Chapter 9.
Preferred Alternative Refinement

The previous chapter identified a CSO control alternative which would reduce annual Denny untreated discharges to one untreated event per year on average, provide a 50 percent system wide annual total suspended solids removal, provide floatable material removal, and disinfect to meet state water quality requirements. The selected preferred CSO control alternative was Alternative 3 - CSO Treatment for Intermittent Discharge Plants.

Chapter 9 describes the preliminary engineering performed to define the final overall system components and configuration for the preferred alternative. For each component, additional preliminary engineering was performed to evaluate alternative outfall discharge locations and refine the Elliott West CSO control facility layout. Modifications to the preferred alternative considered and the rationale supporting those modifications are described in this chapter.

9.1. CSO Control Alternative Refinement

Following selection of a preferred alternative, the project team considered a number of modifications in hopes of improving system performance and/or reducing overall system costs.

9.1.1. Original Preferred CSO Control Alternative

As described in Chapter 8, Alternative 3 was the preferred CSO control approach for the project. This alternative would provide a combination of storage and at-site CSO treatment to control untreated discharges to one untreated discharge event a year (i.e., to control King County's Design Storm 6). The alternative would store combined sewer flows and convey those flows to the West Point Treatment Plant for treatment and disposal or provide at-site CSO treatment before discharge to limit untreated discharges to one event per year. Flows in excess of storage capacity of the tunnel and the conveyance capacity of the Elliott Bay interceptor would receive floatable material control and disinfection prior to discharge through the new Elliott West outfall. In addition, treated flows would be dechlorinated to meet chlorine residual water quality limits. Flows from storms greater than King County Design Storm 6 would produce untreated discharges at the Denny Way CSO outfall. No CSO treatment would be provided for discharges through the Denny Way CSO outfall.

The facilities that constitute the preferred Alternative 3 are shown in Figure 9-1. The manner in which those facilities would function is described as follows:

New Storage Tunnel. A 5,800-foot long, 14.5-foot-diameter Mercer Street tunnel would provide 7.1 million gallons of CSO storage. The tunnel would store flows diverted from the Elliott Bay interceptor, the Lake Union tunnel, the central trunk sewer, the City of

Seattle Phase 2 pipeline, and the new Elliott West CSO pipeline until the Elliott Bay interceptor has sufficient capacity to accommodate additional flows without overflowing.

New Conveyance Facilities. New south Lake Union CSO pipelines, central trunk diversion structure, and Lake Union tunnel regulator would be constructed in the south Lake Union area to convey flows from the City of Seattle Phase 2 project, existing Lake Union tunnel, and existing central trunk to the east end of the new Mercer Street tunnel for storage. A new Elliott West CSO pipeline and Denny Way diversion structure would also be constructed to convey flows from the downstream end of the existing Lake Union tunnel to the Elliott West CSO control facility. Also, a new Elliott West effluent pipeline would be installed to convey treated flows from the CSO control facility to the new Elliott West outfall.

New CSO Control Facilities. The Elliott West CSO control facility would provide floatable material control, disinfection and dechlorination. There would also be new flow control structures to transfer flows between the tunnel and the Elliott Bay interceptor. CSO control facilities that are part of the original preferred alternative also include a 120-mgd influent pump station to pump flows from the Elliott Bay interceptor and the new Elliott West CSO pipeline into the Mercer Street tunnel for CSO storage. All flows would be pumped to the tunnel effluent structure that would provide floatable material removal. Treated effluent flows would then be pumped by a 200.mgd effluent pump to the new Elliott West outfall through a new Elliott West effluent forcemain. The effluent force main would also provide chlorine contact time for disinfection. Dechlorination would be provided at the end of the effluent force main prior to discharge through the outfall into Elliott Bay. New chemical storage facilities would be provided at the Elliott West CSO control facility to store both disinfection and dechlorination chemicals and feed equipment.

New Outfalls and Extension. The original preferred CSO control alternative would discharge treated effluent and untreated CSO into Elliott Bay through separate outfalls. Treated effluent would be discharged through a new 500-foot long, 72-inch diameter Elliott West outfall. Untreated discharges will occur through the new 500 foot long, 96-inch diameter Denny Way CSO outfall extension. Both outfalls would be constructed in a common trench beginning off the existing Denny Way regulator station and would terminate at about 60 to 70 feet below mean lower low water (MLLW).

9.1.2. New CSO Control Refinements Considered

Based on the CSO control approach, additional engineering was then performed for Alternative 3 to define a final CSO control configuration. The additional engineering included the following evaluations:

- An evaluation of alternative locations for the Elliott West outfall.
- An evaluation of alternative depths for the Denny Way CSO outfall extension.

An evaluation of gravity effluent discharge versus pumped effluent discharge.

Each of the additional evaluations is described in greater detail in the following sections.

9.1.3. Revisions to Estimated Flows

All of the evaluations described in Chapter 8 were based on the seven King County design storms. As more fully described in Chapter 10, King County subsequently performed simulations of its sewer system based on actual rainfall data for the period from July 1, 1978, to June 30, 1984. Because the continuous simulations of actual rainfall provide a better means of estimating system performance than simulations based on the design storms, those simulations were used in the performance evaluations described in this chapter.

The continuous simulations based on the 1978-1984 data indicated that the overflow at the Denny Way regulator station was higher than had been calculated using the design storm data and multipliers. Average overflow during the rainfall period averaged about 611 MG rather than the 550 that had been calculated based on design storm. Thus for evaluating hydraulic performance, annual system inflow is estimated to be 611 MG.

9.2. Alternative Elliott West Outfall Location

With the selected CSO control alternative, both the treated and untreated discharges would occur through separate outfalls located at the existing Denny Way regulator station. Following selection of a preferred alternative, a new location for the Elliott West outfall was considered in hopes of finding an outfall configuration that would eliminate the need for effluent pumping and still meet water quality standards. Such an outfall configuration could potentially reduce both system complexity and costs. In addition, an outfall location more that 2,000-feet to the north of the Denny Way regulator station would avoid the sediment cap entirely. The possibility was therefore considered that treated flows might be discharged through an outfall beginning directly off the Elliott West CSO control facility site instead of at the Denny Way regulator station. Such a new location, being much closer to the Elliott West CSO control facility, could have a larger diameter, would have less frictional loss through the shorter pipe, and would have less head loss resulting from saltwater density differential. The outfall would therefore have higher hydraulic capacity. Only relocating the Elliott West outfall was considered; no consideration was given to relocating locating the existing Denny Way CSO outfall as no pumping had ever been contemplated for the existing outfall.

