Appendix 8.3-1

Seasonal/Annual Cooling Tower Impact Program (SACTIP) Analysis

Cooling Tower Plume Modeling Analysis for the Kings River Conservation District Community Power Plant

Prepared By

Atmospheric Dynamics, Inc.
Santa Barbara, CA. 93105

April 2007

Cooling Tower Plume Modeling Analysis
Kings River Conservation District Community Power Plant

Introduction

This report was prepared to summarize an analysis of potential cooling tower visible plume formation at the proposed Kings River Conservation District Community Power Plant (KRCD CPP or Project). This study supports various environmental documents that have been prepared for the proposed project.

KRCD is proposing to use an eight (8) cell wet mechanical-draft cooling tower to reject heat to the atmosphere. The air leaving the cooling towers is usually saturated with moisture and warmer than the ambient air, causing a wet exhaust plume to be created. The saturated exhaust plume may be visible or not depending on the specific meteorological conditions. This plume will also vary in size depending on meteorological conditions and operational factors. Visible plume formation from the two natural gas fired turbines may also form based upon the potential for the exhaust gas to contain water vapor. However, visible plume formation from the turbines was not addressed in the modeling described below as such plume formation is expected to be negligible.

Potential issues associated with cooling tower plumes include the presence of visual plumes and the occurrence of ground level fogging and/or icing episodes that involve the ground contact of visible plumes. In order to evaluate the effects on the local and regional environments, a modeling analysis was conducted to simulate the cooling tower plumes from the proposed project using five (5) years of meteorological data.

Modeling Techniques

The Seasonal/Annual Cooling Tower Impact Program (SACTIP, Version 11-01-90) was used to assess potential impacts from the cooling tower. SACTIP was developed by Argonne National Laboratory[1] for the Electric Power Research Institute (EPRI) to address the following potential adverse impacts of cooling towers:

- plume visibility
- deposition of cooling tower drift
- ground-level fogging and icing
- shadowing by the plume & reduction of solar energy

SACTIP contains algorithms for both natural and mechanical draft cooling towers arranged singly or in clusters. Plume merging and associated enhanced plume rise are treated by the routines contained in the model. While the SACTIP model does not have any official regulatory

[1]Argonne National Laboratory, 1984. Users Manual: Cooling-Tower -Plume Prediction Code. Prepared for Electric Power Research Institute, 3412 Hillview Avenue, Palo Alto, CA 9404, EPRI CS-3403-CCM, April, 1984.

endorsement, this model has been applied for a large number of projects where cooling tower impact assessments were required. The characteristics of the tower and the preparation of the meteorological data set are discussed below.

The characteristics of the proposed cooling tower are listed in Table 1. These input parameters were obtained from the project's engineering consultant based on preliminary design data for the facility. Three ambient conditions were modeled to fully assess the potential range of visible cooling tower impacts: 1) a high temperature condition of 103 degrees F, 2) cold temperature ambient condition of 26 degrees F, and 3) an average temperature condition of 63 degrees F. Attachment A contains other data used in the cooling tower plume analysis.

A five (5) year meteorological data set for the years 1986 through 1990 was constructed using hourly surface observations from the Fresno International Airport meteorological station, located near the proposed project location. The 1986-1990 data set was used over other more recent data sets, as this particular time period and type of data is the most complete with regards to missing data. As discussed below, night-time hours and day-time hours where weather or other visibility obscuring phenomenon would impair visibility were removed from the meteorological data set. Figure 1 displays a wind rose constructed from all hours of the resulting four year data. The average wind speed is 3.12 meters per second (m/s) and high winds greater than 11 m/s are infrequent (less than 2 percent for the five year data set). Wind speeds either missing or less than the starting threshold of the anemometer at the Fresno Air Terminal occur for approximately 15% of the five year data set. A lack of precision for light winds is not expected to unduly influence the outcome of the modeling for ground-level fogging because such fogging effects require plume touchdown and would typically be associated with higher wind conditions.

