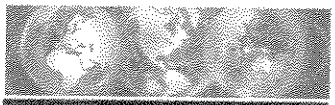

AIR QUALITY REPORT

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AN AIR DISPERSION MODEL COMPARISON STUDY

FOR WEST KINGSTON POWER PLANT

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Golder Associates

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1.0 EXECUTIVE SUMMARY

This addendum has been prepared to help support Jamaica Energy Partners' (JEP's) application for a proposed 65.5-megawatt (MW) power plant, to be located in West Kingston, Jamaica. A draft air modeling report was provided to the International Finance Corporation (IFC) in August 2009 (Golder Associates Inc., 0938-7605), which indicated areas in the vicinity of the proposed power plant where one or more of the predicted maximum sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) concentrations exceeded the Jamaican ambient air quality standards (JAAQS). The air modeling study was performed using the latest procedures recommended by the National Environment & Planning Agency (NEPA) including the use of the American Meteorological Society/U.S. Environmental Protection Agency (USEPA) Regulatory Model (AERMOD). However, the validity of maximum modeled concentrations had never been confirmed for this area from air quality measurements. To address the issue, JEP submitted an air monitoring plan to NEPA in 2009 to conduct continuous pollutant monitoring in the area.

The monitoring plan involved the establishment of two continuous monitoring stations that would continuously measure SO_2, NO_2, ozone, and meteorological data in the area for a 6-month period. Meteorological data from September 19, 2009 to March 18, 2010 were processed into AERMOD input format for the purpose of obtaining maximum hourly and daily SO_2 and NO_2 concentrations at the locations of the two monitoring stations. The predicted and measured SO_2 and NO_2 concentrations were compared at each station using the Robust High Concentration (RHC) procedure (Cox and Tikvart, 1990) and bias factors were calculated for each pollutant and averaging time. The analysis is similar to a previous modeling comparison study that was submitted to IFC for JEP's Dr. Bird Barge Plant (URS, 2006) except that the prior study used the USEPA's Industrial Source Complex (ISC3) model.

The latest analysis results indicate that AERMOD over-predicts peak measured concentrations at each monitoring site for all applicable averaging times for SO_2 and NO_2. Incorporation of the calculated bias factors into the model results in maximum predicted SO_2 and NO_2 concentrations, due to the proposed JEP power plant and existing sources, that are in full compliance with the JAAQS.

2.0 AIR QUALITY AND METEOROLOGICAL MONITORING NETWORK

The ambient monitoring network used to collect air quality and meteorological data used for this analysis consists of two stations that were established in 2009. The Customs station is located approximately 700 meters southeast of the proposed project site and continuously measures SO_2 and NO_2 as well as meteorological parameters. The Garmex station is located approximately 500 meters northwest of the proposed project site and also collects air quality data including ozone.

Air modeling results from the August 2009 draft report were used to help site both ambient monitoring stations close to predicted 1-hour concentration hot-spots. Due to prevailing wind directions from the east-southeast, the Customs station is considered to be upwind of the proposed project site, while the Garmex station is considered to be downwind of the proposed project site.

3.0 GENERAL AIR QUALITY MODELING METHODOLOGY

The modeling analysis followed the same approach that was presented in Section 3.0 of the August 2009 draft report. Any procedures that changed from the previous report are discussed in the following sections.

3.1 Model Selection and Assumptions

AERMOD, Version 07626, was used for the August 2009 draft report. Since that submittal, Version 09292 has been released by the USEPA, and that version was used in this study. The changes made to AERMOD are not expected to significantly affect the technical procedures and methods that estimate concentrations compared to those used in the previous model version.

The Ozone Limiting Method (OLM) was used to predict NO_2 concentrations. The measured hourly ozone data were reviewed and a single ozone value was incorporated into the NO_2 modeling analysis. An ozone value of 25 parts per billion (ppb) was used in the modeling analysis and represents the 91st percentile of the measured ozone concentrations over the 6-month period.

