FINAL
CSO CONCEPTUAL PLAN
AND SYSTEM MASTER PLAN

PART V
SECONDARY TREATMENT
STRATEGIES

December 1994

Massachusetts Water Resources Authority

Metcalf & Eddy
An Air & Water Technologies Company

PART V
CHAPTER NINETEEN
INTRODUCTION

An analysis of the secondary treatment capacity required at the Deer Island treatment plant has been conducted under the secondary treatment strategies task of the system master planning program. This review has been conducted in concert with the development of CSO controls, I/I reductions, and interceptor improvements under the SMP program. Throughout the development of secondary treatment strategies, close coordination has been maintained with on-going efforts under the Deer Island Secondary Treatment Facilities Concept Design Reassessment (DP-29) being conducted by the Program Management Division (PMD) of the MWRA.

SECONDARY TREATMENT STRATEGY OBJECTIVES

The purpose of the secondary treatment strategy task was to develop recommendations for the completion of facilities at Deer Island that, in combination with CSO, I/I, and interceptor strategies, would enable the plant to meet Clean Water Act and NPDES permit requirements and water quality goals in a cost-effective manner. The following objectives were developed to guide this process:

- Meet Clean Water Act requirements and anticipated NPDES permit limits
- Meet receiving water quality standards and beneficial use goals
- Fully utilize those Deer Island facilities that are completed, on-going, or scheduled to be awarded by 1994. (Accept these facilities as part of the baseline conditions)
- Reduce the size, cost, and non-monetary impacts of the currently planned Deer Island facilities that are not yet under design or construction

- Provide for a completed facility that can reliably, as well as cost-effectively, meet its performance objectives

- Reserve site space for future treatment needs, if required.

These objectives were reviewed and refined throughout the development of secondary treatment strategies, as discussed in later chapters of this part of the report.

RELATIONSHIP TO DP-29

As previously discussed, the main purpose of including the development of secondary treatment strategies in the system master plan was to develop recommendations for completion of Deer Island facilities in an integrated manner, along with CSO, I/I, and interceptor strategies. Preliminary studies and on-going data collection efforts suggested that it might be possible to reduce the size and cost of secondary treatment facilities. For example, the March 1991 CSO Peak Shaving Feasibility Study identified potential cost savings associated with the direct conveyance of combined sewage flows to Deer Island. In addition, continuing data collection and analysis indicated that population, flow, and load projections made in conjunction with the 1988 Secondary Treatment Facilities Plan (STFP) were conservative and, if revised, could lead to recommendations for reduced secondary treatment facilities.

Subsequent to the initiation of activities on the secondary treatment strategies task, the MWRA undertook a more detailed evaluation to re-examine STFP recommendations, referred to as DP-29. This effort is being conducted by the MWRA Program Management Division (PMD). Following are key reasons for conducting the DP-29 re-evaluation of secondary treatment requirements:

- MWRA has substantially increased its database of treatment plant influent flows and pollutant loads

- The Deer Island 2.0 mgd pilot plant will provide operating data such as effluent quality and sludge production quantities and quality

- The secondary treatment process selected for Deer Island was current when the STFP was completed, but innovative/emerging technologies that have been developed and advanced since that time warrant consideration

- Contingency plans for potential nitrogen control in the future should be examined

In comparing the background and purposes for evaluating secondary treatment strategies with the DP-29 objectives, it was evident that both the system Master Plan and DP-29 studies shared the need for new data, particularly for increased information on flows and loads. Because the two studies rely on the evaluation of common information, their efforts have been closely coordinated via regular meetings and workshop sessions.

The system master planning program, and the secondary treatment strategies task in particular, has taken the lead in developing flows and loads for alternatives evaluations. Under secondary treatment strategies, a range of secondary treatment capacity has been recommended. Findings from the DP-29 investigations have refined the recommended secondary treatment plan, with a draft recommendation issued in November, 1994. Final recommendations for wastewater treatment facilities will be presented in the DP-29 concept design reassessment report in early 1995.

REPORT ORGANIZATION

This part of the report is organized into the following chapters:

- Chapter Nineteen - Introduction
- Chapter Twenty - Planning Approach. Presents key evaluation factors and criteria for secondary treatment strategies, including design flows and loads, unit process loadings, effluent quality, basis of cost, and other factors.
- Chapter Twenty-One - Evaluation of Alternatives. Describes the alternatives which were evaluated and presents the results of those evaluations.
- Chapter Twenty-Two - Recommended Plan. Presents the recommended secondary treatment alternative and cost savings potential.

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

PART V
CHAPTER TWENTY
PLANNING APPROACH

Key evaluation factors and criteria for conducting this review of secondary treatment requirements include design flows and loads, unit process loadings for liquid and residuals systems, primary and secondary effluent quality, operations and maintenance considerations, preliminary site plans and layout requirements, estimated sludge production, and estimates of potential cost savings. These evaluation factors and criteria form the basis of the approach followed in the secondary treatment strategies planning process.

DESIGN FLOWS AND LOADS

One key objective of the integrated system master planning (SMP) approach was to assess the impact of one strategy area on another. In terms of design flows and loads for secondary treatment strategies, the impact of I/I reduction, interceptor relief, and CSO control strategies was determined and included in the evaluation of secondary treatment alternatives.

Another important consideration with respect to design flows and loads for secondary treatment evaluations is the potential for future service area population growth. The MWRA's Sewerage Facilities Development Department has developed population projections which indicate a net reduction in population during the planning period, through the year 2025. These projections are based on a current population estimate of 2,062,130 persons and a year 2025 population of 1,953,180 persons is estimated. In comparison, the 1988 Secondary Treatment Facilities Plan projected a design year (2020) population of 2,150,000 persons. The current MWRA projection is 196,820 persons, or 9.15 percent lower than the STFP population projection used in sizing the wastewater treatment facilities at Deer Island. Recent Metropolitan Area Planning Council (MAPC) population projections for the period from 1990 to 2020 generally agree with the MWRA's projections.

TABLE 20-1. NORTH AND SOUTH SYSTEM COMMUNITY DRY WEATHER FLOW ESTIMATES AND PROJECTIONS

											With Out Water Conservation			With Water Conservation		
Community	(5) Current Pop. Estimate	(5) 2025 Pop. Project.	Current % Resid. Serviced	Current Pop. Serviced	(1) Current % I/C/I Sewered	Current San. Flow (MGD)	Yr 2025 (4) San. Flow w/o Water Conser. (MGD)	Yr 2025 (2),(4) San. Flow w/ Water Conser. (MGD)	Annual Avg. Infil. (MGD)	Current DWF (MGD)	Yr 2025 (3) DWF w/o Water Conser. (MGD)	Increase (MGD)	Percent Increase (%)	Yr 2025 (3) DWF w/ Water Conser. (MGD)	Increase (MGD)	Percent Increase (%)
Arlington	44630	39986	100.0	44630	100.0	2.60	2.30	2.07	1.70	4.30	4.00	-0.30	-7.02	3.77	-0.53	-12.37
Bedford	12996	13342	71.0	9227	72.2	1.48	2.04	1.84	1.14	2.62	3.18	0.56	21.35	2.98	0.36	13.57
Belmont	24720	21779	100.0	24720	100.0	1.75	1.56	1.40	1.73	3.48	3.29	-0.19	-5.49	3.13	-0.35	-9.97
Boston (North)	408921	388718	100.0	408921	100.0	30.30	28.99	26.09	45.60	75.90	74.59	-1.31	-1.73	71.69	-4.21	-5.55
Brookline (North)	26217	23830	100.0	26217	100.0	2.43	2.27	2.05	2.61	5.04	4.88	-0.16	-3.08	4.66	-0.38	-7.59
Burlington	23302	21141	90.4	21065	90.4	1.72	1.79	1.61	1.85	3.57	3.64	0.07	1.99	3.46	-0.11	-3.02
Cambridge	95802	96348	100.0	95802	100.0	11.42	11.46	10.31	10.61	22.03	22.07	0.04	0.16	20.92	-1.11	-5.04
Chelsea	28710	28823	100.0	28710	100.0	2.14	2.15	1.93	2.10	4.24	4.25	0.01	0.17	4.03	-0.21	-4.89
Everette	35701	32448	100.0	35701	100.0	2.75	2.54	2.28	2.59	5.34	5.13	-0.21	-3.96	4.87	-0.47	-8.71
Lexington	28974	27690	100.0	28974	100.0	2.10	2.02	1.81	4.38	6.48	6.40	-0.08	-1.29	6.19	-0.29	-4.40
Malden	53884	51162	100.0	53884	100.0	3.32	3.14	2.83	3.14	6.46	6.28	-0.18	-2.74	5.97	-0.49	-7.60
Medford	57407	53888	100.0	57407	100.0	3.19	2.96	2.67	6.05	9.24	9.01	-0.23	-2.48	8.72	-0.52	-5.68
Melrose	28150	25123	100.0	28150	100.0	1.96	1.76	1.59	2.57	4.53	4.33	-0.20	-4.34	4.16	-0.37	-8.24
Milton (North)	2031	1836	100.0	2031	100.0	0.22	0.21	0.19	0.16	0.38	0.37	-0.01	-3.34	0.35	-0.03	-8.79
Newton (North)	65349	60103	100.0	65349	100.0	3.72	3.38	3.04	5.28	9.00	8.66	-0.34	-3.79	8.32	-0.68	-7.54
Reading	22539	20872	100.0	22539	100.0	1.17	1.06	0.96	1.06	2.23	2.12	-0.11	-4.86	2.02	-0.21	-9.62
Revere	42786	40452	100.0	42786	100.0	2.75	2.60	2.34	2.75	5.50	5.35	-0.15	-2.76	5.09	-0.41	-7.48
Somerville	76210	67882	100.0	76210	100.0	2.91	2.37	2.13	4.60	7.51	6.97	-0.54	-7.21	6.73	-0.78	-10.36
Stoneham	22203	21567	100.0	22203	100.0	1.80	1.76	1.58	2.14	3.94	3.90	-0.04	-1.05	3.72	-0.22	-5.51
Wakefield	24825	24002	100.0	24825	100.0	2.15	2.10	1.89	1.97	4.12	4.07	-0.05	-1.30	3.86	-0.26	-6.39
Waltham	57878	54159	100.0	57878	100.0	4.50	4.26	3.83	4.80	9.30	9.06	-0.24	-2.60	8.63	-0.67	-7.18
Watertown	33284	31449	100.0	33284	100.0	2.30	2.18	1.96	2.20	4.50	4.38	-0.12	-2.65	4.16	-0.34	-7.50
Willimington	17651	17953	7.2	1271	41.1	0.85	2.41	2.17	0.58	1.43	2.99	1.56	109.19	2.75	1.32	92.33
Winchester	20267	19658	100.0	20267	100.0	1.69	1.65	1.49	2.49	4.18	4.14	-0.04	-0.95	3.98	-0.20	-4.90
Winthrop	18127	16393	100.0	18127	100.0	1.85	1.74	1.56	4.03	5.88	5.77	-0.11	-1.92	5.59	-0.29	-4.87
Woburn	35943	35575	100.0	35943	100.0	5.46	5.44	4.89	6.62	12.08	12.06	-0.02	-0.20	11.51	-0.57	-4.70
North Sub-Total	1308507	1236179		1286121		98.53	96.12	86.51	124.75	223.28	220.87	-2.41	-1.08	211.26	-12.02	-5.38

(1) --- Assume all sewered I/C/I areas are serviced

(2) --- Water conservation is assumed 10% of sanitary flow for year 2025

(3) --- Infiltration assumed to remain constant from current to year 2025

(4) --- Resid. flow project. to year 2025 assumes 100% serviced and 65 gpcd for change in population, I/C/I flow projection assumes 100% serviced

(5) --- Population estimates and projections are based upon Sewerage Facilities Department Planning Program, December 8, 1993

TABLE 20–1 (cont). NORTH AND SOUTH SYSTEM COMMUNITY DRY WEATHER FLOW ESTIMATES AND PROJECTIONS

											With Out Water Conservation			With Water Conservation		
Community	(5) Current Pop. Estimate	(5) 2025 Pop. Project.	Current % Resid. Serviced	Current Pop. Serviced	(1) Current % I/C/I Sewered	Current San. Flow (MGD)	Yr 2025 (4) San. Flow w/o Water Conser. (MGD)	Yr 2025 (2),(4) San. Flow w/ Water Conser. (MGD)	Annual Avg. Infil. (MGD)	Current DWF (MGD)	Yr 2025 (3) DWF w/o Water Conser. (MGD)	Increase (MGD)	Percent Increase (%)	Yr 2025 (3) DWF w/ Water Conser. (MGD)	Increase (MGD)	Percent Increase (%)
Ashland	12066	15535	55.0	6636	82.7	0.50	1.09	0.98	0.34	0.84	1.43	0.59	70.71	1.32	0.48	57.69
Braintree	33836	31332	100.0	33836	100.0	2.57	2.41	2.17	3.57	6.14	5.98	−0.16	−2.65	5.74	−0.40	−6.57
Boston (South)	165362	157192	100.0	165362	100.0	12.46	11.93	10.74	6.20	18.66	18.13	−0.53	−2.85	16.94	−1.72	−9.24
Brookline (South)	28121	25560	100.0	28121	100.0	2.61	2.44	2.20	4.61	7.22	7.05	−0.17	−2.31	6.81	−0.41	−5.69
Canton	18530	18963	71.5	13249	78.1	1.34	1.82	1.64	1.34	2.68	3.16	0.48	17.86	2.98	0.30	11.08
Dedham	23782	20655	90.0	21404	93.8	1.70	1.70	1.53	4.18	5.88	5.88	−0.00	−0.06	5.71	−0.17	−2.94
Framingham	64989	60973	100.0	64989	100.0	5.63	5.37	4.83	2.48	8.11	7.85	−0.26	−3.22	7.31	−0.80	−9.84
Holbrook	11041	11081	56.0	6183	90.7	0.36	0.69	0.62	0.44	0.80	1.13	0.33	40.73	1.06	0.26	32.15
Hingham (6)	12897	12317	38.9	5017	38.9	0.40	1.00	0.90	0.58	0.98	1.58	0.60	61.51	1.48	0.50	51.28
Milton (South)	23694	21425	100.0	23694	100.0	1.44	1.29	1.16	2.33	3.77	3.62	−0.15	−3.91	3.49	−0.28	−7.34
Natick	30510	31864	78.5	23950	78.5	3.12	3.83	3.44	1.22	4.34	5.05	0.71	16.26	4.66	0.32	7.45
Needham	27557	26105	88.1	24278	88.1	2.27	2.48	2.23	1.85	4.12	4.33	0.21	5.16	4.08	−0.04	−0.86
Newton (South)	17236.00	15852.00	100.00	17236	100.0	3.93	3.84	3.46	8.27	12.20	12.11	−0.09	−0.74	11.73	−0.47	−3.88
Norwood	28700	26314	100.0	28700	100.0	2.56	2.40	2.16	2.93	5.49	5.33	−0.16	−2.82	5.09	−0.40	−7.21
Quincy	84985	80252	100.0	84985	100.0	7.10	6.79	6.11	5.39	12.49	12.18	−0.31	−2.46	11.50	−0.99	−7.90
Randolph	30093	28592	95.5	28739	96.1	1.87	1.86	1.68	1.39	3.26	3.25	−0.01	−0.21	3.07	−0.19	−5.92
Stoughton	26777	25923	62.2	16655	91.1	0.91	1.53	1.38	1.33	2.24	2.86	0.62	27.73	2.71	0.47	20.89
Walpole	20212	20901	52.5	10611	73.1	0.92	1.72	1.55	1.13	2.05	2.85	0.80	39.19	2.68	0.63	30.78
Wellesley	26615	24497	90.6	24113	90.6	1.82	1.86	1.68	2.27	4.09	4.13	0.04	1.09	3.95	−0.14	−3.47
Westwood	12557	11811	76.4	9594	76.4	0.73	0.95	0.85	0.73	1.46	1.68	0.22	15.04	1.58	0.12	8.54
Weymouth	54063	49857	91.0	49197	91.0	3.23	3.35	3.02	4.10	7.33	7.45	0.12	1.66	7.12	−0.21	−2.91
South Sub–Total	**753623**	**717001**		**686549**		**57.47**	**60.37**	**54.33**	**56.68**	**114.15**	**117.05**	**2.90**	**2.54**	**111.01**	**−3.14**	**−2.75**
Service Area Total	**2062130**	**1953180**		**1972671**		**156.00**	**156.49**	**140.84**	**181.43**	**337.43**	**337.92**	**0.49**	**0.14**	**322.27**	**−15.16**	**−4.49**

(1) – – – Assume all sewered I/C/I areas are serviced

(2) – – – Water conservation is assumed 10% of sanitary flow for year 2025

(3) – – – Infiltration assumed to remain constant from current to year 2025

(4) – – – Resid. flow project. to year 2025 assumes 100% serviced and 65 gpcd for change in population, I/C/I flow projection assumes 100% serviced

(5) – – – Population estimates and projections are based upon Sewerage Facilities Department Planning Program, December 8, 1993

(6) – – – Population, population projections, and flows indicated for the Sewer District only

The MWRA population projections were used to generate future dry weather wastewater flows both with and without an assumption that water conservation efforts will reduce wastewater flows. The results of these projections are presented in Table 20-1. Without the impact of water conservation, future system-wide dry weather flows were projected to increase by 0.14 percent, or 0.49 mgd; with the impact of water conservation included, future system-wide dry weather flows would decrease by 4.49 percent, or 15.16 mgd. Future flows also assume 100 percent service and sewering of the 43 communities within the MWRA service area, and no increase in I/I during the planning period.

