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**Subject: February 21, 2007 Additional Supplemental Information Request Response, North West Upgrader Project, EPEA Application No. 001-217118, Water Act File No. 00227771**

Dear Sirs:

Enclosed is a description of the water quality model and an analysis of the sensitivity of the modelling results (re: Questions #34, #35 and #36) as requested.

If you have any questions or concerns regarding this matter, please contact Doug Bertsch at (403) 451-4171.

Yours truly,

A handwritten signature in blue ink that reads 'Doug Bertsch'.

Doug Bertsch  
Vice President Regulatory Affairs

cc Brad Gilmour, Bennett-Jones  
Carmen de la Chevrotiere, AENV

Encl.

## North West Upgrading EIA – Effluent Discharge Modeling Sensitivity Analysis

### INTRODUCTION

The identified parameters of interest in the Project's effluent are ammonia, total nitrogen and phenols (North West 2006a, 2006b, 2007). Other water quality parameters are below guidelines under the modelled cases, which represent worst-case conditions (*i.e.*, low river flow and maximum Project loading), and were therefore not included in the sensitivity analysis. The following document outlines the methods and results of determining the sensitivity of the models that were used to predict the concentration of these three parameters.

Specific modelling approaches were used for each parameter. The discussion below provides a description of the assessment models and the model inputs, followed by a discussion on the sensitivity analyses methodologies. The results and implications of the analyses are then discussed.

### MODELLING APPROACHES

#### AMMONIA

The models used to predict ammonia concentrations in the North Saskatchewan River (NSR) were WASP (Water Quality Simulation and Analysis Program) and CORMIX (Cornell Mixing Zone Expert System).

Inputs used in the WASP model include NSR background concentration measured upstream of Gold Bar, NSR flow rate measured at the Low Level Bridge in Edmonton, and loadings from the major industrial and municipal outfalls in the 60 km reach of the river. As requested by Alberta Environment, the revised WASP modeling (North West 2007) included a reduction in ammonia loadings from the Gold Bar WWTP. This revised loadings was the mean for all months in 2005 – 2006 (612.14 kg/day), and did not correspond to the winter conditions mean loading reported for Gold Bar WWTP from 2005 - 2006 for which the modeling was completed (1194.6 kg/day – see Table 3), and therefore uncertainty of the WASP model predictions could not be evaluated. As a result, assumptions of the CORMIX modeling results represent the focus of the uncertainty analysis.

Inputs used in the CORMIX model include NSR background concentration measured at the Fort Saskatchewan Bridge, NSR flow rate measured at the Low Level Bridge in Edmonton, loadings from the Project and the proposed Sturgeon Upgrader project. The sensitivity analysis focuses on the variability of the NSR concentrations and flow and the loadings from the upstream outfalls that discharge large amounts of ammonia in the modeled river reach – Gold Bar Wastewater Treatment Plant (WWTP), Capital Region WWTP, and the Shell Scotford Complex, as well as background concentrations and winter river flows. The other outfalls represent a considerably smaller loading, therefore their inputs were not varied, but

they were included in the analysis. Furthermore, since it is assumed that the Project's effluent concentrations represent typical maximum values and there are no data available on the variation of the Project's effluent, only the uncertainty of the CORMIX model assumption upstream of the proposed Project's outfall were analyzed.

### **TOTAL NITROGEN**

The CORMIX model was used to predict total nitrogen concentrations in the NSR in the area of the Project's effluent discharge.

Inputs used in the CORMIX model include NSR background concentration measured at the Fort Saskatchewan Bridge, NSR flow rate measured at the Low Level Bridge in Edmonton, loadings from the Project, Agrium Redwater and the proposed Sturgeon Upgrader project. The uncertainty analysis focuses on the variability of the background NSR concentration, winter river flows, as well as the variation in loadings from the Gold Bar WWTP, Capital Region WWTP, and Shell Scotford Complex. The variability of the Sturgeon Upgrader and the Project are not included because there are no data available for these facilities to quantify potential variability in loadings. As with ammonia, other outfalls on the NSR represent considerably lesser inputs, therefore, their inputs were not included in the analysis. Furthermore, it is also assumed that the Project's effluent concentrations represent typical maximum values and there are no data available on the variation of the Project's effluent, only the uncertainty of the CORMIX model assumption upstream of the proposed Project's outfall were analyzed.

### **PHENOL**

The CORMIX model was used to predict phenol concentrations in the NSR in the area of the Project's effluent discharge.

Inputs used in the CORMIX model include NSR background concentration measured at the Fort Saskatchewan Bridge, the NSR flow rate measured at the Low Level Bridge in Edmonton, and loadings from the Project and the proposed Sturgeon Upgrader. For the aforementioned reasons, the uncertainty analysis focuses on the variability of background NSR concentrations and winter flows. The variability of the Project and the proposed Sturgeon Upgrader are not included in the analysis, since there are no data available for these facilities and the loadings modelled represent a typical maximum. However, a general statement on the uncertainty of the CORMIX model predictions for phenol is provided.