Given the length of time of the data used in the SACTIP analysis, the data set is considered representative of the climatic conditions of the area where plume formation can occur. Even with this representative data set, short-term variability in conditions can affect the prediction of cooling tower plume impacts. Therefore, the results of the analysis are considered an indicator of likely occurrence and not an absolute predictor of events.

Modeling Results

Cooling Tower

SACTIP was applied to simulate plumes from the proposed cooling towers using the five year meteorological data set and tower design characteristics described previously. Default options were assumed for the input variables controlling the model operation. The five year data set was input into SACTIP to produce a four year average frequency distribution for condensed plume length, condensed plume height, plume shadowing, and ground-level fogging. Although the model provides information on plume shadowing and drift deposition, the focus of our analysis and the discussion that follows is based on visible plume dimensions and ground based fogging.

Table 1. Cooling Tower Input Parameters

Parameter	Value
Type	linear mechanical draft 1 tower, 8 cells
Heat Dissipation Rate (Megawatts)	350
Circulation Rate (gallons per minute)	15,637 (per cell)*
Total Tower Air Flow (kilograms per second)	6803
Max Drift Rate (%)	0.0005
Salt Concentration (milligrams per liter)	1800
Orientation	one bank of 8 in-line cells aligned southeast to northwest
Height (meters)	24.4
Equivalent Total Cell Diameter (meters)	22.4
Exit Velocity & Temperature	variable, calculated by the model assuming saturation conditions

* Total circulated water flow of 125,096 gallons per minute

Conditions favoring a long condensed plume occur more frequently in the fall and winter seasons as atmospheric conditions, such as air temperature and relative humidity, are more favorable during these periods for plume formation. Also, plume formation tends to occur more frequently during night-time hours and during adverse weather conditions. Since the proposed project has committed to a lighting plan that minimizes illumination, these cooling tower plumes would not be visible at night unless illuminated by on-site sources. The SACTIP meteorological data set was modified by removing the nocturnal hours, which accounted for 50% of all the hours in the five year data set. In addition, daytime observations with fog, precipitation, visibility less than three miles, or ceiling heights less than 500 feet were excluded from the meteorological data set because under these conditions, a visible plume from the cooling tower would be obscured by these local weather phenomena. For the Fresno meteorological data set, these adverse weather conditions account for 14.1 % of the total valid (daylight hours) observations. Table 2 summarizes these statistics.

Table 2	Total hours	Day hours	Night Hours Removed from Analysis	Limited Visibility Hours Removed from Analysis	Total Hours Modeled With SACTIP
Year					
1986	8760	4397	4363	675	3722
1987	8760	4397	4363	454	3943
1988	8784	4406	4378	608	3798
1989	8760	4397	4363	783	3614
1990	8760	4397	4363	581	3816

The five (5) year meteorological data set was therefore modified by removing both night-time hours and hours with weather obscuring phenomena. In total, these conditions accounted for 57% of all the hours (day, night, and obscuring weather) in the data set. The SACTIP was then applied to the remaining data set to assess the cooling tower plumes under daytime conditions when a condensed plume would most likely also be visible. Of particular interest was the analysis of visible plume formation during the fall and winter seasons when such formation is most likely. The occurrence of low temperatures coupled with high relative humidity occurs with a greater frequency during these seasons. Plume formation is favored during these types of low temperature/high humidity conditions since the ability of the atmosphere to absorb water vapor is greatly reduced because the air mass is at or near saturation.

Cooling Tower Plume Formation

The SACTIP results for all seasons are summarized in Table 3 below. The annual values indicate that the majority of visible plume lengths will be less than 50 meters (164 feet).