Since year 2025 flows may be lower than future planned condition (year 1997) flows, future planned condition flows were used in conjunction with the impact of I/I, interceptor, and CSO control strategies to develop design flows and loads for secondary treatment strategy analyses. A sensitivity analysis was conducted to assess the impact of increased flow and pollutant loadings due to a potential unexpected population increase of up to 10 percent on selected secondary treatment strategies.

Historical Flow and Load Analysis

Flow and load data from the Deer and Nut Island treatment plant monthly operating reports were used to conduct analyses of historical flows and loads. Data were obtained for the five-year period of January 1, 1989 to December 31, 1993. Analyses were done on dry day data and all day (dry and wet) data, with the following algorithm applied to distinguish dry versus non-dry days:

- A dry day is a day on which 0.00 to 0.09 inch of precipitation occurs
- A non-dry day is defined based on precipitation depth, as follows:
  - 0.10 to 0.29 inch - counts day of precipitation as a non-dry day
  - 0.30 to 0.99 inch - includes day of precipitation and one subsequent day as non-dry days

- 1.00 to 1.99 inch - includes day of precipitation and two subsequent days as non-dry days

- 2.00 inch and above - includes day of precipitation and three subsequent days as non-dry days

This is the same criteria that was applied to distinguish dry versus non-dry days in the March 1991 CSO Peak Shaving Feasibility Study.

The following analyses were performed to characterize flows and pollutant loadings (BOD and TSS) for the period of record:

- Assessment of high versus low groundwater periods
- All day flows
- Dry day flows
- All day pollutant loadings
- Dry day pollutant loadings
- Probability distributions

The approach and results for each of these analyses is presented in the text that follows.

Assessment of High Versus Low Groundwater Periods. Distinct high and low groundwater periods were not discernible for the five years of data analyzed. Total daily flows for the Deer Island and Nut Island treatment plants, and the sum of the two plant flows (referred to as combined plant flows) were plotted along with daily precipitation for the normally high groundwater period of February to May for the years 1989 to 1993 (Figure 20-1). This plot, particularly for the Deer Island and combined plant flows, shows that due to the impact of inflow from both separate and combined sewer areas, the system is very reactive to rainfall. This rainfall responsive characteristic appears to dominate in terms of

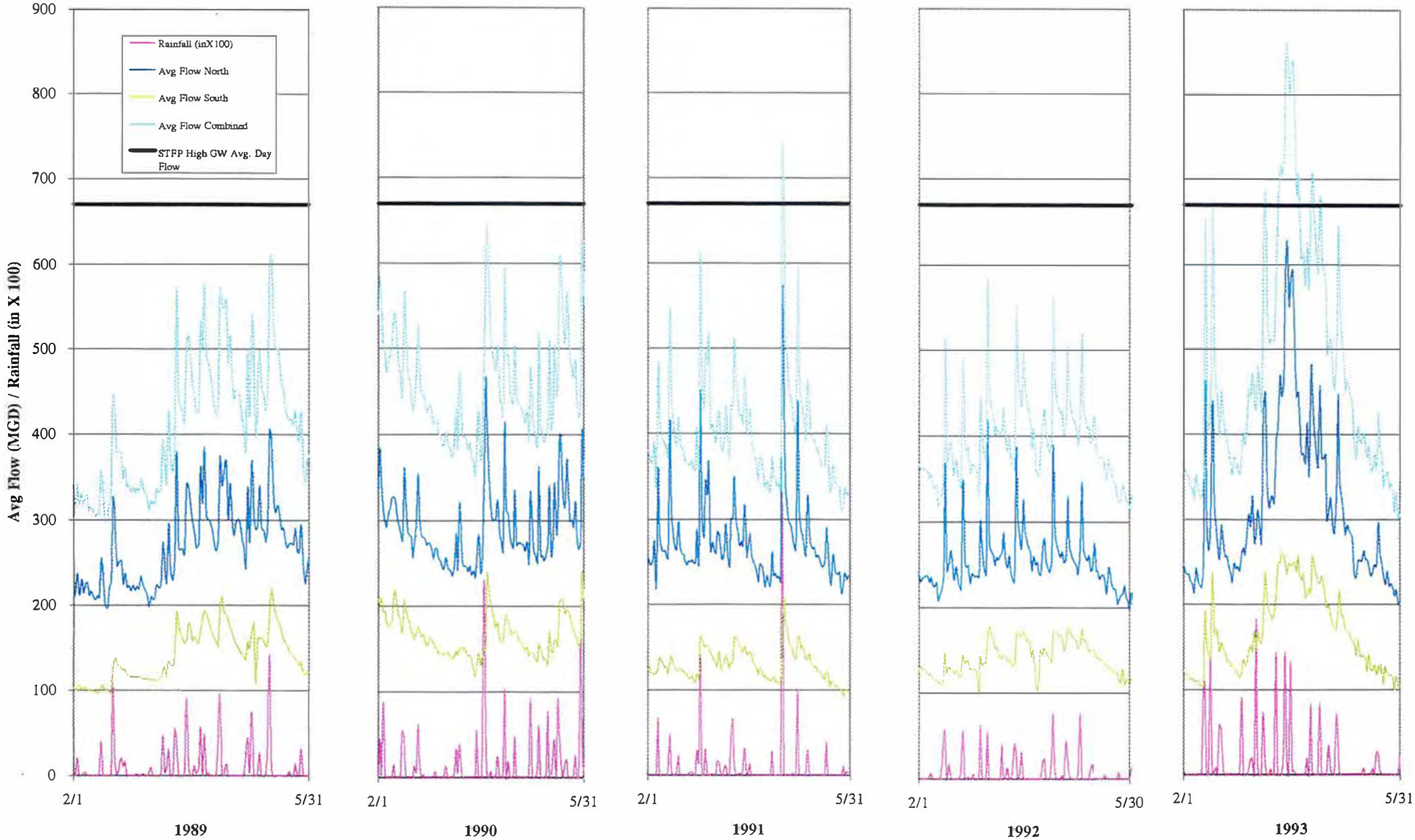

FIGURE 20-1. AVERAGE FLOW AND RAINFALL DURING HIGH GROUND WATER PERIODS

system flow variations. It is also apparent from Figure 20-1 that dry weather flows during the months of February to May do not average 670 mgd, which was the assumption in the 1988 Secondary Treatment Facilities Plan (STFP) that lead to the definition of high versus low groundwater periods. It now appears that the STFP criteria using seasonal average flows are not valid, and plant design should be based on annual average flow.

All Day Flows. The results from analyses of all day flows for the five-year period of record are presented in Table 20-2. The average daily flow values represent the averages of all total daily flows for the five-year period of record. Maximum day flows were determined by selecting the highest total daily flow values in the period of record. Maximum 95 percent and maximum 90 percent daily flows were determined by selecting the flow value within the data series which was exceeded 5 percent and 10 percent of the time, respectively. The peak hour values are presented for Deer Island and Nut Island but not for the combined plant, since the peak hour flows at Deer and Nut Island are not coincident. The values presented represent the highest peak hour flows for the period of record.

Dry Day Flows. The exclusion of non-dry days resulted in gaps in the flow data series. In order to compute moving averages and perform certain other analyses, the gaps were filled. This was done by scanning the data series from a blank both forward and backward in time to find a dry day flow value. The first values found in both directions were averaged to fill the data series between the values found.

The results from analyses of dry day flows from the five-year period of record are presented in Table 20-3. The annual average of all dry day total daily flow values for each of the five years analyzed, and also the average of all dry day total daily flow values for the entire period of record are included. Filled values are included in the computation of these averages. Maximum calendar month values were determined by calculating the 60 monthly averages of dry day total daily flow values for the five-year period and selecting the highest monthly average. The computation of each monthly average includes the filled values. In

TABLE 20-2. AVERAGE DAILY, MAXIMUM DAY, AND PEAK HOUR FLOWS

Description	Deer Island	Nut Island	Combined Plant
Average daily flow (MGD)	259	127	386
Maximum day flow (MGD)	628	299	863
Maximum 95% day flow (MGD)	374	195	567
Maximum 90% day flow (MGD)	328	174	499
Peak hour flow (MGD)	750	334	--

Note: Values in this table are based on data from January, 1989 to December, 1993

TABLE 20-3. DRY DAY FLOW ANALYSES

Description	Deer Island	Nut Island	Combined Plant
1989 Average, dry day total daily flow (MGD)	250	130	380
1990 Average, dry day total daily flow (MGD)	253	130	383
1991 Average, dry day total daily flow (MGD)	243	116	359
1992 Average, dry day total daily flow (MGD)	233	119	352
1993 Average, dry day total daily flow (MGD)	236	120	356
5-Year average, dry day total daily flow (MGD)	243	123	366
Maximum month, dry day flow (MGD)	363	215	578
Maximum 30-day average, dry day flow (MGD)	396	231	626
Maximum day, dry day total daily flow (MGD)	450	262	708
Maximum 98% day, dry day total daily flow (MGD)	-	-	532
Maximum 95% day, dry day total daily flow (MGD)	306	180	480
Maximum 90% day, dry day total daily flow (MGD)	288	165	451

Note: Values in this table are based on data from January, 1989 to December, 1993 addition to determining the maximum calendar month dry day flows, a maximum 30-day moving average dry day flow was computed. Filled values are included in this computation. The maximum 30-day average dry day flow represents the highest 30-day moving average computed. Maximum day flows were determined by selecting the highest dry day total flow values. Maximum 95 percent and maximum 90 percent daily flows were determined by selecting the value within the dry day data series which was exceeded 5 percent and 10 percent of the time, respectively. Filled values in the data series were included in these analyses. The maximum 98 percent dry day total daily flow was computed for the combined plant using only historical flows (filled values were not used).

Pollutant Loadings. The results from analyses of all day and dry day influent pollutant loadings to the Deer and Nut Island treatment plants for the five-year period of record are presented in Tables 20-4 (all day data) and 20-5 (dry day data). For Deer Island, BOD and TSS concentrations for the period of October 1990 to March 1991 have been excluded as automatic sampler relocation efforts resulted in non-representative samples during that timeframe.

In general, pollutant concentration data are available for five or less days per week. In order to produce 3-day, 7-day, and 30-day moving averages, it was necessary to fill blanks in the data series with representative values. This was done by scanning from a blank both forward and backward in time for a maximum of five days to find a value. The first values found in both directions were averaged to fill the data series between the values found. If values were not found in both directions within five days, the data series was not filled and the denominator in the moving average decreased to represent the number of values (actual and filled data values) comprising the moving average.

The five-year average loads in Tables 20-4 and 20-5 are the average of actual dry day pollutant values in the data series and the average of actual all day pollutant values in the series. No filled values were used in computing these averages. For the combined plant

TABLE 20-4. ALL DAY POLLUTANT LOADINGS

Description	Deer Island		Nut Island		Combined Plant	
	BOD	TSS	BOD	TSS	BOD	TSS
5-Year average loads (lb/day)	342,506	351,767	170,014	177,976	512,023	531,089
Maximum day loads (lb/day)	1,439,346	4,530,334	543,855	1,083,622	1,703,482	4,656,403
Maximum 95% day loads (lb/day)	540,956	660,782	266,894	320,807	725,948	889,231
Maximum 90% day loads (lb/day)	469,452	514,319	232,829	257,165	645,326	745,548
Maximum 3-day average loads (lb/day)	1,050,441	3,111,700	438,064	798,426	1,253,874	3,344,369
Maximum 95% 3-day average loads (lb/day)	523,782	660,629	253,885	322,818	692,682	856,585
Maximum 90% 3-day average loads (lb/day)	461,452	504,856	225,313	258,298	641,030	732,816
Maximum 7-day average loads (lb/day)	777,022	2,281,677	336,507	518,774	936,896	2,469,695
Maximum 95% 7-day average loads (lb/day)	511,808	653,256	242,470	304,095	666,812	798,093
Maximum 90% 7-day average loads (lb/day)	452,336	507,061	218,832	256,301	620,913	706,890
Maximum 30-day average loads (lb/day)	578,024	948,722	260,608	350,617	749,296	1,092,724
Maximum 95% 30-day average loads (lb/day)	495,070	641,174	220,641	274,725	644,621	780,952
Maximum 90% 30-day average loads (lb/day)	429,365	540,309	206,281	240,115	603,759	694,990

Note: The values in this table are based on data from January, 1989 to December, 1993

TABLE 20-5. DRY DAY POLLUTANT LOADINGS

Description	Deer Island		Nut Island		Combined Plant	
	BOD	TSS	BOD	TSS	BOD	TSS
5-Year average dry day loads (lb/day)	325,444	305,840	164,568	166,244	501,471	480,276
Maximum day, dry day loads (lb/day)	827,841	4,530,334	489,042	997,921	950,500	4,656,403
Maximum 95% day, dry day loads (lb/day)	490,628	534,080	251,101	295,296	665,593	757,806
Maximum 90% day, dry day loads (lb/day)	441,776	426,588	221,435	237,374	609,444	638,696
Maximum 3-day average dry day loads (lb/day)	732,758	2,671,518	394,570	747,006	862,090	2,797,530
Maximum 95% 3-day average dry day loads (lb/day)	482,065	534,080	244,697	279,962	654,684	752,366
Maximum 90% 3-day average dry day loads (lb/day)	435,008	426,588	218,367	237,056	607,032	626,419
Maximum 7-day average loads (lb/day)	644,811	1,473,717	355,324	558,033	822,659	1,603,330
Maximum 95% 7-day average dry day loads (lb/day)	470,536	559,151	234,963	279,889	632,090	726,184
Maximum 90% 7-day average dry day loads (lb/day)	422,054	411,369	214,383	234,158	597,335	635,085
Maximum 30-day average loads (lb/day)	586,293	783,727	297,591	350,923	734,898	918,693
Maximum 95% 30-day average dry day loads (lb/day)	434,864	531,381	221,399	265,699	605,024	694,375
Maximum 90% 30-day average dry day loads (lb/day)	412,195	452,913	201,231	224,613	567,793	639,824

Note: The values in this table are based on data from January, 1989 to December, 1993 pollutant loads, the five-year averages were computed only for dates when loads were available at both Deer and Nut Island. Maximum day loads were determined by selecting the highest loadings based on actual data values. Maximum 95 percent and maximum 90 percent daily loads were determined by including filled values in the data series, and selecting the value which was exceeded 5 percent and 10 percent of the time, respectively. The maximum 3-day, 7-day, and 30-day moving averages were determined by including filled values in the data series, and represent the highest moving average computed. In addition, maximum 95 percent and maximum 90 percent 3-day, 7-day, and 30-day moving averages were determined by including filled values in the data series and selecting values that were exceeded 5 percent and 10 percent of the time, respectively.

