O. SCATTERGOOD GENERATING STATION

LOS ANGELES DEPT. OF WATER AND POWER—LOS ANGELES, CA

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1.0 GENERAL SUMMARY

Retrofitting the existing once-through cooling system at Scattergood Generating Station (SGS) with closed-cycle wet cooling towers is technically and logistically feasible based on this study's design criteria, and will reduce cooling water withdrawals from Santa Monica Bay by approximately 95 percent. Impingement and entrainment impacts would be reduced by a similar proportion.

The proximity SGS to the south runway at Los Angeles International Airport (LAX) will likely require incorporating plume abatement technologies into any final tower design. The preferred option selected for SGS includes 4 plume-abated wet cooling towers with individual cells arranged in an inline configuration to accommodate limited space at the site.

Construction-related shutdowns are estimated to take approximately 4 weeks per unit (concurrent), although SGS is not expected to incur any financial loss as a result based on 2006 capacity utilization rates for all units. The cooling tower configuration designed under the preferred option complies with all identified local use restrictions and includes necessary mitigation measures, where applicable.

1.1 COST

Initial capital and net presents costs associated with the installation and operation of wet cooling towers at SGS are summarized in Table O–1. Annualized costs based on 20-year average values for the various cost elements are summarized in Table O–2. A detailed cost analysis is presented in Section 4.0 of this chapter.

Table O–1. Cumulative Cost Summary

Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2005 output) ($/MWh)
Total capital and start-up [a]	160,500,000	22.82	107
NPV_{20} [b]	193,700,000	27.54	129

[a] Includes all costs associated with the construction and installation of cooling towers and shutdown loss, if any.
[b] NPV_{20} includes all capital costs, operation and maintenance costs, and energy penalty costs over 20 years discounted at 7 percent.

Table O–2. Annual Cost Summary

Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2005 output) ($/MWh)
Capital and start-up [a]	15,200,000	2.16	10.15
Operations and maintenance	900,000	0.13	0.60
Energy penalty	2,600,000	0.37	1.74
Total SGS annual cost	**18,700,000**	**2.66**	**12.49**

[a] Does not include revenue loss associated with shutdown, if any, which is incurred in Year 0 only.

1.2 ENVIRONMENTAL

Environmental changes associated with a cooling tower retrofit for SGS are summarized in Table O–3 and discussed further in Section 3.4.

Table O–3. Environmental Summary

		Unit 1	Unit 2	Unit 3
Water use	Design intake volume (gpm)	78,000	78,000	188,000
	Cooling tower makeup water (gpm)	3,400	3,400	9,000
	Reduction from capacity (%)	96	96	95
Energy efficiency [a]	Summer heat rate increase (%)	1.28	1.28	1.35
	Summer energy penalty (%)	2.61	2.61	3.84
	Annual heat rate increase (%)	1.27	1.27	1.19
	Annual energy penalty (%)	2.60	2.60	3.68
Direct air emissions [b]	PM_{10} emissions (tons/yr) (maximum capacity)	45	45	108
	PM_{10} emissions (tons/yr) (2005 capacity utilization)	6.3	18.4	17.7

[a] Reflects the comparative increase between once-through and wet cooling systems, but does not account for any operational changes to address the change in efficiency, such as increased fuel consumption (see Section 4.6).
[b] Reflects emissions from the cooling tower only; does not include any increase in stack emissions.

1.3 OTHER POTENTIAL FACTORS

Considerations outside this study's scope may limit the practicality or overall feasibility of a wet cooling tower retrofit at Scattergood.

The final location selected for the Unit 1 and Unit 2 cooling towers will likely require modifications to, or relocation of, the existing switchyard to minimize interference resulting from drift deposition. The selected design of plume-abated towers described in this chapter represents the most plausible installation that can be developed for the SGS based on the information available. Options not considered in this study, such as the relocation of the switchyard, might make alternative configurations more feasible. Constraints on placement and design are discussed further in Section 3.2.3.

2.0 BACKGROUND

The Scattergood Generating Station (SGS) is a natural gas–fired steam electric generating facility located in the city of Los Angeles, Los Angeles County, owned and operated by the Los Angeles Department of Water and Power (LADWP). SGS currently operates three conventional steam turbine units (Unit 1, Unit 2, and Unit 3) with a combined generating capacity of 803 MW. The facility occupies approximately 56 acres of an industrial site across Vista del Mar from Dockweiler State Beach and Santa Monica Bay. A portion of the northern boundary of the property borders the City of Los Angeles Hyperion Wastewater Treatment Plant (WWTP) (Figure O–1).

Table O–4. General Information

Unit	In-service year	Rated capacity (MW)	2005 capacity utilization [a]	Condenser cooling water flow (gpm)
Unit 1	1958	179	26.4%	78,000
Unit 2	1959	179	29.7%	78,000
Unit 3	1974	445	20.6%	188,000
SGS total		**803**	**23.9%**	**344,000**

[a] *Quarterly Fuel and Energy Report—2005* (CEC 2005).

Figure O–1. General Vicinity of Scattergood Generating Station

2.1 COOLING WATER SYSTEM

SGS operates one cooling water intake structure (CWIS) to provide condenser cooling water to the three generating units (Figure O–2). Once-through cooling water is combined with low-volume wastes generated by SGS and discharged through a single submerged outfall to the Pacific Ocean, located approximately 1,200 feet offshore at a depth of 11 feet. Surface water withdrawals and discharges are regulated by NPDES Permit CA0000370, as implemented by Los Angeles Regional Water Quality Control Board (LARWQCB) Order 00-083.[1]

Cooling water is obtained from the Pacific Ocean through a submerged intake conduit terminating 1,600 feet offshore at a depth of approximately 15 feet. The submerged end of the conduit is fitted with a velocity cap to minimize the entrainment of motile fish into the system by converting the vertical flow to a lateral flow, thus triggering a flight response from fish.

The onshore portion of the CWIS comprises eight screen bays, each fitted with a vertical traveling screen with 3/8-inch by 3/4-inch mesh panels. Four screen bays serve Unit 3, while the remaining four are divided between Unit 1 and Unit 2 (two each). Screens are rotated manually every 8 hours. A high-pressure spray removes any debris or fish that have become impinged on the screen face. Captured debris is collected in a dumpster for disposal in a landfill. Downstream of each screen is a circulating water pump. The pumps for Unit 1 and Unit 2 are each rated at 39,000 gallons per minute (gpm), or 56 million gallons per day (mgd). The four pumps for Unit 3 are each rated at 47,000 gpm, or 68 mgd. The total facility capacity is 344,000 gpm, or 495 mgd (LADWP 2005).

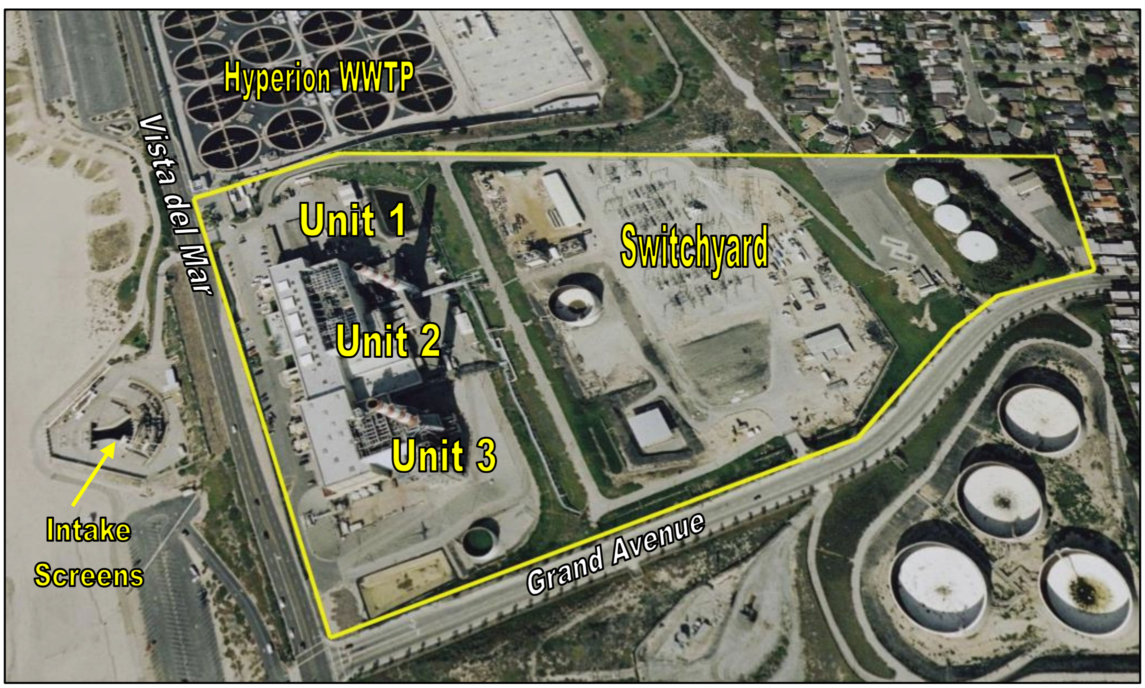

Figure O–2. Site View

[1] LARWQCB Order 00-083 expired on May 10, 2005, but has been administratively extended pending adoption of a renewed order.

At maximum capacity, SGS maintains a total pumping capacity rated at 495 mgd. On an annual basis, SGS withdraws substantially less than its design capacity due to its low generating capacity utilization (23.9 percent for 2005).[2] When in operation and generating the maximum load, SGS can be expected to withdraw water from the Pacific Ocean at a rate approaching its maximum capacity.

2.2 SECTION 316(B) PERMIT COMPLIANCE

The CWIS currently in operation at SGS uses a velocity cap to reduce the entrainment of motile fish through the system, although it is commonly thought of as an impingement-reduction technology because it targets larger organisms. Velocity caps have been shown to reduce impingement rates when compared with a shoreline intake structure. Likewise, the location of the intake structure in an offshore setting may contribute to lower rates of entrainment when compared with a shoreline intake if the near-shore environment is more biologically productive. This study did not evaluate the effectiveness of either measure.

LARWQCB Order 00-083 references an ecological study conducted by SGS from 1977 to 1981 to determine whether the CWIS was compliant with Section 316(b) of the Clean Water Act. Finding 8 of the order, adopted in 2000, notes:

> …the study…adequately addressed the important ecological and engineering factors specified in the guidelines, demonstrated that the ecological impacts of the intake system are environmentally acceptable, and provided evidence that no modifications to design, location, or capacity of the intake structure are required. (LARWQCB 2000, Finding 8)

The order does not contain any numeric or narrative limitations regarding impingement or entrainment resulting from CWIS operation, but does require semiannual monitoring of impingement at the intake structure (coinciding with scheduled heat treatments). Based on the record available for review, SGS has been compliant with this permit requirement.

The LARWQCB has notified SGS of its intent to revisit requirements under CWA Section 316(b), including a determination of best technology available (BTA) for minimization of adverse environmental impact, during the current permit reissuance process. A final decision regarding any Section 316(b)–related requirements has not been made as of the publication of this study.

[2] Unit-level generating data for 2006 were not available for SGS. All capacity utilization references in this chapter refer to 2005 output.

3.0 WET COOLING SYSTEM RETROFIT

3.1 OVERVIEW

This study evaluates the use of saltwater wet cooling towers at SGS, with the current source water (Pacific Ocean) continuing to provide makeup water to the facility. Conversion of the existing once-through cooling system to wet cooling towers will reduce the facility's current intake capacity by approximately 95 percent; rates of impingement and entrainment will decline by a similar proportion. Use of alternative water sources as a replacement for the once-through cooling water currently used at SGS is a potentially feasible option based on the volume of secondary treated water available in the vicinity. In a wet cooling tower system, the use of reclaimed water as the makeup water source (as opposed to the Pacific Ocean) is an attractive alternative when considering additional benefits its use may provide, such as avoidance of conflicts with effluent limitations or air emission standards. Use of reclaimed water is discussed further in Section 3.4.4.

The configuration of the wet cooling towers—their size and location—was based on best professional judgment (BPJ) using the criteria outlined in Chapter 5 and designed to meet the performance benchmarks in the most cost-effective manner. Information not available to this study that offers a more complete characterization of the facility may lead to different conclusions regarding the physical configuration of the towers.

This study developed a conceptual design of wet cooling towers sufficient to meet the cooling demand for each active generating unit at SGS at its rated output during peak climate conditions. Cost estimates are based on vendor quotes developed using the available information and the various design constraints identified at SGS.

The overall practicality of retrofitting the three units at SGS will require an evaluation of factors outside the scope of this study, such as the age and efficiency of the units and their role in the overall reliability of electricity production and transmission in California, particularly the Los Angeles region.

3.2 DESIGN BASIS

3.2.1 CONDENSER SPECIFICATIONS

For this study, the conceptual design of the cooling towers selected for SGS is based on the assumption that the condenser flow rate and thermal load to each will remain unchanged from the current system. Although no provision is included to re-optimize the condenser performance for service with a cooling tower, some modifications to the condenser (tube sheet and water box reinforcement) may be necessary to handle the increased water pressures that will result from the increased total pump head required to raise water to the elevation of the cooling tower risers.[3] The practicality and difficulty of these modifications are dependent on the age and configuration of each unit, but are assumed to be feasible at SGS. Condenser water boxes for all three units are

[3] In this context, re-optimization refers to a comprehensive overhaul of the condenser, such as re-tubing or converting the flow from single to multiple passes. Modifications are generally limited to reinforcement measures to enable the condenser to withstand the increased pressures.

located at grade level and appear to be readily accessible. Additional costs associated with condenser modifications are included in the discussion of capital expenditures (Section 4.3).

Information provided by SGS was largely used as the basis for the cooling tower design. In some cases, the data were incomplete or conflicted with values obtained from other sources. Where possible, questionable values were verified or corrected using other known information about the condenser. For example, the condenser specification sheet for Unit 3 indicates that the condenser's design steam inlet pressure is 1.18 inches HgA for the low-pressure zone and 1.65 inches HgA for the high-pressure zone. Other data note that the Unit 3 turbine, when operating at maximum load, will generally have exhaust backpressure values ranging from 2.5 to 2.8 inches HgA. The reason for the discrepancy is not clear, and insufficient information is available to determine how this would be affected by a conversion to a wet cooling tower system.