3.2 Source Data

A summary of the proposed project's emissions is presented in Table 1 and updates information from Table 3-2 of the August 2009 draft report. The use of 1.8 percent sulfur fuel had been assumed for the proposed JEP power plant in the draft. Due to changing economic conditions since August 2009, JEP now proposes using 2.0 percent sulfur fuel for this project. Another change that has occurred since the submission of the August 2009 draft report is that JEP has been granted permission by the Office of Utilities Regulation (OUR) to increase the plant output from 60 MW to 65.5 MW. This increase does not affect the air dispersion model, since the emissions information (including engine specifications, fuel consumption, emission rates, etc.) originally provided by Wartsila already assumed maximum emission rates for all six engines that are to be installed. Therefore, the stack parameter data for the proposed project remains the same.

The background source information remains the same as presented in the August 2009 draft report for the existing Petrojam facility. The background source data with the future Petrojam facility were not re-evaluated due to uncertainties regarding future development at that facility.

3.3 Meteorological Data

The 5-year meteorological record from the Norman-Manley International Airport (NMIA) for 1999 to 2003, described in Section 3.4 of the draft report, was used to update the SO_2 and NO_2 concentrations for the base case modeling analyses. For the model comparison study, the on-site meteorological variables that were measured from September 19, 2009 to March 18, 2010 included incoming solar radiation, sigma-theta, dry-bulb temperature, wind speed, and wind direction. Additional weather data collected at NMIA for the same time period were obtained to fill in for missing on-site weather parameters and to provide

supplemental cloud data for the modeling analysis. The NMIA weather parameters included relative humidity, station pressure, cloud cover, cloud ceiling height, temperature, wind direction, and wind speed.

The on-site weather data were processed into AERMOD input format using AERMET Version 06341. Land use data for input to AERMET were determined from inspection of aerial images covering the areas around each ambient air monitoring site.

3.4 Receptor Grid

The receptor grid described in Section 3.5 of the draft report was used for the updated base case modeling. For the model comparison study, receptors were located using a similar procedure to that used in the 2006 report. Receptors were placed around each station in a 400-meter by 400-meter Cartesian grid, centered on each monitoring station with 100-meter receptor spacing. The maximum concentration predicted at any receptor within each monitoring station's cluster was used in the model comparison analysis.

3.5 Non-Modeled Background Concentration

To estimate the total air quality concentrations, the modeled source impacts were added to a non-modeled background concentration estimated from existing monitoring data. The non-modeled background concentrations, the same as those used in the draft report, were based on measurements made at NEPA's Cross Roads monitor site (NEPA, 2007).

3.6 Determination of Robust High Concentrations

Similar to the 2006 modeling comparison study, the RHC method was used in this study to estimate maximum pollutant concentrations. The USEPA developed this statistical procedure in 1990 to evaluate how well an air pollutant impact model performed compared with monitored data (Cox and Tikvart, 1990).

Because of the emphasis on highest concentrations, a robust test statistic is calculated that represents a "smoothed" estimate of the high end of the range of concentrations. Because the single highest concentration value is subject to extreme variations, the robust highest concentration approach is preferable in this analysis because it filters out some of these variations. The robust estimate is based on a best fit exponential curve to the upper end of the distribution and is computed as follows:

$$RHC = X(N) + [X - X(N)] \times \ln\left[\frac{3N-1}{2}\right]$$

where: X = average of the N−1 largest values
X(N) = Nth largest value

The value of N is meant to represent the high end of the range of values and is arbitrarily set equal to 26 in the USEPA guidance documents.

Based on the procedures used in the 2006 model comparison study, the adjusted model concentrations for the 1-hour and 24-hour averaging times were based on the lowest RHC ratio computed at either monitoring station. Similarly, the adjusted model annual average concentrations were based on the average of the bias ratio of the two stations.

4.0 STUDY RESULTS AND CONCLUSIONS

A summary of the modeled and measured RHC values for 1- and 24-hour averaging times for SO_2 and for the 1-hour averaging time for NO_2 is presented for each monitoring station in Table 2. The computed bias ratios for the 1- and 24-hour averaging times for each station, as determined from the RHC values presented in Table 2, are summarized in Table 3. Similarly, the bias ratios for the annual averaging time are presented in Table 4.

