E. HARBOR GENERATING STATION

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

Contents

Tables

Figures

Appendices

1.0 GENERAL SUMMARY

Retrofitting the existing once-through cooling system at Harbor Generating Station (HGS) with a closed-cycle wet cooling tower is technically and logistically feasible based on this study's design criteria, and will reduce cooling water withdrawals from Los Angeles Harbor by approximately 94 percent. Impingement and entrainment impacts would be reduced by a similar proportion.

The preferred option selected for HGS includes one conventional wet cooling tower (without plume abatement), with individual cells arranged in a inline configuration to accommodate limited space at the site. This option assumes the availability of adjoining property currently owned by the City of Long Beach to optimally site the cooling tower. Space limitations would appear to preclude plume-abated towers in the design if they were required to mitigate visual impacts. Initial capital costs for the towers would also increase by a factor of 2 or 3.

Construction-related shutdowns are estimated to take approximately 4 weeks per unit (concurrent), although HGS is not expected to incur any financial loss as a result based on 2006 capacity utilization rates for all units.

The proximity of large wastewater treatment facilities may enable HGS to replace the current once-through cooling water volume (81 mgd) with secondary treated effluent. To do so would require installing transmission pipelines several miles through the heavily developed Wilmington and Los Angeles Harbor areas. Because HGS's current outfall is located near the shoreline, discharge of secondary treated water into the harbor may not be permitted. In this case, HGS would be required to ensure treatment prior to discharge or route effluent to another location.

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

As noted above, some questions exist over the availability of sufficient land allowing the optimal cooling tower design and placement. For the purposes of this study, and all costs developed for HGS, it is assumed that this land will be available for use. The analysis does not, however, evaluate the additional costs that may be incurred from purchase or lease of this property.

Initial capital and net present costs associated with installing and operating wet cooling towers at HGS are summarized in Table E–1. Annualized costs based on 20-year average values for the various cost elements are summarized in Table E–2.

Table E–1. Cumulative Cost Summary

Cost Category	Cost ($)	Cost per MWh (rated capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Total capital and start-up [a]	26,000,000	12.63	142
NPC_{20} [b]	28,600,000	13.88	156

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

Table E–2. Annual Cost Summary

Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Capital and start-up	2,500,000	1.21	13.64
Operations and maintenance	100,000	0.05	0.55
Energy penalty	200,000	0.10	1.09
Total HGS annual cost	**2,800,000**	**1.36**	**15.28**

1.2 ENVIRONMENTAL

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

Table E–3. Environmental Summary

		Unit 5
Water use	Design intake volume (gpm)	56,400
	Cooling tower makeup water (gpm)	3,200
	Reduction from capacity (%)	94
Energy efficiency [a]	Summer heat rate increase (%)	0.59
	Summer energy penalty (%)	1.25
	Annual heat rate increase (%)	0.48
	Annual energy penalty (%)	1.14
Direct air emissions [b]	PM_{10} emissions (tons/yr) (maximum capacity)	32
	PM_{10} emissions (tons/yr) (2006 capacity utilization)	2.89

[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 Harbor.

Because parts of Los Angeles Harbor have been listed as impaired for some metals, HGS may face wastewater discharge permit conflicts upon converting to wet cooling towers. If makeup water is obtained from the current source, metal concentrations in the discharge will increase from evaporation in the wet cooling tower. Conflicts with effluent limitations may be mitigated or eliminated through the use of reclaimed water as the makeup source.

The only potential challenge to siting a wet cooling tower at HGS appears to be the availability of a small parcel of land immediately adjacent to the HGS property that is currently owned by the city of Long Beach. Securing the use of this parcel, or a portion thereof, enables a more favorable placement of the wet cooling tower with respect to the generating units and other structures at HGS. If this area is unavailable, existing structures at the site would have to be reconfigured to accommodate a cooling tower. This study assumes the availability of obtaining adjacent land for the desired configuration.

2.0 BACKGROUND

HGS is a natural gas–fired steam electric generating facility located in the Wilmington section of the city of Los Angeles, owned and operated by the Los Angeles Department of Water and Power (LADWP). HGS currently operates seven gas combustion turbines and one steam turbine (Unit 5). A heat recovery steam generator (HRSG) captures exhaust heat from Units 1 and 2 to generate steam for Unit 5. The facility's total capacity is 472 MW, with the combined-cycle portion (Units 1, 2, and 5) accounting for 235 MW. Only the steam portion of the combined-cycle system requires cooling water.[1] HGS occupies an area of approximately 20 acres in the Inner Los Angeles Harbor Complex (ILAHC). (See Table E–4 and Figure E–1.)

Table E–4. General Information

Unit	In-service year	Rated capacity (MW)	2006 capacity utilization [a]	Condenser cooling water flow (gpm)
Unit 5	1994	235 [b]	8.9%	56,400
HGS total		**235**	**8.9**	**56,400**

[a] Quarterly Fuel and Energy Report—2006 (CEC 2006).
[b] Includes gas combustion capacity (2 x 80 MW) and steam turbine capacity (75 MW).

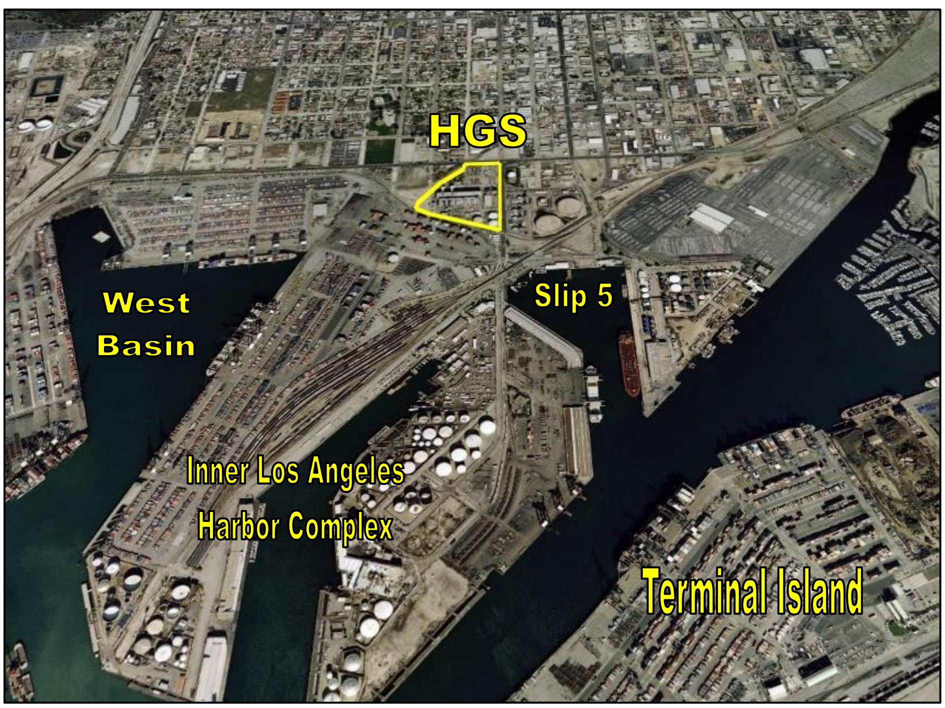

Figure E–1. General Vicinity of Harbor Generating Station

[1] Documents occasionally identify the components of the combined-cycle unit independently: Unit 5 (steam turbine) and Units 1 and 2 (gas turbines). Because the advantage of a combined-cycle system is only obtained when the units function together, reference to "Unit 5" at HGS in this study is taken to mean the combined-cycle unit as a whole.

2.1 COOLING WATER SYSTEM

HGS operates one cooling water intake structure (CWIS) to provide condenser cooling water to the steam portion of the combined-cycle generating unit (Figure E–2). Once-through cooling water is combined with low-volume wastes generated by HGS and discharged through a single outfall to the West Basin of ILAHC. Surface water withdrawals and discharges are regulated by NPDES Permit CA0000361 as implemented by Los Angeles Regional Water Quality Control Board (LARWQCB) Order R4-2003-0101.