Probability Distributions. Annual probability distribution curves showing flow, BOD, and TSS were developed for all day and dry day data at Deer Island, Nut Island, and for the combined plant, and an example is shown on Figure 20-2. Filled data series were used to develop these curves for all data except for the all days flow series, for which no gaps in actual data values exist. The data series were sorted from highest to lowest value, and the highest value assigned 100 percent and the lowest non-zero value assigned 0 percent. Each value between these extremes was assigned its respective percent less than value, and the plots were generated.

Flows and Loads Used in Evaluations

Flow and loading conditions that correspond to typical design criteria and permit requirements were developed for use in conducting secondary treatment strategy evaluations. These are presented in Table 20-6.

Annual average, maximum 30-day, maximum 7-day, maximum day, and maximum hour flows and loads were derived for the following categories:

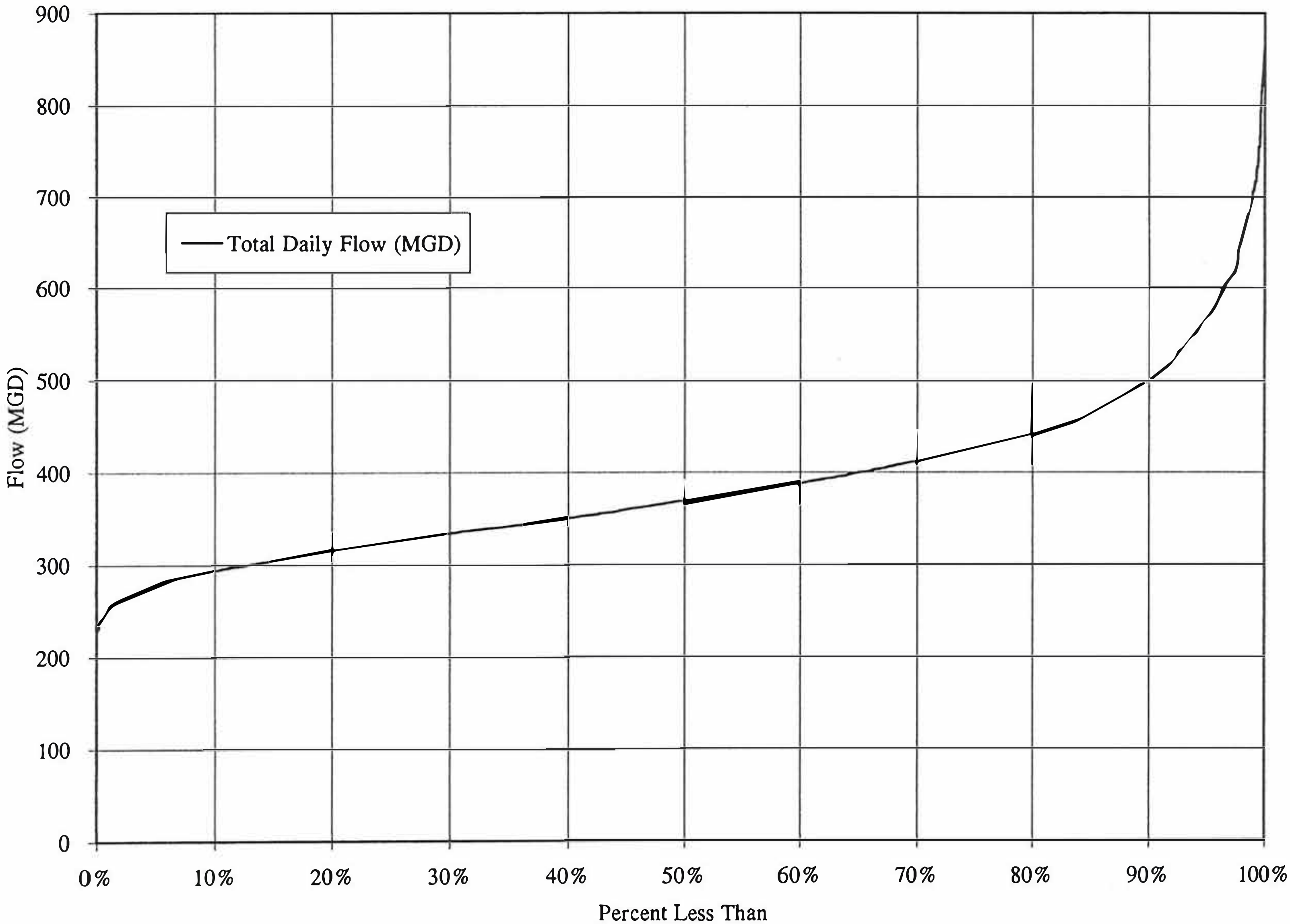

FIGURE 20-2. PROBABILITY DISTRIBUTION FOR COMBINED PLANT ALL DAY FLOWS
(Period From 1/89 to 12/93)

TABLE 20-6. FLOW AND LOADING CONDITIONS FOR SECONDARY TREATMENT STRATEGY EVALUATIONS

Flow/Loading Condition	Bases for Inclusion in Evaluations
• Annual Average	• Corresponds to process design criteria (e.g., settling tank overflow rate, F/M ratio, residuals process loadings, and others)
• Maximum 30-day	• Corresponds to NPDES Permit monthly average limits
• Maximum 7-day	• Corresponds to NPDES Permit weekly average limits
• Maximum Day	• Corresponds to process design criteria
• Maximum Hour	• Corresponds to process (e.g. settling tank overflow rate) and hydraulic (e.g., firm pumping capacity) design criteria

- Future planned conditions; which do not include the impact of I/I, interceptor, or CSO control strategies
- CSO Strategy M2; includes the impact of the draft recommended CSO control plan (Part II), the I/I reduction included in the SMP (Part III), and recommended interceptor relief (Part IV)
- CSO Strategy M2 conditions increased to account for a 10 percent population increase; as a sensitivity analysis to assess the impact of an unanticipated population increase.
- CSO Strategy M; includes the impact of CSO strategy M (refer to Part II) which reflects a higher level of CSO storage than the recommended CSO control plan

Flows used in secondary treatment evaluations were derived using the system-wide EXTRAN model. Annual average flows were generated with future planned condition dry weather flows and a typical precipitation year input to the model. The maximum 30-day, maximum 7-day, maximum day, and maximum hour flows were derived with spring, 1993 dry and wet weather conditions as the model input. In the case of CSO Strategy M and CSO Strategy

M2, the model accounted for the CSO volume captured during storm events, which was returned to the transport system after the storm passed.

Spring, 1993 conditions were selected as model input to derive maximum 30 day, maximum 7 day, maximum day, and maximum hour flows because of the extreme climatic conditions during that period. A total of 38.9 inches of snow fell in Boston during March, 1993, which is the record for March and the second largest snowfall recorded for any month in the 104 year of record (NOAA, March, 1993). This record snowfall contributed to elevated groundwater and river levels as well as runoff, which in turn contributed to high levels of infiltration and inflow. As a result, recorded flows during the spring of 1993 at Deer Island were the highest of the five years of data analyzed.

Loads used in evaluations were derived by computing the incremental flow (the difference between model-predicted flow and historical flow) for each day of the simulation, and multiplying the incremental flow by a representative BOD and TSS concentration. This resulted in an incremental pollutant load which was added to the historical pollutant load for each day of the simulation. This process accounted for higher wet weather pollutant loadings that would be associated with the higher wet weather wastewater flows predicted by the EXTRAN model.

Flows and pollutant loads corresponding to each of these five categories are presented in Tables 20-7 through 20-10.

Comparison of flows and pollutant loadings for CSO Strategy M versus Strategy M2 (tables 20-8 and 20-9) indicates relatively minor variations as a result of different CSO control strategies. Strategy M consists of a higher degree of off-line storage than strategy M2. The final recommended CSO control strategy (M3) is similar to Strategy M2 except that slightly less off-line storage is provided. Due to the minor differences between Strategy M2 and M3 and because the strategy M2 flows and loads would be slightly higher than Strategy M3 flows and loads, plant flows and loads for CSO Strategy M3 were not developed.

TABLE 20-7. FUTURE PLANNED CONDITIONS FLOWS AND LOADS

Flow/Loading Condition	Flow (mgd)	BOD (lb/day)	TSS (lb/day)
Annual Average	361	516,200	548,500
Maximum 30-Day	690	657,000	706,600
Maximum 7-Day	851	717,800	863,700
Maximum Day	990	972,300	1,082,400
Maximum Hour	1,165	-	-

TABLE 20-8. CSO STRATEGY M FLOWS AND LOADS

Flow/Loading Condition	Flow (mgd)	BOD (lb/day)	TSS (lb/day)
Annual Average	363	519,700	553,300
Maximum 30-Day	697	660,100	710,700
Maximum 7-Day	867	720,800	865,000
Maximum Day	1,011	971,400	1,085,300
Maximum Hour	1,211	-	-

TABLE 20-9. CSO STRATEGY M2 FLOWS AND LOADS

Flow/Loading Condition	Flow (mgd)	BOD (lb/day)	TSS (lb/day)
Annual Average	353	516,800	548,000
Maximum 30-Day	689	660,900	711,900
Maximum 7-Day	854	721,200	868,100
Maximum Day	998	974,300	1,091,900
Maximum Hour	1,142	-	-

TABLE 20-10. CSO STRATEGY M2 FLOWS AND LOADS PLUS 10 PERCENT GROWTH

Flow/Loading Condition	Flow (mgd)	BOD (lb/day)	TSS (lb/day)
Annual Average	383	566,800	598,000
Maximum 30-Day	719	710,900	761,900
Maximum 7-Day	884	771,200	918,100
Maximum Day	1,028	1,024,300	1,141,900

UNIT PROCESS LOADINGS

In addition to comparisons between predicted effluent quality versus NPDES permit limits, secondary treatment alternatives were evaluated in terms of typical unit process loading criteria. Typically, unit process criteria are used to size the various unit processes (e.g., the overflow rate in conjunction with design flow is used to size sedimentation basins). In evaluating the secondary treatment alternatives, the Deer Island treatment plant unit processes were already sized and flows known, so the unit process loading criteria were computed and compared to typical design values. The unit process loading criteria against which computed values were compared are presented in Table 20-11. Significant deviations between acceptable target values and computed values indicated potential plant operability concerns, and typically were noted for alternatives that exhibited marginal to unacceptable effluent quality.

EFFLUENT QUALITY

Estimates of primary and secondary effluent quality were made based on available Deer Island pilot plant data, trailer pilot plant data, STFP and MIT projections, plus a literature review of operating results from full-scale operational pure oxygen activated sludge facilities. Blended effluent quality was determined as the flow weighted average of primary and secondary effluent. The on-going pilot plant operation will provide additional information

TABLE 20-11. UNIT PROCESS LOADINGS FOR LIQUID AND RESIDUALS SYSTEMS

	Acceptable/Target Values				
Unit Process Criteria	Annual Average	Maximum 30-Day	Maximum 7-Day	Maximum Day	Maximum Hour
STACKED RECTANGULAR PRIMARY CLARIFIERS					
• Overflow rate, gpd/sf	600	--	--	--	≤2,000
PURE OXYGEN ACTIVATED SLUDGE SYSTEM					
• Aeration tank MLVSS, mg/l	2,000	2,000	2,000	2,000	--
• F/MLVSS, lb/lb	0.6	--	--	≤1.0	--
• SRT, days	2-3	--	--	≥1.0	--
• Volumetric loading, lb. BOD/100 cft.	100	--	--	≤150	--
STACKED RECTANGULAR SECONDARY CLARIFIERS					
• Overflow rate, gpd/sf	600-800	--	--	--	≤1,200
• Solids loading rate, lb/sf/day	≤20	--	--	≤30	--
GRAVITY THICKENERS					
• Solids loading rate, lb/sft/day	20	25	30	30	--
• Hydraulic loading, gpd/sft.	600	600	600	600	--
WASTE ACTIVATED SLUDGE CENTRIFUGES					
• Feed solids, % TSS	0.75	0.75	0.75	0.75	--
• Unit capacity, gpm	400	--	--	<800	--
ANAEROBIC DIGESTION					
• Detention time, days	20	≥15	≥15	≥15	--
• Volumetric loading, lb. VSS/1,000 cft.	100	≤150	≤150	≤150	--

for predicting effluent quality over a range of flows and loads, and plant operating conditions. As the pilot plant operation progresses, the methodology used to predict primary and secondary effluent quality as presented in this report may be re-evaluated and modified.

Primary Effluent Quality

Primary and chemically enhanced primary treatment removals for BOD and TSS were based on an evaluation of Deer Island pilot plant data available through May 1994. Data were reduced to develop relationships between overflow rate versus pollutant removal. Conventional (non-chemical) primary removals were compared to projected removals for primary treatment from the STFP. For CEPT, comparisons were made to projections documented by MIT in the July 1993 "Investigation of Chemically Enhanced Primary Treatment at MWRA and Determination of Its Impact on Secondary Wastewater Treatment Process." The performance relationships used are shown as Figure 20-3 and Table 20-12.

Secondary Effluent Quality

Estimates of secondary treatment performance were based on a review of results from the 1989 Deer Island trailer pilot plant plus a literature review of operational results from several full-scale operational pure oxygen activated sludge facilities. Based on this review, secondary effluent TSS concentrations were conservatively estimated as a function of clarifier overflow rate using the following equation:

$$TSS\ (mg/l) = 0.03 * \text{overflow rate}$$

This approach results in a secondary effluent TSS concentration of 18 mg/l at a final clarifier overflow rate of 600 gpd/sf and 36 mg/l at 1,200 gpd/sf.