9.2.1. Elliott West Outfall Configuration Alternatives

Several alternative configurations for an Elliott West outfall adjacent to the Elliott West CSO control facility were considered, and those alternative configurations are shown in Figure 9-2. The alternative Elliott West outfall configurations include:

- An outfall with a single port discharge at mean lower low water.
- An outfall with a single-port discharge at a depth of 40-feet.
- An outfall with a multiple-port (diffuser) discharge at a depth of 40-feet.

As shown on Figure 9-2, adjacent to the Elliott West site are several existing facilities that would influence the outfall alignment. These facilities are:

- Port of Seattle grain terminal.
- Net pens operated by the Port Elliott Treaty tribes.
- Adjacent waterfront park.
- Designated offshore anchorage area.

9.2.2. Dilution Modeling

The new Elliott West outfall must be able to meet water quality standards, including the standards for fecal coliform. The project team had assumed that “end-of-pipe” fecal coliform counts would not exceed 200 colonies per 100 mL. The end of pipe count of coliform colonies per 100 mL is half as many colonies as the 400 per 100 mL used to evaluate the alternatives in Chapter 8. The project team determined that such an improved chlorination efficiency could be obtained by employing a chlorine contact basin to increase chlorine contact time. There would be adequate space at the site to accommodate such a tank. Since the applicable water quality standard for inner Elliott Bay is 43 colonies per 100 mL, some dilution of the treated effluent would still have to occur following discharge in order to meet water quality standards.

Dilution modeling was performed for each alternative outfall configuration with the UM component of PLUMES software, a dilution model supported by the USEPA. The UM component was used because it allows an estimate of dilution to be made from both single-port and multiple port discharges. Using the PLUMES software and the data that had been collected during the project, a revised dilution model was developed to predict the conservative or “worst case” dilution for each alternative. The model was then used to calculate dilution rates for each configuration under the various hydraulic conditions that the alternative outfall would experience. A prediction of the treated discharge fecal coliform count at the edge of the chronic mixing zone was estimated based on the results of that modeling effort.

Single-Port Discharge at Mean Lower Low Water. Under this alternative, outfall discharge would occur at a point just offshore from the Elliott West site (see Figure 9-2). The point of discharge would be such that the crown of the outfall would remain below the mean lower low water elevation in conformance with the City of Seattle requirement that all outfalls not be exposed at low tide. The end of the outfall was assumed to be about 50-feet offshore. There would be a single, 144-inch diameter discharge port angled upward from horizontal.

The discharge depth of this outfall alternative would not interfere with the marine traffic associated with the Port grain terminal facility. However, the shallow discharge depth results in essentially no dilution of the treated effluent. The estimated fecal coliform level at the edge of the chronic mixing boundary would thus remain at 200 colonies per 100 mL and would exceed the Class A marine water fecal coliform excursion limit of 43 colonies per 100 mL for discharged flows.

Single-Port Discharge at 40-Foot Depth. This alternative was developed to estimate the additional dilution that might be achieved if treated CSOs were discharged at greater depth. The outfall for this alternative would be located about 180-feet offshore, and would be a single, 144-inch diameter discharge port angled upward from horizontal.

As shown on Figure 9-2, the outfall discharge would be located in approximately 40-feet of water just east of the existing Port of Seattle grain terminal pier. This location should not interfere with marine traffic because no marine traffic is allowed east of the existing grain terminal pier because of insufficient water depth. This outfall configuration would provide greater dilution than an outfall discharging at mean lower low water because of a deeper water column in which to dilute the treated effluent. The estimated dilution factor is 2:1 to 3:1 at the edge of the chronic dilution zone for a flow of 80 mgd, the maximum daily effluent flow from the Elliott West facilities.

The predicted fecal coliform level was estimated for varying discharge flow rates based on an "end of pipe" fecal coliform level of 200 colonies per 100 mL. The estimated fecal coliform level at the edge of the chronic mixing boundary exceeds the Class A marine water fecal coliform geometric excursion limit of 43 colonies per 100 mL for discharge flows of 80 mgd.

Multiple-Port Discharge at 40-Foot Depth. This alternative was developed to estimate the additional dilution that might be achieved if treated CSOs were discharged through a multiple-port outfall at the 40-foot depth. The outfall for this alternative would be located about 180-feet offshore, and would have twin 108-inch-diameter outfall pipes, each with a single discharge port angled upward from horizontal.

This outfall configuration would provide greater dilution than a single port outfall discharging at the same depth because the multiple discharges provide additional flow dispersion and dilution. The estimated dilution factor is 5:1 to 6:1 at the edge of the chronic dilution zone for 80 mgd treated discharge flow.

Based on this improved dilution, the estimated fecal coliform level at the edge of the chronic mixing boundary falls below the Class A marine water fecal coliform geometric excursion limit (43 colonies per 100 mL) up to the predicted maximum daily discharge flow of 80 mgd if other modifications are made to the system.

Suggested Outfall Configuration for the Elliott West Site. The multiple port discharge at 40-foot depth was the best alternative among the new configurations considered for the Elliott West outfall. This is because it would comply with the Class A marine water standards for chronic fecal coliform (43 colonies per 100 mL) during the estimated maximum daily discharge flow of 80 mgd, based on an "end of pipe" fecal coliform level of 200 colonies per 100 mL.

9.2.3. Modified System Alternative Configurations

A new alternative CSO control configuration, Alternative 3A, was thus developed based on the outfall dilution modeling results. That new configuration is shown in Figure 9-3. While relocating the Elliott West outfall from the Denny Way regulator station site to directly off the Elliott West CSO control facility site would eliminate the need for effluent pumping and an effluent force main, that alternative raised other concerns.