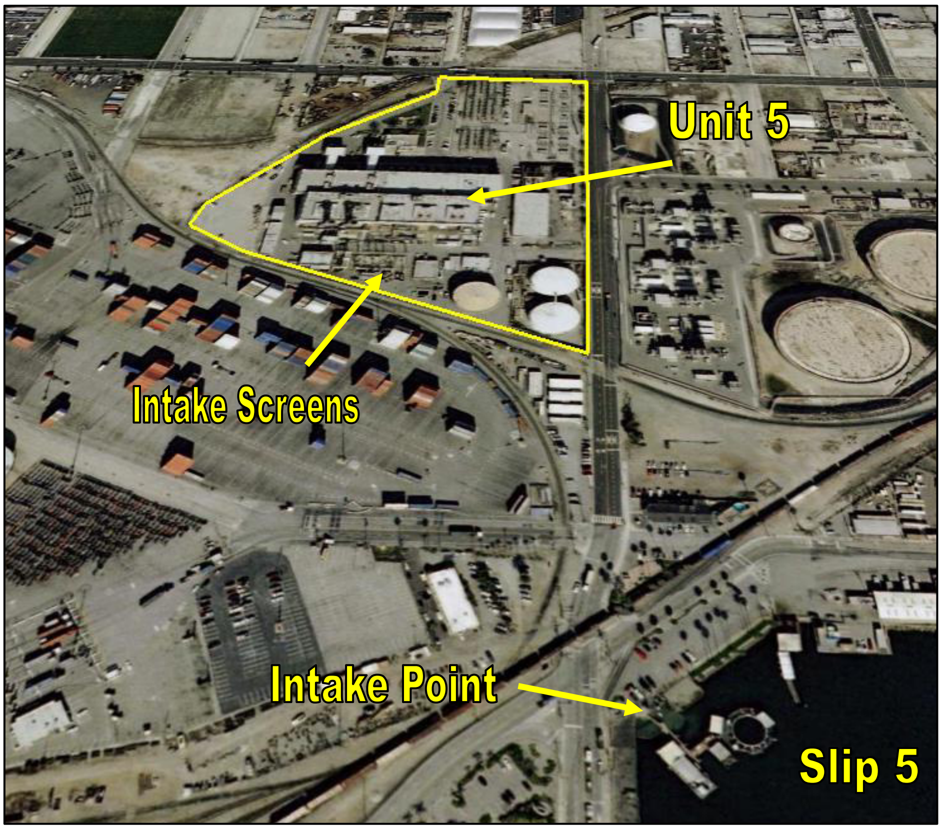

Figure E–2. Site View

Cooling water is obtained from ILAHC through a surface intake located at the shoreline in the northwest corner of Slip 5. Water is transferred to the station through two underground pipes, each approximately 1,100 feet long and 8 feet in diameter. The screenhouse near the station contains six intake bays, although only two are active. The remaining four are blocked with stop logs. Each of the active screen bays is approximately 8 feet wide and fitted with vertical traveling screens with 5/8-inch by 3/8-inch mesh panels. Screens are rotated once per 8-hour shift for 30 minutes. A high-pressure spray removes any debris or fish that have become impinged on the screen face. Captured debris is collected in a sump for disposal. Downstream of each screen is a circulating water pump rated at 37,500 gallons per minute (gpm), for a total facility capacity of 75,000 gpm, or 108 million gallons per day (mgd) (LADWP 2005).

At maximum capacity, HGS maintains a total pumping capacity rated at 108 mgd, with a condenser flow rating of 81 mgd. On an annual basis, HGS withdraws substantially less than its design capacity due to its low generating capacity utilization (8.9 percent for 2006). When in operation and generating the maximum load, HGS can be expected to withdraw water from the ILAHC at a rate approaching its maximum capacity

2.2 SECTION 316(B) PERMIT COMPLIANCE

The CWIS currently in operation at HGS does not use technologies generally considered to be effective at reducing impingement mortality and/or entrainment. HGS conducted an ecological study from 1977 to 1981 to determine whether the CWIS was compliant with Section 316(b) of the Clean Water Act. This study was conducted when the facility withdrew substantially more water than the current capacity (397 versus 108 mgd). LARWQCB Order R4-2003-0101, adopted in 2003, states the following:

> …the study 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 2003, Finding 14)

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, HGS has been compliant with this permit requirement.

The LARWQCB has notified HGS of its intent to revisit requirements under CWA Section 316(b), including a determination of the best technology available (BTA) for minimization of adverse environmental impact, upon expiration of the current order in 2008.

3.0 WET COOLING SYSTEM RETROFIT

3.1 OVERVIEW

The current secondary treated effluent volume in the vicinity of HGS may be sufficient as a substitute for the existing once-through cooling water source (ILAHC). Its use would depend on whether transmission pipelines could be installed in the area and if any conflicts over the use and discharge of secondary treated effluent to the harbor can be addressed. In a wet cooling tower system, the use of reclaimed water as the makeup water source (as opposed to ILAHC) is an attractive alternative when considering additional benefits its use may provide, such as avoidance of conflicts with effluent limitations or air emission standards.

This study evaluates a saltwater cooling tower as a retrofit option at HGS, with the current source water (ILAHC) continuing to provide makeup water to the facility. Converting the existing once-through cooling system to a wet cooling tower will reduce the facility's current intake capacity by approximately 94 percent; rates of impingement and entrainment will decline by a similar proportion.

The wet cooling tower's configuration—size, arrangement, 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 facility characterization may lead to different conclusions regarding the cooling tower's physical configuration.

This study developed a conceptual design of a wet cooling tower sufficient to meet Unit 5's cooling demand 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 HGS.

The overall practicality of retrofitting Unit 5 will require an evaluation of factors outside the scope of this study, such as the unit's age and efficiency and its 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 wet cooling tower conceptual design selected for HGS 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 cooling tower riser elevation.[2] The practicality and difficulty of these modifications are dependent on Unit 5's age and configuration

[2] In this context, re-optimization refers to a comprehensive condenser overhaul that reduces thermal efficiency losses associated with a wet cooling tower's higher circulating water temperatures. Modifications discussed in this study are generally limited to reinforcement measures that enable the condenser to withstand increased water pressures.

but are assumed to be feasible at HGS. Additional costs for condenser modifications are included in the discussion of capital expenditures (Section 4.0).

Information provided by HGS 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.

Parameters used in the development of the cooling tower design are summarized in Table E–5.

Table E–5. Condenser Design Specifications

	Unit 5
Thermal load (MMBTU/hr)	652.5
Surface area (ft^2)	70,000
Condenser flow rate (gpm)	56,400
Tube material	AL6XN (stainless steel)
Heat transfer coefficient ($BTU/hr \cdot ft^2 \cdot °F$)	429
Cleanliness factor	0.85
Inlet temperature (°F)	65
Temperature rise (°F)	23.15
Steam condensate temperature (°F)	100.3
Turbine exhaust pressure (in. HgA)	1.95

For example, the Unit 5 condenser specification sheet describes the condenser's original design when it was placed into service in 1946. As part of the 1992 repowering project, the condenser was re-tubed with a different tube gage (20 BWG versus 18 BWG). No other changes (e.g., materials, calculations, etc.) were indicated.

If the tube gage was changed but the all other parameters remained the same, the heat transfer coefficient would also change. This affects the system's thermal performance and influences the size estimate for the cooling tower. Using other known condenser data (tube material, flow, size, etc.), and following Heat Exchange Institute guidelines, the heat transfer coefficient was recalculated to 429 at the design condenser inlet temperature (65º F). This differs from the value reported on the condenser data sheet (550).

Calculations based on the recalculated heat transfer coefficient and other design specifications yield a higher backpressure at the design water temperature (65º F) than initially reported. This adjusted design backpressure (1.95 inches HgA) appears to be more in line with actual values recorded by HGS when Unit 5 is operating at maximum load.

Calculations are based solely on the data provided. Other factors not available for evaluation in this study may result in different conclusions.

3.2.2 AMBIENT ENVIRONMENTAL CONDITIONS

HGS is located in Los Angeles County in the Wilmington section of the city of Los Angeles. Cooling water is withdrawn from a shoreline intake in ILAHC. Inlet temperature data were not available from HGS. Instead, surface water temperatures used in this analysis were based on monthly average coastal water temperatures as reported in the NOAA *Coastal Water Temperature Guide for Los Angeles, CA* (NOAA 2007).

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 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 78° F.

Monthly maximum wet bulb temperatures used in the development of energy penalty estimates in Section 4.6 were calculated using data obtained from the National Climatic Data Center (NCDC) for San Pedro, CA (NCDC 2006). Climate data used in this analysis are summarized in Table E–6.

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

	Surface (°F)	Ambient wet bulb (°F)
January	58.0	54.4
February	58.0	56.2
March	60.0	57.8
April	60.0	60.8
May	61.0	65.8
June	63.0	68.4
July	66.0	69.4
August	68.0	69.5
September	67.0	65.6
October	66.0	60.4
November	64.0	56.4
December	60.0	55.6

3.2.3 LOCAL USE RESTRICTIONS

3.2.3.1 NOISE

Industrial development in the vicinity of HGS is covered by the City of Los Angeles Municipal Code and the Wilmington-Harbor City 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 heavily industrialized nature of the area, however, and the lack of any residences or sensitive coastal resources nearby, noise impacts are not expected to be an issue. This study used an ambient noise limit of 70 dBA at a distance of 800 feet in selecting the design elements of the wet tower installation. Accordingly, the final design selected for HGS does not require any measures that specifically address noise, such as low-noise fans or barrier walls.

3.2.3.2 BUILDING HEIGHT

HGS is located within the M3 zone according to the planning and zoning code for Los Angeles. This zone is dedicated to light and heavy industry. The building code does not establish specific criteria for building height and instead relies on conditional use permitting that evaluates the specific design of the project. Given the existing height of the current structures at HGS and others in the area, this study selected a height restriction of 50 feet above grade level. The height of the wet cooling tower designed for HGS, from grade level to the top of the fan deck, is 44 feet.