Likewise, backpressure values reported for Unit 1 at maximum load at different times of the year ranged from 2.0 to 2.6 inches HgA. Values in the higher end of the range were reported during months when the inlet water temperatures are typically at their lowest, with the lower values reported during warmer months. Again, the reasons why maximum load backpressures would be higher during colder months than they are during the summer are unclear, but may be correct if they are reflective of conditions that are unknown to this study.

In lieu of detailed operational data, calculations in this study are based on the system design specifications as provided by LADWP. Accordingly, the design backpressure value used for Unit 1 and Unit 2 is 1.5 inches HgA. For Unit 3, the design value is 1.65 inches HgA (for the high-pressure zone). Table O–5 summarizes the condenser design specifications for the three units.

Table O–5. Condenser Design Specifications

	Unit 1	Unit 2	Unit 3
Thermal load (MMBTU/hr)	695	695	1838.2
Surface area (ft^2)	95,100	95,100	237,000
Condenser flow rate (gpm)	78,000	78,000	188,000
Tube material	316 Stainless	316 Stainless	Cu-Ni (90-10)
Heat transfer coefficient (U_d)	340	340	459
Cleanliness factor	0.75	0.75	0.85
Inlet temperature (°F)	60	60	62
Temperature rise (°F)	17.83	17.83	19.51
Steam condensate temperature (°F)	91.7	91.7	94.8
Turbine exhaust pressure (in. HgA)	1.5	1.5	1.65 (hp zone)

3.2.2 AMBIENT ENVIRONMENTAL CONDITIONS

SGS is located in Los Angeles County along the shoreline of the Pacific Ocean approximately 1 mile south-southwest of the south runway at LAX. Cooling water is withdrawn from a submerged offshore location in the Pacific Ocean. Inlet temperature data specific to SGS were not available. Due to the proximity of El Segundo Generating Station (ESGS) and the substantially similar location of its respective intake structures (offshore in Santa Monica Bay), 2005 inlet temperature data provided by ESGS were used for SGS and serve as the basis for monthly once-through cooling water temperature values used in this study.

The wet bulb temperature used in the development of the overall cooling tower design was obtained from American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) publications. Data for Los Angeles at LAX indicate a 1 percent ambient wet bulb temperature of 69° F (ASHRAE 2006). An approach temperature of 12° F was selected based on the site configuration and vendor input. At the design wet bulb and approach temperatures, the cooling towers will yield “cold” water at a temperature of 81° F. Monthly maximum wet bulb temperatures used in the development of energy penalty estimates in Section 4.6 were calculated using data obtained from California Irrigation Management Information System (CIMIS) Monitoring Station 99 in Santa Monica (CIMIS 2006). Climate data used in this analysis are summarized in Table O–6.

Table O–6. Surface Water and Ambient Wet Bulb Temperatures

	Surface (°F)	Ambient wet bulb (°F)
January	59.2	54.3
February	60.3	56.1
March	61.5	57.7
April	63.1	60.7
May	66.0	65.7
June	68.0	68.3
July	71.4	69.3
August	72.2	69.4
September	67.0	65.5
October	63.5	60.3
November	62.0	56.3
December	60.7	55.5

3.2.3 LOCAL USE RESTRICTIONS

3.2.3.1 NOISE

Industrial development at SGS is regulated by the City of Los Angeles Municipal Code and the Westchester-Playa del Rey Community Plan. Both plans outline narrative criteria to be used as a guide for future development, but do not identify numeric noise limits for new construction. Based on consultation with the City of Los Angeles Department of Building and Safety, any measures limiting noise from a wet cooling tower would be addressed through a conditional use permit that evaluates the specific design of the project. Given the proximity of residential areas to the site (less than 800 feet to the east) and the proximity to Dockweiler State Beach (approximately 300 feet) this study used an ambient noise limit of 60 dBA at a distance of 800 feet in selecting the design elements of the wet tower installation. The wet cooling towers designed for SGS include low-noise fans and fan deck barrier walls to minimize noise associated with motor operation. Grade level sound barrier walls are not required.

3.2.3.2 BUILDING HEIGHT

SGS is located within the PF-1 zone, according to the planning and zoning code for Los Angeles. This zone is dedicated to heavy industry. Because it is located within the LAX Safety Corridor, the height of structures is generally limited to 150 feet above the 126-foot elevation contour. Most of the existing structures at SGS are located at an elevation of approximately 30 feet above sea level. East of the power blocks, the grade rises rapidly to a maximum elevation of approximately 155 feet above sea level (Figure O–3). The building code does not establish specific criteria for building height at other elevations within the PF-1 zone and instead relies on conditional use permitting that evaluates the specific design of the project. Given the existing height of the current structures at SGS and the proximity of residential and public recreational areas, this study selected a height restriction of 60 feet above grade level. The height of the wet cooling towers designed for SGS, from grade level to the top of the fan deck barrier wall, is 58 feet.

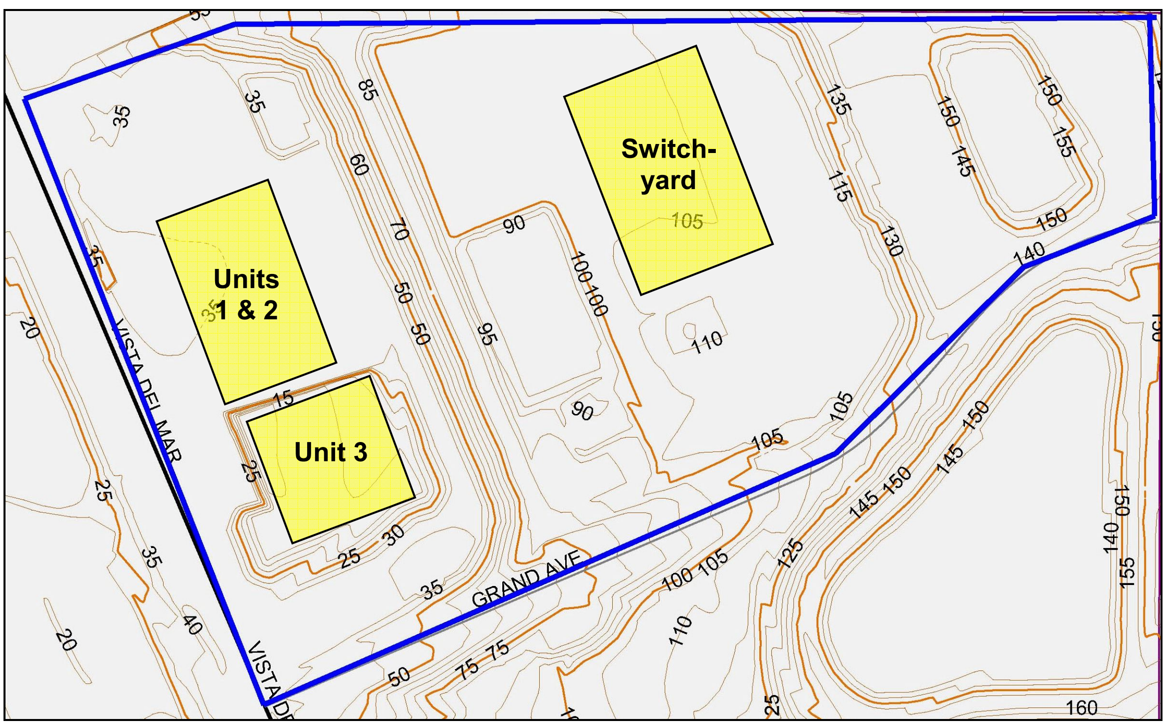

Figure O–3. Elevation Profile of SGS Site

3.2.3.3 PLUME ABATEMENT

Local zoning ordinances do not contain any specific criteria for addressing any impact associated with a wet cooling tower plume. Based on the proximity of SGS to LAX, however, plume abatement measures will likely be required. As shown in Figure O–1, SGS is located approximately 1 mile south-southwest of the airport. Further consideration must be made for the proximity of any eventual cooling tower to coastal recreational areas and the potential visual impact on those resources and nearby residential neighborhoods. California Energy Commission (CEC) siting guidelines and Coastal Act provisions evaluate the total size and persistence of a visual plume with respect to aesthetic standards for coastal resources; significant visual changes resulting from a persistent plume would likely be subject to additional controls.

Plume abatement towers were selected for evaluation at SGS due to the likelihood they would be required to eliminate potential impacts on operations at LAX. Section 3.2.3.5 details the available areas at SGS and placement of plume-abated towers.

3.2.3.4 DRIFT AND PARTICULATE EMISSIONS

Drift elimination measures that are considered best available control technology (BACT) are required for all cooling towers evaluated in this study regardless of their location. State-of-the-art drift eliminators are included for each cooling tower cell at SGS, with an accepted efficiency of 0.0005 percent. Because cooling tower PM_{10} emissions are a function of the rate of drift, drift eliminators are also considered BACT for PM_{10} emissions from wet cooling towers. This efficiency can be verified by a proper in situ test, which accounts for site-specific climate, water, and operating conditions. Testing based on the Isokinetic Drift Test Code published by the Cooling Tower Institute is only required at initial start-up on one representative cell of each tower, for an approximate cost of $60,000 per test, or approximately $240,000 for all four cooling towers at SGS (CTI 1994). This cost is not itemized in the final analysis and is instead included as part of the indirect cost estimate (Section 4.3).

3.2.3.5 FACILITY CONFIGURATION AND AREA CONSTRAINTS

The configuration of the SGS site, at only 56 acres spread across elevations ranging from 30 to 155 feet, creates several challenges in selecting a location for plume-abated cooling towers. As shown in Figure O–4, few areas are available that are large enough to accommodate wet cooling towers without the demolition and relocation of existing structures, and without also causing potential conflicts with other uses.

Area 1 is a small parcel located immediately to the north of Unit 1. The total area of this plot is approximately 30,000 square feet (200 feet by 150 feet). The entrance to SGS is located in this area, as is the lower end of the access road that leads to the upper areas of the property. The eastern edge of this area is currently occupied by a retention basin. Area 2 is a similarly sized parcel immediately south of Unit 3, with a total area of approximately 37,500 square feet (125 feet by 300 feet). This area is currently occupied by a retention basin and treatment tank.

Both areas are located very close to Vista del Mar and would require sufficient setback from the property line. Based on space requirements alone, it is feasible to locate the cooling tower for Unit 1 in Area 1 and the tower for Unit 2 in Area 2. Ultimately, however, these areas were not selected because the rapid rise in elevation to the east where the towers would be placed (rising from 30 to 85 feet) creates a barrier that may disrupt the necessary air flow through the plume-abated towers and negatively impact their performance.

Area 3 is 125,000 square foot parcel (250 feet by 500 feet) located immediately west of the switchyard at an elevation of approximately 100 feet. This area is sufficiently sized to accommodate the cooling towers for Unit 1 and Unit 2, but places them in a less-than-optimal configuration (roughly perpendicular to prevailing winds) and very close to the switchyard, where impacts from drift deposition on sensitive equipment and transmission lines may be significant. Two small cooling towers (used for bearing cooling water), as well as other small structures, are located in this area and would have to be removed or relocated to place cooling towers in this location. Sufficient capacity exists in the new cooling towers to compensate for the lost capacity of the small towers, although it is not known whether the equipment served by these towers would be adversely affected by switching from the current freshwater system to saltwater.

Area 4 is the largest contiguous parcel at SGS that is generally unoccupied, although small structures such as maintenance buildings would have to be relocated to allow placement here. The area, approximately 219,000 square feet (625 feet by 350 feet), is sufficient to accommodate the cooling tower for Unit 3, provided the tower is divided into two separate arrays. The configuration of this area enables towers to be placed in a generally longitudinal orientation with respect to the prevailing winds.

Area 5 is located at the easternmost portion of the facility and is occupied by three water storage tanks. Although this parcel is generally large enough to accommodate some of the necessary cooling towers, it was eliminated from consideration because its proximity to residential areas within the City of El Segundo would make it difficult, if not infeasible, to meet noise limitations in those areas.

Information from the Los Angeles County Assessor indicates that a parcel of land located south of Grand Avenue is currently owned by LADWP. This area is occupied by four decommissioned fuel oil storage tanks. Discussions with facility staff revealed that this area is slated for sale and cannot be used for any development related to SGS.

Based on the cooling tower design limitations discussed above, Area 3 and Area 4 were selected as the locations for the cooling towers. It is noted, however, that wet cooling towers placed in Area 3 will create a strong probability of interference with or damage to sensitive equipment in the switchyard resulting from salt drift deposition. Placement of wet cooling towers in this location will likely require relocation of the switchyard or replacement with gas insulated switchgear (GIS) to avoid these effects.

