would be accommodated in the existing collection, interceptor, and trunk systems. No flow would be diverted into the diversion structure and Elliott West CSO pipeline during low or average flow periods.

In the new Denny diversion structure, the existing Denny/Lake Union and Denny local pipes would be open above the springline once they enter the structure. Wastewater from those pipes would fall over weirs and be diverted into the Elliott West CSO pipeline for conveyance to the Elliott West CSO control facility. The weir elevations at the diversion structure would be 110-feet for the Denny/Lake Union pipeline and 105.5-feet for the Denny local pipeline. Storage capacity would be reached during exceptionally intense storms (such as the November 1978 storm), and flows in the Elliott West CSO pipeline would back up to the diversion structure, causing untreated overflows at the Denny regulator station.

Construction Considerations. A primary construction consideration will be crossing the railroad tracks at the north end of the alignment. The Elliott West Effluent Pipeline, the CSO Pipeline and the system must all cross the tracks for a distance of approximately 400-feet. The heavily used railroad tracks include BNSFRR mainline tracks on the east side of the crossing, and Cargill Grain Terminal tracks on the west side. While preliminary drawings indicated that the CSO and Effluent pipelines would be 84-inch and 96-inch diameter, respectively, it is anticipated that both lower crossing pipes will be 96-inch inside diameter under the tracks. BNSFRR requires a 5.5-foot minimum cover under mainline tracks. With nominal top of track elevation at 112-foot, the invert of the 102-inch EBI at approximately 90.5-feet and the 5.5-feet minimum cover requirement, there is insufficient vertical room to locate the pipelines above the EBI. Initially, the preferred railroad crossing alignment was at invert elevations of approximately 80-feet, to minimize the depth of structures and the pipelines while meeting the vertical constraints described above. Subsequent geotechnical information has revealed that at that depth, there is a high probability that boulders, wooden piles, a high fluctuating water table and mixed face conditions very unfavorable and risky for tunneling operations would be encountered.

The pipelines must meet the E-85 railroad traffic-loading requirement. The Denny area pipeline alignments would be approximately 200-feet west of the EBI alignment for approximately 1,700 feet and approximately 15-feet west of the EBI for the remainder of the alignment. According to information presented in Section 7 of the May 31, 1967, *Final Report, Soils Investigation, Elliott Bay Interceptor* (Metropolitan Engineers), the subsurface profile along the pipeline alignment consists of 20- to 25-feet of mixed fill soils followed by 10- to 15-feet of marine silty sands to clean sands with shell fragments overlying dense or hard glacial soils. The fill appears to be a mixture of silt, sand, and gravel with some fragments of wood, brick, concrete, and glass. The borings encountered cobbles at several locations. Based on sampler penetration resistance values (i.e., blow counts), the fill is medium dense to dense with occasional loose or soft zones. The top of the marine sand layer is typically encountered at elevation 85 feet. The character of the marine sand varied from loose to dense, with loose zones as much as 5- to 7-feet in thickness. The glacial soils consist of hard clay or very dense silty sand and gravel.

Geotechnical investigations conducted for the Denny Way CSO project (Hong West, January 1998) found that on the northern area of the site soils consist of relatively clean controlled fill (predominantly sand and fine gravel and some zones of silt and clay). On the southern area of the site, underlying soils consist largely of uncontrolled rubble fill with large boulders and debris. There is also evidence of contamination that will most likely require special handling and disposal procedures. There is the potential for heave at the south end.

For cost-estimating purposes, Alternative 2A was used where all pipelines were to be placed in the same trench. Imported backfill materials for the pipelines would be compacted to 80 to 85 percent compaction in accordance with WSDOT Test Method No. 613. The cost estimates also assumed that pipe bedding and zone material would have to be imported. Detailed geotechnical investigations would determine bedding and over excavation requirements. Excavations would need to be shored.

Other design and construction considerations include:

- Odor control. Odor control would not be required.
- Groundwater. Groundwater is probable in the excavations and might need treatment to remove contaminants before discharge.
- Architecture. No architectural issues need to be addressed, as all structures would be below grade.
- Staging area. Storage for pipeline material and excavated soil will be needed.
- Surface restoration. Paved and concrete surfaces must be returned to their original condition.
- Landscaping. All affected existing landscaped areas must be restored. No additional landscaping beyond the construction zone is proposed.
- Utility conflicts. No major utility conflicts have been identified.
- Cultural resources. Monitoring of all areas with a high potential for cultural resources (historic and archaeological) must be undertaken during construction.

10.3.4 Mercer Street Tunnel

The Mercer Street tunnel provides most of the storage capacity required by the project to control Lake Union CSOs and the Denny Way CSO to one untreated discharge per year. This section describes the preferred Mercer Street tunnel alignment and final tunnel configuration, and summarizes tunnel construction. The Mercer Street Tunnel is described in more detail in Appendix A-, Design Report.

Tunnel Alignment. The tunnel would be provided with permanent access through the east portal and drop structure and the Elliott West CSO control facility pump station wet well. Access for such equipment as a "Bobcat" type machine is also provided at the wet well.

One of the first alignments evaluated would locate the tunnel with a west invert elevation of 97.0-feet and an east invert elevation of 101.5. The horizontal alignment would be under Mercer Street, turning northward at Broad Street and terminating at Roy Street. This alignment had a conflict with the Broad Street undercrossing structure (where Broad Street crosses under Mercer Street). As-builts revealed that the top of the tunnel bore would pass within 3-feet of the bottom of the pilings supporting the structure. In addition, the tunnel bore would pass within less than one tunnel diameter of the abutment foundation. Weaving the tunnel through the foundation elements would pose a serious risk to the stability of the structure because the required tunnel diameter is so large and because the Broad Street alignment crosses under Mercer Street at about 45 degrees. The undercrossing problem was further complicated by the presence of a number of utility lines in the vicinity of the undercrossing. Utilities in this area include a water main, a 48-inch sewer line, storm drains, and two inverted siphons that serve the Central Trunk sewer. The problem with utilities at the undercrossing added to the need to find a suitable alternative alignment.

The initial tunnel alignment also required the west portal to be located on the east side of Elliott West; not allowing the tunnel to extend to the Elliott West CSO control facility. To locate the portal east of Elliot Avenue West would have required excavation into a potentially unstable hill. Apartment buildings are located at the top of the slope, emphasizing the importance of maintaining hillside stability during construction. One potential method to stabilize the hill would be to use a tied-back retaining wall (approximately 40-feet high). This wall could be constructed to allow the tunneling machine to enter the hillside and would remain in place until the tunneling and lining operations were complete. The portal wall would be buried upon completion of construction of the other west portal components. Shoring would also be required for the sides of the portal. This shoring would need to be designed to allow minimal settlement. It is essential, given the proximity of adjacent structures (particularly on the south side), that settlement tolerances be small.

In addition to shoring, existing utilities would need to be relocated and protected. A 20-inch water line located 10 feet north of the centerline of West Mercer Street would require relocation. The West Mercer Street right-of-way also contains a communication duct on the north side of the right-of-way that must be projected when relocating the water line and during excavation.

In order to convey the tunnel flows to the Elliott West CSO control facility site, a 144-inch pipe would be either laid in a temporary open trench excavation or jacked beneath Elliott Avenue West. There is a potential for utility conflicts that might require open trenching. If open trenching occurs, traffic will be impacted.

Two additional alternative horizontal alignments were analyzed, 1) West Olympic Place and Valley Street, and 2) under Mercer Street to the Seattle Center parking garage, then jogging the tunnel north to Roy Street. The Mercer-Roy alternative was selected because the Olympic Place-Valley Street alternative would impact Kinnear Park at the west end and would require boring under a privately owned structure, the Bayview Manor Retirement Home. In addition, cost estimates indicated that the selected alignment would cost approximately 18 percent less than either of the other two alignments.

A further refinement of the tunnel vertical alignment occurred during the preliminary design phase, resulting in a decision to lower the tunnel by about 20-feet at both east and west portals. The revised vertical alignment allows the tunnel west portal to be located at the Elliott West CSO control facility site, eliminating the need for the hillside shoring and trenching across Elliott Avenue West. By lowering the profile and by reviewing the Broad Street structure, it was determined that the best horizontal alignment was under West Mercer Street the entire length except the east end, which will include a jog from Mercer Street to Roy Street between Dexter Avenue North and 8th Avenue North.

