L. PITTSBURG POWER PLANT

MIRANT DELTA, LLC—PITTSBURG, CA

Contents

Tables

Figures

Appendices

1.0 GENERAL SUMMARY

Retrofitting the existing once-through cooling system at Pittsburg Power Plant (PPP) 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 Suisun Bay by approximately 95 percent. Impingement and entrainment impacts would be reduced by a similar proportion.

The preferred option selected for PPP includes 2 conventional wet cooling towers (without plume abatement), with individual cells arranged in a back-to-back configuration to accommodate limited space at the site. This study assumes that a portion of the existing cooling canal that is part of Unit 7's closed-cycle cooling system can be backfilled to accommodate additional cooling towers. Modifying the canal in this fashion is not expected to negatively impact to the existing towers' performance, although data describing their design specifications and performance were unavailable for review.

Space limitations would not 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 PPP 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 present costs associated with installing and operating wet cooling towers at PPP are summarized in Table L–1. Annualized costs based on 20-year average values for the various cost elements are summarized in Table L–2.

Table L–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]	125,400,000	10.23	280
NPC_{20}[b]	133,900,000	10.92	299

[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 L–2. Annual Cost Summary

Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Capital and start-up	11,800,000	0.96	26.38
Operations and maintenance	500,000	0.04	1.12
Energy penalty	400,000	0.03	0.89
Total PPP annual cost	**12,700,000**	**1.03**	**28.39**

1.2 ENVIRONMENTAL

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

Table L–3. Environmental Summary

		Unit 5	Unit 6
Water use	Design intake volume (gpm)	160,500	160,500
	Cooling tower makeup water (gpm)	6,800	6,800
	Reduction from capacity (%)	96	96
Energy efficiency [a]	Summer heat rate increase (%)	0.75	0.75
	Summer energy penalty (%)	2.58	2.58
	Annual heat rate increase (%)	0.89	0.89
	Annual energy penalty (%)	2.72	2.72
Direct air emissions [b]	PM_{10} emissions (tons/yr) (maximum capacity)	92	92
	PM_{10} emissions (tons/yr) (2006 capacity utilization)	6.86	4.80

[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

None.

2.0 BACKGROUND

Pittsburg Power Plant (PPP) is a natural gas-fired steam electric generating facility located in an unincorporated section of the city of Pittsburg, Contra Costa County, owned and operated by Mirant Delta, LLC. The facility site is in the Sacramento/San Joaquin Delta on the southern bank of Suisun Bay near New York Point. PPP currently operates three steam-generating units (Units 5, 6, and 7), although only Units 5 and 6 use once-through cooling systems. Unit 7 is cooled by a closed-cycle system consisting of two crossflow wet cooling towers and a cooling canal. Units 1–4 have been retired from service. (See Table L–4 and Figure L–1.)

Table L–4. General Information

Unit	In-service year	Rated capacity (MW)	2006 capacity utilization [a]	Condenser cooling water flow (gpm)
Unit 5	1960	325	7.4%	160,500
Unit 6	1961	325	5.2%	160,500
Unit 7	1972	720	1.4%	[b]
PPP total		**1,370**	**3.7%**	**321,000**

[a] Quarterly Fuel and Energy Report—2006 (CEC 2006).
[b] Unit 7 uses a wet cooling tower.

Figure L–1. General Vicinity of Pittsburg Power Plant

2.1 COOLING WATER SYSTEM

PPP operates one cooling water intake structure (CWIS) to provide condenser cooling water to Units 5 and 6 (Figure L–2). Once-through cooling water is combined with low-volume wastes generated by PPP and discharged through a shoreline outfall to Suisun Bay. Surface water withdrawals and discharges are regulated by NPDES Permit CA0004880 as implemented by San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) Order R2-2002-0072.

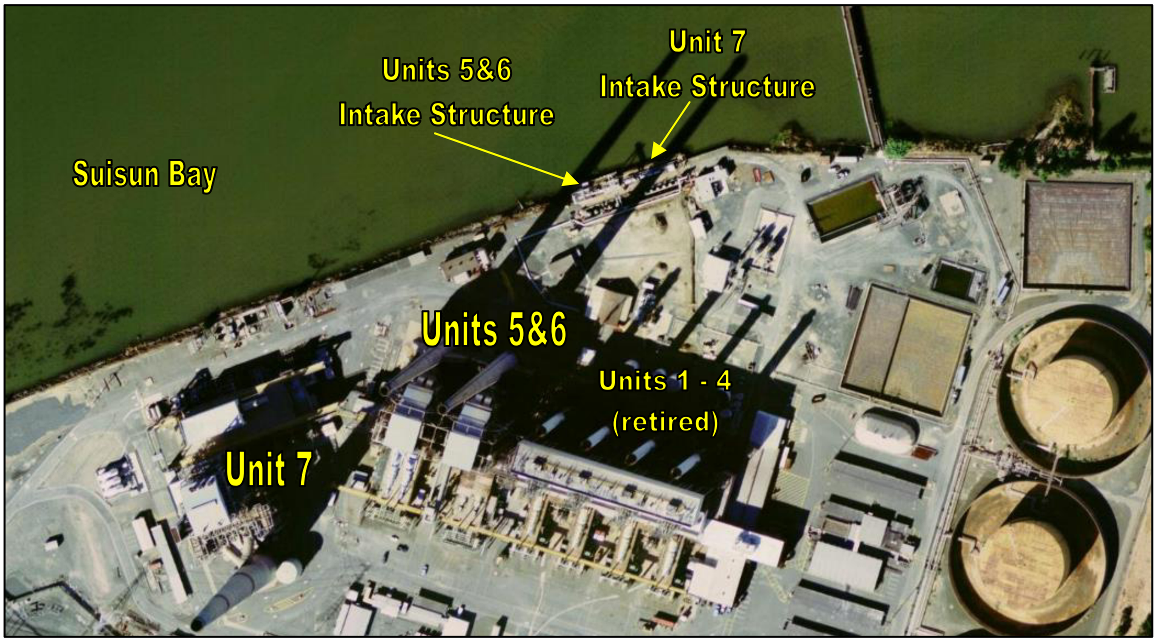

Figure L–2. Site View

Cooling water for Units 5 and 6 is withdrawn from Suisun Bay through a surface intake structure that is flush with the shoreline. Makeup water for Unit 7 is withdrawn from a separate CWIS located adjacent to the Unit 5 and 6 CWIS. This intake was previously used to provide cooling water to Units 1–4.

The Unit 5 and 6 CWIS comprises six screen bays, each fitted with a vertical traveling screen with 3/8-inch mesh panels. Three screen bays serve each unit. Screens are rotated once every 4 hours or based on the pressure differential between the upstream and downstream faces of the screen. 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. After passing through the screens, the water flow combines into two separate channels. Four variable speed drive (VSD) pumps, two for each unit, draw water from the channels to the surface condensers. The pumps for Units 5 and 6 are each rated at 80,250 gallons per minute (gpm), or 116 million gallons per day (mgd), but capable of operating at 60 to 70 percent of the maximum capacity. The maximum rated pumping capacity for Units 5 and 6 is 321,000 gpm, or 462 mgd (SFBRWQCB 2002).

At maximum capacity, PPP maintains a total pumping capacity rated at 462 mgd. On an annual basis, PPP withdraws substantially less than its design capacity due to its low generating capacity utilization (3.7 percent for 2006; 6.3 percent for Units 5 and 6 only). When in operation and generating the maximum load, PPP can be expected to withdraw water from Suisun Bay at a rate approaching its maximum capacity.

2.2 SECTION 316(B) PERMIT COMPLIANCE

The CWIS currently in operation for Units 5 and 6 uses pumps fitted with VSDs that can reduce the intake flow volume by 30 to 40 percent depending on the each unit's operating load, particularly during sensitive spawning and migratory periods in the Delta region. At Pittsburg, this period extends from February through July when larval stages for protected species, such as the Delta smelt, are most abundant. No information was available to evaluate the VSDs' actual operations and the relative changes in intake volume they provide compared with single-speed pumps. In 2006, 80 percent of the Unit 5 and 6 net output coincided with the February to July period (CEC 2006).

Apart from the VSDs, Units 5 and 6 do not currently use other technologies or operational measures that are generally considered to be effective at reducing impingement and entrainment impacts. SFBRWQCB Order R2-2002-0072 notes that in 1986, the former owner, Pacific Gas and Electric (PG&E), implemented a Resources Management Plan to comply with BTA requirements under CWA Section 316(b). The plan required PG&E to stock striped bass fish hatcheries in the Sacramento/San Joaquin Delta and improve its intake structures. In 1992, PG&E submitted a study stating that there were no technological improvements that could achieve impingement and entrainment reductions beyond the current levels.

Finding 32 of the current order, adopted in 2002, notes:

> …[b]ased on the above-referenced CWA 316(b) study, the existing intake structure is the best intake technology available. However, in view of the consultation process and the status of Mirant's [Conservation Program], the BTA may change based on the outcome of the consultation process and implementation of Mirant's Conservation Program. (SFBRWQCB 2002, Finding 32)

Because of the potential to take protected aquatic species, such as Delta smelt and Chinook salmon, the current order requires PPP to develop a comprehensive conservation program (CP) in consultation with U.S. Fish and Wildlife Service, National Marine Fisheries Service, and California Department of Fish and Game. The CP required the installation of an aquatic filter barrier (AFB) if a concurrent pilot evaluation at Contra Costa Power Plant (CCPP) proved effective (the evaluation at CCPP was later discontinued). Mirant is also a participant in the Bay Delta Conservation Plan, which aims to develop a comprehensive conservation and restoration framework that will be compliant with the California Endangered Species Act (CESA) and the federal Endangered Species Act (ESA).

