B. CONTRA COSTA POWER PLANT

MIRANT DELTA, LLC—ANTIOCH, CA

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1.0 GENERAL SUMMARY

Retrofitting the existing once-through cooling system at Contra Costa Power Plant (CCPP) 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 the San Joaquin River by approximately 95 percent. Impingement and entrainment impacts would be reduced by a similar proportion.

The preferred option selected for CCPP 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 option would require temporary relocation of the main access road. Potential interference with the Unit 8 repowering project could not be evaluated. 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 AGS 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 CCPP are summarized in Table B–1. Annualized costs based on 20-year average values for the various cost elements are summarized in Table B–2.

Table B–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]	98,100,000	16.47	692
NPC_{20}[b]	104,300,000	17.51	736

[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 B–2. Annual Cost Summary

Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Capital and start-up	9,300,000	1.56	65.63
Operations and maintenance	500,000	0.08	3.53
Energy penalty	200,000	0.03	1.41
Total CCPP annual cost	**10,000,000**	**1.67**	**70.57**

1.2 ENVIRONMENTAL

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

Table B–3. Environmental Summary

		Unit 6	Unit 7
Water use	Design intake volume (gpm)	149,800	149,800
	Cooling tower makeup water (gpm)	7,000	7,000
	Reduction from capacity (%)	95	95
Energy efficiency [a]	Summer heat rate increase (%)	0.56	0.56
	Summer energy penalty (%)	1.91	1.91
	Annual heat rate increase (%)	0.76	0.76
	Annual energy penalty (%)	2.11	2.11
Direct air emissions [b]	PM_{10} emissions (tons/yr) (maximum capacity)	86.30	86.30
	PM_{10} emissions (tons/yr) (2006 capacity utilization)	0.77	3.34

[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

Contra Costa Power Plant (CCPP) is a natural gas–fired steam electric generating facility located in an unincorporated section of the city of Contra Costa, 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 the San Joaquin River west of the Antioch Bridge. CCPP currently operates two steam generating units (Unit 6 and Unit 7). Units 1–5 have been retired from service, although Unit 3 and Unit 4 are used as synchronous condensers only and do not generate electricity for sale. The former Unit 8 project has since been transferred from Mirant Delta to Pacific Gas and Electric (PG&E) and is now known as the Gateway Generating Station (GGS) project. The GGS project is not part of this study. (See Table B–4 and Figure B–1.)

Table B–4. General Information

Unit	In-service year	Rated capacity (MW)	2006 capacity utilization [a]	Condenser cooling water flow (gpm)
Unit 6	1964	340	0.8%	160,500
Unit 7	1964	340	3.8%	160,500
CCPP total		**680**	**2.3%**	**321,000**

[a] *Quarterly Fuel and Energy Report—2006* (CEC 2006).

Figure B–1. General Vicinity of Contra Costa Power Plant

2.1 COOLING WATER SYSTEM

CCPP operates one cooling water intake structure (CWIS) to provide condenser cooling water to Unit 6 and Unit 7 (Figure B–2). Once-through cooling water is combined with low-volume wastes generated by CCPP and discharged to the San Joaquin River through a 300-foot constructed canal. Surface water withdrawals and discharges are regulated by NPDES Permit CA0004863, as implemented by Central Valley Regional Water Quality Control Board (CVRWQCB) Order 5-01-107.

Cooling water for Unit 6 and Unit 7 is withdrawn from the San Joaquin River through a surface intake structure that is flush with the shoreline. The 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 sump and returned to the estuary.

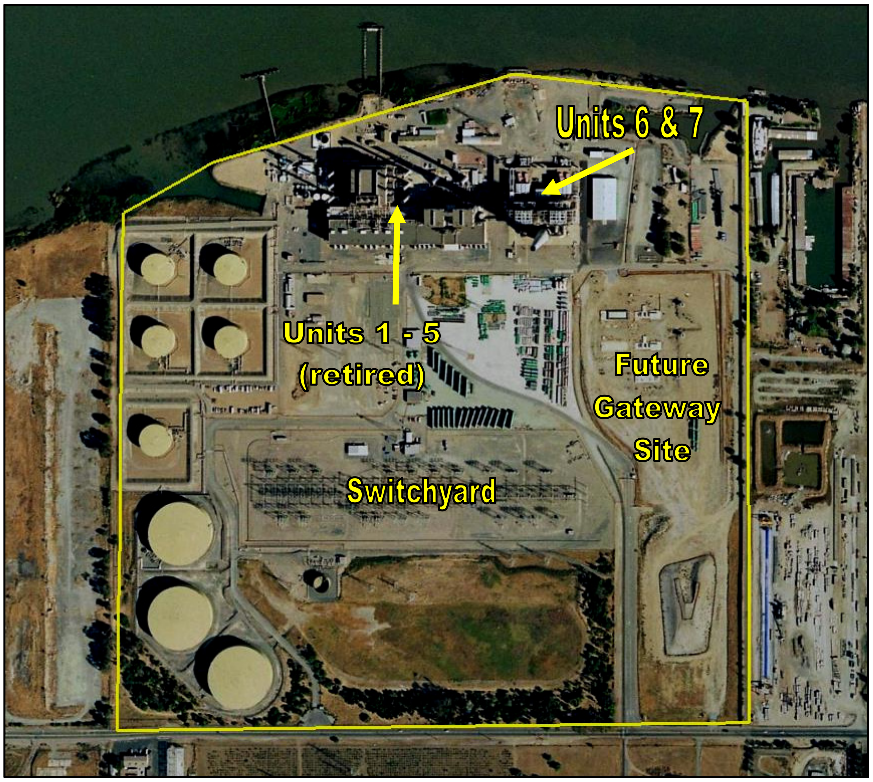

Figure B–2. Site View

After passing through the screens, the water flow diverges into two separate channels. Four variable frequency drive (VFD) pumps, two for each unit, draw water from the channels to the surface condensers. The pumps for Unit 6 and Unit 7 are each rated at 76,400 gallons per minute (gpm), or 110 million gallons per day (mgd), but are capable of operating at 50 percent of the maximum capacity. The maximum rated pumping capacity for Unit 5 and Unit 6 is 321,000 gpm, or 462 mgd (Mirant Delta 2006). Operation of the VFDs is governed by facility protocols that state the following:

> …from May 1 to July 15, a feed forward curve controls the circulating water pump (CWP) speed at 50% speed until 172 MW is achieved. The speed then gradually ramps to 95% speed at 322 MW. The speed is maintained at 95% through a full load of 345 MW. A discharge temperature set point of 85° F also cascades into the control logic to increase or decrease the pump speed as needed. (Mirant Delta 2006)

At maximum capacity, CCPP maintains a total pumping capacity rated at 441 mgd, with a condenser flow rating of 431 mgd (a portion is used for bearing cooling). On an annual basis, CCPP withdraws substantially less than its design capacity due to its low generating capacity utilization. When in operation and generating the maximum load, CCPP can be expected to withdraw water from the San Joaquin River at a rate approaching its maximum capacity.

2.2 SECTION 316(B) PERMIT COMPLIANCE

The CWIS currently in operation for Unit 5 and Unit 6 uses pumps fitted with VFDs that can reduce the intake flow volume by as much as 50 percent, depending on each unit’s operating load, water temperatures, and other limits set in the control logic. This is particularly beneficial during sensitive spawning and migratory periods in the Sacramento/San Joaquin Delta region. At Contra Costa, 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 VFDs’ actual operations and the relative changes in intake volume they provide compared with single-speed pumps. In 2006, 70 percent of the Unit 6 and Unit 7 net output coincided with the February to July period (CEC 2006).

Apart from the VFDs, Unit 6 and Unit 7 do not currently use other technologies or operational measures that are generally considered to be effective at reducing impingement and entrainment impacts. CVRWQCB Order 5-01-107 notes that, in 1986, the former owner, Pacific Gas and Electric (PG&E), implemented a Resources Management Plan to comply with best technology available (BTA) requirements under Clean Water Act (CWA) Section 316(b). The plan required PG&E to stock striped bass fish hatcheries in the Sacramento/San Joaquin Delta and improve its facility’s intake structures. Operations are also coordinated with Mirant Delta’s Pittsburg Power Plant located 7 miles west of the facility, including preferential dispatch of Pittsburg’s Unit 7.