An evaluation was conducted to determine whether the south Lake Union CSO pipeline could be routed farther to the north, thereby reducing construction impacts to Broad Street, a heavily traveled corridor for commuter and special events traffic. Alternative alignments that carried the pipeline to the north, bypassing Broad Street and intersecting the tunnel from the north were analyzed. A relocation of the east portal one block north to Valley Street was considered as a way of shortening the Lake Union CSO pipeline and possibly reducing some costs. However, the result of this evaluation showed that all of the pipeline alignments north of Broad Street were more expensive than the original alignment in Broad Street. As a result, relocation of the east portal to Valley Street was not given further consideration.

The preferred tunnel alignment is shown in Figures 10-30, 10-31, and 10-32. The entire alignment is located within public right-of-way.

The Mercer Street tunnel will require the following permanent easements from the City of Seattle:

1. Elliott Avenue West--from the Elliott West site to the east side of the street.

2. West Mercer Street and Mercer Street--from the east side of Elliott Avenue west to 8th Avenue North.

3. East tunnel portal and drop structure -- at 8th Avenue and Roy Street.

Tunnel Configuration. The Mercer Street tunnel includes the following elements:

- A 6,200-foot-long, 14- to 16-foot diameter tunnel extending beneath West Mercer Street from Elliott Avenue West to near the intersection of Roy Street and 8th Avenue North.

- A drop structure at the east portal near the intersection of 8th Avenue North and Roy Street. The drop structure would connect the tunnel with the Lake Union CSO pipeline and allow entry of flows diverted from the Central Trunk and Lake Union tunnel.

- Access at the west portal which will be incorporated into the Elliott West CSO control facility pump station wet well.

The elements of the Mercer Street tunnel project are described in more detail in the following paragraphs:

Figures 10-30 through 10-32 show the plan and profile of the Mercer Street tunnel. The tunnel alignment lies within existing street rights-of-way. The tunnel would have an invert elevation of 83-feet at the east portal and 75-feet at the west portal. The tunnel lining would either be precast or cast-in-place concrete and could be constructed in either single or multiple passes. Because of the minimal slope, the lining must be as smooth as possible to facilitate movement of debris as the tunnel fills and drains.

The tunnel would be provided with permanent access through the east portal and drop structure. Access from the west portal would be through the Elliott West CSO pump station wet well. No permanent facilities such as wash down water, lighting, or ventilation would be provided. Temporary utilities must be provided as needed during cleaning and other maintenance activities.

This underground concrete structure would be constructed in the excavation made to extract the tunneling machine. The drop structure would contain a spiral drop, which is required to convey the wastewater flows from the Central Trunk to the tunnel. The structure would also receive flows from the south Lake Union CSO pipeline and the Lake Union tunnel CSO pipeline. The drop structure would contain a permanent access shaft for maintaining the tunnel. A concrete lift slab would cover the access shaft. Manhole access would also be provided.

The drop structure would vent when the tunnel fills with wastewater. It is anticipated that this air would require odor control. An underground space in the drop structure would allow room for the odor control equipment. This space would have access to the street above via a hatch and a concrete lift slab.

The west portal will be located on the Elliott West CSO control facility site. The west portal will be the discharge point of the tunnel into the pump station wet well. Maintenance access into the tunnel will be provided through the wet well.

Tunnel Cleaning. Some solids deposition in the tunnel is expected to occur because of the minimal slope and the resulting low water velocities in the tunnel. The amount of deposition depends on the characteristics of the wastewater, amount of water stored in a storm event, and the duration of the storage. The amount of deposited material has not been estimated.

Sediment accumulation in the tunnel can be addressed in several ways:

- The solids could be left in place after the tunnel has drained.
- The tunnel could be designed in such a way as to increase scour.
- The tunnel could be flushed after the storm event has passed and the tunnel has been drained.
- The tunnel could be manually cleaned following draining.

The following paragraphs briefly address these alternatives.

Leave Sediment in Place. Solids deposited in the tunnel would not affect operation of the storage facility until a significant amount had been deposited. Some scouring of the sediments can be expected as the tunnel fills or empties (and higher velocities are present); large amounts of materials probably will be carried out of the tunnel. However, the deposited materials would create a continuing odor problem. It is likely that wastewater would pond in sections of the tunnel as increasing amounts of material are added to the sediments in the tunnel, adding to the odor problem.

This alternative is not recommended because of the likelihood of odor problems from the sediments and trapped wastewater.

Tunnel Modifications. A number of tunnel modification alternatives have been suggested for increasing scour velocity or lowering the friction coefficient so solids move more easily through the tunnel. In some installations, it has been possible to increase scour velocities by installing a low-flow channel in the tunnel invert (also known as a "cunette"). This could concentrate the flow in a smaller channel, thereby increasing the velocity of flow at low flows.

The velocities in the tunnel would be lower than those due to gravity flow because the stored water in the tunnel would be slowly released into the Elliott Bay interceptor. Scouring velocities could be achieved in the channel during some periods of filling and emptying. The cunette allows scouring velocities to occur at lower flows.

The shelves on either side of the cunette will be sloped. Solids would be deposited on these nearly flat areas and would not be transported by flows in the narrow, low-flow channel. The combination of bench and cunette allows velocities to be higher at all times during tunnel fill and draw.

The cunette could be installed to assist in a cleaning phase of the tunnel's operation. This would increase the velocities within the tunnel and assist in removal of solids when a relatively low rate of water is used to clean the tunnel.

Lining the tunnel with plastic may reduce the adhesion between the sediments and the tunnel lining, thereby allowing the solids to move more easily. Lining the tunnel invert, possibly in combination with a washdown or flushing system, could increase the effectiveness of an automatic cleaning system. However, slick conditions at the tunnel invert could pose a risk of injury to maintenance personnel.

Tunnel Flushing. Flushing could be accomplished in various ways. An automatic or manual washdown system designed to use either potable or non-potable water could be mounted in the tunnel. An alternative approach involves constructing a holding tank at the upper end of the tunnel. The tank would be designed to empty suddenly after the tunnel is drained, with the resulting deluge carrying sediments to the lower end of the tunnel for disposal.

A washdown system would consist of a series of spray nozzles along the length of the tunnel. These nozzles would be fed by pipes mounted along the tunnel lining (embedding the pipes in the lining would be costly and difficult to accomplish). The nozzles would operate in a sequential pattern to move debris along the tunnel to the lower end. Although non-potable water could be used for this application, there is no ready source, so potable water would most likely be used. Assuming an effective nozzle pattern could be developed, the primary drawbacks of this system would be the demand for potable water and the maintenance problems associated with debris hanging up on the exposed pipes and nozzles. It may be possible to minimize the latter problem in design of the piping system. However, experience at other CSO tank and conduit installations around the country has shown that such washdown systems rarely operate effectively.

The deluge system, which has been used effectively in Europe, has a simpler design than a washdown system. A holding tank at the upper end of the tunnel fills with wastewater before flows enter the tunnel. The tank retains its contents until the tunnel has been completely drained. The tank empties suddenly after receiving either a mechanical or electrical signal--creating a wall of water that would move along the tunnel, suspending the sediments and carrying them to the lower end for disposal. One example of a deluge system is the HydroSelf Flushing System manufactured by Steinhardt Water Technology Systems. This system has few moving parts and is simple to operate. This type of cleaning method can be incorporated into the Mercer Street tunnel by using upgradient pipe (the south Lake Union CSO pipeline, Lake Union tunnel CSO pipeline) to store flushing water. Gates could be installed to release pulsed flows. Connections for the use of potable water and/or trucked reclaimed water can be made to the system for interactive flushes. The major drawback is the lack of operating experience in this country and the possible lack of experience with circular cross sections.

Manual Cleaning. Manual cleaning would involve personnel entering the tunnel and removing the sediment after the tunnel has been drained. Manual cleaning of more than a mile of tunnel for routine debris removal is unlikely to occur due to staffing demands. Manual cleaning would be more feasible as part of an annual or biannual program of tunnel inspection and maintenance during the dry months of the year.

Recommended Cleaning Method. It is recommended that tunnel flushing using potable, reclaimed, or non-potable water with gates installed to release pulsed flows, be implemented in combination with a tunnel cunette.

Odor Control. The east portal and drop structure would vent air during CSO events, creating odorous conditions. The wastewater would form a vortex as it drops into the tunnel portal, and air can be displaced at the top and bottom of the vortex. Air would be exhausted from the bottom of the vortex and from the top of the drop structure and from the tunnel during the filling phase. It is estimated that the air would contain 1 ppm H_2S. The foul air would be treated in a carbon absorber. Odor control at the west portal would be incorporated into the Elliott West CSO control facility.