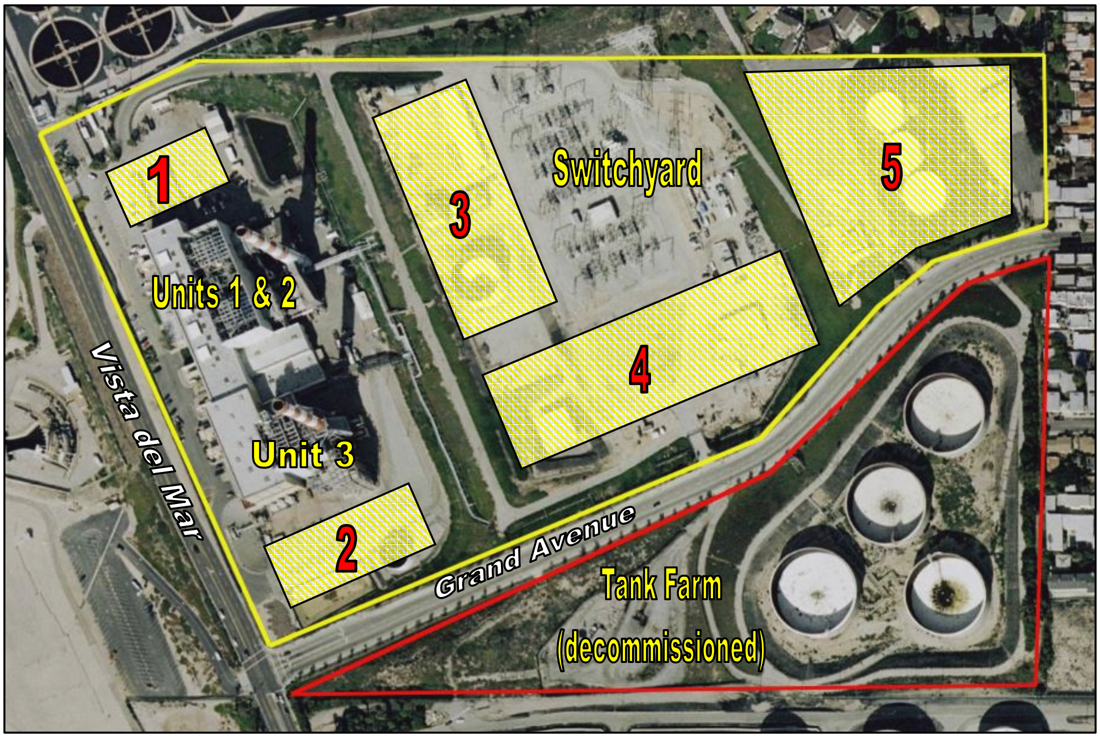

Figure O–4. Cooling Tower Siting Areas

3.3 CONCEPTUAL DESIGN

Based on the design constraints discussed above, four wet cooling towers were selected to replace the current once-through cooling system that currently serves Unit 1, Unit 2, and Unit 3 at SGS. Units 1 and 2 will each be served by an independently functioning tower, while Unit 3 will be served by two separate towers arranged in parallel. The Unit 3 towers will function independently (i.e., have separate pump houses and pumps) but will typically be used in conjunction with each other. Each tower at SGS consists of plume-abated cells configured in a multicell, inline arrangement.

3.3.1 SIZE

Each tower is constructed over a concrete collection basin 4 feet deep. The basin is larger than the footprint of the tower structure, extending an additional 2 feet in each direction. The concrete used for construction is suitable for saltwater applications. The principal tower material is fiberglass reinforced plastic (FRP), with stainless steel fittings. These materials are more resistant to the higher corrosive effects of saltwater.

The size of each tower is primarily based on the thermal load rejected to the tower by the surface condenser and a 12° F approach to the ambient wet bulb temperature. Flow rates through each condenser remain unchanged.

General characteristics of the wet cooling towers selected for SGS are summarized in Table O–7.

Table O–7. Wet Cooling Tower Design

	Tower 1 (Unit 1)	Tower 2 (Unit 2)	Tower Complex 3 (Unit 3)
Thermal load (MMBTU/hr)	695	695	1838
Circulating flow (gpm)	78,000	78,000	188,000
Number of cells	6	6	14
Plume free design point	50°F dry bulb 90% relative humidity	50°F dry bulb 90% relative humidity	50°F dry bulb 90% relative humidity
Tower type	Mechanical draft	Mechanical draft	Mechanical draft
Flow orientation	Counterflow	Counterflow	Counterflow
Fill type	Modular splash	Modular splash	Modular splash
Arrangement	Inline	Inline	Inline
Primary tower material	FRP	FRP	FRP
Tower dimensions (l x w x h) (ft) [1]	288 x 54 x 58	288 x 54 x 58	378 x 54 x 60
Tower footprint with basin (l x w) (ft) [1]	292 x 58	292 x 58	382 x 58

[1] For Unit 3, dimensions are applicable to each individual tower. Tower Complex 3 consists of two separate towers, each with these overall dimensions.

3.3.2 LOCATION

The initial site selection for each tower was based on the desire to locate each tower as close as possible to its respective generating unit to minimize the supply and return pipe distances and any increases in total pump head and brake horsepower. At SGS, the linear distance between the generating units is not significant (approximately 250 feet) and does not present any significant challenges with respect to supply and return pipelines. As noted above, the proximity of cooling towers to the switchyard is likely to cause drift deposition on sensitive equipment and transmission lines. Figure O–5 identifies the approximate location of each tower and supply and return piping.

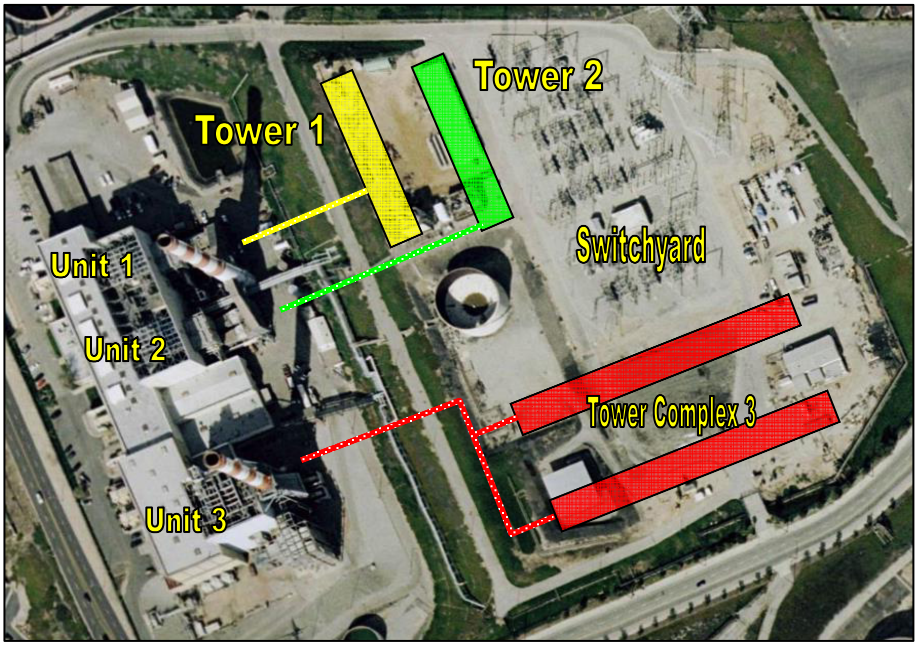

Figure O–5. Location of Cooling Towers

3.3.3 PIPING

The difference in elevation between the tower locations and the power block allows for the placement of most of the main supply and return pipelines above ground on pipe racks. All above-ground pipes are made of FRP. Short sections for the tower supply headers will be placed underground and made of prestressed concrete cylinder pipe (PCCP) suitable for saltwater applications. Pipelines connecting the condenser to the main supply and return lines are also placed above ground, which avoids the potential disruption that may be caused by excavation in and around the power block. The condensers at SGS are located at grade level, enabling a relatively straightforward connection.

Appendix B details the total quantity of each pipe size and type for SGS.

3.3.4 FANS AND PUMPS

Each tower cell uses an independent single-speed fan. The fan size and motor power are the same for each cell in all four towers at SGS.

This analysis includes new pumps to circulate water between the condensers and cooling towers. Pumps are sized according to the flow rate for each tower, the relative distance between the tower and condensers, and the total head required to deliver water to the top of the cooling tower riser. A separate, multilevel pump house is constructed for each cooling tower and is sized to accommodate the motor control centers (MCCs) and appropriate electrical switchgear. The electrical installation includes all necessary transformers, cabling, cable trays, lighting, and lightning protection. A 30-ton overhead crane is also included to allow for pump servicing.

Pumps serving the SGS cooling towers must overcome the difference in elevation between the power block and towers in addition to the elevation of the riser, for an approximate total of 110 feet.

Fan and pump characteristics associated with wet cooling towers at SGS are summarized in Table O–8. The net electrical demand of the fans and new pumps are discussed further as part of the energy penalty analysis in Section 4.6.

Table O–8. Cooling Tower Fans and Pumps

		Tower 1 (Unit 1)	Tower 2 (Unit 2)	Tower Complex 3 (Unit 3)
Fans	Number	6	6	14
	Type	Low noise Single speed	Low noise Single speed	Low noise Single speed
	Efficiency	0.95	0.95	0.95
	Motor power (hp)	211	211	211
Pumps	Number	2	2	4
	Type	50% recirculating Mixed flow Suspended bowl Vertical	50% recirculating Mixed flow Suspended bowl Vertical	50% recirculating Mixed flow Suspended bowl Vertical
	Efficiency	0.88	0.88	0.88
	Motor power (hp)	1,205	1,205	3,636

3.4 ENVIRONMENTAL EFFECTS

Conversion of the existing once-through cooling system at SGS to wet cooling towers will significantly reduce the intake of seawater from the Pacific Ocean and will presumably reduce impingement and entrainment by a similar proportion. Because closed-cycle systems will almost always result in condenser cooling water temperatures higher than those found in a comparable once-through system, wet towers will increase the operating heat rates at each of SGS's steam units, thereby decreasing the facility's overall efficiency. Additional power will also be consumed by the operation of tower fans and circulating pumps. Depending on how SGS chooses to address this change in efficiency, total stack emissions may increase for pollutants such as PM_{10}, SO_2, and NO_x, and may require additional control measures or the purchase of emission credits to meet air quality regulations. No control measures are currently available for CO_2 emissions, which will increase, on a per-kWh basis, by the same proportion as any change in the heat rate. The towers themselves will constitute an additional source of PM_{10} emissions, the annual mass of which will largely depend on the utilization capacity for the generating units served by the tower.

If SGS retains its National Pollutant Discharge Elimination System (NPDES) permit to discharge wastewater to the Pacific Ocean with a wet cooling tower system, it may have to address revised effluent limitations resulting from the substantial change in the quantity and characteristics of the discharge. Impacts from the discharge of elevated temperature wastes associated with the current once-through system, if any, will be minimized through the use of a wet cooling system.

3.4.1 AIR EMISSIONS

SGS is located in the South Central Coast air basin. Air emissions are permitted by the South Coast Air Quality Management District (SCAQMD) (Facility ID 800075).

Drift volumes are expected to be within the range of 0.5 gallons for every 100,000 gallons of circulating water in the towers. At SGS, this corresponds to a rate of approximately 1.75 gpm based on the maximum combined flow in the four towers. As discussed above, drift deposition has the potential to significantly impact the switchyard and transmission equipment.

Total PM_{10} emissions from the SGS cooling towers are a function of the number of hours in operation, overall water quality in the tower, and evaporation rate of drift droplets prior to deposition on the ground. Makeup water at SGS will be obtained from the same source currently used for once-through cooling water (Pacific Ocean). At 1.5 cycles of concentration and assuming an initial total dissolved solids (TDS) value of 35 parts per thousand (ppt), the water within the cooling towers will reach a maximum TDS level of roughly 53 ppt. Any drift droplets exiting the tower will have the same TDS concentration.

The cumulative mass emission of PM_{10} from SGS will increase as a result of the direct emissions from the cooling towers themselves. Stack emissions of PM_{10}, as well as SO_x, NO_x, and other pollutants, will increase due to the drop in fuel efficiency, although the cumulative increase will depend on actual operations and emission control technologies currently in use. Maximum drift and PM_{10} emissions from the cooling towers are summarized in Table O–9.[4]

2005 emission data for these pollutants is summarized in Table O–10 (CARB 2005). In 2005, SGS operated at an annual capacity utilization of 23.9 percent. Using this rate, the additional PM_{10} emissions from the cooling towers would increase the facility total by approximately 47 tons/year, or 106 percent.

Table O–9. Full Load Drift and Particulate Estimates

	PM10 (lbs/hr)	PM10 (tons/year)	Drift (gpm)	Drift (lbs/hr)
Tower 1	10	45	0.4	195
Tower 2	10	45	0.4	195
Tower Complex 3	25	108	0.9	472
Total SGS PM_{10} and drift emissions	**45**	**198**	**1.7**	**862**

Table O–10. 2005 Emissions of SO_x, NO_x, PM_{10}

Pollutant	Tons/year
NO_x	32.6
SO_x	43.2
PM_{10}	44.3

[4] This is a conservative estimate that assumes all dissolved solids present in drift droplets will be converted to PM_{10}. Studies suggest this may overestimate actual emission profiles for saltwater cooling towers (Chapter 4).

3.4.2 MAKEUP WATER

The volume of makeup water required by the four cooling towers at SGS is the sum of evaporative loss and the blowdown volume required to maintain the circulating water in the towers at the design TDS concentration. Drift expelled from the tower represents an insignificant volume by comparison and is accounted for by rounding up estimates of evaporative losses. Makeup water volumes are based on design conditions, and may fluctuate seasonally depending on climate conditions and facility operations. Use of wet cooling towers will reduce once-through cooling water withdrawals from the Pacific Ocean by approximately 95 percent over the current design intake capacity. Table O–11 summarizes the makeup water demand for SGS.

Table O–11. Makeup Water Demand

	Tower circulating flow (gpm)	Evaporation (gpm)	Blowdown (gpm)	Total makeup water (gpm)
Tower 1	78,000	1,200	2,400	3,600
Tower 2	78,000	1,200	2,400	3,600
Tower Complex 3	188,000	2,900	5,900	8,800
Total SGS makeup water demand	**344,000**	**5,300**	**10,700**	**16,000**

One circulating water pump, rated at 39,000 gpm, which is currently used to provide once-through cooling water to the facility, will be retained in a wet cooling system to provide makeup water to all four cooling towers. The capacity of the retained pump exceeds the makeup demand capacity by approximately 23,000 gpm. Any excess capacity will be routed through a bypass conduit and returned to the wet well at a point located behind the intake screens. Recirculating the excess capacity in this manner reduces additional costs that would be incurred if new pumps were required while maintaining the desired flow reduction. The intake of new water, measured at the intake screens, will be equal to the makeup water demand of the cooling towers. Figure O–6 presents a schematic of this configuration.