The site for the 40-foot outfall was within a few hundred feet of salmon net pens operated during the spring (March through June) by the treaty tribes. The discharge of treated effluent during a CSO event in the salmon rearing season so close to the pens might present a hazard to the small salmon being reared there. Furthermore, should the dechlorination system fail, any salmon in the pens might receive a potentially fatal dose of chlorine. The concern over the possible impacts of the outfall on the salmon pens caused the project team to look for ways to reduce or eliminate the risk to the fish in the pens.

As a possible solution to the problem of the risk to the net pen salmon, the project team developed an additional alternative, Alternative 3B, also shown in Figure 9-3. Research of meteorological data indicated that while storms causing combined sewer overflows can happen any month of the year, by far the largest proportion of storms, and the largest storms, occur during the months of November, December, January, and February. During those months, the pens are not in use, so the risk of harm to the salmon does not exist. During the months of March through June, storms and CSO events do occur, but historically, those storms have been smaller and less frequent. It might therefore be possible to increase system storage to the extent that the system would be able to trap and store CSO during the spring months. Based on a review of the historical rainfall record, it was determined that if the tunnel size were increased to 16.5 MG (i.e., about 22-feet in diameter), the system would discharge treated effluent only four times per year, on average. Furthermore, the probability of one of those four storms occurring during the period when the net pens are in operation appeared to be low, about once every five to ten years. Therefore Alternative 3B, consisting of a 22-foot-diameter tunnel and the 40-foot-deep outfall off the Elliott Way site, was developed as an alternative to the original preferred alternative in order to minimize risk to the pens.

Thus two modified alternative configurations, Alternative 3A and Alternative 3B, each including a new outfall located at the Elliott West CSO control facility site, were evaluated. These modified CSO control alternatives, like Alternative 3, the original preferred alternative, provide combinations of storage and at-site CSO treatment to control untreated discharges to one event per year as required by the State of Washington's CSO control requirement. Both modified alternatives would employ an underground tunnel for storage of combined wastewater during storm events. The only difference between the two alternatives is the size of the tunnel: Alternative 3A would require a 14.5 foot diameter tunnel, while Alternative 3B would require a 22-foot-diameter tunnel.

For Alternatives 3A and 3B, flows stored and diverted to the West Point Treatment Plant would receive either secondary treatment or primary treatment and disinfection before discharge. Flows in excess of the tunnel storage capacity and conveyance capacity of the existing Elliott Bay interceptor would receive at least the minimum CSO treatment as per the State of Washington CSO control policy.

All treated discharges to Elliott Bay would receive floatable material removal, and disinfection in a chlorine contact basin and dechlorination to meet state water quality standards for Elliott Bay. Treated discharges into Elliott Bay would be discharged through a new, submerged, Elliott West outfall located at the Elliott West CSO control facility site. Flows in excess of the at-site CSO treatment capacity would be discharged into Elliott Bay through the extended Denny Way CSO outfall without any treatment.

It is estimated that there would be one annual untreated discharge event for either modified Alternative 3A or 3B.

9.2.4. Evaluation of Modified Alternatives

Each modified alternative was compared to the original preferred CSO control alternative with respect to the same parameters used in the preferred alternative selection process described in Chapter 8, namely:

- Predicted CSO control performance (discharge volume and frequency, total suspended solids removal, residual settleable solids, and fecal coliform).
- Economic costs (capital costs, annual operation and maintenance costs, present worth costs, and cost-effectiveness for CSO volume reduction and total suspended solids removal).
- Technical factors (construction risk and difficulty, operability, and implementability).
- Environmental factors (recreational, fisheries, marine vessel traffic, treaty tribe net pens, and water quality).

Predicted CSO Control Performance. Based on simulations using six years of actual rainfall, the predicted CSO control performance for the original preferred alternative, Alternative 3, and modified Alternatives 3A and 3B are listed in Table 9-1.

All three alternatives would reduce untreated CSO discharges by about 99 percent annually. Alternative 3 (the original preferred alternative) and modified Alternative 3A would result in an average of 11 treated annual treated discharges and one annual untreated discharge event into Elliott Bay. Modified Alternative 3B would result in an average of four treated annual treated discharges and one annual untreated discharge event into Elliott Bay. The number of annual treated discharge events for modified Alternative 3B occurring during the spring fisheries season (March through June) would be reduced to one every 5 to 10 years.

Annual system-wide TSS removal would be 60 percent for Alternatives 3 and 3A, and Alternative 3B would provide system-wide TSS removal of 65 percent.

The reason for the higher level of CSO control (i.e., reduced CSO discharge volume, reduced frequency of treated discharge, and increased annual TSS removal) for modified Alternative 3B results from the increased CSO storage volume (16.5 MG) provided by the larger tunnel (22-foot diameter) compared to Alternatives 3 and 3A. More stored wastewater translates to a larger proportion of the annual CSO volume being diverted to West Point for treatment. West Point TSS removal efficiency is assumed to be about 85 percent, higher than the TSS removable achievable with on-site treatment.

Table 9-1. CSO Control Performance Comparison

	Preferred Alternative 3	Modified Alternative 3A	Modified Alternative 3B
Number of treated discharges/year	11	11	4
Number of untreated discharges/year	1	1	1
Discharge events, March to June	0 - 3	0 - 3	1 per 5 to 10 years
Annual CSO volume reduction	99%	99%	99%
Diverted volume to West Point (MG/yr)	476	476	533
Treated discharge volume into Elliott Bay (MG/yr)	127	127	72
Untreated discharge volume (MG/yr)	8	8	5
Annual TSS percent removal	60%	60%	65%
Settleable solids discharge (mL/L/hr)	2 or less for each individual event (0.3 or less based on a long term geometric mean)		
Fecal coliform of discharge @ chronic mixing zone (colonies/100 mL)	43 or less for each individual event		
"End of pipe" fecal coliform (colonies/100 mL)	400	200	200

All three alternatives would remove floatable material and significantly reduce the aesthetic impacts associated with high settleable solids CSO discharges. All three alternatives are predicted to achieve effluent settleable solids equal to a long-term geometric mean of 0.3 mL/L/hr, with a maximum per event limit of 2 mL/L/hr. Discharges from all three alternatives would meet the fecal coliform water quality requirement of a monthly geometric mean of 14 colonies per 100 mL at the edge of the chronic mixing zone, with no more than 10 percent of the samples exceeding 43 colonies per 100 mL. The effluent fecal coliform level at the edge of the chronic dilution zone is predicted to not exceed the maximum monthly chronic fecal coliform excursion limit of 43 colonies per 100 mL.