Construction Considerations. Preliminary geotechnical investigations conducted along the tunnel alignment consisted of nine borings to a depth below the invert of the tunnel, laboratory tests on recovered soil samples, and installation of piezometers to measure groundwater in each hole. These studies indicated that the tunnel would likely be driven through dense clays and dense silts, sands, and gravels. The sands and gravels are anticipated to be water bearing, although the amount and rates of flow are unknown. Groundwater was encountered up to 60-feet above the crown at the west end of the tunnel and approximately 15-feet at the center and east end of the tunnel. Groundwater levels in the piezometers were recorded during the spring and summer of 1996 and are continuing in 1997 to gain a better understanding of the groundwater conditions at the tunnel level.

The Mercer Street tunnel is anticipated to be a “soft ground” structure (mined in soil, not rock). Consistent with generally accepted practices in the industry, mining would likely take place from the low end to the high end of the tunnel (west to east). All spoils handling and staging would be required to take place on the Elliott West CSO control site, which is consistent with a west-to-east mining operation.

Based on geotechnical information obtained to date, it is assumed that a mining machine capable of operating under high groundwater conditions would be used. An alternative, if groundwater conditions are severe, is dewatering from the surface ahead of the mining operation; however, this would increase the impacts of construction on the heavily used Mercer Street traffic corridor.

Mining is expected to follow conventional practices. The tunneling machine would be placed in a trench at the west portal and begin mining to the east. As soil is removed from the face of the tunnel, it would be conveyed to railcars by belt or screw conveyor. When the rail cars are full, they would be moved out of the tunnel to the Elliott West site, and unloaded. Two or three trains of “muck” cars would be used to maintain forward progress at the tunnel face.

As mining proceeds, the tunneling machine moves by jacking against installed sections of the tunnel lining system. Once the hydraulic jacks have been fully extended, they are retracted and a ring of lining is installed. The lining ring elements are conveyed to the machine via the muck train. Once the new ring is installed, the hydraulic jacks are used to jack the tunneling machine forward for another cycle of mining. The tunneling machine would be removed from the tunnel at the east portal after the mining operation is completed. A pit would be constructed at the east portal where the tunnel boring machine could be disassembled and removed. The tunnel will be lined either with a single or multiple-pass lining system. If a multiple-pass lining system is used, final lining would take place after mining operations are complete.

West Portal. The west portal will be located at the Elliott West CSO control facility. Excavation of tunnel spoils will be through this portal. Because of the portal’s depth, it may not be possible to use a rail system to remove spoils from the tunnel. In this case, a clamshell or other removal methods could be used. Tunnel spoils removal will be addressed during final design.

East Portal and Drop Structure. Excavation would be required at the east portal to remove the boring machine from the tunnel. Temporary shoring (either tied back or braced) would be used. Once the tunneling machine is removed and tunnel construction is substantially complete, the east portal and drop structure would be constructed in the excavation. The temporary shoring can serve as forms for the concrete drop structure. Settlement tolerances must be small because of the presence of a masonry structure on the north side.

Dewatering. The tunnel invert and the invert of the pipeline on the west end of the tunnel would be below the water table. Dewatering would be necessary during construction of the east and west portal excavations. After construction dewatering would not be required. This temporary dewatering would be required as long as the excavations are open.

10.3.5 Elliott West CSO Control Facility

The Elliott West CSO control facility would be the treatment component of the Denny Way/Lake Union CSO Control Project. As shown on the site plan in Figure 10-33 and the section views in Figures 10-34 and 10-35, facilities that would provide the CSO treatment (i.e., floatable material control and disinfection) are as follows:

- Pump station
- CSO treatment structure
- Chemical storage and odor control area

Each of these facilities is described in detail in Appendix A - Design Report. The facilities are more briefly described in the following paragraphs.

Wet Well/Dry Well. Flows from the Mercer Street tunnel and diverted flows from the Elliott West pipeline and EBI will discharge to the pump effluent channel. The pump station would be a covered concrete structure that would allow pumps to be removed or serviced in-place. The station would contain a pump room, an electrical and control room, and rooms to accommodate ventilation equipment and carbon adsorbers for collecting and treating the odorous air from the pump station.

The pump station would be configured as a lift station, with each individual pump discharging to the pump discharge channel. A dry pit/wet pit configuration was selected. All the pumps would be the same size and each would have its own variable-speed drive unit. Total station capacity would be 250 mgd, or 174,000 gallons per minute (gpm). The preferred arrangement will have six pumps installed initially with space provided for a seventh future pump. Each duty pump will have the capacity to pump 42 mgd, or 29,000 gallons per minute.

No redundant pump is provided because the facility will be operated intermittently, with all pump standing idle 95 percent of the time. Therefore, there will be ample time for routine maintenance and testing to ensure that the pumps will operate when needed. Based on an 11-year simulation, all six of the pumps would be used only one to three times per year. The average number of times per year that different numbers of pumps are operating is shown in Figure 10-36.

Wet well dimensions are kept to a minimum through the application of variable speed pumping. Odors are kept to a minimum by design features that eliminate turbulence and prevent solids accumulation. Two trash pumps would be provided at the end of the wet well to allow complete drainage following a storm event.

The Elliott Bay interceptor control structure enables wastewater to overflow via the system drain into the pump station. Because of this connection, there is an air path from the Elliott Bay interceptor to the pump station wet well. Wastewater flows continuously in the Elliott Bay interceptor and is known to be high strength, high in sulfide, and odorous. If no ventilation were provided, the odorous air would continuously promote corrosion in the system drain and the pump station wet well both during CSO events and especially during non-storm periods. The nonstorm periods most frequently occur during summer months, when wastewater strength, odors, and corrosion potential are highest.

Exhausting air from the pump station wet well would induce an airflow through, and provide purging of, the system drain. It would also lower the air pressure in the Elliott Bay interceptor and reduce odorous emissions from Elliott Bay interceptor manholes in the vicinity. During a storm event, 7,000 cfm of headspace air will be expelled to the wet well from the Mercer Street tunnel. A continuous ventilation rate of 9,000 cfm would be sufficient to handle the head space air flow during storm events and prevent corrosion from the residual liquid that remains in the tunnel. The carbon unit would be designed to provide 4.6 air changes per hour during non-storm conditions to provide corrosion protection to the wet well and lower end of the tunnel and 12 air changes per hour during storm conditions to provide odor control for the site. For the rare occasion when maintenance access to the wet well is required, temporary ventilation would need to be provided.

Pump Effluent Channel. The pump station effluent will discharge into the pump effluent channel, where floatables control will occur. The floatables control system is intended to remove floatable materials from the stored CSO. Floatable materials include materials such as plastic (bags, bottles, wrappers, utensils, 6-pack holders), metal (bottle caps, cans, foil, wrappers), polystyrene (cups, food containers), rubber, glass, paper (cigarettes, cups), wood, cloth, and other types of waste.

The pump effluent channel will be equipped with vertical fixed screens for floatable material control. As flow is pumped from the wet well, the water level in the channel will rise until the flow passes through weir-mounted, mechanically cleaned, horizontal or vertical screens, where the rake mechanism will return the floatable material retained on the screen directly back to the pump effluent channel. The flow will over-top the screen in case of plugging or emergency. After a storm event, the captured floatable material in the pump effluent channel will be drained into the Elliott Bay interceptor. Any grit or residual settled solids will be removed by a manual washdown system and washed into the Elliott Bay interceptor.

Flow Measurement. Flow will be measured using flow measurement devices on the pump discharge pipelines. Flow to the Elliott Bay Interceptor and to the Elliott West Outfall will be measured, recorded, and totalized.

Disinfection. Disinfection of all flows to the Elliott West outfall would be required. Sodium hypochlorite would be used for chlorine disinfection. The sodium hypochlorite would be injected at a dose of 15 mg/l of free chlorine. Induction mixers similar to Water Champ will be used to mix the sodium hypochlorite into the flow at the effluent end of the outfall channel before discharge to the Elliott West effluent pipeline.

Bacteria kill equations, bacteria loading, water quality standard-based discharge goals and chlorine dosing were employed to predict system effectiveness. The effectiveness of chlorine in disinfection is directly dependent on the chlorine dose, the detention time and the degree of mixing (usually expressed in terms of the velocity gradient), and inversely dependent on suspended solids concentration and pH. Most guidance manuals were developed for continuously operating wastewater treatment plants where day to day variations and the need to minimize the use of chlorine are important factors. In normal treatment plants, the chlorine dose is optimized to provide coliform kills while maintaining a minimum chlorine residual. In an intermittent system with infrequent discharge (e.g. 4 to 20 times per year at Denny), use of a standard wastewater treatment plant disinfection strategy is neither appropriate nor cost-effective.