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. Likewise, community standards for assessing the visual impact associated with a cooling tower plume cannot be determined within the scope of this study. Given the heavily industrialized nature of the area, visual plume impacts are not expected to be a concern with a wet cooling tower at HGS. Accordingly, no plume abatement technologies are included for HGS.

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 HGS, with an accepted efficiency of 0.0005 percent. Because cooling tower PM_{10} emissions are a function of the drift rate, 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 Cooling Tower Institute's Isokinetic Drift Test Code is required at initial start-up on only one representative cell of each tower for an approximate cost of $60,000 per test (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 site's existing configuration and the total available area may require reconfiguration of existing structures or purchase of adjoining lots to enable placement of the cooling tower as designed. As shown in Figure E–3, little room is currently available at the HGS property, with most areas occupied by the power block, switchyard, or fuel tanks. The most practical wet cooling tower location is in the southwest corner of the property, immediately west of Unit 5 and the intake screens (Area 1).

To accommodate a more ideal placement of the 250-foot-long cooling tower, a portion of the area abutting Area 1 would have to be purchased or otherwise secured for use. According to records obtained from the Los Angeles County Assessor, parcels immediately west of the HGS property are owned by the city of Long Beach and believed to be vacant (LACA 2007). The cost and feasibility of obtaining this land was not evaluated in detail.

Area 2 is the only other location at HGS that could conceivably accommodate a wet cooling tower, although it is currently occupied by unidentified structures, which would require removal and/or relocation. Relocation of the switchyard was not considered. The cooling tower configuration developed for this study assumes the availability of Area 1.

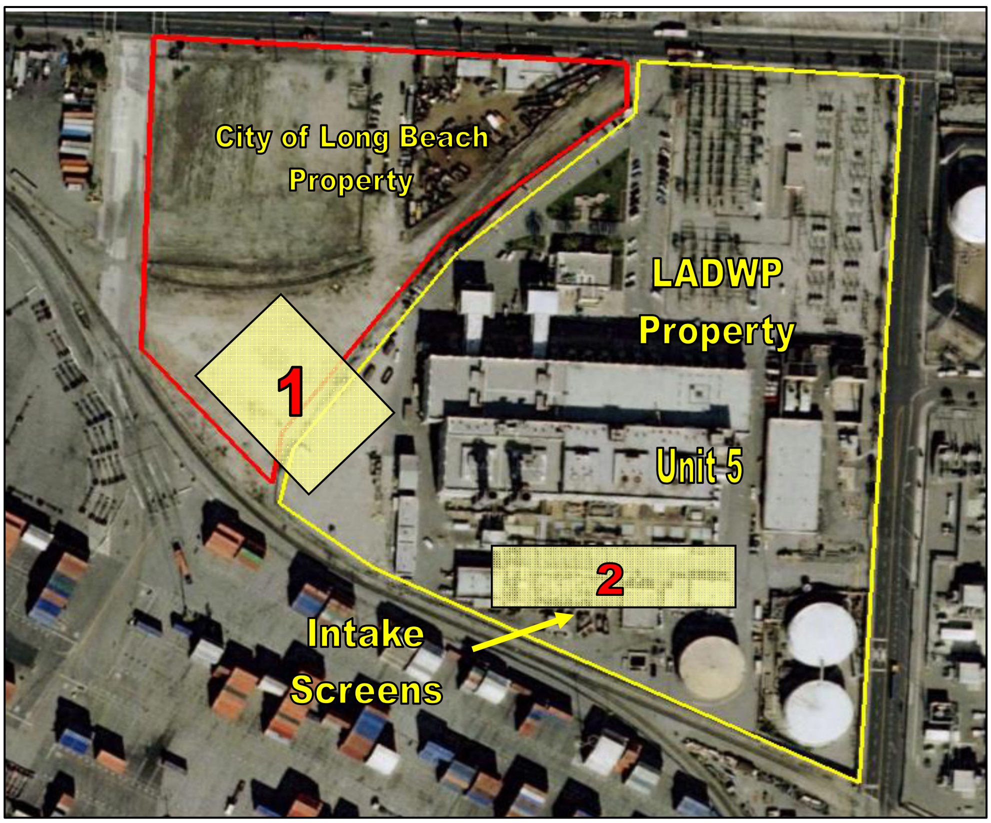

Figure E–3. Site Boundaries

3.3 CONCEPTUAL DESIGN

Based on the design constraints discussed above, one wet cooling tower was selected to replace the current once-through cooling system that serves Unit 5. The tower is configured in a multicell, inline arrangement.

3.3.1 SIZE

The tower is constructed over a concrete collection basin 4 feet deep. The basin is larger than the tower structure's footprint, 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 the 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 HGS are summarized in Table E–7.

Table E–7. Wet Cooling Tower Design

	Tower 1 (Unit 5)
Thermal load (MMBTU/hr)	652.5
Circulating flow (gpm)	56,400
Number of cells	5
Tower type	Mechanical draft
Flow orientation	Counterflow
Fill type	Modular splash
Arrangement	Inline
Primary tower material	FRP
Tower dimensions (l x w x h) (ft)	240 x 48 x 44
Tower footprint with basin (l x w) (ft)	244 x 52

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. Area 1 is located on the opposite side of the facility from Unit 5. To minimize interference with underground structures, this study assumes that supply and return piping can be routed to the existing intake forebay and reuse piping already connected to Unit 5. Figure E-4 identifies the approximate location of each tower and supply and return piping.

3.3.3 PIPING

The main supply and return pipelines for the tower will be located underground and made of prestressed concrete cylinder pipe (PCCP) suitable for saltwater applications. These pipes are 72 inches in diameter. Pipes connecting the condenser to the supply and return lines are made of FRP and placed above ground on pipe racks. Above-ground placement avoids the potential disruption that may be caused by excavation in and around the power block.

All riser piping (extending from the foot of the tower to the water distribution level) is constructed of FRP.

Potential interference with underground obstacles and infrastructure is a concern, particularly at existing sites that are several decades old and have been substantially modified or rebuilt in the interim. Avoidance of these obstacles is considered to the degree practical in this study. Associated costs are included in the contingency estimate and are generally higher than similar estimates for new facilities (Section 4.3).

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

Figure E-4. Cooling Tower Location

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 the tower.

This analysis includes new pumps to circulate water between the condenser and cooling tower. Pumps are sized according to the flow rate for the tower, the relative distance between the tower and condenser, and the total head required to deliver water to the top of each cooling tower riser. A separate, multilevel pump house is constructed for the tower and 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 50-ton overhead crane is also included to allow for pump servicing.

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

Table E–8. Cooling Tower Fans and Pumps

		Tower 1 (Unit 5)
Fans	Number	5
	Type	Single speed
	Efficiency	0.95
	Motor power (hp)	211
Pumps	Number	2
	Type	50% recirculating Mixed flow Suspended bowl Vertical
	Efficiency	0.88
	Motor power (hp)	693

3.4 ENVIRONMENTAL EFFECTS

Converting the existing once-through cooling system at HGS to wet cooling towers will significantly reduce the intake of seawater from ILAHC 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 of HGS's combined-cycle unit, thereby decreasing the facility's overall efficiency. Additional power will also be consumed by the tower fans and circulating pumps.

Depending on how HGS chooses to address this change in efficiency, total stack emissions may increase for pollutants such as $PM_{10,}$ $SO_{x,}$ and NO_x, and may require additional control measures (e.g., electrostatic precipitation, flue gas desulfurization, and selective catalytic reduction) or the purchase of emission credits to meet air quality regulations. The availability of emission reduction credits (ERCs) and their associated cost was not evaluated as part of this study. Both factors, however, may limit the air emission compliance options available to HGS.

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 Unit 5's capacity utilization rate.

If HGS retains its NPDES permit to discharge wastewater to the West Basin of ILAHC with a wet cooling tower system, it may have to address revised effluent limitations resulting from the substantial change in the discharge quantity and characteristics. Thermal impacts from the current once-through system, if any, will be minimized with a wet cooling system.

3.4.1 AIR EMISSIONS

HGS is located in the South Central Coast air basin. Air emissions are permitted by the South Coast Air Quality Management District (SCAQMD) (Facility ID 800170).

Drift volumes are expected to be within the range of 0.5 gallons for every 100,000 gallons of circulating water in the tower. At HGS, this corresponds to a rate of approximately 0.28 gpm based on the maximum flow. No drift-related impacts are expected.

Total PM_{10} emissions from the HGS cooling tower is a function of the number of hours in operation, the overall water quality in the tower, and the evaporation rate of drift droplets prior to deposition on the ground. Makeup water at HGS will be obtained from the same source currently used for once-through cooling water (ILAHC). This water is drawn through the harbor from the Pacific Ocean and is the same as marine water with respect to the total dissolved solids (TDS) concentration. At 1.5 cycles of concentration and assuming an initial 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 HGS will increase as a result of the direct emissions from the cooling tower itself. 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 E–9.[3]

Data summarizing the total facility emissions for these pollutants in 2005 are presented in Table E–10 (CARB 2005). In 2005, HGS operated at an annual capacity utilization rate of 13.8 percent.