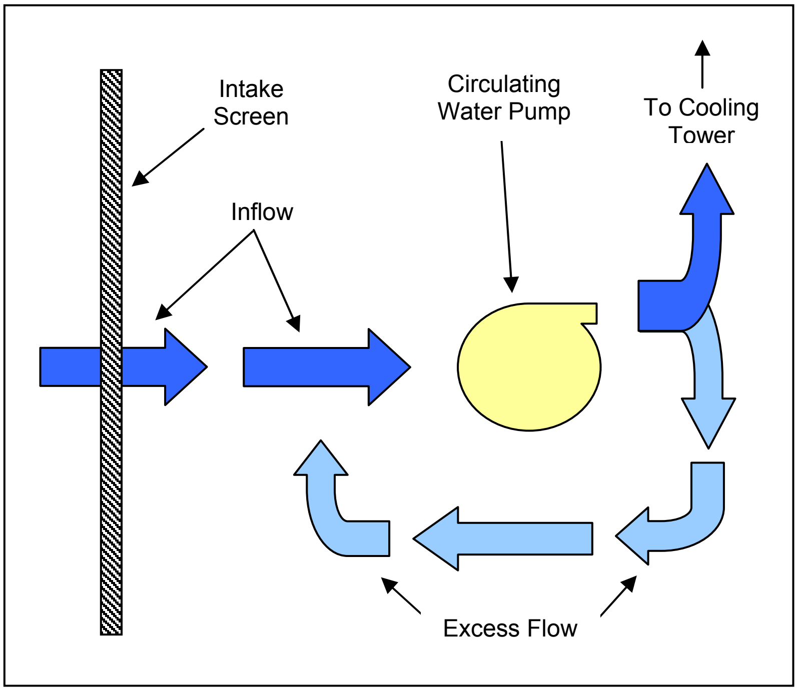

Figure O–6. Schematic of Intake Pump Configuration

The existing once-through cooling system at SGS does not treat water withdrawn from the Pacific Ocean, with the exception of screening for debris and larger organisms and periodic chlorination to control biofouling in the condenser tubes. Heat treatments are also periodically used to control mussel growth on pipes and condenser tubes by raising the temperature of the circulating water to 135º F. Conversion to a wet cooling tower system will not interfere with chlorination or heat treatment operations.

Makeup water will continue to be withdrawn from the Pacific Ocean.

The wet cooling tower system proposed for SGS includes water treatment for standard operational measures, i.e., fouling and corrosion control. Chemical treatment allowances are included in annual operations and maintenance (O&M) costs. It is assumed that the current once-through cooling water quality will be acceptable for use in a seawater cooling tower (with continued screening and chlorination) and will not require any pretreatment to enable its use.

3.4.3 NPDES PERMIT COMPLIANCE

At maximum operation, wet cooling towers at SGS will result in an effluent discharge of approximately 15 mgd of blowdown in addition to other in-plant waste streams—such as boiler blowdown, floor drain wastes, and cleaning wastes. These low-volume wastes may add an additional 0.25 mgd to the total discharge flow from the facility. Unless an alternative discharge is considered, SGS will be required to modify its existing individual wastewater discharge (NPDES) permit. Current effluent limitations for conventional and priority pollutants, as well as thermal discharge limitations, are contained in NPDES Permit CA0000370, as implemented by LARWQCB Order 00-083. All wastewaters are discharged to the Pacific Ocean through a submerged conduit extending approximately 1,200 feet offshore. The existing order contains effluent limitations based on the 1997 Ocean Plan and 1972 Thermal Plan.

SGS will be required to meet technology-based effluent limitations for cooling tower blowdown established under the Effluent Limitation Guidelines (ELGs) for Steam Electric Facilities (40 CFR 423.13(d)(1)). These ELGs set numeric limitations for chromium and zinc (0.2 mg/L and 1.0 mg/L, respectively) while establishing narrative criteria for priority pollutants (no detectable quantity). Because ELGs are technology-based limitations, mixing zones or dilution factors are not applicable when determining compliance; limits must be met at the point of discharge from the cooling tower prior to commingling with any other waste stream. ELGs for cooling tower blowdown target priority pollutants that are contributed by maintenance chemicals and do not apply when limits may be exceeded as a result of background concentrations or other sources. Further discussion can be found in Chapter 4, Section 3.6.

Conversion to wet cooling towers will alter the volume and composition of a facility's wastewater discharge because wet towers concentrate certain pollutants in the effluent waste stream. The cooling towers designed for SGS operate at 1.5 cycles of concentration, i.e., the blowdown discharge will contain a dissolved solids concentration 50 percent higher than the makeup water.

Changes to discharge composition may affect compliance with water quality objectives included in the Ocean Plan. If compliance with these objectives becomes problematic, alternative treatment or discharge methods may be necessary. Compliance may be achieved by altering the discharge configuration in such a way as to increase dilution (e.g., diffuser ports), or by seeking a mixing zone and dilution credits as permissible under the Ocean Plan. Alternately, some low volume waste streams (e.g., boiler blowdown, laboratory drains) may be diverted, with necessary permits, for treatment at a POTW.

If more pollutant-specific treatment methods, such as filtration or precipitation technologies, become necessary to meet WQBELs, the initial capital cost may range from $2 to $5.50 per 1,000 gallons of treatment capacity, with annual costs of approximately $0.5 per gallon of capacity, depending on the method of treatment (FRTR 2002). Hazardous material disposal fees and permits would further increase costs.

This evaluation did not include alternative discharge or effluent treatment measures in the conceptual design because the variables used to determine final WQBELs, which would be used to determine the type and scope of the desired compliance method, cannot be quantified here. Likewise, the final cost evaluation (Section 4.0) does not include any allowance for these possibilities.

Thermal discharge standards are based on narrative criteria established for coastal discharges under the Thermal Plan, which requires that existing discharges of elevated-temperature wastes comply with effluent limitations necessary to assure the protection of designated beneficial uses. The LARWQCB has implemented this provision by establishing a maximum discharge temperature of 100º F during normal operations in Order 00-083 (LARWQCB 2000). Information available for review indicates SGS has consistently been able to comply with this requirement. Because cooling tower blowdown will be taken from the "cold" side of the tower, conversion to a wet cooling system will significantly reduce the discharge temperature (to less than 81º F) and the size of any related thermal plume in the receiving water.

3.4.4 RECLAIMED WATER

The use of reclaimed or alternative water sources could potentially eliminate all surface water withdrawals at SGS. Doing so would completely eliminate impingement and entrainment concerns, and might enable the facility to avoid possible effluent quality and permit compliance issues, depending on the quality of reclaimed water available for use. In addition, wet cooling towers using reclaimed water would be expected to have lower PM_{10} emissions due to the lower TDS levels. The California State Water Resources Control Board (SWRCB), in 1975, issued a policy statement requiring the consideration of alternative cooling methods in new power plants, including the use of reclaimed water, over the use of freshwater (SWRCB 1975). There is no similar policy regarding the use of marine waters, but the clear preference of state agencies is to encourage alternative cooling methods, including the use of reclaimed water, wherever possible.

The present volume of available secondary treated water within a 15-mile radius of SGS (680 mgd) can meet the current once-through cooling demand for all three generating units (495 mgd), although the volume that is reliably available would require pipeline connections to two different sources to ensure an adequate and consistent flow. In lieu of secondary treated water as a replacement for once-through cooling, reclaimed water can be used as makeup water in cooling towers but must meet tertiary treatment and disinfection standards under California Code of Regulations (CCR) Title 22.

If the reclaimed water is not treated to the required levels, SGS would be required to provide sufficient treatment prior to use in the cooling towers. Currently, the West Basin Municipal Water District (WBMWD) treats approximately 30 mgd of secondary water from Hyperion WWTP to tertiary standards. This water is used for various projects throughout the South Bay region, such as the seawater barrier conservation project to protect underground aquifers. WBMWD's current available capacity is insufficient to meet the makeup water demand for the wet cooling towers at SGS (WBMWD 2007). Limited space at SGS will likely make any onsite treatment system problematic, depending on the system's size and configuration.

An additional consideration for the use of reclaimed water is the presence of any ammonia or ammonia-forming compounds in the reclaimed water. The condenser tubes for Unit 3 contain copper alloys (90-10 Cu-Ni) and can experience stress-corrosion cracking as a result of the interaction between copper and ammonia. Treatment for ammonia may include the addition of ferrous sulfate as a corrosion inhibitor or require ammonia-stripping towers to pretreat reclaimed water prior to use in the cooling towers (EPA 2001). The condenser tubes for Unit 1 and Unit 2 are made of 316 stainless steel.

Two publicly owned treatment works (POTWs) were identified within a 15-mile radius of SGS, with a combined discharge capacity of 680 mgd. Figure O–7 shows the relative locations of these facilities to SGS.

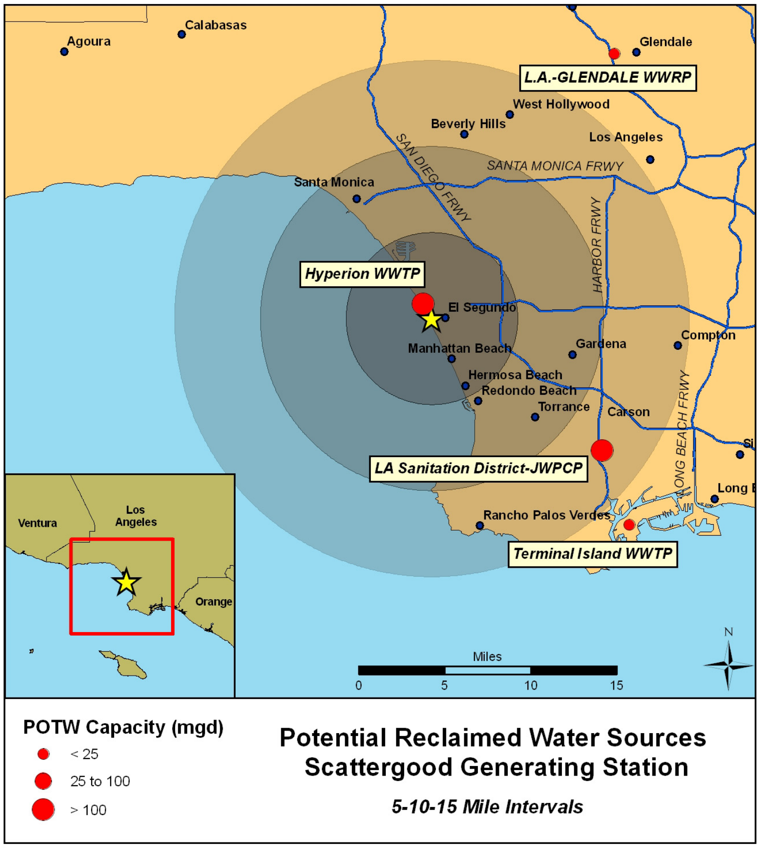

Figure O-7. Reclaimed Water Sources

- *Los Angeles Sanitation District, Hyperion Wastewater Treatment Plant—Los Angeles*
  Discharge volume: 350 mgd
  Distance: Adjacent to north end of SGS
  Treatment level: Secondary

  The CEC evaluated the use of secondary treated water from Hyperion as a replacement for once-through cooling in the Final Staff Assessment (FSA) to the El Segundo Power Replacement (ESPR) project in 2002. While the FSA did not directly consider use of Hyperion water at SGS, the conclusions in that study are generally applicable to SGS, given the similarities between the two facilities in terms of makeup demand and existing configuration.

  The assessment determined that the use of Hyperion's water was technically feasible (as a once-through replacement), although the evaluation was based on a once-through demand of 207 mgd that would have been required for the ESPR. Because the distance offshore (2,100 feet) of the ESGS outfall is insufficient to meet water quality standards for public beaches, secondary water used at ESGS would either be returned to Hyperion for discharge through the Hyperion "5 mile" outfall, treated prior to discharge, or used for another purpose (CEC 2002a).

Any water used in a wet cooling tower at SGS would have to be treated onsite at the facility to meet tertiary treatment standards. Hyperion currently provides only secondary treatment and does not appear to have sufficient area on which to construct a tertiary treatment system. WBMWD does not have sufficient excess capacity to meet the demand of freshwater towers at SGS (10 to 12 mgd). The 2002 FSA deemed tertiary treatment at ESGS infeasible due to the overall size of the treatment facility and the lack of sufficient space at the site (CEC 2002a). The final commission decision, however, found that this option was infeasible (CEC 2005). It is unclear if sufficient area is available at SGS to accommodate a treatment facility in addition to the wet cooling towers.

- *Los Angeles Sanitation District, Joint Water Pollution Control Plant (JWPCP)—Carson*
  Discharge volume: 330 mgd
  Distance: 13 miles southeast
  Treatment level: Secondary

  The facility representative at JWPCP indicated that the effluent is not currently considered a potential source of reclaimed water for irrigation due to high TDS concentrations (brine from the Hyperion WWTP is treated at Carson), but the suitability for use as a makeup water source is not currently known. TDS levels may be less than normally found in seawater and thus be at least comparable to the current makeup water source at SGS. In the future, a portion of the effluent may be used for a new hydrogen plant under consideration by BP (formerly British Petroleum), but no formal agreement currently exists. Even with such an agreement, sufficient capacity would remain to satisfy the full makeup water demand for freshwater towers at SGS (10 to 12 mgd).

The costs associated with installing transmission pipelines (excavation/drilling, material, labor), in addition to design and permitting costs, are difficult to quantify in the absence of a detailed analysis of various site-specific parameters that will influence the final configuration. The nearest facility with sufficient capacity to satisfy SGS's makeup demand (10 to 12 mgd for freshwater towers) is located adjacent to the SGS property (Hyperion). Based on data compiled for this study and others, the estimated installed cost of a 24-inch prestressed concrete cylinder pipe, sufficient to provide 12 mgd to SGS, is $300 per linear foot, or approximately $1.6 million per mile. Additional considerations, such as pump capacity and any required treatment, would increase the total cost.

Regulatory concerns beyond the scope of this investigation may make the use of reclaimed water comparable or preferable to the use of saltwater from marine sources as makeup water. Use of freshwater may reduce or eliminate drift deposition impacts on sensitive equipment. Reclaimed water may enable SGS to reduce PM_{10} emissions from the cooling tower, which is a concern given the current nonattainment status of the South Coast air basin, or eliminate potential conflicts with water discharge limitations. SGS might realize other benefits by using reclaimed water in the form of reduced O&M costs.

At any facility where wet cooling towers are a feasible alternative, reclaimed water may be used as a makeup water source; the practicality of its use, however, is a question of the overall cost, availability, and additional environmental benefit that may be realized.