A strategy that takes full advantage of the dose-detention time relationship using higher chlorine doses to accommodate lower detention times accomplishes the goal at an intermittent facility.

The disinfection strategy developed for the Denny facility was based on observation of performance at the Alki plant during CSO flows with confirmation by bench scale tests with actual Denny overflows. Disinfection data from the Alki plant were analyzed to show the relationship between effluent fecal coliform counts and the product of chlorine dose and detention time. The Alki data are shown in the Figure 10-37. Figure 10-37 also shows a simplified relationship (line) derived from literature values. A dose-detention time value of 60 will achieve an effluent fecal coliform concentration less than the 400 counts/100 ml target (the relationship shown indicates about 150 at this CT value). Thus, if the detention time is 5 minutes, this indicates a necessary chlorine dose of 12 mg/L. The effluent will be dechlorinated prior to discharge to meet the receiving water criteria.

Figure 10-38 shows the results of bench scale disinfection tests using samples collected from actual Denny overflows. Chlorine residuals in these tests ranged from about 1.0 to 7.0 mg/l with contact times of about 1 minute to 20 minutes. The bench scale tests confirm the use of the relationship developed from Alki data.

For dechlorination, sodium bisulfite would be injected immediately upstream of the transition structure to the Elliott West outfall. The sodium bisulfite system would be designed to feed at a maximum rate of 30 mg/l. A diffuser and static mixer will be used to mix the sodium bisulfite in to the Elliott West outfall pipe at the injection structure. Dilution water would be needed to maintain a minimum velocity of 2 feet per second in the 2-inch sodium bisulfite feed line, which conveys sodium bisulfite from the Elliott West site to the transition structure. A 6-inch sleeve or double-containment pipe would be used to contain chemical leaks and provide protection from above ground loads. The control system will include several fail-safe options, which will shut off the sodium hypochlorite feed when the dechlorination system is not functioning. The system will include both alarms and shutoff based on the bisulfite pumps, a flow signal and the chlorine residual analyzer.

Chemical Storage and Feed Facilities. The chemical storage area would be covered, but not completely enclosed. The 4-foot-high concrete walls would contain chemical spills. A chemical feed station with valves and quick disconnect type fittings would be provided for filling the tanks.

The area will include two 7,500-gallon capacity sodium hypochlorite tanks and two 5,500-gallon capacity sodium bisulfite tanks.

Variable-speed, hydraulically actuated metering pumps would be used to transfer the chemicals from the tanks to their respective injection points. The metering pumps would be housed in the chemical storage and feed building. Variable-speed control would be provided because the required amount of chlorine would be expected to vary during a storm and over time as the sodium hypochlorite decays and loses strength.

Odor Control. Odor control will be incorporated into the design of the Elliott West CSO control facility. This area will have high turbulence and emissions when in operation. The area will be ventilated at a rate of 12 air changes per hour. This corresponds to a ventilation rate of 11,900 cfm. The ventilated air will pass through activated carbon filters prior to discharge into the atmosphere.

Electrical Power Supply and Reliability. The estimated electrical power demand at the peak design flows is expected to be 2.5 to 3 megawatts (MW). The majority of the power demand is associated with the pump station. Other electrical demands, such as lighting, sluice gate operators, sump pumps, chemical feed pumps, ventilation equipment, and other miscellaneous equipment will be minimal compared to the pumping loads.

Reliability guidelines established by Ecology recommend two separate independent sources of power be provided from separate electrical substations or from a single substation and onsite standby power generation. These guidelines are intended to ensure that continuously operating wastewater treatment plants are able to continue operation of critical facilities in spite of a failure of one power source. Although some treatment elements are considered critical facilities in a continuously operating treatment plant, a different approach is appropriate for an intermittent facility, because the operational strategy allows for one untreated overflow per year. As discussed below, the chances of an overflow resulting from power failure are very low. Therefore, critical elements of the Elliott West CSO control facility would be limited to gates, lights, and controls necessary to operate the system during power outages.

Discussions with Seattle City Light (City Light) indicate that the Broad Street substation is the closest source of electrical power and is a highly reliable power supply source. Historical data indicate that there have been five significant outages (more than 1 minute in duration) over the last 4 years. None of these outages were simultaneous to both feeders. Furthermore, the possibility of a simultaneous outage on the feeders combined with a significant rainfall event is unlikely. Records and discussions have confirmed that an outage is more likely a result of overhead line transmission failure than from complete substation outage. However, even overhead transmission lines from Broad Street have had a high degree of reliability.

The Canal and Ballard substations were identified as possible sources for utility-supplied backup power. However, Seattle City Light stated that the location to the Elliott West facility, configuration of the existing power distribution system, and the environmental issues related to providing a second independent power source from either of these substations would make the cost prohibitive. In addition, Seattle City Light indicated that the greatest threat to the primary power source (Broad Street substation) is a regional brown out, which would make the Canal and Ballard substations ineffective as an emergency power supply source.

There are five potential alternatives for providing power to the Elliott West CSO control facility from the Broad Street substation. The first alternative consists of two existing overhead feed lines originating from Broad Street substation. These existing feeds, 2600 and 2659, are located on the same poles and pass adjacent to the site along Elliott Avenue West. City Light indicated that the existing feeds provide a strong and reliable distribution system. City Light has already planned improvements to accommodate an additional 12 MW of new electrical load for the proposed Immunex facility to be located near Pier 91. New electrical power loads for the Elliott West CSO control facility could be accommodated and integrated into the planned City Light improvements.

Outage records for the two feeders from January 1, 1993, through September 30, 1996, were obtained from City Light to evaluate their reliability. Seattle City Light does not have outage records covering the last ten years. The records indicate that the existing feeders have been very reliable over that period. The records show a total of five significant outages with an average outage length of less than 1 hour, and at no time have the two feeders been down simultaneously. In addition, there were seven outages of less than 1 minute in duration. The hydraulic model simulations indicate that a small (30 minute) discharge event would have occurred on the same day as one of the outages on one of the feeders. If these two feeders had been the primary and alternate supply over this 4 year period, there would have been no loss of power to the site. When placed in context with the intermittent operation of the Elliott West CSO control facility, these records indicate existing feeders offer a high level of reliability. The estimated planning level construction cost for two separate electrical feed lines from the existing overhead power lines along Elliott Avenue West to the Elliott West CSO control facility is $80,000.

A second power feed alternative consists of connecting to the Broad Street substation through one of the adjacent overhead lines and installing an alternate above ground feed mounted on different power poles. This alternative may have a higher degree of reliability since both preferred and alternate feeds are not mounted on the same poles and are therefore less prone to simultaneous impairment from wind damage, vehicular contact, etc. The estimated City Light planning level construction cost to install a separate power line on different power poles is $250,000.

The third power feed alternative consists of extending two existing underground feed lines for the primary and alternate service for the Elliott West CSO control facility. These two feed lines presently serve the Seattle Center and terminate on its southwest side. The lines serve facilities with high reliability requirements, like the Opera House. This alternative would require extending cable through existing and new conduit from where the cable currently terminates to the Elliott West CSO control facility. The estimated City Light planning level construction cost is $1,200,000 to extend the power feed lines from the southwest side of the Seattle Center to the control facility through a combination of overhead and underground lines. This alternative would provide a higher level of reliability than either of the other two alternatives since it significantly reduces the outage risk inherent with overhead transmission lines. It does not completely eliminate that risk, since the alternate feed does have limited aboveground exposure.

The fourth alternative would be the use of onsite generators. The estimated planning level construction cost for permanent, onsite, 3-MW power generation is estimated to be $3,700,000.

The fifth alternative is to use the Broad Street substation as the sole power supply for the Elliott West CSO control facility. Based on the historical electrical feed line outage records, it appears the existing overhead power lines along Elliott Avenue West provide a level of reliability consistent with the facility operational strategy. Under this approach, no redundant power source would be provided except for a small, onsite power generator that would operate lighting, controls, and motor-operated gates in case of a power outage.

A 150 kW emergency generator set will be installed to provide power for critical equipment such as dewatering pumps, emergency bypass gates, and lighting, controls, and telemetry. Space would be allocated for the future addition of a larger standby generator to allow for possible changes in facility operational strategy, utility reliability, public perception, or CSO discharge requirements.

Protection for the pumps and forcemain against hydraulic transients caused by interruption of power to the motors will be provided in final design. Surge control requirements should be minimal due to the configuration of the station and discharge (very low head and short forcemain).

