4 20.0	23.6	0.63	6.4	0	0.0	0
CAMBRIDGE BRANCH SEWER										
Section 23 – 26	6441	72 77	80 86	74.0 64.0	99	1.88	0	319	6.7	0
EAST BOSTON										
Section 36 – 40	12033	15 45	15 49	15.2 2.5	9.6	4.44	0	2193	12.0	0
REVERE BRANCH SEWER										
Section 61 – 62	5925	48 54	48 54	18.6 18.0	23.1	4.75	0	298	15.0	0
CHELSEA BRANCH SEWER										
Section 11, 56 – 57	8443	22 42	28 42	9.0 4.0	11.1	5.95	0	190	6.9	58.7
NORTH METROPOLITAN RELIEF SEWER										
Section 101 – 105	8692	126 135	126 135	293.9 290.0	191.3	0.62	98.7	0	0.0	0
Section 105 – 108	12667	93 111	93 111	141.0 140.0	172	0.64	0	0	0	0
Section 111 – 114, 168 – 169	30661	36 66	36 69	41.2 25.0	41.4	0.66	0	0	0	0
CAMBRIDGE BRANCH SEWER (UPPER SECTION)										
Section 26 – 28	14988	48 69	54 78	29.1 26.0	64.2	3.1	0	296	13.5	0
NORTH CHARLES										
Section 29 – 30, 63	15766	24 44	28 50	12.0 22.0	24.9	1.26	0	37	1.1	0
SOMERVILLE MEDFORD BRANCH SEWER										
Section 35	6753	39 22	47.5 27.5	10.3 6.0	6	8.9	0	455	18.1	23.2
CHARLESTOWN BRANCH SEWER										
Section 31 – 32	6054	25 37	34 44	8.4 8.0	15.4	2.15	0	278	10.4	0
MALDEN BRANCH SEWER										
Section 54 – 55, 65 – 66	13894	15 36	15 36	4.4 2.0	2.2	2.15	0	218	1.7	0
MALDEN RELIEF SEWER										
Section 54, 95, 196 – 197	8647	30 48	30 48	9.9	2.6	0.78	7.4	0	0.0	0
WAKEFIELD TRUNK SEWER										
Section 40, 54	8613	30 50	30 45	13.1 14.0	12.2	0.57	1.8	0	0.0	0
Section 55	2934	15 18	15 18	2.6 1.7	1.7	1.41	0	282	0.5	0
Section 40	3326	24 50	24 45	13.8 13.0	11.4	0.59	1.6	0	0.0	0
Section 41	8737	24 31	24 31	7.3 5.2	2.8	0.41	2.4	0	0.0	0
Section 49 – 50	8212	12 18.5	12 18.5	2.2 2.3	3	5.83	0	1903	6.0	1625
WAKEFIELD BRANCH RELIEF SEWER										
Section 87, 64, 58 – 59	17325	48 54	48 54	32.7 26.0	16.5	0.61	9.5	0	0.0	0
Section 59 – 60	6486	30 36	30 36	13.4 12.1	8.1	0.8	4	0	0.0	0
STONEHAM TRUNK SEWER										
Section 41 – 42	7233	12 22	12 33	0.9	1	0.9	0	0	0.0	0
STONEHAM EXTENSION SEWER										
Section 51	4123	10 12	10 12	2.6 2.6	1.2	8.26	0	1657	4.3	0