Because of its potential to take protected aquatic species, such as Delta smelt and Chinook salmon, Mirant Delta is required by the current order to develop a comprehensive conservation program (CP) in consultation with the 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 filtration barrier (AFB) if a concurrent pilot evaluation at 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 CCPP to implement the Resources Management Plan. No information from the CVRWQCB 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 CCPP, with the current source water (San Joaquin River) 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 95 percent; rates of impingement and entrainment will decline by a similar proportion. Use of reclaimed water was considered for CCPP 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 CCPP.

The overall practicality of retrofitting both units at CCPP 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 CCPP 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 practicality and difficulty of these modifications are dependent on each unit's age and configuration but are assumed to be feasible at CCPP. Condenser water boxes for both units are

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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.

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 CCPP 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 B–5.

Table B–5. Condenser Design Specifications

	Unit 6	Unit 7
Thermal load (MMBTU/hr)	1,450	1,450
Surface area (ft^2)	135,000	135,000
Condenser flow rate (gpm)	149,800	149,800
Tube material	Aluminum brass	Aluminum brass
Heat transfer coefficient (BTU/hr•ft^2•°F)	587	587
Cleanliness factor	0.85	0.85
Inlet temperature (°F)	63	63
Temperature rise (°F)	19.37	19.37
Steam condensate temperature (°F)	91.7	91.7
Turbine exhaust pressure (in. HgA)	1.5	1.5

3.2.2 AMBIENT ENVIRONMENTAL CONDITIONS

CCPP is located in Contra Costa County along the southern shoreline of Suisun Bay in the Sacramento/San Joaquin Delta. Cooling water is withdrawn at the surface from a shoreline intake structure. Inlet temperature data specific to CCPP were not provided by Mirant Delta. As a substitute, monthly temperature data from the California Department of Water Resources Antioch Monitoring Station (ANH) 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 B–6.

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

	Surface (°F)	Ambient wet bulb (°F)
January	50.0	50.7
February	52.7	52.8
March	58.3	55.3
April	61.5	56.6
May	64.6	59.4
June	67.0	63.0
July	72.3	66.0
August	71.8	64.3
September	70.2	61.3
October	65.2	57.3
November	58.6	55.5
December	51.9	54.5

3.2.3 LOCAL USE RESTRICTIONS

3.2.3.1 NOISE

Industrial development at CCPP is regulated by the Contra Costa General Plan, although the proximity to the city of Antioch 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. Restrictions would be based on the site’s zoning designation according to the Contra Costa General Plan and community noise equivalent levels (CNELs) measured near single-family residences. The cooling towers design for CCPP will have noise levels no greater than 60 dBA measured at 1,500 feet. The nearest residential areas are located more than 2,000 feet from the siting location. Accordingly, the wet cooling towers designed for CCPP do not include noise abatement measures such as low-noise fans or barrier walls.

3.2.3.2 BUILDING HEIGHT

The developed portion of CCPP 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 CCPP 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 CCPP, 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.

The Contra Costa Unit 8 project, as originally designed, would have used a conventional (not plume-abated) cooling tower. Using the selection criteria for this study, plume abatement measures were not considered for CCPP; all towers are of a conventional design. The Final Staff Assessment (FSA) for the Contra Costa Unit 8 project noted disagreement between the California Energy Commission (CEC) and Mirant Delta over the significance of the wet cooling tower visual plume, but did not include any explicit findings of impact. A reference is made requiring the facility to mitigate any plume-related issues arising on local roads but does not make any specific determinations regarding public safety hazards, particularly as they may relate to Antioch Bridge. With respect to plume abatement, this study follows the design conditions from the original Unit 8 project and develops a conventional wet cooling tower configuration for CCPP (CEC 2001).

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 and the potential impact on the Sacramento/San Joaquin Delta viewshed, when considered 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 CCPP 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 incorporation of plume abatement measures. Installing plume-abated cooling towers at CCPP will result in a different configuration (inline instead of back to back) and will require additional space. Space constraints may limit the configurations available for plume-abated towers. A final determination will be made with a better understanding of the boundaries and layout of the GGS project.

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 CCPP, 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 CCPP (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 B–3, the property's total area is fairly compact and generally developed, with few areas located close to residential or commercial areas.

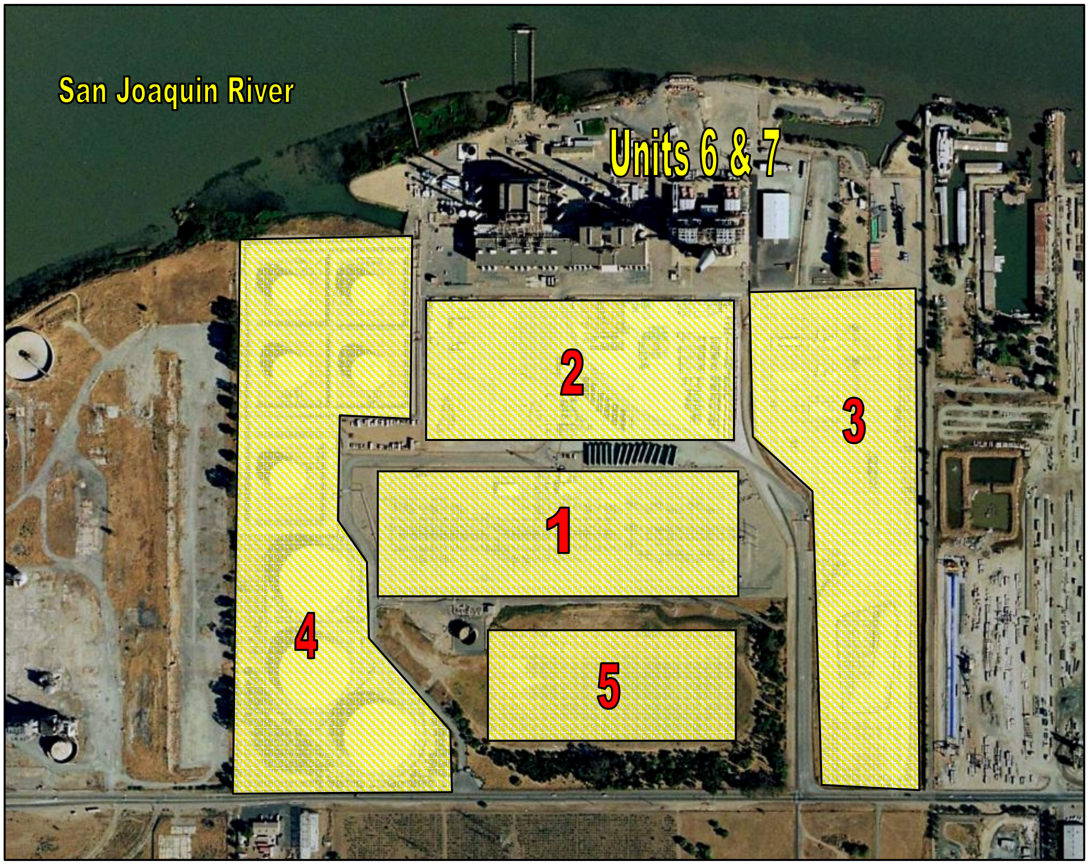

Figure B–3. Cooling Tower Siting Locations

Area 1 is the location of the PG&E switchyard. This study did not consider relocation of switchyards to accommodate cooling towers.

Area 2 is currently unoccupied by large structures, but appears to be used as a laydown area for construction of the GGS (Area 3). Use of this area would require reconfiguring an access and relocating construction staging activities to another location. Placement in this area is preferred because of its proximity to the generating units, but it is unclear how much of this area will be reserved for the GGS site after construction is completed. If this area is available, significantly less piping would be required than for other areas. In this location, supply and return pipe distances for each tower would be approximately 1,000 feet (2,000 feet total for both towers).

Area 4 is currently occupied by active fuel storage tanks. Removal and relocation cannot be evaluated in this study because of the complexity and cost.