Secondary effluent BOD_5 concentrations were estimated for both the soluble and particulate fractions. The soluble fraction was conservatively estimated as a function of the F/MLVSS

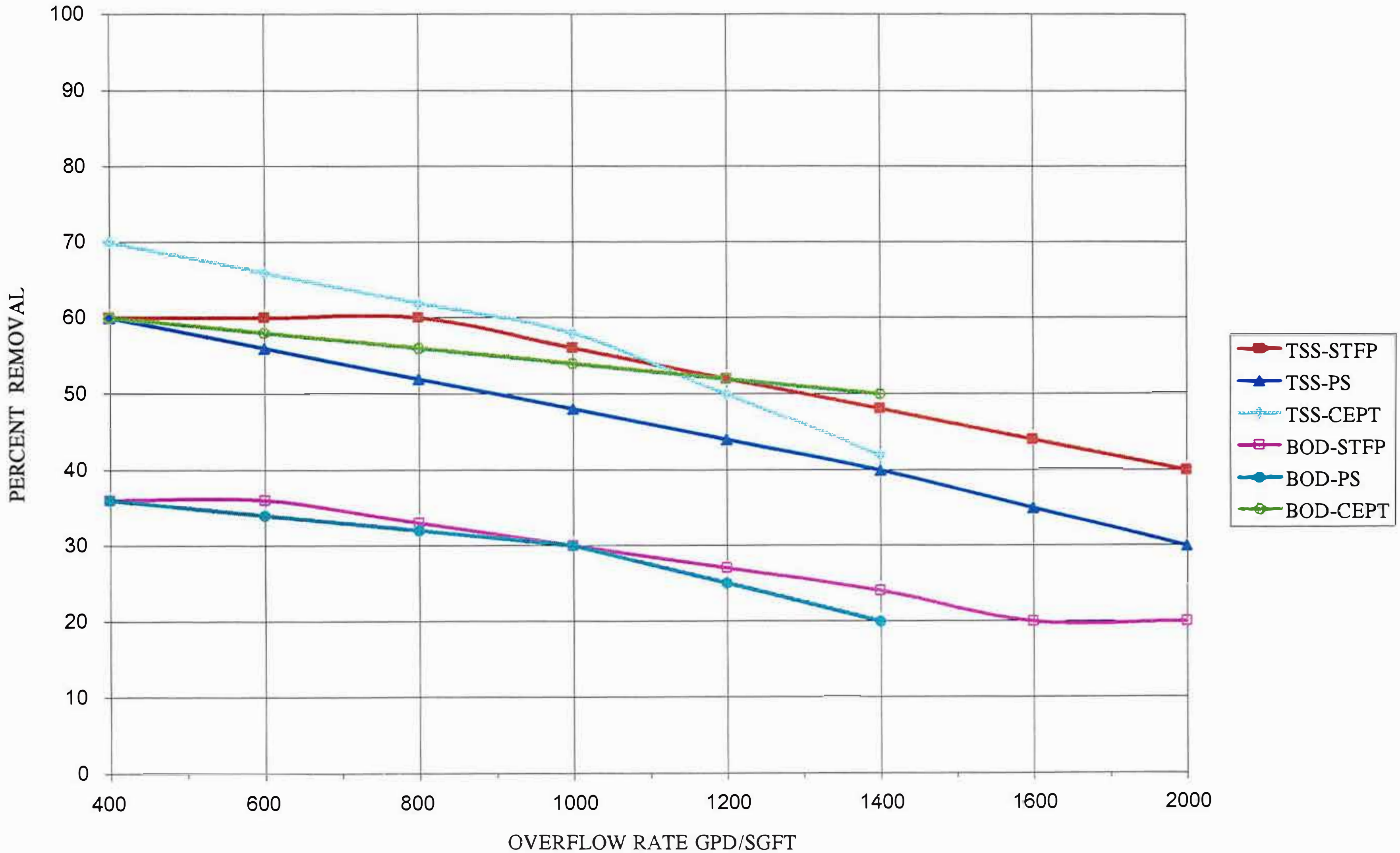

FIGURE 20-3. PRIMARY TREATMENT PERFORMANCE CURVES

TABLE 20-12. PRIMARY TREATMENT PERFORMANCE

Overflow Rate (gpd/sf)	TSS Removal (%)			BOD_5 Removal (%)		
	STFP	Pilot Plant	CEPT Pilot Plant	STFP	Pilot Plant	CEPT Pilot Plant
400	60	60	70	36	36	60
600	60	56	66	36	34	58
800	60	52	62	33	32	56
1,000	56	48	58	30	30	54
1,200	52	44	50	27	25	52
1,400	48	40	42	24	20	50
1,600	44	35	-	20	-	-
2,000	40	30	-	20	-	-

Pilot plant removals are based on a review of November, 1993 to March, 1994 operating records.

ratio in the secondary reactors. The particulate BOD fraction was estimated as a fraction of the effluent TSS concentration. The following equation was applied:

$$BOD_5 = 10.0 * F/MLVSS + 0.6 * TSS$$

The final effluent carbonaceous BOD (CBOD) concentration was estimated as $BOD_5 \div 1.2$.

OPERATIONS AND MAINTENANCE CONSIDERATIONS

Impacts on operations and maintenance must be considered during the reassessment of secondary treatment requirements. The following were considered while conducting secondary treatment strategy evaluations:

- Effluent quality
- Unit process loadings
- Number of standby units
- Feasibility of starting/stopping processes and adding/removing tankage in response to wet weather events

Effluent quality and unit process loading criteria were discussed previously in this chapter.

The number of standby units assumed in evaluating secondary treatment strategies was the same as originally determined in the STFP and included in the project's design to date. If reductions in the number of process units were proposed, these reductions were based on reduced treatment requirements (e.g., lower flows and loads or reduced secondary treatment capacity) and not on reduced stand-by capacity.

In order to operate efficiently and effectively, biological treatment processes require time to acclimate; rapidly changing conditions contribute to process upsets. In addition, process equipment generally requires less maintenance when operated in a continuous manner with regular rotation to equalize wear. Equipment that is started and stopped in response to wet weather events often requires extra maintenance for post-storm clean-up and for exercising the equipment during dry periods. While these considerations played a limited role in evaluating secondary treatment strategy alternatives, they will be increasingly important as the recommended alternative is developed further by the DP-29 study and during design.

PRELIMINARY SITE LAYOUTS

As stated in Chapter Nineteen, an objective of the secondary treatment strategies task was to reserve site space for future treatment needs. This objective was addressed by developing preliminary site layouts for the secondary treatment alternatives. These layouts were developed from the CADD Deer Island site plan available through the Lead Design Engineer (LDE) for the Boston Harbor Project.

ESTIMATED SLUDGE PRODUCTION

Both the primary and secondary treatment processes generate residuals which require subsequent processing to remove excess water. Primary sludge will be gravity thickened and waste activated (secondary) sludge will be centrifuge thickened. Both thickened sludge streams will undergo anaerobic digestion prior to further processing at the Fore River shipyard sludge pelletizing plant.

The various secondary treatment strategy alternatives, as well as changes in flows and loads among flow and load categories (e.g., future planned conditions versus strategy M2 conditions), impact the quantity and quality of residuals generated. Sludge quantities were based on influent loadings, treatment efficiencies, and biological solids production rates. The quantities computed were used to size residuals processes (e.g., to determine the number of centrifuges or anaerobic digesters required) for each of the secondary treatment strategy alternatives, and to compute O&M cost savings for residuals processing at Fore River.

POTENTIAL COST SAVINGS

Potential cost savings were computed in terms of capital and O&M costs. Alternatives were compared based on net present value, in accordance with the Authority's Life Cycle Cost Analysis (LCCA) policy. Capital costs, which include a construction contingency and an allowance for engineering and construction management costs, were obtained from the Construction Manager's (CM) Construction Package Estimate dated August, 1994 for the Boston Harbor Project. O&M costs were derived from the MWRA Current Expense Budget (CEB) projection for 1994 to 2000 for Deer Island Treatment Plant and the Fore River Staging Area residuals facilities. Ferric chloride costs for the CEPT alternatives were based on a unit price of $260 per ton, and polymer costs on $3.00 per pound. Costs for sludge handling at the Fore River Staging Area were based on a unit price of $650 per dry ton.

PART V
CHAPTER TWENTY-ONE
EVALUATION OF ALTERNATIVES

This chapter presents the results of detailed evaluations of secondary treatment alternatives that were conducted in accordance with the planning approach presented in Chapter Twenty. The following alternatives were considered and compared to the currently recommended four battery secondary treatment facilities:

- Two battery secondary
- Chemically enhanced primary treatment (CEPT) plus two battery secondary
- Two and two-thirds battery secondary
- Three battery secondary

These alternatives were sized and evaluated based on flows and loads corresponding to future planned, CSO Strategy M, CSO Strategy M2 (draft recommended CSO control plan with I/I and interceptor improvements incorporated), and CSO Strategy M2 plus 10 percent growth conditions. As discussed in Chapter Twenty, the final recommended CSO control plan (Strategy M3) is similar to the Strategy M2 plan except that it provides less off-line storage. Flows to Deer Island would therefore be slightly lower under Strategy M3, and were not developed. Table 21-1 correlates alternatives that were sized and evaluated versus each flow and load category. Site layouts for each of the above alternatives plus the 4-battery secondary base case as recommended in the 1988 Secondary Treatment Facilities Plan (STFP) are shown on Figures 21-1 to 21-5.

BASIC DESIGN DATA SHEETS

The estimated performance of liquid treatment facilities and the number and performance of residuals processing facilities was assessed by performing computations, as shown on the Basic Design Data Sheets in Appendices O, P, and Q of this report. These data sheets present the following for the unit processes that comprise each alternative:

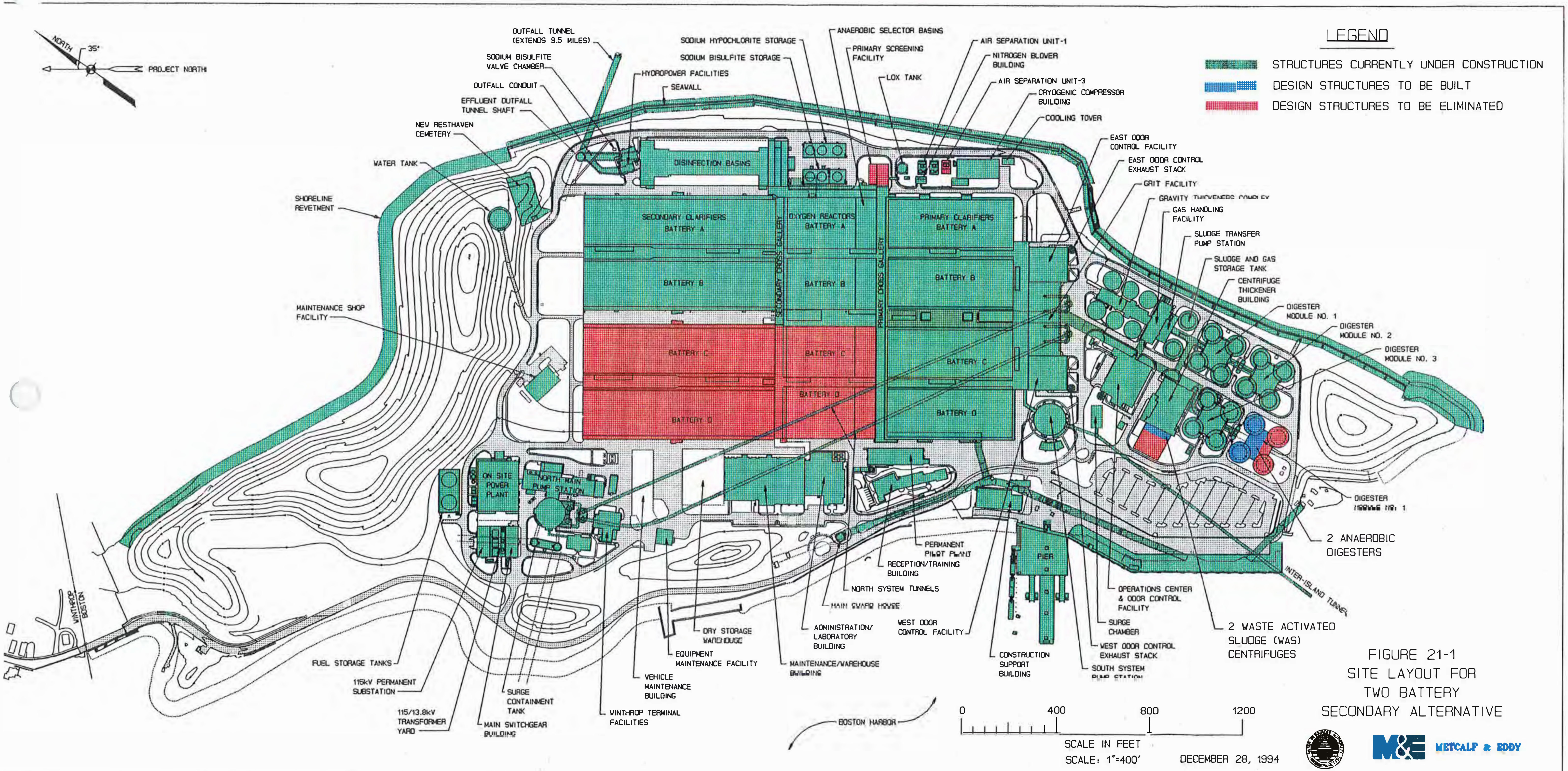

FIGURE 21-1
SITE LAYOUT FOR
TWO BATTERY
SECONDARY ALTERNATIVE

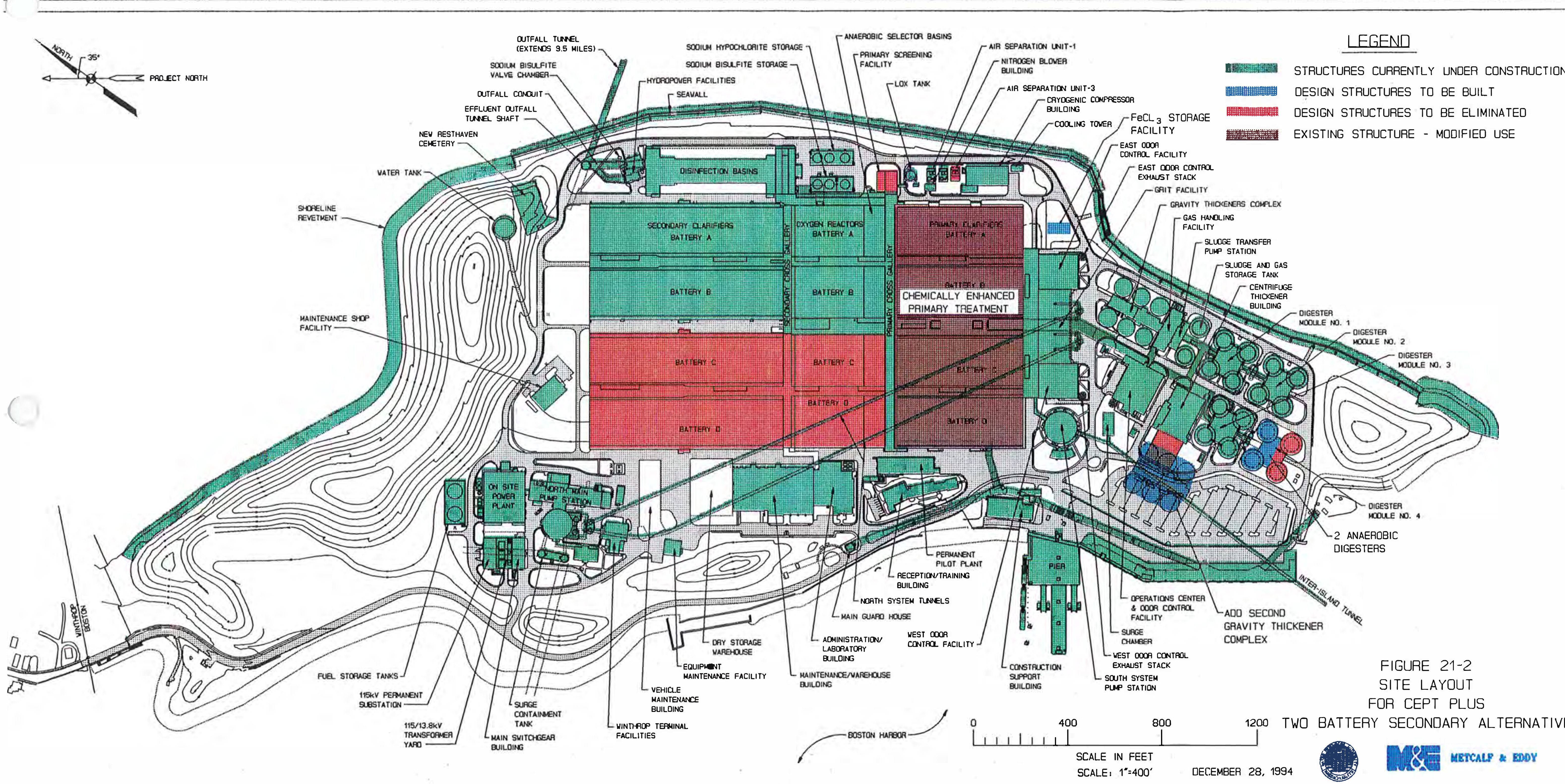

FIGURE 21-2
SITE LAYOUT
FOR CEPT PLUS
TWO BATTERY SECONDARY ALTERNATIVE

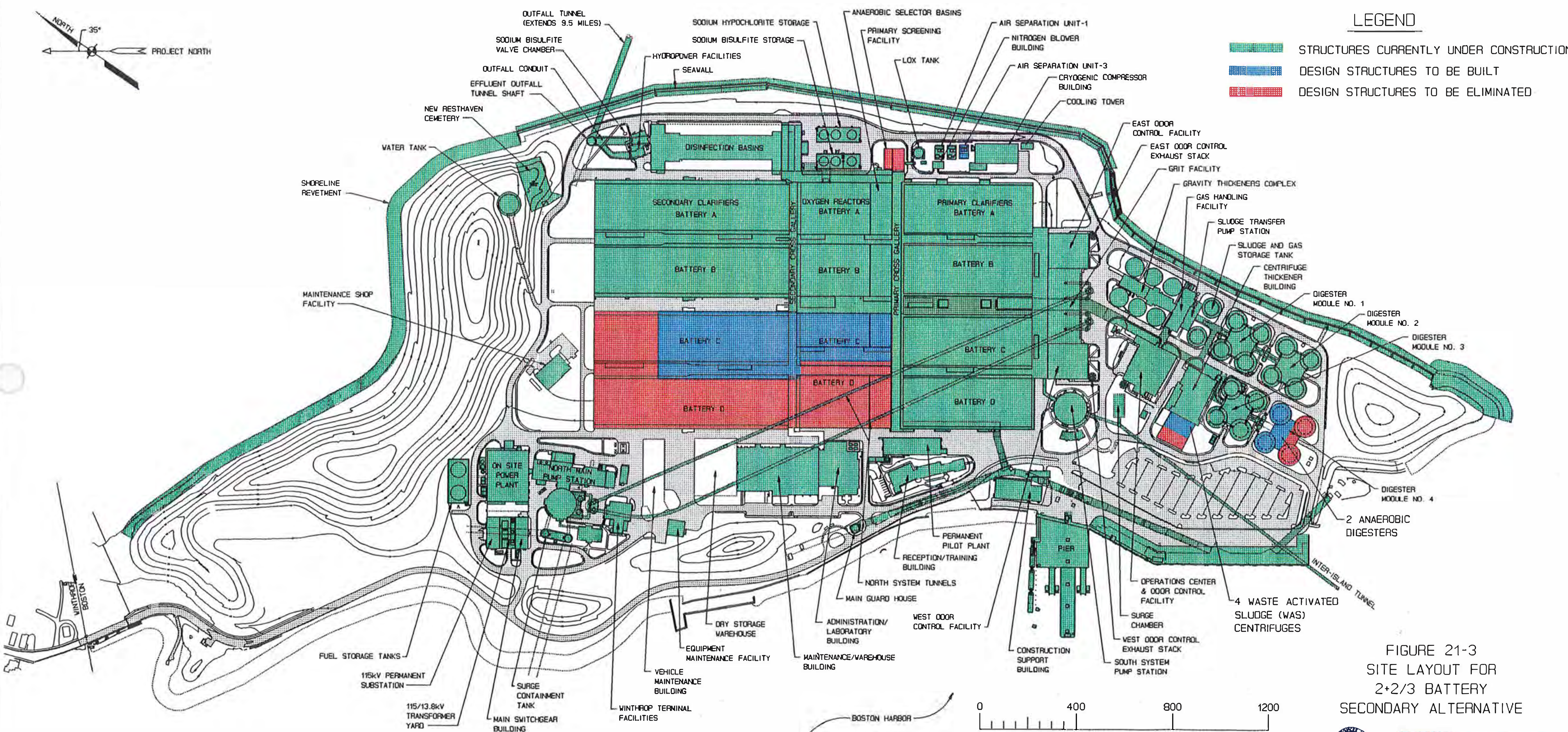

FIGURE 21-3
SITE LAYOUT FOR
2+2/3 BATTERY
SECONDARY ALTERNATIVE

DECEMBER 28, 1994

METCALF & EDDY

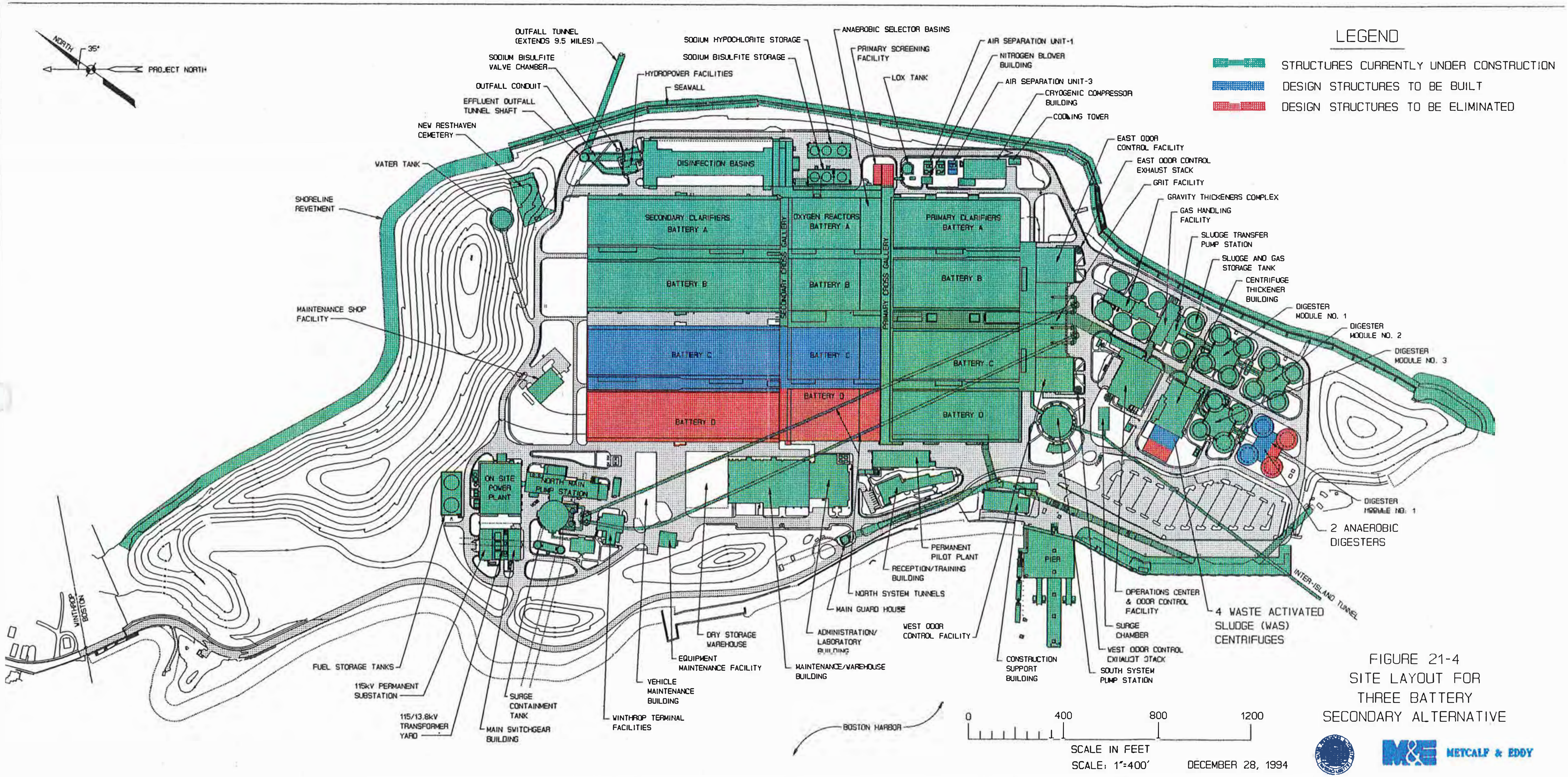

FIGURE 21-4
SITE LAYOUT FOR
THREE BATTERY
SECONDARY ALTERNATIVE

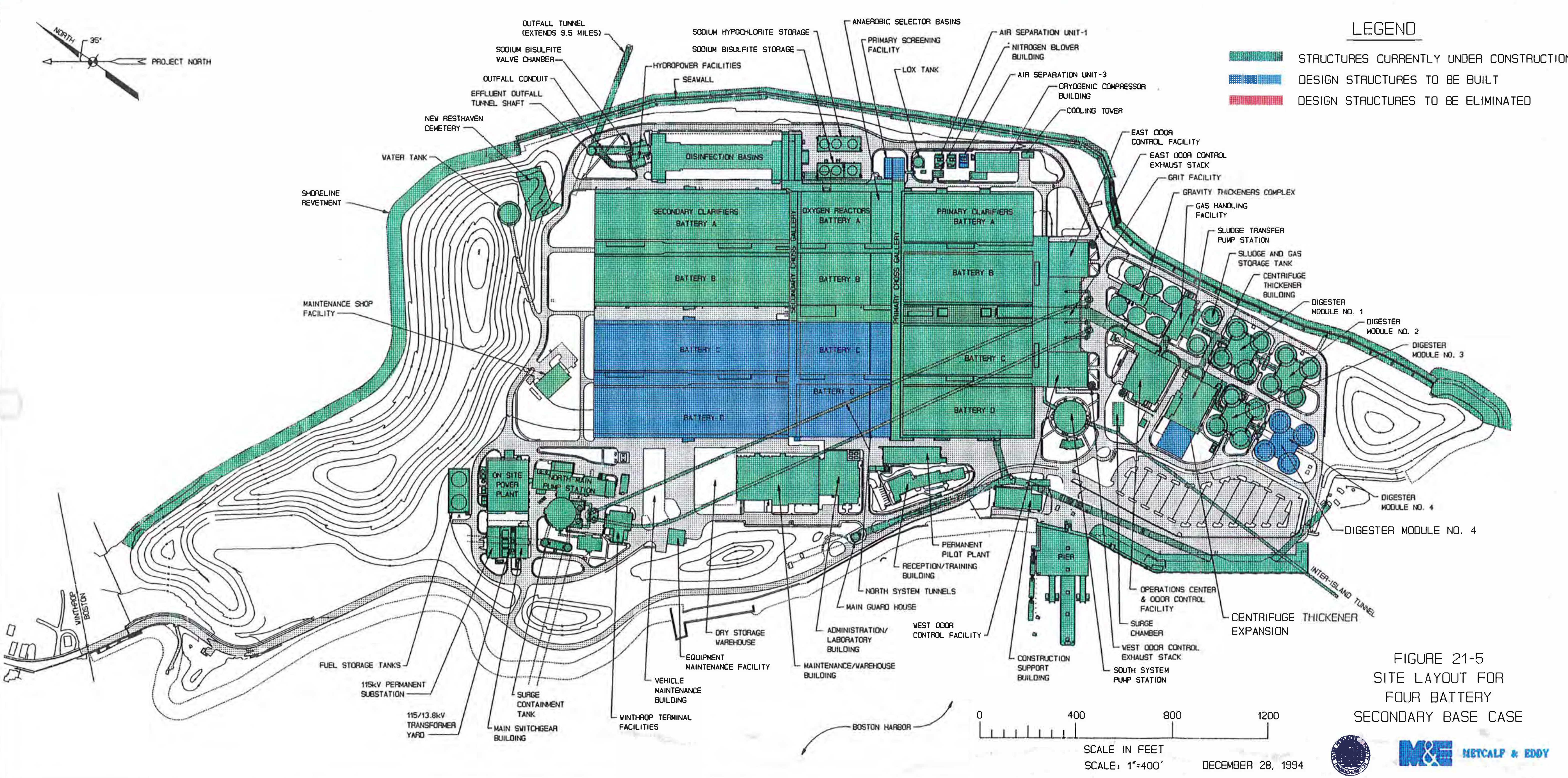

FIGURE 21-5
SITE LAYOUT FOR
FOUR BATTERY
SECONDARY BASE CASE

TABLE 21-1. ALTERNATIVES EVALUATED VERSUS FLOW AND LOAD CATEGORIES

Alternative	Future Planned Conditions	CSO Strategy M	CSO Strategy M2	CSO Strategy M2 Plus 10% Growth
2-battery secondary	X	X	X	
CEPT plus 2-battery secondary	X	X	X	
2 2/3-battery secondary	X	X	X	
3-battery secondary	X	X	X	X
4-battery secondary (base case)	X	X	X	

- Influent flows and pollutant loadings
- Plant recycle loadings
- Number and size of liquid and solids unit process tankage/equipment
- Unit process loadings and operating conditions that result from process sizes and influent flows and loads
- Effluent quality
- Sludge production

Computations are included for annual average, maximum 30-day, maximum 7-day, maximum day, and maximum hour flows and pollutant loadings as applicable.

FUTURE PLANNED CONDITIONS

A full set of alternatives was sized and evaluated for future planned condition flows and pollutant loads. As stated in Chapter Twenty, future planned conditions are defined as the conditions expected in 1997, once full primary treatment capacity is available at Deer Island and after initial CSO controls (SOPs) are in place. Future planned conditions do not include the effects of longer-term system changes, such as water conservation, population decreases, I/I reduction, or the implementation of long-term CSO controls. As indicated by a comparison of Table 20-7 (Future Planned Conditions Flows and Loads) to Table 20-9 (CSO Strategy M2 Flows and Loads), future planned condition flows are slightly higher than CSO Strategy M2 flows, while pollutant loads are slightly higher under CSO Strategy M2 conditions. Evaluation of alternatives under future planned conditions was important both to serve as a baseline for comparing the effects of flow and load categories (e.g., CSO Strategies M and M2) on the alternatives and to determine alternative performance during initial operating years, prior to the effects of longer-term system changes.

Hydraulic Capacity

The four secondary treatment alternatives evaluated have lower hydraulic capacities than the currently recommended four battery secondary treatment facility. Under future planned conditions, there would be differing numbers of occurrences and durations when each alternative's hydraulic capacity would be exceeded. This information is presented in Table 21-2.

When an alternative's hydraulic capacity is exceeded, the excess flow (above the alternative's hydraulic capacity) would receive primary treatment and be blended with secondary effluent. Table 21-2 indicates the relative infrequency of capacity exceedances among the alternatives, and the extreme infrequency of exceeding the hydraulic capacity of a four battery secondary facility under future planned conditions.