Other modeling results (not shown in the table) indicate that plume formation will occur 20% of the time during valid visible hours (daylight hours with non-obscuring weather) only at locations within the facility boundary during all seasons. Larger downwind visible plume lengths (annually) are possible, but the downwind visible plume length will be less than 250 meters (820 feet) for 91 percent of all the hours where a visible plume will form. This results in a plume length exceeding 650 feet for only 9 percent of the time during the season. When translated into total hours for the season, on average, 340 hours per year will have plume lengths up to but not exceeding 250 meters (820 feet). SACTIP also predicts that the visible plume height averages 30 meters and has a median radius of 20 meters (66 feet) overall the seasons as shown in the table. For the winter season, the average plume length (when visible) will be larger, at 75 meters (250 feet). For winter, SACTIP predicts that the visible plume height averages 40 meters with a median radius of 30 meters (100 feet), which is slightly larger than the annual values.

TABLE 3 Seasonal Plume Characteristics from SACTIP

	Annual	*Winter**	*Spring**	*Summer**	*Fall**
Plume Characteristics (m)					
Median Length	50	75	50	50	50
Median Height	30	40	30	30	30
Median Radius	20	30	20	20	20

- Winter Months = December, January, February
- Spring = March, April, May
- Summer = June, July, August
- Fall – September, October, November

Ground level fogging

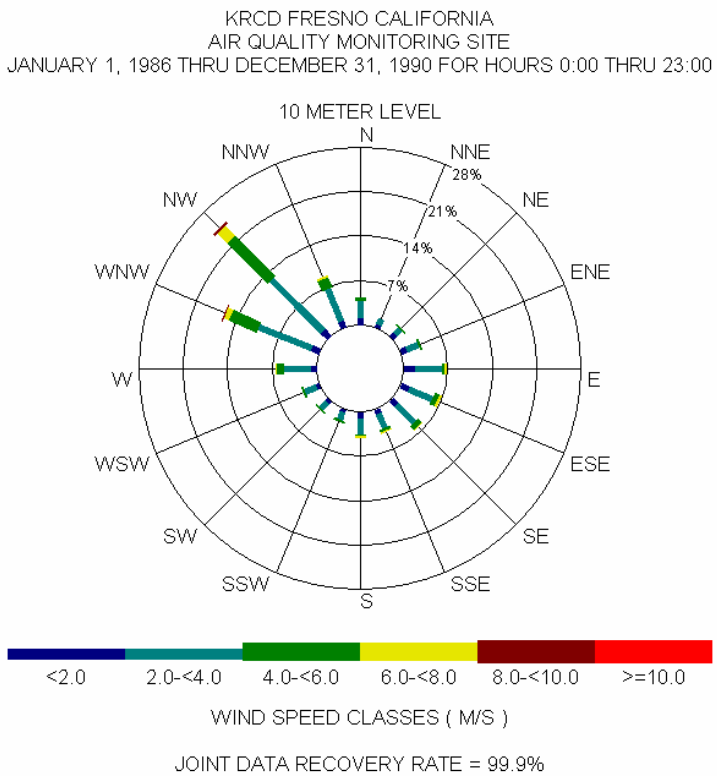
A primary focus of this study is to assess the potential for ground-level fogging on nearby areas. The potential for fogging was assessed with SACTIP. Potential fogging conditions can occur when atmospheric conditions allow the cooling tower plume to generate a cloud that contacts the ground. This can occur under periods of high humidity and favorable temperatures and stabilities with the fog being nucleated or generated by the cooling tower plume. Should fog be generated across a highway or other thoroughfare, it may become a potential hazard and mitigation measures such as signs and traffic assistance may be needed. In order for fogging to affect roadway operations, the cooling tower plume must touchdown on the road surface and be condensed. This requires high winds (low plume rise), the right wind direction, low dew-point depression, and low temperatures.

SACTIP was run with all hours of the five year data base, including nighttime and low-visibility hours. The results of the modeling analysis indicate that there were 13 hours of predicted fogging from the cooling tower at distances up to 500 meters from the facility. Normalizing the fogging output to an annual basis produces approximately three hours per year where the cooling tower could create a ground based plume or fog. There are no major roadways or schools within 500 meters of the plant location, so the generation of ground based plumes is not expected to impact traffic or roadway operations.