[3] 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).

Using this rate, the additional PM_{10} emissions from the cooling tower would increase the facility total by approximately 4.5 tons/year, or 530 percent. [4]

Table E-9. Full Load Drift and Particulate Estimates

	PM_{10} (lbs/hr)	PM_{10} (tons/year)	Drift (gpm)	Drift (lbs/hr)
Tower 1	7	32	0.28	141
Total HGS PM_{10} and drift emissions	**7**	**32**	**0.28**	**141**

Table E-10. 2005 Emissions of SO_x, NO_x, PM_{10}

Pollutant	Tons/year
NOx	23.6
SOx	0.56
PM10	0.85

3.4.2 MAKEUP WATER

The volume of makeup water required by the cooling tower at HGS is the sum of evaporative loss and the blowdown volume required to maintain the tower's circulating water at the design TDS concentration. Drift expelled from the tower represents an insignificant volume by comparison and is accounted for by rounding up evaporative loss estimates. Makeup water volumes are based on design conditions, and may fluctuate seasonally depending on climate conditions and facility operations. Wet cooling towers will reduce once-through cooling water withdrawals from ILAHC by approximately 94 over the current design intake capacity.

Table E-11. Makeup Water Demand

	Tower circulating flow (gpm)	Evaporation (gpm)	Blowdown (gpm)	Total makeup water (gpm)
Tower 1	56,400	1,000	2,100	**3,100**
Total HGS makeup water demand	**56,400**	**1,000**	**2,100**	**3,100**

One circulating water pump, rated at 37,500 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 the cooling tower. The retained pump's capacity exceeds the makeup demand by approximately 34,000 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 cost 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 cooling tower's makeup water demand. Figure E–5 presents a schematic of this configuration.

4 2006 emission data are not currently available from the Air Resources Board Web site. For consistency, the comparative increase in PM_{10} emissions estimated here is based on the 2005 HGS capacity utilization rate instead of the 2006 rate presented in Table E-4. All other calculations in this chapter use the 2006 value.

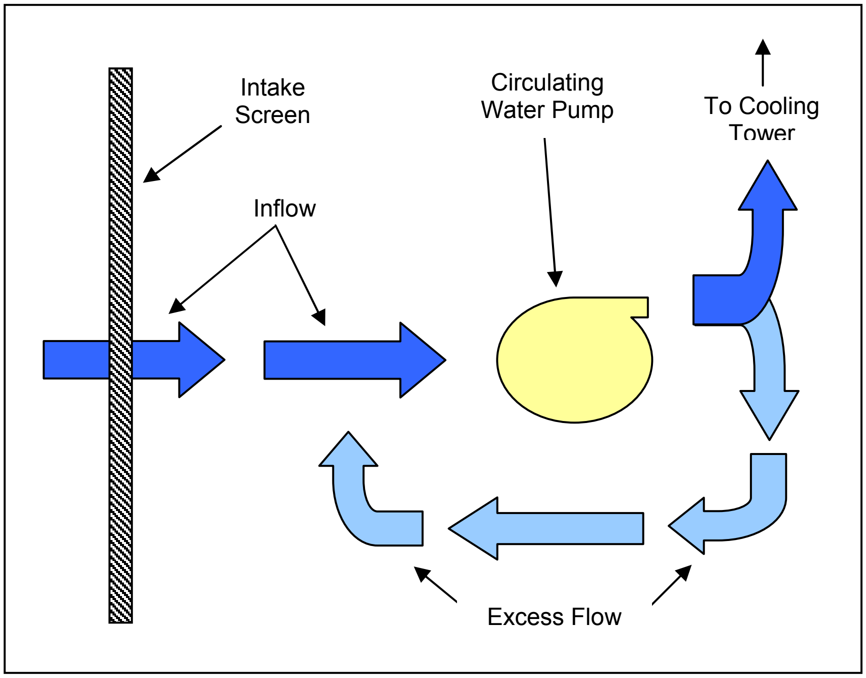

Figure E-5. Schematic of Intake Pump Configuration

The existing once-through cooling system at HGS does not treat water withdrawn from ILAHC, with the exception of screening for debris and larger organisms and periodic chlorination to control biofouling in the condenser tubes. Biofouling is also controlled by passing rubber scrubbers through the condensers and removing any fouling or growth. Conversion to a wet cooling tower system will not interfere with chlorination or scrubbing operations.

Makeup water will continue to be withdrawn from ILAHC.

The wet cooling tower system proposed for HGS includes water treatment for standard operational measures, i.e., corrosion inhibitors, biocides, and anti-scaling agents. An allowance for these additional chemical treatments is included in annual 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, the HGS wet cooling towers will result in an effluent discharge of 3.0 mgd of blowdown in addition to other in-plant waste streams—such as boiler blowdown, regeneration wastes, and cleaning wastes. These low-volume wastes may add an additional 0.0125 mgd to the total discharge flow from the facility. Unless an alternative discharge is considered, HGS 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 CA0000361as implemented by LARWQCB Order R4-2003-0101. All wastewaters are discharged to the West Basin of ILAHC. The existing order contains effluent limitations based on the California Toxics Rule (CTR) and 1972 Thermal Plan.

HGS 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 HGS 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.

Effluent data were not available for review for HGS, but the 2002 303(d) list identifies several segments of the Los Angles Harbor as impaired for cadmium, chromium, lead, mercury, and zinc (USEPA 2002). Total maximum daily loads (TMDLs) for the Los Angeles Harbor may be established in the future, with specific load allocations (LAs) for these pollutants applied to HGS.

Changes to discharge composition may affect compliance with water quality criteria included in the SIP. 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 SIP and Basin 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 discharges within enclosed bays under the Thermal Plan, which requires existing discharges of elevated-temperature wastes to comply with effluent limitations necessary to assure the protection of designated beneficial uses. The LARWQCB has implemented this provision in Order R4-2003-0101 by establishing a maximum discharge temperature of 94º F during normal operations (LARWQCB 2003). Information available for review indicates HGS 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 80º F) and the size of any related thermal plume in the receiving water.

3.4.4 RECLAIMED WATER

Reclaimed or alternative water sources used in conjunction with wet cooling towers could eliminate all surface water withdrawals at HGS. 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 PM10 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 reclaimed water, over the use of freshwater (SWRCB 1975). There is no similar policy regarding marine waters, but the clear preference of state agencies is to encourage alternative cooling methods, including reclaimed water, wherever possible.

The present volume of available secondary treated water within a 15-mile radius of HGS can meet the current once-through cooling demand for Unit 5 (81 mgd). 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, HGS 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 HGS (WBMWD 2007).

Four publicly owned treatment works (POTWs) were identified within a 15-mile radius of HGS, with a combined discharge capacity of 403 mgd. Figure E-6 shows the relative locations of these facilities to HGS.

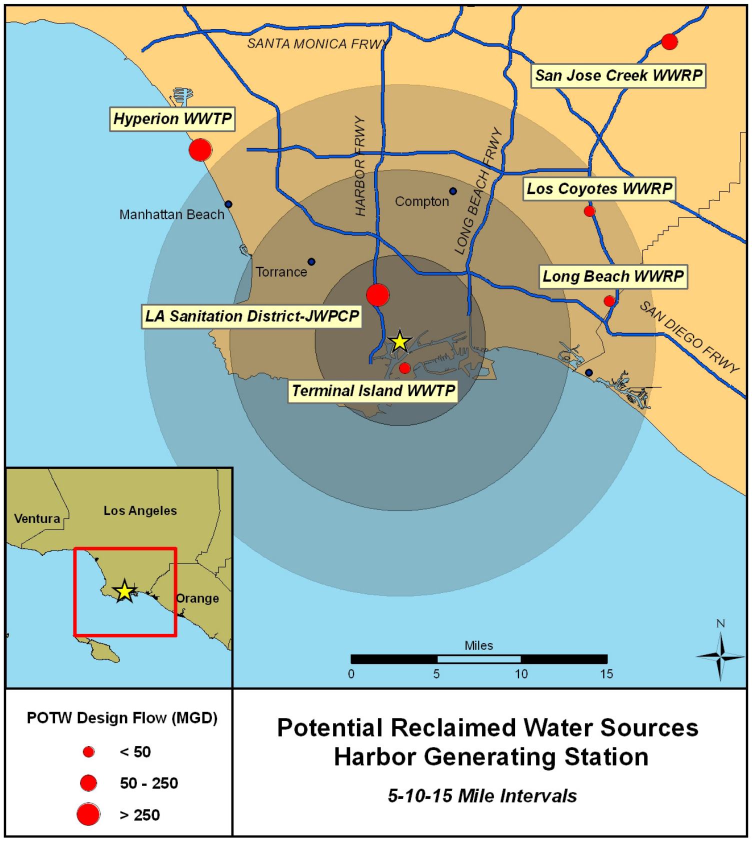

Figure E–6. Reclaimed Water Sources

- *Terminal Island Wastewater Treatment Plant—San Pedro*
  Discharge volume: 20 mgd
  Distance: 1.5 miles S
  Treatment level: 10% tertiary; 90% secondary

  Tertiary treated water is used for local irrigation. A previous study to assess the feasibility of using Terminal Island's reclaimed water at HGS determined the water quality (pH) would have adverse effects on the condenser and cooling system, although treatment systems could be installed onsite to condition the water to an acceptable pH level.[5]

- *Los Angeles Sanitation District, Joint Water Pollution Control Plant (JWPCP)—Carson*
  Discharge volume: 330 mgd
  Distance: 2.5 miles NW
  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

[5] This study was referenced in documents provided by LADWP but not available for review.

thus may be at least comparable to the current makeup water source at HGS. 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 a freshwater tower at HGS (2 to 5 mgd).