TABLE 15–3 (Continued). INTERCEPTOR HYDRAULICS – NORTH SYSTEM

9/28/94

INTERCEPTOR	LENGTH (FT)	SIZE RANGE D x W (IN)		CAPACITY WEIGHTED/ FUNCTIONAL	1 Yr. – 6 Hr. PEAK FLOW (MGD)	MAX. d/D	EXCESS CAPACITY (MGD)	MAX. SURCHARGE		MAXIMUM OVERFLOW DURATION (MIN.)
		D	W					DURATION (MIN)	HEIGHT (FT)	
EDGEWORTH BRANCH SEWER										
Section20A	1530	24	24	4.9	5.2	2.53	0	966	2.8	0
ALEWIFE BROOK SEWER										
Section 43 – 43.5	9256	18 36	18 43	6.8 2.0	2.5	6.8	0	798	7.31	132.3
ALEWIFE BROOK CONDUIT										
Section ABC	13135	36 66	36 66	51.3 49.5	58.3	2.6	0	842	8.98	0
BELMONT BRANCH SEWER										
Section 81	3580	30	30	7.2	6.2	4.9	0	199.7	6.6	1.2
LEXINGTON BRANCH SEWER										
Section 52 – 53	18400	12 18	12 18	2.7 2.5	2.9	5.9	0	432.7	7	0
MYSTIC VALLEY SEWER										
Section 153, 160	8505	15 26	15 28	4.3 4.0	3.4	4.47	0	216	4.09	0
NEW MYSTIC VALLEY SEWER										
Section 109 – 110, 67 – 69	17299	42 72	42 75	17.7 2	10.1	0.39	10.1	0	0.0	0
Section 69 – 70	3513	24 36	36 36	9.6 9.5	3.9	0.46	5.4	0	0.0	0
Section 44 – 46	6102	22 33	28 37	4.7 5.0	3.25	1.36	0	1660	1.7	0
CUMMINGSVILLE BRANCH SEWER										
Section 47	4508	15	15	2.2	0.92	0.34	1.28	0	0.0	0
CUMMINGSVILLE BRANCH RELIEF SEWER										
Section 86	4967	30	30	11.1	13.05	1.49	0	164	1.74	0
READING EXTENSION SEWER										
Section 72 – 75	12040	15 20	15 20	4.9 4.5	1.34	1.82	0	1268	0.37	0
WILMINGTON EXTENSION SEWER										
Section 88 – 90	24114	30 48	30 48	21.7 21.0	6	0.4	0	0	0.0	0
MILBROOK VALLEY SEWER										
Section 77 – 80, 82 – 85	33946	20 36	20 42	8.8 7.0	11.7	3.74	0	2099	7.5	1099
MILLBROOK VALLEY RELIEF SEWER										
Section 151 – 152,92 – 93, 172	35389	30 60	30 60	28.1 25.0	21.3	0.85	3.7	0	0.0	0
NORTH CHARLES RELIEF SEWER										
Section 207A – 207B – 208	5733	92 124	70 49	123.7 113.0	121.3	1.78	0	64	5.46	0
Section 204	2747	88 72	138 72	87.9 150.0	177	2.23	0	120	6.45	0
Section 209	4778	60 36	60 36	28.7 25.0	55.9	1.2	0	58.7	1.22	0
CHARLES RIVER VALLEY SEWER										
Section A – D, 164	23923	54 66	61.5 66	30.5 27.0	33.6	0.73	0	0	0.0	0
Section 165, 191 – 192	13399	42 50	48 57.5	19.1 19.0	12.5	0.62	6.6	0	0.0	0
SOUTH CHARLES RELIEF SEWER										
Section 5, 2	21766	76 108	101.2 108	114.3 100.0	133.8	1.52	0	43.7	7.27	0
Section 3 – 4	16959	60 72	60 72	52.7 52.0	32	0.55	20	0	0.0	0
Section 4 – 4A	9495	42	42	18.6 18.0	7.8	0.46	10.2	0	0.0	0
DORCHESTER INTERCEPTOR										
Section 9 – 15	14757	28 54	42 55.75	13.5 11.5	10	2.18	0	180	6.15	0