All effluent would be dechlorinated to meet the water quality standard of 0.0075 mg/L for residual chlorine at the edge of the chronic mixing zone.

Economic Factors. Comparisons of economic factors involved development of capital and annual operation and maintenance costs for the two modified CSO control alternatives. All three alternatives were then compared on the basis of present worth costs, including salvage values, to determine cost-effectiveness for CSO volume reduction and total suspended solids removal.

Capital costs for the alternatives are shown in Table 9-2. As described in Chapter 8, capital costs were developed by estimating the costs of constructing the components of the various alternatives, then adding cost factors such as contingency, sales tax, King County related costs (e.g., property acquisition, project management), and engineering design and construction management. All costs were prepared in first quarter 1996 dollars based on *Engineering News Record Construction Cost Index (ENR CCI)* of 5537 (the same index used in Chapter 8). Contingency costs ranging from 20 to 35 percent were applied for each type of facility, including pipelines (20 percent), regulator and flow diversion structures (20 percent), marine outfalls (30 percent), tunnel (20 to 25 percent), and CSO treatment and pump stations (35 percent). Other capital costs items included 8.6 percent for sales tax, allowances for property and right-of-way acquisition, King County soft capital costs, and design and construction management.

As shown in Table 9-2, the highest cost alternative is Alternative 3B. Alternative 3B has the most storage capacity and, therefore, the highest tunnel cost. Alternatives 3 and 3A have essentially the same planning level capital costs.

Table 9-2. Total Project Capital Costs (in $millions) for CSO Control Alternatives

(All costs in first quarter 1996 dollars, *ENR CCI = 5537*)	Preferred Alternative 3	Modified Alternative 3A	Modified Alternative 3B
Elliott West facility	$13.0	$9.9	$9.9
Outfalls	$3.7	$3.3	$3.3
South Lake Union conveyance facilities	$4.2	$4.2	$4.2
Mercer Street tunnel	$23.6	$23.6	$42.2
Denny CSO conveyance facilities	$9.7	$14.3	$14.3
Subtotal Base Construction Cost	**$54.2**	**$55.3**	**$73.9**
Contingency	$13.6	$13.6	$19.4
Subtotal Construction Cost	**$67.8**	**$68.9**	**$93.3**
Washington State Sales Tax	$5.8	$5.9	$8.0
Total Estimated Construction Cost	**$73.6**	**$74.8**	**$101.3**
Allied Costs	$32.3	$32.3	$32.3
Total Project Cost	**$105.9**	**$107.1**	**$133.6**

Annual operation and maintenance (O&M) costs were developed based on four major cost categories: labor, power, chemicals, and equipment repair and replacement. In addition, as in Chapter 8, a 25 percent contingency was included for the annual O&M costs. O&M costs are directly dependent upon the number of overflow events. In addition, the West Point treatment costs associated with diverting additional CSO flows to the plant, calculated using a unit cost of $363 per million gallons of flow, were included in the total O&M costs. Those costs represent the increase in West Point's annual O&M costs to handle the Denny Way flows diverted to West Point for treatment and disposal.

Table 9-3 shows the relative O&M costs for each alternative. The table reveals that Alternative 3, requiring both an influent and effluent pump station, has the highest labor, power and equipment repair and replacement costs. Chemical cost is lowest for Alternative 3B because the disinfection requirement is also directly related to the number of discharges. The power and equipment costs for Alternatives 3A and 3B are lower because they have only a single pump station.

Table 9-3. CSO Storage and Treatment Operation and Maintenance Costs (in $thousands)

(All costs in first quarter 1996 dollars, *ENR CCI = 5537*)	Preferred Alternative 3	Modified Alternative 3A	Modified Alternative 3B
Annual Labor	$98	$65	$65
Annual Power	$34	$26	$26
Annual Chemicals	$23	$23	$13
Annual Equipment repair and replacement	$107	$54	$54
Miscellaneous (25 percent)	$66	$42	$39
Annual West Point O&M cost to treat diverted flows	$173	$173	$193
Annual O&M costs, total	$501	$383	$390
Present worth O&M cost (20 years at 7.625 percent)	**$5,060**	**$3,860**	**$3,940**

The bottom row of Table 9-3 shows the present worth value of the annual O&M costs. Present worth represents the investment required to provide a cash stream equal to the annual O&M costs over 20 years. The present worth is influenced by the cost of money or interest: higher interest rates produce a greater cash flow and therefore reduce the original investment. Table 9-3 reflects an USEPA interest rate of 7.625 percent, which produces a present worth factor of 10.10. The present worth factor multiplied by the annual O&M cost will give the present worth of annual O&M costs. No escalation of labor or energy costs was included in the present worth calculations.

An important element in determining the present worth costs for the project as a whole is salvage value. The depreciated value of structures and equipment at the end of the 20 year planning period was used as salvage value. To compute salvage value, structures and equipment were depreciated using straight-line depreciation and a 50.year useful life. The depreciated value after 20 years was then discounted to its present value. Structures included concrete structures such as pump station wet wells, floatable material control structures, regulators and diversion structures, and chemical storage and feed facilities. Conveyance pipelines and the CSO storage tunnel, including the drop structure, were assumed to have a 75 year useful life. Other items of equipment (including influent and effluent pumps, disinfection and dechlorination equipment, standby power generator, electrical and control equipment, and heating and ventilation equipment) were depreciated using a 20 year useful life. Land for the Elliott West site was not considered a depreciable asset and was therefore assumed to have 100 percent salvage value at the end of the 20 year planning period.

A 20 year present worth project cost, expressed in first quarter 1996 dollars, was estimated for each CSO control alternative using capital costs, present worth of O&M costs, and salvage value. No inflation or escalation of costs was used in calculating the present worth costs. Table 9-4 shows the present worth cost for each alternative. The highest present worth cost alternative is Alternative 3B. Alternatives 3 and 3A have essentially the same planning level present worth costs.