The order does not contain any numeric or narrative limitations regarding impingement or entrainment resulting from CWIS operation, but does require PPP to conduct an impingement study following the implementation of any new technologies that may result from the Resources

Management Plan. No information from the SFBRWQCB is available indicating how it intends to proceed with the permit requirements in light of the changes to the Phase II rule.

3.0 WET COOLING SYSTEM RETROFIT

3.1 OVERVIEW

This study evaluates saltwater cooling towers as a retrofit option at PPP, with the current source water (Suisun Bay) continuing to provide makeup water to the facility. Converting the existing once-through cooling system to wet cooling towers will reduce the facility's current intake capacity by approximately 96 percent; rates of impingement and entrainment will decline by a similar proportion. Use of reclaimed water was considered for PPP but not analyzed in detail because the available volume cannot serve as a replacement for once-through cooling water. The proximity of available sources, however, may make reclaimed water an attractive alternative as makeup water for a wet cooling tower system when considering additional benefits its use may provide, such as avoidance of conflicts with effluent limitations or air emission standards.

The wet cooling towers' configuration—their 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 towers' physical configuration.

This study developed a conceptual design of wet cooling towers sufficient to meet each active generating unit'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 PPP.

The overall practicality of retrofitting both units at PPP will require an evaluation of factors outside the scope of this study, such as each unit's age and efficiency and its role in the overall reliability of electricity production and transmission in California, particularly the San Francisco Bay region.

3.2 DESIGN BASIS

3.2.1 CONDENSER SPECIFICATIONS

For this study, the wet cooling tower conceptual design selected for PPP 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.[1] The

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[1] 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.

practicality and difficulty of these modifications are dependent each unit's age and configuration but are assumed to be feasible at PPP. Condenser water boxes for both units are located at grade level and appear to be readily accessible. Additional costs for condenser modifications are included in the discussion of capital expenditures (Section 4.3).

Information provided by PPP 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 5 indicates that the existing tubes (aluminum brass) are scheduled to be replaced with titanium tubes, but no additional information is available stating whether this has occurred. If the tubes have been replaced, the condenser's thermal specifications would change and possibly alter the size selection for a wet cooling tower. In lieu of confirmed data, calculations in this study are based on the system design specifications as provided by Mirant Delta, i.e., with aluminum brass tubes for Units 5 and 6.

Likewise, the design turbine backpressure was not provided by Mirant but assumed to be 1.5 inches HgA based on other known characteristics of the cooling system (tube size, material, surface area, etc.).

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

Table L–5. Condenser Design Specifications

	Unit 5	Unit 6
Thermal load (MMBTU/hr)	1,410	1,410
Surface area (ft^2)	130,166	130,166
Condenser flow rate (gpm)	160,500	160,500
Tube material	Aluminum brass	Aluminum brass
Heat transfer coefficient (BTU/hr•ft^2•°F)	550	550
Cleanliness factor	0.85	0.85
Inlet temperature (°F)	62	62
Temperature rise (°F)	17.58	17.58
Steam condensate temperature (°F)	91.7	91.7
Turbine exhaust pressure (in. HgA)	1.5	1.5

3.2.2 AMBIENT ENVIRONMENTAL CONDITIONS

PPP is located in Contra Costa County along the southern shoreline of Suisun Bay in the San Joaquin/Sacramento River Delta. Cooling water is withdrawn at the surface from a shoreline intake structure. Inlet temperature data specific to PPP were not provided by Mirant Delta. As a substitute, monthly temperature data from the California Department of Water Resources Pittsburg Monitoring Station (PTS) were used in relevant calculations (DWR 2006).

The wet bulb temperature used to develop the overall cooling tower design was obtained from American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) publications. Data for the Contra Costa region indicate a 1 percent ambient wet bulb temperature of 66° F (ASHRAE 2006). A 12° F approach temperature 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 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) monitoring station for Antioch, CA (NCDC 2006). Climate data used in this analysis are summarized in Table L–6.

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

	Surface (°F)	Ambient wet bulb (°F)
January	48.3	50.7
February	52.1	52.8
March	58.8	55.3
April	61.2	56.6
May	65.8	59.4
June	68.5	63.0
July	71.6	66.0
August	70.7	64.3
September	68.7	61.3
October	63.9	57.3
November	57.7	55.5
December	50.9	54.5

3.2.3 LOCAL USE RESTRICTIONS

3.2.3.1 NOISE

Industrial development at PPP is regulated by the Contra Costa General Plan, although the proximity to the city of Pittsburg warrants consideration of that city's applicable policies when actions may conflict with permitted uses. 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 Pittsburg Planning Department, any measures limiting noise from a wet cooling tower would be addressed through a conditional use permit in consultation with the County of Contra Costa Community Development Department that evaluates the project's specific design.

Restrictions would be based on the zoning designation for the site and community noise equivalent levels (CNELs) outlined in the General Plan's Noise Element and measured at the nearest point of impact. The cooling towers designed for PPP will have ambient noise levels no greater than 60 dBA measured at 1,000 feet. The nearest residential areas are located over 3,000 feet from the siting location. Accordingly, the wet cooling towers designed for PPP do not include noise abatement measures such as low-noise fans or barrier walls.

3.2.3.2 BUILDING HEIGHT

The developed portion of PPP is located within the heavy industry (HI) zone according to the Contra Costa General Plan. This zone is dedicated to industrial uses and does not have a restriction with regard to structural height. Given the existing height of the current structures at PPP 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 PPP, from grade level to the top of the fan deck, is 56 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. Using the selection criteria for this study, plume abatement measures were not considered for PPP; all towers are a conventional design. The plume from wet cooling towers at PPP is not expected to adversely impact nearby infrastructure; the nearest area of immediate concern is California State Highway 4, located approximately 1.5 miles to the south. In addition, the two cooling towers that currently serve Unit 7 do not incorporate plume abatement technologies.

Community standards for assessing the visual impact associated with a cooling tower plume cannot be determined within the scope of this study. The proximity of nearby residential and commercial areas, when viewed in the context of CEC siting guidelines, may contribute to the selection of an alternate design if a wet cooling tower retrofit is undertaken at PPP in the future. These guidelines assess the total size and persistence of a visual plume with respect to aesthetic standards for bay/delta resources. Significant visual changes resulting from the plume may warrant incorporating of plume abatement measures. Installing plume-abated cooling towers at PPP will result in a different configuration (inline instead of back-to-back) and require additional space. Given the large area currently available at PPP, plume-abated towers can be installed without facing any added logistical obstacles.

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 PPP, 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, or approximately $120,000 for both cooling towers at PPP (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 existing site's configuration does not present significant challenges to identifying a location for conventional cooling towers, although the selected location results in long distances between the towers and their respective generating units. As shown in Figure L–3, the property's total area is large and generally undeveloped, with few areas located close to residential or commercial areas.

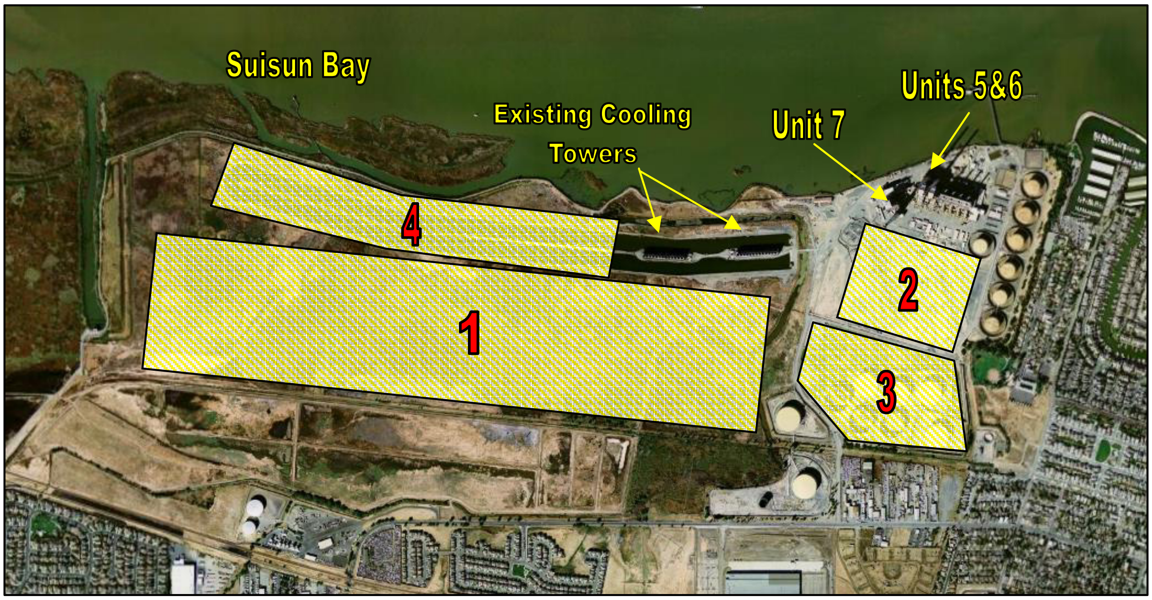

Figure L–3. Cooling Tower Siting Locations

Area 1 is the largest unoccupied parcel at PPP, with a total area greater than 500 acres. This area is undeveloped and consists of marshes and wetlands west of Willow Creek. The general area is identified as open space by the city of Pittsburg General Plan, although it is unclear how this would affect development in the area. This area was eliminated from consideration because it is undeveloped. Other developed areas would likely be prioritized to limit disruption to open spaces.