TABLE 15–4. INTERCEPTOR HYDRAULICS – SOUTH SYSTEM

9/28/94

INTERCEPTOR	LENGTH (FT)	SIZE RANGE D (IN)	SIZE RANGE W (IN)	CAPACITY WEIGHTED/ FUNCTIONAL (MGD)	1 Yr – 6 Hr PEAK FLOW (MGD)	MAX d/D	EXCESS CAPACITY (MGD)	MAX. SURCHARGE DURATION (MIN)	MAX. SURCHARGE HEIGHT (FT)	MAXIMUM OVERFLOW DURATION (MIN)
HIGH LEVEL SEWER										
Section 75 – 74	6,035	78	84	68.3 67.5	34.0	0.56	0.0	0.0	0.0	0.0
Section 73 – 66	24,617	108 111	108 122	138.3 148	103.0	0.82	45.0	0.0	0.0	0.0
Section 65 – 56	18,398	127	139	209.9 211	189.0	0.79	22.0	0.0	0.0	0.0
Section 55 – 45	29,357	132 135	144 150	246.1 246	226.0	0.73	20.0	0.0	0.0	0.0
BRAINTREE–RANDOLPH EXTENSION SEWER										
Section 128A – 126	26,226	30 48	30 48	22.0 21.5	14.4	0.65	7.1	0.0	0.0	0.0
BRAINTREE–WEYMOUTH EXTENSION SEWER										
Section 125 – 124	3,657	30 50	30 50	17.1 18.0	14.6	0.65	3.4	0.0	0.0	0.0
BRAINTREE–WEYMOUTH BY–PASS										
STA 125R/1318 – 125R/0	8,413	42 60	42 60	62.1 35.0	22.9	0.64	12.1	0.0	0.0	0.0
BRAINTREE–WEYMOUTH EXTENSION REHAB.										
Section 124	4,761	42	42	13.6 11.5	12.2	0.64	0.0	0.0	0.0	0.0
Section 123 – 122	5,469	60 66	60 66	50.0 35.0	12.8	0.57	22.2	0.0	0.0	0.0
NEW NEPONSET VALLEY SEWER										
Section 115 – 111	28,334	54	60	24.2 24.0	0.06	.19	23.9	0.0	0.0	0.0
Section 110 – 107	14,977	72	75	51.0 51.0	34.3	.57	16.7	0.0	0.0	0.0
NEW NEPONSET VALLEY RELIEF SEWER										
Sta. /5482 – /1122	5,441	54	54	19.8 19.5	10.2	.49	9.3	0.0	0.0	0.0
WESTWOOD EXTENSION SEWER										
Section 136 – 135	10,610	30 36	30 36	7.4 7.0	3.7	.55	3.3	0.0	0.0	0.0
WALPOLE EXTENSION SEWER										
Section 117 – 116	10,836	48 54	51 54	20.0 20.0	11.4	.65	8.6	0.0	0.0	0.0
WALPOLE EXTENSION RELIEF SEWER (WERS)										
	4,888	30 42	30 42	9.4 11.0	4.7	.58	6.3	0.0	0.0	0.0
STOUGHTON EXTENSION SEWER										
Section 121 – 119	4,385	27	36	21.2 20.0	6.5	.28	13.5	0.0	0.0	0.0
Section 120 – 119	4,471	27 33	36 36	10.8 10.0	3.9	.39	6.1	0.0	0.0	0.0
STOUGHTON EXTENSION RELIEF SEWER (SERS)										
STA. /13865 – /10000	4,145	24 30	24 30	24.6 13.3	3.7	.42	5.8	0.0	0.0	0.0
STA. /5491 – /953	5,575	36	36	13.1 10.0	3.7	.44	4.3	0.0	0.0	0.0
NEPONSET VALLEY SEWER										
Section 25 – 21	13,724	45 48	46 49.5	22.2 27.0	23.3	1.9	0.0	39	3.4	0.0
Section 20 – 15	13,397	48 54	49.7 55.5	32.8 29.0	56.46	3.2	0.0	163	8.6 (Flooding)	16.3
UPPER NEPONSET VALLEY SEWER										
Section 28 – 26	11,602	26 45	26.7 46.5	10.6 11.0	18.9	1.3	0.0	417	0.56	0.0
Section 29 – 30	6,715	24 18 15	24 18 15	4.7 4.0	6.73	6.7	0.0	1700	11.5	317.8 (Flooding)
WELLESLEY EXTENSION SEWER										
Section 101 – 98	14,174	33 36	36 42	8.7 8.5	5.8	.47	2.7	0.0	0.0	0.0