Table 9-4. Present Worth Project Cost Comparisons (in millions)

(All costs in first quarter 1996 dollars, *ENR CCI = 5537*)	Preferred Alternative 3	Modified Alternative 3A	Modified Alternative 3B
Total Project Cost	$105.9	$107.1	$133.6
Present worth O&M cost	$5.1	$3.9	$3.9
Less Salvage Value	($9.2)	($10.3)	($18.4)
Total Present Worth Cost	**$101.8**	**$100.7**	**$119.1**

The following cost / benefit relationships have been identified for the alternatives to facilitate selection of a final preferred configuration for the Denny Way / Lake Union CSO Control Project.

- Relationship between present worth costs and reduction and discharge volume (i.e., volume of flows diverted to West Point Treatment Plant).
- Relationship between present worth costs and suspended solids removed.

Table 9-5 compares the cost effectiveness of each alternative with respect to CSO volume reduction. Each of the alternatives would store some of the CSO that would otherwise overflow at Denny Way (or Lake Union or the Dexter regulator) without the project. Without this project, 611 MG of CSO would overflow at Denny Way annually. The second row of the table shows number of million gallons being diverted be each alternative. By comparing the number of gallons diverted to West Point with the present worth project cost, the cost per million gallons of CSO diverted to West Point can be computed. The bottom line in Table 9-5 indicates Alternatives 3 and 3A have the lowest unit cost for flow diverted to West Point. Alternative 3B has the highest unit cost.

Table 9-5. Cost of Annual CSO Volume Discharge Reduction (in $millions)

(All costs in first quarter 1996 dollars, *ENR CCI = 5537*)	**Preferred Alternative 3**	**Modified Alternative 3A**	**Modified Alternative 3B**
Present worth cost of alternative (in millions)	$101.8	$100.7	$119.1
Volume diverted to West Point (MG/yr)	476	476	533
Volume treated and discharged at Elliott West CSO site (MG/yr)	127	127	72
Total volume reduction (MG/yr)	603	603	605
Cost per gallon of CSO treated	**$ 0.17**	**$ 0.17**	**$ 0.20**

Total influent suspended solids at Denny Way generated by CSOs is estimated to be approximately 365,000 pounds per year. Solids reduction in the Denny Way system is a combination of the solids reduction that takes place at the site and the solids removal that occurs at West Point for the flows diverted there. Table 9-6 shows the cost per pound of TSS removed. Alternatives 3 and 3A have the lowest unit costs for suspended solids removal and Alternative 3B has the highest.

Table 9-6. Cost of Annual CSO Suspended Solids Removal

(All costs in first quarter 1996 dollars, *ENR CCI = 5537*)	**Preferred Alternative 3**	**Modified Alternative 3A**	**Modified Alternative 3B**
Present worth cost of alternative (in millions)	$101.8	$100.7	$119.1
Annual pounds of suspended solids removed	219,000	219,000	238,000
Cost per pound of solids removed	**$460**	**$460**	**$500**

Technical Factors. The alternatives were also evaluated according to several technical factors, including construction risk and difficulty, operability, and implementability. This evaluation rated the alternatives as above average, average, or below average. This rating system is somewhat subjective, but it does identify alternatives with clear advantages or disadvantages compared to others. The comparison factors are described below, and technical evaluation is summarized in Table 9-7.

The construction risk was determined through a qualitative evaluation of the complexity of the type of construction. Alternatives 3A and 3B are considered to have additional risks because of micro-tunneling the twin outfall discharge pipelines underneath the BNSFRR tracks compared to conventional “cut and cover” pipeline construction.

Table 9-7. Technical Factors Comparison

	Preferred Alternative 3	Modified Alternative 3A	Modified Alternative 3B
Construction risk and difficulty	Average: Requires construction of tunnel, pump stations, CSO treatment facilities and pipelines in urban areas.	Above Average: Twin micro-tunneled pipelines under RR tracks in high groundwater and difficult soils.	Above Average: Twin micro-tunneled pipelines under RR tracks in high ground-water and difficult soils. Larger tunnel required.
Operability (Ease of operation and maintenance)	Average: Relatively simple with tunnel storage, pumping and disinfection	Above Average: Similar to Alternative 3, except that there is only a single pump station.	
Implementability (Public acceptance)	Average: Potential public opposition to pump stations/ disinfection facilities at Elliott West and to shallow outfall at Denny Way.	Below Average: Potential opposition to large diameter outfalls located near the Port of Seattle grain terminal facilities, and from the Indian tribes for discharging near their fish rearing net pen operations.	
Implementability (Permitting)	Average: Outfalls will be constructed in a location where existing outfall is already permitted.	Below Average: Construction of outfall directly off shore of the Elliott West site will probably necessitate relocation of the existing tribal fish net pens. Net pen relocation will require permits and may take 2 to 3 years to obtain.	

The operation of the CSO control alternatives was determined quantitatively by estimating annual O&M costs, and qualitatively by considering several operational factors, such as level of operational control required, periodic cleaning required for floatable material control structures, seasonal and intermittent operation, operational flexibility to respond to different storm intensities and durations, and the ability to meet discharge limits. For example, a influent single pump station and effluent discharge by gravity is considered more desirable than multiple pump stations and a force main effluent discharge pipeline.

An opinion of possible public acceptance of, or opposition to, the implementation of the alternatives (or to specific components of the alternatives) was developed. For example, it was assumed that construction of the twin large diameter outfalls near the tribal fish net pens and the Port of Seattle grain terminal operations will cause greater opposition to the project.

Environmental. Possible environmental impacts associated with each alternative are summarized in Table 9-8.