Summary

A cooling tower modeling analysis was conducted using SACTIP and five years of Fresno Air Terminal meteorological data. Model simulations indicate that visible plumes will occur, but will be moderate in size (height and length). The probability of formation of long visible plumes in excess of 250 meters is less than ten percent. Ground fogging conditions are only expected to occur for up to three hours per year and when they are present, they are not expected to interfere with roadway operations.

Figure 1
Annual Wind Rose (1986-1990)
Fresno, CA Airport



Attachment A
Data Used in Cooling Tower Plume Modeling Analysis

HRSG Exhaust Design Parameters for Plume Abatement Modeling

	Conditions			
Heat Rate Case	Case 2	Case 3	Case 4	Case 5
Plant Configuration	2x1	2x1	2x1	2x1
CTG Load Point	Base Load	Base Load	Base Load	Base Load
Ambient Temperature, deg F	103	85	63	26
Relative Humidity	20.1	25	40	60
Ambient Pressure, psia	14.52	14.52	14.52	14.52
Fogger Status	ON	ON	ON	OFF
Steam Injection Status	ON	OFF	OFF	OFF
	GE Option			
Exhaust Mass Flow, lb/h	3,532,001	3,507,000	3,607,000	3,792,002
Moisture Content, %wt	9.43	5.65	5.30	4.75
Exhaust Temperature, deg F	187	191	190	190
Exhaust Volumetric Flow, acfm	1,018,114	994,335	1,019,102	1,068,414
Stack Diameter, ft	18.0	18.0	18.0	18.0
Exhaust Velocity, ft/s	66.7	65.1	66.7	70.0
	Siemens Option			
Exhaust Mass Flow, lb/h	3,870,106	3,865,421	3,982,275	4,182,271
Moisture Content, %wt	9.42	5.72	5.35	4.85
Exhaust Temperature, deg F	188	193	192	195
Exhaust Volumetric Flow, acfm	1,116,135	1,099,407	1,127,830	1,187,377
Stack Diameter, ft	18.0	18.0	18.0	18.0
Exhaust Velocity, ft/s	73.1	72.0	73.9	77.8

Cooling Tower Performance at Ambient Conditions

	Hot Ambient	Average Ambient	Cold Ambient
Ambient Temperature (degF)	103	63	26
Relative Humidity (%)	20	40	60
Plant Output (MW gross)	550,652	595,980	627,408
Steam Turbine Load (MW gross)	194,252	205,780	207,407
Circulating Water Flow (lbs/hr)	62,342,684	62,342,684	62,342,684
Circulating Water Flow (gpm)	124,561	124,561	124,561
CT Inlet Temperature	98	86	88
CT Outlet Temperature	79	66	67
CT Heat Load (Btu/hr x 10^6)	1,184.51	1,247	1,309
CT Heat Load (MW)	347	365	384
Number of CT Cells (full speed)	8	8	5
Number of CT Cells (half speed)	-	-	1
Number of CT Cells (off)	-	-	2
Heat Dissipation per Cell (Btu/hr x 10^6)	148	156	164
Heat Dissipation per Cell (MW)	43	46	48
Circulation Rate (gpm)	124,561	124,561	124,561
Air Flow per cell Full Speed (ACFM)	1,575,307	1,575,240	1,575,549
Air Flow per cell Half Speed (ACFM)	-	-	787,775
Air Flow per cell Full Speed (lbs/hr)	6,551,034	6,735,076	6,746,993
Air Flow per cell Half Speed (lbs/hr)	-	-	3,373,496
Salt Content(mg/l)	1,800	1,800	1,800
Orientation	NW-SE	NW-SE	NW-SE
Overall Dimensions	476'x76'	476'x76'	476'x76'
Height (ft)	80	80	80
Cell Diameter (ft)	26	26	26

Note: The Cooling Tower liquid (circulating water) to gas (evaporation) mass flow ratios for the Hot Ambient, Average Ambient and Cold Ambient conditions are 1.2, 1.2 and 1.7 respectively.