Area 5 is currently unoccupied and borders the southern property line along Wilbur Avenue. The area does not appear to present any significant challenges to its use. No residential or commercial areas are nearby; agricultural operations are located across Wilbur Avenue, but would not experience any negative impacts related to noise or visual impairment. Use of Area 5 places the cooling towers at a substantial distance from their respective generating units and increases the overall piping and pump costs. In contrast to Area 2, which would require 2,000 feet total of piping, Area 5 would require 9,000 feet of large-diameter piping for both towers.

Based on the information available, this study selected Area 5 as the most practical location to accommodate two wet cooling towers for CCPP.

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 Unit 6 and Unit 7 at CCPP. Each unit will be served by an independently functioning tower with separate pump houses and pumps. Both towers at CCPP 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 4 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 CCPP are summarized in Table B–7.

Table B–7. Wet Cooling Tower Design

	Tower 1 (Unit 6)	**Tower 2 (Unit 7)**
Thermal load (MMBTU/hr)	1,450	1,450
Circulating flow (gpm)	149,800	149,800
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 its respective generating unit to minimize the supply and return pipe distances and any increases in total pump head and brake horsepower. At CCPP, the linear distance between the generating units and towers is significant and impacts the overall cost of the project (Figure B–4).

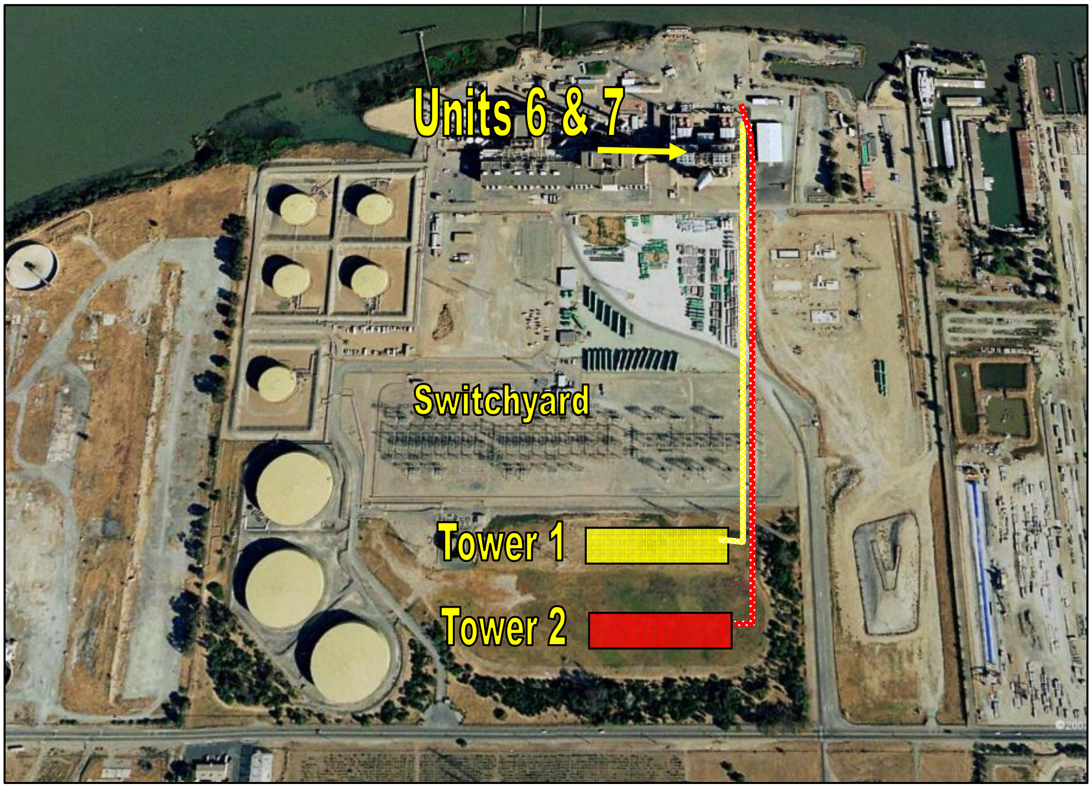

Figure B–4. Cooling Tower Locations

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. 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 CCPP 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 CCPP.

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 CCPP are summarized in Table B–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 B–8. Cooling Tower Fans and Pumps

		Tower 1 (Unit 6)	Tower 2 (Unit 7)
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)	2,205	2,205

3.4 ENVIRONMENTAL EFFECTS

Converting the existing once-through cooling system at CCPP to wet cooling towers will significantly reduce the intake of brackish water from the San Joaquin River 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 CCPP'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 CCPP 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 CCPP.

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 CCPP retains its National Pollutant Discharge Elimination System (NPDES) permit to discharge wastewater to the San Joaquin River 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

CCPP 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 A0018).

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 CCPP, this corresponds to a rate of approximately 1.6 gpm based on the maximum combined flow from both towers. Because the area selected for wet cooling towers is downwind from sensitive structures with respect to the prevailing wind direction, salt drift deposition is not likely to be a significant concern from the cooling towers. Agricultural operations are located south of the facility but are unlikely to be impacted.

Total PM_{10} emissions from the CCPP 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 CCPP will be obtained from the same source currently used for once-through cooling water (San Joaquin River). Water in this area of the Sacramento/San Joaquin Delta is heavily influenced by freshwater inflows from the San Joaquin River, but is also affected by tidal cycles in the delta region and seasonal impoundments and releases upstream. 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 CCPP 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 B–9.

Data summarizing the total facility emissions for these pollutants in 2005 are presented in Table B–10 (CARB 2005). In 2005, CCPP operated at an annual capacity utilization rate of 5.5 percent. Using this rate, the additional PM_{10} emissions from the cooling towers would increase the facility total by approximately 9.5 tons/year, or 180 percent.[2]

Table B–9. Full Load Drift and Particulate Estimates

	PM_{10} (lbs/hr)	PM_{10} (tons/year)	Drift (gpm)	Drift (lbs/hr)
Tower 1	20	86	0.8	375
Tower 2	20	86	0.8	375
Total CCPP PM_{10} and drift emissions	**40**	**172**	**1.6**	**750**

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

Pollutant	Tons/year
NO_x	26.2
SO_x	1.1
PM_{10}	5.3

3.4.2 MAKEUP WATER

The volume of makeup water required by both cooling towers at CCPP 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 B–11).

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[2] 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 CCPP capacity utilization rate instead of the 2006 rate presented in Table B–4. All other calculations in this chapter use the 2006 value.

Table B–11. Makeup Water Demand

	Tower circulating flow (gpm)	Evaporation (gpm)	Blowdown (gpm)	Total makeup water (gpm)
Tower 1	149,800	2,400	4,800	**7,200**
Tower 2	149,800	2,400	4,800	**7,200**
Total CCPP makeup water demand	**299,600**	**4,800**	**9,600**	**14,400**

One circulating water pump, rated at 76,400 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 62,000 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 towers' makeup water demand. Figure B–5 presents a schematic of this configuration.

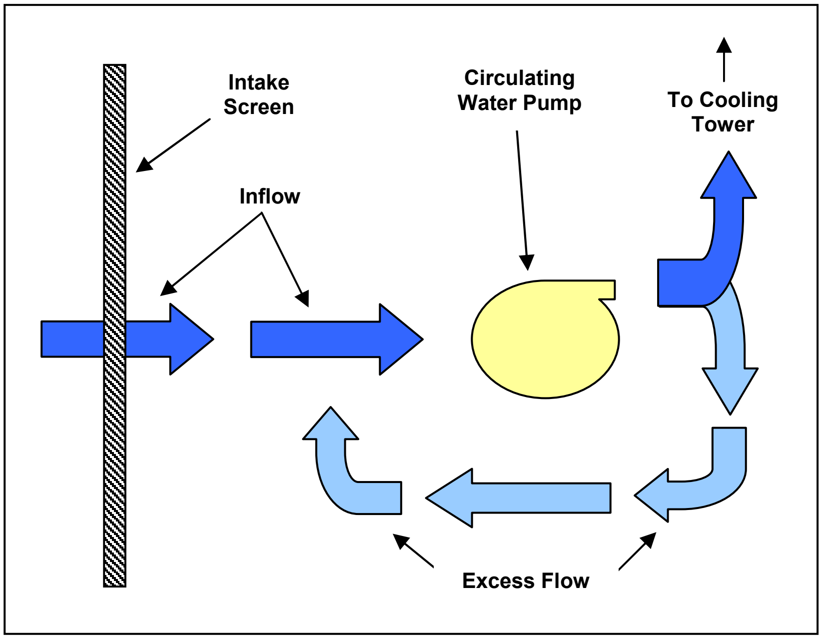

Figure B–5. Schematic of Intake Pump Configuration

The existing once-through cooling system at CCPP 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 and intake conduits. Conversion to a wet cooling tower system will not interfere with chlorination operations.