TABLE 15–4 (Continued). INTERCEPTOR HYDRAULICS – SOUTH SYSTEM

9/28/94

INTERCEPTOR	LENGTH (FT)	SIZE RANGE (IN) D	W	CAPACITY WEIGHTED/ FUNCTIONAL (MGD)	1 Yr – 6 Hr PEAK FLOW (MGD)	MAX. d/D	EXCESS CAPACITY (MGD)	MAX. SURCHARGE DURATION (MIN)	HEIGHT (FT)	MAXIMUM OVERFLOW DURATION (MIN)
WELLESLEY EXTENSION RELIEF SEWER										
Section 138 – 138	13,186	60 84	60 84	47.2 41	25.9	.52	15.1	0.0	0.0	0.0
Section 131 – 129	25,594	48 54	48 54	23.5 21.5	11.6	.36	10.6	0.0	0.0	0.0
Section 137 – 137A	14,091	84	84	92.2 91.0	41.1	.45	49.9	0.0	0.0	0.0
WELLESLEY EXTENSION SEWER REPLACEMENT										
C5/19732 – C2/5154	22,093	60	60	37.7 35.0	24.3	.58	11.7	0.0	0.0	0.0
C2/4893 – C4/8396	9,617	54	54	28.1 26.0	14.6	.43	12.1	0.0	0.0	0.0
C4/6859 – C1/2970	6,859	60	60	37.0 35.0	17.7	.41	18.1	0.0	0.0	0.0
FRAMINGHAM EXTENTION SEWER REHABILITATION										
Section 134	6,320	40	40	17.4 17.0	6.3	0.48	10.2	0.0	0.0	0.0
Section 134 – 132	24,556	46 48	46 54	28.8 26.0	14.1	.53	11.9	0.0	0.0	0.0
PROPOSED FERS GRAVITY PORTION										
GS/10074 – GS/4943	5,322	36	36	54.0 18.0	3.6	.65	2.6	0.0	0.0	0.0
GS/4752 – GS/682	4,753	48 60	48 60	26.7 15.0	15.4	.59	5.6	0.0	0.0	0.0
BRIGHTON BRANCH SEWER										
Section 87 – 83	15,393	63 69	66 72	41.1 41.0	22.1	.48	18.9	0.0	0.0	0.0
Section 82 – 80	11,338	75 84	78 84	64.0 61.0	34.1	.47	27.4	0.0	0.0	0.0
HYDE PARK BRANCH SEWER										
Section 31	160	54	60	40.3	3.7	.55	36.6	0.0	0.0	0.0

PART IV

CHAPTER SIXTEEN

DEVELOPMENT OF PROJECT COSTS

Project costs were developed at a level of detail commensurate with the master planning level of detail to which alternatives were developed. In determining planning factors that might impact costs, consideration was given to alternative methods of interceptor relief such as replacement versus construction of a supplementary parallel conduit. Factors which impacted this determination included the size and age of the existing sewer, constructibility issues, and the relative difficulty of maintaining or bypassing flows during construction. This chapter presents the approach followed to develop estimated project costs for the interceptor relief, in-line storage, and flow transfer strategies under consideration.

RELIEF STRATEGIES

The methodology for estimating costs of interceptor construction took into consideration the costs of various items including:

- excavation
- paving
- gravel
- backfill
- manholes
- traffic
- bypass pumping
- utility relocations
- connections to existing services

- mobilization/demobilization

These cost items were then expressed as a function of pipe length, (L), or length times depth (L x D) as appropriate. The cost of the pipe itself, in place, was added. The cost for pipe in place was based on current costs for equipment, labor, materials, overhead and profit. Pipe material cost was based on reinforced concrete sewer pipe. This figure was then increased by approximately ten percent to allow for potential material cost increases such as special coatings or linings, or heavier wall pipe in very deep installations.