- *Long Beach Wastewater Treatment Plant—Long Beach*
  Discharge volume: 20 mgd
  Distance: 10 miles E
  Treatment level: Tertiary

  Approximately 50 percent is currently used for irrigation in the vicinity of the plant. The remaining capacity could supply the makeup water demand for a freshwater cooling tower at HGS (2 to 5 mgd).

- *Los Coyotes Wastewater Reclamation Plant—Cerritos*
  Discharge volume: 33 mgd
  Distance: 13 miles NE
  Treatment level: 30 % tertiary; 70 % secondary

  Approximately 10 MGD are treated to tertiary standards and reused for irrigation at various locations in the area, leaving approximately 23 mgd available as a makeup water source. This volume is sufficient to provide the makeup flow requirement for a freshwater tower, although HGS would have to make arrangements for treatment prior to use.

The nearest facility with sufficient capacity to satisfy HGS's makeup demand (2 to 5 mgd as a freshwater tower) is located approximately 1.5 miles from the site (Terminal Island). Installation of a transmission pipeline may face significant obstacles in crossing areas of the Los Angeles Harbor. Based on data compiled for this study and others, the estimated installed cost of an 18--inch prestressed concrete cylinder pipe, sufficient to provide 5 mgd to HGS, is $280 per linear foot, or approximately $1.5 million per mile. Additional considerations, such as pump capacity and any required treatment, would increase the total cost. Likewise, obstacles presented by navigational concerns across Los Angeles Harbor may increase costs.

Regulatory concerns beyond the scope of this investigation, however, may make reclaimed water (as a makeup water source) comparable or preferable to saltwater from ILAHC. Reclaimed water may enable HGS to eliminate potential conflicts with water discharge limitations or reduce PM_{10} emissions from the cooling tower, which is a concern given the South Coast air basin's current nonattainment status.

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, depends on the overall cost, availability, and additional environmental benefit that may occur.

3.4.5 THERMAL EFFICIENCY

A wet cooling tower at HGS will increase the condenser inlet water temperature by a range of 9 to 18° F above the surface water temperature, depending on the ambient wet bulb temperature at the time. Unit 5 is designed to operate at the conditions described in Table E–12. The resulting monthly difference between once-through and wet cooling tower condenser inlet temperatures is described in Figure E–7.

Table E–12. Design Thermal Conditions

	Unit 5
Design backpressure (in. HgA)	1.95
Design water temperature (°F)	65
Turbine inlet temp (°F)	900
Turbine inlet pressure (psia)	850
Full load heat rate (BTU/kWh) [a]	8,500

[a] CEC 2002.

Backpressures for the once-through and wet cooling tower configurations were calculated for each month using the design criteria described in the sections above and ambient climate data. In general, backpressures associated with the wet cooling tower were elevated by 0.5 to 1.1 inches HgA compared with the current once-through system (Figure E–7).

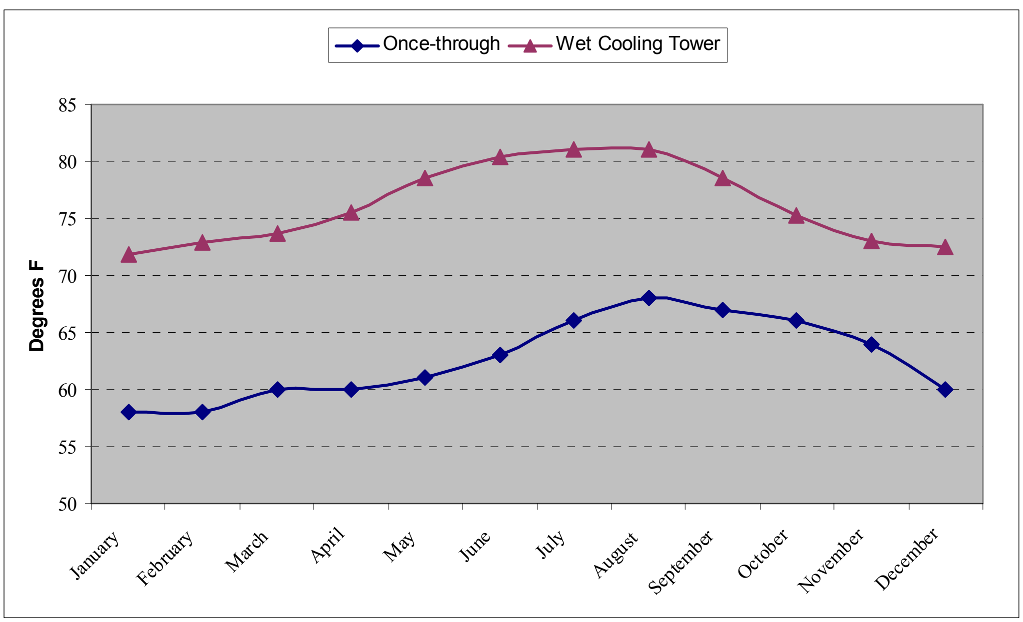

Figure E–7. Condenser Inlet Temperatures

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 full load rating.[6] 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 full load operating heat rate (Figure E–8) to develop estimated correction curve (Figure E–9).

The difference between the estimated once-through and closed-cycle heat rates for each month represents the approximate heat rate increase that would be expected when converting to wet cooling towers.

Table E–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 calculate the monetized value of these heat rate changes (Section 4.6). Month-by-month calculations are presented in Appendix A.

Table E–13. Summary of Estimated Heat Rate Increases

	Unit 5
Peak (July-August-September)	0.59%
Annual average	0.48%

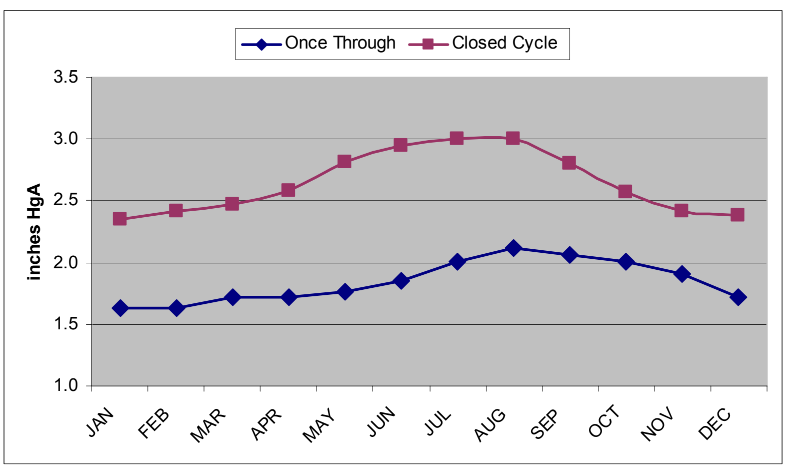

Figure E–8. Estimated Backpressures (Unit 5)

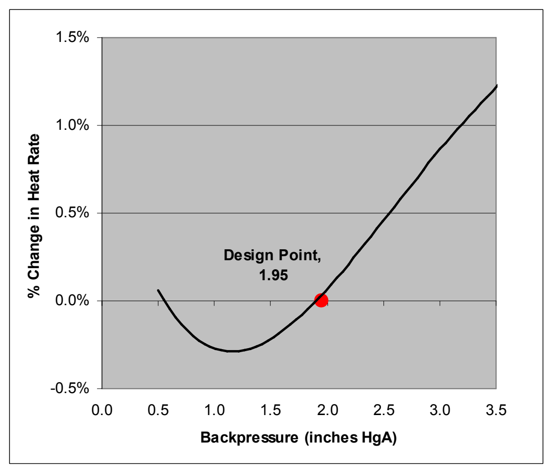

Figure E–9. Estimated Heat Rate Correction (Unit 5)

[6] Changes in thermal efficiency estimated for HGS are based on the design specifications provided by the facility. This may not reflect system modifications that might influence actual performance. In addition, the age of the units and the operating protocols used by HGS might result in different calculations.