The first power feed alternative, including two separate electrical feed lines is recommended. It is possible to estimate the order of magnitude of the probability of a major power outage at the Denny site with the City Light data. The feeder outage data indicates that outages are not associated with major rainfall events and thus may occur on any day of the year. The observed reliability of the dual feeder system indicates that a major power outage at the Denny facility would occur only when there is a failure at the substation which has an occurrence frequency on the order on once in ten years. Since these events (heavy rainfall and substation failure) are independent, the joint probability is the product of the discharge probability (11 times every 365 days) and the probability of a substation outage (1 day in 10 years):

$$11/365*(1/10)=0.003 \text{ or about once in 300 years}$$

From the observations, the probability of simultaneous failure of both feeders to the site is even lower. If it were assumed that substation outages and major rainfall events were interdependent, the probability of an outage occurring during a discharge event would be once in ten years. Thus, the range of expected probability of outage associated with a discharge event ranges from once in ten to once in 300 years. This range of probability indicates that the occurrence of an untreated overflow associated with power outage will be so infrequent as to have a negligible effect on the overall long-term annual average. Due to this infrequency, strict application of the Criteria Book requirements to an intermittent facility would have little or no impact on the overall reliability of the facility to provide the treatment it is intended to provide. Therefore, King County proposes to provide two separate electrical feed lines to the Elliott West CSO Facility.

Construction Considerations. Construction considerations for the Elliott West CSO control facility include subsurface conditions, potential seismic impacts, below-grade structure foundations, above-grade structures, and dewatering. Each of these elements is discussed below.

Subsurface Conditions. Preliminary geotechnical investigations at the Elliott West site consisted of two exploratory borings extending to a depth of 78-feet below the existing ground surface. Based on the borings, the site appears underlain by a sequence of fill, beach deposits, glaciolacustrine deposits, and pre-Vashon drift. The fill soils consisted of poorly graded sand with gravel. Wood debris was observed in one boring location, and soil borings performed by others at the site noted brick and concrete debris in the fill soils. The fill soils appear to be approximately 12- to 15-feet thick from the ground surface. Beach deposits were observed directly below the fill soils. The beach deposits extended to a depth of about 28-feet below the existing ground surface. The beach deposits generally consisted of loose to medium dense, poorly graded sand with silt. Glaciolacustrine deposits were observed directly below the beach deposits. The deposits consist of very stiff to hard silt and clay with fine sand and silt partings, and the deposits extended to a depth of about 61- to 71-feet below ground surface. The pre-Vashon drift was observed directly below the glaciolacustrine deposit and consists of very dense silty sand and sandy silt with gravel. The drift extended to the bottom of the borings.

All areas with a high potential for cultural resources (historic and archaeological) will be monitored during construction.

Groundwater was encountered at depths of about 1.5 and 5.5-feet below ground surface during the borings. Groundwater readings were performed on a monthly basis from summer 1996 until spring 1997. From preliminary engineering work, the groundwater elevation was assumed to be 5 feet below ground surface, and flotation protection was recommended based on this groundwater elevation.

Potential Seismic Impacts**.** The existing fill/beach deposits could liquefy during a strong earthquake. Observations made during past earthquakes suggest that liquefaction could induce significant settlement and lateral ground displacements. The potential impacts of liquefaction-induced ground displacement to the proposed structures may be mitigated by over excavation or densifying the fill/beach deposits with stone columns. Pile foundations extending below the liquefiable soils may also be considered. However, vertical piles may not be sufficient to withstand the lateral loads resulting from a seismic event; use of batter piles may also be required.

Below-grade Structure Foundations**.** Based on the current proposed configuration, the pump station will be well below the assumed groundwater elevation of 105-feet. Under such a condition, large uplift pressures resulting from the high groundwater level would act on the structure. The uplift pressure may be resisted by the use of an 8- to 10-foot-thick concrete or “tremie” slab.

The bottom of the pump station excavation is anticipated to be located in glacial deposits and no additional foundation support method will be required. The two-story pump station electrical and mechanical rooms will be constructed using the same foundation systems as described for the above-grade structures.

Above-grade Structures. The CSO treatment structure and two-story electrical and mechanical rooms in the pump station will require the placement of compacted structural fill to raise the grade to the level of the proposed structures. Deep foundations will be required because of the presence of loose to medium dense fill and beach deposits, and high potential for liquefaction. There are two proposed methods for the foundation support system: pile foundations or in-place densification. The piles will be 18-inch-diameter augercast concrete piles with a design load of approximately 70 tons. The in-place densification method may include *in situ* vibration.

The chemical storage and odor control area will require the placement of structural fill to raise the grade to the level of the proposed structure. The foundation support system will consist of the over excavation of the near surface fill deposits and replacement with compacted structural fill.

Dewatering. Lowering groundwater levels for excavation could result in settlement of the fill soils. The potential impacts of dewatering on existing adjacent structures must be evaluated. It should also be noted that, as Elliott Bay is only a few hundred feet away from the site, dewatering systems may be pumping both fresh water and saltwater, depending on the duration of dewatering, tidal influence, groundwater gradients, depths of dewatering wells, and other factors. Other contaminants could be present at the site as well. Special groundwater disposal methods may therefore be required.

10.3.6 New Outfall and Existing CSO Outfall Extension

A new outfall would be required to discharge treated effluent from the Elliott West CSO control facility to Elliott Bay. In addition, an extension to the existing Denny Way CSO outfall would be required to comply with Seattle code requirements that outfalls be submerged at low tide. Currently, the Denny Way CSO outfall is completely above the water surface at low tide.

The conclusions of this preliminary design effort were based on preliminary information developed in the field, experience with similar projects, and the project team's best professional judgment. Changes to the design described in this report may be required as more information, particularly site-specific geotechnical information, is obtained. Detailed information on the design of the outfalls is given in Appendix A –Design Report.

Outfall Location. The control project described in the *1995 Denny Report* included both an outfall, that would be required for the discharge of flows from the Elliott West CSO control facility site (the Elliott West outfall), and an extension of the existing outfall at the foot of Denny Way (the Denny Way CSO outfall extension). The Elliott West outfall was shown to extend 1,600-feet offshore from just south of the Port of Seattle grain terminal. The Denny Way CSO outfall extension was shown to be 150-feet long.

Locating an outfall involves consideration of engineering, economic, and environmental factors, as well as constraints imposed by existing facilities. Several existing facilities adjacent to the Elliott West site would affect selection of an outfall alignment. These facilities include:

1. Port of Seattle grain terminal.

2. Designated offshore anchorage area.

3. Adjacent waterfront parks.

4. Fish pens operated by Point Elliott Treaty tribes.

5. Existing Denny Way CSO outfall.

Outfall location alignments for the Elliott West outfall that have been considered include 1) an outfall directly west of the Elliott West site, and 2) an outfall directly west of the existing Denny regulator. Only the Denny regulator alignment was considered for the Denny Way CSO outfall extension, since it needs to be close to the Denny regulator due to hydraulic constraints. Comparison of the two alternatives resulted in a decision to locate both outfalls at the Denny regulator site. This alternative is preferred for a number of reasons, including:

1. It is highly likely that terminating any outfall in the existing designated ship anchorage area would be dangerous from an outfall maintenance/repair standpoint, and obtaining a permit could be difficult. The Denny location is close to the southern boundary of the anchorage area.

2. The City of Seattle shoreline code requires that outfalls not be exposed above the mean lower low water level. That requirement will necessitate a transition structure from the existing outfall at Denny Way down to a submerged pipe section. The incremental cost of adding the Elliott West outfall to that transition structure would be relatively low.

3. The effluent pipeline required to locate the outfall south of the Elliott West site may be able to follow the corridor proposed for the Elliott West CSO pipeline from the Denny area north to the Elliott West site.

4. The effluent pipeline could be used to provide chlorine contact time to increase the efficiency of the disinfection process, thus avoiding the need for a chlorine contact tank at the Elliott West site.

Preferred Outfall Configuration. The alignment of the Elliott West outfall (shown on Figure 10-39) would start from the existing Denny Way CSO outfall location at the foot of Denny Way. The outfall would extend in a southwesterly direction so the discharge points for the outfall would be just offshore from the western edge of the existing sediment cap and outside the designated ship anchorage area. The sediment cap was installed in 1990, before the new secondary treatment facilities at West Point were constructed, to cover sediments contaminated by the local discharge of combined sewage over many years. Discharges from the new outfall would have the potential for scouring the cap sands.