### **BACKGROUND**

The model results are limited by the availability of comprehensive effluent and receiving water quality data. In the absence of a comprehensive dataset, an uncertainty analysis is sometimes carried out to determine the frequency of expected model conditions.

The first step in assessing the uncertainty of the model was to obtain statistical data for the model inputs listed above. The data used in the uncertainty analysis is summarized in Table 1 through Table 4. Only mean loading data were available for the Shell Scotford Complex. Therefore, the average ammonia (136.4 kg/day) and estimated Total N (290.7 kg/day) loadings were varied based on an historical expected standard deviation (equal to approximately 50% of the mean).

**Table 1 - NSR Flow Data**

Statistical Parameters	Flow m <sup>3</sup> /s
Minimum	19.8
Median	113
Mean	119.1
Maximum	261
Standard Deviation	33.02
Coefficient of Variation	0.28
Count	3,728

**Source:** Daily Flows measured in Nov - Feb from 1974 to 2004 at Low Level Bridge WSC Gauging Station

**Table 2 – NSR Concentration Data, NH3 and TN**

Statistical Parameters	NH <sub>3</sub> mg/L	TKN+NO <sub>3</sub> /NO <sub>2</sub> mg/L
Minimum	0.0025	0.0280
Median	0.009	0.131
Mean	0.015	0.218
Maximum	0.103	1.006
Standard Deviation	0.020	0.240
Coefficient of Variation	1.31	1.10
Count	27	27

**Source:** NAQUADAT database measured data at the 50 Street Pedestrian Bridge between 1998 and 2002

**Table 3 – NSR Concentration Data, Phenols**

Statistical Parameters	Phenols mg/L
Minimum	0.001
Median	0.002
Mean	0.003
Maximum	0.009
Standard Deviation	0.0022
Coefficient of Variation	0.76
Count	13

**Source:** NAQUADAT database measured data at the Fort Saskatchewan Bridge between 1982 and 2002.

**Table 4 – Gold Bar WWTP Data**

Statistical Parameters	NH <sub>3</sub> kg/d	TKN+NO <sub>3</sub> kg/d
Minimum	68.1	836.0
Median	980.4	2,924.6
Mean	1,194.6	3,228.0
Maximum	10,626.3	23,363.8
Standard Deviation	112.9	228.9
Coefficient of Variation	0.1	0.1
Count	315	77

**Source:** Daily Samples from Jan 1, 2005 to Dec 31, 2006. (Measurements from June 1 to Nov 1 were not included in statistical calculations because they were considerably lower during that time of year. The limit from June to November is 5 mg/L where as the limit from November to June is 10 mg/L).

**Table 5 – Capital Region WWTP Data**

Statistical Parameters	NH <sub>3</sub> kg/d	TKN+NO <sub>3</sub> kg/d
Minimum	7.0	0.0
Median	182.8	1,025.7
Mean	235.7	1,052.2
Maximum	1,393.2	2,569.5
Standard Deviation	202.4	290.7
Coefficient of Variation	0.86	0.28
Count	610	518

**Source:** Daily Samples from May 1, 2005 to Dec 31, 2006. (May 1 marks the start of increased treatment for ammonia and phosphorous. Seasonal variation was not noted in effluent, as it was at the Gold Bar WWTP, therefore data from the entire year was used in statistical calculations.)

## ASSESSMENT METHODS

The uncertainty analysis for the CORMIX modelling was performed through a Monte Carlo simulation that randomized upstream conditions that influence water quality above the proposed Project’s outfall, namely, water quality parameter loadings, background concentrations, and flows in the NSR. The goal of the uncertainty analysis was to determine to what degree the background water quality data at the Fort Saskatchewan Bridge (used in the CORMIX modeling) are representative of water quality in the NSR immediately upstream of the Project’s outfall.

Potential average cross-sectional concentrations upstream of the Project’s outfall were reproduced within a Microsoft Excel spreadsheet through the formulation of a mass balance equation that accounts for variations in NSR conditions of water quality parameter loadings, background concentrations, and flows. Background concentrations at the Fort Saskatchewan Bridge, which were applied in the CORMIX modelling, were evaluated within the context of potential background variability upstream of the Gold Bar WWTP, variability of loadings from the Gold Bar WWTP and Capital Region WWTP, as well winter river flow variability.

The Monte Carlo simulation was performed through a randomization of effluent loading input from the Gold Bar WWTP, Capital Region WWTP, and Shell Scotford outfalls using the mean and standard deviation of loadings for these outfalls as presented in Tables 3 and 4 and by assuming a normal distribution for these parameters. This randomization was performed for Total N, but was not feasible for ammonia concentrations due to several non-detectable measurements reported for this parameter. Therefore, for Ammonia, mean upstream concentrations were used within the Monte Carlo simulation. The NSR flows were also randomized given the known range of flows during winter (Table 1). The Monte Carlo simulation was performed for 500 random combinations of these parameters.