3.4.5 THERMAL EFFICIENCY

The use of wet cooling towers at SGS will increase the temperature of the condenser inlet water by a range of 9 to 13° F above the surface water temperature, depending on the ambient wet bulb temperature at the time. The generating units at SGS are designed to operate at the conditions described in Table O–12. The resulting monthly difference between once-through and wet cooling tower condenser inlet temperatures at SGS is described in Figure O–8.

Table O–12. Design Thermal Conditions

	Unit 1	Unit 2	Unit 3
Design backpressure (in. HgA)	1.5	1.5	1.65
Design water temperature (°F)	60	60	62
Turbine inlet temp (°F)	1,000	1,000	1,000
Turbine inlet pressure (psia)	1,850	1,850	3,500
Full load heat rate (BTU/kWh) [1]	9,459	9,564	9,276

[1] CEC 2002b.

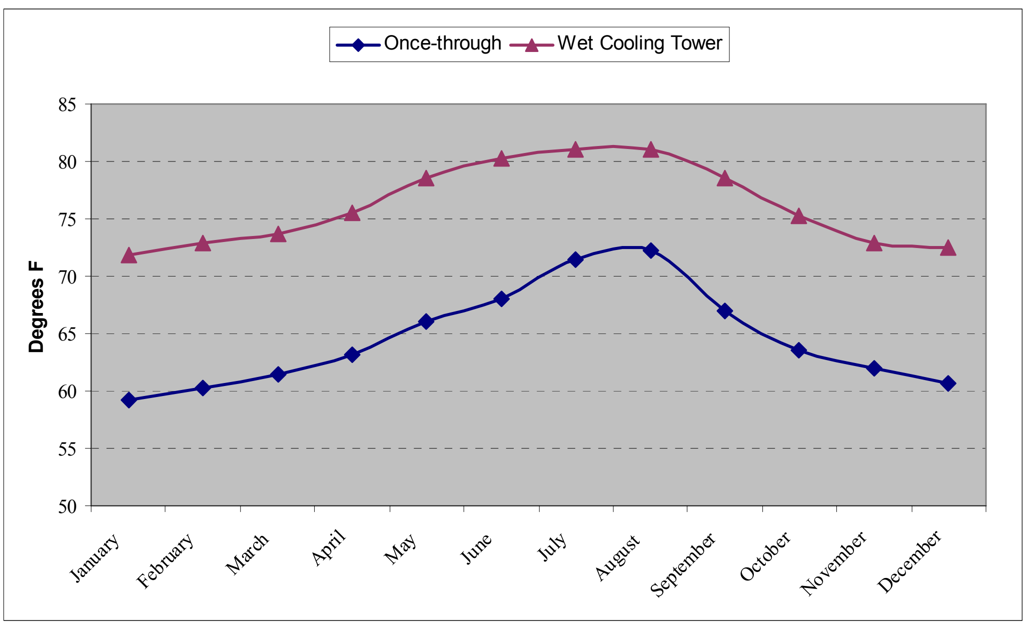

Figure O–8. Condenser Inlet Temperatures

Backpressures for the once-through and wet cooling tower configurations were calculated using the design criteria described in the sections above on a monthly basis using ambient climate data.

In general, backpressures associated with the wet cooling tower were elevated by 0.5 to 0.8 inches HgA compared with the current once-through system (Figure O–9, Figure O–11, and Figure O–13).

Heat rate adjustments were calculated by comparing the theoretical change in available energy that occurs at different turbine exhaust backpressures, assuming the thermal load and turbine inlet pressure remain constant, i.e., at the maximum load rating. The relative change at different backpressures was compared with the value calculated for the design conditions (i.e., at design turbine inlet and exhaust backpressures) and plotted as a percentage of the maximum operating heat rate to develop estimated correction curves (Figure O–10, Figure O–12, and Figure O–14). A comparison was then made between the relative heat rates of the once-through and wet cooling systems for a given month. The difference between these two values represents the net increase in heat rate that would be expected in a converted system.

Table O–13 summarizes the annual average heat rate increase for each unit as well as the increase associated with the peak demand period of July-August-September. Monthly values were used to develop an estimate of the monetized value of these heat rate changes (Section 4.6.2). Month-by-month calculations are presented in Appendix A.

Table O–13. Summary of Estimated Heat Rate Increases

	Unit 1	Unit 2	Unit 3
Peak (July-August-September)	1.28%	1.28%	1.35%
Annual average	1.27%	1.27%	1.19%

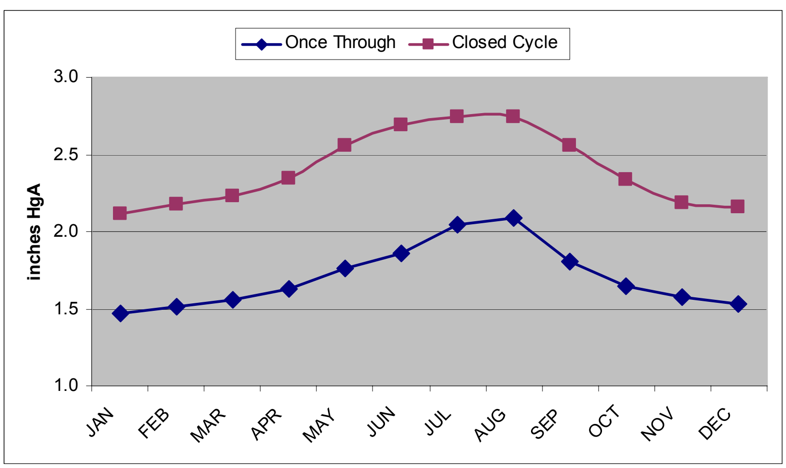

Figure O–9. Estimated Backpressures (Unit 1)

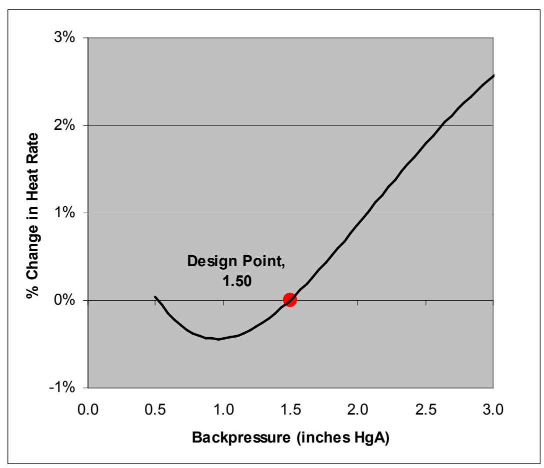

Figure O–10. Estimated Heat Rate Correction (Unit 1)

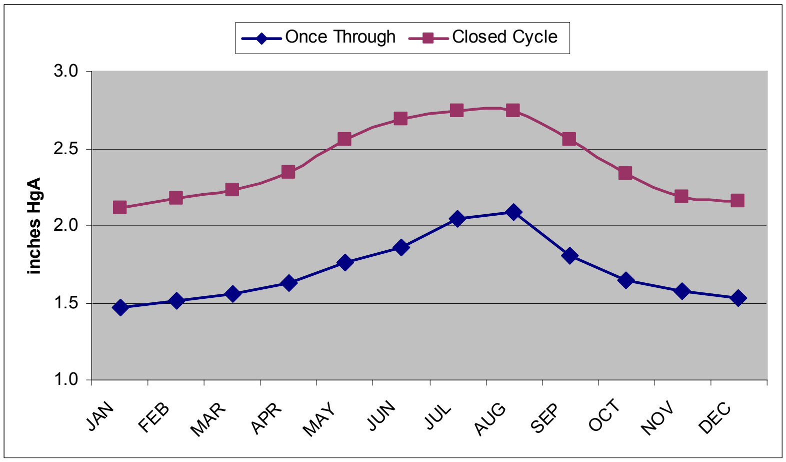

Figure O–11. Estimated Backpressures (Unit 2)

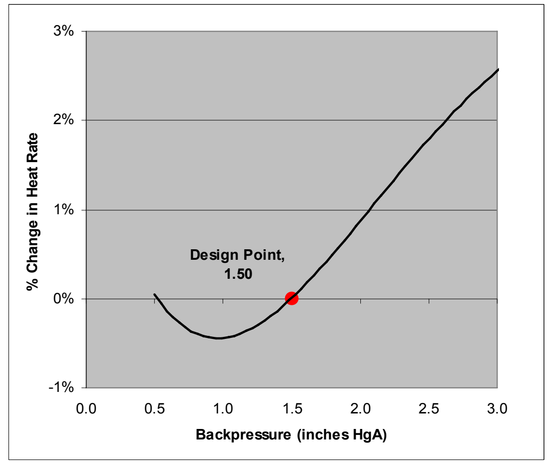

Figure O–12. Estimated Heat Rate Correction (Unit 2)

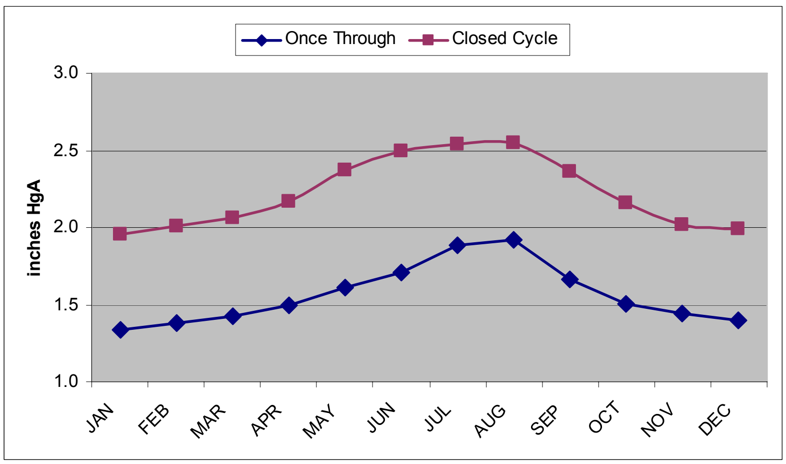

Figure O–13. Estimated Backpressures (Unit 3)

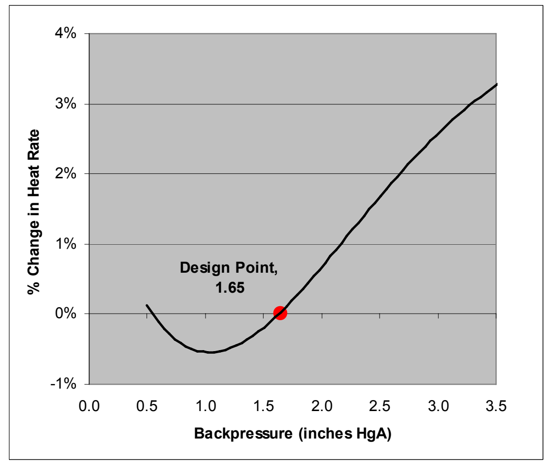

Figure O–14. Estimated Heat Rate Correction (Unit 3)

4.0 RETROFIT COST ANALYSIS

The wet cooling system retrofit estimate for SGS is based on incorporating plume-abated wet cooling towers as a replacement for the existing once-through system that serves the three generating units. Standard cost elements for this project include the following:

- Direct (cooling tower installation, civil/structural, mechanical, piping, electrical, and demolition)
- Indirect (smaller project costs not itemized)
- Contingency (allowance for unknown project variables)
- Operations and maintenance (nonenergy-related cooling tower operations)
- Energy penalty (includes increased parasitic use from fans and pumps as well as decreased thermal efficiency)
- Revenue loss from shutdown (net loss in revenue during construction phase)

The cost analysis does not include allowances for elements that are not quantified in this study, such as land acquisition, effluent treatment, or air emission reduction credits. The methodology used to develop cost estimates is discussed in Chapter 5.

4.1 COOLING TOWER INSTALLATION

The requirement to use plume-abated towers at SGS increases the per-cell cost by a factor of approximately 2.7 over the cost of conventional tower cells (compared with the cost of cells designed for ESGS). Table O–14 summarizes the design-and-build cost estimate for each tower developed by vendors, inclusive of all labor and management required for their installation.

Table O–14. Wet Cooling Tower Design-and-Build Cost Estimate

	Unit 1	Unit 2	Unit 3	SGS total
Number of cells	6	6	14	**26**
Cost/cell ($)	1,633,333	1,633,333	1,821,429	**1,734,615**
Total SGS D&B cost ($)	**9,800,000**	**9,800,000**	**25,500,000**	**45,100,000**

4.2 OTHER DIRECT COSTS

A significant portion of the cost incurred for the wet cooling tower installation results from the various support structures and materials (pipes, pumps, etc.), as well the necessary equipment and labor required to prepare the cooling tower site and connect the towers to the cooling system. At SGS, these costs comprise approximately 45 percent of the initial capital cost. Line item costs are detailed in Appendix B.

Deviations from or additions to the general cost elements discussed in Chapter 5 are discussed below. Other direct costs (non–cooling tower) are summarized in Table O–15.

Table O–15. Summary of Other Direct Costs

	Equipment ($)	Bulk material ($)	Labor ($)	SGS total ($)
Civil/structural/piping	4,800,000	17,800,000	14,400,000	37,000,000
Mechanical	9,000,000	0	500,000	9,500,000
Electrical	1,600,000	3,100,000	2,000,000	6,700,000
Demolition	0	0	400,000	400,000
Total SGS other direct costs	**15,400,000**	**20,900,000**	**17,300,000**	**53,600,000**

- *Civil, Structural, and Piping*
  The configuration of the SGS site allows each tower to be located within relative proximity to its respective generating unit. Most pipes are above ground and made of FRP.
- *Mechanical and Electrical*
  Initial capital costs in this category reflect incorporating new pumps (eight total) to circulate cooling water between the towers and condensers. No new pumps are required to provide makeup water from the Pacific Ocean. Electrical costs are based on the battery limit after the main feeder breakers. Because the cooling towers are located at an elevation approximately 70 feet above the condensers, larger-capacity pumps are required to circulate water from the condenser to the top of the riser.
- *Demolition*
  Costs for the demolition of the existing cooling towers and other small structures are included for SGS.