Makeup water will continue to be withdrawn from the San Joaquin River.

The wet cooling tower system proposed for CCPP includes water treatment for standard operational measures, i.e., corrosion inhibitors, biocides, and antiscaling agents. An allowance for these additional chemical treatments is included in annual operations and maintenance (O&M) costs. It is assumed that the current once-through cooling water quality will be acceptable for use in a seawater cooling tower (with continued screening and chlorination) and will not require any pretreatment to enable its use.

3.4.3 NPDES PERMIT COMPLIANCE

At maximum operation, wet cooling towers at CCPP 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 0.5 mgd to the total discharge flow from the facility. Unless an alternative discharge is considered, CCPP 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 CA0004863, as implemented by CVRWQCB Order R-01-107. All once-through cooling water and process wastewaters are discharged through a shoreline outfall to the San Joaquin River. The existing order contains effluent limitations based on the California Toxics Rule (CTR) and the1972 Thermal Plan and the Sacramento and San Joaquin River Basins Water Quality Control Plan ("Basin Plan").

CCPP 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 CCPP 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 meet other criteria specified by the Thermal Plan (SWRCB 1972). CCPP 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 37º F at flood tide (CVRWQCB 2001). 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 CCPP 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 CCPP. 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 CCPP (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 the use of reclaimed water because the conversion of CCPP'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, CCPP 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 CCPP 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 CCPP, with a combined discharge capacity of 62 mgd. Figure B–6 shows the relative locations of these facilities to CCPP.

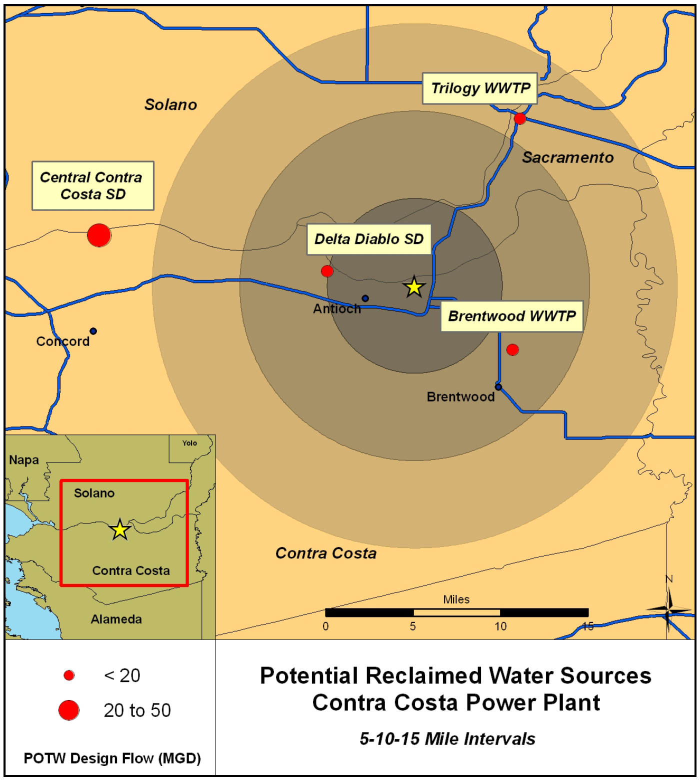

Figure B–6. Reclaimed Water Sources

- *Delta Diablo Sanitation District (DDSD)—Antioch*
  Discharge volume: 14 mgd
  Distance: 5 miles W
  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 CCPP (9 to 12 mgd), although arrangements for tertiary treatment would have to be made prior to its use.

- *Trilogy Wastewater Treatment Plant—Rio Vista*
  Discharge volume: 0.5 mgd
  Distance: 11 miles W
  Treatment level: Secondary

  The small volume of water that might be available from this facility is impractical for use at CCPP.

- *Brentwood Wastewater Treatment Plant—Brentwood*
  Discharge volume: 5 mgd
  Distance: 8 miles SE
  Treatment level: Tertiary

  All effluent is treated to tertiary standards and discharged to Marsh Creek. No current claims or uses of treated effluent were identified. The available volume could provide 50 percent of the makeup water requirement for freshwater towers at CCPP.

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. No single facility has sufficient capacity to provide CCPP with the required volume of cooling water. Two facilities would have to be accessed to obtain sufficient water (DDSD and Brentwood).The nearest facility with sufficient capacity to satisfy CCPP's makeup demand (9 to 12 mgd for freshwater towers) is located 9.5 miles west of the facility (Central Contra Costa Sanitation District). Depending on seasonal flows, the available volume may not be sufficient and would require some means of a backup cooling system or source.

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 CCPP, 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 CCPP 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 CCPP will increase the condenser inlet water temperature by a range of 5 to 19° F above the surface water temperature, depending on the ambient wet bulb temperature at the time. The generating units at CCPP are designed to operate at the conditions described in Table B–12. The resulting monthly difference between once-through and wet cooling tower condenser inlet temperatures is described in Figure B–7.

Table B–12. Design Thermal Conditions

	Unit 6	Unit 7
Design backpressure (in. HgA)	1.5	1.5
Design water temperature (°F)	63	63
Turbine inlet temp (°F)	1,050	1,050
Turbine inlet pressure (psia)	2,400	2,400
Full load heat rate (BTU/kWh) [a]	9,592	9,428

[a] CEC 2006.

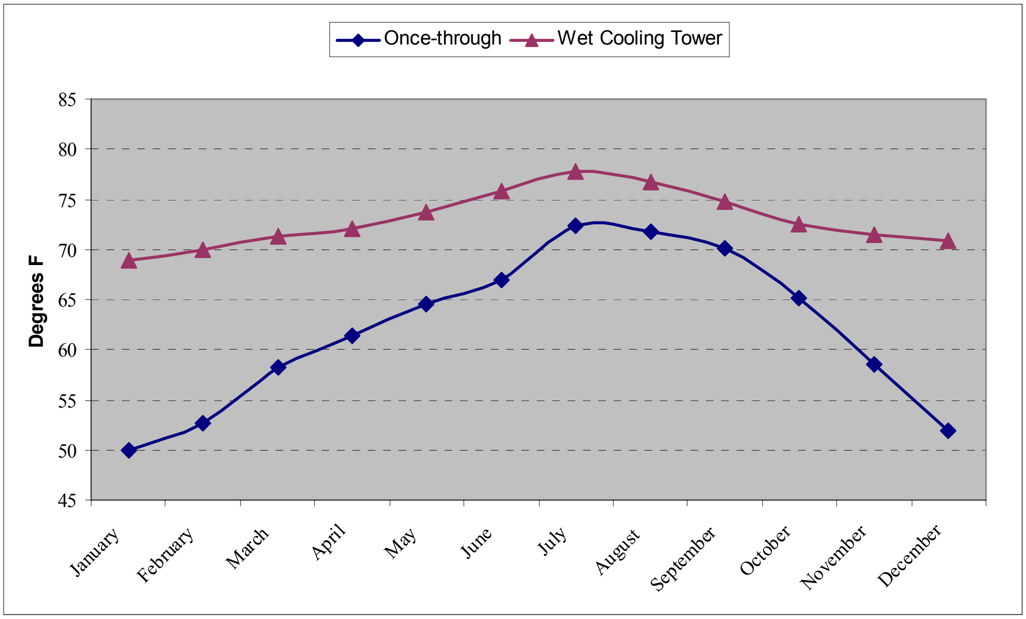

Figure B–7. Condenser Inlet Temperatures

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 (Table B–6). In general, backpressures associated with the wet cooling tower were elevated by 0.35 to 0.85 inches HgA compared with the current once-through system (Figure B–8 and Figure B–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. 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 to develop estimated correction curves (Figure B–9 and Figure B–11).[5]

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 B–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 4.6.2). Month-by-month calculations are presented in Appendix A.