Unit Process Requirements

A summary of unit process requirements for liquid and residuals unit processes required to treat future planned condition flows and loads is presented in Table 21-3. More detailed information on these unit process requirements is provided in the Basic Design Data Sheets

TABLE 21-2. FREQUENCY AND DURATION OF CAPACITY EXCEEDANCE FOR SECONDARY TREATMENT ALTERNATIVES UNDER FUTURE PLANNED CONDITIONS

Parameter	4-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary	2-Battery Secondary	CEPT plus 2-Battery Secondary
• Hydraulic Capacity, mgd	1,080	810	720	540	540
• Number of Exceedances					
- in a Typical Year	2	14	24	41	41
- in a Critical 30-day Period (Spring, 1993)	2	10	8	4	4
• Hours of Exceedance					
- in a Typical Year	3	79	123	312	312
- in a Critical 30-day Period (Spring, 1993)	12	125	266	636	636
• Percent of Time Exceeded					
- in a Typical Year	0.03	0.90	1.40	3.55	3.55

in Appendices O, P, and Q. Table 21-3 indicates equipment/tankage quantities for the pure oxygen activated sludge system, stacked rectangular secondary clarifiers, gravity thickeners, WAS centrifuge system, and the anaerobic digestion process for each of the secondary treatment alternatives under future planned conditions. Reductions in equipment/tankage versus the 4-battery secondary base case form the basis for capital and O&M cost savings presented later in this chapter.

Effluent Quality

A conservative prediction of effluent concentrations of BOD_5, CBOD, and TSS for the secondary treatment alternatives under future planned conditions is presented in Table 21-4. These values represent blended effluent concentrations where the secondary treatment capacity of an alternative exceeds the flow condition. For example, the 43 mg/l BOD_5 concentration for the 2-battery secondary alternative (secondary treatment capacity of 540 mgd) for the maximum 30-day (690 mgd) flow condition represents blended primary and

TABLE 21-3. TREATMENT FACILITY SUMMARY FOR SECONDARY TREATMENT ALTERNATIVES UNDER FUTURE PLANNED CONDITIONS

Process/Features	Original 4-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary	2-Battery Secondary	CEPT Plus 2-Battery Secondary
• Pure Oxygen Activated Sludge System					
- Number of Anaerobic Selector/Aeration Tanks	12	9	8	6	6
- Number in Service	12	9	8	6	6
• Stacked Rectangular Secondary Clarifiers					
- Number of Clarifiers	72	54	48	36	36
- Number in Service	64	48	42	32	32
• Gravity Thickeners					
- Number of Units	6	6	6	6	12
- Number in Service	5	5	5	5	11
• WAS Centrifuge System					
- Number of Units	20	16	16	14	12
- Number in Service(1)	16	14	14	11	5
• Anaerobic Digestion					
- Number of Primary Digesters	14	12	12	12	12
- Number of Secondary Digesters	2	2	2	2	2
- Number of Sludge Storage Tanks	2	2	2	2	2

1. Number of centrifuges in service is the highest number in service required under the various flow and loading conditions (annual average, 30-day maximum, 7-day maximum, maximum day)

TABLE 21-4. EFFLUENT QUALITY FOR SECONDARY TREATMENT ALTERNATIVES UNDER FUTURE PLANNED CONDITIONS

	Effluent Standard			4 - Battery Secondary			3 - Battery Secondary			2 2/3 - Battery Secondary			2 - Battery Secondary			CEPT Plus 2 - Battery Secondary		
Flow Condition	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l
Annual Average, 361 mgd	-	-	-	12	10	12	17	14	16	17	14	18	22	18	24	21	18	24
Maximum 30-Day, 690 mgd	30	25	30	21	18	23	25	21	31*	30	25	36*	**43**	**36**	**45**	**35**	**29**	**44**
Maximum 7-Day, 851 mgd	45	40	45	26	22	29	33	27	38	38	32	43	**50**	**41**	**53**	37	31	**49**

Notes:

1. Effluent standard violations are shown in **BOLD FACE TYPE** and are shaded.
2. Effluent quality values are conservative estimates that can be refined after pilot plant operations increase available data. Values presented are ± 2 to 5 mg/l.

* These and other effluent concentrations in this table were based on no use of clarification aids. With provision of a polymer system (as recommended by DP-29) effluent TSS concentrations of less than 30 mg/l would be expected, resulting in no permit violations.

secondary effluent. Table 21-4 also presents effluent standards and shows potential standard violations in bold face type and shaded. Four violations were predicted for the CEPT plus 2-battery alternative, with one violation in excess of 10 mg/l. For the 2-battery alternative, violations of effluent standards were predicted under all flow conditions and for all parameters (BOD_5, CBOD, and TSS).

Residuals Quantities

Predicted residuals quantities for the secondary treatment alternatives under future planned conditions are presented in Table 21-5. The table indicates that primary sludge production is constant for all alternatives except for CEPT plus 2-battery secondary, which would produce 30 to 40 percent more primary sludge due to chemical addition.

Two factors impact waste activated sludge (WAS) production:

- Sludge yield, in terms of pounds of TSS produced per pound of BOD applied
- Effluent TSS concentration

For the non-CEPT alternatives, as the number of secondary batteries decreases, the sludge yield would increase (increasing WAS production) and the effluent TSS concentration would increase (decreasing WAS production). These opposing factors result in the comparative waste activated sludge loads in Table 21-5. Waste activated sludge production for the CEPT plus 2-battery alternative is lower than for the non-CEPT alternatives due to higher BOD removals in the chemical primary process.

There is less difference among the alternatives in terms of digested sludge quantities versus waste activated sludge quantities. Alternatives with more secondary batteries generally result

TABLE 21-5. RESIDUALS QUANTITIES FOR SECONDARY TREATMENT ALTERNATIVES UNDER FUTURE PLANNED CONDITIONS

Residual Process Stream/Flow and Pollutant Loading Condition	4-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary	2-Battery Secondary	CEPT Plus 2-Battery Secondary
• Primary Sludge, lb/day					
- Annual Average	354,200	354,200	354,200	354,200	463,400
- Maximum 30-Day	373,800	373,800	373,800	373,800	481,000
- Maximum 7-Day	417,100	417,100	417,100	417,100	578,400
- Maximum Day	435,700	435,700	435,700	435,700	591,300
• Waste Activated Sludge, lb/day					
- Annual Average	289,100	313,121	307,000	325,004	160,600
- Maximum 30-Day	328,800	378,900	378,900	296,600	124,700
- Maximum 7-Day	451,500	486,300	432,200	324,200	149,900
- Maximum Day	634,500	566,300	503,400	377,600	151,400
• Digested Sludge, lb/day					
- Annual Average	333,000	345,100	342,000	351,085	325,900
- Maximum 30-Day	363,300	388,600	388,600	347,100	317,200
- Maximum 7-Day	448,100	465,600	438,400	383,900	381,400
- Maximum Day	550,100	515,800	484,100	420,600	389,000

in more digested sludge and the CEPT plus 2-battery secondary alternative produces the least.

Cost

The capital, annual O&M, and total present worth costs for the secondary treatment alternatives under future planned conditions are presented in Table 21-6. This table also presents potential savings versus the 4-battery secondary alternative for each of the other alternatives. The 2-battery secondary alternative would provide the greatest capital, annual O&M, and present worth cost savings. The CEPT plus 2-battery secondary alternative has the next highest capital and present worth savings but has the lowest annual O&M cost savings primarily due to chemical costs. As expected, the 2 2/3- and 3-battery secondary

TABLE 21-6. COSTS AND POTENTIAL SAVINGS FOR SECONDARY TREATMENT ALTERNATIVES UNDER FUTURE PLANNED CONDITIONS

Cost ($ million)	4-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary	2-Battery Secondary	CEPT Plus 2-Battery Secondary
• Capital Cost	2,500	2,380	2,353	2,242	2,252
- Savings vs. 4-Battery Secondary	--	120	147	258	248
• Annual O&M Cost	73.9	69.6	69.0	68.6	71.2
- Savings vs. 4-Battery Secondary	--	4.3	4.9	5.3	2.7
• Present Worth Cost	3,506	3,327	3,292	3,176	3,221
- Savings vs. 4-Battery Secondary	--	179	214	330	285

alternatives would provide lower cost savings than the 2-battery alternatives. The 2-battery alternatives, however, do not provide reliable secondary effluent quality.

CSO STRATEGY M

A full set of alternatives was sized and evaluated for treatment plant flows and loads corresponding to CSO Strategy M which, as described in Chapter Twenty, reflects a higher level of CSO storage than the draft or final recommended CSO control plan, (Strategies M2 and M3, respectively). This higher level of CSO storage would result in slightly higher flows and loads to Deer Island compared to the recommended CSO control plan. In addition, CSO Strategy M does not include the I/I reductions included in Part Three of the SMP or the recommended interceptor relief projects in Part Four. The CSO Strategy M flows and pollutant loadings therefore provide for a direct comparison to future planned condition flows and loads, since the only difference between these flow and load categories is the inclusion of CSO controls in Strategy M. As discussed in Chapter Twenty, there are only minor differences between future planned condition versus Strategy M flows and loads, and only minor differences were noted in secondary treatment alternatives developed for future planned versus Strategy M conditions. This indicates that changes in the recommended CSO control plan could be made without significantly impacting recommendations for secondary treatment facilities.

Hydraulic Capacity

The frequency of occurrences and durations for the exceedance of each alternative's hydraulic capacity under CSO Strategy M is presented in Table 21-7. These results are similar to those presented in Table 21-2 for future planned condition flows, and indicate the relative infrequence of capacity exceedances among the alternatives.

Unit Process Requirements

A summary of unit process requirements for liquid and residuals unit processes required to treat CSO Strategy M flows and loads is presented in Table 21-8, and with the exception of the number of WAS centrifuges required in service, are the same as presented in Table 21-3 for future planned conditions. More detailed information on these unit process requirements is provided in the Basic Design Data Sheets in Appendices O, P, and Q. Reductions in equipment/tankage versus the 4-battery secondary base case, as presented in Table 21-8, form the basis for capital and O&M cost savings presented later in this chapter.

Effluent Quality

Predicted effluent concentrations of BOD_5, CBOD, and TSS for the secondary treatment alternatives under CSO Strategy M conditions are presented in Table 21-9. The table also presents effluent standards and shows standard violations in bold face type and shaded. Results are similar to those presented in Table 21-4 for future planned conditions.
Four violations are predicted for the CEPT plus 2-battery alternative; one violation is in excess of 10 mg/l.

TABLE 21-7. FREQUENCY AND DURATION OF CAPACITY EXCEEDANCE FOR SECONDARY TREATMENT ALTERNATIVES UNDER CSO STRATEGY M CONDITIONS

Parameter	4-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary	2-Battery Secondary	CEPT Plus 2-Battery Secondary
• Hydraulic Capacity, mgd	1,080	810	720	540	540
• Number of Exceedances					
- in a Typical Year	3	13	22	39	39
- in a Critical 30-day Period (Spring, 1993)	2	9	9	4	4
• Hours of Exceedance					
- in a Typical Year	8	83	130	292	292
- in a Critical 30-day Period (Spring, 1993)	15	142	267	646	646
• Percent of Time Exceeded					
- in a Typical Year	0.09	0.94	1.48	3.32	3.32

For the 2-battery alternative, violations were predicted under all flow conditions and for all parameters (BOD_5, CBOD, and TSS).

Residuals Quantities

Predicted residuals quantities for the secondary treatment alternatives under CSO Strategy M are presented in Table 21-10. These results are consistent with those presented in Table 21-5 for future planned conditions. Primary sludge production is constant for all alternatives except for CEPT plus 2-battery, which would produce 18 to 36 percent more primary sludge due to chemical addition. Waste activated sludge production is generally slightly higher for CSO Strategy M versus future planned conditions for annual average and maximum 30-day

TABLE 21-8 TREATMENT FACILITY SUMMARY FOR SECONDARY TREATMENT ALTERNATIVES UNDER CSO STRATEGY M CONDITIONS

Process/Features	Original 4-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary	2-Battery Secondary	CEPT Plus 2-Battery Secondary
• Pure Oxygen Activated Sludge System					
- Number of Anaerobic Selector/Aeration Tanks	12	9	8	6	6
- Number in Service	12	9	8	6	6
• Stacked Rectangular Secondary Clarifiers					
- Number of Clarifiers	72	54	48	36	36
- Number in Service	64	48	42	32	32
• Gravity Thickeners					
- Number of Units	6	6	6	6	12
- Number in Service	5	5	5	5	11
• WAS Centrifuge System					
- Number of Units	20	16	16	14	12
- Number in Service(1)	16	14	14	10	5
• Anaerobic Digestion					
- Number of Primary Digesters	14	12	12	12	12
- Number of Secondary Digesters	2	2	2	2	2
- Number of Sludge Storage Tanks	2	2	2	2	2

1. Number of centrifuges in service is the highest number in service required under the various flow and loading conditions (annual average, 30-day maximum, 7-day maximum, maximum day)

TABLE 21-9. EFFLUENT QUALITY FOR SECONDARY TREATMENT ALTERNATIVES UNDER CSO STRATEGY M CONDITIONS

	Effluent Standard			4 - Battery Secondary			3 - Battery Secondary			2 2/3 - Battery Secondary			2 - Battery Secondary			CEPT Plus 2 - Battery Secondary		
Flow Condition	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l
Annual Average, 363 mgd	-	-	-	12	10	12	16	13	16	17	14	18	23	19	24	21	17	24
Maximum 30-Day, 697 mgd	30	25	30	21	18	23	26	22	31*	30	25	36*	**43**	**36**	**45**	**35**	**29**	**45**
Maximum 7-Day, 867 mgd	45	40	45	26	29	22	33	28	39	39	32	43	**50**	**41**	**53**	37	31	**52**

Note:

1. Effluent standard violations are shown in **BOLD FACE TYPE** and are shaded.

2. Effluent quality values are conservative estimates that can be refined after pilot plant operations increase available data. Values presented are ± 2 to 5 mg/l.

* These and other effluent concentrations in this table were based on no use of clarification aids. With provision of a polymer system (as recommended by DP-29) effluent TSS concentrations of less than 30 mg/l would be expected, resulting in no permit violations.

TABLE 21-10. RESIDUALS QUANTITIES FOR SECONDARY TREATMENT ALTERNATIVES UNDER CSO STRATEGY M CONDITIONS

Residual Process Stream/Flow and Pollutant Loading Condition	4-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary	2-Battery Secondary	CEPT Plus 2-Battery Secondary
• Primary Sludge, lb/day					
- Annual Average	356,300	356,300	356,300	356,300	465,800
- Maximum 30-Day	376,000	376,000	376,000	376,000	442,300
- Maximum 7-Day	417,800	417,800	417,800	417,800	519,600
- Maximum Day	436,800	436,800	436,800	436,800	594,400
• Waste Activated Sludge, lb/day					
- Annual Average	290,900	315,100	309,100	327,300	161,800
- Maximum 30-Day	329,400	379,800	379,800	294,200	96,300
- Maximum 7-Day	451,300	477,100	424,100	318,100	74,300
- Maximum Day	619,500	549,100	488,100	366,100	130,800
• Digested Sludge, lb/day					
- Annual Average	335,000	347,200	344,200	353,300	327,900
- Maximum 30-Day	364,800	390,200	390,200	347,100	282,400
- Maximum 7-Day	448,400	461,400	434,700	381,200	312,200
- Maximum Day	543,200	503,500	477,000	415,500	380,200

flows and loads due to higher BOD loadings. For maximum 7-day and maximum day flows and loads, the effect of higher CSO Strategy M flows and corresponding higher effluent TSS loads results in slightly lower waste activated sludge production versus future planned conditions. These trends are also noted for digested sludge quantities.