4.3 INDIRECT AND CONTINGENCY

Indirect costs are calculated as 25 percent of all direct costs (civil/structural, mechanical, electrical, demolition, and cooling towers). An additional allowance is included for reinforcement of the condenser to withstand the increased pressures resulting from incorporation of wet cooling towers. Each condenser may require reinforcement of the tube sheet bracing with 6-inch by 1inch steel, and water box reinforcement/replacement with 5/8-inch carbon steel. Based on the data outlined in Chapter 5, a conservative estimate of 5 percent of all direct costs is included to account for possible condenser modifications.

The contingency cost is calculated as 25 percent of the sum of all direct and indirect costs, including condenser reinforcement. At SGS, potential costs in this category include relocation or demolition of small buildings and structures and the potential interference with underground structures. Modifications or upgrades to sensitive equipment may be necessary to counteract drift deposition. Soils were not characterized for this analysis. SGS is situated at 30 feet above sea level adjacent to the Pacific Ocean. Seawater intrusion or the instability of sandy soils may require additional pilings to support any large structures built at the site. Initial capital costs are summarized in Table O–16.

Table O–16. Summary of Initial Capital Costs

	Cost ($)
Cooling towers	45,100,000
Civil/structural/piping	37,000,000
Mechanical	9,500,000
Electrical	6,700,000
Demolition	400,000
Indirect cost	24,700,000
Condenser modification	4,900,000
Contingency	32,100,000
Total SGS capital cost	**160,400,000**

4.4 SHUTDOWN

A portion of the work relating to installing wet cooling towers can be completed without significant disruption to the operations of SGS. Units will be offline depending on the length of time it takes to integrate the new cooling system and conduct acceptance testing. For SGS, a conservative estimate of 4 weeks per unit was developed. Based on 2005 generating output, however, no shutdown is forecast for any of the three units. Therefore, the cost analysis for SGS does not include any loss of revenue associated with shutdown at SGS.

This analysis did not consider shutdown with respect to the required availability of a particular generating unit, nor can it automatically be assumed that the generating profile for 2006 will be the same in each subsequent year. Net output data from 2006 may not reflect any contractual obligations that mandate a particular unit's availability during a given time period.

4.5 OPERATIONS AND MAINTENANCE

O&M costs for a wet cooling tower system at SGS include routine maintenance activities; chemicals and treatment systems to control fouling and corrosion in the towers; management and labor; and an allowance for spare parts and replacement. Annual costs are calculated based on the circulating water flow capacity of the towers using a base cost of $4.00/gpm in Year 1 and $5.80/gpm in Year 12, with an annual escalator of 2 percent (USEPA 2001). Year 12 costs increase based on the assumption that maintenance needs, particularly for spare parts and replacements, will be greater for years 12–20. Annual O&M costs, based on the design circulating water flow for the four cooling towers at SGS (344,000 gpm), are presented in Table O–17. These costs reflect maximum operation.

Table O–17. Annual O&M Costs (Full Load)

	Year 1 ($)	Year 12 ($)
Management/labor	344,000	499,525
Service/parts	551,200	799,240
Fouling	482,300	699,335
Total SGS O&M cost	**1,377,500**	**1,998,100**

4.6 ENERGY PENALTY

The energy penalty is divided into two components: increased parasitic use resulting from the additional electrical demand of cooling tower fans and pumps; and the decrease in thermal efficiency resulting from elevated turbine backpressure values. Monetizing the energy penalty at SGS requires some assumption as to how the facility will choose to alter its operations to compensate for these changes, if at all. One option would be to accept the reduced amount of revenue-generating electricity available and absorb the economic loss ("production loss option"). A second option would be to increase the firing rate to the turbine (i.e., consume more fuel) and produce the same amount of revenue-generating electricity as had been obtained with the once-through cooling system ("increased fuel option"). A more likely option, however, is some combination of the two.

Ultimately, the manner in which SGS would alter operations to address efficiency changes is driven by considerations unknown to this study (e.g., corporate strategy, contractual obligations, operating protocols and turbine pressure tolerances). In all summary cost estimates, this study calculates the energy penalty's monetized value by assuming the facility will use the increased fuel option to compensate for reduced efficiency and generate the amount of electricity equivalent to the estimated shortfall. With this option, the energy penalty is equivalent to the financial cost of additional fuel and is nominally less costly than the production loss option. This option, however, may not reflect long-term costs such as increased maintenance or system degradation that may result from continued operation at a higher-than-designed turbine firing rate.[5]

The energy penalty for SGS is calculated by first estimating the increased parasitic demand from the cooling tower pumps and fans, expressed as a percentage of each unit's or unit pair's rated capacity. Likewise, the change in the unit's heat rate is also expressed as a capacity percentage.

4.6.1 INCREASED PARASITIC USE (FANS AND PUMPS)

Depending on ambient conditions or the operating load at a given time, SGS may be able to take one or more cooling tower cells offline and still obtain the required level of cooling. This would also reduce the cumulative electrical demand from the fans. For the purposes of this study,

[5] Increasing the thermal load to the turbine will raise the circulating water temperature exiting the condenser. The cooling towers selected for this study are designed with a maximum water return temperature of approximately 120º F. Depending on each unit's operating conditions (i.e., condenser outlet temperature), the degree to which the thermal input to the turbine can be increased may be limited.

however, operations are evaluated at the design conditions, i.e., maximum load; no allowance is made for seasonal changes. The increased electrical demand associated with operation of the cooling tower fans is summarized in Table O–18.

Table O–18. Cooling Tower Fan Parasitic Use

	Tower 1	Tower 2	Tower Complex 3	SGS total
Units served	Unit 1	Unit 2	Unit 3	--
Generating capacity (MW)	179	179	445	**803**
Number of fans (one per cell)	6	6	14	**26**
Motor power per fan (hp)	211	211	211	--
Total motor power (hp)	1,263	1,263	2,947	**5,473**
MW total	0.94	0.94	2.20	**4.08**
Fan parasitic use (% of capacity)	**0.53%**	**0.53%**	**0.49%**	**0.51%**

The addition of new circulating water pump capacity for the wet cooling towers will also increase the parasitic use of electricity at SGS. Makeup water will continue to be withdrawn from the Pacific Ocean through the use of one of the existing circulating water pumps; the remaining pumps will be retired. The net increase in pump-related parasitic usage is the difference between the new wet cooling tower configuration (new plus retained pumps) and the existing once-through configuration. Because one of the main design assumptions maintains the existing flow rate through each condenser, the new circulating pumps are single speed and are assumed to operate at their full rated capacity when in use. The increased electrical demand associated with operation of the cooling tower pumps is summarized in Table O–19.

Table O–19. Cooling Tower Pump Parasitic Use

	Tower 1	Tower 2	Tower Complex 3	SGS total
Units served	Unit 1	Unit 2	Unit 3	--
Generating capacity (MW)	179	179	445	**803**
Existing pump configuration (hp)	680	680	3,000	**4,360**
New pump configuration (hp)	2,609	2,609	14,945	**20,164**
Difference (hp)	1,929	1,929	11,945	**15,804**
Difference (MW)	1.4	1.4	8.9	**11.8**
Net pump parasitic use (% of capacity)	**0.80%**	**0.80%**	**2.00%**	**1.47%**

4.6.2 HEAT RATE CHANGE

Adjustments to the heat rate were calculated based on the ambient conditions for each month and reflect the estimated difference between operations with once-through and wet cooling tower systems. As noted above, the energy penalty analysis assumes SGS will increase its fuel consumption to compensate for lost efficiency as well as the increased parasitic load from fans and pumps. The higher turbine firing rate will increase the thermal load rejected to the condenser, which, in turn, results in a higher backpressure value and corresponding increase in the heat rate. No data are available describing the changes in turbine backpressures above the design thermal loads. For the purposes of monetizing the energy penalty only, this study conservatively assumed an additional increase in the heat rate of 0.5 percent at the higher firing rate; the actual effect at AGS may be greater or less. Changes in the heat rate for each unit at SGS are presented in Figure O–15 through Figure O–17.

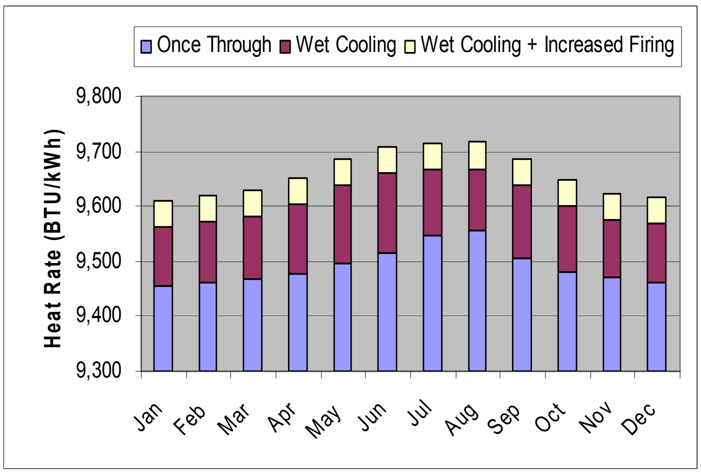

Figure O–15. Estimated Heat Rate Change (Unit 1)

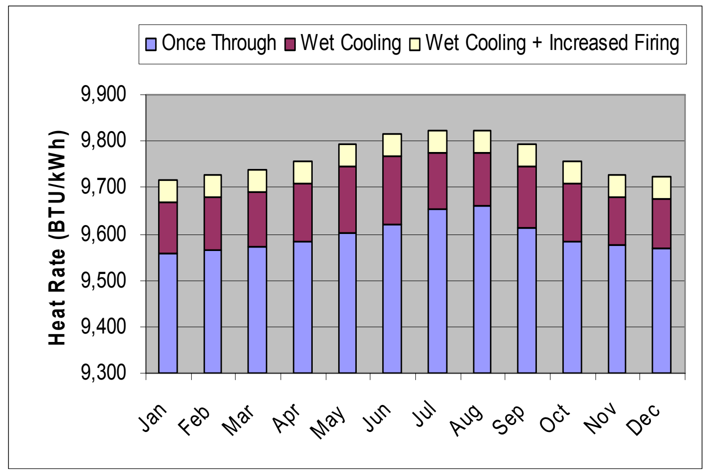

Figure O–16. Estimated Heat Rate Change (Unit 2)

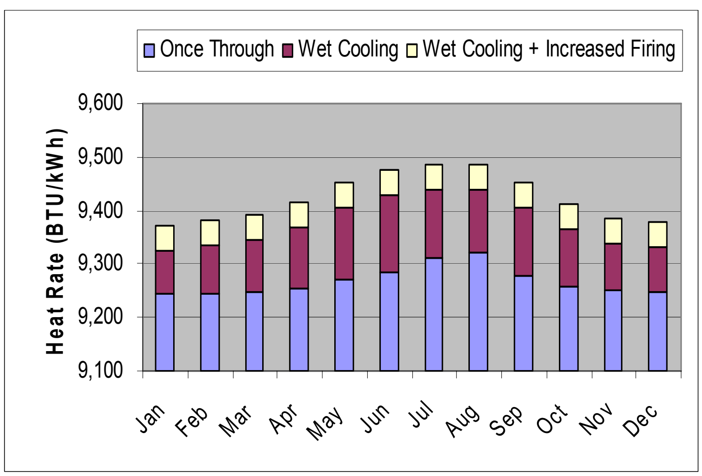

Figure O–17. Estimated Heat Rate Change (Unit 3)

4.6.3 CUMULATIVE ESTIMATE

Using the increased fuel option, the cumulative value of the energy penalty is obtained by first calculating the relative costs of generation ($/MWh) for the once-through and overfired wet cooling systems. The cost of generation for SGS is based on the relative heat rates developed in Section 4.6.2 and the average monthly wholesale natural gas cost ($/MMBTU) (ICE 2006a). The difference between these two values represents the increased cost, per MWh, that results from incorporating wet cooling towers. The net difference in cost, per month, is applied to the net MWh generated for the particular month, and summed to determine an annual estimate. Based on 2005 output data, the annual energy penalty for SGS will be approximately $1.5 million. Table O–20 though Table O–22 summarize the energy penalty estimates for each unit.