The facility's switchyard is located in Area 2. While this area would enable placement of the towers close to the generating units, the cost and complexity of relocating switchyard equipment precludes further consideration.

Area 3 is currently occupied by several large fuel storage tanks, some of which remain in use while others are in various stages of decommissioning. Because other areas are available, this parcel was not considered further.

Area 4 is an extension of the cooling canal west of the existing Unit 7 cooling towers. The available space in the canal (approximately 41 acres) is more than adequate to accommodate the wet cooling towers designed for Units 5 and 6. Placement in this area, however, will require backfilling a portion of the canal. Based on the canal's size and the estimated thermal load for Unit 7, any disruption to the canal's flow caused by additional towers is not expected to be significant. The new cooling towers for Units 5 and 6 will not use the open canal for cooling; all water will be routed directly from the cold water basin to the condenser.

3.3 CONCEPTUAL DESIGN

Based on the design constraints discussed above, two wet cooling towers were selected to replace the current once-through cooling system that serves Units 5 and 6 at PPP. Each unit will be served by an independently functioning tower with separate pump houses and pumps. Both towers at PPP consist of conventional cells arranged in a multicell, back-to-back configuration.

3.3.1 SIZE

Each 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 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 PPP are summarized in Table L–7.

Table L–7. Wet Cooling Tower Design

	Tower 1 (Unit 5)	Tower 2 (Unit 6)
Thermal load (MMBTU/hr)	1,410	1,410
Circulating flow (gpm)	160,500	160,500
Number of cells	12	12
Tower type	Mechanical draft	Mechanical draft
Flow orientation	Counterflow	Counterflow
Fill type	Modular splash	Modular splash
Arrangement	Back-to-back	Back-to-back
Primary tower material	FRP	FRP
Tower dimensions (l x w x h) (ft)	324 x 96 x 56	324 x 96 x 56
Tower footprint with basin (l x w) (ft)	328 x 100	328 x 100

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 the respective generating units to minimize the supply and return pipe distances and any increases in total pump head and brake horsepower. At PPP, the linear distance between the generating units and towers is large (approximately 4,000 feet) but does not present any significant challenges for placing the supply and return pipelines (Figure L–4).

Figure L–4. Cooling Tower Locations

3.3.3 PIPING

The main supply and return pipelines to and from both towers will be located underground and made of prestressed concrete cylinder pipe (PCCP) suitable for saltwater applications. These pipes range in size from 72 to 84 inches in diameter. The distance between towers 1 and 2 and their respective generating units requires roughly 15,000 feet of PCCP for the supply and return lines. Pipes connecting the condensers 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. The condensers at PPP are all located at grade level, enabling a relatively straightforward connection.

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

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 each tower.

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 towers and condensers, and the total head required to deliver water to the top of each cooling tower riser. A separate, multilevel pump house is constructed for each 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 PPP are summarized in Table L–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 L–8. Cooling Tower Fans and Pumps

		Tower 1 (Unit 5)	**Tower 2 (Unit 6)**
Fans	Number	12	12
	Type	Single speed	Single speed
	Efficiency	0.95	0.95
	Motor power (hp)	211	211
Pumps	Number	2	2
	Type	50 % recirculating Mixed flow Suspended bowl Vertical	50 % recirculating Mixed flow Suspended bowl Vertical
	Efficiency	0.88	0.88
	Motor power (hp)	3,182	3,182

3.4 ENVIRONMENTAL EFFECTS

Converting the existing once-through cooling system at PPP to wet cooling towers will significantly reduce the intake of seawater from Suisun Bay 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 both of PPP's steam units, thereby decreasing the facility's overall efficiency. Additional power will also be consumed by the tower fans and circulating pumps.

Depending on how PPP 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 PPP.

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 capacity utilization rate for the generating units served by each tower.

If PPP retains its NPDES permit to discharge wastewater to Suisun Bay 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

PPP is located in the San Francisco Bay Area air basin. Air emissions are permitted by the Bay Area Air Quality Management District (BAAQMD) (Facility ID A0012).

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 PPP, this corresponds to a rate of approximately 1.6 gpm based on the maximum combined flow both towers. Because the area selected for wet cooling towers is located at a substantial distance from sensitive structures, salt drift deposition is not likely to be a significant concern.

Total PM_{10} emissions from the PPP 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 PPP will be obtained from the same source currently used for once-through cooling water (Suisun Bay). Water within the bay is heavily influenced by freshwater inflows from the Sacramento and San Joaquin Rivers, but is also affected by tidal cycles in the delta region. Water is considered to be brackish, with salinity levels varying by season and tide. For the purposes of this study, cooling towers were developed based on marine total dissolved solids (TDS) concentrations. 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 PPP 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 L–9.[2]

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[2] 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).

Data summarizing the total facility emissions for these pollutants in 2005 are presented in Table L–10 (CARB 2005). In 2005, PPP operated at an annual capacity utilization rate of 6.3 percent. Using this rate, the additional PM_{10} emissions from the cooling towers would increase the facility total by approximately 12 tons/year, or 29 percent.[3]

Table L–9. Full Load Drift and Particulate Estimates

	PM_{10} (lbs/hr)	PM_{10} (tons/year)	Drift (gpm)	Drift (lbs/hr)
Tower 1	21	92	0.8	402
Tower 2	21	92	0.8	402
Total PPP PM_{10} and drift emissions	**42**	**184**	**1.6**	**804**

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

Pollutant	Tons/year
NO_x	71.3
SO_x	7.2
PM_{10}	40.6

3.4.2 MAKEUP WATER

The volume of makeup water required by both cooling towers at PPP is the sum of evaporative loss and the blowdown volume required to maintain the circulating water in each tower at the design TDS concentration. Drift expelled from the towers 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 Suisun Bay by approximately 96 percent over the current design intake capacity.

Table L–11. Makeup Water Demand

	Tower circulating flow (gpm)	Evaporation (gpm)	Blowdown (gpm)	Total makeup water (gpm)
Tower 1	160,500	2,400	4,600	7,000
Tower 2	160,500	2,400	4,600	7,000
Total PPP makeup water demand	**321,000**	**4,800**	**9,200**	**14,000**

One circulating water pump, rated at 80,250 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 each cooling tower. The retained pump's capacity exceeds the makeup demand by approximately 66,000 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

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[3] 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 PPP capacity utilization rate instead of the 2006 rate presented in Table L-4. All other calculations in this chapter use the 2006 value.

intake screens, will be equal to the cooling towers' makeup water demand. Figure L–5 presents a schematic of this configuration.

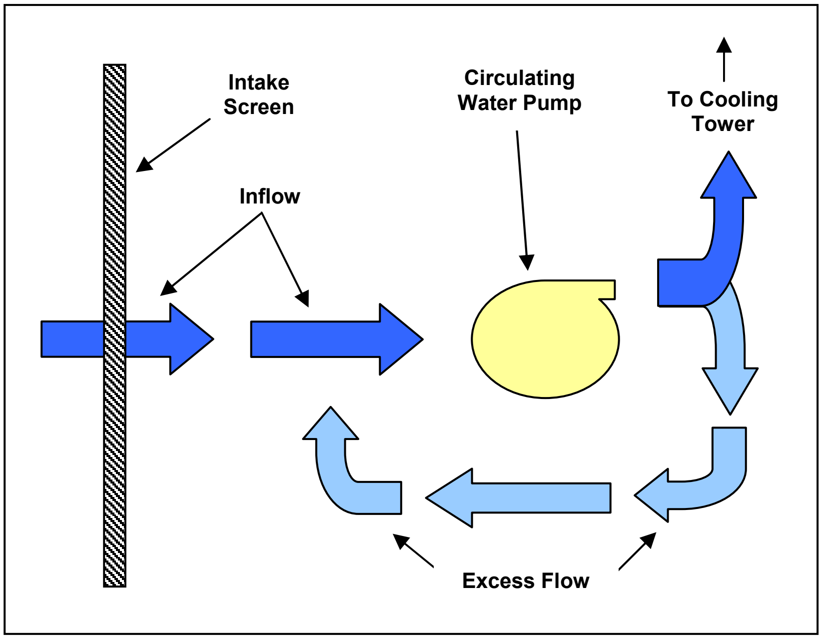

Figure L–5. Schematic of Intake Pump Configuration

The existing once-through cooling system at PPP does not treat water withdrawn from Suisun Bay with the exception of screening for debris and larger organisms and periodic chlorination to control biofouling in the condenser tubes. Conversion to a wet cooling tower system will not interfere with chlorination operations.

Makeup water will continue to be withdrawn from Suisun Bay.

The wet cooling tower system proposed for PPP 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, wet cooling towers at PPP will result in an effluent discharge of approximately 13 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 0.8 mgd to the total discharge flow from the facility. Unless an alternative discharge is considered, PPP 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 CA0004880 as implemented by SFBRWQCB Order R2-2002-0072. All once-through cooling water and process wastewaters are discharged through a shoreline outfall to Suisun Bay. The existing order contains effluent limitations based on the California Toxics Rule (CTR), the 1972 Thermal Plan and the San Francisco Bay Basin Water Quality Control Plan ("Basin Plan").

PPP 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 PPP 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 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.