Table B–13. Summary of Estimated Heat Rate Increases

	Unit 6	Unit 7
Peak (July-August-September)	0.56%	0.56%
Annual average	0.76%	0.76%

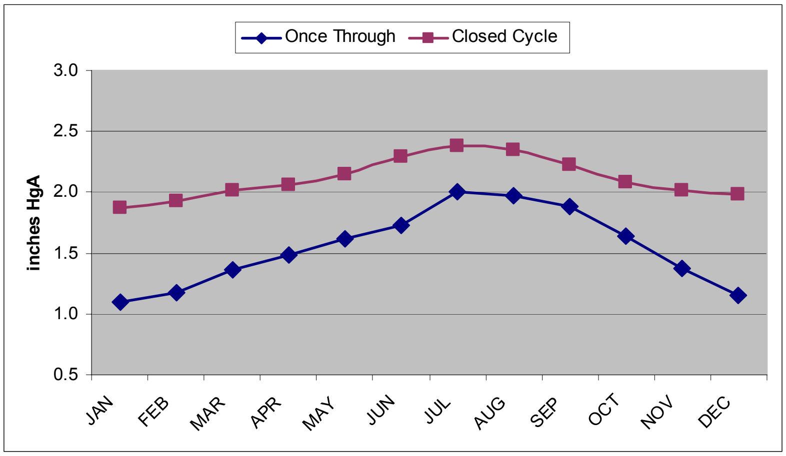

Figure B–8. Estimated Backpressures (Unit 6)

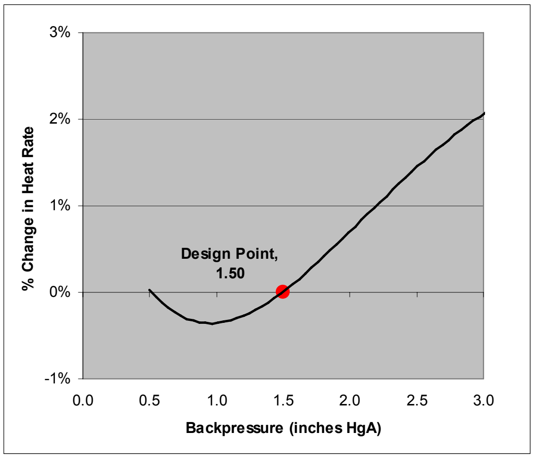

Figure B–9. Estimated Heat Rate Correction (Unit 6)

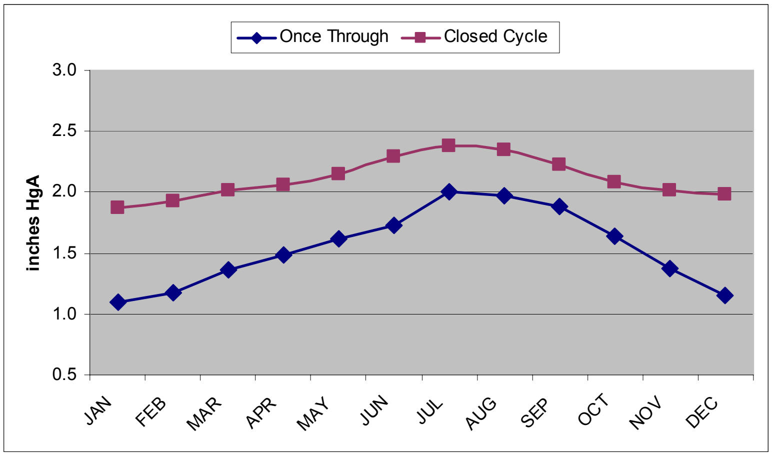

Figure B-10. Estimated Backpressures (Unit 7)

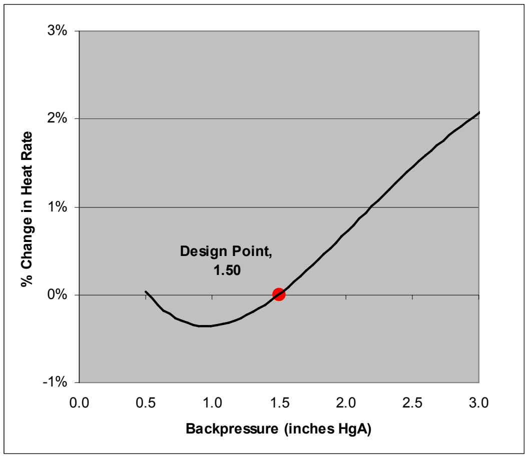

Figure B-11. Estimated Heat Rate Correction (Unit 7)

4.0 RETROFIT COST ANALYSIS

The wet cooling system retrofit estimate for CCPP 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

The wet cooling system retrofit estimate for CCPP is based on incorporating a conventional wet cooling tower as a replacement for the existing once-through system. Table B–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 B–14. Wet Cooling Tower Design-and-Build Cost Estimate

	Unit 6	**Unit 7**	**CCPP total**
Number of cells	12	12	**24**
Cost/cell ($)	531,667	531,667	**531,667**
Total CCPP D&B cost ($)	**6,380,000**	**6,380,000**	**12,760,000**

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 CCPP, 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 B–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 9,000 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 B–15. Summary of Other Direct Costs

	Equipment ($)	Bulk material ($)	Labor ($)	CCPP total ($)
Civil/structural/piping	4,900,000	17,000,000	12,900,000	**34,800,000**
Mechanical	6,000,000	0	600,000	**6,600,000**
Electrical	1,300,000	2,700,000	2,300,000	**6,300,000**
Demolition	0	0	0	**0**
Total CCPP other direct costs	**12,200,000**	**19,700,000**	**15,800,000**	**47,700,000**

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 CCPP, 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. CCPP is situated near sea level adjacent to the San Joaquin River. 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 B–16.

Table B–16. Summary of Initial Capital Costs

	Cost ($)
Cooling towers	12,800,000
Civil/structural/piping	34,800,000
Mechanical	6,600,000
Electrical	6,300,000
Demolition	0
Indirect cost	15,100,000
Condenser modification	3,000,000
Contingency	19,600,000
Total CCPP capital cost	**98,200,000**

4.4 SHUTDOWN

A portion of the work relating to installing wet cooling towers can be completed without significant disruption to the operations of CCPP. Units will be offline depending on the length of time it takes to integrate the new cooling system and conduct acceptance testing. For CCPP, 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 CCPP does not include any loss of revenue associated with shutdown at CCPP.

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

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

	Year 1 cost ($)	Year 12 cost ($)
Management/labor	300,000	435,000
Service/parts	480,000	696,000
Fouling	420,000	609,000
Total CCPP O&M cost	**1,200,000**	**1,740,000**

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 CCPP 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 CCPP 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.[3]

The energy penalty for CCPP 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.

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[3] 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.

4.6.1 INCREASED PARASITIC USE (FANS AND PUMPS)

Depending on ambient conditions or the operating load at a given time, CCPP 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 B–18.

Table B–18. Cooling Tower Fan Parasitic Use

	Tower 1	**Tower 2**	**CCPP total**
Units served	Unit 6	Unit 7	--
Generating capacity (MW)	340	340	**680**
Number of fans (one per cell)	12	12	**24**
Motor power per fan (hp)	211	211	--
Total motor power (hp)	2,526	2,526	**5,052**
MW total	1.88	1.88	**3.76**
Fan parasitic use (% of capacity)	**0.55%**	**0.55%**	**0.55%**

Additional circulating water pump capacity for the wet cooling towers will also increase the parasitic electricity usage at CCPP. Makeup water will continue to be withdrawn from the San Joaquin River 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 B–19.