Table O–20. Unit 1 Energy Penalty—Year 1

Month	Fuel cost ($/MMBTU)	Once-through system		Wet towers w/ increased firing		Difference ($/MWh)	2005 output (MWh)	Net cost ($)
		Heat rate (BTU/kWh)	Cost ($/MWh)	Heat rate (BTU/kWh)	Cost ($/MWh)			
January	6.00	9,454	56.72	9,609	57.66	0.93	43,793	**40,772**
February	5.50	9,460	52.03	9,620	52.91	0.88	2,675	**2,361**
March	4.75	9,466	44.97	9,630	45.74	0.78	726	**565**
April	4.75	9,477	45.01	9,651	45.84	0.83	0	**0**
May	4.75	9,497	45.11	9,687	46.01	0.90	0	**0**
June	5.00	9,514	47.57	9,708	48.54	0.97	27,209	**26,367**
July	6.50	9,548	62.06	9,716	63.15	1.09	10,083	**11,022**
August	6.50	9,556	62.11	9,716	63.16	1.04	12,240	**12,778**
September	4.75	9,506	45.15	9,686	46.01	0.86	0	**0**
October	5.00	9,479	47.39	9,648	48.24	0.85	26,023	**22,028**
November	6.00	9,469	56.82	9,622	57.73	0.91	72,208	**65,994**
December	6.50	9,462	61.50	9,617	62.51	1.01	23,786	**23,929**
							Unit 1 total	**205,816**

Table O-21. Unit 2 Energy Penalty—Year 1

Month	Fuel cost ($/MMBTU)	Once-through system		Wet towers w/ increased firing		Difference ($/MWh)	2005 output (MWh)	Net cost ($)
		Heat rate (BTU/kWh)	Cost ($/MWh)	Heat rate (BTU/kWh)	Cost ($/MWh)			
January	6.00	9,559	57.35	9,716	58.30	0.94	55,471	**52,196**
February	5.50	9,565	52.61	9,727	53.50	0.89	58,955	**52,588**
March	4.75	9,571	45.46	9,737	46.25	0.79	59,964	**47,134**
April	4.75	9,582	45.51	9,758	46.35	0.84	60,751	**50,743**
May	4.75	9,603	45.61	9,795	46.53	0.91	68,799	**62,732**
June	5.00	9,620	48.10	9,816	49.08	0.98	70,651	**69,182**
July	6.50	9,653	62.75	9,823	63.85	1.10	63,113	**69,707**
August	6.50	9,662	62.80	9,824	63.86	1.05	67,671	**71,383**
September	4.75	9,611	45.65	9,794	46.52	0.87	60,432	**52,410**
October	5.00	9,584	47.92	9,755	48.78	0.86	42,084	**36,002**
November	6.00	9,574	57.45	9,728	58.37	0.92	0	**0**
December	6.50	9,567	62.19	9,723	63.20	1.02	36,084	**36,688**
							Unit 2 total	**600,765**

Table O-22. Unit 3 Energy Penalty—Year 1

Month	Fuel cost ($/MMBTU)	Once-through system		Wet towers w/ increased firing		Difference ($/MWh)	2005 output (MWh)	Net cost ($)
		Heat rate (BTU/kWh)	Cost ($/MWh)	Heat rate (BTU/kWh)	Cost ($/MWh)			
January	6.00	9,243	55.46	9,372	56.23	0.78	5,606	**4,363**
February	5.50	9,246	50.85	9,383	51.61	0.76	0	**0**
March	4.75	9,249	43.93	9,393	44.62	0.68	9,164	**6,251**
April	4.75	9,256	43.96	9,414	44.72	0.75	7,071	**5,315**
May	4.75	9,270	44.03	9,454	44.90	0.87	0	**0**
June	5.00	9,284	46.42	9,478	47.39	0.97	60,965	**59,069**
July	6.50	9,313	60.53	9,487	61.66	1.13	187,673	**212,140**
August	6.50	9,320	60.58	9,487	61.67	1.09	153,272	**166,416**
September	4.75	9,277	44.06	9,452	44.90	0.83	114,331	**95,428**
October	5.00	9,257	46.29	9,411	47.06	0.77	96,667	**74,521**
November	6.00	9,251	55.51	9,384	56.31	0.80	0	**0**
December	6.50	9,247	60.10	9,380	60.97	0.86	0	**0**
							Unit 3 total	**623,503**

4.7 NET PRESENT COST

The Net Present Cost (NPC) of a wet cooling system retrofit at SGS is the sum of all annual expenditures over the 20-year life span of the project and discounted according to the year in which the expense is incurred and the selected discount rate. The NPC represents the total change in revenue streams, in 2007 dollars, that SGS can expect over 20 years as a direct result of converting to wet cooling towers. The following values were used to calculate the NPC at a 7 percent discount rate:

- *Capital and Start-up.* Includes all capital, indirect, contingency, and shutdown costs. All costs in this category are incurred in Year 0. (See Table O–16.)
- *Annual O&M.* Base cost values for Year 1 and Year 12 are adjusted for subsequent years using a 2 percent year-over-year escalator. Because SGS has a relatively low capacity utilization factor, O&M costs for the NPV calculation were estimated at 50 percent of their maximum value. (See Table O–17.)
- *Annual Energy Penalty.* Sufficient information is not available to this study to forecast future generating capacity at SGS. In lieu of annual estimates, this study uses the net MWh output from 2006 for Year 1 through Year 20, including a year-over-year wholesale price escalation of 5.8 percent (based on the Producer Price Index). (See Table O–20 through Table O–22.)

Using these values, the NPC_{20} for SGS is $194 million. Appendix C contains detailed annual calculations used to develop this cost.

4.8 ANNUAL COST

The annual cost incurred by SGS for the retrofit of the once-through cooling system is the sum of the annual amortized capital cost plus the annual average of O&M and energy penalty expenditures. Capital costs are amortized at a 7 discount rate over 20 years. O&M and energy penalty costs are calculated in the same manner as for the NPC_{20} (Section 4.7).

Table O–23. Annual Cost

Discount rate (%)	Capital ($)	Annual O&M ($)	Annual energy penalty ($)	Annual cost ($)
7.00	15,200,000	900,000	2,600,000	**18,700,000**

4.9 COST-TO-GROSS REVENUE COMPARISON

Financial data available to conduct a detailed analysis of the economic impact that a wet cooling system retrofit will have on annual revenues for SGS are limited. As a publicly-owned utility, LADWP's gross revenues will include costs for transmission and distribution. An approximation of gross annual revenues was calculated using public data sources (US EIA 2005) that showed LADWP's average annual retail rate was $96/MWh. This rate was applied to the monthly net generating outputs for each unit in 2005 (CEC 2005) to arrive at a facility-wide revenue estimate. This estimate does not reflect seasonal adjustments that may translate to higher or lower per-

MWh retail rates through the year, nor does it include other liabilities such as taxes or other operational costs.

The estimated gross revenue for SGS is summarized in Table O–24. A comparison of annual costs to annual gross revenue is summarized in Table O–25.

Table O–24. Estimated Gross Revenue

	Wholesale price ($/MWh)	Net generation (MWh)			Estimated gross revenue ($)			
		Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	SGS total
January	96	43,793	55,471	5,606	4,204,171	5,325,182	538,193	**10,067,545**
February	96	2,675	58,955	0	256,835	5,659,718	0	**5,916,553**
March	96	726	59,964	9,164	69,684	5,756,544	879,767	**6,705,995**
April	96	0	60,751	7,071	0	5,832,130	678,824	**6,510,954**
May	96	0	68,799	0	0	6,604,719	0	**6,604,719**
June	96	27,209	70,651	60,965	2,612,032	6,782,496	5,852,613	**15,247,141**
July	96	10,083	63,113	187,673	968,008	6,058,889	18,016,594	**25,043,491**
August	96	12,240	67,671	153,272	1,175,042	6,496,437	14,714,156	**22,385,634**
September	96	0	60,432	114,331	0	5,801,517	10,975,779	**16,777,296**
October	96	26,023	42,084	96,667	2,498,163	4,040,090	9,280,060	**15,818,314**
November	96	72,208	0	0	6,931,965	0	0	**6,931,965**
December	96	23,786	36,084	0	2,283,492	3,464,026	0	**5,747,518**
SGS total		**218,743**	**643,975**	**634,749**	**14,240,870**	**39,511,034**	**44,387,767**	**98,139,672**

Table O–25. Cost-Revenue Comparison

Estimated gross annual revenue ($)	Initial capital		O&M		Energy penalty		Total annual cost	
	Cost ($)	% of gross	Cost ($)	% of gross	Cost ($)	% of gross	Cost ($)	% of gross
143,800,000	15,200,000	10.6	900,000	0.6	2,600,000	1.8	**18,700,000**	**13.0**

5.0 OTHER TECHNOLOGIES

Within the scope of this study, and using the OPC resolution's stated goal of reducing impingement and entrainment by 90–95 percent as a benchmark, the effectiveness of other technologies commonly used to address such impacts could not be conclusively determined for use at SGS. As with many existing facilities, the location and configuration of the site complicates the use of some technologies that might be used successfully elsewhere. A more detailed analysis that also comprises a biological evaluation may determine the applicability of one or more of these technologies to SGS. A brief summary of the applicability of these technologies follows.

5.1 MODIFIED RISTROPH SCREENS—FINE MESH

The principal concern with this technology is the successful return of viable organisms captured on the screens to the source water body. SGS currently withdraws its cooling water through a submerged conduit extending approximately 1,600 feet offshore at a depth of 20 feet. Returning any collected organisms to a similar location would be impractical. It is unclear whether organisms could be returned to a near-shore location closer to the facility and remain viable.

5.2 BARRIER NETS

Barrier nets are unproven in an open ocean environment.

5.3 AQUATIC FILTRATION BARRIERS

Aquatic filtration barriers (AFBs) are unproven in an open ocean environment.

5.4 VARIABLE SPEED DRIVES

Variable speed drives (VSDs) were not considered for analysis at SGS because the technology alone cannot be expected to achieve the desired level of reductions in impingement and entrainment, nor could it be combined with another technology to yield the desired reductions. Pumps that have been retrofitted with VSDs can reduce overall flow intake volumes by 10–35 percent over the current once-through configuration (USEPA 2001). The actual reduction, however, will vary based on the cooling water demand at different times of the year. At peak demand, the pumps will essentially function as standard circulating water pumps and withdraw water at the maximum rated capacity, thus negating any potential benefit. Use of VSDs may be an economically desirable option when pumps are retrofitted or replaced for other reasons, but they were not considered further for this study.

5.5 CYLINDRICAL FINE-MESH WEDGEWIRE

Fine-mesh cylindrical wedgewire screens have not been deployed or evaluated at open coastal facilities for applications as large as would be required at SGS (approximately 380 mgd). To function as intended, cylindrical wedgewire screens must be submerged in a water body with a consistent ambient current of 0.5 feet per second (fps). Ideally, this current would be unidirectional, so that screens may be oriented properly and any debris impinged on the screens will be carried downstream when the airburst cleaning system is activated.

Fine-mesh wedgewire screens for SGS would be located offshore in the Pacific Ocean, west of the facility. Limited information regarding the subsurface currents in the near-shore environment near SGS is available. Data suggest that these currents are multidirectional depending on the tide and season and fluctuate in terms of velocity, with prolonged periods below 0.5 fps (SCCOOS 2006). To attain sufficient depth (approximately 20 feet) and an ambient current that might allow deployment, screens would need to be located 2,000 feet or more offshore. Discussions with vendors who design these systems indicated that distances more than 1,000 to 1,500 feet become problematic due to the inability of the airburst system to maintain adequate pressure for sufficient cleaning (Someah 2007). Together, these considerations preclude further evaluation of fine-mesh cylindrical wedgewire screens at SGS.

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Appendix A. Once-Through and Closed-Cycle Thermal Performance

		Unit 1			Unit 2			Unit 3		
		Once through	Closed cycle	Net increase	Once through	Closed cycle	Net increase	Once through	Closed cycle	Net increase
JAN	Backpressure (in. HgA)	1.47	2.12	**0.65**	1.47	2.12	**0.65**	1.34	1.95	**0.61**
	Heat rate Δ (%)	*-0.05*	*1.08*	***1.14***	*-0.05*	*1.08*	***1.13***	*-0.36*	*0.54*	***0.90***
FEB	Backpressure (in. HgA)	1.51	2.18	**0.67**	1.51	2.18	**0.67**	1.38	2.01	**0.63**
	Heat rate Δ (%)	*0.01*	*1.20*	***1.19***	*0.01*	*1.20*	***1.19***	*-0.33*	*0.65*	***0.98***
MAR	Backpressure (in. HgA)	1.56	2.23	**0.67**	1.56	2.23	**0.67**	1.43	2.06	**0.64**
	Heat rate Δ (%)	*0.08*	*1.30*	***1.22***	*0.08*	*1.30*	***1.22***	*-0.29*	*0.75*	***1.04***
APR	Backpressure (in. HgA)	1.63	2.35	**0.72**	1.63	2.35	**0.72**	1.49	2.17	**0.68**
	Heat rate Δ (%)	*0.19*	*1.52*	***1.33***	*0.19*	*1.52*	***1.33***	*-0.22*	*0.98*	***1.20***
MAY	Backpressure (in. HgA)	1.76	2.56	**0.80**	1.76	2.56	**0.80**	1.61	2.37	**0.76**
	Heat rate Δ (%)	*0.41*	*1.90*	***1.50***	*0.41*	*1.90*	***1.50***	*-0.06*	*1.41*	***1.47***
JUN	Backpressure (in. HgA)	1.86	2.69	**0.84**	1.86	2.69	**0.84**	1.71	2.50	**0.79**
	Heat rate Δ (%)	*0.58*	*2.12*	***1.54***	*0.58*	*2.12*	***1.54***	*0.08*	*1.66*	***1.58***
JUL	Backpressure (in. HgA)	2.04	2.74	**0.70**	2.04	2.74	**0.70**	1.88	2.54	**0.66**
	Heat rate Δ (%)	*0.94*	*2.20*	***1.27***	*0.94*	*2.20*	***1.27***	*0.40*	*1.76*	***1.37***
AUG	Backpressure (in. HgA)	2.09	2.75	**0.66**	2.09	2.75	**0.66**	1.92	2.55	**0.62**
	Heat rate Δ (%)	*1.02*	*2.21*	***1.19***	*1.02*	*2.21*	***1.19***	*0.48*	*1.77*	***1.29***
SEP	Backpressure (in. HgA)	1.81	2.56	**0.75**	1.81	2.56	**0.75**	1.66	2.37	**0.71**
	Heat rate Δ (%)	*0.49*	*1.89*	***1.40***	*0.49*	*1.89*	***1.40***	*0.01*	*1.40*	***1.39***
OCT	Backpressure (in. HgA)	1.64	2.33	**0.69**	1.64	2.33	**0.69**	1.51	2.16	**0.65**
	Heat rate Δ (%)	*0.21*	*1.49*	***1.28***	*0.21*	*1.49*	***1.28***	*-0.20*	*0.95*	***1.16***
NOV	Backpressure (in. HgA)	1.58	2.19	**0.61**	1.58	2.19	**0.61**	1.45	2.02	**0.57**
	Heat rate Δ (%)	*0.11*	*1.21*	***1.10***	*0.11*	*1.21*	***1.10***	*-0.27*	*0.66*	***0.94***
DEC	Backpressure (in. HgA)	1.53	2.16	**0.63**	1.53	2.16	**0.63**	1.40	1.99	**0.60**
	Heat rate Δ (%)	*0.03*	*1.16*	***1.13***	*0.03*	*1.16*	***1.13***	*-0.32*	*0.61*	***0.93***

Note: Heat rate delta represents change from design value calculated according to estimated ambient conditions for each month.