Existing thermal discharges to an estuary are limited to a maximum discharge temperature of 20º F above the receiving water's natural temperature, may not exceed 86º F, and must meet other criteria specified by the Thermal Plan (SWRCB 1972). PPP applied for, and received, an exception to this Thermal Plan requirement. The current order permits the discharge of elevated-temperature wastes that do not exceed the natural receiving water temperature by more than 28º F at flood tide (SFBRWQCB 2002). No information was available to assess compliance with this permit 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 78º F) and the size of any related thermal plume in the receiving water, thus enabling PPP to meet the initial requirements of the Thermal Plan.

3.4.4 RECLAIMED WATER

Reclaimed or alternative water sources used in conjunction with wet cooling towers could eliminate all surface water withdrawals at PPP. 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 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 reclaimed water within a 15-mile radius of PPP (62 mgd) does not meet the current once-through cooling demand; thus, reclaimed water is only applicable as a source of makeup water for a wet cooling tower system. This study did not pursue a detailed investigation of reclaimed water’s use because the conversion of PPP’s once-through cooling system to saltwater cooling towers meets the performance benchmarks for impingement and entrainment impact reductions discussed in the 2006 California Ocean Protection Council (OPC) Resolution on Once-Through Cooling Water (see Chapter 1).

To be acceptable for use as makeup water in cooling towers, reclaimed water 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, PPP would be required to arrange for sufficient treatment, either onsite or at the source facility, prior to its use in the cooling towers.

An additional consideration for reclaimed water is the presence of any ammonia or ammonia-forming compounds in the reclaimed water. All the condenser tubes at PPP contain copper alloys (aluminum brass) and can experience stress-corrosion cracking as a result of the interaction between copper and ammonia. Treatment for ammonia may include adding ferrous sulfate as a corrosion inhibitor or require ammonia-stripping towers to pretreat reclaimed water prior to use in the cooling towers (USEPA 2000).

Three publicly owned treatment works (POTWs) were identified within a 15-mile radius of PPP, with a combined discharge capacity of 62 mgd. Figure L–6 shows the relative locations of these facilities to PPP.

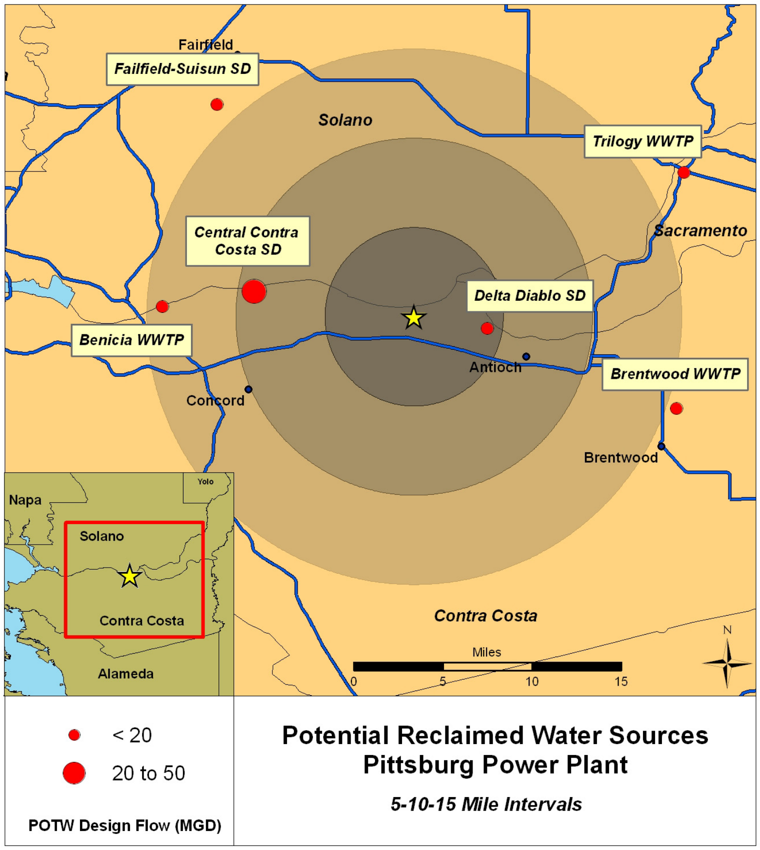

Figure L–6. Reclaimed Water Sources

- *City of Benicia Wastewater Treatment Plant—Benicia.*
  Discharge volume: 3 mgd
  Distance: 13 miles W
  Treatment level: Secondary

  All water is treated to secondary standards. No claims to or uses of treated effluent were identified. Using this water as a makeup source would require tertiary treatment as well as installing a transmission pipeline across Suisun Bay or the Carquinez Strait to reach PPP. The available capacity would be sufficient to provide approximately one-third of the makeup water required for freshwater cooling towers at PPP (9 to 12 mgd).

- *Central Contra Costa Sanitation District (CCCSD)—Concord.*
  Discharge volume: 45 mgd
  Distance: 9.5 miles W
  Treatment level: 33 % Secondary; 67 % Tertiary

  CCCSD has the capacity to treat approximately 30 mgd of effluent to tertiary treatment standards. Most reclaimed water produced by the facility is used for local irrigation projects and other non-potable uses. The balance of effluent that is treated to secondary standards (15 mgd) would be sufficient to provide all makeup water required for freshwater cooling towers at PPP (9 to 12 mgd), although arrangements for tertiary treatment would have to be made prior to its use.

- *Delta Diablo Sanitation District (DDSD)—Antioch.*
  Discharge volume: 14 mgd
  Distance: 4.5 miles E
  Treatment level: 40 % Secondary; 60 % Tertiary

  DDSD has the capacity to treat approximately 8 mgd of effluent to tertiary treatment standards. Reclaimed water is currently used as makeup water for the Los Medanos Energy Center, Delta Energy Center, and small irrigation projects in the region. The balance of effluent that is treated to secondary standards (6 mgd) would be sufficient to provide two-thirds of the freshwater tower makeup demand at PPP (9 to 12 mgd), although arrangements for tertiary treatment would have to be made prior to its use.

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 PPP's makeup demand (9 to 12 mgd for freshwater towers) is located 9.5 miles west of the facility (CCCSD).

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 PPP, 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, however, may make reclaimed water (as a makeup water source) comparable or preferable to brackish water from Suisun Bay. Reclaimed water may enable PPP to eliminate potential conflicts with water discharge limitations or reduce PM_{10} emissions from the cooling tower, which is a concern given the San Francisco Bay Area 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

Wet cooling towers at PPP will increase the condenser inlet water temperature by a range of 6 to 21° F above the surface water temperature, depending on the ambient wet bulb temperature at the time. The generating units at PPP are designed to operate at the conditions described in Table L–12. The resulting monthly difference between once-through and wet cooling tower condenser inlet temperatures is described in Figure L–7.

Table L–12. Design Thermal Conditions

	Unit 5	Unit 6
Design backpressure (in. HgA)	1.5	1.5
Design water temperature (°F)	62	62
Turbine inlet temp (°F)	1,000	1,000
Turbine inlet pressure (psia)	2,000	2,000
Full load heat rate (BTU/kWh) [a]	7,510	7,510

[a] Mirant Delta 2006.

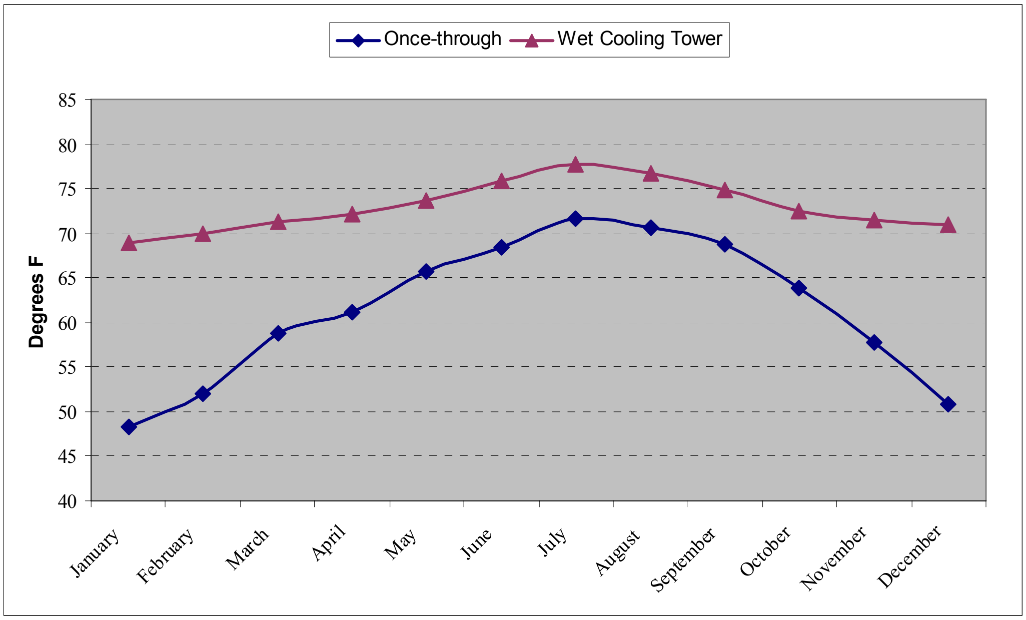

Figure L–7. Condenser Inlet Temperatures

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 1.0 to 1.15 inches HgA compared with the current once-through system (Figure L–8 and Figure L–10).

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.[4] The relative change at different backpressures was compared with the value calculated for the design conditions (i.e., at design

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[4] Changes in thermal efficiency estimated for PPP 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 PPP might result in different calculations.

turbine inlet and exhaust backpressures) and plotted as a percentage of the full load operating heat rate to develop estimated correction curves (Figure L–9 and Figure L–11).