The alignment for the Denny Way CSO outfall extension would move the point of untreated discharges about 90 to 120 feet offshore from its present location so that the existing outfall would remain submerged during the lowest tidal conditions. Treated effluent would be conveyed from the Elliott West CSO control facility by means of a 96- to 108-inch-diameter, approximately 3,000-foot long effluent pipeline beginning at the tunnel discharge structure and extending south to a thrust block to be built where the pipeline turns toward the water. From the thrust block, the outfall would extend to a transition structure, which would be built to decrease the elevation of the Elliott West outfall and the Denny Way CSO outfall extension to where they would be beneath the water surface of Elliott Bay during low tide. Twin outfalls would extend into Elliott Bay from the transition structure. The Elliott West outfall pipe would terminate in single port discharge at a water depth of 60- to 70-feet mean lower low water (MLLW), which is the normal tidal datum for offshore work. In the area studied, a 60- to 70-foot-deep outfall results in an outfall pipe length of about 490-feet.

The Elliott West outfall would be pile supported, consisting of precast reinforced concrete cradles and pile cap supported by three driven piles. The Elliott West outfall pipe would terminate with a single port (Figure 10-39). Figure 10-40 depicts three possible typical sections of the pipe. The pipeline may be at the mudline, buried to mid-depth with a concrete matress or buried to full depth as shown. Final outfall cross section will be determined during final design. A possible variation would be a multiport discharge, either in the form of several isolated ports or a more conventional diffuser section. These more complicated discharge arrangements have not been included due to their additional cost and because such discharge arrangements entail possible operational and maintenance difficulties. The Elliott West outfall is shown with a duck bill type of check valve on the end. Check valves are designed to prevent saltwater intrusion and entry of marine life into an outfall pipeline. However, check valves present maintenance and operational difficulties due to the infrequent CSO discharges.

The Denny Way CSO outfall extension would be a 96- to 120-inch-diameter outfall pipe, constructed in the same trench as the Elliott West outfall and terminating approximately 90-feet off shore. The crown of the outfall pipe would be 12-feet below MLLW to ensure that the pipe would remain below the surface of Elliott Bay during the lowest tide conditions. The extension will need to be angled upward or designed in such a way that scouring of the sediment cap sands is minimized. Specific measures to prevent erosion of the cap will be developed during final project design.

EBI Overflow at Denny Regulator. The current EBI overflow at the Denny regulator is at the crown of the interceptor, at approximately an elevation of 100-feet. In the new configuration, this overflow elevation needs to be raised to elevation 102.3 to achieve once per year CSO control.

Construction Considerations. Most of the outfall elements would be built by floating construction equipment. This equipment would include derrick barges to lift pipe sections, dredge unsuitable soils, place rock and gravel fills, and provides a platform to construct the transition structure. Deck barges, tugs, and workboats would support the derrick barges.

Construction of the transition structure would require driving temporary steel sheet piling and permanent piling. Concrete construction would probably require shore-based concrete trucks and concrete pumps. Dewatering pumps, lay-down area, and construction access roads would also be based on shore.

The short connection pipe between the effluent pipeline and the transition structure would be conventional, pile-supported pipe construction. That work would involve driving and removing sheet piling, driving steel bearing piles, excavation, backfill, and concrete cap construction. Due to the pipe's short length, the entire pipe excavation may be open at one time, thus hindering park user access across the corridor. The contractor will be required to provide a detour route and meet safety and control requirements.

During outfall construction, clean sediments and soils will be used as backfill or disposed of at the open water Puget Sound Dredge Disposal Application site in Elliott Bay. However, the outfall alignment will encounter contaminated materials, and construction will require special techniques to prevent their dispersion. Specific construction techniques to prevent dispersion would be prescribed on the contaminants encountered along the final outfall alignment.

Because of the large volume and the type of contaminants (organic and inorganic) likely to be encountered, treatment of the contaminated sediments and discharge to a clean water site will probably not be an option. Other disposal options will be evaluated, including capping and recapping and confined disposal at shoreline or upland sites. Contaminated materials will be disposed of in accordance with applicable regulations.

10.4 Operation and Maintenance Staffing Requirements

Operations and maintenance staffing requirements have been projected for operating King County's Denny Way/Lake Union CSO Control Project. Staffing requirements have been estimated for the following groups:

- *Administration*--Manages offsite facilities such as pumping stations, regulators, and disinfection facilities.

- *Operations*--Responsible for operation of the pumping stations, regulators, and disinfection facilities, including laboratory testing for process control and regulatory reporting.

- *Offsite Facilities Maintenance*--Performs light preventative maintenance of equipment and upkeep of Elliott West grounds; performs periodic cleaning of Elliott West structures after CSO events; performs periodic inspections of facilities to report physical conditions; performs major repairs of tunnel, pipelines, equipment, and regulators.

Table 10-6 lists a preliminary estimate of staffing levels for the project. Major factors affecting staffing levels include:

- Frequency of operation
- Complexity of operations
- Frequency of cleaning after CSO events
- Level of automated control

Table 10-6.
Proposed Staffing of Denny Way/Lake Union Facilities

Staff category	Number of full-time equivalent (FTE) people[a]
Administration	0.1
Operations	0.4
Offsite facilities maintenance	1.0
Total staffing requirement	**1.5**

[a] One full-time equivalent employee is based on 1,850 hours per year.

10.5 Predicted System Performance

10.5.1 Floatable Materials Control

The pump station effluent will discharge into the pump effluent channel, where floatables control will occur. The floatables control system is intended to remove floatable materials from the stored CSO. Floatable materials include materials such as plastic (bags, bottles, wrappers, utensils, 6-pack holders), metal (bottle caps, cans, foil, wrappers), polystyrene (cups, food containers), rubber, glass, paper (cigarettes, cups), wood, cloth, and other types of waste.

The pump effluent channel will be equipped with horizontal or vertical fixed screens for floatable material control. As flow is pumped from the wet well, the water level in the channel will rise until the flow passes through weir-mounted, mechanically cleaned, horizontal or vertical screens, where the rake mechanism will return the floatable material retained on the screen directly back to the pump effluent channel. The screens will remove anything above 3/16-inch in dimension. Floatables removal in excess of 90% is expected. The flow will over-top the screen in case of plugging or emergency. After a storm event, the captured floatable material in the pump effluent channel will be drained into the Elliott Bay interceptor. Any grit or residual settled solids will be removed by a manual washdown system and washed into the Elliott Bay interceptor.

10.5.2 Total Suspended Solids Reduction

The proposed facilities will provide TSS removal by diverting stored CSO flows to West Point for treatment, and removing TSS in the tunnel. A hydraulic analysis of the system described in detail in Section 10.2 indicated that approximately 50% of the total flow entering the Denny system will be diverted to West Point on an annual basis, and 50% will be discharged through the Elliott West outfall as treated CSO effluent. The hydraulic analysis of the system assumed year 2020 base flow conditions and a peak West Point flow of 440 mgd. In that analysis, the Interbay pump station was operated in such a way as to prevent the peak flow at West Point from exceeding 440 mgd. The set point for discharge from the tunnel to the EBI was set such that most Denny CSO flows to West Point arrive before or after peak flows, and the plant is operating in secondary treatment mode. West Point Treatment Plant influent flows up to 300 mgd receive full secondary treatment, and flows above 300 mgd and up to 440 mgd receive primary treatment and disinfection.

The flow conditions at West Point with and without Denny flows during the Design Storm 6 event are shown in Figure 10-41, along with flows at Interbay and flows from Denny to the EBI. Figure 10-41 shows that Denny flows do not contribute to the peak flow during the event. Rather, Denny flows arrive at West Point both before and after the peak occurs. Figure 10-42 shows that 95% of the flows will be transferred when the West Point flow rate is below 300 mgd. Since the flow is not arriving during peak times, 95% of the Denny flows under Design Storm 6 conditions would receive secondary treatment at West Point. Based on historic TSS removal rate and flow rate data from West Point (Figure 10-43), long-term average TSS removal rates for Denny flows at West Point were calculated for flows arriving at West Point flow rates below 300 mgd (89% TSS removal) and above 300 mgd (59% TSS removal).