4.0 RETROFIT COST ANALYSIS

The wet cooling system retrofit estimate for HGS is based on incorporating a conventional wet cooling tower as a replacement for the existing once-through system for Unit 5. 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)
- Revenue loss from shutdown (net loss in revenue during construction phase)
- Operations and maintenance (non–energy related cooling tower operations)
- Energy penalty (includes increased parasitic use from fans and pumps as well as decreased thermal efficiency)

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

In general, the cooling tower configuration selected for HGS conforms to a typical design; noise control, or plume abatement measures were not required. Table E–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 E–14. Wet Cooling Tower Design-and-Build Cost Estimate

	Unit 5
Number of cells	5
Cost/cell ($)	520,000
Total HGS D&B cost ($)	2,600,000

4.2 OTHER DIRECT COSTS

A significant portion of wet cooling tower installation costs result from the various support structures, materials, equipment and labor necessary to prepare the cooling tower site and connect the towers to the condenser. At HGS, these costs comprise approximately 50 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 E–15.

- *Civil, Structural, and Piping*
  The HGS site configuration allows the tower to be located within relative proximity to Unit 5.
- *Mechanical and Electrical*
  Initial capital costs in this category reflect the new pumps (two) to circulate cooling water between the towers and condensers. No new pumps are required to provide makeup water from ILAHC. Electrical costs are based on the battery limit after the main feeder breakers.
- *Demolition*
  No demolition costs are required.

Table E–15. Summary of Other Direct Costs

	Equipment ($)	Bulk material ($)	Labor ($)	HGS total ($)
Civil/structural/piping	1,000,000	3,200,000	3,100,000	**7,300,000**
Mechanical	2,100,000	0	200,000	**2,300,000**
Electrical	1,300,000	1,500,000	1,000,000	**3,800,000**
Demolition	0	0	0	**0**
Total HGS other direct costs	**4,400,000**	**4,700,000**	**4,300,000**	**13,400,000**

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 condenser water box and tube sheet reinforcement to withstand the increased pressures associated with a recirculating system. Each condenser may require reinforcement of the tube sheet bracing with 6-inch x 1-inch steel, and water box reinforcement/replacement with 5/8-inch carbon steel. Based on the estimates 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 HGS, potential costs in this category include relocating or demolishing small buildings and structures and potential interferences from underground structures.

Subsidence has been an ongoing concern in the Los Angeles Harbor area. 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 E–16.

Table E–16. Summary of Initial Capital Costs

	Cost ($)
Cooling towers	2,600,000
Civil/structural/piping	7,300,000
Mechanical	2,300,000
Electrical	3,800,000
Demolition	0
Indirect cost	4,000,000
Condenser modification	800,000
Contingency	5,200,000
Total HGS capital cost	**26,000,000**

4.4 SHUTDOWN

A portion of the work relating to installing wet cooling towers can be completed without significant disruption to the operations of HGS. Units will be offline depending on the length of time it takes to integrate the new cooling system and conduct acceptance testing. For HGS, a conservative estimate of 4 weeks for Unit 5 was developed. Based on 2006 generating output, however, no shutdown is forecast for either unit. Therefore, the cost analysis for HGS does not include any loss of revenue associated with shutdown.

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

Operations and maintenance (O&M) costs for a wet cooling tower system at HGS 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 combined tower flow rate 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 two cooling towers at HGS (56,400 gpm), are presented in Table E–17. These costs reflect maximum operation.

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

	Year 1 cost ($)	Year 12 cost ($)
Management/labor	56,400	81,780
Service/parts	90,240	130,848
Fouling	78,960	114,492
Total HGS O&M cost	225,600	327,120

4.6 ENERGY PENALTY

The energy penalty is divided into two components: increased parasitic use from the added electrical demand from tower fans and pumps; and the decrease in thermal efficiency from elevated turbine backpressures. Monetizing the energy penalty at HGS 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 for sale 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"). The degree to which a facility is able, or prefers, to operate at a higher firing rate, however, produces the more likely scenario—some combination of the two.

Ultimately, the manner in which HGS 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.[7]

The energy penalty for HGS is calculated by first estimating the increased parasitic demand from the cooling tower pumps and fans, expressed as a percentage of each unit'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, HGS 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, however, operations are evaluated at the design conditions, i.e., full load; no allowance is made

[7] 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.

for seasonal changes. The increased electrical demand from cooling tower fan operation is summarized in Table E–18.

Table E–18. Cooling Tower Fan Parasitic Use

	Tower 1
Units served	Unit 5
Generating capacity (MW)	235
Number of fans (one per cell)	5
Motor power per fan (hp)	211
Total motor power (hp)	1,053
MW total	0.78
Fan parasitic use (% of capacity)	**0.33**

Depending on ambient conditions or the operating load at a given time, HGS 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, however, operations are evaluated at the design conditions, i.e., full load; no allowance is made for seasonal changes. The increased electrical demand from cooling tower fan operation is summarized in Table E–18.

Additional circulating water pump capacity for the wet cooling towers will also increase the parasitic electricity usage at HGS. Makeup water will continue to be withdrawn from ILAHC with 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. For calculation purposes, this study assumes full-load operation to estimate the cost of increased parasitic use.

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 cooling tower pump operation is summarized in Table E–19.

Table E–19. Cooling Tower Pump Parasitic Use

	Tower 1
Units served	Unit 5
Generating capacity (MW)	235
Existing pump configuration (hp)	720
New pump configuration (hp)	1,746
Difference (hp)	1,026
Difference (MW)	0.8
Net pump parasitic use (% of capacity)	**0.33%**

4.6.2 HEAT RATE CHANGE

Heat rate adjustments were calculated based on each month's ambient climate conditions and reflect the estimated difference between operations with once-through and wet cooling tower systems. As noted above, the energy penalty analysis assumes HGS will increase its fuel consumption to compensate for lost efficiency and 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 HGS may be greater or less. Changes in the heat rate for each unit at HGS are presented in Figure E–10.

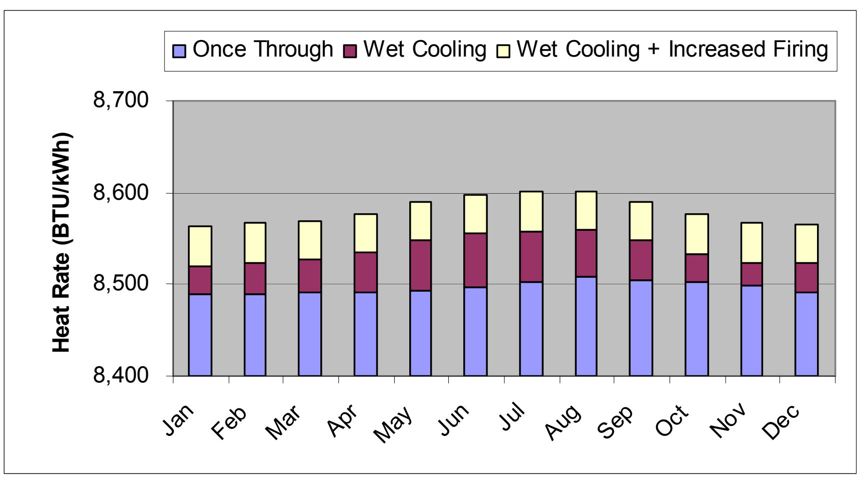

Figure E–10. Estimated Heat Rate Change (Unit 5)

4.6.3 CUMULATIVE ESTIMATE

Using the increased fuel option, the energy penalty's cumulative value is obtained by first calculating the relative costs of generation ($/MWh) for the once-through system and the wet cooling system adjusted for a higher turbine firing rate. The cost of generation for HGS is based on the relative heat rates developed in Section and the average monthly wholesale natural gas cost ($/MMBTU) (ICE 2006a). The difference between these two values represents the monthly increased cost, per MWh, that results from converting to wet cooling towers. This value is then applied to the net MWh generated for the each month and summed to calculate the annual cost.

Based on 2006 output data, the Year 1 energy penalty for HGS will be approximately $100,000. In contrast, the energy penalty's value calculated with the production loss option would be approximately $165,000. Together, these values represent the range of potential energy penalty costs for HGS. Table E–20 summarizes the Year 1 energy penalty estimate for Unit 5 using the increased fuel option.

Table E–20. Unit 5 Energy Penalty—Year 1

Month	Fuel cost ($/MMBTU)	Once-through system		Wet towers w/ increased firing		Difference ($/MWh)	2006 output (MWh)	Net cost ($)
		Heat rate (BTU/kWh)	Cost ($/MWh)	Heat rate (BTU/kWh)	Cost ($/MWh)			
January	6.00	8,490	50.94	8,563	51.38	0.44	15,473	6,754
February	5.50	8,490	46.70	8,566	47.12	0.42	0	0
March	4.75	8,492	40.34	8,570	40.71	0.37	0	0
April	4.75	8,492	40.34	8,577	40.74	0.40	1,325	536
May	4.75	8,493	40.34	8,590	40.80	0.46	17,793	8,223
June	5.00	8,496	42.48	8,598	42.99	0.51	31,925	16,299
July	6.50	8,502	55.26	8,601	55.91	0.64	63,693	40,965
August	6.50	8,507	55.30	8,601	55.91	0.61	29,560	18,059
September	4.75	8,505	40.40	8,590	40.80	0.41	10,146	4,110
October	5.00	8,502	42.51	8,576	42.88	0.37	0	0
November	6.00	8,498	50.99	8,567	51.40	0.41	13,293	5,509
December	6.50	8,492	55.20	8,565	55.67	0.48	128	61
							Unit 5 total	**100,516**

4.7 NET PRESENT COST

The Net Present Cost (NPC) of a wet cooling system retrofit at HGS is the sum of all annual expenditures over the project's 20-year life span 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 HGS 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 E–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 HGS has a relatively low capacity utilization factor, O&M costs for the NPC calculation were estimated at 35 percent of their maximum value. (See Table E–17.)
- *Annual Energy Penalty*. Insufficient information is available to this study to forecast future generating output at HGS. In lieu of annual estimates, this study uses the net MWh output from 2006 as the calculation basis for Years 1 through 20. Wholesale prices include a year-over-year price escalator of 5.8 percent (based on the Producer Price Index). The energy penalty values are based on the increased fuel option discussed in Section 4.6. (See Table E–20.)