Table B–19. Cooling Tower Pump Parasitic Use

	Tower 1	Tower 2	CCPP Total
Units served	Unit 6	Unit 7	--
Generating capacity (MW)	340	340	**680**
Existing pump configuration (hp)	1,040	1,040	**2,080**
New pump configuration (hp)	4,669	4,669	**9,338**
Difference (hp)	3,629	3,629	**7,258**
Difference (MW)	2.7	2.7	**5.4**
Net pump parasitic use (% of capacity)	**0.80%**	**0.80%**	**0.80%**

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

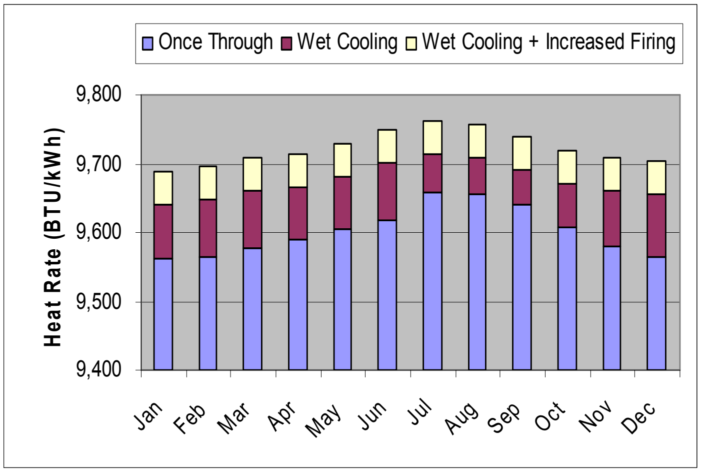

Figure B–8. Estimated Heat Rate Change (Unit 6)

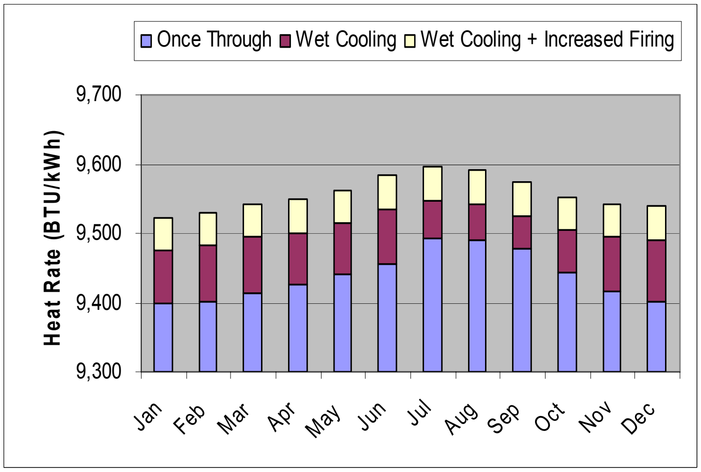

Figure B–9. Estimated Heat Rate Change (Unit 7)

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 ($/MWh) for the once-through system and the wet cooling system adjusted for a higher turbine firing rate. The cost of generation for CCPP is based on the relative heat rates developed in Section 4.6.2 and the average monthly wholesale natural gas cost ($/MMBTU) (ICE 2006a). The difference between these two values represents the monthly increased cost, per MWh, that results from converting to wet cooling towers. This value is then applied to the net MWh generated for each month and summed to calculate the annual cost.

Based on 2006 output data, the Year 1 energy penalty for CCPP will be approximately $90,000. In contrast, the energy penalty's value calculated with the production loss option would be approximately $210,000. Together, these values represent the range of potential energy penalty costs for CCPP. Table B–20 and Table B–21 summarize the energy penalty estimates for each unit using the increased fuel option.

Table B–20. 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	9,563	57.38	9,688	58.13	0.75	0	**0**
February	5.50	9,566	52.61	9,696	53.33	0.72	0	**0**
March	4.75	9,578	45.50	9,708	46.11	0.62	0	**0**
April	4.75	9,590	45.55	9,715	46.15	0.59	0	**0**
May	4.75	9,605	45.62	9,729	46.21	0.59	0	**0**
June	5.00	9,619	48.09	9,750	48.75	0.65	3,940	**2,575**
July	6.50	9,658	62.78	9,763	63.46	0.68	21,958	**14,868**
August	6.50	9,655	62.75	9,758	63.42	0.67	630	**422**
September	4.75	9,641	45.80	9,740	46.26	0.47	0	**0**
October	5.00	9,608	48.04	9,718	48.59	0.55	0	**0**
November	6.00	9,579	57.47	9,709	58.25	0.78	0	**0**
December	6.50	9,565	62.17	9,704	63.08	0.91	0	**0**
							Unit 6 total	**17,865**

Table B–21. Unit 7 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	9,399	56.40	9,522	57.13	0.74	0	**0**
February	5.50	9,402	51.71	9,531	52.42	0.71	0	**0**
March	4.75	9,414	44.72	9,542	45.33	0.61	0	**0**
April	4.75	9,426	44.77	9,549	45.36	0.58	0	**0**
May	4.75	9,441	44.84	9,563	45.42	0.58	7,322	**4,256**
June	5.00	9,455	47.27	9,583	47.92	0.64	15,364	**9,876**
July	6.50	9,493	61.71	9,596	62.37	0.67	52,729	**35,111**
August	6.50	9,489	61.68	9,591	62.34	0.66	20,061	**13,223**
September	4.75	9,477	45.01	9,573	45.47	0.46	19,707	**9,044**
October	5.00	9,444	47.22	9,552	47.76	0.54	0	**0**
November	6.00	9,415	56.49	9,543	57.26	0.77	0	**0**
December	6.50	9,401	61.11	9,538	62.00	0.89	0	**0**
							Unit 7 total	**71,510**

4.7 NET PRESENT COST

The net present value (NPC) of a wet cooling system retrofit at CCPP 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 CCPP 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 B–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 CCPP 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 B–17.)
- *Annual Energy Penalty.* Sufficient information is not available to this study to forecast future generating output at CCPP. In lieu of annual estimates, this study uses the net MWh output from 2006 as the calculation basis for years 1–20. 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 B–20 and Table B–21.)

Using these values, the NPC_{20} for CCPP is $104 million. Appendix C contains detailed annual calculations used to develop this cost.

4.8 ANNUAL COST

The annual cost incurred by CCPP 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 B–22.

Table B–22. Annual Cost

Discount rate (%)	Capital cost ($)	Annual O&M ($)	Annual energy penalty ($)	Annual cost ($)
7.00%	9,300,000	500,000	200,000	**10,000,000**

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 CCPP's annual revenues are limited. 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 CCPP 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 CCPP is summarized in Table B–23. A comparison of annual costs to annual gross revenue is summarized in Table B–24.

Table B–23. Estimated Gross Revenue

	Wholesale price ($/MWh)	Net generation (MWh)		Estimated gross revenue ($)		
		Unit 6	Unit 7	Unit 6	Unit 7	CCPP total
January	66	0	0	0	0	**0**
February	61	0	0	0	0	**0**
March	51	0	0	0	0	**0**
April	51	0	0	0	0	**0**
May	51	0	7,322	0	373,422	**373,422**
June	55	3,940	15,364	216,700	845,020	**1,061,720**
July	91	21,958	52,729	1,998,178	4,798,339	**6,796,517**
August	73	630	20,061	45,990	1,464,453	**1,510,443**
September	53	0	19,707	0	1,044,471	**1,044,471**
October	57	0	0	0	0	**0**
November	66	0	0	0	0	**0**
December	67	0	0	0	0	**0**
	CCPP total	**26,528**	**115,183**	**2,260,868**	**8,525,705**	**10,786,573**

Table B–24. Cost-to-Gross 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
10,800,000	9,300,000	86	500,000	4.6	200,000	1.9	**10,000,000**	**93**

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 CCPP.

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 CCPP. 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. CCPP currently withdraws its cooling water through a shoreline CWIS on the southern bank of the San Joaquin River. 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 the San Joaquin River before a conclusive determination can be made.

5.2 BARRIER NETS

If impingement is a significant concern at CCPP, a barrier net could conceivably be placed in the San Joaquin River 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 river'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 the San Joaquin River allow. Based on estimates developed for the Phase II rule, barrier net initial capital costs for CCPP 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 CCPP was proposed as part of a Habitat Conservation Program contained in the existing order. 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 CCPP. 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

Variable speed drives (VSDs) are currently installed at CCPP, 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 CCPP.

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

Data obtained from U.S. Geological Survey (USGS) stream flow gages for the San Joaquin River in the vicinity of CCPP show average ambient currents exceed 0.5 fps for more than 92 percent of the time (Figure B–14) (USGS 2007). Prior to screen installation, more accurate current measurements in the precise screen location would have to be taken.