In addition to removal at West Point, TSS will also settle out from flow entering the east end of the tunnel as it travels to the wet well. TSS in flows entering the tunnel from the west end during tunnel discharge mode will flow directly to the wet well and no TSS removal is expected. Tunnel influent is split between the east and west ends, with 60% of the flow coming in from the east end (323 MG/yr) on an annual basis and 40% of the flow coming in from the west end (236 MG/yr). Flows through the 6,200-ft long tunnel during discharge events generally occur with forward velocities well less than one foot per second. TSS removal in the tunnel can be computed by treating it as a linear clarifier--particles with a settling velocity greater than the depth of the tunnel divided by the transit time will be removed. Based on a solids analysis presented in Appendix B-Denny Way CSO Solids Analysis, TSS entering at the east end of the tunnel with a settling velocity greater than 0.07 cm per second will settle to the tunnel bottom based on the Design Storm 6 peak hourly flow of 103 mgd. CSO sampling during pre-design indicated that under design storm 6 conditions, 37% of the influent TSS had settling velocities greater than 0.07 cm per second. Since most of the hydrograph is at flow rates below the peak, more than 37% TSS removal is expected for flows from the east end during the design storm 6 event. This value is thus a lower bound on the expected removals. Higher removal is actually expected for Design Storm 6 and for most other annual discharge events that have lower forward velocities in the tunnel.

The annual tunnel flow balance is shown in Figure 10-44. System-wide TSS removal incorporates both TSS removal in the tunnel and TSS removal at West Point. System-wide TSS removal is summarized in Figure 10-45 and Table 10-7. On average, a total of 559 MG per year will enter the tunnel, with 8 MG/yr discharged at the Denny Way CSO outfall extension untreated. Flows discharged from the tunnel are divided evenly on an annual basis between diversion to West Point (278 MG/yr) and discharge through the Elliott West outfall as treated CSO effluent (281 MG/yr). Of the 278 MG/yr diverted to West Point, 263 MG will arrive when flows are below 300 mgd and will receive secondary treatment at an average of 89% TSS removal. 15 MG/yr will be diverted from the tunnel at times when West Point flows are above 300 mgd and will receive blended primary/secondary treatment at 59% TSS removal. Of the 281 MG/yr discharged through the Elliott West outfall, approximately half of that flow annually (139 MG/yr) comes in at the east end of the tunnel and a minimum 37% TSS removal through settling in the tunnel is expected. The other half (142 MG/yr) of the flow discharged to the Elliott West outfall enters the tunnel at the west end at the wet well and no TSS removal is expected. Summing flows and influent and effluent TSS loads, the Denny system is expected to achieve a minimum of 53% annual system-wide removal. It should be noted that with the removals expected at West Point, a removal rate in the Denny project tunnel of 26% (well below the calculated 37% removal) is required to meet the annual system-wide goal of 50% TSS removal.

Table 10-7

Systemwide TSS Removal

Flow Component	MG/yr	Percent TSS Removal	lb TSS Influent at Denny	lb TSS Discharge
To West Pt. @ Flow > 300 mgd	15	59	12,510	5,129
To West Pt. @ Flow < 300 mgd	263	89	219,342	24,128
Min. Denny Tunnel treatment*	139	37	115,926	73,033
Denny CSO treatment No TSS removal	142	0	118,428	118,428
Total treated	559	53	466,206	220,718
Untreated	8	n/a	--	--

*Treatment required for 50% TSS removal = 26

	MG	lb TSS
Influent to Denny Project	559	466,206
Discharge at Denny	281	191,461
Discharge at West Point	278	29,257
% TSS removal		53%

10.5.3 Settleable Solids

Since the intent of settleable solids monitoring is to prevent the build up of a sludge blanket at the point of discharge and to prevent an unaesthetic discharge, sediment monitoring and floatable control serves as a surrogate measure. Sediment monitoring will provide a control on the sludge blanket potential, and floatable control will monitor the aesthetic impact.

If, however, the settleable solids monitoring is required, an analysis of a settleable solids limit would be needed. The preliminary draft Denny Way/Lake Union CSO Control Facilities Plan (May 1997) proposed a maximum effluent limit of 2.0 mL/L/hr for settleable solids. Review of the monitoring results for the Denny regulator indicate that the actual effluent settleable solids concentrations ranged from 1 to 4 mL/L/hr for the four storm events sampled. No settleable solids removal will be provided in the Elliott West CSO control facility.

The average settling velocities of sewage particles are believed to decrease as the TSS concentration is reduced by storm water inflow because the natural flocculation of the particles is less at lower concentrations. Smaller particles have lower settling velocities.

Ecology prescribes a volumetric test to measure settleable solids. This test measures the volume of material that settles to the bottom of a cone-shaped jar in one hour. Test samples may include debris (leaves, hair, heavier plastic particles, etc.) with near neutral buoyancy which is unlikely to settle in a treatment plant or in the receiving water. Such particles may also result in voids in the material collected at the bottom of the cone. These voids increase measured values inappropriately. From a design standpoint, there is no rational method of estimating primary treatment plant performance based on volumetric measurement of settleable solids. Plant designers must resort to empirical observations.

Experience at the Alki Treatment Plant with storm-related combined sewer flows indicates that the influent settleable solids will range from 1 to 10 mL/L/hr. Corresponding effluent settleable solids values at Alki range from 0.1 (the detection limit) to 5 mL/L/hr, regardless of the surface overflow rate of the clarifier there. At the Carkeek Park Treatment Plant, effluent settleable solids have ranged from 0.1 to 4 mL/L, again regardless of the surface overflow rate.

The Ecology standard for effluent settleable solids is 0.3 mL/L and has been applied at Carkeek Park on a monthly average basis. Effluent settleable solids concentrations naturally vary, with some above and some below the Ecology limit. Because of that natural variation, and because of the limitations of the test itself, it is difficult to impossible to achieve the Ecology limit with each and every discharge at a primary treatment plant. Frequently at Denny, there will be months where only one discharge event occurs, and for those months, the monthly average will be the value measured for the single occurrence. As a result, if a monthly average is used to determine compliance with the Ecology standard, there are likely to be a number of months when the facilities record a violation of the Ecology limit, even though for the year as a whole, the average discharge may be less than 0.3 mL/L/hr.

If the limit is taken as an average over many events, such as all the events that occur during a year, there is an increased probability that the effluent measurements will meet the limit. At continuously operating treatment plants, for example, over a month-long period, there are many days when the effluent is less than 0.3 mL/L and a few days with higher values. Because of the frequency of lower values, the monthly average is usually below the Ecology limit. In CSO application, however, the system will discharge treated effluent intermittently (about 15 times per year), and will not have many values to contribute to a monthly average.

For the above reasons, application of the Ecology limit as a short-term or monthly average is inappropriate. Two alternative methods are available:

- Application as an average over one or more years
- Application of an event maximum

Application of the Ecology limit as an average over one or more years for a CSO system is consistent with the intent of the regulation, and with its application to continuously operating facilities. This is a preferred alternative approach. The long-term average reflects the true environmental impacts associated with settleable solids, or more directly, the tendency to accumulate discharged solids near the outfall. Application as a maximum involves definition of a maximum value, which, if met in statistical context with all other expected values, provides assurance that the long-term average of all events will meet the standard. A similar approach is used by the USEPA in setting toxicity criteria where effluent measurements are infrequent (*Technical Support Document for Water Quality-Based Toxics Control, EPA/505/2-90-001, March 1991).* With the USEPA approach, the maximum criterion is set so that there is some confidence (typically the 95 percent probability level) that values at or below the limit are members of a population of measurements whose long-term mean will be equal to or below the desired mean limit. From a given series of measurements, the mean and standard deviation is determined. The desired long-term limit plus a multiple of the standard deviation is used to define the maximum value expected with the specified confidence limit. Because recorded data of this type is always above some detection limit (with the highest frequency of values near the detection limit), it is necessary to derive statistics using the logarithms of the recorded values and transform the results back to normal values (antilogarithm).

Application of this approach to Carkeek Park effluent data is shown in Figure 10-46. The effluent values recorded in the 1995-1996 wet season are shown. The annual mean (a geometric mean is shown corresponding to the mean of the logarithms of the values) of these values is just below the Ecology limit of 0.3 mL/L/hr. In addition, the computed 95 percent confidence limit is shown as just above 2.0 mL/L/hr. This indicates that 95 percent of all measured values having a long-term geometric mean of 0.3 mL/L/hr will be 2.0 mL/L/hr or smaller. Applying the

USEPA methodology, a maximum event limit of 2.0 mL/L/hr would be set as a permit limit. If this approach were adopted, it must be recognized that occasional values above 2.0 mL/L/hr will occur. For example, Figure 10-46 also shows the upper 99 percent confidence limit as approximately 4.0 mL/L. Occasional measurements that high can still belong to a population of measurements with a long-term mean of 0.3 mL/L/hr.

By virtue of the CSO volumes stored and diverted to West Point, the preferred alternative would reduce the annual discharge of settleable solids over 50 percent, limiting discharge to only the larger rainstorms of the year. Based on the limited influent settleable solids sampling data gathered to date, the preferred alternative would be expected to meet an effluent limit of 2.0 mL/L/hr during periods of treated discharge, and an average of 0.3 mL/L/hr settleable solids on a long-term basis.