Using these values, the NPC_{20} for HGS is $28.6 million. Appendix C contains detailed annual calculations used to develop this cost.

4.8 ANNUAL COST

The annual cost incurred by HGS for a wet cooling tower retrofit is the sum of annual amortized capital costs plus the annual average of O&M and energy penalty expenditures. Capital costs are amortized at a 7 percent discount rate over 20 years. O&M and energy penalty costs are calculated in the same manner as for the NPC20 (Section 4.7). Revenue losses from a construction-related shutdown, if any, are incurred in Year 0 only and not included in the annual cost summarized in Table E–21.

Table E–21. Annual Cost

Discount rate	Capital Cost ($)	Annual O&M ($)	Annual energy penalty ($)	Annual cost ($)
7.00%	2,500,000	100,000	200,000	2,800,000

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 HGS 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 2006 (CEC 2006) 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 HGS is summarized in Table E–22. A comparison of annual costs to annual gross revenue is summarized in Table E–23.

Table E–22. Estimated Gross Revenue

	Wholesale price ($/MWh)	Net generation (MWh)	Estimated gross revenue ($2007)	
		Unit 5	Unit 5	HGS total
January	96	15,473	1,485,408	**1,485,408**
February	96	0	0	**0**
March	96	0	0	**0**
April	96	1,325	127,200	**127,200**
May	96	17,793	1,708,128	**1,708,128**
June	96	31,925	3,064,800	**3,064,800**
July	96	63,693	6,114,528	**6,114,528**
August	96	29,560	2,837,760	**2,837,760**
September	96	10,146	974,016	**974,016**
October	96	0	0	**0**
November	96	13,293	1,276,128	**1,276,128**
December	96	128	12,288	**12,288**
HGS total		**183,336**	**17,600,256**	**17,600,256**

Table E–23. 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
17,600,000	2,500,000	14.2	100,000	0.6	200,000	1.1	**2,800,000**	**15.9**

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 HGS. As with many existing facilities, the site's location and configuration complicate 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 HGS. A brief summary of these technologies' applicability 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. HGS currently withdraws its cooling water through a conduit at Slip 5 in ILAHC and screens the water for debris at the facility after the water travels approximately 1,100 feet underground. While installing fine-mesh screens and a fish return at the location of the existing screens would not be practical, it is conceivable that this configuration could be installed at the shoreline in Slip 5, assuming there is sufficient space. A detailed evaluation would address the site-specific biology and physical dynamics of the source water to determine whether organisms returned to the water could remain viable and avoid re-impingement on the screens.

5.2 BARRIER NETS

Barrier nets can conceivably be placed in Slip 5. The ILAHC, however, is a major shipping channel, and any location selected for a barrier net is likely to interfere with navigation within the harbor.

5.3 AQUATIC FILTRATION BARRIERS

Aquatic filtration barriers (AFBs) can conceivably be placed in Slip 5, but doing so would restrict access to most of the area. The ILAHC is a major shipping channel, and any location selected for an AFB is likely to interfere with navigation within the harbor.

5.4 VARIABLE SPEED DRIVES

Variable speed drives (VSDs) were not considered for analysis at HGS 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 to 50 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

The difficulties surrounding placement of fine-mesh wedgewire screens within ILAHC would appear to preclude their use at HGS. The ILAHC is a major shipping channel, and any location selected for submerged wedgewire screens is likely to interfere with navigation within the harbor.

6.0 REFERENCES

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). 2006. *AHSRAE Handbook—Fundamentals (Design Conditions for Los Angeles, CA).* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA.

CARB (California Air Resources Board). 2005. *Facility Emissions Data: Harbor Generating Station.* < http://arb.ca.gov/app/emsinv/facinfo/facinfo.php>. Accessed August 10, 2007.

CEC (California Energy Commission). 2002. Resource, Reliability and Environmental Concerns of Aging Power Plant Operations and Retirements. California Energy Commission, Sacramento, CA.

— . 2006. *Quarterly Fuel and Energy Report (QFER).* California Energy Commission, Sacramento, CA.

CTI (Cooling Tower Institute). 1994. *Isokinetic Drift Test Code.* Cooling Tower Institute, Houston, TX.

FRTR (Federal Remediation Technologies Roundtable). 2002. *Remediation Technologies Screening Matrix and Reference Guide, 4th Edition.* Federal Remediation Technologies Roundtable, Washington, DC.

ICE (Intercontinental Exchange). 2006a. *Wholesale Natural Gas Prices—Citygate Trading Hub.* <https://www.theice.com/marketdata/naNaturalGas/naNatGasHistory.jsp>. Accessed June 3, 2007.

— . 2006b. *Wholesale Electricity Prices—SP 15 Trading Hub.* <https://www.theice.com/marketdata/naPower/naPowerHistory.jsp>. Accessed July 14, 2007.

LACA (Los Angeles County Office of the Assessor). 2007. Property Assessment Information. Los Angeles County Office of the Assessor. Los Angeles, CA. <http://assessor.lacounty.gov/extranet/Datamaps/Pais.aspx>. Accessed August 15, 2007.

LADWP (Los Angeles Department of Water and Power). 2005. *Clean Water Act Section 316(b) Proposal for Information Collection for Harbor Generating Station.* Los Angeles Department of Water and Power, Los Angeles, CA.

LARWQCB (Los Angeles Regional Water Quality Control Board). 2003. Order No. R4-2003-0101. Los Angeles Regional Water Quality Control Board, Los Angeles, CA.

NCDC (National Climatic Data Center). 2006. Climate Normals—San Pedro, CA. National Climatic Data Center, Asheville, NC.

NOAA (National Oceanographic and Atmospheric Administration). 2007. *National Oceanographic Data Center—Coastal Water Temperature Guide, Los Angeles*. <http://www.nodc.noaa.gov/dsdt/cwtg/index.html>. Accessed March 1, 2007.

SWRCB (California State Water Resources Control Board). 1972. Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California. California State Water Resources Control Board, Sacramento, CA.

— . 1975. Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Power Plant Cooling. Resolution 75-58. California State Water Resources Control Board, Sacramento, CA.

USEPA (U.S. Environmental Protection Agency). 2000. *Wastewater Technology Fact Sheet: Ammonia Stripping*. EPA-832-F-00-019. U.S. Environmental Protection Agency, Washington, DC.

— . 2001. Technical Development Document for the Final Regulations Addressing Cooling Water Intake Structures for New Facilities. U.S. Environmental Protection Agency, Washington, DC.

— . 2002. Section 303(d) List Fact Sheet for Los Angeles Watershed (2002). U.S. Environmental Protection Agency, Washington, DC. <http://iaspub.epa.gov/tmdl/huc_rept.control?p_huc=18070105&p_huc_desc=LOS%20ANGELES&p_cycle=2002>.

WBMWD (West Basin Municipal Water District). 2007. Summary of Current Projects. West Basin Municipal Water District, Carson, CA. <http://www.westbasin.com/currentprojects.html>.