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 L–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 L–13. Summary of Estimated Heat Rate Increases

	Unit 5	Unit 6
Peak (July-August-September)	0.75%	0.75%
Annual average	0.89%	0.89%

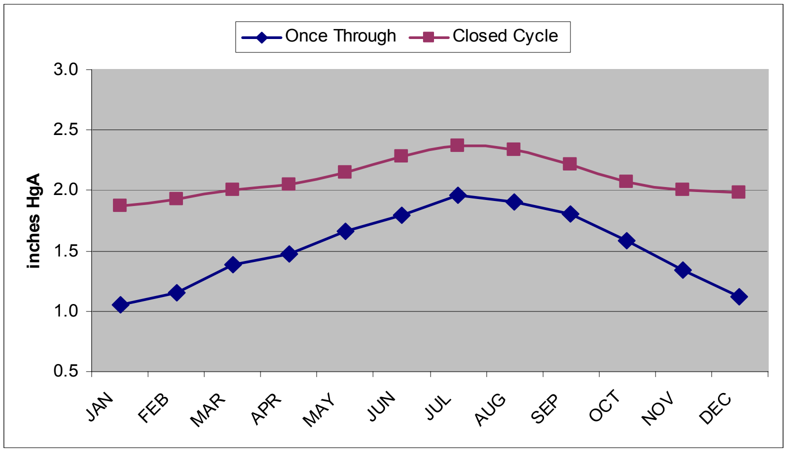

Figure L–8. Estimated Backpressures (Unit 5)

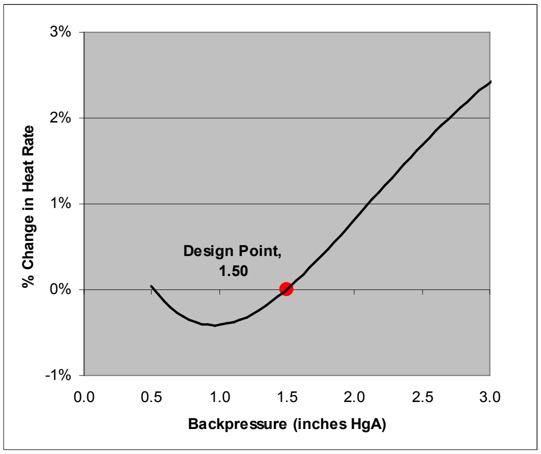

Figure L–9. Estimated Heat Rate Correction (Unit 5)

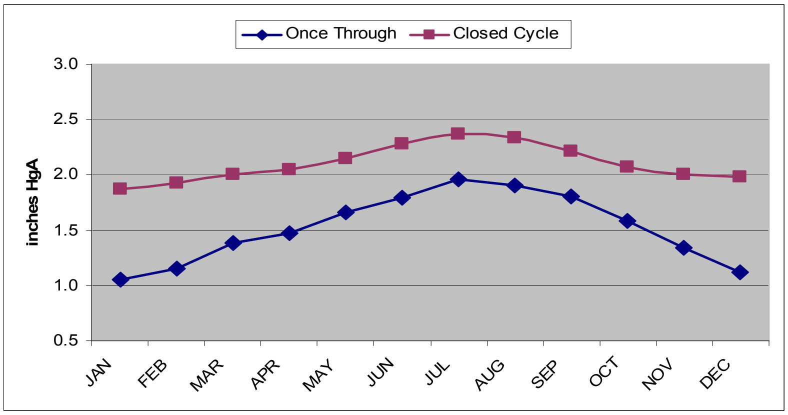

Figure L–10. Estimated Backpressures (Unit 6)

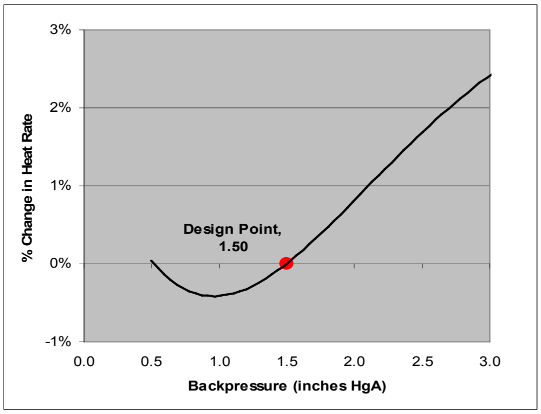

Figure L–11. Estimated Heat Rate Correction (Unit 6)

4.0 RETROFIT COST ANALYSIS

The wet cooling system retrofit estimate for PPP is based on incorporating conventional wet cooling towers as a replacement for the existing once-through system for each unit. 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 PPP conforms to a typical design; no significant variations from a conventional arrangement were needed. Table L–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 L–14. Wet Cooling Tower Design-and-Build Cost Estimate

	Unit 5	Unit 6	PPP total
Number of cells	12	12	**24**
Cost/cell ($)	566,667	566,667	**566,667**
Total PPP D&B cost ($)	**6,800,000**	**6,800,000**	**13,600,000**

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 PPP, these costs comprise approximately 80 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 L–15.

- *Civil, Structural, and Piping*
  The cooling towers' location with respect to the generating units represents the largest single increase in cost over an average configuration. More than 15,000 feet of large diameter pipe are required to service both cooling towers.
- *Mechanical and Electrical*
  Initial capital costs in this category reflect the new pumps (four total) to circulate cooling water between the towers and condensers. No new pumps are required to provide makeup water from Suisun Bay. Electrical costs are based on the battery limit after the main feeder breakers.
- *Demolition*
  No demolition costs are required.

Table L–15. Summary of Other Direct Costs

	Equipment ($)	Bulk material ($)	Labor ($)	PPP total ($)
Civil/structural/piping	5,300,000	26,600,000	16,600,000	**48,500,000**
Mechanical	7,600,000	0	700,000	**8,300,000**
Electrical	1,600,000	2,700,000	2,500,000	**6,800,000**
Demolition	0	0	0	**0**
Total PPP other direct costs	**14,500,000**	**29,300,000**	**19,800,000**	**63,600,000**

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 PPP, potential costs in this category include relocating or demolishing small buildings and structures and potential interferences from underground structures.

Soils were not characterized for this analysis. PPP is situated near sea level adjacent to Suisun Bay. The area in which cooling towers will be located is surrounded by marshes and wetlands that may require additional pilings to support any large structures built at the site. Initial capital costs are summarized in Table L–16.

Table L–16. Summary of Initial Capital Costs

	Cost ($)
Cooling towers	13,600,000
Civil/structural/piping	48,500,000
Mechanical	8,300,000
Electrical	6,800,000
Demolition	0
Indirect cost	19,300,000
Condenser modification	3,900,000
Contingency	25,100,000
Total PPP capital cost	**125,500,000**

4.4 SHUTDOWN

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

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 PPP 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 PPP (321,000 gpm), are presented in Table L–17. These costs reflect maximum operation.

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

	Year 1 cost ($)	**Year 12 cost ($)**
Management/labor	321,000	465,450
Service/parts	513,600	744,720
Fouling	449,400	651,630
Total PPP O&M cost	**1,284,000**	**1,861,800**

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 PPP 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 PPP 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 PPP 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, PPP 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

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[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.

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

Table L–18. Cooling Tower Fan Parasitic Use

	Tower 1	Tower 2	PPP total
Units served	Unit 5	Unit 6	--
Generating capacity (MW)	325	325	**650**
Number of fans (one per cell)	12	12	**24**
Motor power per fan (hp)	211	211	--
Total motor power (hp)	2,526	2,526	**5,053**
MW total	1.88	1.88	**3.77**
Fan parasitic use (% of capacity)	**0.58%**	**0.58%**	**0.58%**

Additional circulating water pump capacity for the wet cooling towers will also increase the parasitic electricity usage at PPP. Makeup water will continue to be withdrawn from Suisun Bay 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. Final estimates, therefore, allocate the retained pump's electrical demand to each tower based on the proportion of the facility's generating capacity it services. Operating fewer towers or tower cells will alter the allocation of the retained pump's electrical demand, but not the total demand.

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 L–19.

Table L–19. Cooling Tower Pump Parasitic Use

	Tower 1	Tower 2	PPP total
Units served	Unit 5	Unit 6	--
Generating capacity (MW)	325	325	**650**
Existing pump configuration (hp)	1,200	1,200	**2,400**
New pump configuration (hp)	6,664	6,664	**13,327**
Difference (hp)	5,464	5,464	**10,927**
Difference (MW)	4.1	4.1	**8.1**
Net pump parasitic use (% of capacity)	**1.25%**	**1.25%**	**1.25%**

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 PPP 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 PPP may be greater or less. Changes in the heat rate for each unit at PPP are presented in Figure L–12 and Figure L–13.