The resulting formula used to estimate the cost of each project is as follows:

$$\text{Cost} = 6.7 \times (L \times D) + 57.3 \times L + \text{Pipe Cost}$$

Cost in the formula is a base construction cost, and Pipe Cost is the pipe cost in place as described above. Values used for pipe cost in place are presented in Table 16-1.

TABLE 16-1. PIPE COST IN PLACE

Pipe Size (in.)	Cost ($/linear ft.)	Pipe Size (in.)	Cost ($/linear ft.)
24	50	66	170
30	60	72	200
36	70	78	250
48	100	84	300
54	125	90	325
60	146	96	355

The base construction cost was increased to account for sheeting, dewatering, and utility relocation on a site-specific basis using engineering judgement. The result was a construction cost that was then burdened to derive an estimated capital cost. Factors utilized to derive estimated capital cost include a 25 percent construction contingency and a 20 percent allowance for engineering and construction management costs. This result was multiplied by a factor of 1.08 to the projected ENR of 6936 used for all SMP projects.

STORAGE STRATEGIES

The method of cost development for storage strategies was to identify and estimate the cost of the major cost elements that comprised each in-line storage alternative. The major cost elements were:

- In-place cost of the storage device (e.g., electrically or hydraulically operated sluice gate, inflatable weir)
- Construction of a structure on the storage conduit to house the storage device
- Allowance for remote telemetry and control equipment

For the purpose of this estimate, it was assumed that each storage location would be equipped with an inflatable weir as the storage device. Other types of hydraulic control devices, such as electrically, hydraulically, or pneumatically actuated sluice gates, may be appropriate at certain locations. These details would be resolved in subsequent stages of project development. The cost for inflatable weir systems in-place was based on information provided by inflatable weir suppliers. Costs were obtained for a 7 ft. and 12 ft. long weir, complete with all equipment such as compressors and control systems required for operation. Costs for other weir lengths were prorated.

The cost of a structure to house the storage device was based on a quantity take-off of a conceptual design of appropriate depth and size to house the inflatable weir, as well as an adjacent chamber for equipment. The location selected for a control structure on an interceptor was assumed to be reasonably convenient, such that construction would not present any unusual difficulties. This assumption is possible because the exact location of the control structure has an insignificant impact on system performance, thus it can be adjusted within the proper general area to achieve the desired storage.

An allowance of eight percent of equipment cost was included to account for remote telemetry and control requirements of in-system storage alternatives.

The storage device (inflatable weir), control structure, and telemetry and control allowance costs were added to derive an estimated construction cost for in-system storage alternatives. The construction cost was burdened to derive an estimated capital cost using the same factors as for relief strategy costs.

TRANSFER STRATEGIES

The two transfer strategies considered were both pumped transfers from the North System to the South System. The method of cost development for both pumped transfers was to utilize cost curves for sewage pumping stations, adjusted based on engineering judgement and comparisons with other similar pumping stations. The force mains were estimated based on quantity take-offs.

Ward Street - High Level Sewer Transfer

A reasonable location to locate a pumping station in the Ward Street Headworks area is at the location of the former Ward Street Pumping Station that has been abandoned and demolished. When this station was demolished, the superstructure was in part used to fill and cover most of the substructure and foundation that was left in place. Because this would probably make construction more difficult than usual, engineering judgement was applied to increase the cost as compared to the average curve for the size pumping station required. The force main cost was based on sliplining one abandoned 48-inch force main at a cost of $290 per linear foot.

South Charles - Brighton Branch Sewer Transfer

This facility was assumed to be located in MDC park land between Nonantum Road and the Charles River. The force main would be installed under residential streets, passing through a bridge under the Conrail, Boston & Albany line and the Massachusetts Turnpike. The construction of the station itself is estimated to be slightly less costly than an average pumping station of this size because there would be ample space for construction, including a staging area, and the station would be relatively shallow, probably not over 22 feet deep to bottom of the excavation. The force main construction would be of average difficulty for an urban residential street area.