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

		Unit 5		
		Once through	Closed cycle	Net increase
JAN	Backpressure (in. HgA)	1.63	2.35	**0.71**
	Heat rate Δ (%)	*-0.37*	*0.74*	***1.11***
FEB	Backpressure (in. HgA)	1.63	2.41	**0.78**
	Heat rate Δ (%)	*-0.37*	*0.88*	***1.25***
MAR	Backpressure (in. HgA)	1.72	2.47	**0.75**
	Heat rate Δ (%)	*-0.30*	*1.00*	***1.30***
APR	Backpressure (in. HgA)	1.72	2.59	**0.87**
	Heat rate Δ (%)	*-0.30*	*1.26*	***1.57***
MAY	Backpressure (in. HgA)	1.76	2.81	**1.05**
	Heat rate Δ (%)	*-0.26*	*1.75*	***2.01***
JUN	Backpressure (in. HgA)	1.86	2.95	**1.09**
	Heat rate Δ (%)	*-0.15*	*2.04*	***2.19***
JUL	Backpressure (in. HgA)	2.00	3.00	**1.00**
	Heat rate Δ (%)	*0.08*	*2.15*	***2.07***
AUG	Backpressure (in. HgA)	2.11	3.01	**0.89**
	Heat rate Δ (%)	*0.27*	*2.16*	***1.89***
SEP	Backpressure (in. HgA)	2.06	2.81	**0.75**
	Heat rate Δ (%)	*0.17*	*1.74*	***1.57***
OCT	Backpressure (in. HgA)	2.00	2.57	**0.57**
	Heat rate Δ (%)	*0.08*	*1.23*	***1.15***
NOV	Backpressure (in. HgA)	1.90	2.42	**0.52**
	Heat rate Δ (%)	*-0.08*	*0.90*	***0.98***
DEC	Backpressure (in. HgA)	1.72	2.39	**0.67**
	Heat rate Δ (%)	*-0.30*	*0.83*	***1.13***

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 ($)	
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 400 ft) and cable racks	t	40	--	--	2,500	100,000	17.00	105	71,400	**171,400**
Allocation for sheet piling and dewatering	lot	1	--	--	500,000	500,000	5,000.00	100	500,000	**1,000,000**
Allocation for testing pipes	lot	1	--	--	--	--	2,000.00	95	190,000	**190,000**
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	1	--	--	50,000	50,000	500.00	95	47,500	**97,500**
Backfill for PCCP pipe (reusing excavated material)	m3	891	--	--	--	--	0.04	200	7,128	**7,128**
Bedding for PCCP pipe	m3	320	--	--	25	8,000	0.04	200	2,560	**10,560**
Bend for PCCP pipe 16" diam (allocation)	ea	7	--	--	3,000	21,000	20.00	95	13,300	**34,300**
Bend for PCCP pipe 72" diam (allocation)	ea	3	--	--	18,000	54,000	40.00	95	11,400	**65,400**
Building architectural (siding, roofing, doors, painting…etc)	ea	1	--	--	57,500	57,500	690.00	75	51,750	**109,250**
Butterfly valves 30" c/w allocation for actuator & air lines	ea	7	30,800	215,600	--	--	50.00	85	29,750	**245,350**
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 54" c/w allocation for actuator & air lines	ea	8	60,900	487,200	--	--	55.00	85	37,400	**524,600**
Check valves 48"	ea	2	66,000	132,000	--	--	24.00	85	4,080	**136,080**
Concrete basin walls (all in)	m3	125	--	--	225	28,125	8.00	75	75,000	**103,125**
Concrete elevated slabs (all in)	m3	145	--	--	250	36,250	10.00	75	108,750	**145,000**
Concrete for transformers and oil catch basin (allocation)	m3	200	--	--	250	50,000	10.00	75	150,000	**200,000**
Concrete slabs on grade (all in)	m3	557	--	--	200	111,400	4.00	75	167,100	**278,500**
Ductile iron cement pipe 12" diam. for fire water line	ft	700	--	--	100	70,000	0.60	95	39,900	**109,900**
Excavation and backfill for fire line & make-up (using excavated material for backfill except for bedding)	m3	2,388	--	--	--	--	0.08	200	38,208	**38,208**
Excavation for PCCP pipe	m3	1,336	--	--	--	--	0.04	200	10,688	**10,688**
Fencing around transformers	m	50	--	--	30	1,500	1.00	75	3,750	**5,250**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
Flange for PCCP joints 30"	ea	5	--	--	2,260	11,300	16.00	95	7,600	**18,900**
Foundations for pipe racks and cable racks	m3	95	--	--	250	23,750	8.00	75	57,000	**80,750**
FRP flange 30"	ea	19	--	--	1,679	31,904	50.00	85	80,750	**112,654**
FRP flange 48"	ea	12	--	--	3,000	36,000	75.00	85	76,500	**112,500**
FRP flange 54"	ea	14	--	--	5,835	81,689	80.00	85	95,200	**176,889**
FRP pipe 48" diam.	ft	220	--	--	331	72,842	0.70	85	13,090	**85,932**
FRP pipe 54" diam.	ft	850	--	--	426	361,845	0.80	85	57,800	**419,645**
Harness clamp 16" c/w external testable joint	ea	40	--	--	1,715	68,600	14.00	95	53,200	**121,800**
Harness clamp 72" c/w internal testable joint	ea	20	--	--	2,440	48,800	18.00	95	34,200	**83,000**
Joint for FRP PIPE 48" diam.	ea	10	--	--	1,300	13,000	75.00	85	63,750	**76,750**
Joint for FRP pipe 54" diam.	ea	30	--	--	1,324	39,732	85.00	85	216,750	**256,482**
PCCP pipe 16" dia. For make-up	ft	700	--	--	98	68,600	0.50	95	33,250	**101,850**
PCCP pipe 72" diam.	ft	300	--	--	507	152,100	1.30	95	37,050	**189,150**
Riser (FRP pipe 30" diam X 40 ft)	ea	5	--	--	14,603	73,015	100.00	85	42,500	**115,515**
Structural steel for building	t	80	--	--	2,500	200,000	20.00	105	168,000	**368,000**
CIVIL / STRUCTURAL / PIPING TOTAL	**--**	**--**	**--**	**1,019,600**	**--**	**3,120,952**	**--**	**--**	**3,123,304**	**7,263,856**
ELECTRICAL	--	--	--	--	--	--	--	--	--	**--**
4.16 kv cabling feeding MCC's	m	1,000	--	--	75	75,000	0.40	85	34,000	**109,000**
4.16kV switchgear - 4 breakers	ea	1	250,000	250,000	--	--	150.00	85	12,750	**262,750**
460 volt cabling feeding MCC's	m	500	--	--	70	35,000	0.40	85	17,000	**52,000**
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	--	--	500,000	500,000	5,000.00	85	425,000	**925,000**
Allocation for cable trays and duct banks	m	600	--	--	75	45,000	1.00	85	51,000	**96,000**
Allocation for lighting and lightning protection	lot	1	--	--	75,000	75,000	750.00	85	63,750	**138,750**
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	1	--	--	50,000	50,000	1,000.00	85	85,000	**135,000**
Local feeder for 1000 HP motor 4160 V (up to MCC)	ea	2	--	--	40,000	80,000	150.00	85	25,500	**105,500**
Local feeder for 200 HP motor 460 V (up to MCC)	ea	5	--	--	18,000	90,000	150.00	85	63,750	**153,750**
Oil Transformer 10/13.33MVA xx-4.16kV	ea	2	190,000	380,000	--	--	150.00	85	25,500	**405,500**
Primary breaker(xxkV)	ea	4	45,000	180,000	--	--	60.00	85	20,400	**200,400**
Primary feed cabling (assumed 13.8 kv)	m	3,000	--	--	175	525,000	0.50	85	127,500	**652,500**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
ELECTRICAL TOTAL	--	--	--	**1,330,000**	--	**1,475,000**	--	--	**1,012,350**	**3,817,350**
MECHANICAL	--	--	--	--	--	--	--	--	--	--
Allocation for ventilation of buildings	ea	1	25,000	25,000	--	--	250.00	85	21,250	**46,250**
Cooling tower for units 1,2 and 5	lot	1	2,600,000	2,600,000	--	--	--	--	--	**2,600,000**
Overhead crane 50 ton in (in pump house) Including additional structure to reduce the span	ea	1	500,000	500,000	--	--	1,000.00	85	85,000	**585,000**
Pump 4160 V 1000 HP	ea	2	800,000	1,600,000	--	--	420.00	85	71,400	**1,671,400**
MECHANICAL TOTAL	--	--	--	**4,725,000**	--	**0**	--	--	**177,650**	**4,902,650**

Appendix C. Net Present Cost Calculation

Project year	Capital/start-up ($)	O & M ($)	Energy penalty Unit 5	Total ($)	Annual discount factor	Present value ($)
0	26,000,000	--	--	26,000,000	1	**26,000,000**
1	--	67,680	100,516	168,196	0.9346	**157,196**
2	--	69,034	106,376	175,409	0.8734	**153,203**
3	--	70,414	112,577	182,992	0.8163	**149,376**
4	--	71,823	119,141	190,963	0.7629	**145,686**
5	--	73,259	126,087	199,346	0.713	**142,133**
6	--	74,724	133,438	208,162	0.6663	**138,698**
7	--	76,219	141,217	217,436	0.6227	**135,397**
8	--	77,743	149,450	227,193	0.582	**132,226**
9	--	79,298	158,163	237,461	0.5439	**129,155**
10	--	80,884	167,384	248,268	0.5083	**126,194**
11	--	82,502	177,142	259,644	0.4751	**123,357**
12	--	100,099	187,470	287,568	0.444	**127,680**
13	--	102,101	198,399	300,500	0.415	**124,707**
14	--	104,143	209,966	314,108	0.3878	**121,811**
15	--	106,226	222,207	328,432	0.3624	**119,024**
16	--	108,350	235,161	343,511	0.3387	**116,347**
17	--	110,517	248,871	359,388	0.3166	**113,782**
18	--	112,727	263,380	376,108	0.2959	**111,290**
19	--	114,982	278,735	393,717	0.2765	**108,863**
20	--	117,282	294,986	412,267	0.2584	**106,530**
Total						**28,582,655**