The adjusted air modeling results are presented in Table 5. The total air quality impacts are based on adding the adjusted modeled concentration to a non-modeled background concentration.

The spatial distribution of the adjusted annual average SO_2 concentrations due to all sources with the proposed JEP power plant burning 2 percent sulfur fuel is presented in Figure 1. The spatial distributions of the adjusted 24- and 1-hour average SO_2 concentrations due to all sources with the proposed JEP power plant burning 2 percent sulfur fuel are presented in Figures 2 and 3, respectively. The spatial distributions of the adjusted annual and 1-hour average NO_2 concentrations due to all sources with the proposed JEP power plant's emissions of nitrogen oxides of 1,850 milligrams per normal cubic meter (mg/Nm^3) are presented in Figures 4 and 5, respectively.

The results indicate that AERMOD is over-predicting SO_2 and NO_2 concentrations in the vicinity of the proposed project. The over-prediction, based on comparison with 6 months of measured SO_2 and NO_2 data, indicate the maximum concentrations for these pollutant are currently meeting the JAAQS and are expected to be in compliance with the JAAQS after the construction of the proposed project.

5.0 REFERENCES

Cox WM, JA Tikvart. 1990. A statistical procedure for determining the best performing air quality simulation model. Atmos. Environ., 24A(9): 2387-2395.

National Environmental and Planning Agency (NEPA). 2007. http://www.nepa.gov.jm.

URS Corporation, 2006. Air Dispersion Model Verification Study and Impact Analysis for the JEP2 Barge Plant.

TABLE 1
JEP WEST KINGSTON POWER PLANT EMISSIONS USED FOR MODELING ANALYSIS

Source Description	Source ID	Emissions [a]										IFC EH&S Guidelines [d]		
		SO_2 [b]			NO_x			TSP/PM_{10}			CO			
		(lb/hr)	(g/s)	(mg/Nm^3) [c]	(lb/hr)	(g/s)	(mg/Nm^3) [c]	(lb/hr)	(g/s)	(mg/Nm^3) [c]	(lb/hr)	(g/s)	PM (mg/Nm^3)	SO_2 (mg/Nm^3)	NO_x (mg/Nm^3)
Engine 1	JEPHB1	201.6	25.40	1,016	367.0	46.24	1,850	9.9	1.25	50.0	12.5	1.58	50	1,170	1,850
Engine 2	JEPHB2	201.6	25.40	1,016	367.0	46.24	1,850	9.9	1.25	50.0	12.5	1.58	50	1,170	1,850
Engine 3	JEPHB3	201.6	25.40	1,016	367.0	46.24	1,850	9.9	1.25	50.0	12.5	1.58	50	1,170	1,850
Engine 4	JEPHB4	201.6	25.40	1,016	367.0	46.24	1,850	9.9	1.25	50.0	12.5	1.58	50	1,170	1,850
Engine 5	JEPHB5	201.6	25.40	1,016	367.0	46.24	1,850	9.9	1.25	50.0	12.5	1.58	50	1,170	1,850
Engine 6	JEPHB6	201.6	25.40	1,016	367.0	46.24	1,850	9.9	1.25	50.0	12.5	1.58	50	1,170	1,850

Note:
lb/hr = pounds per hour
g/s = grams per second
mg/Nm^3 = milligrams per normal cubic meter

[a] Based on information provided by Wartsila (2009).
[b] Based on maximum hourly fuel consumption of 2,285.7 kg/hr and maximum sulfur content of 2.0% by weight.
[c] Based on exhaust flow rate of 25 m^3 at 20°C (39 m^3 at 183.6°C).
[d] International Finance Corporation (2008), Environmental, Health, and Safety Guidelines for Thermal Power Plants burning liquid fuels (plant >50 MWth to <300 MWth, cylinder bore >400 mm).