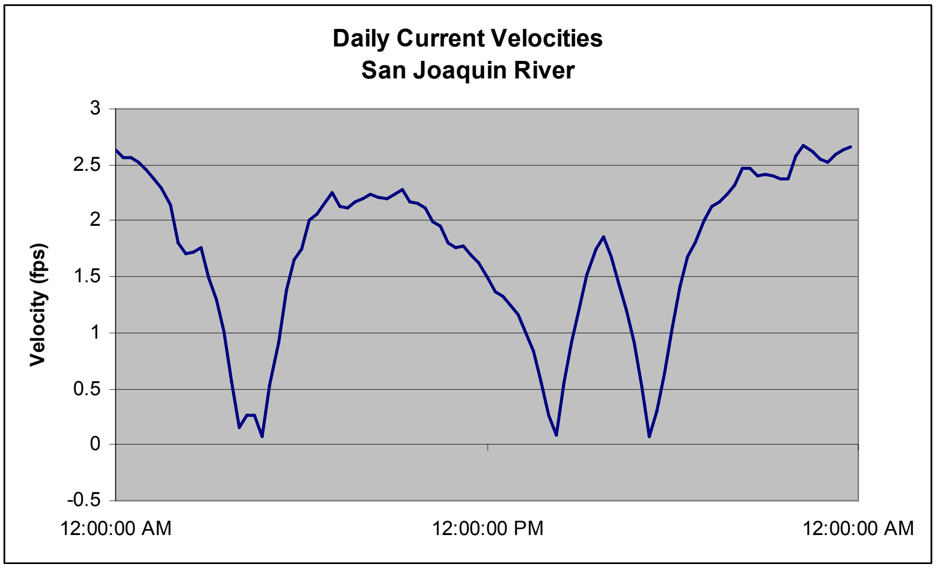

Figure B–10. Diurnal San Joaquin River Currents (Jersey Point)

Based on the limited data available, a conceptual plan and cost for fine-mesh wedgewire screens was developed for an installation at CCPP. Fine-mesh wedgewire screens for CCPP would be installed offshore in Suisun Bay approximately 950 feet north of the Unit 6 and Unit 7 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 CCPP is shown in Figure B–11. Approximate costs are summarized in Table B–25.

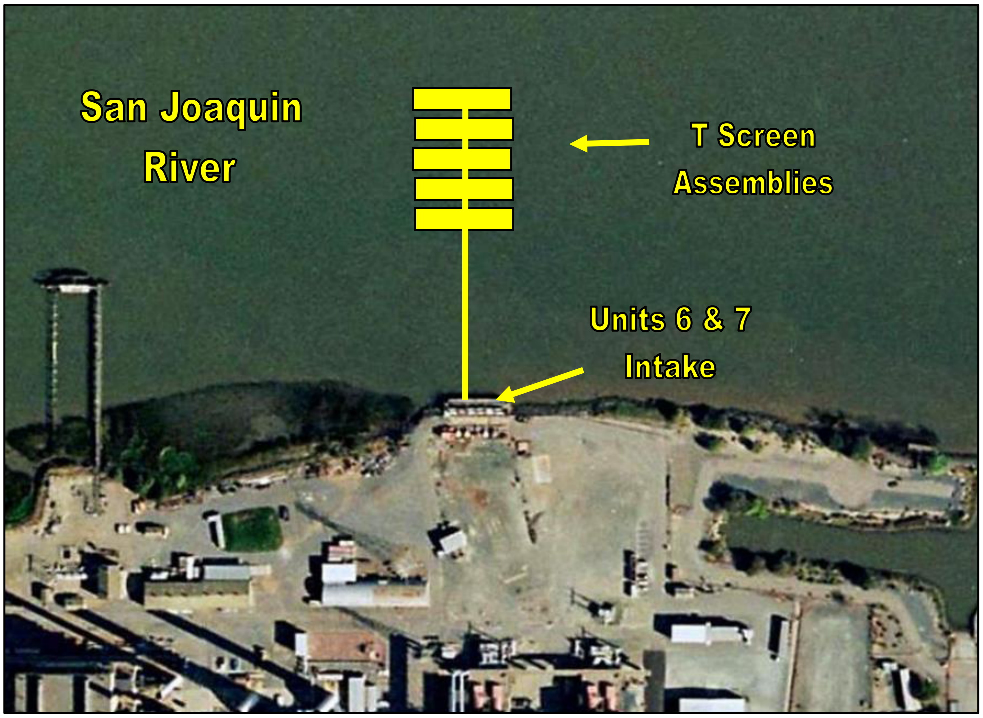

Figure B–11. Approximate Cylindrical Wedgewire Screen Location

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

	Installed cost ($)
5 T-screens (84" x 300") [a]	1,940,000
Piping (120") [b]	4,600,000
Indirect / contingency	925,000
CCPP total	**7,465,000**

[a] T-screen cost includes airburst 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 1			Unit 2		
		Once through	**Closed cycle**	**Net increase**	**Once through**	**Closed cycle**	**Net increase**
JAN	Backpressure (in. HgA)	1.09	1.87	**0.78**	1.09	1.87	**0.78**
	Heat rate Δ (%)	*-0.30*	*0.50*	***0.80***	*-0.30*	*0.50*	***0.80***
FEB	Backpressure (in. HgA)	1.17	1.93	**0.76**	1.17	1.93	**0.76**
	Heat rate Δ (%)	*-0.28*	*0.59*	***0.86***	*-0.28*	*0.59*	***0.86***
MAR	Backpressure (in. HgA)	1.36	2.01	**0.65**	1.36	2.01	**0.65**
	Heat rate Δ (%)	*-0.15*	*0.71*	***0.85***	*-0.15*	*0.71*	***0.85***
APR	Backpressure (in. HgA)	1.49	2.05	**0.57**	1.49	2.05	**0.57**
	Heat rate Δ (%)	*-0.02*	*0.78*	***0.80***	*-0.02*	*0.78*	***0.80***
MAY	Backpressure (in. HgA)	1.61	2.15	**0.54**	1.61	2.15	**0.54**
	Heat rate Δ (%)	*0.13*	*0.93*	***0.79***	*0.13*	*0.93*	***0.79***
JUN	Backpressure (in. HgA)	1.72	2.29	**0.57**	1.72	2.29	**0.57**
	Heat rate Δ (%)	*0.28*	*1.14*	***0.86***	*0.28*	*1.14*	***0.86***
JUL	Backpressure (in. HgA)	2.00	2.38	**0.38**	2.00	2.38	**0.38**
	Heat rate Δ (%)	*0.69*	*1.27*	***0.58***	*0.69*	*1.27*	***0.58***
AUG	Backpressure (in. HgA)	1.97	2.34	**0.37**	1.97	2.34	**0.37**
	Heat rate Δ (%)	*0.65*	*1.22*	***0.57***	*0.65*	*1.22*	***0.57***
SEP	Backpressure (in. HgA)	1.89	2.22	**0.34**	1.89	2.22	**0.34**
	Heat rate Δ (%)	*0.52*	*1.03*	***0.52***	*0.52*	*1.04*	***0.52***
OCT	Backpressure (in. HgA)	1.64	2.08	**0.44**	1.64	2.08	**0.44**
	Heat rate Δ (%)	*0.17*	*0.81*	***0.64***	*0.17*	*0.81*	***0.64***
NOV	Backpressure (in. HgA)	1.37	2.02	**0.64**	1.37	2.02	**0.64**
	Heat rate Δ (%)	*-0.14*	*0.72*	***0.85***	*-0.14*	*0.72*	***0.85***
DEC	Backpressure (in. HgA)	1.15	1.98	**0.84**	1.15	1.98	**0.84**
	Heat rate Δ (%)	*-0.29*	*0.67*	***0.95***	*-0.29*	*0.67*	***0.95***