Table 9-8. Comparison of Environmental Factors

	Preferred Alternative 3	Modified Alternative 3A	Modified Alternative 3B
Recreational usage (Increased recreation usage)	Outfall construction would close park for 6 to 8 months. Some discharges occur during peak recreation times.	Park would not be closed for outfall construction. Some discharges occur during peak recreation times.	Park would not be closed for outfall construction. Fewer discharges during peak recreation times.
Fish and shellfish (Enhanced fishers and shellfish resources, aquatic habitat)	Copper and other dissolved mineral concentrations lower outside mixing zone	Copper, other metals may exceed water quality standards at net pens. Risk to net pens of dechlorination failure highest.	
Water quality (Improvement over current CSO conditions)	More turbidity during construction. Less near shore dissolved copper and other metals.	Less turbidity during construction because of lower excavation requirements and shorter duration. Higher risk of dissolved copper and other metals near shore.	
Marine vessels (Disruption to boats and vessels)	Possible disruption during 6 to 8 mos. of construction.	Outfall out of ship anchorage area. Possible disruption of port barges only. Construction disruption limited to three months.	
Odor (Potential for odors)	Low potential for odor generation.	Slightly higher potential for odors because of chlorine contact basin.	
Sediment quality	Increased sediment cap disturbance. Only one sediment impact zone to permit.	Less cap disturbance; Elliott West outfall avoids cap entirely. Two sediment impact zones must be permitted.	

The major environmental factors used to evaluate the CSO control alternatives are recreational impacts, impacts to fish and shellfish resources, water quality impacts, traffic impacts, and construction impacts to treaty tribes' commercial fishing activities and to possible cultural resources along pipeline alignments and other excavations associated with the project. The separate project supplemental EIS and NEPA environmental assessment documents address the environmental impacts in detail.

Public recreational use was divided into the following categories: primary contact recreation (e.g., swimming), sport fishing, boating, and aesthetic enjoyment. An estimate of the discharge frequency for each month of the year was developed, in order to determine the impact. It was assumed that discharges during the summer season, when recreational use is high, are less desirable than discharges during the low recreational winter months.

Potential impacts upon existing shellfish and fisheries resources were evaluated. There are existing fish rearing pens near the Elliott West discharge location, as well as established migratory fish patterns. Special consideration was given to the impacts to the existing tribal fish net pen operations.

Areas of railroad, streets, and marine traffic may be disturbed as a result of the construction of all alternatives. Street traffic would be impacted by the short-term street closures during construction of pipelines, storm sewers, and underground storage facilities buried beneath streets. Railroad traffic may be impacted by temporary disruption of side railing access during construction. Marine traffic may be impacted during construction of new outfall structures. Special consideration was given to the impacts upon the existing Port of Seattle grain terminal operations.

9.2.5. Final Preferred Elliott West Outfall Location and Configuration

Alternative 3, the original preferred alternative, remained the preferred configuration for the Elliott West outfall, and the Elliott West outfall discharge site would remain located at the existing Denny Way regulator station. Although Alternatives 3 and 3A have similar economic costs and the same cost effectiveness for solids removal and CSO volume reduction, Alternative 3 configuration is preferred primarily because of the potential adverse environmental impacts associated with relocation of the Elliott West outfall to near the existing tribal net pens. Alternative 3B costs nearly $20 million more than the other two alternatives.

9.3. Alternative Denny CSO Outfall Extension Configuration

The project team then reviewed alternative configurations for the Denny Way CSO outfall extension to determine if the preferred CSO outfall configuration had sufficient hydraulic capacity to handle storms larger than Design Storm 6. For the preferred alternative, Alternative 3, both the Elliott West outfall and the Denny Way CSO extension would terminate approximately 500-feet offshore from the existing Denny Way regulator station.

To determine the peak hydraulic capacity of the untreated Denny Way CSO outfall extension, results of King County hydraulic simulations of the system were reviewed. King County performed simulations of the sewer system using actual rainfall for the period July 1, 1978 through June 30, 1995. The highest peak flow observed in those simulations occurred November 3, 1978. This storm contains short-term intensities near the maximums observed in the record. It ranks second in maximum hour rainfall and, contains a higher 10 minute intensity that the storm (June 29, 1952) that has a higher peak hour rainfall total. The November 3, 1978, storm produced a higher simulated peak than several storms that exceeded its peak 2 hour and 3 hour totals. Because of its characteristics (including season) and hydraulic limitations in the system, the November 3, 1978 storm is an appropriate one to examine for peak hydraulic capacity needs in the system.

The November 3, 1978, storm produced a peak total Denny flow (sum of treated and untreated outfalls) of about 485 to 495 mgd in the King County simulations. Examination of restrictions in the sewer system not fully accounted for in the model yielded a peak total flow estimate in the range of 330 to 360 mgd if the Interbay pump station were operating at its design maximum flow of 133 mgd. If provision is made for the potential throttling of the Interbay pump station in such an event, the peak flow would be 100 to 125 mgd higher. An additional 7 to 8 mgd should also be added to the peak for potential inclusion of the City of Seattle's Vine Street overflow in the project, bringing the total potential peak flow for design to the range of 460 to 490 mgd. Hydraulic calculations show that with the tide elevation at its maximum height and Interbay pumping only 5 mgd, a capacity of approximately 272 mgd is required in the Denny Way CSO outfall extension to discharge system overflows.

9.3.1 Denny Way CSO Outfall Extension Configuration Alternatives

The Denny Way CSO outfall extension configuration described for Alternative 3 could discharge untreated CSO flows up to 150 mgd. Since the predicted untreated CSO discharge flow may exceed 272 mgd during especially large storms, a revision of the Denny Way CSO outfall extension configuration was necessary. Two alternative Denny Way CSO outfall extension configurations were developed and evaluated. The two new configurations are shown in Figure 9-4 and described below.

Twin CSO Outfalls: CSO Outfall at 60-Foot Depth with Emergency CSO Bypass at 12-Foot Depth. This alternative would have two untreated outfalls discharging into Elliott Bay: a 96-inch-diameter, 500-foot-long outfall, constructed in the same trench as the Elliott West outfall and terminating 60-to 70-feet below MLLW, and a 60-inch-diameter, 100-foot-long emergency bypass outfall, terminating 12-feet below MLLW. Untreated flows up to 150 mgd would be discharged through the 96-inch-diameter outfall, while the flows in excess of 150 mgd up to the November 1978 storm event (272 mgd) would be discharged through the emergency CSO bypass.

Single CSO Outfall at 12-Foot Depth. This alternative would have a single, 96-inch diameter, approximately 100-foot-long outfall extension, terminating 12-feet below MLLW. Untreated flows up to the November 1978 storm event (272 mgd) would be discharged through that outfall.