10.5.4 Receiving Water Quality

King County performed a preliminary water quality assessment (WQA) in which the receiving water quality in the vicinity of the new Elliott West outfall was estimated after annual reductions in discharge volume and TSS and offshore discharge (*Water Quality Assessment,* King County Department of Natural Resources, October 1995). This study indicated that concentrations of nine contaminants of concern (heavy metals and organic pollutants) would be below water quality standards. However, bacterial standards would be exceeded without disinfection. As the preferred alternative includes an outfall at lesser depth than assumed in the WQA, the new water quality conditions are discussed in the following paragraphs.

Fecal Coliforms. The project will include chlorination disinfection for bacterial control followed by dechlorination to meet receiving water chlorine concentration standards. It is assumed, and confirmed by Ecology, that due to the intermittent nature of discharges, an end-of-pipe coliform limit of 400 colonies per 100 mL will be the permit limit. Ecology also specifies a receiving water standard for fecal coliforms requiring that the monthly geometric mean of concentrations be equal to or less than 14 colonies per 100 mL. They also specify that no more than 10 percent of samples (3 days per month) can exhibit concentrations greater than 43 colonies per 100 mL. This standard is applied at the edge of the outfall's chronic mixing zone boundary.

Ecology applies the receiving water criteria for the maximum monthly flow condition for continuously operating treatment plants and typically takes this as the maximum monthly average flow occurring in the last 3 years. For intermittent discharges, the maximum monthly flow definition is less straightforward. The occurrence of average monthly flow values was discussed earlier. For use in assessing compliance with the receiving water standard, resulting concentrations were assessed at several flow conditions, including the peak day flow (average of flows occurring during Design Storm 6), and monthly average flows, with occurrence frequencies ranging from once per year to four times per year.

With the assumed 400 colonies per 100 mL end-of-pipe condition and the dilution afforded by the 60 to 70-foot-deep outfall, the resulting coliform concentrations at the boundary of the outfall chronic mixing zone are shown in Table 10-8. The project is estimated to discharge no more than five events per month, and usually three or fewer times per month. In the simulated month with the highest number of expected discharges, expected discharge volumes range from about 1 to 30 MG occurring within a calendar day. Even on the peak day flow (the average of the non-zero discharge values occurring during Design Storm 6), the receiving water concentration would not exceed the excursion limit. Thus, Table 10-8 indicates that the project will rarely if ever cause an exceedence of the 43 colonies per 100 mL excursion limit– leaving these excursions for natural variability. Since treated discharge occurrences are infrequent and usually small (80 percent of the predicted event discharge volumes are less than 30 MG), the discharges will not cause the geometric mean of the receiving water fecal coliform concentrations to exceed 14 colonies per 100 mL.

Table 10-8.
Fecal Coliform Concentrations at Chronic Mixing Zone Boundary

Discharge Condition	Frequency Flow is Equaled or Exceeded	Flow, mgd	60-ft Chronic Outfall Dilution	Receiving Water Coliform Concentration, Colonies/100 mL
50th percentile monthly average	4 per year	8	52:1	<14
85th percentile monthly average	1 per year	45	13:1	31
Peak day flow[a]	1 per year	70	10:1	40
Peak day discharge[b]	1 per year	37 MG	15:1	27

[a] Average of non-zero flows during Design Storm 6 discharge event.
[b] Total volume of discharge during Design Storm 6 in a 24-hour day.

Toxic Pollutants. Ecology applies receiving water acute and chronic toxic pollutant concentration limits at the peak day flow and the maximum month flow, respectively, for continuously operating treatment plants. As noted in Table 10-5, the volume of discharge within a 24-hour day with an occurrence frequency of once per year is 37 MG. Using this as a daily flow rate, the outfall dilution at the acute boundary would be about 13:1. The monthly average discharge flows range from 8 to 45 mgd. Corresponding chronic dilutions range from 13:1 to 52:1. Examination of the receiving water quality limits using these dilution factors indicates that the only toxic pollutant of concern is copper.

King County estimated the upper 95 percent confidence limit on the mean of total recoverable copper concentrations in CSOs in general to be about 43.6 micro-grams/L in the WQA using data from the middle 1980s. The acute water quality standard for marine waters is 2.5 µg/L, indicating an acute dilution of about 17:1 would be required. This dilution would be achieved at a flow of 25 to 30 mgd for the 60-foot-deep outfall at the acute mixing zone boundary. Thus, at the once per year treated discharge, the receiving water criteria might be exceeded slightly if no copper removal occurred in the Denny Way/Lake Union facilities. (Note that if average current speed were assumed in the analysis that may be more appropriate for intermittent conditions, there would be no exceedence.) The potential problem with copper is unclear at this time since some removal is expected and because the influent data are relatively old, because copper in Denny discharges is 30 to 50 percent dissolved, and because the exceedence is small. Further sampling at the Elliott West outfall, specifically, will be needed to better define existing concentrations. Source control efforts by the City of Seattle (water supply alkalinity adjustment) and King County (pretreatment standards) will also be effective in reducing copper concentrations.

10.6 Proposed NPDES Permit Requirements

An NPDES permit would be required for the Denny Way/Lake Union CSO Control Project. Either the permit would be specific to the new facilities or the West Point NPDES permit would contain permit provisions specific to the Denny Way/Lake Union Project facilities. In either case, that permit would establish discharge limits and conditions for the new facilities. The following are the specific discharge limits being proposed for the new facilities.

10.6.1 Total Suspended Solids Removal

The TSS removal requirement should be 50 percent, established on the basis of system-wide removal. System-wide TSS removal includes solids removed at the new facilities as well as solids removed at West Point for the flows stored at the new facilities and eventually diverted to West Point.

10.6.2 Suspended Solids Monitoring

Monitoring for suspended solids removal will include monitoring flow rates and suspended solids concentrations in the treated discharge from the Elliott West outfall and in the flow diverted from the project to the EBI. Percent TSS removals at West Point during diversion of flow from the project will also be recorded. Annual TSS removal for the project will be computed by an annual mass balance. The sum of the treated discharge and diversion to the EBI at the project will be used to compute the influent TSS to the project. The treated discharge mass and the representative discharge at West Point will be used to compute the system-wide effluent TSS.

10.6.3 Settleable Solids

For application in the discharge permit, it is proposed that settleable solids performance be measured by a once-per-permit-cycle sediment sampling performed according to the sediment management standards (WAC 173-204). This provides a more direct measure of potential impact than effluent limits.

10.6.4 Fecal Coliform

The fecal coliform limit should be based on a technology-based standard of 400 colonies per 100 mL. This is the same effluent fecal coliform level applied to the West Point treatment for an average weekly limit. As shown in Section 10.5.4, the project will meet the state water quality standards for chronic fecal coliform for Class A marine waters based on an "end-of-pipe" fecal coliform limit of 400 colonies per 100 mL.

10.6.5 Residual Chlorine

In order to meet Class A marine waters water quality standards for chronic residual chlorine, it is proposed to provide dechlorination to meet the residual chlorine level of 0.0075 mg/L. Based on predicted peak day discharge of 37 mgd and an outfall chronic dilution factor of 15:1, the proposed residual chlorine level is 0.1125 mg/L for "end of pipe".

10.6.6 Fecal Coliform and Chlorine Residual Sampling and Monitoring

It is proposed to test for chlorine residual following dechlorination, to measure whether the dechlorination has been effective, rather than measuring the residual available prior to dechlorination.

The sample will be taken at the Outfall transition structure, downstream of the dechlorination injection and mixing location. Either a grab sample or a refrigerated automatic sampler could be utilized for the fecal coliform sample. The sampler would be located in the existing Denny Regulator structure and be operated when the pumps operate in the CSO Treatment mode.

The residual chlorine can be measured with a residual analyzer that would operate continuously, and be regularly calibrated. The analyzer would be located inside the exiting Denny Regulator structure. For process control, a sample could also be taken upstream of the dechlorination facility to check the chlorine residual prior to dechlorination if sample tubing and valving are provided to allow pumping from either direction. The sampling locations are shown in Figure 10-47.

The signal from the chlorine residual analyzer will be hard wired to the Elliott West Facility. The PLC will be programmed to shut down the hypochlorite feed pumps and provide an alarm in case the chlorine residual exceeds a certain setpoint for a defined period. This will provide a "fail safe" shut off to prevent release of chlorinated effluent to Elliott Bay.