Appendix B. Itemized Capital Costs

Description	Unit	Qty	Equipment		Bulk material		Labor			--	Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	Other	
CIVIL / STRUCTURAL / PIPING	--	--	--	--	--	--	--	--	--	--	--
Allocation for other accessories (bends, water hammers…)	lot	1	--	--	500,000	500,000	4,000.00	85	340,000	--	**840,000**
Allocation for pipe racks (approx 3000 ft) and cable racks	t	300	--	--	2,500	750,000	17.00	105	535,500	--	**1,285,500**
Allocation for retaining walls	lot	1	--	--	500,000	500,000	5,000.00	100	500,000	--	**1,000,000**
Allocation for sheet piling and dewatering	lot	2	--	--	500,000	1,000,000	5,000.00	100	1,000,000	--	**2,000,000**
Allocation for site surface finishing around cooling towers, repair of grass and slope protections damaged during works	lot	1	--	--	100,000	100,000	1,000.00	100	100,000	--	**200,000**
Allocation for testing pipes	lot	2	--	--	--	--	2,000.00	95	380,000	--	**380,000**
Allocation for Tie-Ins to existing condenser's piping	lot	1	--	--	250,000	250,000	2,000.00	85	170,000	--	**420,000**
Allocation for trust blocks	lot	2	--	--	25,000	50,000	250.00	95	47,500	--	**97,500**
Backfill for PCCP pipe (reusing excavated material)	m3	4,745	--	--	--	--	0.04	200	37,960	--	**37,960**
Bedding for PCCP pipe	m3	629	--	--	25	15,725	0.04	200	5,032	--	**20,757**
Bend for PCCP pipe 72" diam (allocation)	ea	12	--	--	18,000	216,000	40.00	95	45,600	--	**261,600**
Building architectural (siding, roofing, doors, painting…etc)	ea	4	--	--	57,500	230,000	690.00	75	207,000	--	**437,000**
Bulk excavation to get 90 ft finished level including allocation of 15$/m3 for transport toward disposal site	m3	20,000	--	--	--	--	0.04	200	160,000	300,000	**460,000**
Butterfly valves 30" c/w allocation for actuator & air lines	ea	31	30,800	954,800	--	--	50.00	85	131,750	--	**1,086,550**
Butterfly valves 36" c/w allocation for actuator & air lines	ea	16	33,600	537,600	--	--	50.00	85	68,000	--	**605,600**
Butterfly valves 48" c/w allocation for actuator & air lines	ea	4	46,200	184,800	--	--	50.00	85	17,000	--	**201,800**
Butterfly valves 60" c/w allocation for actuator & air lines	ea	8	75,600	604,800	--	--	60.00	85	40,800	--	**645,600**
Butterfly valves 72" c/w allocation for actuator & air lines	ea	8	96,600	772,800	--	--	75.00	85	51,000	--	**823,800**
Butterfly valves 96" c/w allocation for actuator & air lines	ea	4	151,200	604,800	--	--	75.00	85	25,500	--	**630,300**

Description	Unit	Qty	Equipment		Bulk material		Labor			--	Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	Other	
Carbon Steel Pipe 12" diam. Butt welded	ft	1,200	--	--	100	120,000	1.40	85	142,800	--	**262,800**
Check valves 24"	ea	6	40,000	240,000	--	--	12.00	85	6,120	--	**246,120**
Check valves 30"	ea	3	44,000	132,000	--	--	16.00	85	4,080	--	**136,080**
Check valves 48"	ea	4	66,000	264,000	--	--	24.00	85	8,160	--	**272,160**
Check valves 72"	ea	4	138,000	552,000	--	--	32.00	85	10,880	--	**562,880**
Concrete basin walls (all in)	m3	599	--	--	225	134,775	8.00	75	359,400	--	**494,175**
Concrete elevated slabs (all in)	m3	434	--	--	250	108,500	10.00	75	325,500	--	**434,000**
Concrete for transformers and oil catch basin (allocation)	m3	200	--	--	250	50,000	10.00	75	150,000	--	**200,000**
Concrete for trestles (excluding piles)	m3	517	--	--	250	129,250	10.00	75	387,750	--	**517,000**
Concrete slabs on grade (all in)	m3	3,534	--	--	200	706,800	4.00	75	1,060,200	--	**1,767,000**
Excavation for PCCP pipe	m3	7,605	--	--	--	--	0.04	200	60,840	--	**60,840**
Fencing around transformers	m	50	--	--	30	1,500	1.00	75	3,750	--	**5,250**
Flange for PCCP joints 24"	ea	3	--	--	1,725	5,175	12.00	95	3,420	--	**8,595**
Flange for PCCP joints 30"	ea	28	--	--	2,260	63,280	16.00	95	42,560	--	**105,840**
Foundations for pipe racks and cable racks	m3	700	--	--	250	175,000	8.00	75	420,000	--	**595,000**
FRP flange 30"	ea	94	--	--	1,679	157,840	50.00	85	399,500	--	**557,340**
FRP flange 48"	ea	16	--	--	3,000	48,000	75.00	85	102,000	--	**150,000**
FRP flange 60"	ea	16	--	--	7,786	124,569	100.00	85	136,000	--	**260,569**
FRP flange 72"	ea	28	--	--	20,888	584,855	200.00	85	476,000	--	**1,060,855**
FRP flange 96"	ea	8	--	--	40,000	320,000	500.00	85	340,000	--	**660,000**
FRP pipe 24" diam.	ft	2,000	--	--	95	189,200	0.30	85	51,000	--	**240,200**
FRP pipe 30" diam.	ft	1,600	--	--	121	194,044	0.40	85	54,400	--	**248,444**
FRP pipe 48" diam.	ft	80	--	--	331	26,488	0.60	85	4,080	--	**30,568**
FRP pipe 60" diam.	ft	3,000	--	--	615	1,844,700	0.90	85	229,500	--	**2,074,200**
FRP pipe 72" diam.	ft	310	--	--	851	263,934	1.20	85	31,620	--	**295,554**
FRP pipe 96" diam.	ft	1,400	--	--	2,838	3,973,200	1.75	85	208,250	--	**4,181,450**
Harness clamp 72" c/w internal testable joint	ea	100	--	--	2,440	244,000	18.00	95	171,000	--	**415,000**
Joint for FRP pipe 24" diam.	ea	50	--	--	901	45,030	35.00	85	148,750	--	**193,780**
Joint for FRP pipe 30" diam.	ea	40	--	--	1,126	45,026	50.00	85	170,000	--	**215,026**
Joint for FRP pipe 48" diam.	ea	2	--	--	2,129	4,257	70.00	85	11,900	--	**16,157**
Joint for FRP pipe 72" diam.	ea	10	--	--	3,122	31,218	200.00	85	170,000	--	**201,218**
Joint for FRP pipe 96" diam.	ea	35	--	--	17,974	629,090	600.00	85	1,785,000	--	**2,414,090**
Joint for FRP pipe 60" diam.	ea	75	--	--	1,797	134,805	100.00	85	637,500	--	**772,305**
PCCP pipe 72" diam.	ft	2,000	--	--	507	1,014,000	1.30	95	247,000	--	**1,261,000**
Piles for trestles	ea	72	--	--	5,000	360,000	50.00	100	360,000	--	**720,000**

Description	Unit	Qty	Equipment		Bulk material		Labor			--	Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	Other	
Pipe bridge gantries	m.t.	447	--	--	2,500	1,117,500	17.00	105	797,895	--	**1,915,395**
Pipe bridge trestles	m.t.	163	--	--	2,500	407,500	17.00	105	290,955	--	**698,455**
Riser (FRP pipe 30" diam X 55 ft)	ea	26	--	--	15,350	399,095	150.00	85	331,500	--	**730,595**
Structural steel for building	t	190	--	--	2,500	475,000	20.00	105	399,000	--	**874,000**
CIVIL / STRUCTURAL / PIPING TOTAL	**--**	**--**	**--**	**4,847,600**	**--**	**17,739,355**	**--**	**--**	**14,400,952**	**300,000**	**37,287,907**
DEMOLITION	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Demolition of tanks and shelter on south-west corner of Terrace Drive and Grand Ave	lot	1	--	--	--	--	250.00	100	25,000	--	**25,000**
Demolish 1 tank approx 100 ft diameter (located west of 230 kv switchyard	lot	1	--	--	--	--	1,500.00	100	150,000	--	**150,000**
Demolish building located north-east of the 138 kv substation (approx. 200 ft X 50 ft)	lot	1	--	--	--	--	2,000.00	100	200,000	--	**200,000**
Demolish cooling towers located east of 138 kv switchyard	lot	1	--	--	--	--	500.00	85	42,500	--	**42,500**
DEMOLITION TOTAL	**--**	**--**	**--**	**0**	**--**	**0**	**--**	**--**	**417,500**	**--**	**417,500**
ELECTRICAL	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
4.16 kv cabling feeding MCC's	m	3,000	--	--	75	225,000	0.40	85	102,000	--	**327,000**
4.16kV switchgear - 5 breakers	ea	1	280,000	280,000	--	--	230.00	85	19,550	--	**299,550**
480 volt cabling feeding MCC's	m	1,500	--	--	70	105,000	0.40	85	51,000	--	**156,000**
480V Switchgear - 1 breaker 3000A	ea	4	30,000	120,000	--	--	80.00	85	27,200	--	**147,200**
Allocation for automation and control	lot	1	--	--	750,000	750,000	7,500.00	85	637,500	--	**1,387,500**
Allocation for cable trays and duct banks	m	3,000	--	--	75	225,000	1.00	85	255,000	--	**480,000**
Allocation for lighting and lightning protection	lot	1	--	--	90,000	90,000	900.00	85	76,500	--	**166,500**
Dry Transformer 2MVA xxkV-480V	ea	4	100,000	400,000	--	--	100.00	85	34,000	--	**434,000**
Lighting & electrical services for pump house building	ea	4	--	--	20,000	80,000	250.00	85	85,000	--	**165,000**
Local feeder for 1200 HP motor 4160 V (up to MCC)	ea	4	--	--	42,000	168,000	150.00	85	51,000	--	**219,000**
Local feeder for 200 HP motor 460 V (up to MCC)	ea	26	--	--	15,000	390,000	140.00	85	309,400	--	**699,400**
Local feeder for 4000 HP motor 4160 V (up to MCC)	ea	4	--	--	50,000	200,000	200.00	85	68,000	--	**268,000**
Oil Transformer 10/13.3MVA xx-4.16kV	ea	3	190,000	570,000	--	--	150.00	85	38,250	--	**608,250**
Primary breaker(xxkV)	ea	6	45,000	270,000	--	--	60.00	85	30,600	--	**300,600**

Description	Unit	Qty	Equipment		Bulk material		Labor			--	Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	Other	
Primary feed cabling (assumed 13.8 kv)	m	5,000	--	--	175	875,000	0.50	85	212,500	--	**1,087,500**
ELECTRICAL TOTAL	**--**	**--**	**--**	**1,640,000**	**--**	**3,108,000**	**--**	**--**	**1,997,500**	**--**	**6,745,500**
MECHANICAL	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Allocation for ventilation of buildings	ea	4	25,000	100,000	--	--	250.00	85	85,000	--	**185,000**
Cooling tower for unit 1	lot	1	9,800,000	9,800,000	--	--	--	--	--	--	**9,800,000**
Cooling tower for unit 2	lot	1	9,800,000	9,800,000	--	--	--	--	--	--	**9,800,000**
Cooling tower for unit 3	lot	1	25,500,000	25,500,000	--	--	--	--	--	--	**25,500,000**
Overhead crane 30 ton in (in pump house)	ea	4	75,000	300,000	--	--	100.00	85	34,000	--	**334,000**
Pump 4160 V 1200 HP	ea	4	800,000	3,200,000	--	--	420.00	85	142,800	--	**3,342,800**
Pump 4160 V 4000 HP	ea	4	1,360,000	5,440,000	--	--	800.00	85	272,000	--	**5,712,000**
MECHANICAL TOTAL	**--**	**--**	**--**	**54,140,000**	**--**	**0**	**--**	**--**	**533,800**	**--**	**54,673,800**

Appendix C. Net Present Cost Calculation

Project Year	Capital / Startup ($)	O & M ($)	Energy Penalty ($)			Total ($)	Annual Discount Factor	Present Value ($)
			Unit 1	Unit 2	Unit 3			
0	160,600,000	--	--	--		160,600,000	1	**160,600,000**
1	--	689,000	205,815	600,765	623,503	2,119,083	0.9346	**1,980,495**
2	--	702,780	217,814	635,789	659,853	2,216,237	0.8734	**1,935,661**
3	--	716,836	230,513	672,856	698,323	2,318,527	0.8163	**1,892,614**
4	--	731,172	243,952	712,083	739,035	2,426,242	0.7629	**1,850,980**
5	--	745,796	258,174	753,598	782,121	2,539,689	0.713	**1,810,798**
6	--	760,712	273,226	797,533	827,718	2,659,188	0.6663	**1,771,817**
7	--	775,926	289,155	844,029	875,974	2,785,084	0.6227	**1,734,272**
8	--	791,444	306,012	893,236	927,044	2,917,736	0.582	**1,698,122**
9	--	807,273	323,853	945,311	981,090	3,057,528	0.5439	**1,662,989**
10	--	823,419	342,733	1,000,423	1,038,288	3,204,863	0.5083	**1,629,032**
11	--	839,887	362,715	1,058,748	1,098,820	3,360,170	0.4751	**1,596,417**
12	--	1,019,031	383,861	1,120,473	1,162,881	3,686,246	0.444	**1,636,693**
13	--	1,039,412	406,240	1,185,796	1,230,677	3,862,125	0.415	**1,602,782**
14	--	1,060,200	429,924	1,254,928	1,302,426	4,047,478	0.3878	**1,569,612**
15	--	1,081,404	454,989	1,328,090	1,378,357	4,242,840	0.3624	**1,537,605**
16	--	1,103,032	481,514	1,405,518	1,458,715	4,448,780	0.3387	**1,506,802**
17	--	1,125,093	509,587	1,487,460	1,543,759	4,665,898	0.3166	**1,477,223**
18	--	1,147,594	539,296	1,574,179	1,633,760	4,894,828	0.2959	**1,448,380**
19	--	1,170,546	570,737	1,665,953	1,729,008	5,136,244	0.2765	**1,420,172**
20	--	1,193,957	604,011	1,763,078	1,829,809	5,390,855	0.2584	**1,392,997**
Total								**193,755,463**