9.3.2. Denny Way CSO Outfall Extension Alternative Evaluation

Each untreated outfall alternative was compared with respect to the following parameters.

- Predicted untreated discharge frequency.
- Economic costs.
- Technical factors.
- Environmental factors.

Predicted Untreated Discharge Frequency. The twin CSO outfall alternative would have one untreated discharge (peak flow of 150 mgd) per year through the 96-inch-diameter, 500-foot-long outfall, and one untreated discharge (peak flow of 130 mgd) every three to five years through the emergency CSO bypass. The single CSO outfall alternative would also have one untreated discharge per year. The difference is that the single outfall would be able to pass peak flow of 272 mgd which occurs every three to five years.

Economic. Capital costs were developed on the same basis as described previously in this chapter. The first quarter 1996 capital costs for the two alternatives, including 30 percent contingency, sales tax and allied costs, are $8.7 million for the twin CSO outfall alternative (i.e., 500-foot long CSO outfall extension plus emergency bypass) and $6.3 million for the single, 100-foot long CSO outfall alternative.

Technical Factors. The twin CSO outfall alternative would require constructing two outfalls, one nearly 500-feet long, in addition to the Elliott West outfall directly off the existing Denny Way regulator station.

The single CSO outfall alternative would only require the construction of a single 100-foot-long outfall in addition to the Elliott West outfall.

Environmental Factors. A primary environmental difference between the two CSO outfall alternatives is their impacts on sediments. The twin outfall alternative would require a 96-inch-diameter outfall to be constructed through the existing sediment cap and would require special handling of the contaminated sediment material excavated from beneath the cap during construction. In addition, operation of the bypass could scour the sediment cap sands, although the bypass would operate only once every three to five years. No excavation through the existing sediment cap would be required for the single CSO outfall. However, the single CSO outfall extension would have the potential for scouring the cap sands once every year, on average.

Both alternatives are likely to require permits for two sediment impact zones. The twin CSO outfall alternative could use the same impact zone that has been permitted for the Elliott West outfall, since the longer outfall would terminate at the same location as the Elliott West outfall. However, the emergency bypass is likely to require a sediment impact zone of its own to be permitted. The single CSO outfall would require separate sediment impact zones for the Elliott West outfall and the Denny Way CSO outfall extension.

A second environmental difference between the two alternatives involves water quality at the shoreline. The single CSO outfall alternative will discharge untreated wastewater essentially right at the shore line every year, while the twin CSO outfall alternative will discharge untreated wastewater adjacent to the shore only once every three to five years. Most untreated discharges will occur about 500-feet offshore. However, wind and current conditions likely to be encountered during large CSO events is likely to bring the untreated wastewater back to shore quickly after it is discharged, albeit in a somewhat diluted condition.

In general, the environmental differences between the two CSO outfall alternatives are minimal.

9.3.3. Preferred Denny Way CSO Outfall Extension Configuration

The single untreated discharge configuration was selected as the preferred Denny Way CSO outfall extension configuration because it is the more cost-effective discharge configuration for the untreated outfall and it would not require excavation through the existing sediment cap. Because the outfall would discharge towards the sediment cap about once a year on average, special provisions will need to be made during the design of the outfall extension to protect the cap from scouring.

9.4. Treated Effluent Discharge System

The original preferred alternative called for both influent and effluent pumping. Influent pumping at the Elliott West CSO control facility would be required to convey flows from the Elliott West CSO pipeline and Elliott Bay interceptor into the Mercer Street tunnel for CSO storage. When the storage capacity of the tunnel and the Elliott Bay interceptor are exceeded, flows would be discharged to the effluent pump station. The discharged flows would receive CSO treatment, including floatable material control and disinfection, prior to discharge into Elliott Bay. During most flow and tide conditions, treated effluent pumping would be required in order for treated flows to be discharged through the Elliott West outfall.

9.4.1. Gravity Effluent Discharge Alternatives

Alternative treated effluent discharge systems were evaluated to determine the feasibility of eliminating the effluent pump station and allowing gravity-pressure discharge of the treated effluent from the Elliott West CSO control facility to Elliott Bay. In designing a gravity discharge system, designers face a trade off between keeping the water surface elevation low and using a very large diameter effluent pipeline and outfall or elevating the water surface in order to get by with a smaller pipeline and outfall. Two alternative configurations were developed and evaluated based on that trade off.

Elevated Effluent Discharge Structure at the Elliott West CSO Control Facility. The effluent discharge structure could be elevated such that discharged flows would be conveyed by gravity into Elliott Bay through the new Elliott West outfall, eliminating the need for the effluent pump station. The size of the new Elliott West effluent pipeline would need to be 84 inches in diameter to allow gravity-pressure flow. An 84-inch pipeline would be 12-inches larger than the 72-inch-diameter effluent force main called for in the original preferred alternative. In order to make this alternative work, however, the water surface elevation at the Elliott West CSO control facility would have to be elevated to above elevation 125-feet (1988 Metro datum) for Design Storm 6 flows. Such a water surface elevation could be achieved with a single pump station. As with the original preferred alternative, flows from the Elliott Bay interceptor and the Elliott West CSO pipeline could initially flow by gravity directly into the tunnel. However, as the tunnel fills, the flows would drop into the pump station wet well, from where they would be lifted up into the tunnel via a channel called the floatables control channel. Eventually, when the tunnel is full, the gated connection between the tunnel and the floatable control channel would close. At that time, flows from the Elliott Bay interceptor and the Elliott West CSO pipeline, and overflow from the storage tunnel, would all three drop into the pump station wet well and be lifted to about elevation 125-feet to the floatables control channel, which would then fill completely and discharge by overflowing to the effluent channel. Effluent would pass under a floatables control baffle, over a weir into the effluent channel for chlorination, and from there by gravity through the 84-inch-diameter Elliott West effluent pipeline and Elliott West outfall. The pump station would need to have a capacity of at least 200 mgd at a wet well elevation of 99-feet as that is the peak effluent flow during Design Storm 6.