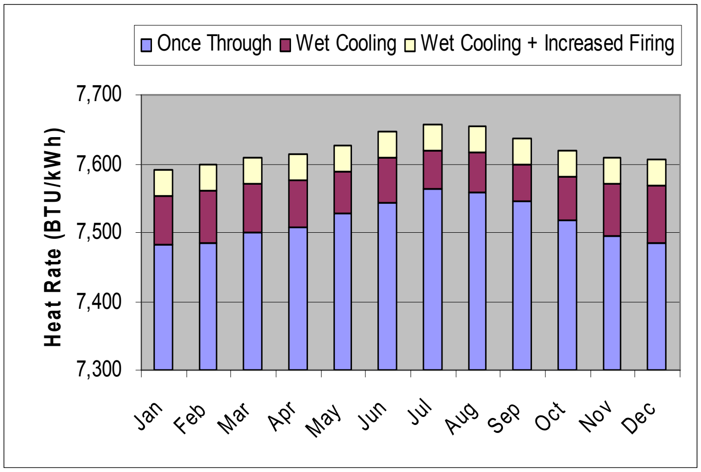

Figure L–12. Estimated Heat Rate Change (Unit 5)

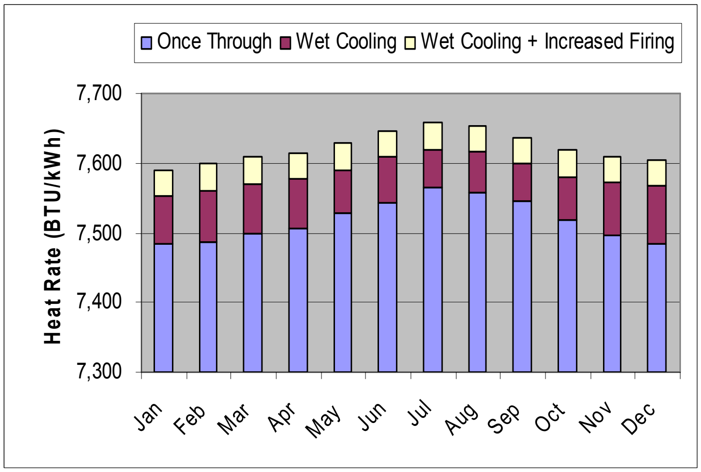

Figure L–13. Estimated Heat Rate Change (Unit 6)

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 ($/MWh) for the once-through system and the wet cooling system adjusted for a higher turbine firing rate. The cost of generation for PPP is based on the relative heat rates developed in Section 3.4.5 and the average monthly wholesale natural gas cost ($/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 PPP will be approximately $207,000. In contrast, the energy penalty's value calculated with the production loss option would be approximately $660,000. Together, these values represent the range of potential energy penalty costs for PPP. Table L–20 and Table L–21 summarize the energy penalty estimates for each unit using the increased fuel option.

Table L–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	7,483	44.90	7,590	45.54	0.64	0	0
February	5.50	7,486	41.17	7,598	41.79	0.62	11,236	6,962
March	4.75	7,499	35.62	7,609	36.14	0.52	13,283	6,920
April	4.75	7,507	35.66	7,615	36.17	0.51	51,821	26,522
May	4.75	7,527	35.75	7,628	36.23	0.48	0	0
June	5.00	7,543	37.72	7,646	38.23	0.52	11,111	5,732
July	6.50	7,564	49.17	7,658	49.78	0.61	55,858	34,014
August	6.50	7,558	49.13	7,654	49.75	0.62	0	0
September	4.75	7,545	35.84	7,637	36.28	0.44	0	0
October	5.00	7,518	37.59	7,618	38.09	0.50	14,319	7,115
November	6.00	7,496	44.98	7,609	45.66	0.68	50,788	34,570
December	6.50	7,484	48.65	7,605	49.43	0.78	2,966	2,328
							Unit 5 total	**124,163**

Table L–21. Unit 6 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	7,483	44.90	7,590	45.54	0.64	0	0
February	5.50	7,486	41.17	7,598	41.79	0.62	15,970	9,895
March	4.75	7,499	35.62	7,609	36.14	0.52	51	27
April	4.75	7,507	35.66	7,615	36.17	0.51	0	0
May	4.75	7,527	35.75	7,628	36.23	0.48	47,074	22,474
June	5.00	7,543	37.72	7,646	38.23	0.52	10,335	5,331
July	6.50	7,564	49.17	7,658	49.78	0.61	74,260	45,220
August	6.50	7,558	49.13	7,654	49.75	0.62	0	0
September	4.75	7,545	35.84	7,637	36.28	0.44	0	0
October	5.00	7,518	37.59	7,618	38.09	0.50	0	0
November	6.00	7,496	44.98	7,609	45.66	0.68	180	123
December	6.50	7,484	48.65	7,605	49.43	0.78	0	0
							Unit 6 total	**83,070**

4.7 NET PRESENT COST

The Net Present Cost (NPC) of a wet cooling system retrofit at PPP 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 PPP 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 L–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 PPP has a relatively low capacity utilization factor, O&M costs for the NPC calculation were estimated at 30 percent of their maximum value. (See Table L–17.)
- *Annual Energy Penalty.* Insufficient information is available to this study to forecast future generating output at PPP. 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 L–20 and Table L–21.)

Using these values, the NPC_{20} for PPP is $134 million. Appendix C contains detailed annual calculations used to develop this cost.

4.8 ANNUAL COST

The annual cost incurred by PPP 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 NPC_{20} (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 L–22.

Table L–22. Annual Cost

Discount rate	Capital Cost ($)	Annual O&M ($)	Annual energy penalty ($)	Annual cost ($)
7.00%	11,800,000	500,000	400,000	**12,700,000**

4.9 COST-TO-GROSS REVENUE COMPARISON

Limited financial data are available to conduct a detailed analysis of the economic impact that a wet cooling system retrofit will have on PPP's annual revenues. The facility's gross annual revenue can be approximated using 2006 net generating data (CEC 2006) and average wholesale prices for electricity as recorded at the SP 15 trading hub (ICE 2006b). This estimate, therefore, does not reflect any changes that may result from different wholesale prices or contract agreements that may increase or decrease the gross revenue summarized below, nor does it account for annual fixed revenue requirements or other variable costs.

The estimate of gross annual revenue from electricity sales at PPP is a straightforward calculation that multiplies the monthly wholesale cost of electricity by the amount generated for the particular month. The estimated gross revenue for PPP is summarized in Table L–23. A comparison of annual costs to annual gross revenue is summarized in Table L–24.

Table L–23. Estimated Gross Revenue

	Wholesale price ($/MWh)	Net generation (MWh)			Estimated gross revenue ($)			
		Unit 5	Unit 6	Unit 7	Unit 5	Unit 6	Unit 7	PPP total
January	66	0	0	0	0	0	0	**0**
February	61	11,236	15,970	0	685,396	974,170	0	**1,659,566**
March	51	13,283	51	0	677,433	2,601	0	**680,034**
April	51	51,821	0	0	2,642,871	0	0	**2,642,871**
May	51	0	47,074	0	0	2,400,774	0	**2,400,774**
June	55	11,111	10,335	35,395	611,105	568,425	1,946,725	**3,126,255**
July	91	55,858	74,260	52,602	5,083,078	6,757,660	4,786,782	**16,627,520**
August	73	0	0	0	0	0	0	**0**
September	53	0	0	0	0	0	0	**0**
October	57	14,319	0	0	816,183	0	0	**816,183**
November	66	50,788	180	0	3,352,008	11,880	0	**3,363,888**
December	67	2,966	0	0	198,722	0	0	**198,722**
PPP total		**211,382**	**147,870**	**87,997**	**14,066,796**	**10,715,510**	**6,733,507**	**31,515,813**

Table L–24. 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
31,500,000	11,800,000	37	500,000	1.6	400,000	1.3	**12,700,000**	**40**

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 PPP.

Among these technologies, however, and within the framework of this study, fine-mesh wedgewire screens exhibit the greatest potential for successful deployment. A final conclusion as to their applicability will have to be based on a more detailed site-specific investigation of the source water's physical characteristics. A more detailed analysis that also comprises a biological evaluation may determine the applicability of one or more of these technologies to PPP. 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. PPP currently withdraws its cooling water through a shoreline CWIS on the southern bank of Suisun Bay. Modifying the existing traveling screens to include fine-mesh panels and a return system would require expanding the existing CWIS and identifying a suitable return location to prevent re-impingement. These modifications, and the potential for success, are plausible but require detailed investigation of the potentially affected species in Suisun Bay before a conclusive determination can be made.

5.2 BARRIER NETS

If impingement is a significant concern at PPP, a barrier net could conceivably be placed in Suisun Bay as an impingement control measure in addition to flow reduction methods. Successful deployment of a barrier net would depend on how far offshore the net would extend and whether this would interfere with the bay's navigational or recreational uses. Debris loadings in the Delta as well as the impact from any storms or tidal movements would also need to be addressed before deployment.

Costs for barrier nets are not significant and depend on the net's size and the amount of maintenance required. Seasonal deployments may be possible, and thereby reduce costs, if migratory patterns in Suisun Bay allow. Based on estimates developed for the Phase II rule, barrier net initial capital costs for PPP range from \$160,000 to \$200,000 with annual O&M costs of approximately \$30,000 to \$40,000 (USEPA 2004). Maintenance costs include replacement of net panels, which can be high depending on the frequency of replacement.

5.3 AQUATIC FILTRATION BARRIERS

An evaluation of an aquatic filtration barrier (AFB) at Mirant's Contra Costa Power Plant was proposed as part of a Habitat Conservation Program for CCPP and PPP. Difficulties pertaining to the AFB's installation and maintenance at one of Mirant's New York facilities precluded a complete evaluation at CCPP. Maintenance concerns were driven by fouling and the inability to maintain a sufficiently clean fabric (Mirant Delta 2006). AFBs have not been demonstrated to be effective in an estuarine environment at the scale necessary for PPP. Any such installation would have to address the potential for high sediment loads and fouling that would adversely affect performance.

5.4 VARIABLE SPEED DRIVES

VSDs are currently installed at PPP, but no information was available to evaluate their use and any relative reductions in impingement or entrainment.