TABLE 2
SUMMARY OF CALCULATED RHC VALUES

Pollutant	Averaging Time	Customs Station		Garmex Station	
		$RHC_{modeled}$	$RHC_{measured}$	$RHC_{modeled}$	$RHC_{measured}$
SO_2	1-hr	1737.16	152.87	2973.19	256.63
	24-hr	102.15	29.65	577.18	57.62
NO_2	1-hr	375.95	77.06	360.83	60.30

Note: The robust high concentration (RHC) value is calculated using the following equation:

$$RHC = X(N) + [X - X(N)] \times \ln[(3N - 1)/2] \text{ in } ug/m^3$$

Where,

N = the number of values at the high end of the distribution of values,
i.e., N = 26 based on the value used by the US EPA in their 1990 paper titled "A Statistical Procedure for Determining the Best Performing Air Quality Simulation Model" (Cox, 1990).

X(N) = the Nth largest value, $\mu g/m^3$

X = the average of the the N-1 largest values, $\mu g/m^3$

TABLE 3
SUMMARY OF CALCULATED RHC RATIOS

Pollutant	Averaging Time	Customs Station $RHC_{modeled} / RHC_{measured}$	Garmex Station $RHC_{modeled} / RHC_{measured}$
SO_2	1-hr	11.36	11.59
	24-hr	3.44	10.02
NO_2	1-hr	4.88	5.98

TABLE 4
ANNUAL AVERAGE BIAS FACTOR DETERMINATIONS

Pollutant		Customs Station Concentration ($\mu g/m^3$)	Customs Station Ratio of Modeled Concentration to Measured Concentration	Garmex Station Concentration ($\mu g/m^3$)	Garmex Station Ratio of Modeled Concentration to Measured Concentration	Composite Bias Factor[a]
SO_2	Modeled	22.0	2.73	333.0	24.82	**13.77**
	Measured	8.1		13.4		
NO_2	Modeled	10.5	0.50	29.9	1.79	**1.14**
	Measured	21.1		16.7		

[a] Average of both monitoring stations ratios of modeled concentration to measured concentration.

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TABLE 5
SUMMARY OF PREDICTED CONCENTRATIONS FOR THE AAQS ANALYSES WITH EXISTING SOURCES AT MAXIMUM EMISSIONS, 100% ANNUAL CAPACITY FACTOR

Pollutant	Averaging Time	Modeled Concentrations[a] (ug/m^3)	Non-Modeled Background[c] (ug/m^3) (a)	RHC Ratio[d]	Adjusted Modeled Concentrations (ug/m^3) (b)	Total (a + b)	2006 Jamaican AAQS (ug/m^3)
SO_2[e]	1-Hour	2778	7.6	11.36	245	252	700
	24-Hour	551	7.6	3.44	160	168	365
	Annual	137	7.6	13.77	10	18	80
NO_2[b]	1-Hour	1092	16.3	4.88	224	240	400
	Annual	60	16.3	1.14	53	69	100

[a] Concentrations are based on highest predicted concentrations from AERMOD using 5 years of meteorological data for 1999 to 2003 consisting of surface and upper air data from Kingston/Norman Manley International Airport.

[b] NO_x to NO_2 conversion was based on the Ozone Limiting Method, with a fixed ozone concentration of 25 ppb.

[c] Based on average measurements from NEPA's Cross Roads monitor, 2007.

[d] The lowest robust high concentration (RHC) ratio was used for the 1-hr and 24-hr averaging times, see Table 3. For the annual averaging time, the composite bias factor was used, as shown in Table 4.

[e] Existing sources at maximum emissions (3.0% S).

FIGURES

LEGEND

- Modeled Contours
- Domain
- Exceeds AAQS

NOTES

REFERENCES

Modeling: Golder, 2010; Aerial: Microsoft Virtual Earth, 2009.