## RESULTS

### UNCERTAINTY ANALYSIS

Results of the uncertainty analysis are presented in Table 6.

**Table 6 – Uncertainty Analysis: Mean and Standard Deviation (mg/L) of Monte Carlo Simulation Results**

Applied		Monte Carlo Simulation			
NH <sub>3</sub>	TN	NH <sub>3</sub>		TN	
		Mean	Stdev	Mean	Stdev
0.27	0.67	0.175	0.078	0.792	0.283

Notes:

NH<sub>3</sub> – Ammonia

TN – Total Nitrogen

Stdev – Standard Deviation

### **AMMONIA**

The ammonia concentration applied upstream of the proposed Project's outfall (0.27 mg/L) is greater than one standard deviation of the mean concentration produced by the Monte Carlo simulation ( $0.175 \pm 0.078$  mg/L). The distribution of expected ammonia concentrations upstream of the Project's as produced by the Monte Carlo simulation suggests that an upstream concentration equal to or greater than that applied in the CORMIX modeling can be expected to occur with a frequency of approximately 6%.

The results for ammonia suggest that the upstream conditions applied to the CORMIX modeling are conservative and are likely to occur at a frequency of less than 10%. Furthermore, water quality monitoring of the NSR demonstrates that ammonia concentrations on the west bank of the NSR are approximately 3 to 10 times lower than on the east bank of the NSR, and approximately 2 to 5 times lower than in the middle of the river (Focus 2004; Focus 2005; Golder Associates 1995). We therefore have a high degree of confidence that the downstream ammonia concentrations predicted by CORMIX are conservative and are likely to occur with a frequency of much less than 10%.

With respect to the sensitivity of the CORMIX model predictions, aside from the uncertainty in upstream concentrations addressed above, the only input parameters that would influence results to any significant degree are effluent flow and concentration, as well as river flow. Any variation in the magnitude of these model input parameters would produce a more or less proportionate response in model predictions. Since effluent flow and concentration were modeled at their maximum levels, and the 7Q10 NSR flow rate was applied, we estimate the confidence of our prediction to exceed 90%.

### **TOTAL NITROGEN**

Predicted mean Total N concentrations applied upstream of the proposed Project's outfall (0.67 mg/L) are within one standard deviation below the mean concentration produced by the Monte Carlo simulation ( $0.792 \pm 0.283$  mg/L). The distribution of expected Total N concentrations upstream of the Project as produced by the Monte Carlo simulation suggests that an upstream concentration equal to or greater than that applied in the CORMIX modeling can be expected to occur with a frequency of approximately 64%. However, as with ammonia, monitoring of Total N concentrations in the NSR demonstrates that Total N concentrations on the west bank of the NSR are approximately 2 times lower than in the center of the river. Therefore, although the application of the median Total N concentration at the Fort Saskatchewan Bridge as an upstream background may have underestimated average Total N concentrations in the NSR, if the lateral distribution of Total N concentrations is taken into account in the Monte Carlo simulation, then application of a Total N concentration of 0.67 mg/L directly upstream of the Project's outfall on the west bank of the NSR is likely associated with a degree of confidence greater than 90%.

As with the sensitivity of the CORMIX model ammonia predictions, any variation in the magnitude of other model input parameters would produce a more or less proportionate response in model predictions. Since effluent flow and concentration were modelled at their maximum levels, and the 7Q10 NSR flow rate was applied, we estimate the confidence of the Total N predictions to be in the order of 90%.

### **PHENOLS**

As previously stated, the difficulty in assessing the uncertainty in predicted phenol concentrations relates directly to the unavailability of phenol loadings data from other dischargers on the NSR. In assessing the potential variability of phenol loadings, the only parameters for which data are available are upstream concentration at the Fort Saskatchewan Bridge and winter river flow rate. Since median concentrations at the Fort Saskatchewan Bridge were applied in the CORMIX modeling, we would expect upstream phenol concentrations greater than the median to occur with a frequency of approximately 50%. However, due to the aforementioned, known lateral variability of water quality parameter concentrations in the NSR, the upstream phenol concentration applied in the CORMIX modeling likely occurs with a frequency considerably less than 50% directly upstream of the proposed Project's outfall. In addition, since the discharge from the Project and proposed Sturgeon Upgrader will represent the only known inputs of phenols on the west bank of the NSR, and these were modeled at their maximum effluent concentrations and flows against a 7Q10 river flow rate, we consider the CORMIX modeled phenol concentrations to possess a high degree of confidence.

### **CONCLUSIONS**

Given the variability of the effluent loading conditions, background water quality, and the hydrologic conditions of the NSR, uncertainty in the model predictions is expected. The confidence level of the model predictions is considered to be moderate to high. Based on the findings of this analysis, it is concluded that the CORMIX model can be used with a high degree of confidence for assessing the potential effects of water quality parameter loadings from the Project on the water quality of the NSR.

## REFERENCES

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