5.5 CYLINDRICAL FINE-MESH WEDGEWIRE

Cylindrical wedgewire screens have been deployed in estuarine settings with physical characteristics similar to those that would be experienced in the Sacramento/San Joaquin Delta. Fine-mesh applications may be susceptible to fouling or clogging due to sediment loads, but may be feasible at PPP.

To function as intended, cylindrical wedgewire screens must be submerged in a water body with a consistent ambient current of 0.5 fps. Ideally, this current is unidirectional so that screens may be oriented properly and any debris impinged on the screens will be carried downstream when the air-burst cleaning system is activated.

Data obtained from USGS stream flow gages for the Sacramento River in the vicinity of PPP show average ambient currents exceed 0.5 fps for more than 95 percent of the time (Figure L–14) (USGS 2007). Prior to screen installation, more accurate current measurements in the precise screen location would have to taken.

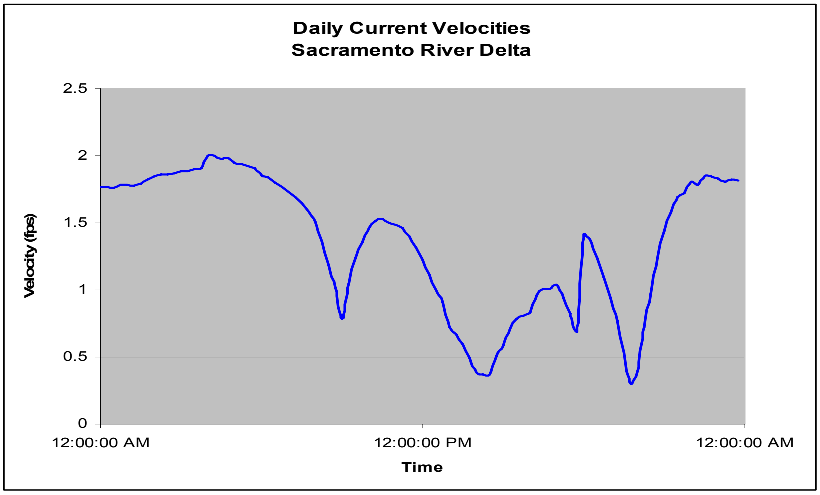

Figure L–14. Diurnal Sacramento River Currents

Based on the limited data available, a conceptual plan and cost for fine-mesh wedgewire screens was developed for an installation at PPP. Fine-mesh wedgewire screens for PPP would be installed offshore in Suisun Bay approximately 800 feet north of the Unit 5 and 6 CWIS. This location is deep enough for five 84-inch diameter screen assemblies; shoreline or bulkhead wall placement would require dredging in front of the intake, dismantling the dock and continued maintenance to prevent sediment buildup. The screens' general placement at PPP is shown in Figure L–15. Approximate costs are summarized in Table L–25.

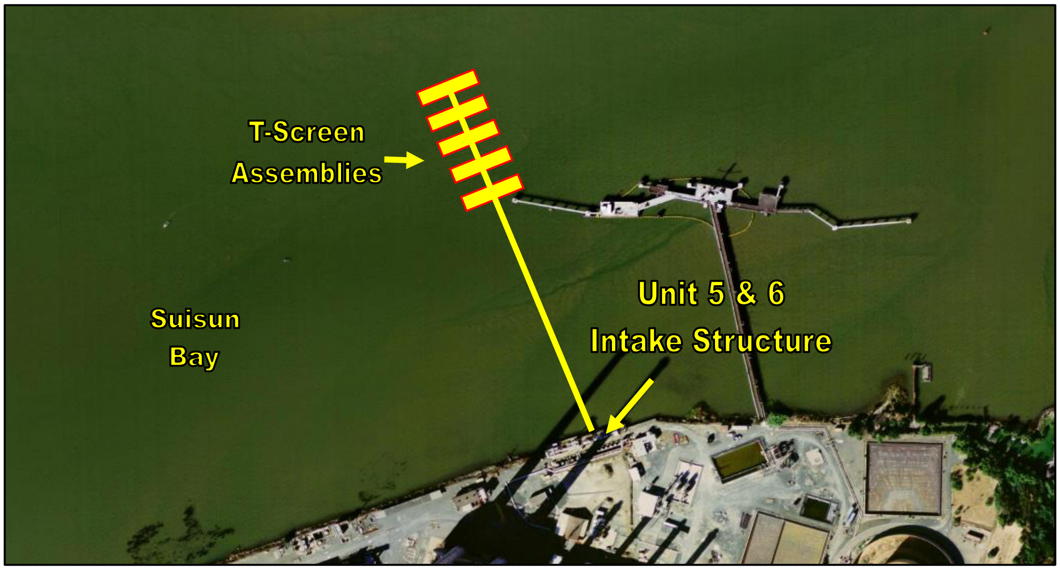

Figure L–15. Approximate Cylindrical Wedgewire Screen Location

Table L–25. Estimated Cost of Fine-Mesh Wedgewire Screens

	Installed cost ($)
5 T-screens (84" x 300")	1,940,000
Piping (120")	4,000,000
Indirect / contingency	891,000
PPP total	**6,831,000**

(a) T-screen cost includes air-burst cleaning system (GLV 2007).
(b) PCCP piping costs based on vendor price quotes and installation estimates for 120" pipe used in this study. Underwater installation costs may vary.

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

		Unit 5			Unit 5		
		Once through	Closed cycle	Net increase	Once through	Closed cycle	Net increase
JAN	Backpressure (in. HgA)	1.05	1.87	**0.82**	1.05	1.87	**0.82**
	Heat rate Δ (%)	*-0.36*	*0.57*	***0.93***	*-0.36*	*0.57*	***0.93***
FEB	Backpressure (in. HgA)	1.16	1.93	**0.77**	1.16	1.93	**0.77**
	Heat rate Δ (%)	*-0.33*	*0.67*	***1.00***	*-0.33*	*0.67*	***1.00***
MAR	Backpressure (in. HgA)	1.38	2.00	**0.62**	1.38	2.00	**0.62**
	Heat rate Δ (%)	*-0.15*	*0.81*	***0.96***	*-0.15*	*0.81*	***0.96***
APR	Backpressure (in. HgA)	1.47	2.05	**0.57**	1.47	2.05	**0.57**
	Heat rate Δ (%)	*-0.04*	*0.89*	***0.93***	*-0.04*	*0.89*	***0.93***
MAY	Backpressure (in. HgA)	1.66	2.14	**0.48**	1.66	2.14	**0.48**
	Heat rate Δ (%)	*0.23*	*1.06*	***0.83***	*0.23*	*1.06*	***0.83***
JUN	Backpressure (in. HgA)	1.79	2.28	**0.49**	1.79	2.28	**0.49**
	Heat rate Δ (%)	*0.44*	*1.31*	***0.87***	*0.44*	*1.31*	***0.87***
JUL	Backpressure (in. HgA)	1.96	2.37	**0.41**	1.96	2.37	**0.41**
	Heat rate Δ (%)	*0.73*	*1.47*	***0.74***	*0.73*	*1.47*	***0.74***
AUG	Backpressure (in. HgA)	1.91	2.33	**0.43**	1.91	2.33	**0.43**
	Heat rate Δ (%)	*0.64*	*1.41*	***0.77***	*0.64*	*1.41*	***0.77***
SEP	Backpressure (in. HgA)	1.80	2.21	**0.41**	1.80	2.21	**0.41**
	Heat rate Δ (%)	*0.46*	*1.19*	***0.73***	*0.46*	*1.19*	***0.73***
OCT	Backpressure (in. HgA)	1.59	2.07	**0.48**	1.59	2.07	**0.48**
	Heat rate Δ (%)	*0.11*	*0.93*	***0.82***	*0.11*	*0.93*	***0.82***
NOV	Backpressure (in. HgA)	1.35	2.01	**0.66**	1.35	2.01	**0.66**
	Heat rate Δ (%)	*-0.19*	*0.82*	***1.01***	*-0.19*	*0.82*	***1.01***
DEC	Backpressure (in. HgA)	1.12	1.98	**0.85**	1.12	1.98	**0.85**
	Heat rate Δ (%)	*-0.34*	*0.76*	***1.10***	*-0.34*	*0.76*	***1.10***