Cost

The capital, annual O&M, and total present worth costs for the secondary treatment alternatives under CSO Strategy M conditions are presented in Table 21-11. This table also presents potential savings versus the 4-battery secondary alternative for each of the other alternatives. Due to the fact that the unit process requirements are the same for CSO Strategy M and future planned conditions, and the relatively minor differences in parameters

TABLE 21-11. COSTS AND POTENTIAL SAVINGS FOR SECONDARY TREATMENT ALTERNATIVES UNDER CSO STRATEGY M CONDITIONS

Cost ($ million)	4-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary	2-Battery Secondary	CEPT Plus 2-Battery Secondary
• Capital Cost	2,500	2,380	2,353	2,242	2,252
- Savings vs. 4-Battery Secondary	--	120	147	258	248
• Annual O&M Cost	73.9	69.6	69.0	68.6	71.2
- Savings vs. 4-Battery Secondary	--	4.3	4.9	5.3	2.7
• Present Worth Cost	3,506	3,327	3,292	3,176	3,221
- Savings vs. 4-Battery Secondary	--	179	214	330	285

that impact O&M costs (e.g., flows, pollutant loadings, sludge quantities), the costs and potential savings for alternatives based on CSO Strategy M conditions are the same as for alternatives based on future planned conditions.

CSO STRATEGY M2

A full set of alternatives was sized and evaluated for treatment plant flows and loads corresponding to CSO Strategy M2 (the draft recommended CSO control plan). As described in Chapter Twenty, CSO Strategy M2 flows and loads also incorporate the impact of the I/I reduction included in Part Three of the SMP, and recommended interceptor relief discussed in Part Four. The annual average flow is 8 mgd (approximately 2 percent) lower under CSO Strategy M2 versus future planned conditions, while pollutant loadings are slightly higher. The lower annual average flow is the result of infiltration reductions and higher loads are the result of the capture of additional CSO volume. Under maximum 30-day, maximum 7-day, and maximum day conditions, CSO Strategy M2 flows and loads are slightly higher than future planned condition flows and loads (with the exception of the 30-day maximum flow). As demonstrated by the following discussion, these minor differences in flows and pollutant loads do not significantly impact recommendations for secondary treatment facilities.

Hydraulic Capacity

The frequency of occurrences and durations for the exceedance of each alternative's hydraulic capacity under CSO Strategy M2 is presented in Table 21-12. These results are similar to those presented in Tables 21-2 and 21-7 for future planned condition and CSO Strategy M flows, respectively, and indicate the relative infrequence of capacity exceedances among the alternatives.

Unit Process Requirements

A summary of unit process requirements for liquid and residuals unit processes required to treat CSO Strategy M2 flows and loads is presented in Table 21-13. These requirements are the same as for CSO Strategy M (Table 21-8), and with the exception of the number of WAS centrifuges required in service, are the same as presented in Table 21-3 for future planned conditions. More detailed information on these unit process requirements is provided in the Basic Design Data Sheets in Appendices O, P, and Q. Reductions in equipment/tankage versus the 4-battery secondary base case, as presented in Table 21-13, form the basis for capital and O&M cost savings presented later in this chapter.

Effluent Quality

Predicted effluent concentrations of BOD_5, CBOD, and TSS for the secondary treatment alternatives under CSO Strategy M2 conditions are presented in Table 21-14. The table also presents effluent standards and shows violations in bold face type and shaded. Results are similar to those presented in Tables 21-4 and 21-9 for future planned and CSO Strategy M conditions. Four violations are predicted for the CEPT plus 2-battery alternative; one is in

TABLE 21-12. FREQUENCY AND DURATION OF CAPACITY EXCEEDANCE FOR SECONDARY TREATMENT ALTERNATIVES UNDER CSO STRATEGY M2 CONDITIONS

Parameter	4-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary	2-Battery Secondary	CEPT Plus 2-Battery Secondary
• Hydraulic Capacity, mgd	1,080	810	720	540	540
• Number of Exceedances					
- in a Typical Year	2	15	22	39	39
- in a Critical 30-day Period (Spring, 1993)	2	9	9	4	4
• Hours of Exceedance					
- in a Typical Year	4	79	125	285	285
- in a Critical 30-day Period (Spring, 1993)	14	124	260	638	638
• Percent of Time Exceeded					
- in a Typical Year	0.05	0.90	1.42	3.24	3.24

excess of 10 mg/l. For the 2-battery alternative, violations are predicted under all flow conditions and for all parameters (BOD_5, CBOD, and TSS).

Residuals Quantities

Predicted residuals quantities for the secondary treatment alternatives under CSO Strategy M2 are presented in Table 21-15. These results are consistent with those presented in Tables 21-5 and 21-10 for future planned and CSO Strategy M conditions, respectively.

TABLE 21-13. TREATMENT FACILITY SUMMARY FOR SECONDARY TREATMENT ALTERNATIVES UNDER CSO STRATEGY M2 CONDITIONS

Process/Features	Original 4-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary	2-Battery Secondary	CEPT Plus 2-Battery Secondary
• Pure Oxygen Activated Sludge System					
- Number of Anaerobic Selector/Aeration Tanks	12	9	8	6	6
- Number in Service	12	9	8	6	6
• Stacked Rectangular Secondary Clarifiers					
- Number of Clarifiers	72	54	48	36	36
- Number in Service	64	48	42	32	32
• Gravity Thickeners					
- Number of Units	6	6	6	6	12
- Number in Service	5	5	5	5	11
• WAS Centrifuge System					
- Number of Units	20	16	16	14	12
- Number in Service(1)	16	14	14	10	5
• Anaerobic Digestion					
- Number of Primary Digesters	14	12	12	12	12
- Number of Secondary Digesters	2	2	2	2	2
- Number of Sludge Storage Tanks	2	2	2	2	2

1. Number of centrifuges in service is the highest number in service required under the various flow and loading conditions (annual average, 30-day maximum, 7-day maximum, maximum day)

TABLE 21-14. EFFLUENT QUALITY FOR SECONDARY TREATMENT ALTERNATIVES UNDER CSO STRATEGY M2 CONDITIONS

	Effluent Standard			4 - Battery Secondary			3 - Battery Secondary			2 2/3 - Battery Secondary			2 - Battery Secondary			CEPT Plus 2 - Battery Secondary		
Flow Condition	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l
Annual Average, 353 mgd	-	-	-	12	10	12	16	13	16	17	14	18	22	18	24	21	17	24
Maximum 30-Day, 689 mgd	30	25	30	21	18	23	26	22	31*	30	25	36*	**42**	**35**	**45**	**35**	**29**	**45**
Maximum 7-Day, 854 mgd	45	40	45	26	22	29	33	27	38	38	32	43	**50**	**41**	**53**	37	31	**52**

Note:

1. Effluent standard violations are shown in **BOLD FACE TYPE** and are shaded.
2. Effluent quality values are conservative estimates that can be refined after pilot operations increase available data. Values presented are ± 2 to 5 mg/l.

* These and other effluent concentrations in this table were based on no use of clarification aids. With provision of a polymer system (as recommended by DP-29) effluent TSS concentrations of less than 30 mg/l would be expected, resulting in no permit violations.

TABLE 21-15. RESIDUALS QUANTITIES FOR SECONDARY TREATMENT ALTERNATIVES UNDER CSO STRATEGY M2 CONDITIONS

Residual Process Stream/Flow and Pollutant Loading Condition	4-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary	2-Battery Secondary	CEPT Plus 2-Battery Secondary
• Primary Sludge, lb/day					
- Annual Average	352,900	352,900	352,900	352,900	460,800
- Maximum 30-Day	376,600	376,600	376,600	376,600	484,100
- Maximum 7-Day	419,300	419,300	419,300	419,300	581,300
- Maximum Day	439,500	439,500	439,500	439,500	596,500
• Waste Activated Sludge, lb/day					
- Annual Average	290,100	314,400	308,600	327,100	162,700
- Maximum 30-Day	332,000	382,500	382,500	299,700	99,600
- Maximum 7-Day	453,800	487,000	432,900	324,700	78,100
- Maximum Day	625,800	561,500	499,100	374,300	135,400
• Digested Sludge, lb/day					
- Annual Average	332,800	345,100	342,100	351,400	325,700
- Maximum 30-Day	366,500	391,900	391,900	350,200	306,200
- Maximum 7-Day	450,400	467,200	439,900	385,300	346,700
- Maximum Day	547,800	515,400	483,900	421,000	383,600

Primary sludge production is constant for all alternatives except for CEPT plus 2-battery, which would produce 30 to 40 percent more primary sludge due to chemical addition.

Waste activated sludge production is generally slightly higher for CSO Strategy M2 versus future planned conditions for annual average, maximum 30-day, and maximum 7-day flows and loads due to higher BOD loadings. For maximum day flows and loads, the effect of higher Strategy M2 flows and correspondingly higher effluent TSS loads results in slightly lower waste activated sludge production versus future planned conditions.

In comparing waste activated sludge quantities between CSO Strategy M2 and CSO Strategy M, higher quantities are noted for CSO Strategy M under average annual flow and load conditions due to higher BOD loadings. For maximum 30-day, maximum 7-day, and maximum day conditions, higher quantities are noted for CSO Strategy M2, as Strategy M has higher flows and correspondingly higher effluent TSS loads.

Digested sludge quantities for CSO Strategy M2 are generally slightly higher than for future planned conditions, except for maximum day flows and loads. In comparing CSO Strategy M2 versus CSO Strategy M, the CSO Strategy M2 digested sludge quantities are higher except for annual average flows and loads.

Cost

The capital, annual O&M, and total present worth costs for the secondary treatment alternatives under CSO Strategy M2 conditions are presented in Table 21-16. This table also presents potential savings versus the 4-battery secondary alternative for each of the other alternatives. The costs and potential savings for alternatives based on CSO Strategy M2 conditions are the same as for alternatives based on future planned and CSO Strategy M conditions. This is due to the fact that the unit process requirements are the same for CSO Strategy M2, CSO Strategy M, and future planned conditions, and due to the relatively minor differences among the flow and loading conditions that impact O&M costs.

IMPACTS OF POTENTIAL GROWTH

As described in Chapter Twenty, the impact of an approximate 10 percent increase in service area population (approximately 200,000 persons) on flows and loads for CSO Strategy M2 conditions was assessed. Each flow condition (annual average, maximum 30-day, maximum 7-day, and maximum day) was increased by 30 mgd (150 gpcd), and each BOD and TSS loading condition was increased by 50,000 lb/day (0.25 lb/cap./day). The resulting flow and pollutant loadings were presented in Table 20-10.

TABLE 21-16. COSTS AND POTENTIAL SAVINGS FOR SECONDARY TREATMENT ALTERNATIVES UNDER CSO STRATEGY M2 CONDITIONS

Cost ($ million)	4-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary	2-Battery Secondary	CEPT Plus 2-Battery Secondary
• Capital Cost	2,500	2,380	2,353	2,242	2,252
- Savings vs. 4-Battery Secondary	--	120	147	258	248
• Annual O&M Cost	73.9	69.6	69.0	68.6	71.2
- Savings vs. 4-Battery Secondary	--	4.3	4.9	5.3	2.7
• Present Worth Cost	3,506	3,327	3,292	3,176	3,221
- Savings vs. 4-Battery Secondary	--	179	214	330	285

Only the 3-battery secondary treatment alternative was developed using flows and pollutant loadings that included 10 percent population growth. The 2-battery secondary and CEPT plus 2-battery secondary alternatives were predicted to provide unacceptable effluent quality for flows and loads that did not include 10 percent growth, and performance of the 2 2/3-battery secondary alternative was marginal. If the 2 2/3-battery alternative were implemented and a 10 percent population increase occurred, it might be necessary to construct the additional 1/3-battery to obtain a 3-battery secondary process.

Predicted effluent quality for the 3-battery secondary alternative under CSO Strategy M2 conditions, with and without the impact of a 10 percent population growth, is presented in Table 21-17. Predicted effluent values are the same to 2 mg/l higher when the impact of growth is included.

This analysis indicates that a population increase of up to 10 percent would have a relatively minor impact on the 3-battery secondary treatment alternative.

TABLE 21-17. EFFLUENT QUALITY FOR THE 3-BATTERY SECONDARY TREATMENT ALTERNATIVE WITH AND WITHOUT 10 PERCENT POPULATION GROWTH

	Effluent Standard			CSO Strategy M2 Conditions			CSO Strategy M2 Conditions Plus 10 Percent Growth		
Flow and Pollutant Loading Condition	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l
Annual Average	-	-	-	16	13	16	16	13	17
Maximum 30-Day	30	25	30	26	22	31*	27	22	32*
Maximum 7-Day	45	40	45	33	27	38	35	29	40

Note: 1. Effluent quality values are conservative estimates that can be refined after pilot plant operations increase available data. Values presented are ± 2 to 5 mg/l.

* These and other effluent concentrations in this table were based on no use of clarification aids. With provision of a polymer system (as recommended by DP-29) effluent TSS concentrations of less than 30 mg/l would be expected, resulting in no permit violations.

PART V

CHAPTER TWENTY-TWO

SECONDARY TREATMENT RECOMMENDATIONS

Based on the evaluation of alternatives presented in Chapter Twenty-One, the recommended secondary treatment capacity to be provided would be between 720 to 810 mgd. This corresponds to between 2 2/3- to 3-batteries of secondary treatment facilities based on the present battery configuration. The 2-battery secondary and CEPT plus 2-battery secondary alternatives were eliminated based on the number and magnitude of predicted effluent violations under the maximum 30-day and maximum 7-day (spring, 1993) conditions. A CEPT alternative with 1/2 to 2/3 of secondary battery C capacity may be viable, although it may no longer have a cost advantage over the conventional primary, 2 2/3-battery secondary treatment alternative.

Site layouts for the 2 2/3- and 3-battery alternatives are shown on Figures 22-1 and 22-2. The plant configuration and operation, effluent quality, residuals impacts and potential cost savings associated with the recommended plan are presented for future planned and CSO Strategy M2 conditions in the text that follows. As discussed in Chapter Twenty-One, future planned conditions are representative of plant performance during initial operating years and CSO Strategy M2 conditions are representative of the impact of draft recommended CSO, I/I, and interceptor improvements included in the system master plan. Due to the minor variations among future planned, strategy M, and strategy M2 conditions, strategy M2 conditions are also representative of the final recommended CSO improvements (Strategy M3).

PLANT CONFIGURATION AND OPERATION

The plant configuration for the recommended 2 2/3- to 3-battery secondary treatment capacity range is presented in Table 22-1. The processes and features required are the same for future planned and CSO Strategy M2 flow and pollutant loading conditions.