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 extra works related to installation of pipes under the road (building a temporary deviation road, traffic control & signalization, removing these temporary installations and putting the site back like it was before.	lot	1	--	--	250,000	250,000	2,500.00	100	250,000	**500,000**
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 600 ft) and cable racks	t	60	--	--	2,500	150,000	17.00	105	107,100	**257,100**
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	33,868	--	--	--	--	0.04	200	270,944	**270,944**
Bedding for PCCP pipe	m3	5,236	--	--	40	209,440	0.04	200	41,888	**251,328**
Bend for PCCP pipe 24" diam (allocation)	ea	12	--	--	3,000	36,000	20.00	95	22,800	**58,800**
Bend for PCCP pipe 72" diam (allocation)	ea	12	--	--	18,000	216,000	40.00	95	45,600	**261,600**
Bend for PCCP pipe 84" diam (allocation)	ea	18	--	--	20,000	360,000	50.00	95	85,500	**445,500**
Building architectural (siding, roofing, doors, painting…etc)	ea	2	--	--	250,000	500,000	3,000.00	82	492,000	**992,000**
Butterfly valves 30" c/w allocation for actuator & air lines	ea	32	30,800	985,600	--	--	50.00	95	152,000	**1,137,600**
Butterfly valves 72" c/w allocation for actuator & air lines	ea	12	96,600	1,159,200	--	--	75.00	95	85,500	**1,244,700**
Butterfly valves 84" c/w allocation for actuator & air lines	ea	16	124,600	1,993,600	--	--	75.00	95	114,000	**2,107,600**
Check valves 30"	ea	4	44,000	176,000	--	--	16.00	95	6,080	**182,080**
Check valves 72"	ea	4	138,000	552,000	--	--	32.00	95	12,160	**564,160**
Concrete basin walls (all in)	m3	372	--	--	250	93,000	8.00	82	244,032	**337,032**
Concrete elevated slabs (all in)	m3	646	--	--	275	177,650	10.00	82	529,720	**707,370**
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	2,931	--	--	220	644,820	4.00	82	961,368	**1,606,188**
Ductile iron cement pipe 12" diam. for fire water line	ft	3,500	--	--	100	350,000	0.60	95	199,500	**549,500**
Excavation and backfill for fire line, blowdown & make-up (using excavated material for backfill except for bedding)	m3	13,594	--	--	--	--	0.08	200	217,504	**217,504**
Excavation for PCCP pipe	m3	53,501	--	--	--	--	0.04	200	428,008	**428,008**
Fencing around transformers	m	50	--	--	33	1,650	1.00	82	4,100	**5,750**
Flange for PCCP joints 24"	ea	8	--	--	1,725	13,800	14.00	95	10,640	**24,440**
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	140	--	--	275	38,500	8.00	82	91,840	**130,340**
FRP flange 30"	ea	96	--	--	1,679	161,198	50.00	95	456,000	**617,198**
FRP flange 72"	ea	24	--	--	20,888	501,304	200.00	95	456,000	**957,304**
FRP flange 84"	ea	20	--	--	33,381	667,621	300.00	95	570,000	**1,237,621**
FRP pipe 72" diam.	ft	200	--	--	851	170,280	1.20	95	22,800	**193,080**
FRP pipe 84" diam.	ft	1,400	--	--	946	1,324,400	1.50	95	199,500	**1,523,900**
Harness clamp 24" c/w external testable joint	ea	20	--	--	1,715	34,300	14.00	95	26,600	**60,900**
Harness clamp 30" & 36"c/w internal testable joint	ea	125	--	--	2,000	250,000	16.00	95	190,000	**440,000**
Harness clamp 72" c/w internal testable joint	ea	80	--	--	2,440	195,200	18.00	95	136,800	**332,000**
Harness clamp 84" c/w internal testable joint	ea	450	--	--	2,845	1,280,250	20.00	95	855,000	**2,135,250**
Joint for FRP pipe 72" diam.	ea	12	--	--	3,122	37,462	200.00	95	228,000	**265,462**
Joint for FRP pipe 84" diam.	ea	40	--	--	5,014	200,552	300.00	95	1,140,000	**1,340,552**
PCCP pipe 24" dia. For blowdown	ft	400	--	--	98	39,200	0.50	95	19,000	**58,200**
PCCP pipe 30" dia. for make-up	ft	2,500	--	--	125	312,500	0.70	95	166,250	**478,750**
PCCP pipe 72" diam.	ft	1,600	--	--	507	811,200	1.30	95	197,600	**1,008,800**
PCCP pipe 84" diam.	ft	9,000	--	--	562	5,058,000	1.50	95	1,282,500	**6,340,500**
Riser (FRP pipe 30" diam X55 ft)	ea	24	--	--	15,350	368,395	150.00	95	342,000	**710,395**
Structural steel for building	t	315	--	--	2,500	787,500	20.00	105	661,500	**1,449,000**
CIVIL / STRUCTURAL / PIPING TOTAL	**--**	**--**	**--**	**4,866,400**	**--**	**16,939,702**	**--**	**--**	**12,894,414**	**34,700,516**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
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**
480 volt cabling feeding MCC's	m	750	--	--	70	52,500	0.40	110	33,000	**85,500**
480V Switchgear - 1 breaker 3000A	ea	4	30,000	120,000	--	--	80.00	110	35,200	**155,200**
Allocation for automation and control	lot	1	--	--	750,000	750,000	7,500.00	110	825,000	**1,575,000**
Allocation for cable trays and duct banks	m	2,500	--	--	75	187,500	1.00	110	275,000	**462,500**
Allocation for lighting and lightning protection	lot	1	--	--	100,000	100,000	1,000.00	110	110,000	**210,000**
Dry Transformer 2MVA xxkV-480V	ea	4	100,000	400,000	--	--	100.00	110	44,000	**444,000**
Lighting & electrical services for pump house building	ea	2	--	--	45,000	90,000	500.00	110	110,000	**200,000**
Local feeder for 250 HP motor 460 V (up to MCC)	ea	24	--	--	18,000	432,000	150.00	110	396,000	**828,000**
Local feeder for 2500 HP motor 4160 V (up to MCC)	ea	4	--	--	42,000	168,000	170.00	110	74,800	**242,800**
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	4,500	--	--	175	787,500	0.50	110	247,500	**1,035,000**
ELECTRICAL TOTAL	--	--	--	**1,330,000**	--	**2,680,000**	--	--	**2,292,400**	**6,302,400**
MECHANICAL	--	--	--	--	--	--	--	--	--	--
Allocation for ventilation of buildings	ea	2	100,000	200,000	--	--	1,000.00	95	190,000	**390,000**
Cooling tower for unit 6	lot	1	6,380,000	6,380,000	--	--	--	--	--	**6,380,000**
Cooling tower for unit 7	lot	1	6,380,000	6,380,000	--	--	--	--	--	**6,380,000**
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 2500 HP	lot	4	1,200,000	4,800,000	--	--	580.00	95	220,400	**5,020,400**
MECHANICAL TOTAL	--	--	--	**18,760,000**	--	**0**	--	--	**600,400**	**19,360,400**

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	98,100,000	--	--	--	98,100,000	1	**98,100,000**
1	--	360,000	17,866	71,509	449,375	0.9346	**419,986**
2	--	367,200	18,907	75,678	461,785	0.8734	**403,323**
3	--	374,544	20,010	80,090	474,644	0.8163	**387,452**
4	--	382,035	21,176	84,759	487,970	0.7629	**372,272**
5	--	389,676	22,411	89,701	501,787	0.713	**357,774**
6	--	397,469	23,717	94,930	516,117	0.6663	**343,888**
7	--	405,418	25,100	100,465	530,983	0.6227	**330,643**
8	--	413,527	26,563	106,322	546,412	0.582	**318,012**
9	--	421,797	28,112	112,520	562,430	0.5439	**305,905**
10	--	430,233	29,751	119,080	579,064	0.5083	**294,338**
11	--	438,838	31,485	126,023	596,346	0.4751	**283,324**
12	--	532,440	33,321	133,370	699,131	0.444	**310,414**
13	--	543,089	35,263	141,145	719,498	0.415	**298,591**
14	--	553,951	37,319	149,374	740,644	0.3878	**287,222**
15	--	565,030	39,495	158,083	762,607	0.3624	**276,369**
16	--	576,330	41,798	167,299	785,427	0.3387	**266,024**
17	--	587,857	44,234	177,052	809,143	0.3166	**256,175**
18	--	599,614	46,813	187,374	833,802	0.2959	**246,722**
19	--	611,606	49,542	198,298	859,447	0.2765	**237,637**
20	--	623,838	52,431	209,859	886,128	0.2584	**228,976**
Total							**104,325,047**