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	95	380,000	**880,000**
Allocation for pipe racks (approx 800 ft) and cable racks	t	80	--	--	2,500	200,000	17.00	105	142,800	**342,800**
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	95	190,000	**440,000**
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	52,725	--	--	--	--	0.04	200	421,800	**421,800**
Bedding for PCCP pipe	m3	7,985	--	--	40	319,400	0.04	200	63,880	**383,280**
Bend for PCCP pipe 30" & 36" diam (allocation)	ea	40	--	--	5,000	200,000	25.00	95	95,000	**295,000**
Bend for PCCP pipe 72" diam (allocation)	ea	20	--	--	18,000	360,000	40.00	95	76,000	**436,000**
Bend for PCCP pipe 84" diam (allocation)	ea	150	--	--	20,000	3,000,000	50.00	95	712,500	**3,712,500**
Building architectural (siding, roofing, doors, painting…etc)	ea	2	--	--	250,000	500,000	3,000.00	82	492,000	**992,000**
Butterfly valves 24" c/w allocation for actuator & air lines	ea	4	28,000	112,000	--	--	50.00	95	19,000	**131,000**
Butterfly valves 30" c/w allocation for actuator & air lines	ea	28	30,800	862,400	--	--	50.00	95	133,000	**995,400**
Butterfly valves 60" c/w allocation for actuator & air lines	ea	4	75,600	302,400	--	--	60.00	95	22,800	**325,200**
Butterfly valves 72" c/w allocation for actuator & air lines	ea	20	96,600	1,932,000	--	--	75.00	95	142,500	**2,074,500**
Butterfly valves 84" c/w allocation for actuator & air lines	ea	12	124,600	1,495,200	--	--	75.00	95	85,500	**1,580,700**
Check valves 30"	ea	4	44,000	176,000	--	--	16.00	95	6,080	**182,080**
Check valves 60"	ea	4	108,000	432,000	--	--	30.00	95	11,400	**443,400**
Concrete basin walls (all in)	m3	350	--	--	250	87,500	8.00	82	229,600	**317,100**
Concrete elevated slabs (all in)	m3	538	--	--	275	147,950	10.00	82	441,160	**589,110**
Concrete for transformers and oil catch basin (allocation)	m3	200	--	--	275	55,000	10.00	82	164,000	**219,000**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
Concrete slabs on grade (all in)	m3	2,730	--	--	220	600,600	4.00	82	895,440	**1,496,040**
Ductile iron cement pipe 12" diam. for fire water line	ft	4,000	--	--	100	400,000	0.60	95	228,000	**628,000**
Excavation and backfill for fire line & make-up (using excavated material for backfill except for bedding)	m3	16,437	--	--	--	--	0.08	200	262,992	**262,992**
Excavation for PCCP pipe	m3	84,245	--	--	--	--	0.04	200	673,960	**673,960**
Fencing around transformers	m	50	--	--	33	1,650	1.00	82	4,100	**5,750**
Flange for PCCP joints 30"	ea	24	--	--	2,260	54,240	16.00	95	36,480	**90,720**
Flange for PCCP joints 72"	ea	8	--	--	9,860	78,880	25.00	95	19,000	**97,880**
Flange for PCCP joints 84"	ea	16	--	--	13,210	211,360	30.00	95	45,600	**256,960**
Foundations for pipe racks and cable racks	m3	190	--	--	275	52,250	8.00	82	124,640	**176,890**
FRP flange 24"	ea	8	--	--	1,419	11,352	40.00	95	30,400	**41,752**
FRP flange 30"	ea	88	--	--	1,679	147,765	50.00	95	418,000	**565,765**
FRP flange 60'	ea	16	--	--	7,785	124,565	100.00	95	152,000	**276,565**
FRP flange 72"	ea	40	--	--	20,888	835,507	200.00	95	760,000	**1,595,507**
FRP flange 84"	ea	8	--	--	33,381	267,048	300.00	95	228,000	**495,048**
FRP pipe 24" diam.	ft	600	--	--	95	56,760	0.30	95	17,100	**73,860**
FRP pipe 60" diam.	ft	160	--	--	615	98,384	0.90	95	13,680	**112,064**
FRP pipe 84" diam.	ft	1,200	--	--	946	1,135,200	1.50	95	171,000	**1,306,200**
FRP pipe 96" diam.	ft	200	--	--	2,838	567,600	1.75	95	33,250	**600,850**
Harness clamp 30" & 36"c/w internal testable joint	ea	220	--	--	2,000	440,000	16.00	95	334,400	**774,400**
Harness clamp 72" c/w internal testable joint	ea	100	--	--	2,440	244,000	18.00	95	171,000	**415,000**
Harness clamp 84" c/w internal testable joint	ea	800	--	--	2,845	2,276,000	20.00	95	1,520,000	**3,796,000**
Joint for FRP pipe 24" diam.	ea	20	--	--	901	18,012	35.00	95	66,500	**84,512**
Joint for FRP pipe 84" diam.	ea	40	--	--	5,014	200,552	300.00	95	1,140,000	**1,340,552**
Joint for FRP pipe 60" diam.	ea	8	--	--	1,797	14,379	100.00	95	76,000	**90,379**
Joint for FRP pipe 96" diam.	ea	10	--	--	17,974	179,740	600.00	95	570,000	**749,740**
PCCP pipe 30" dia. for make-up	ft	4,000	--	--	125	500,000	0.70	95	266,000	**766,000**
PCCP pipe 72" diam.	ft	1,600	--	--	507	811,200	1.30	95	197,600	**1,008,800**
PCCP pipe 84" diam.	ft	15,200	--	--	562	8,542,400	1.50	95	2,166,000	**10,708,400**
Riser (FRP pipe 30" diam X55 ft)	ea	24	--	--	15,350	368,400	150.00	95	342,000	**710,400**
Structural backfill under towers & pump houses	m3	90,000	--	--	15	1,350,000	0.06	82	442,800	**1,792,800**
Structural steel for building	t	320	--	--	2,500	800,000	20.00	105	672,000	**1,472,000**

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 TOTAL	**--**	**--**	**--**	**5,312,000**	**--**	**26,557,694**	**--**	**--**	**16,644,462**	**48,514,156**
ELECTRICAL	--	--	--	--	--	--	--	--	--	--
4.16 kv cabling feeding MCC's	m	1,500	--	--	75	112,500	0.40	110	66,000	**178,500**
4.16kV switchgear - 4 breakers	ea	1	250,000	250,000	--	--	150.00	110	16,500	**266,500**
460 volt cabling feeding MCC's	m	1,000	--	--	70	70,000	0.40	110	44,000	**114,000**
480V Switchgear - 1 breaker 3000A	ea	6	30,000	180,000	--	--	80.00	110	52,800	**232,800**
Allocation for automation and control	lot	1	--	--	1,000,000	1,000,000	10,000.00	110	1,100,000	**2,100,000**
Allocation for cable trays and duct banks	m	1,500	--	--	75	112,500	1.00	110	165,000	**277,500**
Allocation for lighting and lightning protection	lot	1	--	--	150,000	150,000	1,500.00	110	165,000	**315,000**
Dry Transformer 2MVA xxkV-480V	ea	6	100,000	600,000	--	--	100.00	110	66,000	**666,000**
Lighting & electrical services for pump house building	ea	4	--	--	20,000	80,000	250.00	110	110,000	**190,000**
Local feeder for 200 HP motor 460 V (up to MCC)	ea	24	--	--	18,000	432,000	150.00	110	396,000	**828,000**
Local feeder for 4000 HP motor 4160 V (up to MCC)	ea	4	--	--	50,000	200,000	200.00	110	88,000	**288,000**
Oil Transformer 10/13.33MVA xx-4.16kV	ea	2	190,000	380,000	--	--	150.00	110	33,000	**413,000**
Primary breaker(xxkV)	ea	4	45,000	180,000	--	--	60.00	110	26,400	**206,400**
Primary feed cabling (assumed 13.8 kv)	m	3,000	--	--	175	525,000	0.50	110	165,000	**690,000**
ELECTRICAL TOTAL	**--**	**--**	**--**	**1,590,000**	**--**	**2,682,000**	**--**	**--**	**2,493,700**	**6,765,700**
MECHANICAL	--	--	--	--	--	--	--	--	--	--
Allocation for ventilation of buildings	ea	2	100,000	200,000	--	--	1,000.00	95	190,000	**390,000**
Cooling tower for unit 5	lot	1	6,800,000	6,800,000	--	--	--	--	--	**6,800,000**
Cooling tower for unit 6	lot	1	6,800,000	6,800,000	--	--	--	--	--	**6,800,000**
Overhead crane 50 ton in (in pump house) Including additional structure to reduce the span	ea	2	500,000	1,000,000	--	--	1,000.00	95	190,000	**1,190,000**
Pump 4160 V 4000 HP	ea	4	1,600,000	6,400,000	--	--	800.00	95	304,000	**6,704,000**
MECHANICAL TOTAL	**--**	**--**	**--**	**21,200,000**	**--**	**0**	**--**	**--**	**684,000**	**21,884,000**

Appendix C. Net Present Cost Calculation

Project year	Capital/start-up ($)	O & M ($)	Energy penalty ($)		Total ($)	Annual discount factor	Present value ($)
			Unit 1	Unit 2			
0	125,400,000	--	--	--	125,400,000	1	125,400,000
1	--	385,200	124,162	83,069	592,430	0.9346	553,685
2	--	392,904	131,400	87,912	612,216	0.8734	534,709
3	--	400,762	139,061	93,037	632,860	0.8163	516,603
4	--	408,777	147,168	98,461	654,406	0.7629	499,247
5	--	416,953	155,748	104,201	676,902	0.713	482,631
6	--	425,292	164,828	110,276	700,396	0.6663	466,674
7	--	433,798	174,438	116,705	724,941	0.6227	451,420
8	--	442,474	184,607	123,509	750,590	0.582	436,843
9	--	451,323	195,370	130,710	777,403	0.5439	422,829
10	--	460,350	206,760	138,330	805,440	0.5083	409,405
11	--	469,557	218,814	146,395	834,765	0.4751	396,597
12	--	569,711	231,571	154,929	956,211	0.444	424,558
13	--	581,105	245,072	163,962	990,138	0.415	410,907
14	--	592,727	259,359	173,521	1,025,607	0.3878	397,730
15	--	604,582	274,480	183,637	1,062,699	0.3624	385,122
16	--	616,673	290,482	194,343	1,101,498	0.3387	373,078
17	--	629,007	307,417	205,673	1,142,097	0.3166	361,588
18	--	641,587	325,340	217,664	1,184,591	0.2959	350,520
19	--	654,419	344,307	230,354	1,229,079	0.2765	339,840
20	--	667,507	364,380	243,784	1,275,670	0.2584	329,633
Total							**133,943,619**