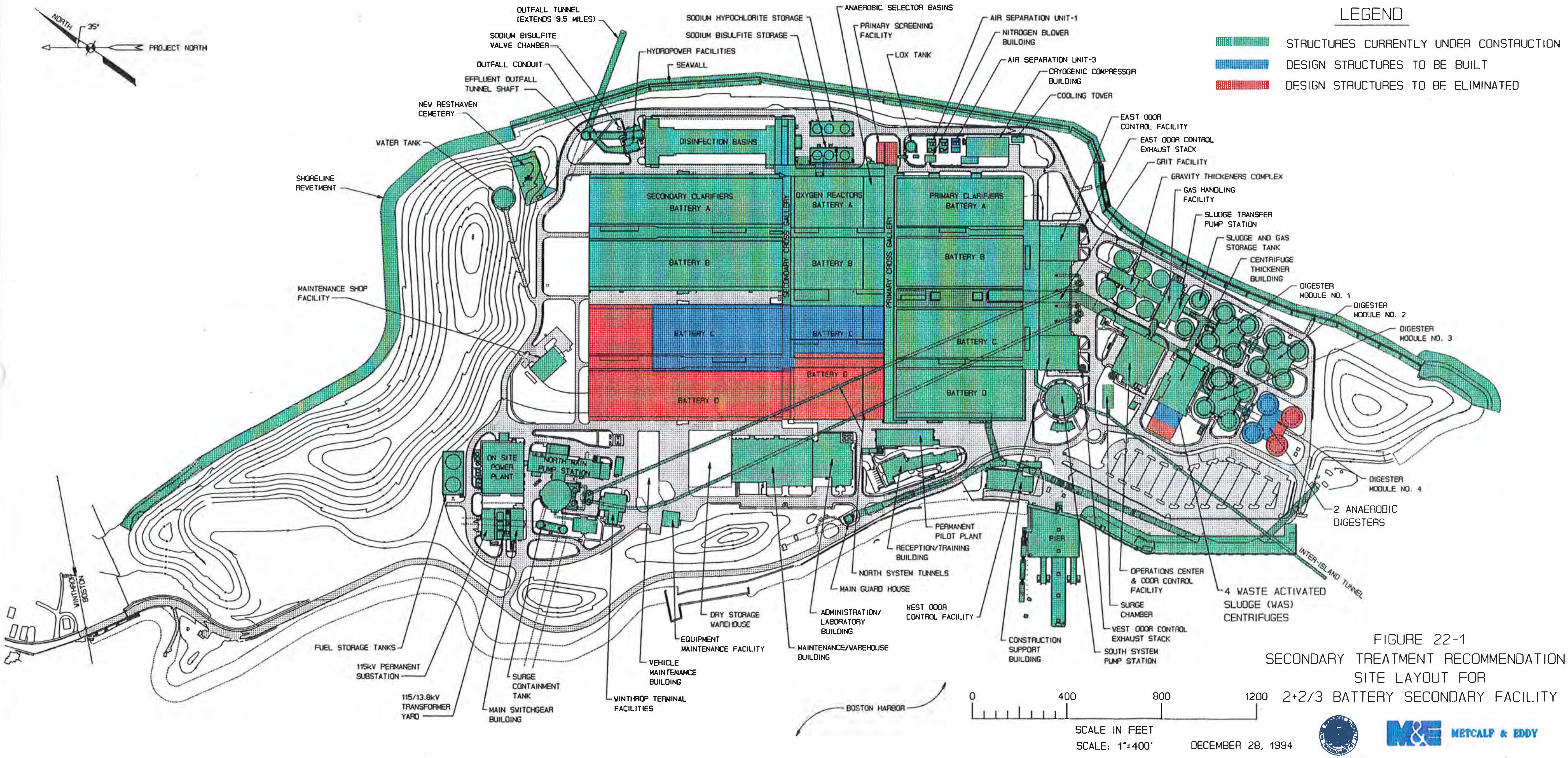

FIGURE 22-1
SECONDARY TREATMENT RECOMMENDATION
SITE LAYOUT FOR
2+2/3 BATTERY SECONDARY FACILITY

DECEMBER 28, 1994

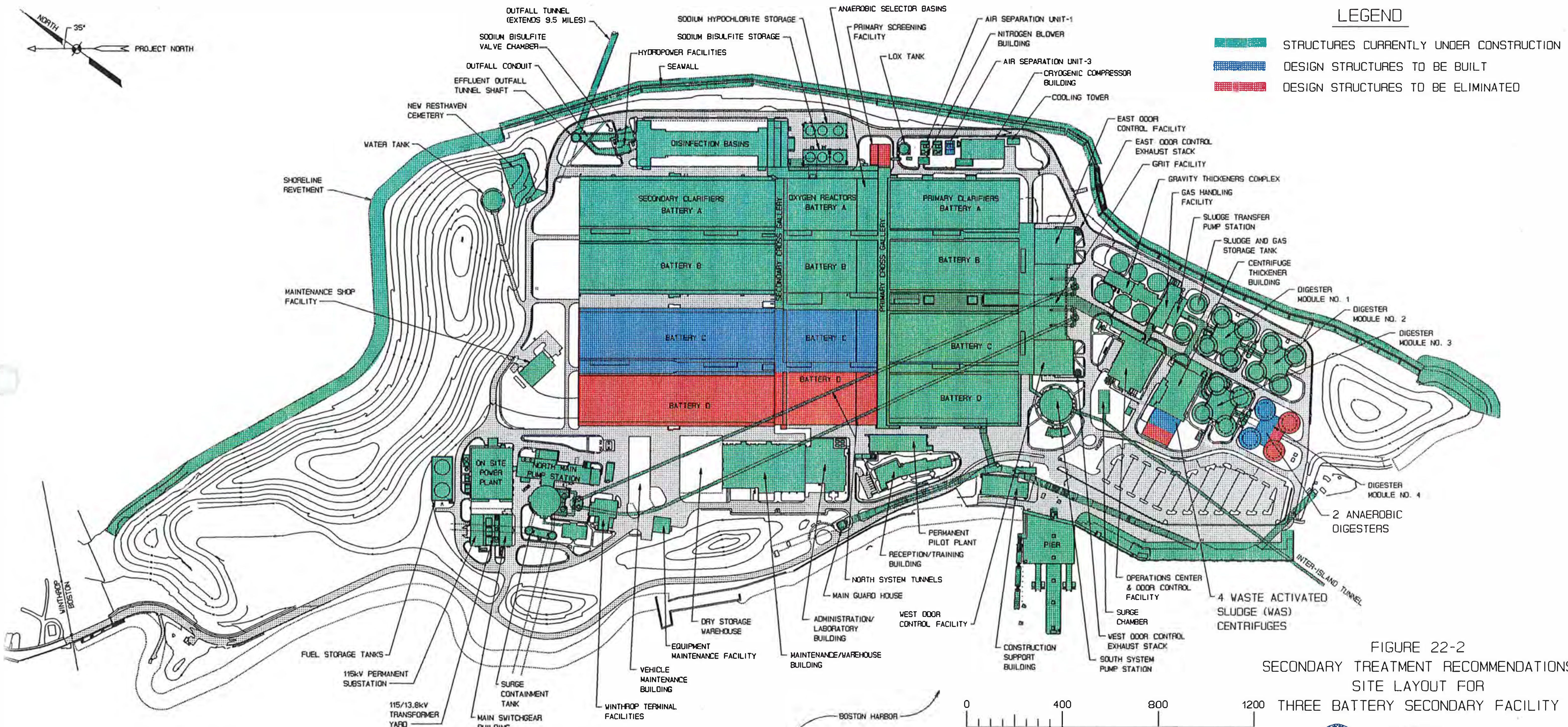

FIGURE 22-2
SECONDARY TREATMENT RECOMMENDATIONS
SITE LAYOUT FOR
THREE BATTERY SECONDARY FACILITY

SCALE: 1"=400'

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M&E METCALF & EDDY

TABLE 22-1. TREATMENT FACILITY SUMMARY FOR RECOMMENDED SECONDARY TREATMENT STRATEGY

Process/Features	3-Battery Secondary	2 2/3-Battery Secondary
• Pure Oxygen Activated Sludge System		
- Number of Anaerobic Selector/Aeration Tanks	9	8
- Number in Service	9	8
• Stacked Rectangular Secondary Clarifiers		
- Number of Clarifiers	54	48
- Number in Service	48	42
• Gravity Thickeners		
- Number of Units	6	6
- Number in Service	5	5
• WAS Centrifuge System		
- Number of Units	16	16
- Number in Service(1)	14	14
• Anaerobic Digestion		
- Number of Primary Digesters	12	12
- Number of Secondary Digesters	2	2
- Number of Sludge Storage Tanks	2	2

1. Number of centrifuges in service is the highest number in service required under the various flow and loading conditions (annual average, 30-day maximum, 7-day maximum, maximum day)

TABLE 22-2. FREQUENCY AND DURATION OF CAPACITY EXCEEDANCE FOR RECOMMENDED SECONDARY TREATMENT STRATEGY

	Future Planned Conditions		CSO Strategy M2 Conditions	
Parameter	3-Battery Secondary	2 2/3-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary
• Hydraulic Capacity, mgd	810	720	810	720
• Number of Exceedances				
- in a Typical Year	14	24	15	22
- in a Critical 30-day Period (Spring, 1993)	10	8	9	9
• Hours of Exceedance				
- in a Typical Year	79	123	79	125
- in a Critical 30-day Period (Spring, 1993)	125	266	124	260
• Percent of Time Exceeded				
- in a Typical Year	0.90	1.40	0.90	1.42

As shown in Table 22-2, the capacity of a 3-battery secondary facility would be exceeded less than 1 percent of the time during a typical year, and the capacity exceedance for a 2 2/3-battery secondary facility would be approximately 1.4 percent of the time during a typical year. These percentages are representative of both future planned and CSO Strategy M2 conditions.

EFFLUENT QUALITY

Predicted effluent quality for the recommended 2 2/3- to 3-battery secondary treatment capacity range is presented in Table 22-3. In comparing predicted effluent quality for a 3-battery secondary facility under future planned versus CSO Strategy M2 conditions, it is noted that effluent concentrations vary by only 0 to 1 mg/l. No differences in effluent quality were predicted for a 2 2/3-battery secondary facility under future planned versus CSO Strategy M2 conditions.

TABLE 22-3. EFFLUENT QUALITY FOR RECOMMENDED SECONDARY TREATMENT STRATEGY

	Effluent Standard			Future Planned Conditions						CSO Strategy M2 Conditions					
				3 - Battery Secondary			2 2/3 - Battery Secondary			3 - Battery Secondary			2 2/3 - Battery Secondary		
Flow and Pollutant Loading Condition	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l	BOD_5, mg/l	CBOD, mg/l	TSS, mg/l
Annual Average	-	-	-	17	14	16	17	14	18	16	13	16	17	14	18
Maximum 30-Day	30	25	30	25	21	31*	30	25	36*	26	22	31*	30	25	36*
Maximum 7-Day	45	40	45	33	27	38	38	32	43	33	27	38	38	32	43

Note: 1. Effluent quality values are conservative estimates that can be refined after pilot plant operations increase available data. Values presented are ± 2 to 5 mg/l.

* These and other effluent concentrations in this table were based on no use of clarification aids. With provision of a polymer system (as recommended by DP-29) effluent TSS concentrations of less than 30 mg/l would be expected, resulting in no permit violations.

RESIDUALS IMPACTS

Predicted primary, waste activated, and digested sludge quantities for the recommended 2 2/3- to 3-battery secondary treatment capacity range are presented in Table 22-4. As shown in this table, there are relatively minor differences between 2 2/3 versus 3 battery alternatives for either future planned or CSO Strategy M2 conditions. In comparing like number battery options for future planned versus CSO Strategy M2 conditions, even smaller differences in sludge quantities are noted. This indicates that for a given secondary treatment plant configuration, no significant impact on residuals production would be expected between future planned and CSO Strategy M2 conditions.

The analysis conducted under the SMP program indicated that two of the four anaerobic digesters in digester module 4, plus four additional WAS centrifuges might be required. Findings from the DP-29 study indicate that these additional residuals facilities will not be required.

COST IMPACTS

Costs and potential savings for the recommended secondary treatment strategy are presented in Table 22-5. As discussed in Section Three, the costs and potential savings are the same for future planned and CSO Strategy M2 flow and pollutant loading conditions. This is because the unit process requirements are the same, and because only minor differences exist in flow and loading conditions that impact O&M costs. In comparison to the presently recommended 4-battery secondary treatment facility, capital cost savings on the order of $120 to $147 million and annual O&M cost savings of $4 to $5 million could be realized by implementation of the recommended secondary treatment strategy.

TABLE 22-4. RESIDUALS QUANTITIES FOR RECOMMENDED SECONDARY TREATMENT STRATEGY

Residual Process Stream/Flow and Pollutant Loading Condition	Future Planned Conditions		CSO Strategy M2 Conditions	
	3-Battery Secondary	2 2/3-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary
• Primary Sludge, lb/day				
- Annual Average	354,200	354,200	352,900	352,900
- Maximum 30-Day	373,800	373,800	376,600	376,600
- Maximum 7-Day	417,100	417,100	419,300	419,300
- Maximum Day	435,700	435,700	439,500	439,500
• Waste Activated Sludge, lb/day				
- Annual Average	313,100	307,000	314,400	308,600
- Maximum 30-Day	378,900	378,900	382,500	382,500
- Maximum 7-Day	486,300	432,200	487,000	432,900
- Maximum Day	566,300	503,400	561,500	499,100
• Digested Sludge, lb/day				
- Annual Average	345,100	342,000	345,100	342,100
- Maximum 30-Day	388,600	388,600	391,900	391,900
- Maximum 7-Day	465,600	438,400	467,200	439,900
- Maximum Day	515,800	484,100	515,400	483,900

TABLE 22-5. COSTS AND POTENTIAL SAVINGS FOR RECOMMENDED SECONDARY TREATMENT STRATEGY CONDITIONS

Cost ($ million)	4-Battery Secondary	3-Battery Secondary	2 2/3-Battery Secondary
• Capital Cost	2,500	2,380	2,353
- Savings vs. 4-Battery Secondary	--	120	147
• Annual O&M Cost	73.9	69.6	69.0
- Savings vs. 4-Battery Secondary	--	4.3	4.9
• Present Worth Cost	3,506	3,327	3,292
- Savings vs. 4-Battery Secondary	--	179	214

ON-GOING INVESTIGATIONS

Additional pilot plant results will provide information to better predict effluent quality over a range of flows, loads, and operating conditions. These data may support higher or lower primary and secondary removals. The ongoing pilot plant operation will also serve to refine predictions of sludge yields, oxygen requirements, return sludge rates, and plant operability in general.

DP-29 RECOMMENDATIONS

The "Final Draft Recommended Plan for Completion of the Deer Island Facilities", prepared by the DP-29 consultant, recommends that a minimum secondary treatment capacity of 710 mgd is necessary in order to meet permit standards for maximum 7-day and maximum month conditions. This conclusion was reached by performing a statistical flow blending analysis that predicted effluent quality during time periods when the secondary treatment unit capacity is exceeded. The analysis started with a base secondary treatment capacity of 530 mgd (adequate to treat all dry weather flows). The secondary treatment capacity was increased and effluent quality predicted, in iterative fashion, until the secondary treatment size was adequate to avoid permit violations.

To provide for plant symmetry and provide an additional layer of operating safety, DP-29 recommended construction of the complete Battery C, with a capacity rating of 780 mgd, 70 mgd above the base recommendation.

The potential for a 1 mg/l TSS violation was predicted for the 3 battery alternative by the SMP analysis. The DP-29 study rates the 3 battery secondary option at 780 mgd, and includes provision of a polymer system. This system will aid the settling process during high flow periods, and provide a level of safety to avoid permit violations for TSS in particular. With the provision of the polymer system for use during peak events, the SMP analysis and the DP-29 study both predict no permit violations with a 3-battery secondary treatment plant.

The MWRA's final recommendation for the wastewater treatment plant will be presented in the DP-29 report.