4,500 2,250 0 4,500
Feet

1	04/01/10	DES	REVISED CONTOURS	NRL	SRM	RVW

PROJECT

JEP West Kingston Power Plant

TITLE

Annual Average SO_2 Concentrations (ug/m3) for All Sources at Maximum Emissions and JEP at 2.0 %S

Golder Associates
Gainesville, Florida

PROJECT No.		093-87605	FILE No.	09387605A27	
DESIGN	AB	10/8/2009	SCALE AS SHOWN	REV. 1	
GIS	AB	10/8/2009			
CHECK	SM	10/8/2009			
REVIEW	SM	10/8/2009			

FIGURE 1

LEGEND

- Modeled Contours
- Modeling Domain
- Exceeds AAQS

NOTES

REFERENCES

Modeling: Golder, 2010; Aerial: Microsoft Virtual Earth, 2009.

1	04/01/10	DES	REVISED CONTOURS	NRL	DHK	RVW

PROJECT

JEP West Kingston Power Plant

TITLE

24-Hour Average SO_2 Concentrations (ug/m3) for All Sources at Maximum Emissions and JEP at 2.0 %S

Golder Associates
Gainesville, Florida

PROJECT No.		093-87605	FILE No.	093876058.28	
DESIGN	AB	10/8/2009	SCALE: AS SHOWN	REV. 1	
GIS	AB	10/8/2009			
CHECK	SM	10/8/2009			
REVIEW	DM	10/8/2009			

FIGURE 2

LEGEND

- Modeled Contours
- Modeling Domain
- Exceeds AAQS

NOTES

REFERENCES

Modeling: Golder, 2010; Aerial: Microsoft Virtual Earth, 2009.

4,500 2,250 0 4,500 Feet

1	04/01/10	DES	REVISED CONTOURS	NRL	CHK	RVW

PROJECT

JEP West Kingston Power Plant

TITLE

1-Hour Average SO_2
Concentrations (ug/m3) for All Sources at Maximum Emissions and JEP at 2.0 %S

Golder Associates
Gainesville, Florida

PROJECT No.		093-87605	FILE No.	09387605A29
DESIGN	AB	10/8/2009	SCALE AS SHOWN	REV. 1
GIS	AB	10/8/2009		
CHECK	SM	10/8/2009	FIGURE 3	
REVIEW	BM	10/8/2009		

Map Document: G:\PROJECTS\2009\093-87605 JEP Hunts Bay\A - Air Modeling\Rev_1\MapDocuments\09387605A29_Rev1_SO201.mxd | Modified 4/1/2010 11:29:07 AM | Plotted 4/1/2010 1:40:33 PM by rlamar

LEGEND

- Modeled Contours
- Modeling Domain
- Exceeds AAQS

NOTES

REFERENCES

Modeling: Golder, 2010; Aerial: Microsoft Virtual Earth, 2009.

4,500 2,250 0 4,500 Feet

1	04/01/10	DES	REVISED CONTOURS	NRL	SRM	RVW

PROJECT

JEP West Kingston Power Plant

TITLE

Annual Average NO_2 concentrations (ug/m3) for All Sources and JEP at 1850 mg/Nm3 (milligram per normal cubic meter)

Golder Associates
Gainesville, Florida

PROJECT No.		093-87605	FILE No.		09387605A30
DESIGN	AB	10/8/2009	SCALE: AS SHOWN	REV.	1
GIS	AB	10/8/2009			
CHECK	SM	10/8/2009	FIGURE 4		
REVIEW	SM	10/8/2009			

LEGEND

- Modeled Contours
- Modeling Domain
- Exceeds AAQS

NOTES

REFERENCES

Modeling: Golder, 2010; Aerial: Microsoft Virtual Earth, 2009.

4,500 2,250 0 4,500 Feet

1	04/01/10	DES	REVISED CONTOURS	NRL	SRM	RVW

PROJECT

JEP West Kingston Power Plant

TITLE

1-Hour Average NO_2 concentrations (ug/m3) for All Sources and JEP at 1850 mg/Nm3 (milligram per normal cubic meter)

Golder Associates
Gainesville, Florida

PROJECT No.		093-87605	FILE No.	093876005A31
DESIGN	AB	10/6/2009	SCALE: AS SHOWN	REV. 1
GIS	AB	10/6/2009		
CHECK	SM	10/6/2009		
REVIEW	BM	10/6/2009		

FIGURE 5