The Elliott West CSO pipeline would be a 66-inch-diameter, 2,600-foot-long gravity pipeline that would carry overflows from the Denny Way diversion structure to the Elliott West CSO control facility. The new 2,450-foot long, 84-inch-diameter Elliott West effluent pipeline would also need to be built to convey treated effluent from the Elliott West facility to the new Elliott West outfall. It was assumed that both pipelines would be constructed in a single trench paralleling and just east of the Elliott Bay interceptor, between the interceptor and the westernmost BNSFRR main line railroad track with the westerly portion of the new pipelines within the existing Elliott Bay interceptor easement from the Port of Seattle. The 84-inch gravity-pressure effluent pipeline would lie above the 66-inch gravity Elliott West CSO pipeline in the same trench. There is sufficient room between the interceptor and the railroad tracks to place the two pipes, although the westernmost track might have to be taken out of service while the pipelines are being constructed.

Low Effluent Discharge Structure. This alternative would also require only a single pump station and a gravity-pressure effluent pipeline. Influent pumping would be required to convey flows from the Elliott West CSO pipeline and Elliott Bay interceptor overflows to the Mercer Street tunnel for CSO storage. The water surface level in the tunnel discharge structure would rise to maximize the storage in the tunnel. When the storage capacity of the tunnel and the Elliott Bay interceptor are exceeded, flows would be discharged from the tunnel to the effluent discharge structure where the flows would receive CSO treatment, including floatable material control and disinfection, prior to discharge into Elliott Bay. The water level in the effluent discharge structure would be held to about 114-feet in order to allow the tunnel to drain to the effluent discharge structure by gravity. Because the pump station would be required to handle only west end flows, a smaller pump station could be used for the low discharge alternative than for the elevated discharge alternative described above (120 mgd for the low discharge vs. 200 mgd for the elevated discharge for Design Storm 6 flows). In order for the treated flows to be conveyed by gravity flow into Elliott Bay through the new Elliott West outfall, the new Elliott West effluent pipeline and the Elliott West outfall diameters would have to be increased to 120-inches in diameter, however.

In order to prepare a preliminary cost estimate for this alternative, it was assumed that the two pipelines would not share a common trench because there is insufficient area to construct both the 66-inch diameter Elliott West CSO and 120-inch diameter Elliott West effluent pipelines along the same alignment corridor described for the elevated discharge alternative. Instead, it was assumed that the effluent pipeline would be located west of the Port of Seattle railroad sidings, along the eastern side of the Myrtle Edwards Park fence, while the CSO pipeline would follow the alignment described above for the elevated discharge alternative. This arrangement has the advantage of narrowing the combined width of the trench and construction access required for the CSO pipeline.

Placement of the effluent pipeline away from the railroad track and along the fence line would eliminate the need to provide a pipeline capable of withstanding the railroad traffic loadings throughout its entire length. This alignment would involve additional construction cost due to the need to shore two trenches instead of one, however.

9.4.2. Treated Effluent Discharge System Alternatives Evaluation

The original preferred alternative (with both an influent and an effluent pump station) was compared to the two gravity discharge alternatives with respect to performance, economic costs, and technical and environmental factors.

Performance. From a system performance perspective, all three alternatives would meet the hydraulic design goal of passing all flows during Design Storm 6, the one per year event, in that all three configurations would discharge up to 200 mgd of treated effluent to Elliott Bay during all tide conditions

Economic Costs. Economic comparisons of the recommended CSO control Alternative 3 and the gravity-pressure alternatives are shown on Table 9-9. All costs were prepared on the same basis as described previously in this chapter. The alternatives were compared based on total present worth costs, including capital, operation and maintenance, and salvage values.

Table 9-9. Effluent Discharge System Alternative Costs (in $millions)

(All costs in first quarter 1996 dollars, *ENR CCI = 5537*)	Preferred Alternative 3	Elevated Effluent Discharge Structure	Low Effluent Discharge Structure
Total project cost	$105.9	$101.4	$105.4
Present worth O&M cost (20 years at 7.625 percent)	$5.1	$3.9	$3.2
Less salvage value	($9.2)	($10.3)	($11.7)
Total present worth cost	**$101.8**	**$95.1**	**$97.5**

Both gravity flow alternatives have lower present worth costs than original preferred alternative, Alternative 3. The lower costs result from the elimination of the one pump station and resulting lower annual operation and maintenance costs.

Technical Factors. The gravity-pressure effluent alternatives are easier to operate and maintain than the original preferred alternative with its two pump stations because the flow would be pumped to a constant discharge water surface elevation (either above elevation 125- or 114-feet) and the pumps would essentially operate as a low head lift station. Under the original preferred alternative, the effluent pumps would operate against varying discharge head conditions, depending upon the Elliott Bay tide elevations.

In addition, the two gravity effluent alternatives would have longer disinfection detention times than preferred alternative because of their lower effluent pipeline velocities. Based on a maximum daily treated effluent flow rate of 80 mgd, the detention times would be 14 minutes for the elevated discharge alternative and 28 minutes for the low discharge alternative, compared to the 10 minutes detention time provided with the original preferred alternative. Additional detention time would increase the effectiveness of the disinfection system and reduce chemical demand.

Environmental Factors. There would be a slight reduction in noise and energy consumption with the gravity-discharge alternatives as compared to the original preferred alternative because of the reduced pumping requirements.

9.5. Modified Preferred Alternative

Based on the additional engineering and evaluation done on the original preferred alternative, several modifications were made. The smaller of the two pump stations was eliminated from the configuration, and the treated effluent would flow by gravity to Elliott Bay from an elevated effluent discharge structure (above elevation 125.) The Elliott West effluent force main would be increased in size from 72-inches in diameter to 84-inches and would become a gravity pipeline rather than a force main. The diameter of the Elliott West outfall pipe would be increased from 72- to 84-inches as well. The Elliott West outfall pipe would remain offshore from the Denny Way regulator station. As described in Chapters 6 and 8, the pipeline would extend about 500-feet offshore to just beyond the Denny Way sediment cap, where it would terminate in 60- to 70-feet of water. The Denny Way CSO outfall extension would be shortened so that it would terminate approximately 90-feet offshore, the crown of the outfall extension pipe being about 12-feet below mean lower low water so that it would remain submerged during the lowest tides. The preferred alternative thus modified is more completely described in Chapter 10.